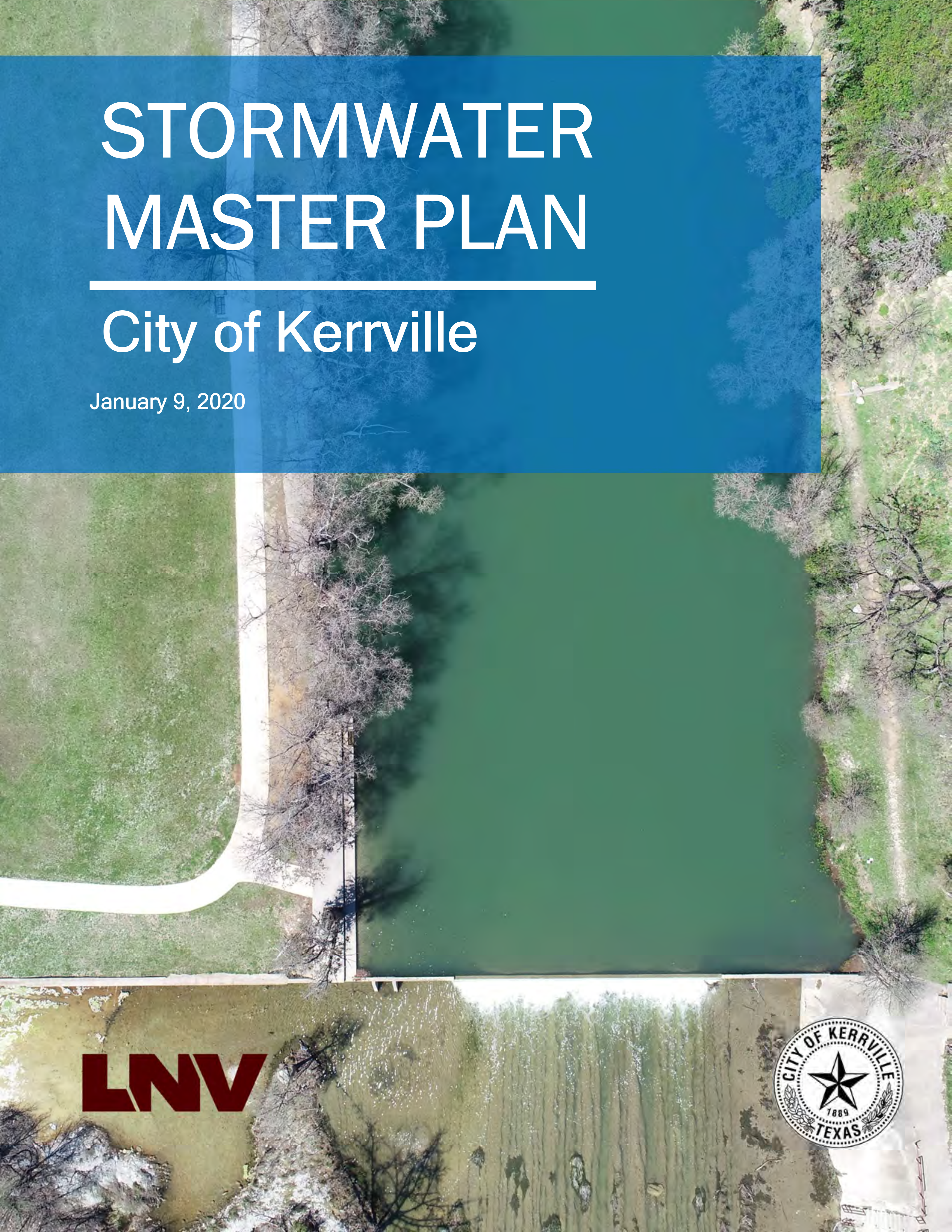


STORMWATER MASTER PLAN

City of Kerrville

January 9, 2020

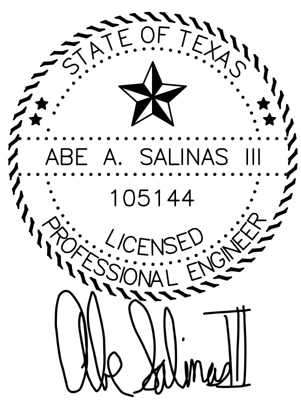
LNV

City of Kerrville
Stormwater Master Plan

Submitted to:

City of Kerrville

January 9, 2020



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APPENDICES

EXECUTIVE SUMMARY

This Stormwater Master Plan serves to evaluate the current state of stormwater management practices and the condition of storm drains, streams, and watersheds for the City of Kerrville. This document is intended to provide a roadmap for implementing stormwater planning and infrastructure projects that support a more sustainable community by providing a framework for managing stormwater, streams, and watersheds for the next 15 to 20 years and identifying opportunities to provide sustained funding sources to complete the identified projects.

The contents of this plan provide the following:

An overview of the city's storm drainage network, associated dams, streams and other stormwater facilities to provide information on how to best manage the system in the coming years. Key results from this assessment including identifying the city's:

- 10 major watersheds, the total drainage areas, and estimated peak flows;
- 10 major streams and providing an overview of known flood risks and documented historical floods;
- Major storm drain network of pipes, culverts, and creeks;
- Low water crossings subject to frequent overtopping and hazardous conditions;
- Dam and detention pond inventory with known hazard classifications, and identification of city-owned dams;
- Land use development patterns and anticipated future growth;
- Existing storm drainage system needs and providing recommendations for improvements.

An evaluation of fourteen problem areas experiencing frequent flooding, erosion or other stormwater related issues and providing proposed solutions, probable project costs, and a priority list for project implementation.

- Probable cost to implement the 14 identified Capital Improvement Projects is estimated to be $21M.
- The top five project priority locations were identified as follows: Take it Easy Drainage Channel Improvements, Lois Street Drainage Improvements, Hill Country Drive Drainage Improvements, Kroc Center Outfall and Clay Street Storm Drain System Improvements, and East Main to Pinto Trail Drainage Channel Improvements.

Recommendations for updating the city's drainage criteria and land development codes to comply with new and evolving stormwater regulations, pollution reduction goals and best management practices. Evaluations and recommendations include:

- Adoption of the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation data, guidelines for development, and remapping of the FEMA regulatory floodplains;
- Updates to the City's Code of Ordinances and Land Development Codes;
- Updates to the City's Drainage Criteria Manual;
- Identification for opportunities to protect and enhance water quality;
- Consideration of future stormwater management programming and planning projects.

Locating funding resources to generate a consistent stream of revenue, identify opportunities for partnerships, and identify grants that will support the implementation of selected planning and capital improvement projects.

Provide the city with an implementation strategy and plan for completing the identified planning and capital improvement projects.

Summary of Project Total Costs and Rankings

Ranking	ID	Project Name	Project Score	Estimated Project Cost
1	I	Take It Easy Drainage Channel	771	$ 2,291,913
2	J	Lois St. (Woodlawn to Ox Dr.)	718	$ 189,899
3	F	Hill Country at SH16	677	$ 2,429,607
4	G & H	Kroc Center Detention Pond Clay St. (Schreiner to SH27)	644	$ 8,967,501
5	A	East Main to Pinto Trail	588	$ 979,520
6	K2	Circle Avenue	587	$ 188,800
7	L	Jack Drive	552	$ 2,373,793
7	M	Coronado at Junction Highway	552	$ 494,195
9	E	Spring St. - Erosion at Outfall	528	$ 744,073
10	K1	Harper Street	524	$ 1,808,431
11	B	Park St. Low Water Crossing	413	$ 200,000
11	C	First St. Low Water Crossing	413	$ 200,000
13	D	Fourth St. Low Water Crossing	368	$ 200,000
			Total Project Costs	$ 21,067,733

Stormwater Project Planning List

Project Name	Type	Description	Priority Level	Estimated Cost Range
Dam Inspection and Maintenance Program	Program	Develop a standard dam inspection and maintenance program to be completed by staff.	High	$15,000 / year
Kerrville Flood Protection Plan Study (Hydrologic and Hydraulic Studies - FEMA Streams)	Study	Restudy all significant streams within the city and reassess community flood risk using NOAA Atlas 14 precipitation data, updated hydrologic modeling, updated terrain information, and detailed hydraulic modeling. Identify potential future projects to be completed to mitigate flooding and general management of the basin.	High	$400,000-$800,000
Louise Hays Dam Repairs	Design & Construction	Repair of concrete buttress dam structure due to seepage and spalling of concrete.	High	$1,000,000
Stormwater Drainage Design Manual Update	Manual	Update the city's drainage design and criteria manual to reflect current industry best practices and projected city growth.	High	$50,000

Project Name	Type	Description	Priority Level	Estimated Cost Range
Storm Drain System Inventory and Assessment	Data Collection	Update the city's current storm drain system inventory in GIS and assess the condition of existing infrastructure including storm drains, culverts, detention ponds, and other drainage facilities to identify storm drains needing replacement.	Medium	$10,000 / year
Regional Detention Pond Study and Fee-in-Lieu of Program	Study	Perform a study of the city's watersheds and anticipated growth for each basin to identify detention needs, where regional detention may be provided and where mandatory detention should be required to mitigate adverse impacts.	Medium	$60,000
Design Review Checklist	Manual	Develop a detailed stormwater design review checklist to verify proposed developments meet city criteria and ordinance requirements.	Medium	$5,000 - $10,000
Stormwater Utility Fee Study	Study	Study the potential for implementing a city-wide stormwater utility fee program to generate revenue responsible for maintaining the city's existing storm drainage system and to assist with the funding of capital projects. The fee is roughly estimated to generate $500,000 to $1,000,000 per year.	Medium	$70,000
Flood Warning System	Design & Construction	Install automatic gate flood warning systems at Quinlan Creek, Town Creek, and other known low water crossings.	Medium	$200,000 per location
Water Quality Protection Plan	Study	Study to implement water quality protection measures within the watersheds and protect natural riparian areas.	Medium	$80,000
Flood Complaint Database	Data Collection	Maintain a city complaint database to document flooding incidents, identified issues, and photographs to assist with identifying priority projects and hot spot areas.	Low	$5,000 / year

INTRODUCTION

PURPOSE OF STUDY

On February 13, 2019, the City of Kerrville authorized LNV, Inc. to perform a master planning study for the city's storm drainage system including:

1. Review of available drainage studies, construction plans, topography, GIS inventory and other available data pertinent to the project.
2. Evaluation of fourteen identified problem drainage areas, as identified by City staff and approved by City Council.
3. Development of proposed solutions for each problem area (including estimations of probable project costs) and ranking of the projects into a priority list for consideration and addition into the city's Capital Improvement Plan project list.
4. Review current drainage policy and criteria to identify where improvements may be needed and recommend changes as appropriate.
5. Present a recommendations list of capital projects, planning studies and policy updates to be completed by the City.
6. Provide an implementation and funding strategy for completion of the identified projects.

This Stormwater Master Plan document will serve to update the previously adopted *Storm Drainage System Study* completed in 1983 by Hogan & Rasor, Inc.

The planning area is generally limited to within the city limits, as represented in **Figure 1**.

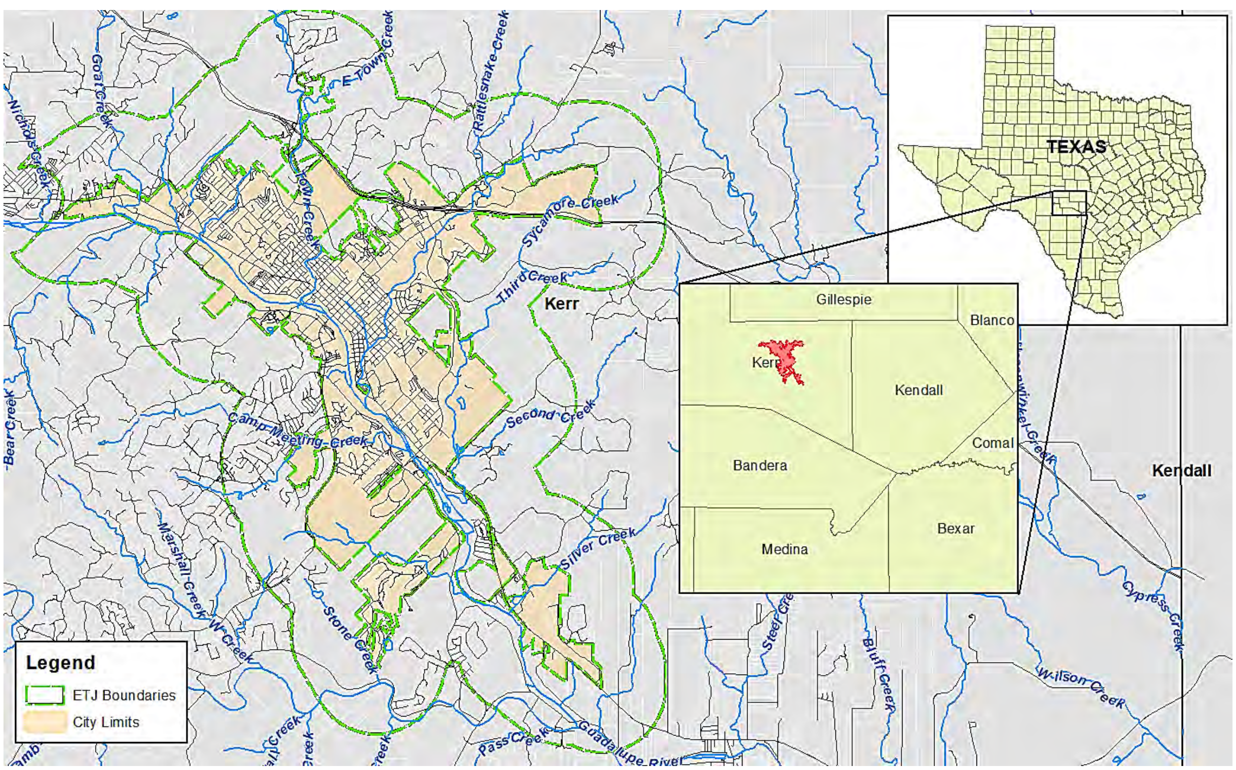

Figure 1 - Study Location Map

PROJECT APPROACH

For the city-wide stormwater master plan update, this study intends to evaluate the multiple components of the city's drainage system to identify areas of needed improvement through infrastructure planning, design, construction, and maintenance.

The study approach begins by providing an overview and considerations to the city's watersheds, drainage system infrastructure, and known creek flooding issues. The report then investigates the city's fourteen identified problem areas to develop conceptual solutions and probable costs associated with reducing flood damage risks, improving public safety, enhancing economic commerce and protecting the environment. Finally, this plan evaluates the city's current drainage policy and criteria to identify areas for potential updates.

This plan will then provide a roadmap for implementation which includes adopting best practices for managing future development, prioritizing and implementing identified city projects, providing a list of potential funding sources and identifying other additional stormwater planning considerations.

Lastly, this plan is intended to serve as a living document which should include minor yearly updates to the drainage capital improvement project list and major master plan updates every 5 to 10 years.

STUDY PRIMARY OBJECTIVES:

- Provide a plan and strategy for implementing the identified priority projects as related to capital improvements, existing storm drainage systems, city-owned dams, floodplain management, and land development.
- Promote cost-efficient solutions that enhance the effectiveness of allocated funds to ensure quality services are provided to the community.
- Promote the continued maintenance and rehabilitation of city-owned drainage infrastructure.
- Protect water quality for both surface and groundwater sources.
- Preservation of riparian habitat and natural streams, creeks and river areas.

2050 COMPREHENSIVE PLAN GUIDING PRINCIPLES

The following guiding principles provided by the *2050 Comprehensive Plan* have been utilized in the development of this study.

- **W1: Develop and maintain long-range water plans that prioritize infrastructure needs and identify funding sources and take a regional approach to planning.**
- **W3: Address water quality challenges with proven solutions**
    - **W3.1:** Examine all potential solutions to improving water quality that could be applicable to Kerrville.
    - **W3.4:** Examine the possibility of adopting maximum impervious cover limits and enhanced drainage design standards around/adjacent to the river to ensure water quality.
    - **W3.6:** Collaborate with UGRA and others in their efforts to reduce surface water pollutants and debris in the river.
- **W4: Preserve natural riparian areas**
    - **W4.1:** Map current riparian areas and determine potential future impacts associated with the potential loss of these areas and establish minimum and optimum sizes for riparian zones.
    - **W4.2:** Pursue zoning ordinance amendments to support riparian area protection.
    - **W4.4**: Encourage the establishment of a riparian protection zone in the floodplain permitting process to address water quality considerations.
    - **W4.5:** Consider adding water quality review to the floodplain permitting process.
    - **W4.6:** Develop standard maintenance protocols for riparian areas, including the option of leaving the areas in a natural condition
    - **W4.7:** Restore damaged riparian areas in riverside parks.
- **W7: Develop and maintain a long-range plan for stormwater/drainage management, addressing and prioritizing infrastructure needs and identify funding sources.**
    - **W7.1:** Take a holistic approach to stormwater and drainage management based on the level of growth anticipated in the Kerrville 2050 Comprehensive Plan.
    - **W7.2**: Update the City's floodplain ordinance to be consistent with Kerrville 2050 Comprehensive Plan.
    - **W7.3:** Explore a variety of options, including bond funding or city-wide drainage fees, to address drainage infrastructure concerns.
    - **W7.4**: As a part of the drainage plan, focus on regional versus single-site detention.
    - **W7.5**: Consider allowing a fee-in-lieu of improvements for development of regional detention versus onsite detention.

- **W8: Focus more on on-site green/bio stormwater infrastructure to support water quality and quantity goals.**
    - **W8.1:** Establish reasonable guidelines or standards to encourage more green infrastructure.
    - **W8.2**: Develop drainage design standards (including "green" design options), on-site retention requirements, and water quality standards.

- **W9: Enhance efforts aimed at water conservation, better stormwater management on private property and measures such as rainwater harvesting and other innovative approaches to help manage water usage.**
    - **W9.1:** Provide financial or other incentives for rainwater harvesting.
    - **W9.3:** Maximize the use of surface water in the city and surrounding areas to help maintain groundwater levels.
    - **W9.4:** Label storm drains citywide to reduce/eliminate dumping of grass clippings and other waste.
    - **W9.5:** Implement a strong water conservation plan to include additional conservation measures and programs.

EXISTING DRAINAGE SYSTEM

OVERVIEW

The City of Kerrville lies within Kerr County and in the Edwards Plateau geologic formation. The city is located within the Upper Guadalupe River watershed and is directly affected by flood waters from the Guadalupe River and the sub-watersheds associated with Town Creek, Quinlan Creek, Camp Meeting Creek, Elm Creek, Third Creek, Second Creek, Bear Creek, Goat Creek, and an unnamed Tributary (Lime Creek).

The geography of the region for the city is characteristic of the Texas Hill Country which includes rugged and stony hills, steep terrain, followed by relatively flat areas. Stormwater runoff is collected in the various creeks and ultimately discharged into the Guadalupe River. Existing topographic elevation values within the city limits, range anywhere between 1,527 to 2,035 feet above the Mean Sea Level (MSL). In addition, a number of small and large springs feed into surrounding creeks and function as a recognized quality of life contributor and attraction to visitors of the area.

The City of Kerrville is within the Edwards Aquifer Contributing Zone and is contained by the Edwards-Trinity Aquifer which serves as a primary source of drinking water for the region. Therefore, the city is responsible for restricting development or discharges that could adversely affect the quality of water that contributes to groundwater recharge.

The city's drainage system includes closed-system storm drains, open channels, detention ponds, flood control dam structures, and existing natural creeks and tributaries that drain to the Guadalupe River. Many of the streams, creeks, and river areas in and around the city are privately owned and without maintenance requirements. This limits the city's ability to manage development adjacent to these areas and makes it difficult to manage stormwater volume and quantity.

The city's continued growth will place new strains on the existing stormwater drainage system. To deal with this growth, this stormwater plan provides guidance for updating development criteria and ordinances for enforcement. Additional information may be found in the **Evaluation of Drainage Policy and Criteria** section of this report.

The following subsections provide a detailed summary of the city's major watersheds, streams, storm drain networks, dam and detention pond inventory, land use development patterns and recommended considerations for maintaining and improving the city's current system.

MAJOR WATERSHEDS

The City of Kerrville is located within the Upper Guadalupe River Basin and has a total contributing drainage area of approximately 510 square miles at the Guadalupe River. Within the city limits, there are nine major sub-watersheds with a total contributing drainage area of 90.1 square miles. These watersheds are known to contribute to groundwater recharge and to spring flows along the various tributaries of the Guadalupe. Among those springs are Colbath Springs of Bear Creek, Goat Springs of Goat Creek, Rapid Springs of Town Creek, Cypress Springs, and Indian Springs. Each of these springs are part of the Glen Rose Limestone of the Edwards Aquifer.

The city's contributing watersheds are further identified and illustrated in **Figure 2**. According to FEMA's Flood Insurance Study (FIS) report, the hydrologic analysis utilized to derive peak flow runoff rates for Town Creek, Quinlan Creek, Elm Creek, and Camp Meeting Creek was last studied by detailed methodologies in 1997. In addition, Goat Creek, Third Creek, Second Creek, Bear Creek, and Unnamed Tributary (Lime Creek) have not had any detailed analysis performed and are presently utilizing FEMA approximate methodologies to determine peak flow.

The city's watersheds are within the Upper Guadalupe River Authority (UGRA) which is responsible for managing the watersheds and water resources of the Upper Guadalupe River through the protection and management of water quantity, quality and sustainability in the Guadalupe River watershed within Kerr County.

Identified Major Watersheds within the study area include:

Table 1 - Major Watersheds Summary for Kerrville, TX

Watershed Name	Study Date	FEMA Method of Analysis	Drainage Area (sq. mi.)	100-Year Peak Flow (cfs)	500-Year Peak Flow (cfs)
Goat Creek Basin	1997	FEMA Approx. Methodologies	19.03	N/A	N/A
Town Creek Basin	1997	HEC-1	23.32	18,210	23,730
Quinlan Creek Basin	1997	HEC-1	12.45	11,070	14,470
Third Creek Basin	1997	FEMA Approx. Methodologies	7.90	N/A	N/A
Second Creek Basin	1997	FEMA Approx. Methodologies	5.37	N/A	N/A
Unnamed Tributary (Lime Creek)	1997	Unknown	2.90	N/A	N/A
Elm Creek Basin	1997	HEC-1	1.27	1,996	2,560
Bear Creek Basin	1997	FEMA Approx. Methodologies	7.61	N/A	N/A
Camp Meeting Creek Basin	1997	HEC-1	10.24	10,120	12,900
Guadalupe River Basin at UGRA Dam	1997	USGS Flood Flow Frequency Analysis	510	215,000	360,000

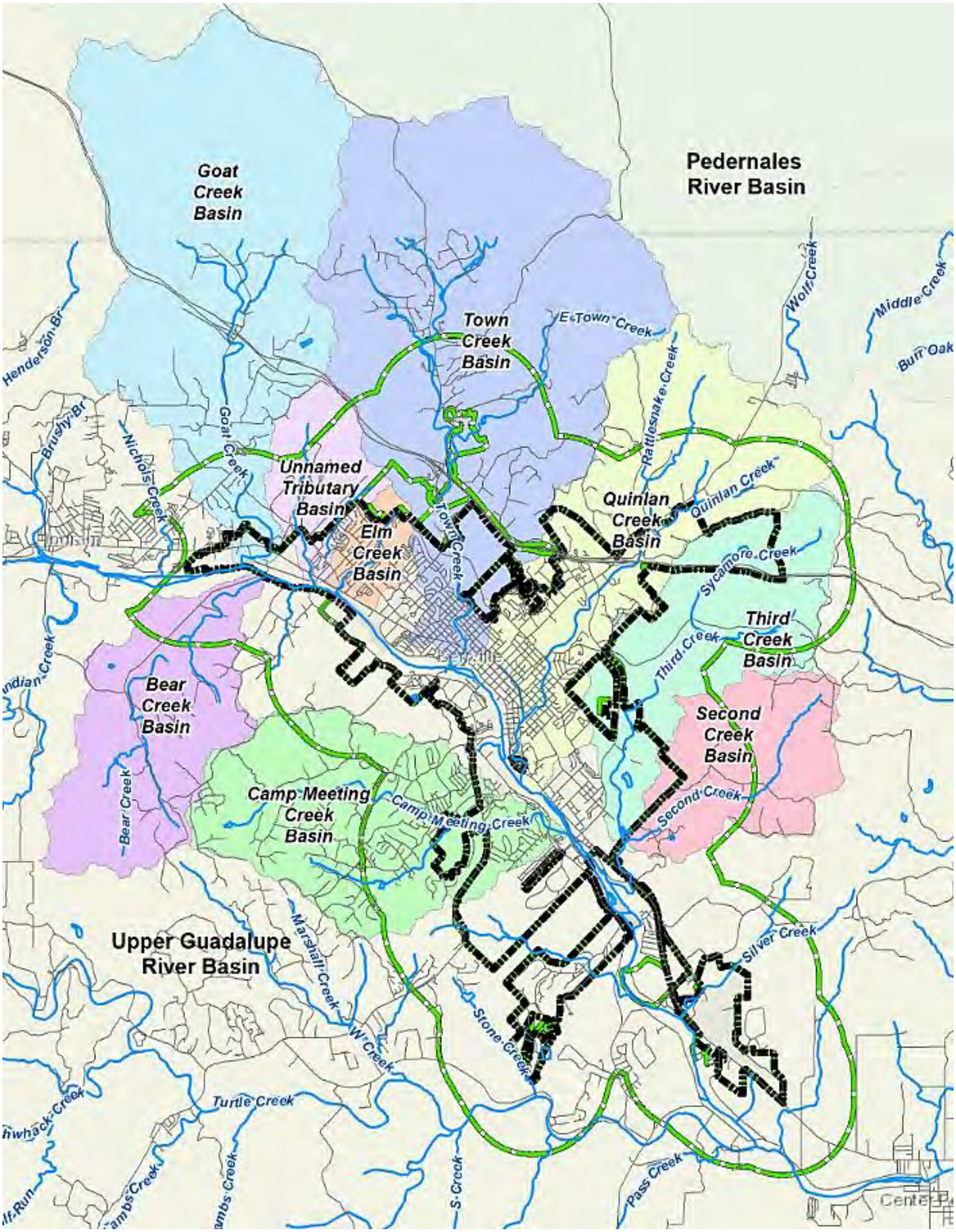

Figure 2 - Major Watersheds of Kerrville

GOAT CREEK

Goat Creek Basin has a total drainage area of 19.03 square miles with only a small portion of the watershed, 0.23 square miles, within the city limits. The watershed consists of medium intensity development at the downstream end with impervious surfaces accounting for 50% to 79% of the total cover. North of the city limits within Kerr County, which represents the majority of the basin area, consists of low-intensity development, developed open space and shrubland with an estimated impervious cover of less than 20%.

TOWN CREEK

Town Creek Basin has a total drainage area of 23.32 square miles with 1.85 square miles within the city limits, which generally consists of the area south of IH-10. The watershed consists of medium intensity and undeveloped shrubland north of IH-10. Town Creek and East Town Creek merge together at a fork just north of IH-10 and runs south/southeast through the city of Kerrville and into the Guadalupe River. South of IH-10, the watershed consists of medium to high-intensity development which include established, high populated residential areas with an estimated impervious cover of 60% to 85%. Town Creek, within the city limits, is known to be susceptible to flooding and is therefore sensitive to increases in impervious cover. A series of regulating weirs / small dams and low water crossings are located along Town Creek and East Town Creek.

QUINLAN CREEK

Quinlan Creek Basin has an overall drainage area of 12.45 square miles with 4.85 square miles within the city limits. It is one of the largest contributing creeks in the City of Kerrville and consists of several low water crossings susceptible to frequent overtopping. Its upstream watershed resides mostly north of IH-10 and consists of low-intensity development with an estimated impervious cover of less than 20%. The downstream watershed, south of IH-10, is medium intensity development with an estimated impervious area of 40% to 60%.

THIRD CREEK

Third Creek Basin contributes 7.9 square miles of catchment at the confluence with Second Creek with 2.2 square miles of basin area within the city limits which outflows into the Guadalupe River, downstream of Kerrville. Third Creek can generally be described as a low impact watershed with the majority of the basin being open space shrubland with an impervious area estimated to be less than 20%. The impervious area for the lower portion of the basin is estimated to be up to 30% to 40%, some areas consisting mostly of residential and recreational areas.

SECOND CREEK

Second Creek Basin contributes 5.37 square miles of catchment at the confluence with Third Creek, with 4% of the drainage area within the city limits. Second Creek, located further southeast of Kerrville than Third Creek, can be described as having very similar upstream and downstream characteristics as Third Creek. Upstream impervious cover is estimated to be less than 20% with a downstream impervious cover estimated to be up to 35% to 40%. Both Second Creek and Third Creek converge and discharge into the Guadalupe River.

UNNAMED TRIBUTARY (LIME CREEK)

Unnamed Tributary Basin, also known as Lime Creek, has a total drainage area of 2.9 square miles with 0.44 square miles within the city limits. Located in the northwestern reach of Kerrville, the Unnamed Tributary is one of the smaller watersheds that extends south of IH-10 between Goat Creek Basin and Town Creek Basin. Consisting mostly of sparse development and open spaced shrubland, Unnamed Tributary watershed can be described as a low-intensity development area and is estimated to have less than 20% impervious cover.

ELM CREEK

Elm Creek Basin has a total drainage area of 1.27 square miles with 1.0 square mile being within the city limits. Land use in this basin consists mostly of moderate density residential development with more heavily developed commercial land use to the south along SH27. Future land use scenarios identified in the 2050 Comprehensive Plan indicate continued residential growth in the far north end of the basin, which will add to the amount of impervious cover and runoff for this drainage basin.

BEAR CREEK

Bear Creek Basin has an overall drainage area of 7.61 square miles and is located outside of the city limits. 1.08 square miles of the Bear Creek Basin is within the existing Kerrville Extra Territorial Jurisdiction (ETJ) Limits. The basin consists of large tracts of land primarily used for agricultural use or rural residential homes. Based on the 2050 Comprehensive Plan, future land uses are projected to be similar to existing land use conditions.

CAMP MEETING CREEK

Camp Meeting Creek Basin has an overall drainage area of 10.23 square miles, with 1.42 square miles within the Kerrville city limits. The basin within the city limits contain the River Hills Country Club & Subdivision. The western area of the basin is comprised mostly of large lot single family homes and agricultural land uses. Towards the eastern parts of the basin, a denser residential pattern begins to take shape with developed opens spaces (Riverhills Golf Course). Impervious cover for this basin is relatively low, estimated at 20%, and is concentrated on the eastern edge of the basin. Future development along SH16 south of Riverhills Country Club & Subdivision is anticipated.

MAJOR STREAMS

The City of Kerrville contains 10 major creeks and tributaries as identified in **Table 2** and as identified by the FEMA Flood Insurance Study (FIS) report dated March 3, 2011 (**Figure 3 thru Figure 7**). The principal flood problems include overflows, flooding and overtopping of low water crossings along Quinlan Creek, Town Creek and the Guadalupe River.

Detailed hydraulic modeling and mapping of the major streams within the city were last performed in 1997 using the U.S. Army Corps of Engineers (USACE) HEC-2 modeling software for Town Creek, Quinlan Creek, Camp Meeting Creek, Elm Creek, and the Guadalupe River. No detailed modeling or mapping has been conducted for Goat Creek, Third Creek, Second Creek, Unnamed Tributary Creek, and Bear Creek. Minor revisions to the floodplain mapping were performed and issued in 2011.

Additionally, new precipitation data has been released by NOAA, as discussed in further detail in section **NOAA Atlas 14 Considerations**, which is anticipated to increase the limits of the floodplain inundation boundary for all FEMA mapped streams. To address these changes in the associated flood damages risk, it is recommended that remapping efforts be considered and planned for in coordination with FEMA, the TWDB, Kerr County and community stakeholders.

Table 2 - FEMA Studied Streams Summary for Kerrville, TX[1]

Stream Name	Study Date	FEMA Map Effective Date	Method of Analysis	Stream Length (mi.)	Parcels Count 100-Year Floodplain	Structures Count 100-Year Floodplain
Goat Creek	1997	2011	FEMA Approx. Methodologies	6.1	29	6
Town Creek	1997	2011	HEC-2	8.7	184	44
Quinlan Creek	1997	2011	HEC-2	7.6	282	127
Third Creek	1997	2011	FEMA Approx. Methodologies	6.2	39	15
Second Creek	1997	2011	FEMA Approx. Methodologies	4.2	4	0
Unnamed Tributary (Lime Creek)	1997	2011	FEMA Approx. Methodologies	2.7	85	72
Elm Creek	1997	2011	HEC-2	1.7	164	119
Bear Creek	1997	2011	FEMA Approx. Methodologies	6.0	0	0
Camp Meeting Creek	1997	2011	HEC-2	4.0	80	10
Guadalupe River Basin at UGRA Dam	1997	2011	HEC-2	-	299	197

[1] Parcel and structure count only includes properties within the city limits. Calculation is estimated by using the effective FEMA Floodplain, Kerr County Appraisal District Parcel Data, and City of Kerrville GIS building footprints.

FEMA PREVIOUS STUDIES TIMELINE AND SUMMARY

1977: The original Federal Insurance Administration (FIA) study was completed in July/August 1977, which covered all significant flooding sources for the City of Kerrville and the unincorporated areas of Kerr County respectively. Hydrologic and hydraulic analysis was performed by Turner Collie & Braden under Contract No. H-3937.

1997: A restudy of the original 1977 FIA study was completed in September 1997. Hydrologic and hydraulic analysis was performed by the United States Army Corps of Engineers (USACE), Fort Worth District, for the Federal Management Agency (FEMA) under Interagency Agreement No. EMW-93-E-4115, Project Order No. 1.

- Letter of Map Revision (LOMR) was incorporated in the restudy.

2008: A second countywide revision was completed in August 2008. Work, completed by MAPVI, compiled existing data to convert the previous Kerr County Federal Insurance Study (FIS) into digital format. Contract No. EMT-2002-CO-0052.

2011: The countywide Flood Insurance Study was revised March 3, 2011, to reflect updates to the vertical datum to North American Vertical Datum of 1988 (NAVD88).

2011: A Letter of Map Revision (LOMR) was issued on May 12, 2011 to remap an unnamed tributary of Town Creek, approximately 1,600 feet downstream of FM 783 (Harper Road) to approximately 830 ft upstream of FM 783 (Harper Road).

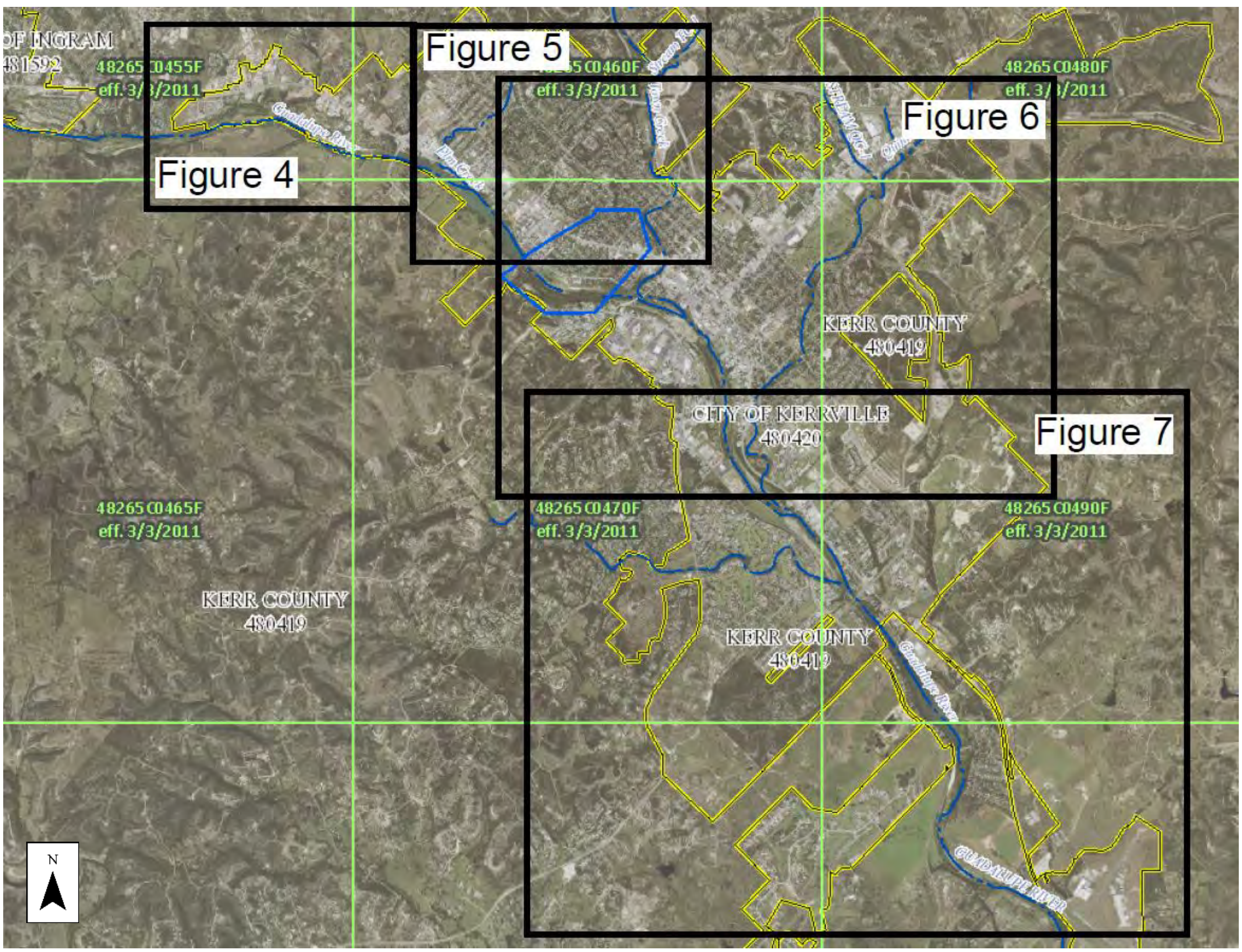

Figure 3 - FEMA National Flood Hazard Key Map

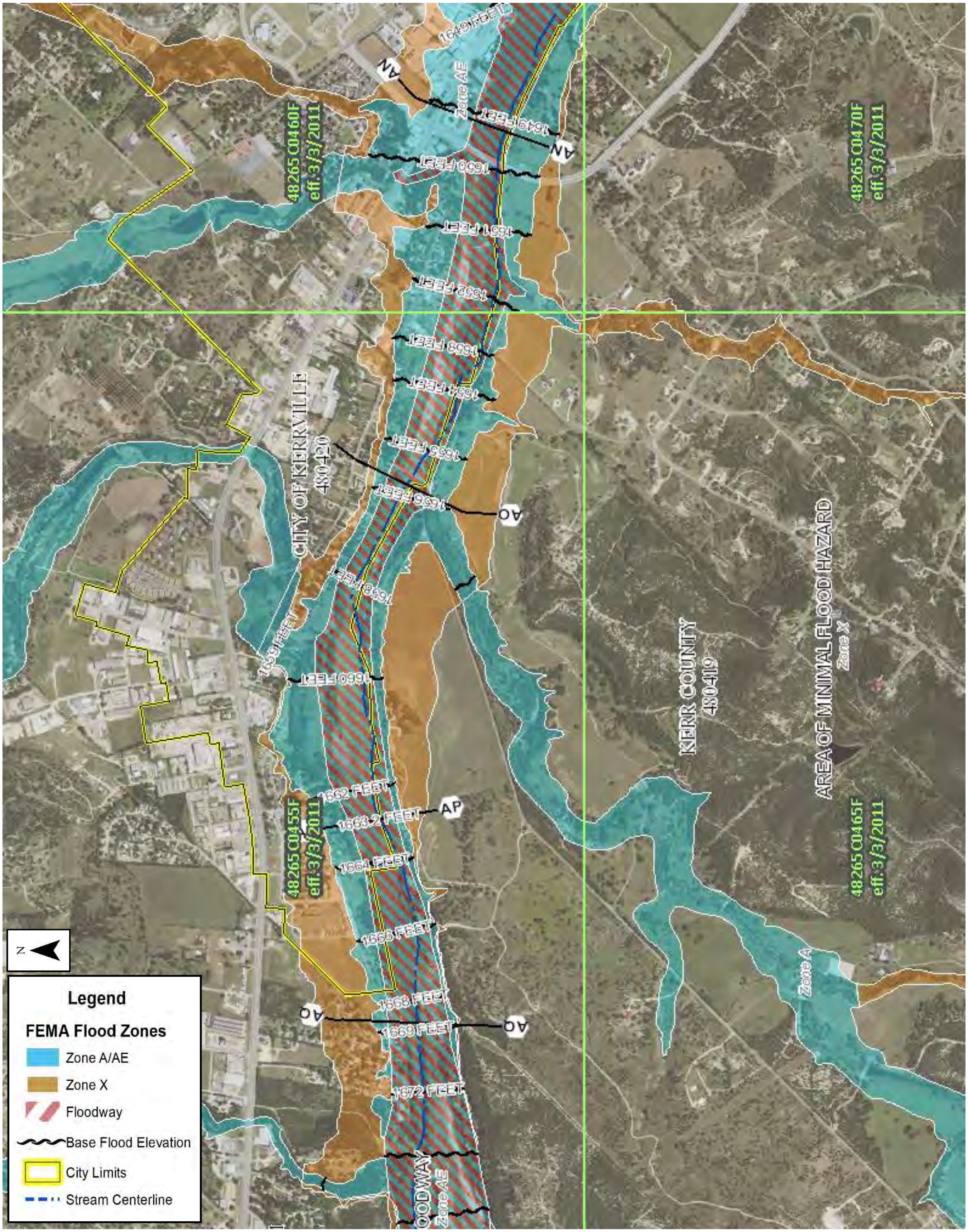

Figure 4 - FEMA National Flood Hazard Layer

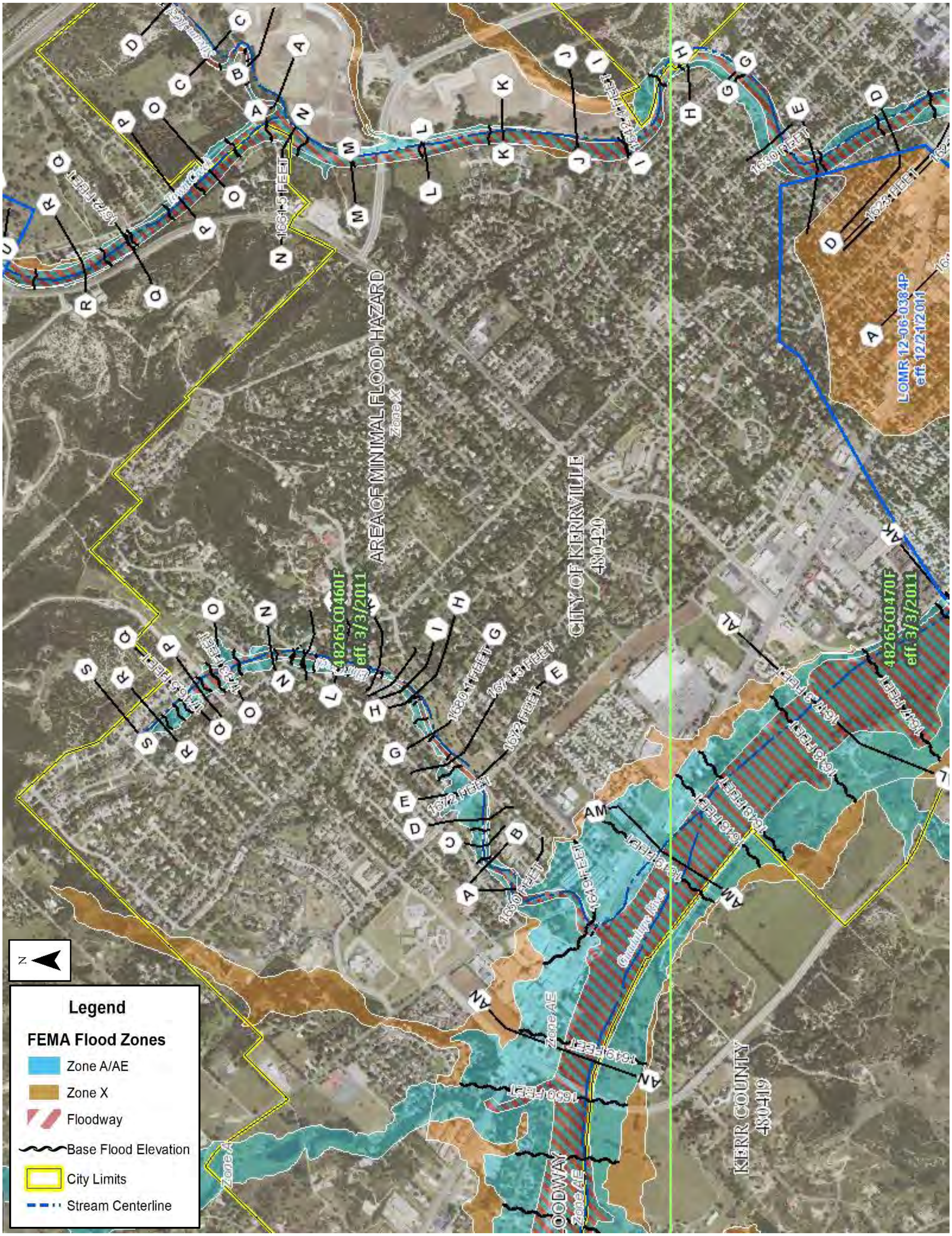

Figure 5 - FEMA National Flood Hazard Layer

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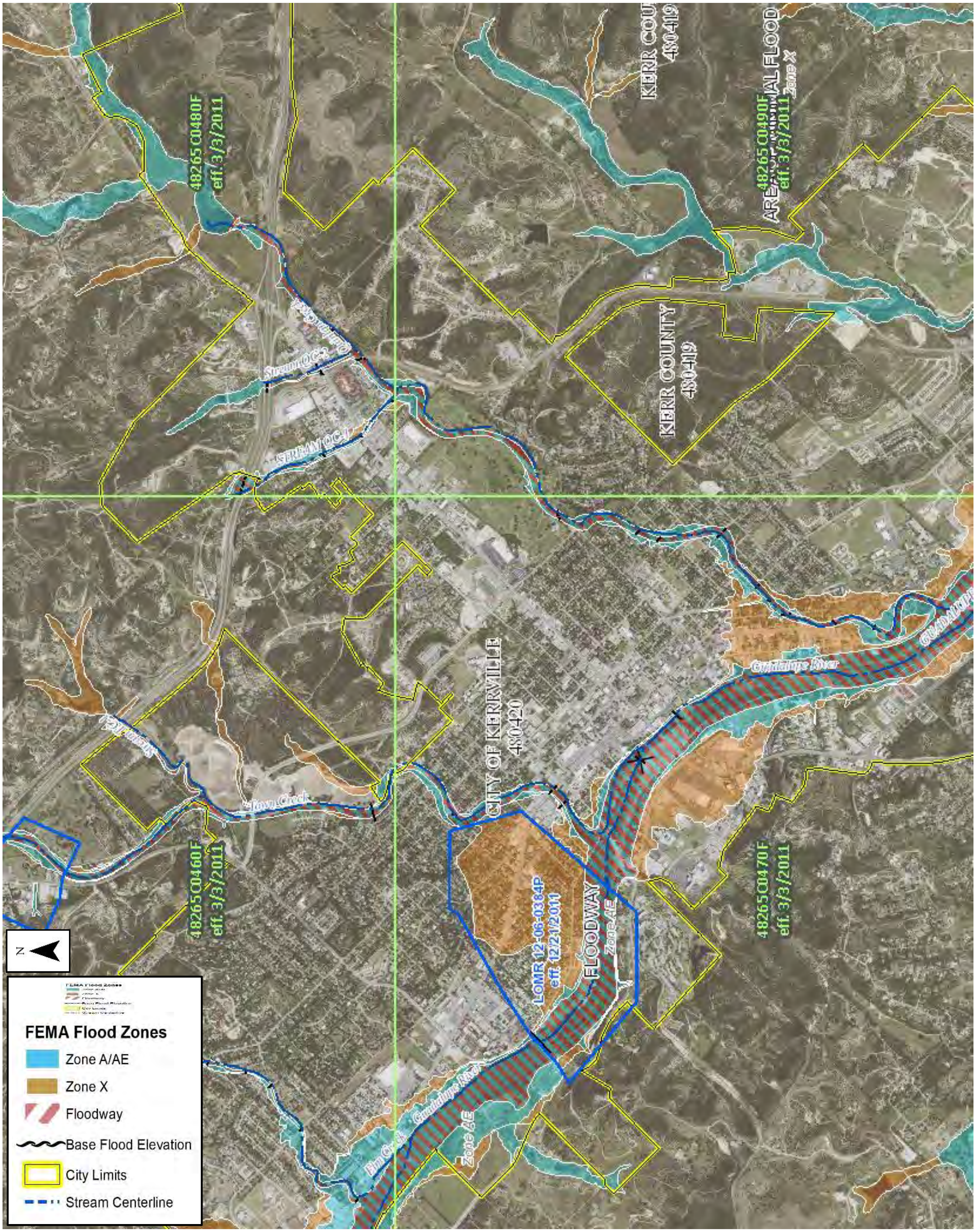

Figure 6 -FEMA National Flood Hazard Layer

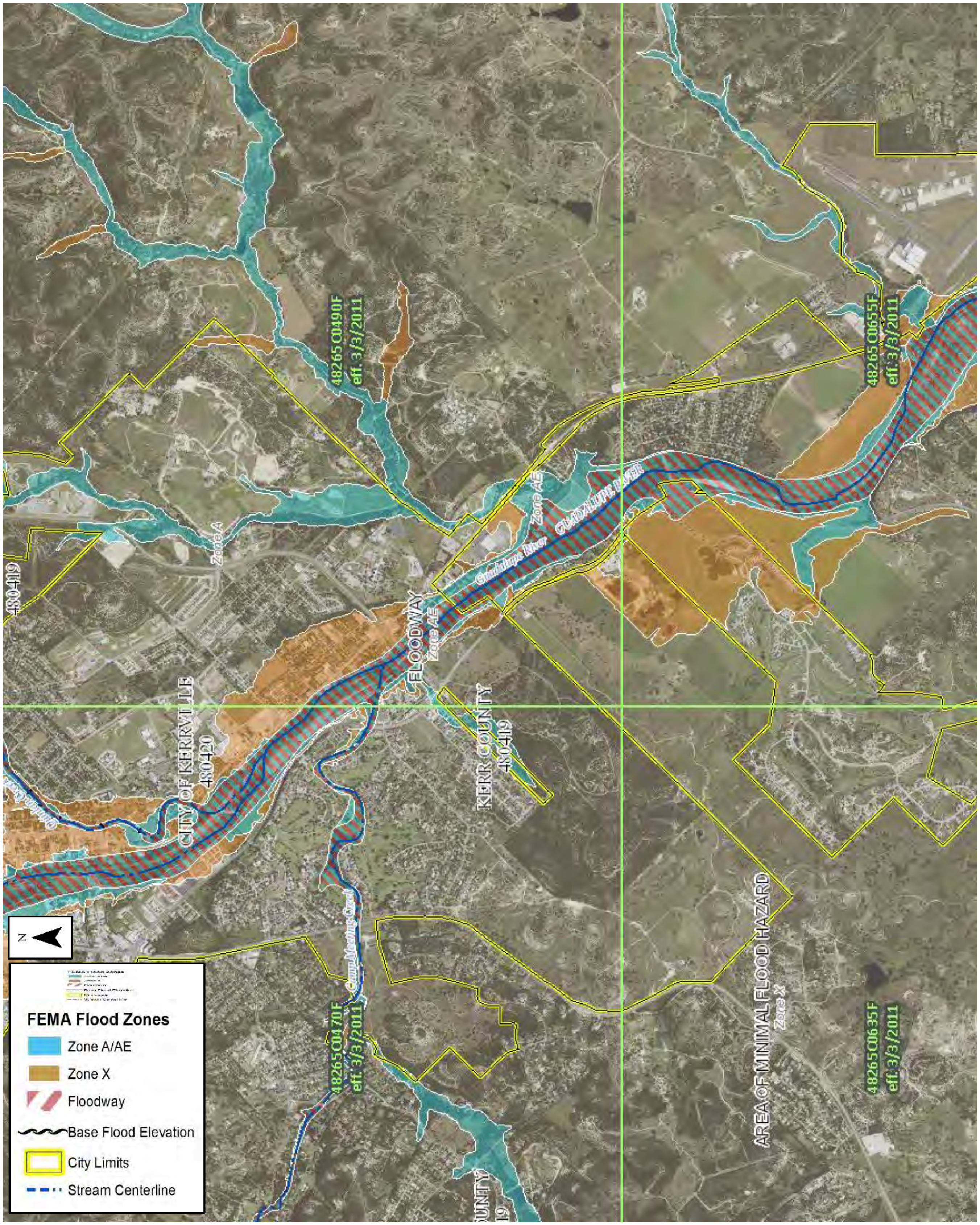

Figure 7 - FEMA National Flood Hazard Layer

HISTORICAL FLOODS

Table 3 shows the top 21 recorded historical flood events that occurred along the Guadalupe River near Kerrville, TX as measured by USGS Gage 08166200 for a period of record from 1932 to 2016. Major flood events are shown to typically occur during the warmer summer months from May thru September. Many of the storms that develop during this time of year start with moist air that will move in from the Gulf of Mexico. These centers of low pressure ascend the Balcones escarpment as they move north, where cool drier air mixes with the rich atmospheric moisture and can lead to potentially heavy rainfall. Slow moving storms are of concern due to the potential for heavy sustained flooding on local and regional levels over a period of several days. This was the situation on August 1st thru the 4th in 1978 when the remnants of tropical storm Amelia moved into the South-Central Texas region and brought widespread property damage and loss of life.

The historical flood of record for the upper Guadalupe River Basin, west of Kerrville, occurred from a rainfall event that lasted from June 30 to July 2, 1932 which amounted to over 35 inches of rain in about 36 hours, as observed at the State Fish Hatchery above Ingram (Major Texas Floods of 1932) which resulted in peak discharges estimated at 196,000 cfs. The rainfall event documented record-breaking stages for all streams above Kerrville and on the Guadalupe River to a point below Spring Branch. Along the streams, many homes, resorts, camps, and other facilities were destroyed (**Figures 9 thru 10**).

The largest flood of record for Quinlan Creek occurred on July 5, 2002, where an accumulated rainfall of approximately 25.0 inches to 30.0 inches was observed between July 1st through the 22nd at the headwaters of Quinlan Creek resulting in a peak discharge estimated at 36,000 cfs. Flooding resulted in heavy damage of property, instability of critical facilities and required a federal assessment and funding assistance **(Figures 11 thru 12).** Over 23 homes were reportedly purchased and demolished, citywide infrastructure was damaged or compromised, and emergency contracts were permitted; fiscal recovery of this storm took over five years.

These historical flood events serve as a stark reminder of the stream power of the Guadalupe River and its associated tributaries and highlights the importance of managing flood risk, development within the floodplain and the need for effective early flood warning systems that serve to protect life and public safety.

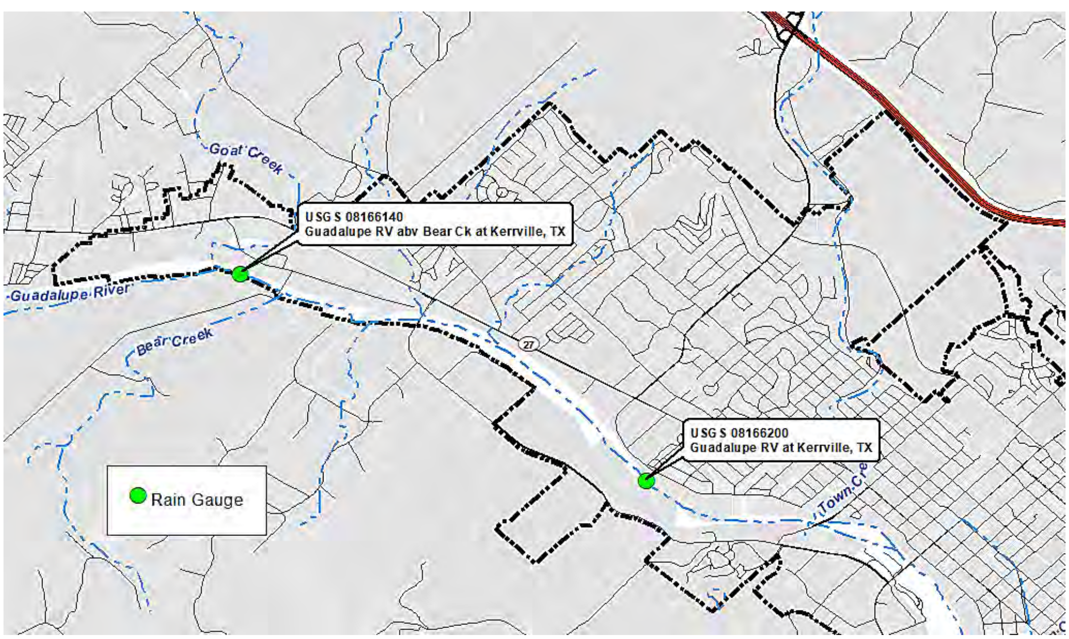

Figure 8 – City of Kerrville Rain Gauge Locations

Rev. 1-9-20

Table 3 - Peak Recorded Flood Events on Guadalupe River at Kerrville, TX (Guadalupe Park) (Source: USGS NWIS)

Rank	Water Year	Month	Date	Peak Flow (cfs)	Gage Height[1] (ft.)
1*	1978	August	08/01/1978	240,000	40.90
2	1932	July	07/02/1932	196,000	39.00
3	1987	July	07/17/1987	141,000	37.72
4	2004	June	06/09/2004	72,700	20.53
5	2000	October	10/23/2000	55,700	17.94
6	1996	October	10/28/1996	54,400	17.73
7	1988	July	07/11/1988	45,900	28.81
8	1986	September	09/26/1986	45,800	28.80
9	2007	May	05/25/2007	39,400	15.21
10	2002	July	07/05/2002	35,900	14.56
11	2010	April	04/16/2010	30,700	13.51
12	1998	August	08/23/1998	15,700	9.81
13	1994	May	05/13/1994	14,100	9.35
14	2016	May	05/29/2016	11,100	8.38
15	1990	August	08/03/1990	10,700	8.22
16	1991	December	12/21/1991	8,710	7.49
17	2012	May	05/11/2012	4,670	5.69
18	1999	June	06/20/1999	3,320	4.87
19	1995	June	06/29/1995	3,240	4.88
20	2015	May	05/24/2015	2,810	4.61
21	1996	September	09/15/1996	2,400	4.33

**Flood Stage Impacts*

**Note 1978 flood not recorded at USGS 08166200 gauge at Kerrville. Peak flows at Spring Branch of 158,000 cfs and 240,000 cfs at Comfort, TX.*

Flood Stage Impacts

35 ft. Major flooding inundates many lowest homes and businesses in Kerrville. Lowest homes and mobile homes flood above Center Point to near Comfort. Secondary and primary roads and bridges in the flood plain are extremely dangerous. Near the USGS 1:100 year flood level.

32 ft. Disastrous flooding of lowest homes and businesses in Kerrville. Numerous homes and mobile homes flood downstream above Center Point to near Comfort. Above the USGS 1:50 year flood level.

28 ft. Flow is near the level of the July 17, 1987 "Bus Tragedy" flood. Major flooding inundates lowest homes and businesses in Kerrville. Numerous homes and mobile home parks flood above Center Point to near Comfort. Near the USGS 1:50 year flood level.

26 ft. Flow reaches the parking lot of a park just below the UGRA Dam on the left bank. Several lowest homes and buildings in Kerrville begin flooding. Flow exceeds the USGS 1:25 year flood level.

24 ft. Flow is near the USGS 1:25 year flood level. Flooding is life-threatening from the headwaters to below Comfort. Lowest homes above Center Point to below Comfort flood.

20 ft. Major flooding threatens structures near the river in Kerrville and evacuations are probable below Kerrville.

17 ft. Flow reaches the first floor of a resort and restaurant upstream left bank. Near the USGS 1:10 year flood.

13 ft. Flow is over the left bank. Secondary and primary roads and bridges are flooded. The swimming pool and tennis court in a resort and restaurant upstream left bank flood. Flow is near the USGS 1:5 year flood level.

9 ft. Flow is over the right bank with no significant damage.

7 ft. Flow is over the right bank.

[1] See "Flood Stage Impacts" for a definition of flood stage risk relationship with historical gage height data.

Figure 9 – Guadalupe River, July 1, 1932 (Source: Kerr County Historical Commission)
Figure 10 - Guadalupe River, July 1, 1932 (Source: Kerr County Historical Commission)

Figure 11 – Property and Home Damage in Kerrville, TX after flood July 2002. Largest Flood of Record for Quinlan Creek. (Source: City of Kerrville)
Figure 12 – Nancy Beth Drive, Kerrville TX after flood July 2002. Largest Flood of Record for Quinlan Creek. (Source: City of Kerrville)

MAJOR STORM DRAIN NETWORK INVENTORY

The City of Kerrville's public storm drain network consists of approximately 7,790 LF of open channels, 26,400 LF of pipes and 430 inlets maintained by the city. In addition, TxDOT owns and maintains another 3,835 LF of open channels and 16,600 LF of storm drain pipes that are within the city limits.

City staff dedicates approximately 3,000 hours yearly to drainage and rehabilitation work with responsibilities including cleaning, grading, and erosion control for the city's storm drainage system. In addition, the city recently adopted a Drainage Maintenance and Rehabilitation Program to maintain and enhance the city's existing infrastructure.

Figure 13 illustrates the existing major storm drain network within the city as provided by the City of Kerrville's GIS Department and subsequently updated by LNV with any observed missing components to the storm drainage network inventory. The inventoried drainage structures include roadside ditches, detention ponds, storm drains, inlets, culverts, and bridges. Storm drain material consists mostly of reinforced concrete pipe, followed by a number of corrugated metal pipes. Major storm drains generally discharge into Town Creek, Quinlan Creek, Camp Meeting Creek and/or the Guadalupe River.

A storm drainage system capacity study was not performed as part of this plan and is recommended to be completed as a subsequent evaluation.

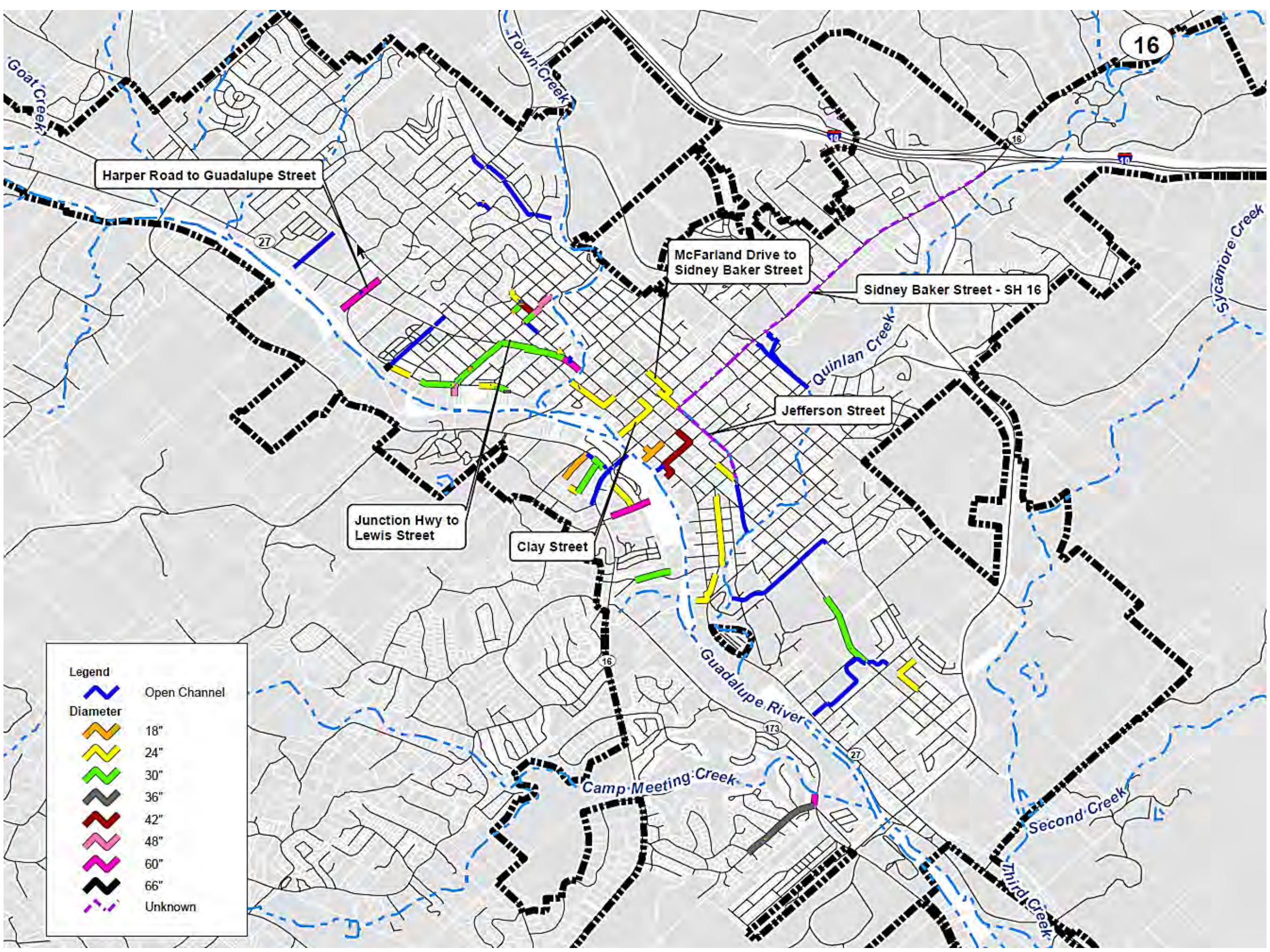

Figure 13 - Kerrville Major Storm Drain Network

LOW WATER CROSSINGS

The City of Kerrville has an estimated nineteen low water crossings within the city limits (**Figure 14**). These numerous crossings were intended as a low-cost solution to provide roadway connectivity across streams such as Quinlan Creek and Town Creek. Overtopping is a consistent occurrence caused by frequent storm events, additionally, large storm events generate excessive overtopping restricting low water crossing usage up to thirty minutes. Crossings are often a public safety hazard during large storm events where flood depths can create dangerous conditions capable of sweeping away vehicles and impairing the ability for emergency responders to access areas of the city.

The low water crossings were identified using the TNRIS Low Water Crossing inventory with additional points added by LNV for hazardous crossings not included in the database. The duration of roadway overtopping is brief, typically lasting less than a half hour.

Several of the problem areas identified by the city for consideration as part of this plan are located along Quinlan Creek including First Street, Fourth Street, and Park Street. Preliminary hydraulic models were developed utilizing FEMA effective hydrologic flows to assess the overtopping of the roadways and the potential for roadway improvements to elevate the roadway above the 25-year or 50-year storm event. During this iterative process, it was determined that each crossing would require a substantial bridge-class structure and significant upstream and downstream channel improvements to mitigate the rise in the floodway elevation. Therefore, it was determined that elevating the roadway was not practical without evaluating the stream and watershed holistically and providing a comprehensive channel and roadway improvement project for the length of the stream.

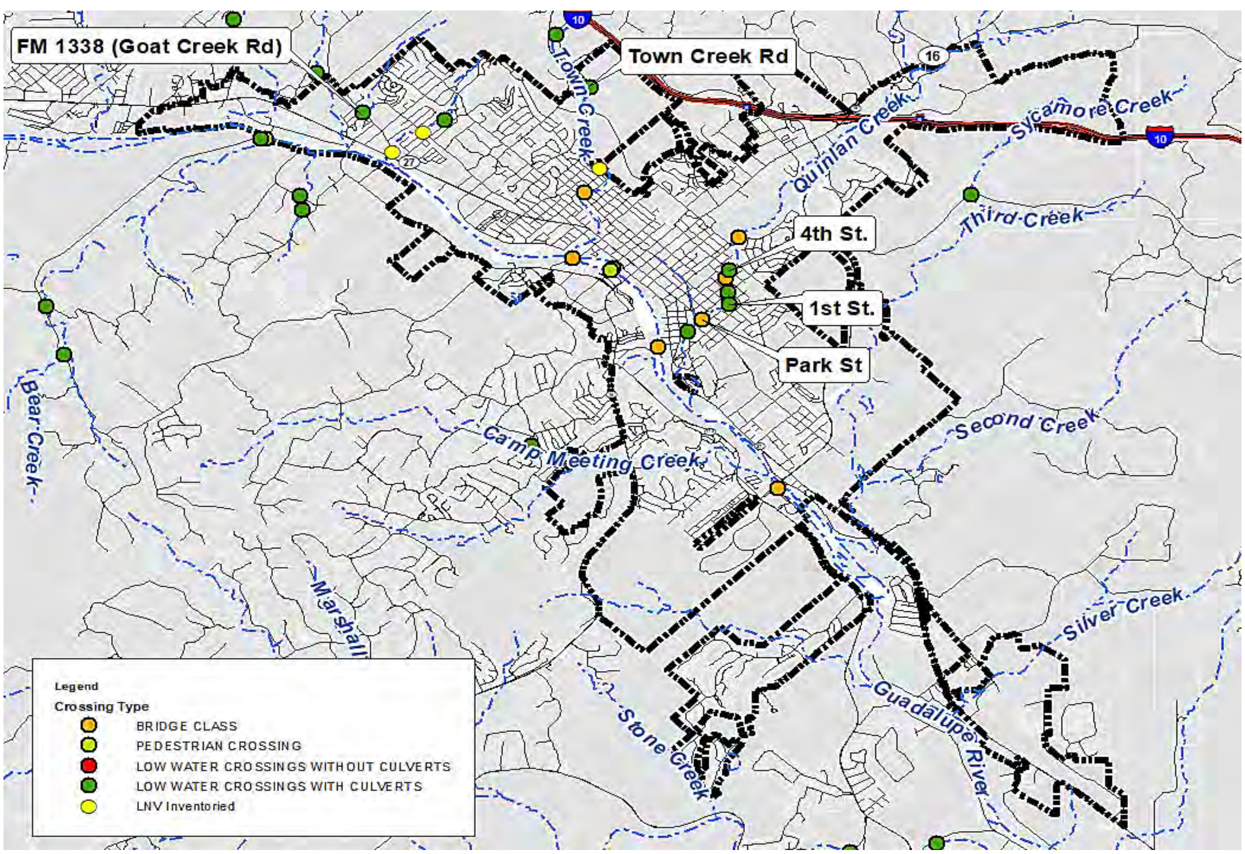

Figure 14 - Low Water Crossing Inventory (Source: TNRIS)

DAM AND DETENTION POND INVENTORY

Ten dams were identified within the City of Kerrville, as illustrated in **Figure 15** and **Table 4**, including Nimitz Lake Dam (Kerrville Ponding Dam), Louise Hays Dam (Kerrville Lake Dam), Kroc Center Detention Dam, Reuse Pond Dam, Lake Happy Dam, and Riverhill Lake Dam. Additional low hazard dams with unidentified names were located on Town Creek near the City of Kerrville Sports Complex (Town Creek Private Dam #1), Town Creek near Silver Saddle Drive (Town Creek Private Dam #2) and Quinlan Creek at Texas Lions League (Quinlan Creek Private Dam #1). These dams serve various purposes such as flood control, recreation, municipal and irrigation uses. A summary of identified city-owned dams is provided in the subsequent sections.

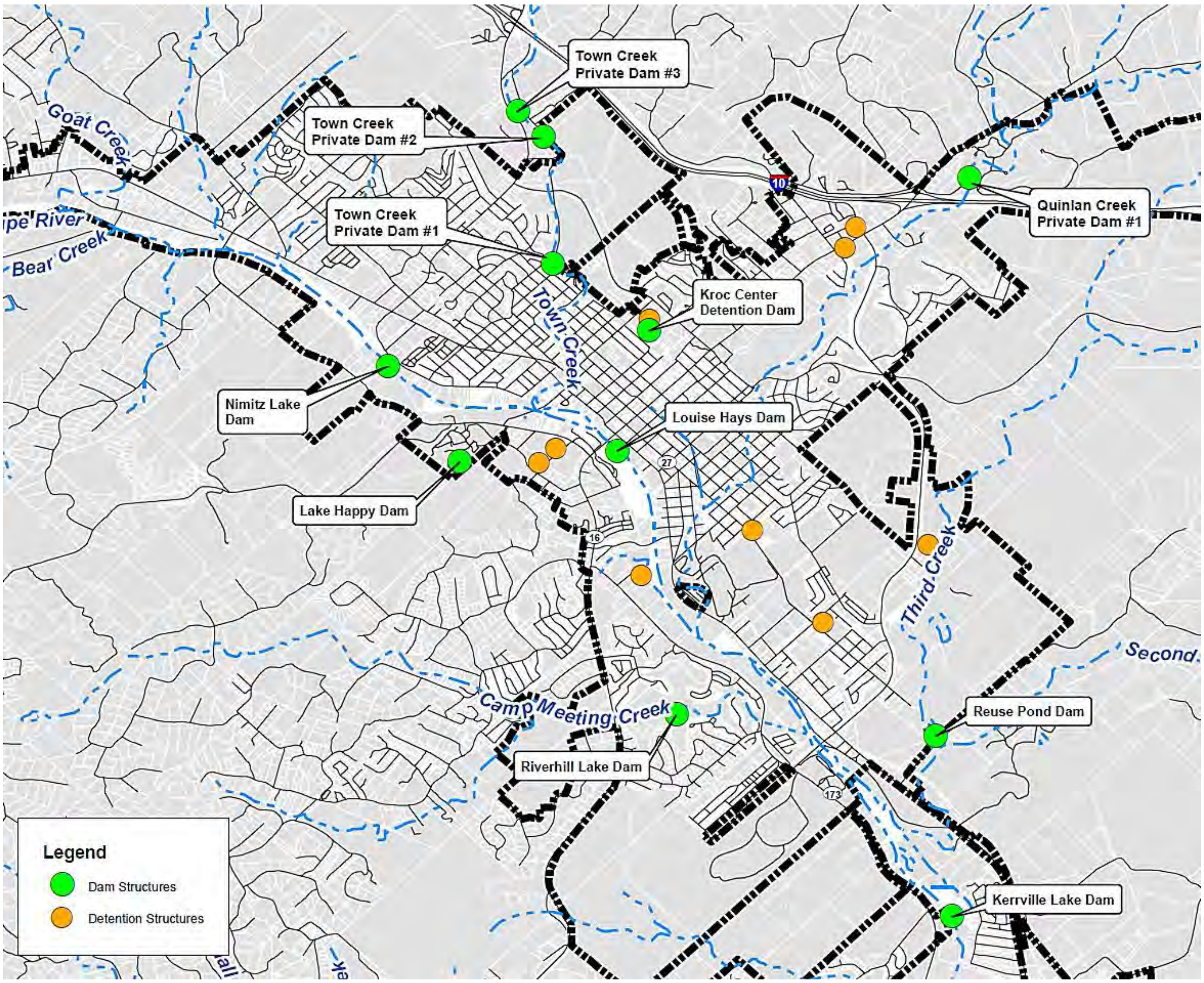

Figure 15 - Dam and Detention Pond Inventory

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Table 4 - Dam Inventory within Kerrville, TX

Name	NID	River	Purpose	Owner	Dam Type	Hazard Classification	Dam Height (ft.)	Storage Volume (ac-ft)	Year Built
Nimitz Lake Dam (Kerrville Ponding Dam)	TX04650	Guadalupe River	Irrigation/ Municipal	City of Kerrville	Concrete Embankment	Significant Hazard	35	840	1980
Flat Rock Dam	TX02457	Guadalupe River	Recreation	Kerr County	Concrete Embankment	TBD	20	820	1956
Louise Hays Dam	N/A	Guadalupe River	Recreation	City of Kerrville	Concrete Buttress	TBD	-	-	1950
Kroc Center Detention Dam	TX09581	Town Creek	Flood Control	City of Kerrville	Earth Embankment	High Hazard	8	36	2009
Reuse Pond Dam	TX07488	Third Creek	Other	City of Kerrville	Earth Embankment	High Hazard	31	291	2018
Lake Happy Dam	TX05884	Guadalupe River	Recreation	Kerrville State Hospital	Earth Embankment	TBD	30	84	1974
Riverhill Lake Dam	TX04408	Camp Meeting Creek	Irrigation	Riverhill Country Club	Earth Embankment	High Hazard	23	250	1967
Quinlan Creek Private Dam #1	N/A	Quinlan Creek	-	Private	Concrete	TBD	-	-	-
Town Creek Private Dam #1	N/A	Town Creek	-	Private	Concrete	TBD	-	-	-
Town Creek Private Dam #2	N/A	Town Creek	-	Private	Concrete	TBD	-	-	-

NIMITZ LAKE DAM (KERRVILLE PONDING DAM)

Nimitz Lake and Dam (Kerrville Ponding Dam) is the city's most significant dam structure which is a relatively small channel dam on the Guadalupe River that serves as a water supply for the City of Kerrville. The dam was constructed in 1980 and major repairs were completed in January 1985 due to seepage problems in the abutments and overtopping damages that resulted in the loss of a portion of the concrete cap and significant erosion of the clay core over approximately one-third of the length of the dam. The subsequent structural repairs and choice of roller compacted concrete have proven to hold up during overtopping flood flows.

The dam was originally owned by the Upper Guadalupe River Authority and purchased by the City of Kerrville in April 1998. In 2011, the city renamed the reservoir Nimitz Lake in honor of World War II Navy Fleet Admiral Chester W. Nimitz.

In 2015, a Volumetric Survey was performed by the TWDB for Nimitz Lake and a storage capacity of 735 acre-feet of water and a maximum allowable impoundment capacity of 840 acre-feet was determined. Sedimentation continues to be a major concern for the upper reaches of the lake near the dam. The conclusions of the study recommended resurveying the lake in 10 years or after a major flood event.

LOUISE HAYS DAM

Louise Hays Dam (**Figure 16**) is not an identified dam in the USACE National Inventory of Dams (NID) list. The dam is estimated to have been completed in the 1950s. The dam type is a concrete buttress dam structure that has experienced issues of seepage and concrete spalling over the years.

Figure 16 - Kerrville Flooding at Louise Hays Dam May 29, 2016 (Source: Kerrville Photo.com)

KROC CENTER DETENTION DAM

The Kroc Center Detention Dam was constructed in 2009 as a small sized earthen flood control dam and is classified by TCEQ as a high hazard dam due to the risk of public safety in the event of a breach. The dam's outlet structure (service spillway) and emergency spillway discharge into a drainage channel before being released onto the adjacent, residential George Street. Outflow through the service spillway was designed to discharge a maximum of 35 cfs onto the street to minimize existing downstream drainage problems. The resulting drawdown time for the pond is estimated at 7.2 hours for the 100-year storm event.

The pond and its associated discharge of water onto George Street has remained a problem for the city and is included as one of the city's identified problem areas for analysis as part of this study.

REUSE POND DAM

The City of Kerrville's Reuse Pond Dam, a 95-million-gallon pond constructed in 2018, is an earthen embankment dam with the purpose of impounding water for consumptive use by the city. The Reuse Dam is located at the confluence of Third Creek and Second Creek. The Reuse Pond receives flow from the nearby City of Kerrville Waste Water Treatment Plant (WWTP) via a 24" gravity-fed reuse line and a 12" reuse force main distributes water from the pond into the reuse distribution network.

According to the Kerrville Water Reuse Pond Design Report, a dam breach event for the reuse pond would result in a discharge rate of 50,700 cfs. A breach of the dam during a storm event could result in inundation to properties downstream of the dam, along Spur 100 and SH-27.

LAND USE DEVELOPMENT PATTERNS

The City of Kerrville is projected to have steady growth over the next 30 years which will create new strains on the city's drainage system by impacting the volume of runoff received by local streets, storm drains, and waterways, as well as the water quality that enters the city's natural riparian areas and rivers.

City development has primarily occurred along the northern side of the Guadalupe River within the Elm Creek, Quinlan Creek, and Town Creek Basins. The highest impervious cover is concentrated along Junction Highway and Sidney Baker Street, with the majority of all basins remain generally undeveloped as natural shrubland (**Figure 17**).

According to the *2050 Comprehensive Plan*, the city's growth as identified by the targeted strategic catalyst areas is primarily located along the banks of the Guadalupe River along Town Creek near IH-10 and up the length of Sidney Baker Sreet (SH-16) (Quinlan Creek Basin) (**Figure 18**).

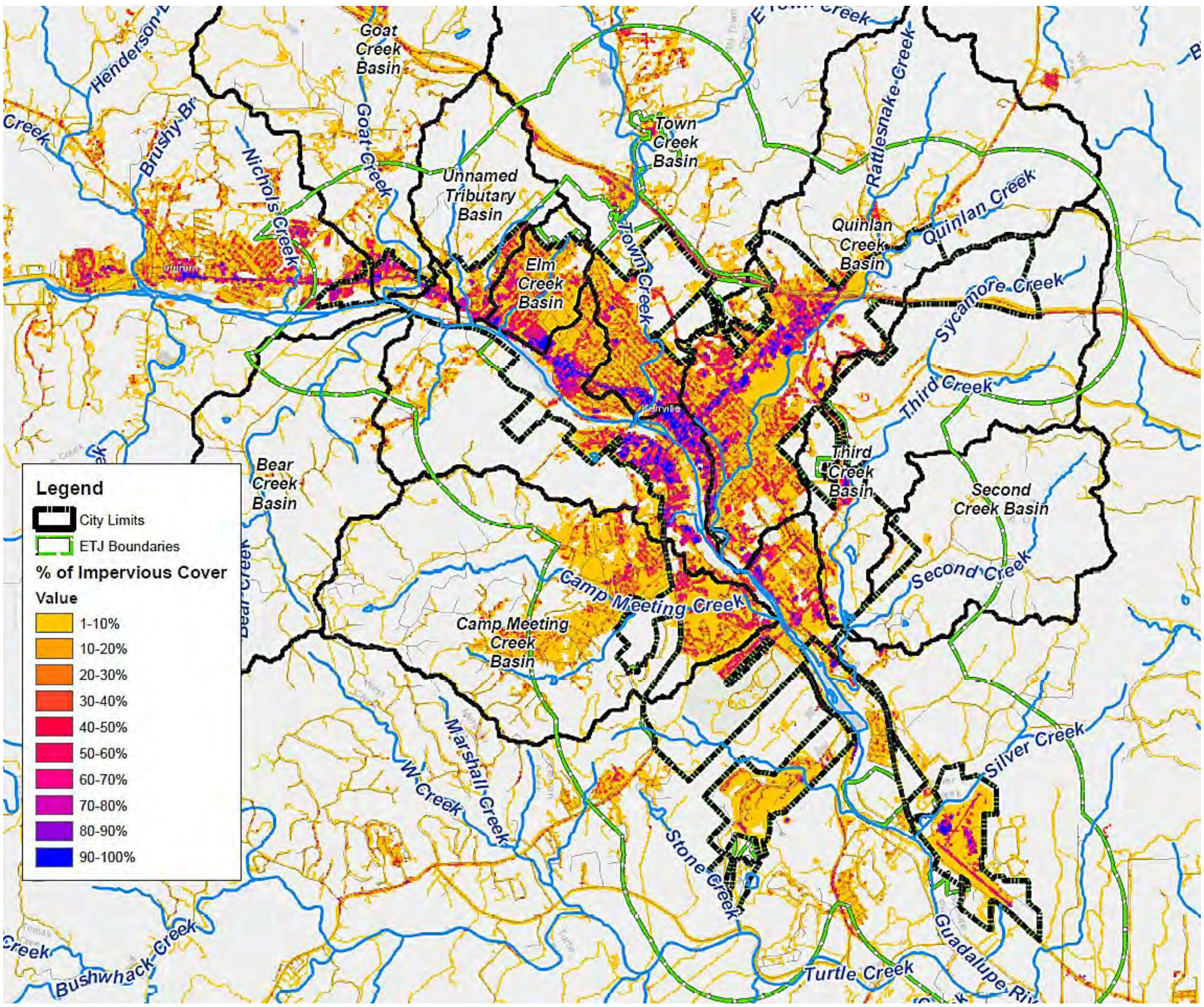

Figure 17 - NLCD 2011 Percent Developed Imperviousness (CONUS)

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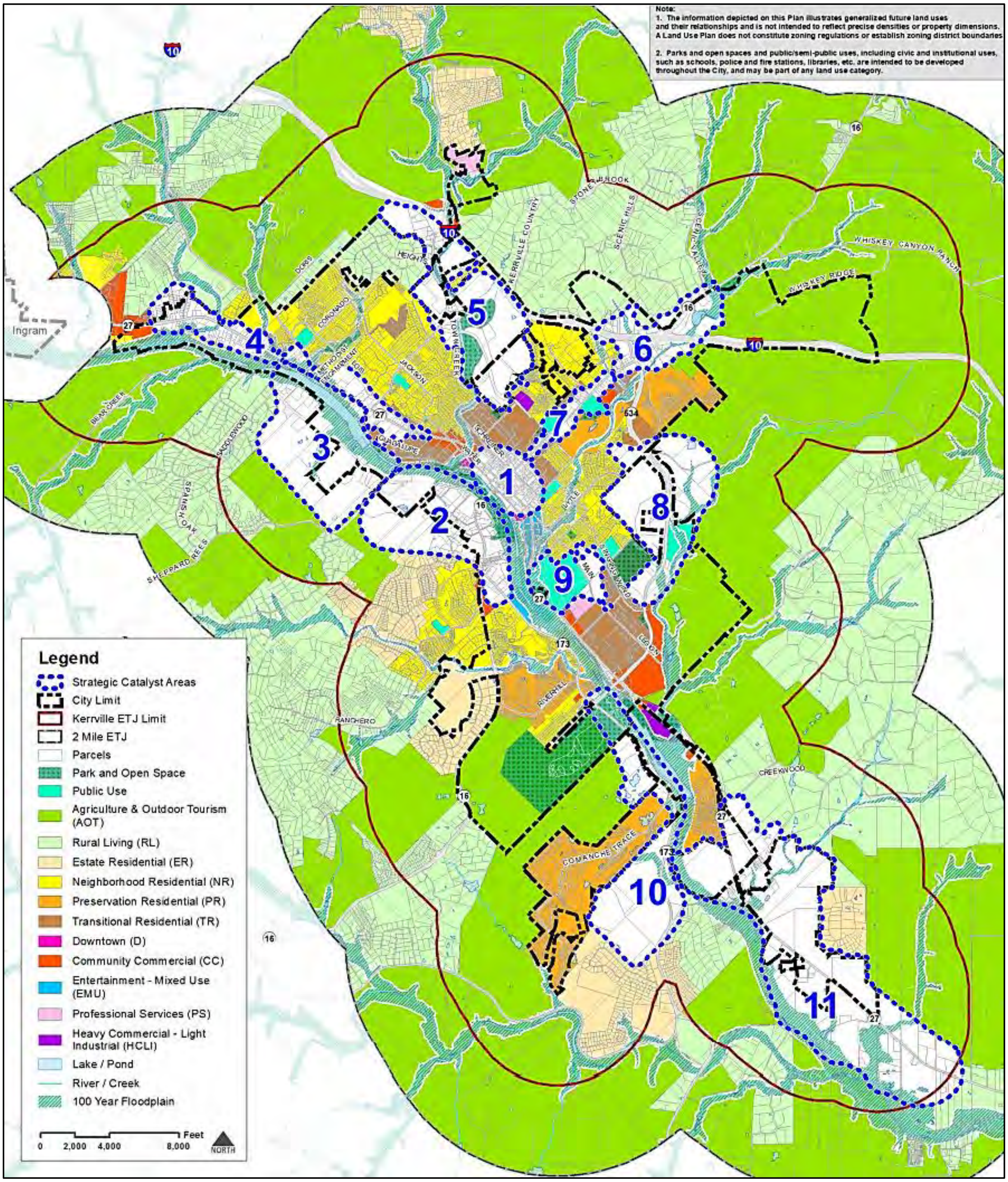

Figure 18 - City of Kerrville Future Land Use Map (Source: 2050 Comprehensive Plan)

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FUTURE LAND USE

The *2050 Comprehensive Plan* identifies several Special Catalyst Areas (SCAs) throughout the city. These SCAs contain various levels of mixed land use patterns that are appropriate for each individual area, yet flexible enough to accommodate residential, commercial, and industrial all within the same relative location. The SCAs with the most potential for new buildings and growth are SCA-5 (Town Creek Road/ Holdsworth Drive.), SCA-6 (IH-10 & SH16), SCA-8 (Loop 534), SCA-10 (Hwy 173), and SCA-11 (Hwy 27).

The SCA-6 (IH-10 & SH16 Intersection) and SCA-9 (Schreiner University area) present significant opportunity for development based on the 2050 Comprehensive Plan. This potential development will likely increase the amount of runoff that drains to Quinlan Creek due to impervious cover needed for development. Three of the identified problem areas (First St, Fourth St, and Park St) in this report could be impacted by any significant residential or commercial development in SCA-6 or SCA-9.

The city can expect to see residential development within the existing city limits as well as the Extra Territorial Jurisdiction (ETJ) in the future. Residential development is anticipated along existing road corridors of State Highway 16 (north and south), State Highway 173 (south), and State Ranch Road 783. The potential for residential development also exists on the land south of Spur 98 and Goat Creek Road (north from State Highway 27 towards Interstate Highway 10). **Figure 20 and Figure 21** depict an example of changing land use and increased development in the city.

POPULATION GROWTH

The Kerrville 2050 Comprehensive Plan projects steady growth for the study area (City proper and 2-mile ETJ) with a population estimated of 33,000 in 2015 and projected to grow to 37,866 to 45,637 people by 2050 (**Figure 19**). According to U.S. Census records, the average household size is 2.19 which represents to correspondent increase in households over the next 30 years of approximately 2,222 to 5,851 households.

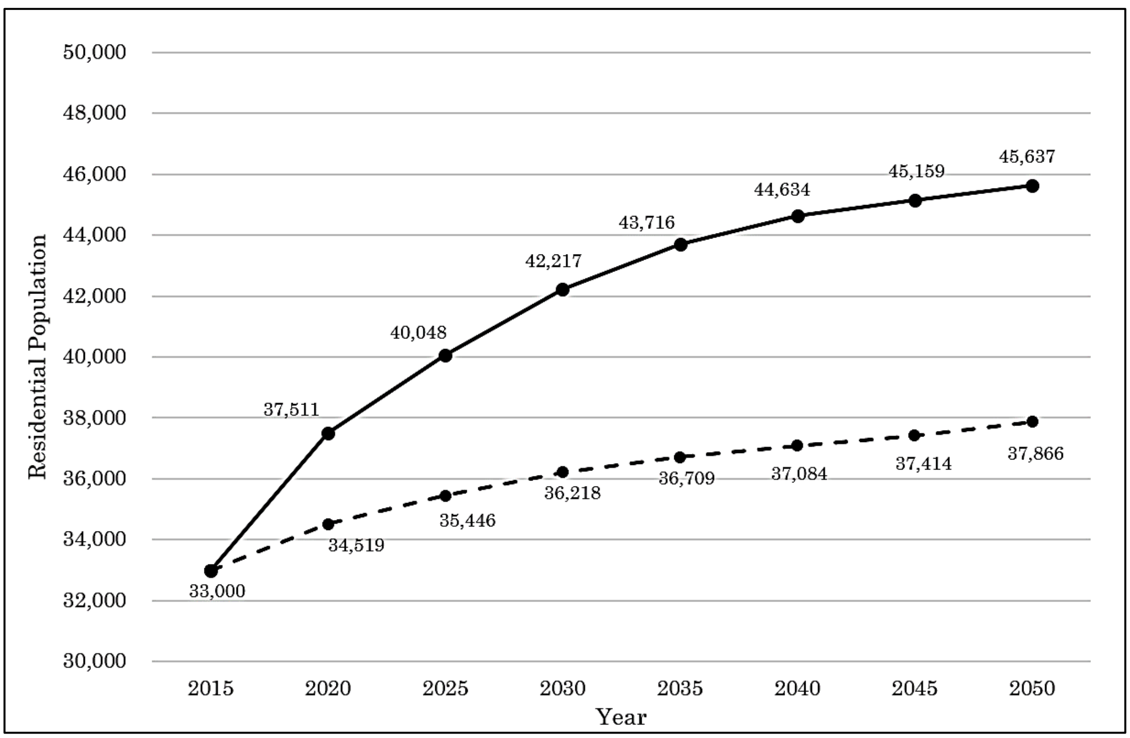

Figure 19 - Kerrville 2050 Comprehensive Plan Projected Population growth

Figure 20 - 1995 Land Use

Figure 21 - 2018 Land Development

PROBLEM AREA IDENTIFICATION

OVERVIEW

The City of Kerrville identified fourteen project areas for further investigation and development of proposed solutions as part of this Stormwater Master Plan Report (**Figure 22**). Additional problem areas exist within the city and are anticipated to be addressed in subsequent updates to this Stormwater Master Plan.

Each project area was evaluated using approximate methodologies to assess a probable improvement option to address the stormwater concern. Detailed information regarding hydrologic and hydraulic methodologies may be found in **Appendix D – Technical Support Data**. Project costs were estimated with considerations to the costs associated with planning and design, construction, permitting, land acquisition and utility adjustment needs and are located in **Appendix B – City-Wide Drainage CIPs**. The solutions and costs presented in this report are conceptual-level and additional detailed analysis will be required for all projects presented prior to implementation. Additionally, each of the projects was evaluated and scored based on criteria for public safety, economics, project timing, and environmental considerations (See **PRIORITIZATION OF DRAINAGE CIP PROJECTS** section for additional information.)

The fourteen problem areas evaluated by this plan consist of six in the Quinlan Creek Basin, four in the Town Creek Basin, one in the Elm Creek Basin, one in the Unnamed Tributary (Lime Creek) Basin, and two in the Upper Guadalupe River Basin.

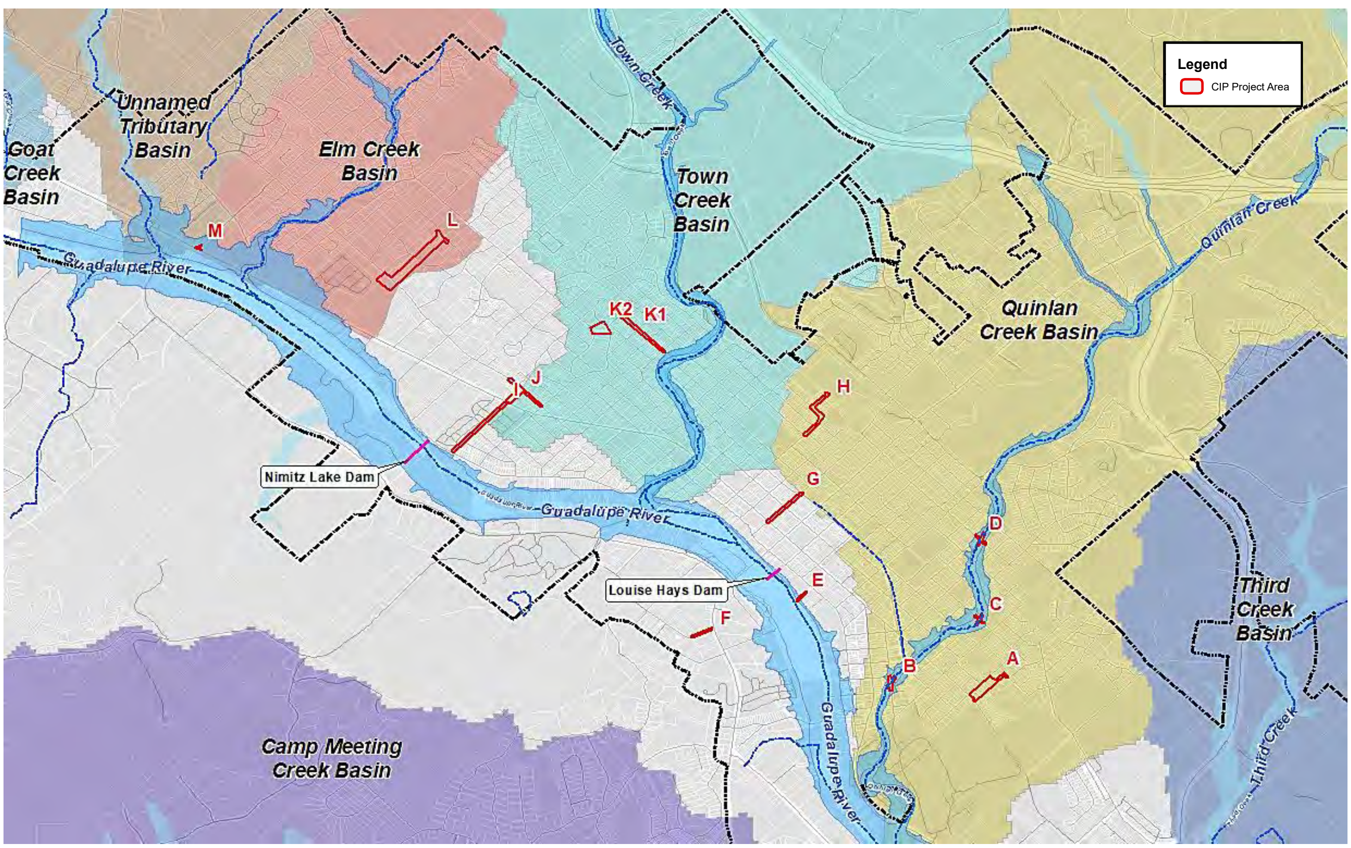

Figure 22 - Problem Areas Map

PROJECT AREA LIST AND DESCRIPTIONS

A. EAST MAIN TO PINTO TRAIL EARTHEN CHANNEL

Primary Concerns: Structural flooding, erosion/channel stability

Project Description: Undersized drainage channel, bank overtopping, property flooding, and erosion stability are the main concerns in this area. The drainage pattern generally flows in a southwesterly direction. Runoff makes its way along Tomahawk Trail and continues across Singing Wind Road towards Pinto Trail. Runoff is then captured by a concrete trapezoidal channel that transitions into an earthen channel at a relatively steep slope resulting in erosion and channel stability issues. During significant storm events, flow overtops the channel at the 90-degree bend or bypasses the channel. Further downstream towards East Main Street, flow is known to overtop the western bank towards Westminster Street.

Peak Flow Summary: Drainage Area = 83.6 acres at Pinto Trail and Tomahawk Trail (**Appendix B Exhibit A01**).

Peak Flows – Ultimate Conditions Q_{25} = 430 cfs, Q_{50} = 491 cfs, Q_{100} = 555 cfs. (**Appendix B Exhibit A02**)

Figure 23 - Pinto Trail Project Area Map

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Figure 24 - Earthen Drainage Channel Facing Upstream

Figure 25 - Pinto Trail Channel Facing Downstream

B. PARK STREET – LOW WATER CROSSING

Primary Concerns: Frequent roadway overtopping, flooding, public safety, limited emergency access

Project Description: Flooding, dangerous roadway conditions and frequent roadway closures during most rain events have been reported. Quinlan Creek at Park Street drains approximately 7,400 acres and ultimately discharges into the Guadalupe River. Quinlan Creek is mapped as a FEMA Regulatory Zone AE Floodplain with a floodway. Park Street Low Water Crossing consists of one - 3' x 10' box culvert with an estimated full flow capacity of 282 cfs, which is less than 5% of the 5-year frequency storm event.

Peak Flow Summary: Drainage Area = 7,450 acres at Park Street low water crossing (**Appendix B Exhibit B01**)

FEMA Peak Flows – Existing Conditions Q_{10} = 5,750 cfs, Q_{50} = 9,350 cfs, Q_{100} = 10,830 cfs (**Appendix B Exhibit B02**)

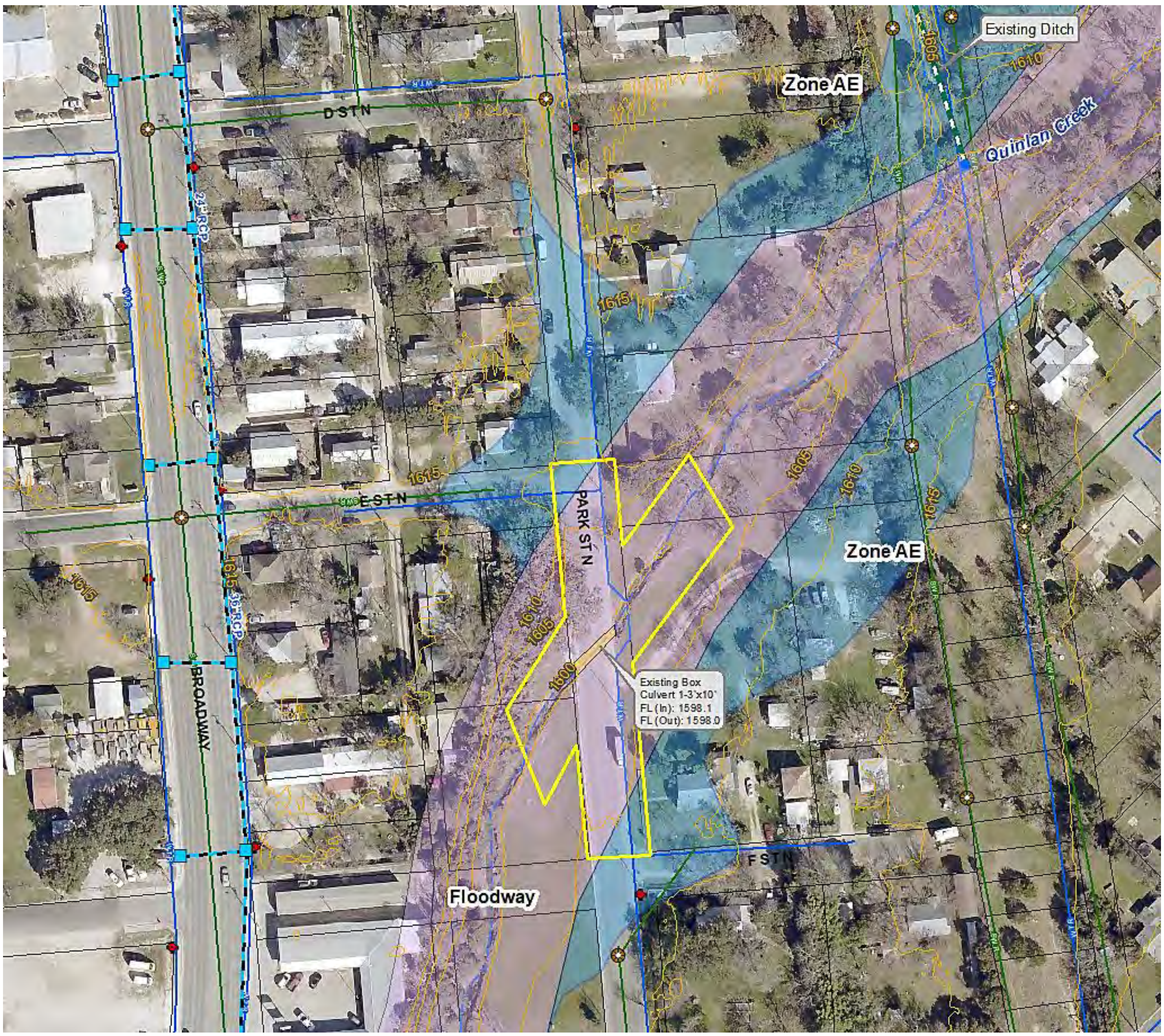

Figure 26 - Park Street Project Area Map

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Figure 27 – Park Street Facing Downstream

Figure 28 - Flooding at the Park Street Low Water Crossing – April 2019 (Source - City of Kerrville)

C. FIRST STREET – LOW WATER CROSSING

Primary Concerns: Frequent roadway overtopping, flooding, public safety, limited emergency access

Project Description: Flooding, dangerous roadway conditions and frequent roadway closures during most rain events have been reported. The First Street Low Water Crossing consists of five – 24" RCPs providing a combined full flow capacity of approximately 141 cfs which is roughly 2.5% of the 5-year frequency storm event.

Peak Flow Summary: Drainage Area = 6,930 acres at First Street Low Water Crossing (**Appendix B Exhibit C01**)

FEMA Peak Flows – Existing Conditions Q_{10} = 5,560 cfs, Q_{50} = 8,980 cfs, Q_{100} = 10,400 cfs (**Appendix B Exhibit C02**)

Figure 29 - First Street Project Area Map

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Figure 30 – First Street Low Water Crossing

Figure 31 - Flooding at the First Street Low Water Crossing – April 2019 (Source - City of Kerrville)

D. FOURTH STREET – LOW WATER CROSSING

Primary Concerns: Frequent roadway overtopping, flooding, public safety, limited emergency access

Project Description: Flooding, dangerous roadway conditions and frequent roadway closures during most rain events have been reported. Fourth Street Low Water Crossing consists of two – 24" RCPs providing a combined capacity of approximately 32 cfs which is roughly 1% of the 5-year frequency storm event.

Peak Flow Summary: Drainage Area = 6,740 acres at Fourth Street Low Water Crossing (**Appendix B Exhibit D01**)
FEMA Peak Flows – Existing Conditions Q_{10} = 5,110 cfs, Q_{50} = 8,080 cfs, Q_{100} = 9,350 cfs (**Appendix B Exhibit D02**)

Figure 32 - Fourth Street Project Area Map

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Figure 33 – Fourth Street Culvert Facing Downstream

Figure 34 - Flooding at the Fourth Street Low Water Crossing – April 2019 (Source - City of Kerrville)

E. SPRING STREET – EROSION AT OUTFALL

Primary Concerns: Erosion/channel stability, loss of property

Project Description: Excessive erosion at the Spring Street outfall is the main concern in this area. Discharge from a 54” RCP is collected within a gabion mattress channel and discharged down a steep embankment into the Guadalupe River. Soil instability has resulted in head cutting, undermining of the soils beneath the gabion structure and mass wasting of the stream bank. Left unprotected, the erosion is at risk of further incising upstream.

Peak Flow Summary: Drainage Area = 34.8 acres (**Appendix B Exhibit E01**)
Peak Flows – Ultimate Conditions Q_{25} = 228 cfs, Q_{50} = 260 cfs, Q_{100} = 294 cfs (**Appendix B Exhibit E02**)

Figure 35 - Spring Street Project Area Map

Figure 36 – Channel Erosion at Spring Street

Figure 37 – Channel Failure at Guadalupe River Bank

F. HILL COUNTRY DRIVE AT SH 16

Primary Concerns: Roadway flooding, property damage to vehicles

Project Description: Street and property flooding are the main issues in this area. The roadway profile is in a sag with two - 36" CMPs located at the flowline of the roadway sag. The storm drain is at grade resulting in frequent roadway overtopping, street closures, and stalling of vehicles.

Peak Flow Summary: Drainage Area = 23 acres at Hill Country Drive and Sidney Baker Street (SH 16). **(Appendix B Exhibit F01)**
Peak Flows – Ultimate Conditions Q_{25} = 184 cfs, Q_{50} = 211 cfs, Q_{100} = 238 cfs **(Appendix B Exhibit F02)**

Figure 38 - Hill Country Drive Project Area Map

Figure 39 – Hill Country Culvert at Sidney Baker Street Intersection (Upstream Side)

Figure 40 - Hill Country Drive Flooding (Source: Kerrville Daily Times)

G. CLAY STREET (SCHREINER TO SH27):

Primary Concerns: Roadway flooding, structural flooding

Project Description: A relatively large area of runoff drains toward Clay Street, including contributing discharge from the Kroc Center Detention Pond outfall. The runoff received exceeds the capacity of the undersized storm drainage system which includes generally 24" or 30" CMPs. Additional flooding is experienced on Jefferson Street, Schreiner Street and other adjacent streets with flow discharged to the south towards the Guadalupe River or east towards Quinlan Creek.

Peak Flow Summary: Drainage Area = 188 acres (**Appendix B Exhibit G01**)
Peak Flows – Ultimate Conditions Q_{25} = 656 cfs, Q_{50} = 735 cfs, Q_{100} = 819 cfs. (**Appendix B Exhibit G02**)

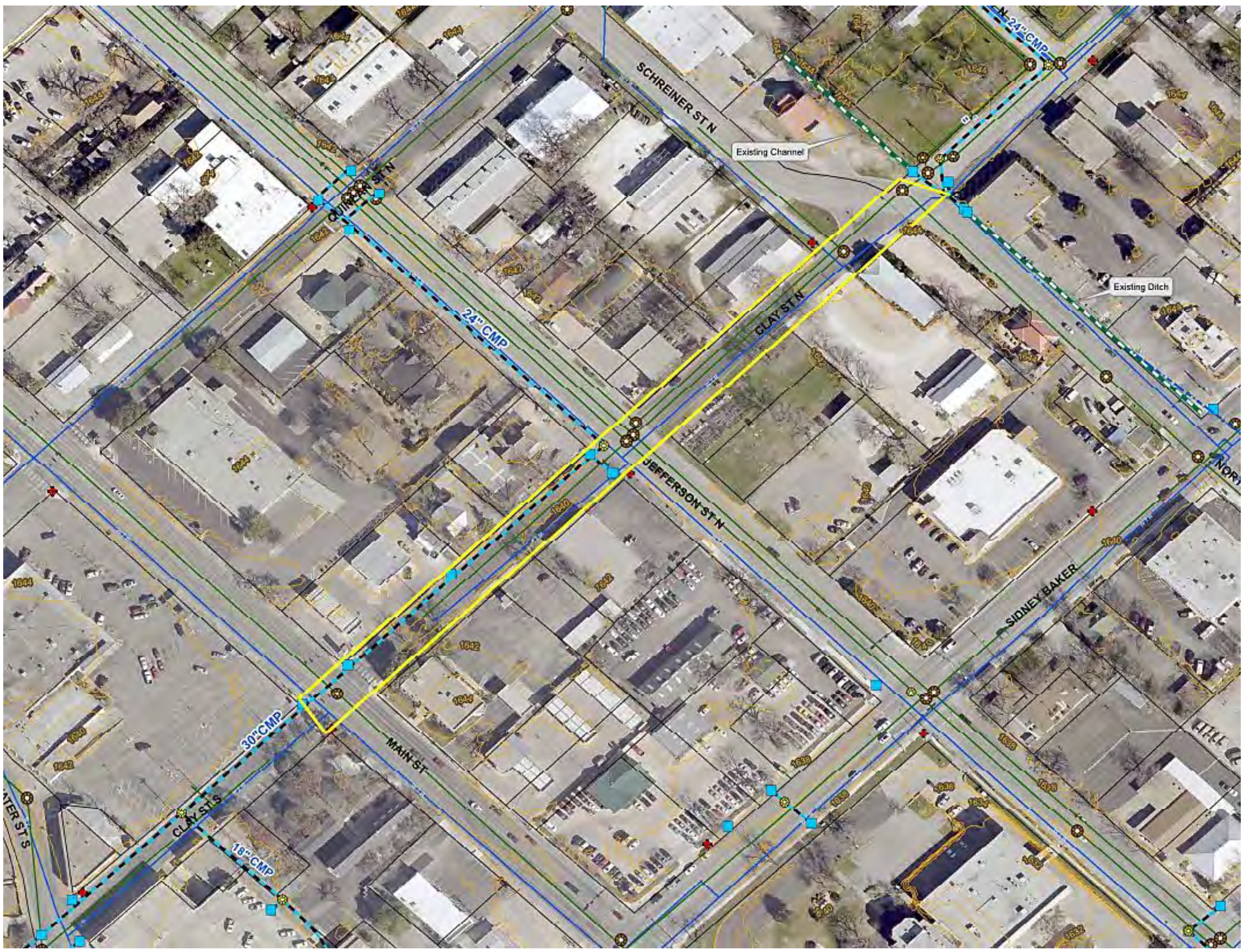

Figure 41 - Clay Street Project Area Map

Figure 42 – Stormwater Inlet at Clay Street

Figure 43 – Roadside Ditch at Clay Street

H. KROC CENTER DETENTION POND AND SPILLWAY OUTFALL

Primary Concerns: Structural damages, extended duration of roadway flooding, accelerated deterioration of roadway pavement.

Project Description: Widespread street and property flooding are the main concerns in this area. Kroc Center Detention Pond, classified by TCEQ as a High Hazard Dam, is designed to hold runoff from a watershed area consisting of approximately 120 acres. During large storm events, the detention pond fills up to near full capacity, resulting in a steady extended release from the pond outfall, discharging onto George, Miller and Hays Streets with no subsurface drainage system resulting in accelerated pavement deterioration.

Peak Flow Summary: Drainage Area = 120 acres (**Appendix B Exhibit H01**)
Peak Flows – Ultimate Conditions Q_{25} = 814 cfs, Q_{50} = 930 cfs, Q_{100} = 1,052 cfs. (**Appendix B Exhibit H02**)

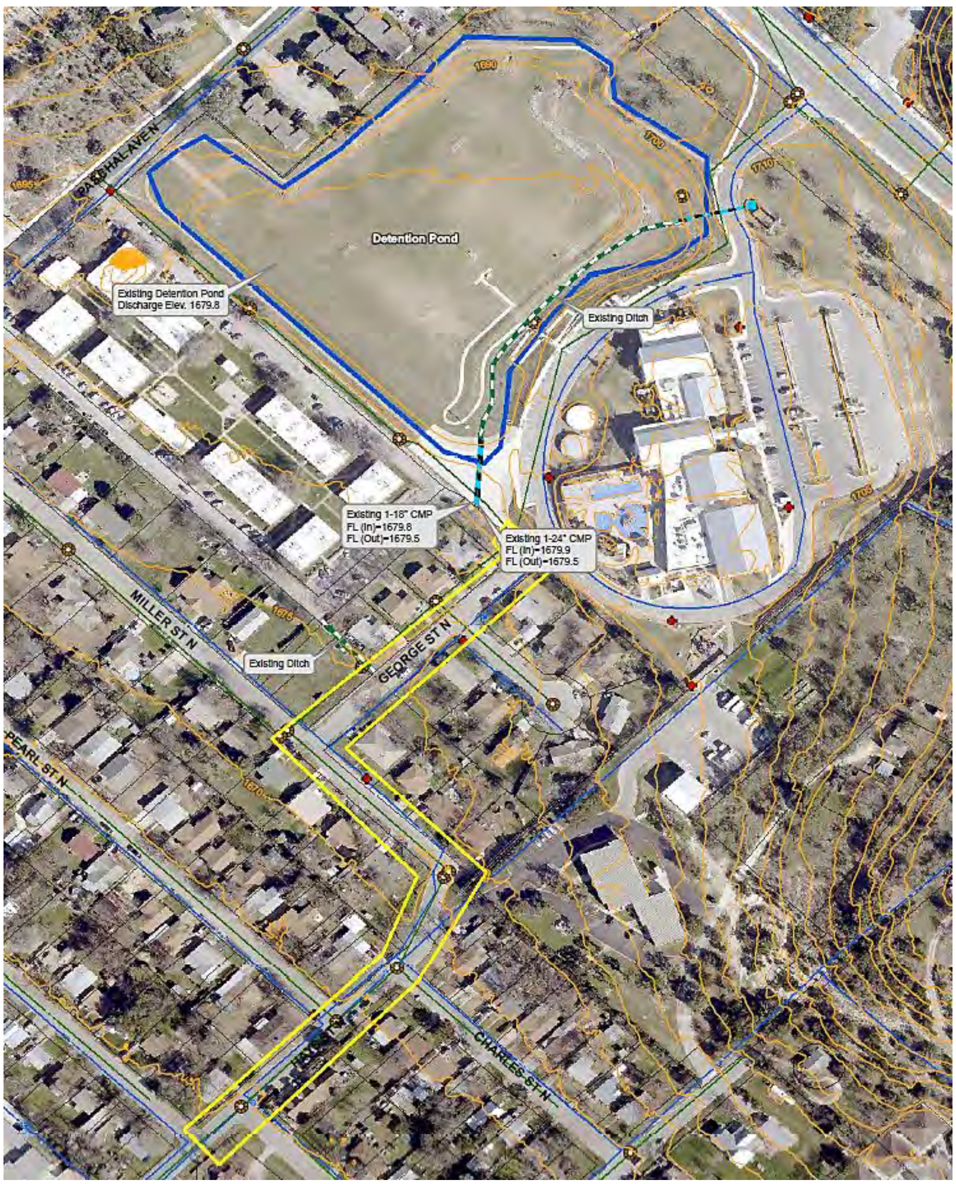

Figure 44 - Kroc Center Project Area Map

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Figure 45 – Outflow Structure for Kroc Center Detention Pond

Figure 46 - Kroc Center Draining onto George Street - Looking Downstream – April 2019 (Source - City of Kerrville)

I. TAKE IT EASY CHANNEL (SH27 TO GUADALUPE ST.)

Primary Concerns: Erosion/channel stability, loss of property, channel capacity

Project Description: Steep channel banks have resulted in instabilities and slope failures due to the erosive velocities in the channel. Take It Easy Channel is generally bounded from Guadalupe Street at the downstream and extends to Junction Highway. Approximately 320 acres of stormwater runoff drains into an open channel and into the Take It Easy drainage channel is then captured by a 66" storm pipe that outfalls into the Guadalupe River.

Peak Flow Summary: Drainage Area = 320 acres (**Appendix B Exhibit I01**)
Peak Flows – Ultimate Conditions Q_{25} = 920 cfs, Q_{50} = 1,050 cfs, Q_{100} = 1,180 cfs. (**Appendix B Exhibit I02**)

Figure 47 - Take It Easy Channel Project Area Map

Figure 48 – Unstable Side Slope for Take It Easy Channel

Figure 49 – Channel Profile for Take It Easy Channel Facing Downstream

J. LOIS STREET (BETWEEN WOODLAWN AND OX)

Primary Concerns: Structural flooding, roadway flooding, emergency access

Project Description: Street flooding, roadway closures, property flooding, and structural flooding are the main concerns in this area. Runoff generally drains to the south/southeast and is captured by a shallow drainage channel with a concrete bottom and discharges across five – 3.5' x 5' oval CMPs into Take It Easy Channel. Due to the insufficient capacity of the Junction Highway culverts, the shallow and relatively flat drainage channel backs up water in the system that then spills over onto adjacent properties.

Peak Flow Summary: Drainage Area = 135 acres (**Appendix B Exhibit J01**)
Peak Flows – Ultimate Conditions Q_{25} = 613 cfs, Q_{50} = 698 cfs, Q_{100} = 787 cfs. (**Appendix B Exhibit J02**)

Figure 50 - Lois Street Project Area Map

Figure 51 – Undersized Concrete Ditch at Lois Street

Figure 52 - Flooding at Lois Street – April 24, 2019 (Source - Residents)

K. HARPER ST. BETWEEN CULBERSON AVE. (K1) & LEWIS AVE AND CIRCLE AVE (K2)

Primary Concerns: Roadway flooding, slope stability erosion, sediment accumulation in roadway.

Project Description: Problem Area K has been separated into two sub-areas referred to as K1 for Harper Street which is associated with roadway flooding due to a relatively flat terrain with insufficient slope to drain runoff. Problem Area K2 is associated with the runoff received from Jackson Road draining down a steep earthen embankment towards Circle Avenue which has resulted in excessive erosion, gully formations and sediment washout into the roadway.

Peak Flow Summary: K1 Drainage Area = 13 acres; K2 = 23 acres (**Appendix B Exhibit K01**)
Peak Flows – K1 Ultimate Conditions Q_{25} = 66 cfs, Q_{50} = 75 cfs, Q_{100} = 85 cfs;
K2 Ultimate Conditions Q_{25} = 170 cfs, Q_{50} = 194 cfs, Q_{100} = 219 cfs
(**Appendix B Exhibit K02**)

Figure 53 - Harper Street Project Area Map

Figure 54 – Culberson Avenue Facing Downstream

Figure 55 – Circle Avenue Earthen Channel Erosion

L. JACK DRIVE – UNDERSIZED INLET

Primary Concerns: Street flooding, property flooding

Project Description: Street flooding and ponding are the main issues in this area. Approximately 27 acres drain to Jack Drive. Overland flow generally travels in a southwesterly direction across Jackson Road and flows towards an undersized inlet on Jack Drive with unknown downstream connectivity. Overtopping of Jackson Road is known to frequently occur with overland runoff travelling across multiple lots in a southwesterly direction towards Virginia Drive and Lois Street.

Peak Flow Summary: Drainage Area = 27 acres at Jack Drive (**Appendix B Exhibit L01**)
Peak Flows – Ultimate Conditions Q_{25} = 127 cfs, Q_{50} = 145 cfs, Q_{100} = 163 cfs. (**Appendix B Exhibit L02**)

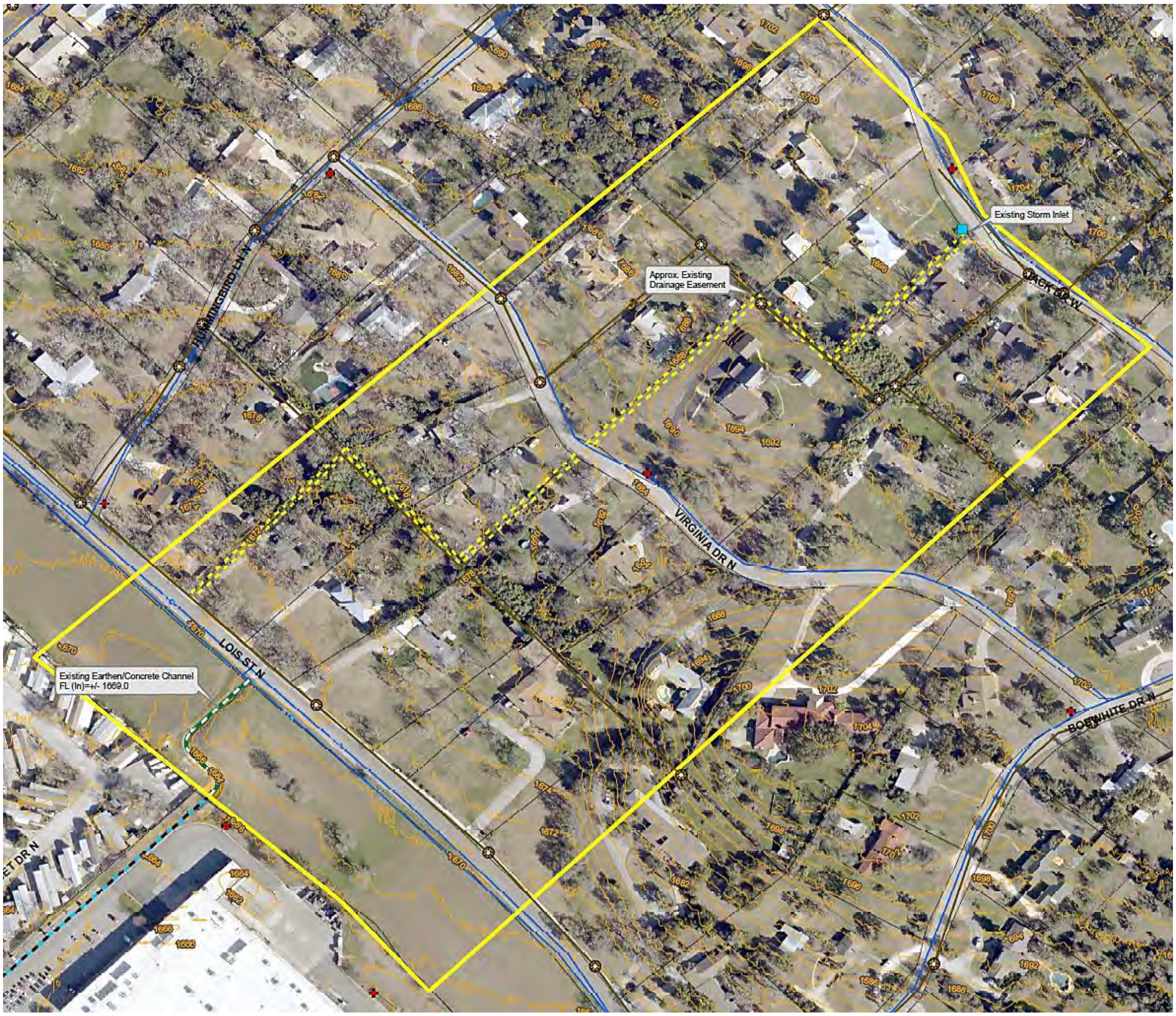

Figure 56 - Jack Drive Project Area Map

Figure 57 – Outflow of Undersized Storm Drain at Jack Drive Facing Upstream

Figure 58 - Inadequate Inlet Capacity at Jack Drive - April 24, 2019 (Source - Residents)

M. INTERSECTION OF CORONADO DR. AND JUNCTION HWY

Primary Concerns: Roadway flooding

Project Description: Street flooding and ponding at the intersection is the main drainage concern in this area. Approximately 8 acres of contributing drainage area collects at the low lying area at the northern side of the intersection of Coronado Drive and Junction highway, where runoff ponds due to lack of positive drainage.

Peak Flow Summary: Drainage Area = 8 acres at Coronado Drive and Junction Highway (**Appendix B Exhibit M01**)
Peak Flows – Ultimate Conditions Q_{25} = 79 cfs, Q_{50} = 90 cfs, Q_{100} = 102 cfs. (**Appendix B Exhibit M02**)

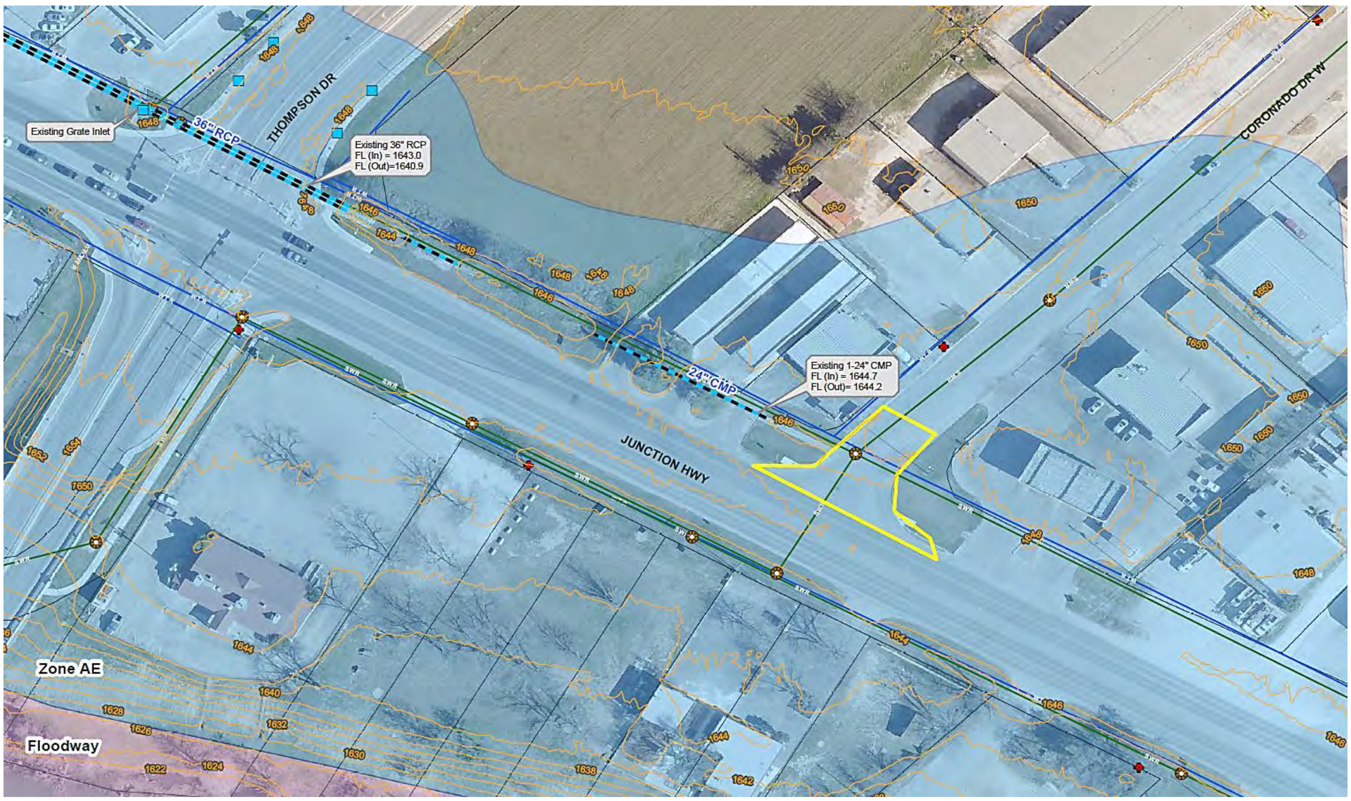

Figure 59 - Coronado Drive Project Area Map

Figure 60 – Intersection of Coronado Drive and Junction Highway (Facing South)

Figure 61 – Ponding at Coronado Drive at Junction Highway Intersection (Facing Southeast)

PROJECT POTENTIAL SOLUTIONS

Each of the fourteen selected project areas, as identified by the City of Kerrville, was evaluated using approximate methodologies for analysis and determination of conceptual solutions. Each problem area was then scored based on the relative severity of problem as further described by the **Prioritization of Drainage Projects** section of this report. Detailed information regarding hydrologic and hydraulic methodologies may be found in **Appendix D – Technical Support Data**. Project costs were estimated in 2019 dollars with considerations to the costs associated with planning and design, construction, permitting, land acquisition and utility adjustment needs and are located in **Appendix B – City-Wide Drainage CIPs**. The solutions and costs presented in this report are at a conceptual-level and additional detailed analysis will be required for all projects prior to implementation.

Refer to **Appendix B** for project summary sheets and detailed conceptual solutions exhibits.

Projects implemented in future years should consider a 6%-7% increase, per year, to the total project cost.

A. PINTO TRAIL

The Pinto Trial conceptual design solution intends to provide flood relief to the properties adjacent to the channel at risk of flooding and removing them from the localized 100-year floodplain for ultimate conditions. To minimize the potential for adverse impacts downstream, it is recommended that channel improvements extend further downstream from Main Street to Acorn Boulevard by increasing the capacity of the existing earthen channel. Further investigations and detailed hydraulic analysis is required to further assess channel sizing and culvert capacity.

Project assumes that Parcel 534019, at the upstream end of the project, is owned by the City of Kerrville and will therefore not require any land acquisition.

The project scope of work is summarized as follows:

1. Widen the existing channel between Acorn Boulevard and East Main Street for a length of approximately 1,320 LF of grass-lined trapezoidal channel with an 8-foot bottom width, 3.5-foot depth and 6:1 side slope.
2. Widen the existing channel between East Main Street to Pinto Trail for a length of approximately 690 LF and replace with a mechanically stabilized earth (MSE) rectangular concrete segmental block wall system with a 15-foot bottom width, 3-foot depth and vertical side slopes (**Figure 62**).
3. Construct a grass-lined trapezoidal channel from Tomahawk Drive and transition to the proposed MSE rectangular channel.
4. Hydro-mulch or grass seed the proposed earthen channels.

Refer to **Appendix B Exhibit A03** for the proposed improvements exhibit.

The total opinion of probable engineering and construction costs for this project is estimated to be $0.8 to $1 million. See **Appendix B** for an itemized breakdown of quantities and costs.

Figure 62 – Project Area Conceptual Layout

B. PARK STREET LOW WATER CROSSING

The conceptual design solutions evaluated in this study explored opportunities to replace the low water crossing at Park Street at Quinlan Creek with a structure that provides minimum flood protection from the 50-year storm event. Multiple iterations were considered in varying combinations that included replacement of the existing culverts, channel widening, and capacity improvements and reprofiling the roadway. Efforts were made in the conceptual modeling process to identify opportunities to mitigate adverse impacts associated with the proposed improvements with respect to the FEMA Floodway and Floodplain. Each option provided minimal benefits, were very high in cost, and at best provide conveyance capacity for up to the 5-year storm event before overtopping. Therefore, it was determined that individual roadway culvert replacements did not provide an adequate cost-benefit to recommend implementation. Therefore, as an alternate to mitigate and improve public safety, it is recommended that automated flood gates be installed at each low water crossing.

Refer to **Appendix B Exhibit B03** for the proposed improvements exhibit showing extent of anticipated channel and culvert improvements required for 5-year frequency storm event flood protection.

The total opinion of probable engineering and construction costs for this solution is estimated at approximately $3.2 Million for channel and culvert capacity improvements. The recommended mitigating solution of an Automated Flood Gate System is estimated to cost approximately $200,000. See **Appendix B** for the itemized breakdown of quantities and costs.

The project scope of work for culvert and channel improvements are summarized as follows:

1. Perform a detailed hydrologic and hydraulic study of Quinlan Creek to better quantify the flood risk conditions and evaluate alternatives to address Park Street, First Street, and Fourth Street.
2. Construct channel widening and capacity improvement through the length of the channel and replace the culvert crossings at Park, First and Fourth Streets with bridge-class culverts that mitigate adverse impacts to the FEMA Floodway and Floodplain.

Recommended Mitigating Solutions of work is summarized as follows:

Install a High-Water Alert Lifesaving Technology (HALT) flashing light and automated flood gate to alert drivers of dangerous waters and encourage alternative routes.

Figure 63. Flood Detection System Automated Gate Example

C. FIRST STREET LOW WATER CROSSING

Conceptual design was evaluated for Quinlan Creek at First Street low water crossing to alleviate existing flooding situation and road blockage. Iterative design calculations were performed to increase the flow carrying capacity of the culvert. Various options for improvements such as channel modification, roadway regrading, and culvert replacement were considered. Efforts were made in the conceptual modeling process to identify opportunities to mitigate adverse impacts associated with the proposed improvements with respect to the FEMA Floodway and Floodplain. Each option provided minimal benefits, were very high in cost, and at best provide conveyance capacity for up to the 5-year storm event before overtopping. Therefore, it was determined that individual roadway culvert replacements did not provide an adequate cost-benefit to recommend implementation. Therefore, as an alternate to mitigate and improve public safety, it is recommended that automated flood gates be installed at each low water crossing.

The total opinion of probable engineering and construction costs for this solution is estimated at approximately $4.9 Million for channel and culvert capacity improvements. The recommended mitigating solution of an Automated Flood Gate System is estimated to cost approximately $200,000. See **Appendix B** for the itemized breakdown of quantities and costs.

The project scope of work is summarized as follows:

1. Perform a detailed hydrologic and hydraulic study of Quinlan Creek to better quantify the flood risk conditions and evaluate alternatives to address Park Street, First Street, and Fourth Street.
2. Construct channel widening and capacity improvement through the length of the channel and replace the culvert crossings at Park, First and Fourth Streets with bridge-class culverts that mitigate adverse impacts to the FEMA Floodway and Floodplain.

Recommended Mitigating Solutions of work is summarized as follows:

Install a High-Water Alert Lifesaving Technology (HALT) flashing light and automated flood gate to alert drivers of dangerous waters and encourage alternative routes.

Figure 64 - Flood Detection System Automated Gate Example

D. FOURTH STREET LOW WATER CROSSING

As discussed earlier, conceptual solutions for low water crossing were analyzed and cost-effective solution of automated flood gates are recommended for optimum utilization of resources. Undersized culverts at Fourth Street are only capable to convey 20 cfs with a roadway flooding depth of 9.38 ft for a 100-year storm. According to the FEMA FIS study, drainage area contributes approximately 9,350 cfs at this low water crossing and most of the flow overtops the existing roadway elevation set at 1628.5 ft. Iterative drainage design calculations were performed to provide optimum design. Each option provided minimal benefits, were very high in cost, and at best provide conveyance capacity for up to the 2-year storm event before overtopping. Therefore, it was determined that individual roadway culvert replacements did not provide an adequate cost-benefit to recommend implementation. Therefore, as an alternate to mitigate and improve public safety, it is recommended that automated flood gates be installed at each low water crossing. **Appendix D** shows the hydraulic models results.

The total opinion of probable engineering and construction costs for this solution is estimated at approximately $1.6 Million for channel and culvert capacity improvements. The recommended mitigating solution of an Automated Flood Gate System is estimated to cost approximately $200,000 . See **Appendix B** for the itemized breakdown of quantities and costs.

The project scope of work is summarized as follows:

1. Perform a detailed hydrologic and hydraulic study of Quinlan Creek to better delineate the flood risk conditions and evaluate alternatives to address Park Street, First Street, and Fourth Street.
2. Construct channel widening and capacity improvement through the length of the channel and replace the culvert crossings at Park, First and Fourth Streets with bridge-class culverts that mitigate adverse impacts to the FEMA Floodway and Floodplain.

Recommended Mitigating Solutions of work is summarized as follows:

Install a High-Water Alert Lifesaving Technology (HALT) flashing light and automated flood gate to alert drivers of dangerous waters and encourage alternative routes.

Figure 65 - Flood Detection System Automated Gate Example

E. SPRING STREET – EROSION AT OUTFALL

An existing 54" RCP storm drain dischages into an existing rock-filled gabion channel that then flows down a steep drop off plunging into the Guadalupe River. The existing gabion mattress has failed and the earthen channel bank is at risk of further incising upstream if left in its current condition. Solutions for this problem involve extending the existing 54" storm drain, regrading and compacting the earthen channel to stabilize the erosion that has taken place, and constructing a concrete baffled chute to convey flow down the steep channel embankment with a stilling basin to dissipate energy before dischaging into the Guadalupe River. No downstream adverse impacts have been identified with this project. Further geotechnical investigations and detailed anaylsis are required.

Figure 66 - Baffled Chute Energy Dissipater (Source: USBR EM-25)

The project scope is summarized as follows:

1. Remove existing concrete headwall and extend the existing 54" RCP approximately 100 LF.
2. Construct new concrete headwall.
3. Construct a 20' wide by 70' long concrete baffled chute with 5' high side walls, maximum longitudinal slope of 2:1.
4. Regrade and compact significant slope failures at a 3:1 maximum slope.
5. Construct stilling basin and transition to rock rip-rap at the outfall.

The total opinion of probable engineering and construction costs for this project is estimated to be $600,000 to $750,000. See **Appendix B** for an itemized breakdown of quantities and costs.

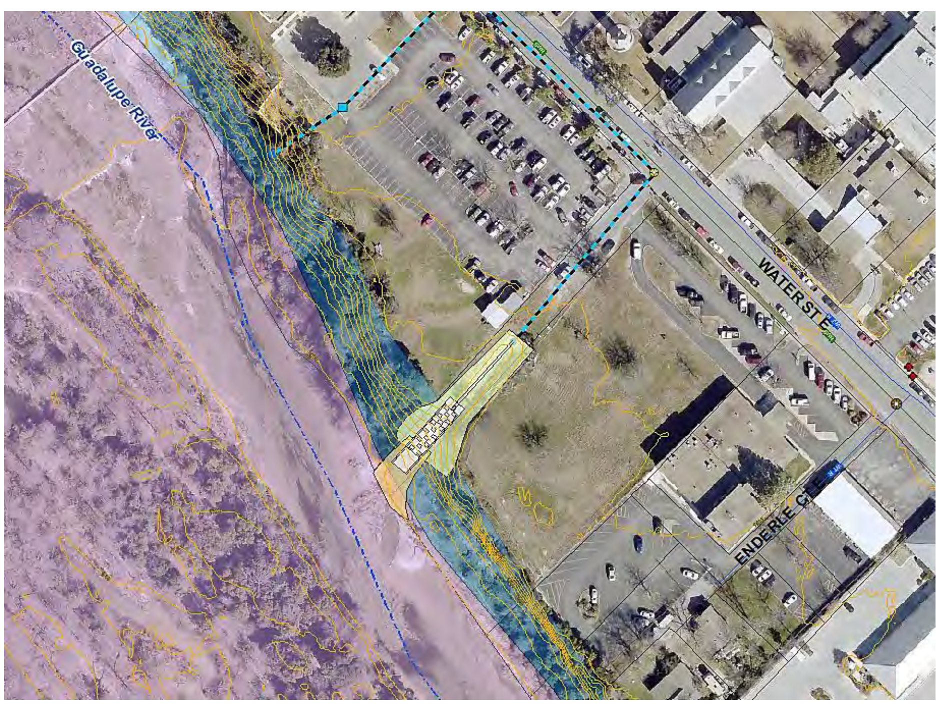

Figure 67 - Conceptual Drainage Chute at Spring Street

F. HILL COUNTRY DRIVE AT SH 16

The intersection of Hill Country Drive and Sidney Baker Street (State Highway 16) experiences frequent property and street flooding due to Hill Country Drive's low lying roadway condition and two – 36" corrugated metal pipes (CMP) with inverts set at the low point in the roadway. The proposed solutions for this project are divided into two phases. Phase 1 consists of raising the roadway profile and regrading Hill Country Drive by approximately 11 inches while adding positive slope toward the existing two 36" CMP pipes. Because of the limited capacity of the two existing 36" CMPs at the intersection, Phase 2 consists of increasing the downstream pipe capacity at Hill Country Drive by replacing the two – 36" CMPs with a trench box connected into two 6' wide by 3' tall box culverts from Hill Country Dr to the existing TxDOT maintained trapezoidal channel near the intersection of Park Lane and Sidney Baker Street. The Phase 2 box culvert would increase capacity from 42 cfs to 185 cfs and will provide capacity for approximately the 25-year frequency storm event for ultimate conditions. Phase 2 capacity improvements equal to approximately 87% of the total 50-year storm event under ultimate conditions.

Increasing the capacity of the storm drains and discharging into the channel downstream has the potential to result in adverse impacts. Although the existing TxDOT drainage channel is believed to have adequate capacity, further study downstream to the outfall at the Guadalupe River is recommended prior to project final decision and construction.

The project scope is summarized as follows:

1. Raise Hill Country Drive by approximately 11 inches and regrade to establish positive drainage toward existing storm drain system. (Phase 1)
2. Replace the existing two 36" CMP with two 6' x 3' box culvert from intersection to existing TxDOT channel. (Phase 2)
3. Construct trench drain box at Hill Country Drive, just west of SH 16. (Phase 2)

The total opinion of probable engineering and construction costs for this project is estimated to be $0.25 million for Phase 1 and $2.2 million for Phase 2, for a total of approximately $2.4 million. See **Appendix B** for an itemized breakdown of quantities and costs.

Figure 68 – Hill Country Drive Conceptual Drainage Improvements (Phase 1 and 2)

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G. CLAY STREET (SCHREINER TO SH27) &

H. KROC CENTER DETENTION POND AND SPILLWAY OUTFALL

The proposed design for Clay Street and the Kroc Center Detention Pond are intended to provide flood relief downstream of the Kroc Center along George Street, Hays Street and south of McFarland Street. Proposed improvements consist of reconfiguring and reconstructing the existing Kroc Center outlet structure to directly discharge into a proposed storm drain system to prevent the pond from directly releasing into the street. Clay Street drainage improvements include connecting to the Kroc Center Pond outlet and upsizing, connecting, and extending the stormwater network with a series of storm drain inlets and reinforced concrete box pipes extending down to the Guadalupe River. The proposed drainage improvements are intended to provide 100-year detention at the Kroc Center with the downstream storm drain system sized to contain 25-year flows in the pipes and 100-year within the road right-of-way. No adverse impacts have been identified downstream. A more detailed conceptual layout is provided in **Appendix B.**

The project scope or work is summarized as follows:

1. Construct an outlet riser structure within the Kroc Center Detention Pond and connect outfall directly into the proposed storm drain pipe.
2. Construct approximately 460 LF of 6' x 4' reinforced concrete box pipe from the Kroc Center to George Street.
3. Construct approximately 284 LF of 6' x 4' reinforced concrete box pipe from Miller Street to Hays Street.
4. Construct approximately 1,273 LF of 6' x 4' reinforced concrete box pipe from Hays Street to McFarland Street.
5. Construct approximately 920 LF of 9' x 4' reinforced concrete box pipe from McFarland Street to Clay Street.
6. Construct approximately 750 LF of 9' x 4' reinforced concrete box pipe on Clay Street between McFarland Street and Jefferson Street.
7. Construct approximately 940 LF of 9' x 5' reinforced concrete box pipe from on Clay Street between Jefferson Street and Water Street.
8. Construct approximately 220 LF of 10' x 5' reinforced concrete box pipe along Clay Street to outfall at the Guadalupe River.
9. Provide a stilling basin with baffle box at the outlet structure.
10. Construct four - 20 foot on grade curb inlets along George Street.
11. Construct eight - 20 foot on grade curb inlets along Hays Street.
12. Construct one - 20 foot on grade curb inlets along McFarland Street.
13. Construct eight - 20 foot on grade curb inlets along Clay Street.
14. Reconstruct / Regrade roads along proposed storm drainage alignment to establish positive drainage toward storm drain system.

The total opinion of probable engineering and construction costs for this project is estimated to be $7 million to $9 million. See **Appendix B** for an itemized breakdown of quantities and costs.

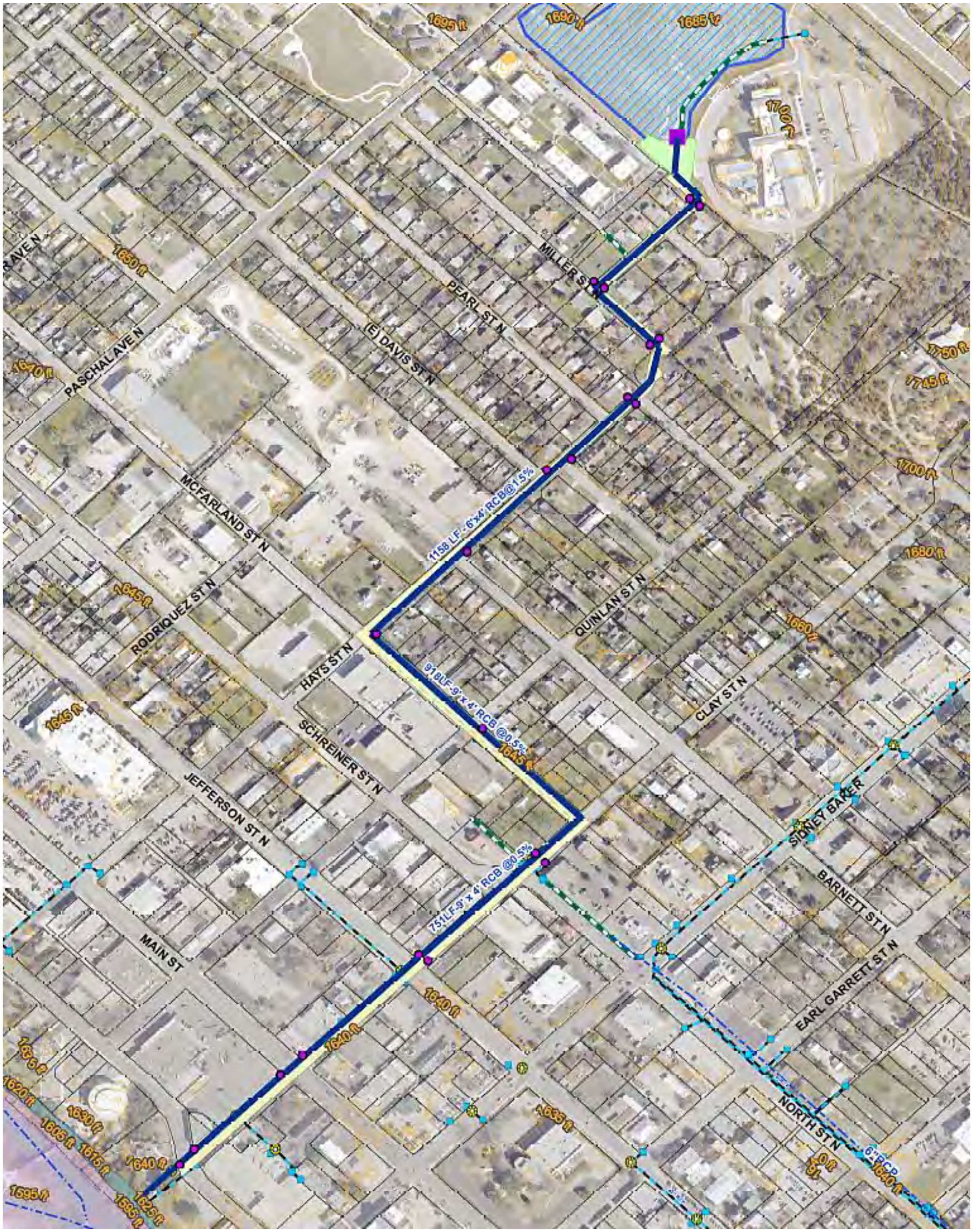

Figure 69 – Conceptual Storm Drainage System for Kroc Center and Clay Street.

I. TAKE IT EASY CHANNEL (SH27 TO GUADALUPE STREET.)

Take It Easy Channel proposed improvements are intended to primarily stabilize the nearly vertical channel bank side slopes from further erosion placing the adjacent RV park and residential neighborhood at risk and to provide improved conveyance for the upstream drainage system from Junction Highway to Lois Street. Implementation of the proposed design is intended to provide at a minimum, protection for the 25-year storm event under ultimate conditions. No adverse downstream impacts have been identified.

The project scope of work is summarized as follows:

1. Tie into existing 66" CMP at Guadalupe Street and extend one 12' x 6' RCB approximately 800 LF upstream within Take It Easy Channel.
2. Backfill Take it Easy Channel above 12' x 6' RCB and reconstruct a trapezoidal overflow channel and stabilize channel with erosion control blankets.
3. Reconstruct remaining 700 LF of channel with a 3' tall rectangular channel with 2:1 side slopes tied to existing grade. Proposed channel geometry includes a rectangular channel constructed of a concrete segmental mechanically stabilized earth (MSE) wall system with a 12' bottom width, 3' depth and 2:1 side slopes reinforced with turf reinforced matting tied into existing grade.

The total opinion of probable engineering and construction costs for this project is estimated to be $1.8 to $2.3 million. See **Appendix B** for an itemized breakdown of quantities and costs.

Figure 70 – Conceptual Channel Improvements at Take It Easy Channel

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J. LOIS STREET (BETWEEN WOODLAWN AND OX)

The proposed conceptual solution evaluated is intended to address the frequent street flooding on Lois Street and the slow draining channel between Junction Highway and Lois Street. Proposed channel improvements are intended to effectively pass a 25-year frequency storm event under ultimate conditions. This project is dependent on Take It Easy Channel downstream improvements occurring first, which include lowering the channel bottom to accommodate larger box culverts at Junction Highway and increasing the channel depth from Junction Highway to Lois Street.

The project scope of work is summarized as follows:

1. Coordinate with TxDOT to determine replacement of existing five 3.5' x 5' Oval CMP pipes with approximately three 6' x 6' RCBs. In addition, lower the culvert to match the proposed flowline of Take It Easy Channel.
2. Upsize the existing concrete channel by constructing a trapezoidal channel with an 11-foot bottom width, 3-foot depth, and 20-foot top width, construct retaining walls along portions of limited easement or to protect significant tress.
3. Regrade a portion of Lois Street to increase positive flow towards the improved drainage channel.

The total opinion of probable engineering and construction costs for this project is estimated to be $170,000 to $200,000. See **Appendix B** for an itemized breakdown of quantities and costs. Replacement of TxDOT culverts at Junction Highway are to be coordinated and determined and are not included in the estimate.

Figure 71 – Conceptual Channel Improvements at Lois Street

K. HARPER STREET BETWEEN CULBERSON AVENUE AND LEWIS AVENUE (K1)

Proposed design at Harper Street is intended to relieve localized flooding and excessive ponding that occurs throughout Harper Street. A proposed storm drain system is intended to capture up to the 25-year storm event under ultimate conditions with discharge into Town Creek. No adverse downstream effects were identified in this conceptual analysis; however, a detailed analysis should be completed prior to final design and construction.

The project scope of work is summarized as follows:

1. Regrade existing roadway to remove low spots on the road near Pershing Avenue intersection.
2. Construct four 20-foot curb inlets (on grade) along Harper Street between Culberson Avenue and Pershing Avenue.
3. Construct two 10-foot curb inlets (in sag) at the intersection of Harper Street and Pershing Avenue.
4. Construct four 10-foot curb inlets (on grade) at the intersection of Patton Avenue and Harper Street.
5. Construct four 10-foot curb inlets (on grade) at the intersection of Lewis Street and Harper Street.
6. Construct four stormwater manholes along Harper Street at an intersection of Culberson Avenue, Pershing Avenue, Patton Avenue, and Lewis Avenue.
7. Construct baffle blocks at the storm drain outfall to reduce flow velocities and dissipate energy discharging into Town Creek.
8. Perform roadway asphalt mill and overlay resurfacing after installation of proposed storm drain system.
9. Construct full length curb and gutter on both sides along Harper Street.

The total opinion of probable engineering and construction costs for this project is estimated to be $1.5 million to $1.8 million. See **Appendix B** for an itemized breakdown of quantities and costs.

Figure 72 – Conceptual Street Drainage Improvements at Harper Street

K. CIRCLE AVENUE DRAINAGE CHANNEL (K2)

Proposed conceptual solution is recommended to alleviate sedimentation and erosion issues at the intersection of Culberson Ave and Circle Avenue. Vertical elevation drops 40 feet over 300 foot channel length which results in high-velocity flow along the natural grass channel. The proposed solution will adequately pass 25-year storm peak flow under ultimate conditions. The runoff will flow to its current downstream flow path which has no reports of flooding issues.

The project scope of work is summarized as follows:

1. Regrade 410 SY of Jackson Road to provide gradual transition to the proposed channel.
2. Remove 242 LF of existing concrete curb along Jackson Road.
3. Construct 242 LF of concrete curb and gutter section.
4. Construct 330 LF hard armored slope drain chute with stilling basin and baffle blocks.
5. Provide curb cuts along Circle Avenue for gradual transition of channel flow.

The total opinion of probable engineering and construction costs for this project is estimated to be $190,000. See **Appendix B** for an itemized breakdown of quantities and costs.

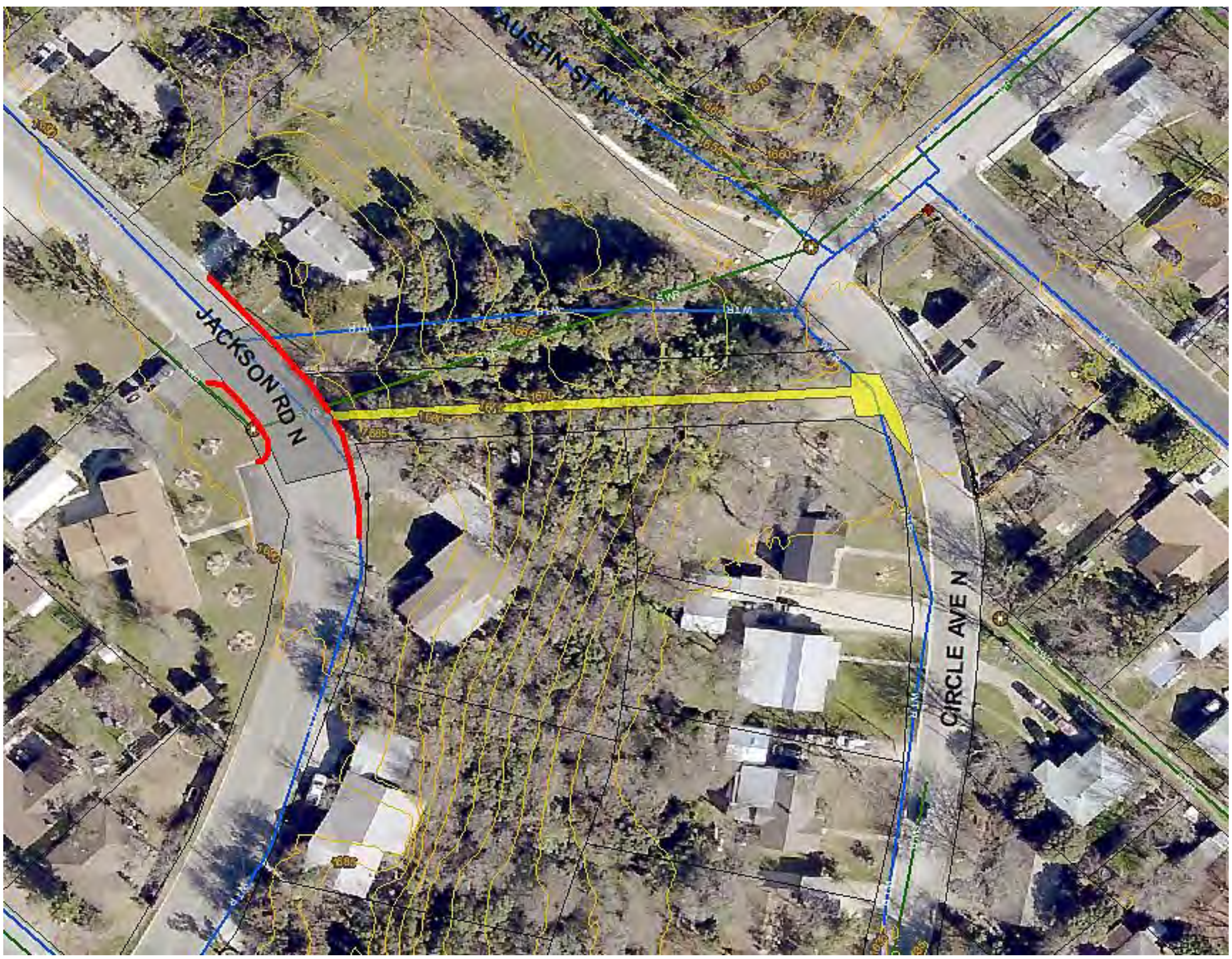

Figure 73 – Conceptual Drainage Chute at Circle Avenue

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L. JACK DRIVE – UNDERSIZED INLET

The conceptual solution is intended to relieve road and property flooding from occurring directly downstream of Jack Drive's existing undersized inlet. The proposed storm drain pipe system has been designed to collect runoff for up to the 25-year storm event with excess flow conveyed by surface drainage. The proposed system will capture runoff at Jack Drive via a 42" RCP storm drain with jack and bore construction methods for areas where significant structures, trees and other features would be highly impacted. Additional investigations are required prior to final design and construction. The alignment presented for the proposed storm drain is conceptual and is subject to change during final design.

The project scope of work is summarized as follows:

1. Regrade 8,065 SF of Jack Drive and construct roadway curbs to increase inlet interception within the roadway. Provide 35 SY of full depth roadway repair at Virginia Drive.
2. Regrade 6,200 SF and provide 90 SY of full depth repair of Lois Street for improved drainage conditions to proposed channel alignment.
3. Install one – 5' X 5' grate inlet in sag at lowest elevation at Lois Street.
4. Construct 1,230 LF of 42" storm pipe within the existing city owned drainage easement.
5. Construct 426 LF of 48" storm pipe by jack and bore between the residence of 1228 and 1230 Lois Street within a proposed drainage easement or within existing easements. Alignment presented is illustrated for estimating purposes only.
6. Regrade and construct 220 LF of earthen trapezoidal channel between Lois Street and Sunset Drive with a 5-foot bottom width and a 4-foot depth.

The total opinion of probable engineering and construction costs for this project is estimated to be $2.4 million. See **Appendix B** for an itemized breakdown of quantities and costs.

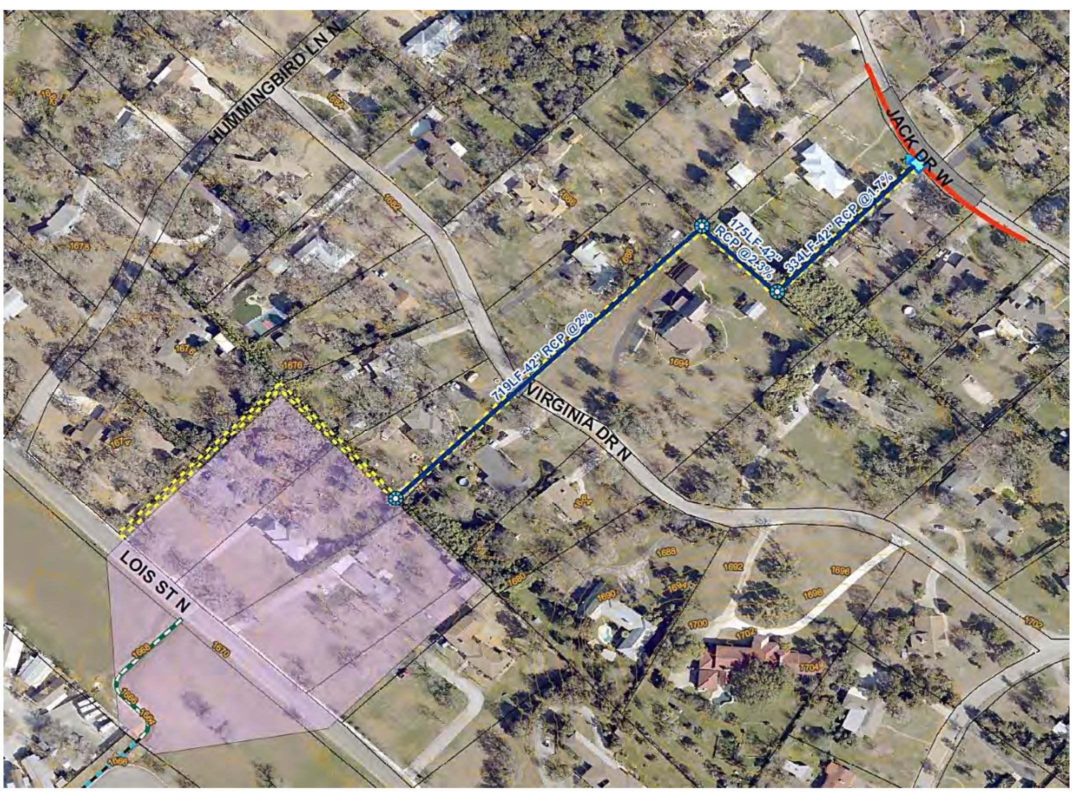

Figure 74 – Conceptual Drainage Improvements at Jack Drive

M. INTERSECTION OF CORONADO DR. AND JUNCTION HWY

Conceptual solution is intended to alleviate street ponding and nuisance flooding at Coronado Drive north of Junction Highway. The proposed solution has been sized to convey the 25-year storm event under ultimate conditions by constructing a trench drain and storm pipe system to capture runoff and discharge into the Guadalupe River. No downstream adverse effects were identified in this study.

The project scope of work is summarized as follows:

1. Regrade approximately 565 SY of Coronado Drive to increase inlet interception.
2. Construct 210 LF of concrete curb near the intersection at Coronado St and Junction Highway.
3. Regrade/relocate existing ditch located at the intersection to the low point on the road.
4. Install one – 3.5' x 30' trench drain at the intersection.
5. Install approximately 420 LF of 36" storm pipe along city own property by open cut and approximately 110 LF by jack and bore under TxDOT roadway.
6. Construct headwall with energy dissipation such as a stilling basin with baffle block at the outlet.
7. Provide rock riprap to provide erosion protection at the Guadalupe River.

The total opinion of probable engineering and construction costs for this project is estimated to be $495,000. See **Appendix B** for an itemized breakdown of quantities and costs.

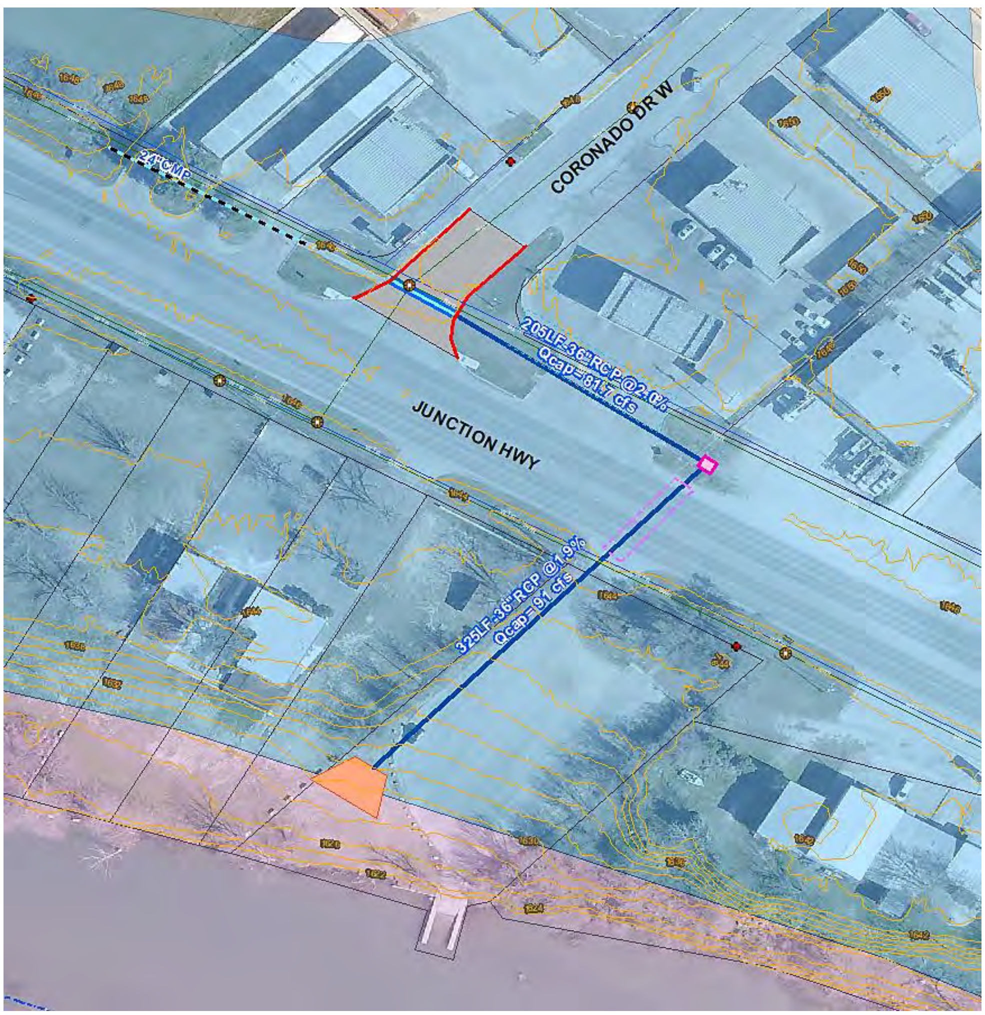

Figure 75 – Conceptual Drainage/Street Improvements at Coronado Drive

OPINION OF PROBABLE PROJECT COSTS

An opinion of the probable project costs were developed for each study location based on the conceptual improvements presented by this plan. **Table 5** provides the summarized costs for each problem area separated out by the following major categories: general, roadway, utilities, and drainage improvements. Estimations are provided in 2019 dollars and a cost index adjustment should be applied for improvements occurring into the future. Refer to **Appendix B – CITY-WIDE DRAINAGE CIPs** for the itemized cost breakdowns and exhibits for the proposed conceptual solutions.

Each project total construction cost subtotal is divided into five categories: General costs include Mobilization (11%), Insurances and Bonds (3%), Preparation of Right-of-Way (4%), Traffic Control Plan (3%), and Storm Water Pollution Prevention Plan (SW3P) (1%). Roadway construction costs are directly related to street maintenance and roadway construction improvements. Drainage costs are related to stormwater structures such as pipes, culverts, and channels. Design, permitting and land acquisition costs are related to all other elements required for the project completion. Land acquisition costs were estimated by multiplying the current total land value by 170%. The preliminary engineering study, design, engineering and surveying costs are based on percent construction fee curves and overall project complexity.

Project unit prices are based on 2019 average low bid prices obtained from TxDOT, Bexar County / City of San Antonio, and recent bid tabs for similar projects. All project total costs include a 25% contingency for unforeseen expenses. All project solutions are based on approximate methodologies and limited data and therefore are conceptual and subject to change. Probable construction costs should be adjusted for inflation and changing market conditions when projecting into the future.

Table 5 - Summary of Probable Project Costs

ID	Project Priority Rank	Project Name	General	Roadway	Utilities	Drainage	Design, Permitting, Land Acquisition Costs	Total Project Costs[1]
A	5	East Main to Pinto Trail	$ 111,710	$ 210	$ 22,500	$ 565,237	$ 104,949	**$ 979,520**
B	11	Park St. Low Water Crossing	$ -	$ -	$ -	$ -	$ -	**$ 200,000**
C	11	First St. Low Water Crossing	$ -	$ -	$ -	$ -	$ -	**$ 200,000**
D	13	Fourth St. Low Water Crossing	$ -	$ -	$ -	$ -	$ -	**$ 200,000**
E	9	Spring St. - Erosion at Outfall	$ 83,370	$ -	$ -	$ 438,787	$ 91,377	**$ 744,073**
F1 & F2	3	Hill Country at SH16 Ph I	$ 32,001	$ 123,336	$ 7,500	$ 14,625	$ 27,729	**$ 249,557**
		Hill Country at SH16 Ph II	$ 280,803	$ 363,424	$ 16,800	$ 896,151	$ 233,577	**$ 2,180,050**
G & H	4	Kroc Center Detention Pond Clay St. (Schreiner to SH27)	$ 1,183,734	$ 1,121,475	$ 547,000	$ 3,712,132	$ 861,570	**$ 8,967,501**
I	1	Take It Easy Drainage Channel	$ 297,871	$ 118,320	$ -	$ 1,235,639	$ 227,127	**$ 2,291,913**
J	2	Lois St. (Woodlawn to Ox Dr.)	$ 34,404	$ 59,721	$ 59,040	$ 37,620	$ 28,618	**$ 189,899**
K1	10	Harper Street	$ 232,936	$ 332,090	$ 179,800	$ 505,310	$ 193,760	**$ 1,808,431**
K2	6	Circle Avenue	$ 23,684	$ 40,702	$ 3,900	$ 63,053	$ 24,626	**$ 188,800**
L	7	Jack Drive	$ 293,948	$ 128,901	$ 68,500	$ 1,138,724	$ 336,202	**$ 2,373,793**
M	7	Coronado at Junction Highway	$ 63,372	$ 53,485	$ 24,800	$ 209,770	$ 54,911	**$ 494,195**
Summary of Probable Cost			$ 3,767,096	$ 2,768,357	$ 1,100,540	$ 13,352,677	$ 4,166,502	**$ 21,067,733**

[1] Total project costs include all projected expenditures thru project completion

Notes: 2019 Dollars, assume 6% to 7% cost increase each year

PRIORITIZATION OF DRAINAGE CIP PROJECTS

A Stormwater Capital Improvement Plan (CIP) project priority list was developed for the City of Kerrville to assist with the development of a multi-year program that aims to address the goals and objectives for city-owned public facilities. This project list is intended to create and/or replace physical infrastructure assets with facilities that provide improvements that reduce the risks to public safety, improve economic development potential and enhance environmental features.

The goal of the provided project list and costs are to assist the city in the planning and budgeting process. The project list summarizes the improvements, provides estimated costs, schedule, and identified potential sources of funding.

The project scoring method applied has been developed to objectively assess and rank projects into a priority list. This priority list should not be considered as the final absolute ranking nor does it represent the expected order for implementation but instead should be utilized to assign relative priority.

Additional detailed information on the methodology and ranking system may be found in **Appendix D**.

PROJECT RANKING & PRIORITIZATION SUMMARY

Each proposed project has been prioritized by a scoring and ranking system to assess the city's relative infrastructure improvement priorities based on the identified principal categories of public safety, economic effect, project timing and environmental impacts.

The method applied consists of first weighting each primary category against the other primary category to develop a pairwise comparison. The pairwise comparison matrix developed is provided in **Table 6** which compares the principal categories in pairs to judge the higher priority or importance versus another principal category. Each pairwise comparison scores importance as 3 for more important, 2 equally important or 1 as less important.

Table 6 - Pairwise Principal Category Ranking

Criteria	Public Safety	Economic	Project Timing	Environment	CATEGORY WEIGHT
Public Safety		3	3	3	**9**
Economic	1		3	2	**6**
Project Timing	1	1		2	**4**
Environment	1	2	3		**6**

Each problem area is then scored based on sub-categories within the primary category as presented in **Table 7**. As an example, public safety includes scoring for risk associated with property and structural flooding, roadway flooding, roadway emergency services access, frequency of flood damages and erosion potential. A total weighted score can then be developed using the following formulas:

$$Principal\ Category\ x\ Sub\ Category\ Points = Total\ Category\ Score$$

$$Public\ Safety\ Total + Economic\ Total\ + Project\ Timing\ Total + Environment\ Total = Total\ Final\ Score$$

Table 7 – Subcategory Ranking Descriptions

Category / Weight	Sub Category	Point Value Range Description	Point Value	Example Project: Project Score	Example Project: Weighted Score
Public Safety (Weight 9)	Structural Flooding for 100-year (1% AEP), estimated (Pre-Project Conditions)	Low Risk (0 structures flooded) Moderate Risk (1-10 structures flooded) High Risk (10+ structures flooded or critical facility effected)	0 5 10	5	**45**
	Roadway Flooding for 100-Year (1% AEP) (Pre-Project Conditions)	No road overtopping Local road overtopping Collector road overtopping Arterial road overtopping	0 4 7 10	7	**63**
	Roadway Emergency Services Access for 25-year (4% AEP) storm-event (Pre-Project Conditions)	Access not impacted Access minimally impacted Alternative route required / limited access (duration 0 ≤ x ≤ 1 hour) No access or alternative route available (duration x ≥ 1 hour)	0 2 6 10	2	**18**
	Frequency of Flood Damages (Pre-Project Conditions)	Minimal (100-year < X) Moderate (25-year < X ≤ 100-year) High (1-year < X ≤ 25-year) Very High (X ≤ 1-year)	1 4 7 10	4	**36**
	Erosion / Channel Stability	No erosion Stable (minimal erosion) Unstable (risk of property loss) Highly unstable (risk of structure damage or accelerated property loss)	0 2 6 10	10	**90**
	Drainage Service (Post-Project Protection)	≤10 Year (10% AEP) 10 Year (10% AEP) - 25-Year (4% AEP) 25 Year (4% AEP) - 100-Year (1% AEP) ≥100-Year (1% AEP)	1 4 6 10	10	**90**
Economic (Weight 6)	Project Cost	High Cost ($2 million < X) Moderate Cost ($1 million < X ≤ $2 million) Low Cost (≥ $1 million)	2 6 10	6	**36**
	Funding Source / Availability	Unidentified funding sources General Fund Future Municipal Bonds (2020-? Bond Program) Cost-Share Potential (Federal or State grants, Inter-local agreements)	0 4 7 10	4	**24**
	Development/Redevelopment Post-Project (residential and commercial)	Negative impact (reduced development and/or business potential) No significant impact (no change to development and/or business potential) Positive impact (development potential, improved land value, sales, etc.)	0 5 10	10	**60**
Project Timing (Weight 4)	Permitting	Significant Permitting & Mitigation Federal permitting (Section 404 IP, other) Limited permitting local/state/federal (Nationwide, TCEQ WPAP) Local permitting only	0 2 6 10	10	**40**
	Land/Easement Acquisition	Condemnation/buy-outs may be required Limited easement/land acquisition needs (no impact to structures) No additional easements or acquisition anticipated	1 3 5	3	**12**
	Project Readiness (est. time until completion)	Long Range (X > 2 years) Mid-Range (1-year < X ≤ 2 year) Short-Range (X ≤ 1 year)	1 3 5	3	**12**
	Project Dependency	Project is dependent on other upstream/downstream improvements occurring before this project to mitigate flooding issues Project is independent of any upstream/downstream improvements to mitigate flooding issues Project must be constructed before other related projects to solve flooding issues in basin	0 5 10	5	**20**
Environment (Weight 6)	Water Quality Impacts Post-Project	Negative impact (WQ reduced due to increased impervious cover, etc.) No significant impact Positive impact (WQ enhanced with LID/BMP features)	0 7 15	7	**42**
	Riparian Impacts Post-Project (habitat, natural waterways, trees, wetlands, etc.)	Negative impacts (loss of natural riparian areas) No impacts (no significant change to natural riparian areas) Positive impacts (preserves or creates natural riparian areas)	0 7 15	0	**0**
				Project Ranking Score	588

*AEP = Annual Exceedance Probability

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Total ranking scores are determined by accumulating each subcategory rank augmented by appropriate category weight. Full ranking project scores and overall ranking values may be seen in **Appendix D**.

The intention of the weighting system method selected was to provide a customized quantitative and impartial process for ranking project priorities based on specific needs and considerations. The resulting process provides the relative project priority list as represented in **Table 8**

Table 8 - Prioritized Drainage CIP Project List

Ranking	ID	Project Name	Project Score	Estimated Project Cost		
1	I	Take It Easy Drainage Channel	771	$	2,291,913	
2	J	Lois St. (Woodlawn to Ox Dr.)	718	$	189,899	
3	F	Hill Country at SH16	677	$	2,429,607	
4[2]	G & H	Kroc Center Detention Pond Clay St. (Schreiner to SH27)	644	$	8,967,501	
5	A	East Main to Pinto Trail	588	$	979,520	
6	K2	Circle Avenue	587	$	188,800	
7	L	Jack Drive	552	$	2,373,793	
7	M	Coronado at Junction Highway	552	$	494,195	
9	E	Spring St. - Erosion at Outfall	528	$	744,073	
10	K1	Harper Street	524	$	1,808,431	
11	B	Park St. Low Water Crossing	413	$	200,000	[1]
11	C	First St. Low Water Crossing	413	$	200,000	[1]
13	D	Fourth St. Low Water Crossing	368	$	200,000	[1]
			Total Project Costs	$	21,067,733	

[1] Alternative solution: High-Water Alert Lifesaving Technology (HALT) $200,000

[2] Capital Improvement Projects G & H have been combined into one project.

EVALUATION OF DRAINAGE POLICY AND CRITERIA

NOAA ATLAS 14 CONSIDERATIONS

On September 27, 2018, the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Design Studies Center released an update to Texas's rainfall frequency values, which redefines the amount of rainfall it takes to qualify as a 100-, 500-, and 1,000-year storm event. The newly updated data is intended to supersede the *USGS Water Resources Investigations Report 98-4044* (USGS 1998) and *NOAA Technical Paper No. 40 for Rainfall Frequency Atlas of the United States* (TP-40 1963) and represents the best available data for stormwater and floodplain design and analysis.

The study, published as *NOAA Atlas 14, Volume 11 Precipitation-Frequency Atlas of the United States* (Atlas 14), has found that previously identified 50-year rainfall values in the City of Kerrville drainage manual were equivalent to the 25-year rainfall estimates for Atlas 14 for the City. 24-hour precipitation depth for the 100-year storm has increased from 9.36 inches to 12.1 inches, which shows a rise of 2.74 inches as shown in **Figure 76**. Previously designed drainage structure may show hydraulic inadequacy when compared to the new rainfall estimates.

Comparison of rainfall intensities are provided in **Table 9**.

Table 9 - Comparison of Rainfall Intensities (inches per hour)

Duration	25 Yr			50 Yr			100 Yr		
	Atlas 14	City of Kerrville	Difference	Atlas 14	City of Kerrville	Difference	Atlas 14	City of Kerrville	Difference
5-min	10.90	11.3	-0.40	12.40	12.76	-0.36	14.00	14.17	-0.17
10-min	8.73	8.82	-0.09	9.98	9.94	0.04	11.30	11.11	0.19
15-min	7.21	7.31	-0.10	8.22	8.24	-0.02	9.28	9.24	0.04
30-min	5.00	4.99	0.01	5.68	5.61	0.07	6.40	6.31	0.09
60-min	3.31	3.20	0.11	3.78	3.59	0.19	4.27	4.05	0.22
2-hr	2.16	1.97	0.19	2.51	2.21	0.30	2.89	2.5	0.39
3-hr	1.67	1.47	0.20	1.95	1.65	0.30	2.27	1.86	0.41
6-hr	1.03	0.88	0.15	1.22	0.99	0.23	1.44	1.11	0.33
12-hr	0.60	0.52	0.08	0.72	0.58	0.14	0.86	0.66	0.20
24-hr	0.35	0.31	0.04	0.42	0.35	0.07	0.50	0.39	0.11

Comparison of precipitation depth are provided in **Table 10**.

Table 10 - Comparison of Precipitation Depths (inches)

Duration	25 Yr			50 Yr			100 Yr		
	Atlas 14	City of Kerrville	Difference	Atlas 14	City of Kerrville	Difference	Atlas 14	City of Kerrville	Difference
5-min	0.907	1.83	-0.92	1.04	2.40	-1.36	1.17	3.01	-1.84
10-min	1.46	1.11	0.35	1.66	1.46	0.20	1.88	1.84	0.04
15-min	1.8	0.77	1.03	2.06	1.00	1.06	2.32	1.27	1.05
30-min	2.5	0.36	2.14	2.84	0.47	2.37	3.2	0.59	2.61
60-min	3.31	0.15	3.16	3.78	0.19	3.59	4.27	0.24	4.03
2-hr	4.33	3.94	0.39	5.02	4.42	0.60	5.77	5.00	0.77
3-hr	5	4.41	0.59	5.87	4.95	0.92	6.82	5.58	1.24
6-hr	6.16	5.28	0.88	7.32	5.94	1.38	8.63	6.66	1.97
12-hr	7.27	6.24	1.03	8.69	6.96	1.73	10.3	7.92	2.38
24-hr	8.44	7.44	1.00	10.1	8.40	1.70	12.1	9.36	2.74

Table 11 shows the 24-hour rainfall data comparison for the City of Kerrville and 2018 Atlas 14 precipitation estimates and **Figure 76** provides a graphical comparison of rainfall frequency rain events for TP-40 versus Atlas 14 precipitation data.

Table 11 - Comparison of 24-Hr Rainfall Data

Frequency Event	Annual Chance of Probability	Average 24-Hour Precipitation Depth (Inches)	
		City of Kerrville	Atlas 14 (2018)
500 Yr	0.2%	13.5*	17.6
100 Yr	1%	9.36	12.1
50 Yr	2%	8.40	10.1
25 Yr	4%	7.44	8.44
10 Yr	10%	6.48	6.49
5 Yr	20%	5.28	5.23
2 Yr	50%	3.84	3.92
** USGS Precipitation*			

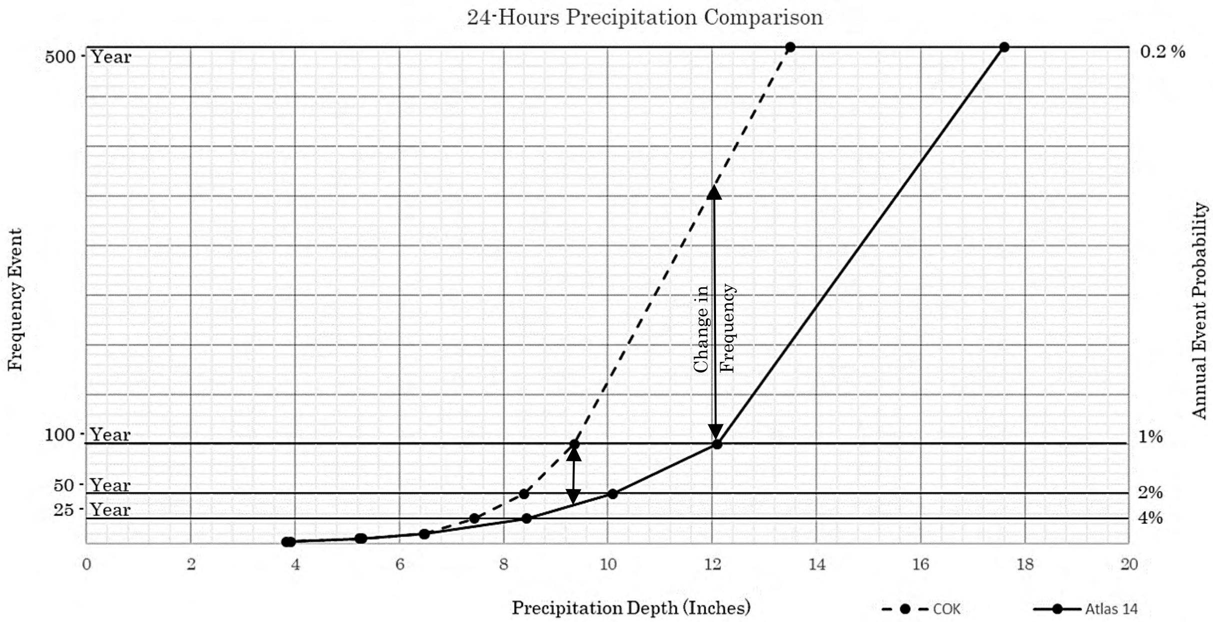

Figure 76 - Comparison of 24-Hr Precipitation with Atlas 14 Estimates

RECOMMENDATION:

- Adoption of Atlas 14 and updating city ordinances and drainage criteria manual to reflect best available data.
- All plats submitted prior to amending city code with Atlas 14 values may use the rainfall data effective at the time of submittal. However, a design check should be required to check for adverse impacts utilizing the Atlas 14 data. If an adverse impact is determined, appropriate mitigation should be considered as appropriate.
- Phased developments, such as residential subdivisions, should be required to bring the drainage system into compliance based on a city determined timeline.
- Single-phased developments previously approved and currently under construction that has been deemed out of compliance will be handled on a case by case basis to determine mitigation steps or if an Administrative Exception will be granted.
- Floodplain remapping utilizing Atlas 14 rainfall data should occur to update the Digital Flood Insurance Rate Maps (DFIRM) for the City of Kerrville and Kerr County. This effort to remap the floodplains is anticipated to take approximately one year once the process is started. Therefore, a lag period where the effective floodplain maps are not reflecting the flood risk using best available rainfall data. During this period where Atlas 14 is adopted but remapping has not occurred, it is recommended that plats, permits, and adverse impact analyses utilize Atlas 14 data while FEMA CLOMR/LOMR submittals utilize previously adopted city rainfall data.
- Finished floor elevations (FFE) for residential and commercial buildings:
  - Prior to Atlas 14 adoption, FFE should be based on ultimate conditions base flood elevations (BFE) using current rainfall data, plus 1 foot of freeboard.
  - After Atlas 14 adoption, FFE should be based on ultimate conditions BFE using Atlas 14 rainfall data, plus 1 foot of freeboard.

CODE OF ORDINANCES AND DESIGN CRITERIA

The currently effective city stormwater drainage policy and criteria were reviewed to identify where improvements may be needed and recommend changes as appropriate. This review of the municipal codes, subdivision ordinances, and drainage design criteria is intended to provide a general list of recommendations and the intentions of this review are not to prepare changes ready for adoption. Instead, these are to be used as guidance and for planning future policy and criteria updates.

The detailed and itemized comments are provided in **Appendix C**.

MUNICIPAL CODES

The City's Municipal Codes *Section 54 Floods*, and *Chapter 118 Waterways* were reviewed to identify potential improvements to the codes.

The recommended changes, additions and modifications to Article II Floodplain Management Sections 31 Purpose and Methods, 32 Definitions, 33 General Provisions, 34 Administration, 35 Provisions for flood hazard reduction, and Chapter 118 Article II City water impoundment regulations Sections 32 Definitions with added sections for provisions for enforcement, provisions for defining allowable development within the regulatory floodplain, and provisions for prohibited development within the regulatory floodplain.

SUBDIVISION ORDINANCES

The City's Subdivision Ordinance was last updated in October 2008. Articles for plat approval procedure, minimum design standards, minimum development procedures, and recommended additional sections were reviewed for potential updates to the city ordinances.

The recommended changes provide considerations for additions and modifications to the development of drainage facilities to protect properties from adverse impacts, additions to flood control requirements, detention/retention, impervious cover, drainage considerations during construction, drainage improvement responsibilities, maintenance responsibilities, and water quality improvements.

DRAINAGE DESIGN CRITERIA

The City's *Drainage Design Criteria Manual* was last updated in 2013. The design criteria was reviewed for potential updates and improvements.

The recommend changes include additions, modifications and deletions to the determination of design discharge, time of concentration methodology and calculations, rainfall intensity updates to NOAA Atlas 14 data, unit hydrograph loss methods, street drainage requirements, channel flow, access easements, interceptor channel requirements, maintenance considerations, bridge/culvert design frequency, freeboard and roadway overtopping requirements, velocity protection and control devices, and detention pond requirements.

WATER QUALITY CONSIDERATIONS

The City of Kerrville is situated along the banks of the Guadalupe River which is fed by natural springs emanating from the Edwards Aquifer. Groundwater from the Edwards Group is estimated to provide the Guadalupe River watershed an average annual flow of 78,921 acre-feet or about 7 million gallons per day. In addition, Kerr County historically has been recorded to be one of the most abundant areas with natural springs resulting from the Edwards-Trinity Aquifers. These springs produce sparkling clean water that feeds into the city's creeks as it meanders through the rugged terrain and rolling hills towards the Guadalupe River (**Figure 77**). As such, the importance of the water quality, groundwater recharge, and the recreational and scenic amenities of the Guadalupe River are among the most important priorities of the city as identified in the *2050 Comprehensive Plan*.

To protect and enhance water quality, the city is challenged with determining methods for preserving natural stream areas, reducing the impacts of impervious cover, and the associated non-point source pollution.

The City of Kerrville is located within the Upper Guadalupe River Authority jurisdictional area which presently provides initiatives for improving water quality in Kerr County including the construction of water and sediment control basins designed to slow down overland flow and control the release of floodwater downstream.

Table 12 presents the list of impaired streams as classified by the EPA and **Figure 78** illustrates the U.S. Fish and Wildlife Service Wetlands Inventory of potential riparian and wetland areas within the city.

Figure 77 - Karsted Terrain and Subsurface Aquifer Characteristics (Source: Kerr County Hydrogeology Report, 2008)

Table 12 - Waterbody Impairment Report (Source: EPA)

Stream Name	Date Assessed	Reported Condition	Pollution Categories	What's Being Done
Goat Creek	N/A	Unknown	Unknown	No TMDL Cleanup Plans; dischargers regulated by permits; no polluted runoff control projects
Town Creek	2010	Impaired for primary recreation/ swimming	Bacteria and other microbes	No TMDL Cleanup Plans; no dischargers regulated by permits; no polluted runoff control projects
Quinlan Creek	2010	Impaired for primary recreation/ swimming	Bacteria and other microbes	No TMDL Cleanup Plans; dischargers regulated by permits; polluted runoff control projects exist
Third Creek	N/A	Unknown	Unknown	No TMDL Cleanup Plans; no dischargers regulated by permits; polluted runoff control projects exist
Second Creek	N/A	Unknown	Unknown	No TMDL Cleanup Plans; no dischargers regulated by permits; polluted runoff control projects exist
Unnamed Tributary (Lime Creek)	N/A	Unknown	Unknown	N/A
Elm Creek	N/A	Unknown	Unknown	N/A
Bear Creek	N/A	Unknown	Unknown	No TMDL Cleanup Plans; no dischargers regulated by permits; no polluted runoff control projects
Camp Meeting Creek	2010	Impaired for aquatic life use; primary recreation/ swimming use good	Low oxygen	No TMDL Cleanup Plans; no dischargers regulated by permits; polluted runoff control projects exist
Guadalupe River Basin at UGRA Dam	2010	General use good; other categories not assessed	No impairment data reported	2007 TMDL Cleanup Plan for Bacteria and Other Microbes; no dischargers regulated by permits; polluted runoff control projects exist.
Kerrville Lake	2007	Unknown		2007 TMDL Cleanup Plan for Bacteria and Other Microbes; no dischargers regulated by permits; polluted runoff control projects exist

TMDL – Total Max Daily Load

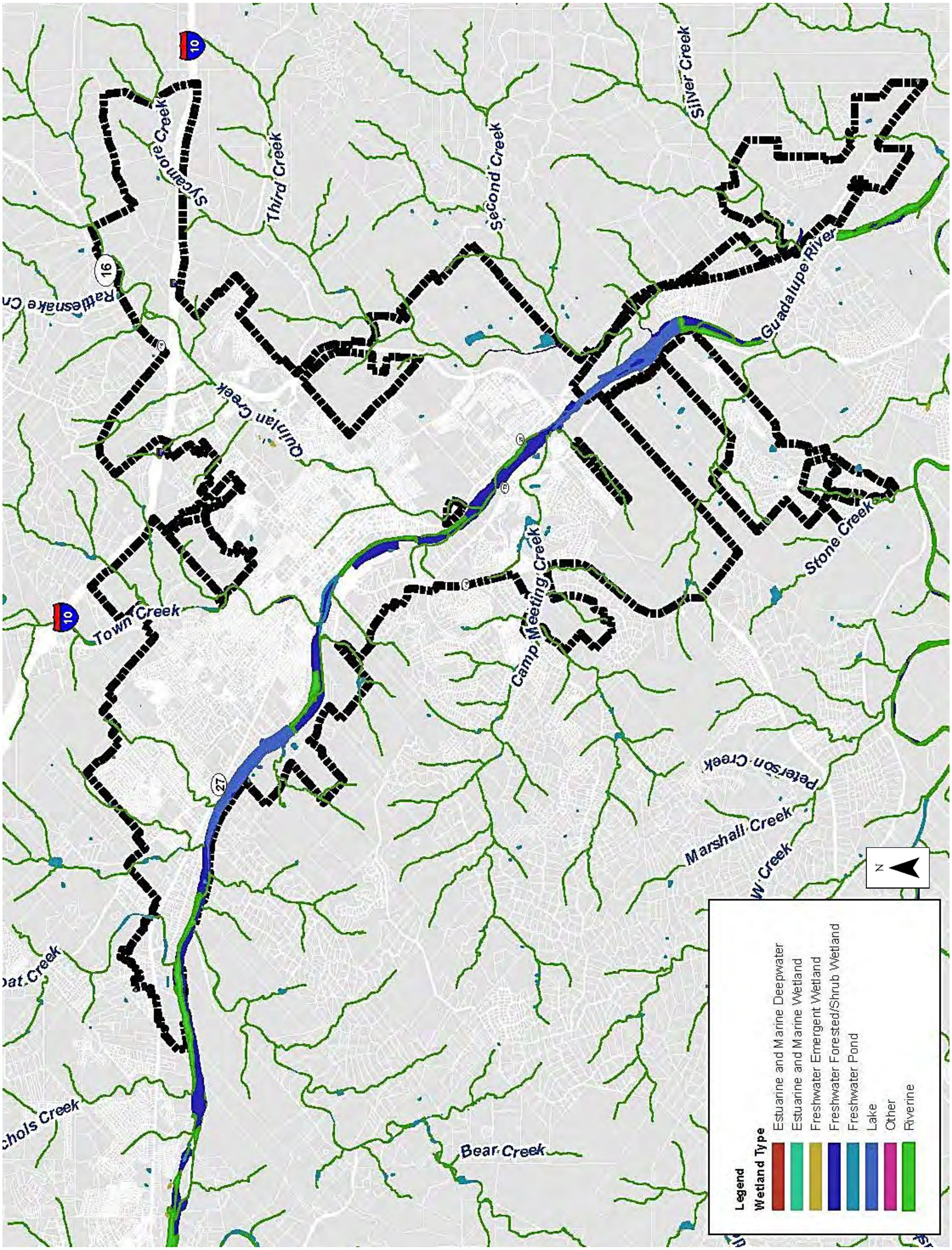

Figure 78 - USFWS Wetlands Inventory

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RECOMMENDATIONS:

- Develop a Water Quality Protection Plan to identify recommended areas for protection, identify potential strategic retrofit solutions, water quality measures integrated into identified capital improvement projects, and updates to the city's land development code.

- Evaluate opportunities for each multi-purpose and stormwater project at the preliminary design phase to assess the viability of providing water quality best management practices (BMPs) and give priority to implementing water quality improvements within identified protection zones as developed in the Water Quality Protection Plan.

- Provide municipal code requirements for protecting existing natural riparian areas with natural channel design solutions, stream buffer requirements, and stream protection volume.

- Identify areas in the city for regional detention facilities that will mitigate increases in runoff volume and reduce the need to impact natural riparian areas downstream.

- Continued monitoring and enforcement of the city's municipal separate storm drain system (MS4) program which is intended to provide public outreach and education, illicit discharge detection and elimination, construction site stormwater runoff control, post-construction stormwater management in new development and redevelopment, and pollution prevention and good housekeeping measures for municipal operations.

- Study and update land development codes to provide watershed specific water quality regulations including such additions as fee-in-lieu of water quality, fee-in-lieu of detention, stream buffer protection, water quality protection zones, and stream protection volume.

- Implement a Water Conservation Plan and Erosion Control Plan.

IMPLEMENTATION STRATEGY

This Stormwater Master Plan is the first city-wide planning update in more than 35 years. As such, there is a significant amount of stormwater management policy updates, planning and capital project requirements to address over the coming years. The Implementation Strategy presented by this plan is intended to provide recommendations for the phasing of programs and projects to address and prioritize stormwater management needs over the short-term and long-term up to 20 years.

STORMWATER PROGRAMS AND PLANNING

The Stormwater Master Plan serves to identify overall goals, priorities and a strategy for addressing the city's stormwater management needs which extends beyond identifying and completing capital improvement projects. In addition, there are a number of identified stormwater programs and planning studies needed to effectively address flood control, water quality, erosion, and future development that are not covered by this plan. These program and planning items have been identified in **Table 13**. The projects are identified in relative priority levels and should be addressed as resources and potential funding becomes available. Refer to the next section, **Potential Funding Sources,** for funding guidance.

Table 13 - Stormwater Project Planning List

Project Name	Type	Description	Priority Level	Estimated Cost Range
Dam Inspection and Maintenance Program	Program	Develop a standard dam inspection and maintenance program to be completed by staff.	High	$15,000 / year
Kerrville Flood Protection Plan Study (Hydrologic and Hydraulic Studies - FEMA Streams)	Study	Restudy all significant streams within the city and reassess community flood risk using NOAA Atlas 14 precipitation data, updated hydrologic modeling, updated terrain information, and detailed hydraulic modeling. Identify potential future projects to be completed to mitigate flooding and general management of the basin.	High	$400,000-$800,000
Louise Hays Dam Repairs	Design & Construction	Repair of concrete buttress dam structure due to seepage and spalling of concrete.	High	$1,000,000
Stormwater Drainage Design Manual Update	Manual	Update the city's drainage design and criteria manual to reflect current industry best practices and projected city growth.	High	$50,000
Storm Drain System Inventory and Assessment	Data Collection	Update the city's current storm drain system inventory in GIS and assess the condition of existing infrastructure including storm drains, culverts, detention ponds, and other drainage facilities to identify storm drains needing replacement.	Medium	$10,000 / year

Project Name	Type	Description	Priority Level	Estimated Cost Range
Regional Detention Pond Study and Fee-in-Lieu of Program	Study	Perform a study of the city's watersheds and anticipated growth for each basin to identify detention needs, where regional detention may be provided and where mandatory detention should be required to mitigate adverse impacts.	Medium	$60,000
Design Review Checklist	Manual	Develop a detailed stormwater design review checklist to verify proposed developments meet city criteria and ordinance requirements.	Medium	$5,000 to $10,000
Stormwater Utility Fee Study	Study	Study the potential for implementing a city-wide stormwater utility fee program to generate revenue responsible for maintaining the city's existing storm drainage system and to assist with the funding of capital projects. The fee is roughly estimated to generate $500,000 to $1,000,000 per year.	Medium	$70,000
Flood Warning System	Design & Construction	Install automatic flood gate warning systems at Quinlan Creek, Town Creek, and other known low water crossings.	Medium	$200,000 per location
Water Quality Protection Plan	Study	Study to implement water quality protection measures within the watersheds and protect natural riparian areas.	Medium	$80,000
Flood Complaint Database	Data Collection	Maintain a city complaint database to document flooding incidents, identified issues, and photographs to assist with identifying priority projects and hot spot areas.	Low	$5,000 / year

CAPITAL IMPROVEMENT PROJECTS

The stormwater capital improvement projects presented in this report will require additional effort to plan, design, and permit before they may be constructed. These identified priority projects and identified conceptual-level costs are intended to be incorporated into the City's CIP for further project development.

The management and implementation of capital projects is the responsibility of the City's Public Works and Engineering Departments. An outcome of this master planning process will be to provide the city with a repeatable methodology for rating, ranking, and prioritizing stormwater capital projects.

The rating and ranking method applied to projects identified for consideration have been used to develop a project priority list. The priority list presented in this report is not necessarily the final ranking nor does it represent the expected order for implementation but indicates a relative priority.

The final Stormwater CIP includes the top 14 project recommendations summarized in **Table 8**. The top five projects are regarded as having the highest priority.

Additionally, several factors can influence the actual implementation sequence. For example, a financial constraint or a partnership opportunity could emerge and influence project sequencing or flood control projects should be addressed by beginning with improving conveyance at the downstream end of a system to reduce the backwater in the upstream reaches. The priority rankings are thus a relative guide.

Finally, because the city's goals, resources, and issues are constantly changing, this plan is designed to be re-evaluated each year to reaffirm or reprioritize the stormwater capital improvement project list. Additional projects may be added and existing projects may be revised utilizing the Project Worksheet template located in **Appendix E**.

POTENTIAL FUNDING SOURCES

As part of this report's planning effort, potential funding sources have been identified for consideration by the City. The list presented is intended for informational purposes only and is intended to provide guidance on where funding may be acquired through local municipal tax and user-fee funding, general obligation bonds, revolving state and federal grants, disaster recovery grants, and inter-agency public partnerships. **Table 14** provides a storm water utility fee comparison of revenue generated per capita for comparable cities and **Table 15** summarizes the available stormwater potential funding sources by program, agency, and annual ceiling limits.

To address the city's stormwater management needs it is important to identify a consistent source of funding to ensure that short-term and long-term plans can be implemented. Additionally, stormwater infrastructure should be treated as a large-scale community asset that should be evaluated at the watershed level to effectively manage flood control, erosion, and water quality issues.

Each of the projects identified for consideration and future funding will need to be evaluated on an annual basis to reassess projects for implementation based upon city available funding, external funding sources, various agencies and donations, and cost-share opportunities through interlocal agreements with the county.

Methods for implementing a steady fund for addressing the highest priority and basic maintenance needs may be accomplished by the following:

- **Stormwater Utility Fee** – A fee assessed, similar to water or sewer enterprise funds, based on the amount of stormwater a property generates which is directly related to impervious cover from such things as buildings and parking lots. This sustainable funding mechanism is dedicated to recovering the costs of stormwater infrastructure regulatory compliance, planning, maintenance, capital improvements, repair, and replacement. Based on cities of similar size and revenues generated, it is estimated that the City of Kerrville would raise approximately $800,000 per year based on revenue per capita which would include revenue from both residential and commercial properties (**Table 14**).

Table 14 - Stormwater Utility Fee City Comparison

	Population Estimate	Revenue*	Revenue / Capita
Georgetown	58,723	$ 3,377,480	$ 57.52
Keller	44,940	$ 1,474,997	$ 32.82
Lancaster	59,708	$ 1,576,407	$ 26.40
San Marcos	54,076	$ 5,800,000	$ 107.26
University Park	25,201	$ 453,052	$ 17.98
Colleyville	26,674	$ 972,082	$ 36.44
Schertz	37,938	$ 1,141,000	$ 30.08
Fredericksburg	14,014	$ 477,607	$ 34.08
Median	**41,239**	**$ 1,307,999**	**$ 33.45**
Kerrville (Estimated)	**24,292**	**$ 812,594**	**$ 33.45**

**2016-17 actual revenues or projected 2019 revenues*

- **Property Taxes/General Fund** – A portion of property taxes can be transferred into the stormwater management fund. These funds are generally subject to great competition from other worthy municipal programs. It is common for stormwater management to take a lower priority and thus creates a less reliable source of funding. In addition, stormwater services typically bear no relationship to the assessed value of the property and therefore might not be equitable.

- **Bond Programs** – General Obligation Bonds (GO), Revenue Bonds (RB), Certificates of Obligation (CO) are various types of debt the city may elect to incur to fund major capital expenditures. A voter-approved general obligation bond program such as a Capital Improvements Bond may be chosen to meet the demand for growth and services as appropriate.

- **Grants and Low-Interest Loans** – Various revolving stormwater management grants are available through the Texas Water Development Board (TWDB), Department of Housing and Urban Development (HUD), the General Land Office (GLO), U.S. Army Corps of Engineers (USACE), and other agencies. The potential for grant funding should be examined annually to identify matching requirements, application due dates, and which projects should seek grant aid.

- **Disaster Recovery Grant Funding** – FEMA and the Texas Department of Emergency Management (TDEM) administer grant funding as related to Disaster Declaration Proclamations which are often declared by Governor's or Presidential orders to provide community assistance. Inevitably, disasters will occur, and when they do, the City should seek to apply for state and federal assistance.

- **Interlocal Cooperation Agreements** – The City and Kerr County are able to enter into interlocal agreements for the purposes of cost sharing planning and construction projects that affect both jurisdictional areas. An example of a cost-share agreement may be related to flood protection planning for major rivers and streams that are shared by both political subdivisions.

Table 15 - Stormwater Potential Funding Sources

Source Type	Program Name	Agency	Annual Ceiling ($)	Schedule	Suggested Use of Funds / Notes
Local	City issued bond financing	COK	TBD	TBD	Issue general obligation bonds issued with the approval of the electorate for capital improvement and general public improvements for use to fund the design and construction of the project including Stormwater Revenue Bonds and General Obligation Bonds.
Local	General Fund	COK	TBD	Annual	A portion of property taxes can be transferred into the stormwater management fund. These funds are generally subject to great competition from other worthy municipal programs.
Local	Stormwater Utility Fee	COK	Est. $500k to $1M	Annual	A fee assessed, similar to water or sewer enterprise funds, based on the amount of stormwater a property generates which is directly related to impervious cover from such things as buildings and parking lots.
Local	Sales Tax for Drainage and Water Quality Projects	COK	Est. $300,000 / year	TBD	Propose to transfer sales tax revenue to a special tax/drainage district.
Gov. Fed	Hazard Mitigation Grant Program (HMGP)	TDEM / FEMA	Varies	Disaster Declaration Required	FEMA provides funding to support cost-effective post-disaster projects provided on a 75/25 match in funding for mitigation projects. Benefit-Cost Ratio must be greater than 1.0.
Gov. State	Flood Protection Grant	TWDB	TBD	Annual	Flood protection grants for flood protection planning, flood early warning systems, flood response (during or after a flood event)
Gov. Fed	Flood Mitigation Assistance Grant Program (FMA)	TWDB/ FEMA	Varies	Annual	Community Flood Mitigation: Advance Assistance $100,000; Projects a cost share up to $10,000,000; Technical Assistance up to $50,000; Flood Mitigation Planning up to $100,000.
Gov. Fed	Pre-Disaster Mitigation Program (PDM)	FEMA	Varies	Annual	Assists with implementing a sustained pre-disaster natural hazard mitigation program. Funding maximum $4 million for mitigation projects; $150,00 for mitigation plan updates.
Gov. Fed	Community Development Block Grant	TDA/ HUD	$350,000	Annual	Assists with housing, economic development, and measures to reduce damages in future storms.
Gov. Fed	Continuing Authorities Program (CAP)	USACE	$10M	Annual	The Corps' CAP program provides a plan, design, and implementation for certain types of water resources projects for such things as flood control, dredging, streambank and erosion protection, and environment. Feasibility phase is limited to $100,000 and then a 50/50 cost-share.
Gov-State	Inter-local Agreement (Kerrville-Kerr County)	TBD	TBD	TBD	Contractual relationship entered into between two or more local units of government and/or between a local unit of government and a non-profit organization for the joint usage and/or development of sports fields, regional parks, or other facilities
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PROPOSED STORMWATER PROJECT IMPLEMENTATION PLAN

Provided below is a generalized overview of the project development and implementation process. The phases supported by this Stormwater Master Plan are related to Phase 1 Strategic Planning solutions.

Project Development Process

- **PHASE 2 / 3: Preliminary Engineering Analysis and Report (9-18 months)**
  - Identify detailed modeling and quantification of problems
  - Identify environmental permitting, land acquisition and utility adjustment needs.
  - Begin environmental assessment / environmental impact statement and other permits, as necessary.
  - Evaluate feasible design alternatives and select the option for implementation.
  - Develop a construction phasing plan if the project needs to be done at different times.
  - Begin negotiation process, if required, for land acquisition, easements, and right-of-way.
  - Secure land acquisition and easement needs.
- **PHASE 3 / 4: Design Phase (6-12 months)**
  - Develop construction documents including plans, specifications, bid documents, and detailed cost estimates.
  - Receive environmental and permitting clearances, as required.
  - Coordinate with utility providers on required utility adjustments.
- **PHASE 4: Construction Phase (6-24 months per phase)**
  - Begin construction activities.
  - Monitor and inspect the progress of construction.
  - Future Maintenance Procedure Establishment

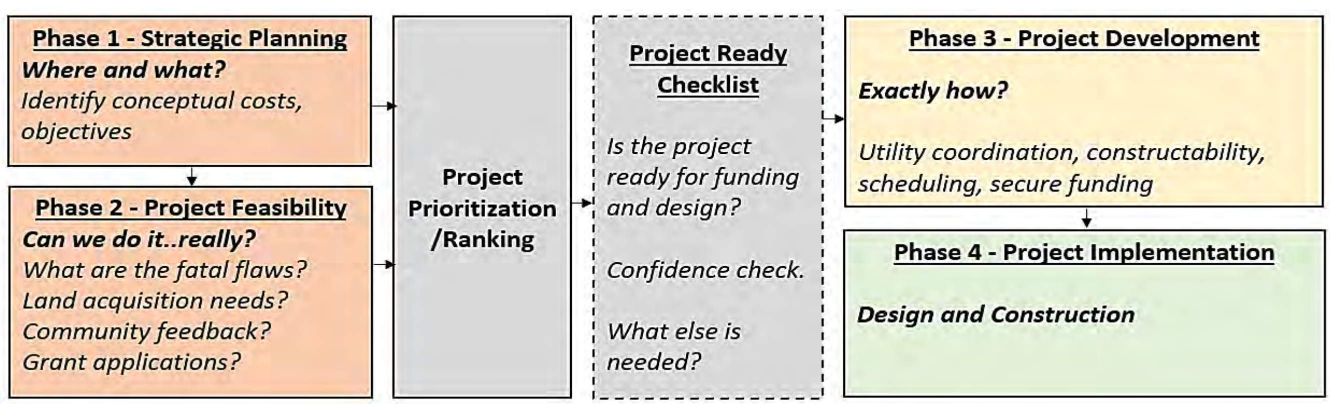

Figure 79 - Capital Improvement Program Lifecycle Process

Table 16 - Proposed Project Implementation Plan

	Project Name	Estimated Total Project Cost
Stormwater Programs and Planning Studies	Dam Inspection and Maintenance Program	$15,000/YR
	Flood Protection Plan Study (H&H, remapping)[1]	$400,000 to $800,000
	Storm Drain System Inventory and Assessment	$10,000/YR
	Regional Detention Pond Study and Fee-in-Lieu of Program	$60,000
	Stormwater Drainage Criteria Manual Update	$50,000
	Design Review Checklist	$5,000 to $10,000
	Stormwater Utility Fee Study	$70,000
	Flood Complaint Database	$5,000/YR
	Water Quality and Erosion Control Program Study	$80,000
	Flood Warning System (4 Locations)	$200,000
Stormwater Capital Improvement Projects	Louise Hays Dam Structural Repairs Phase 1 - Planning/Design Phase 2 - Construction	$1,000,000
	Take it Easy Channel Improvements	$2,291,900
	Lois Street Drainage Improvements[2]	$189,900
	Hill Country Drive Phase 1 – Drainage Improvements	$249,600
	Hill Country Drive Phase 2 - Downstream Improvements[2]	$2,180,100
	Kroc Center Detention Pond Clay Street Drainage Improvements	$8,967,500
	Pinto Trail Channel Improvements	$979,500
	Circle Avenue	$188,800
	Jack Drive Drainage Improvements	$2,373,800
	Coronado Drive Drainage Improvements[2]	$494,200
	Spring Street Erosion Control	$744,100
	Harper Street Drainage Improvements	$1,808,400
	Park Street Low Water Crossing	$200,000
	First Street Low Water Crossing	$200,000
	Fourth Street Low Water Crossing	$200,000
	TOTALS (ROUNDED)	**$23,400,000**

* 2019 dollars; Assume 6% to 7% increase each additional year

[1] Partnership opportunities with Kerr County
[2] Partnership opportunities with TxDOT

APPENDIX A - EXHIBITS

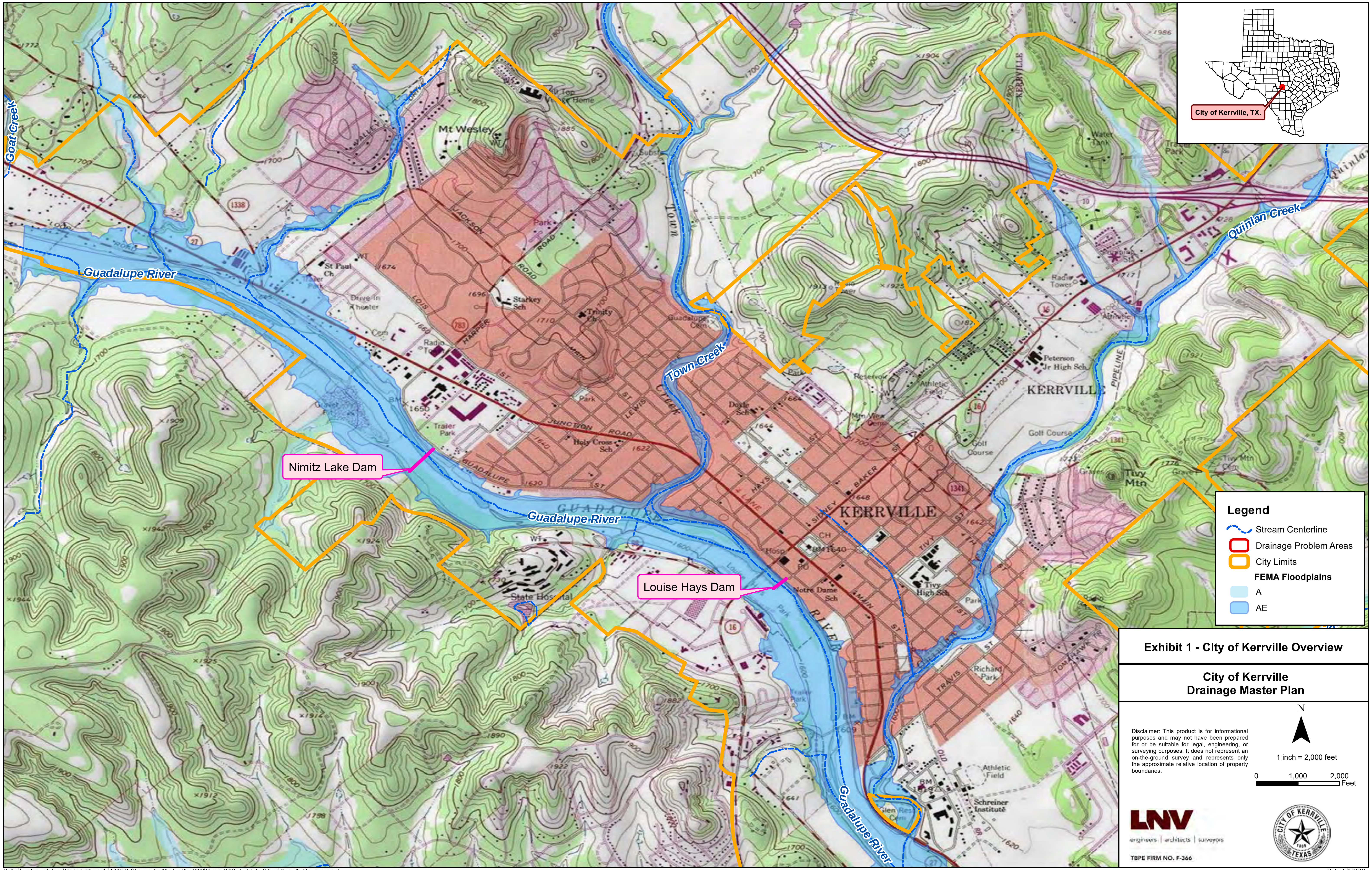

Exhibit 1 - CIty of Kerrville Overview

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

LNV
engineers | architects | surveyors

TBPE FIRM NO. F-366

CITY OF KERRVILLE TEXAS 1889

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Date: 5/3/2019

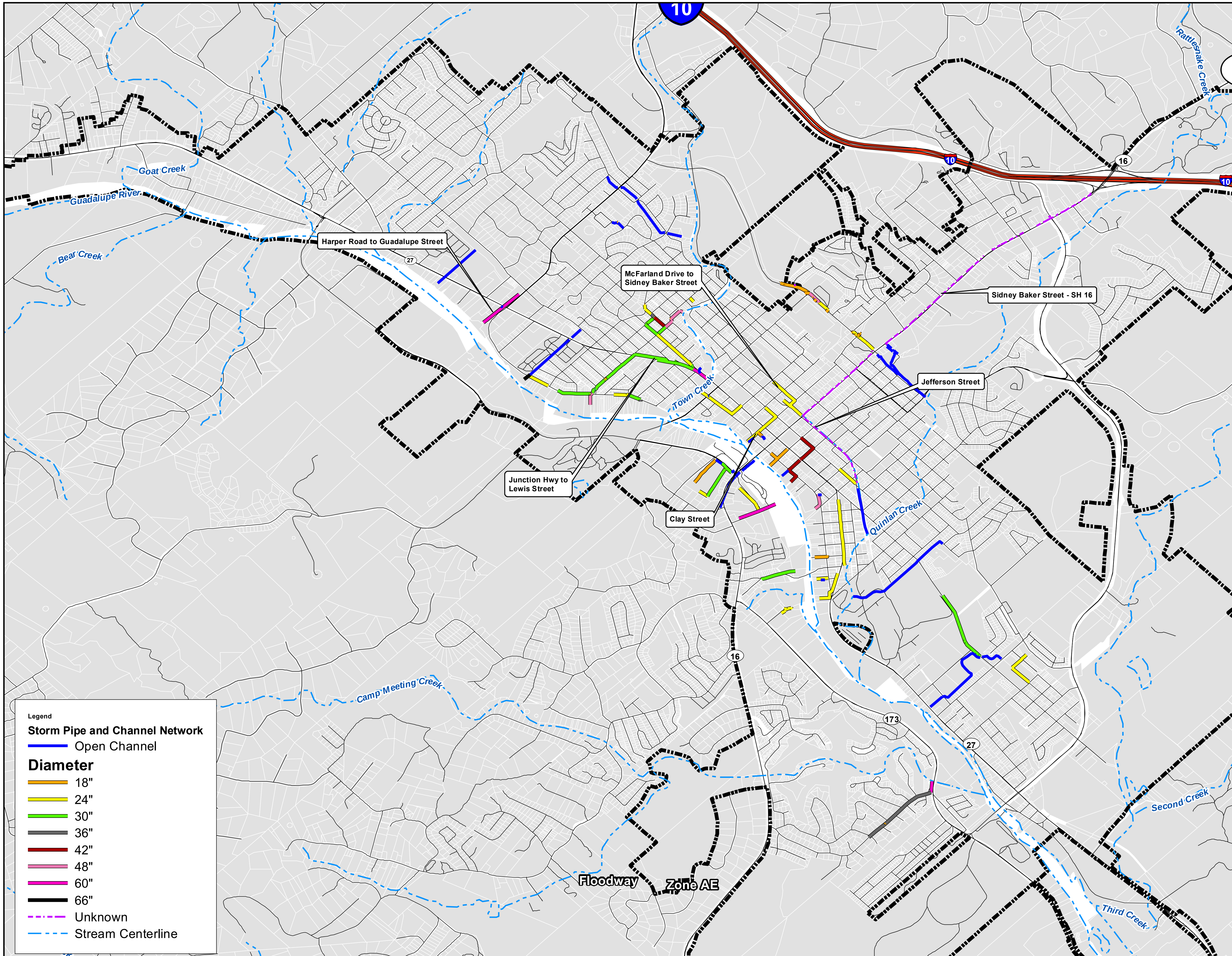

Exhibit 2 - Existing Storm Network Overview

City of Kerrville
Drainage Master Plan

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LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

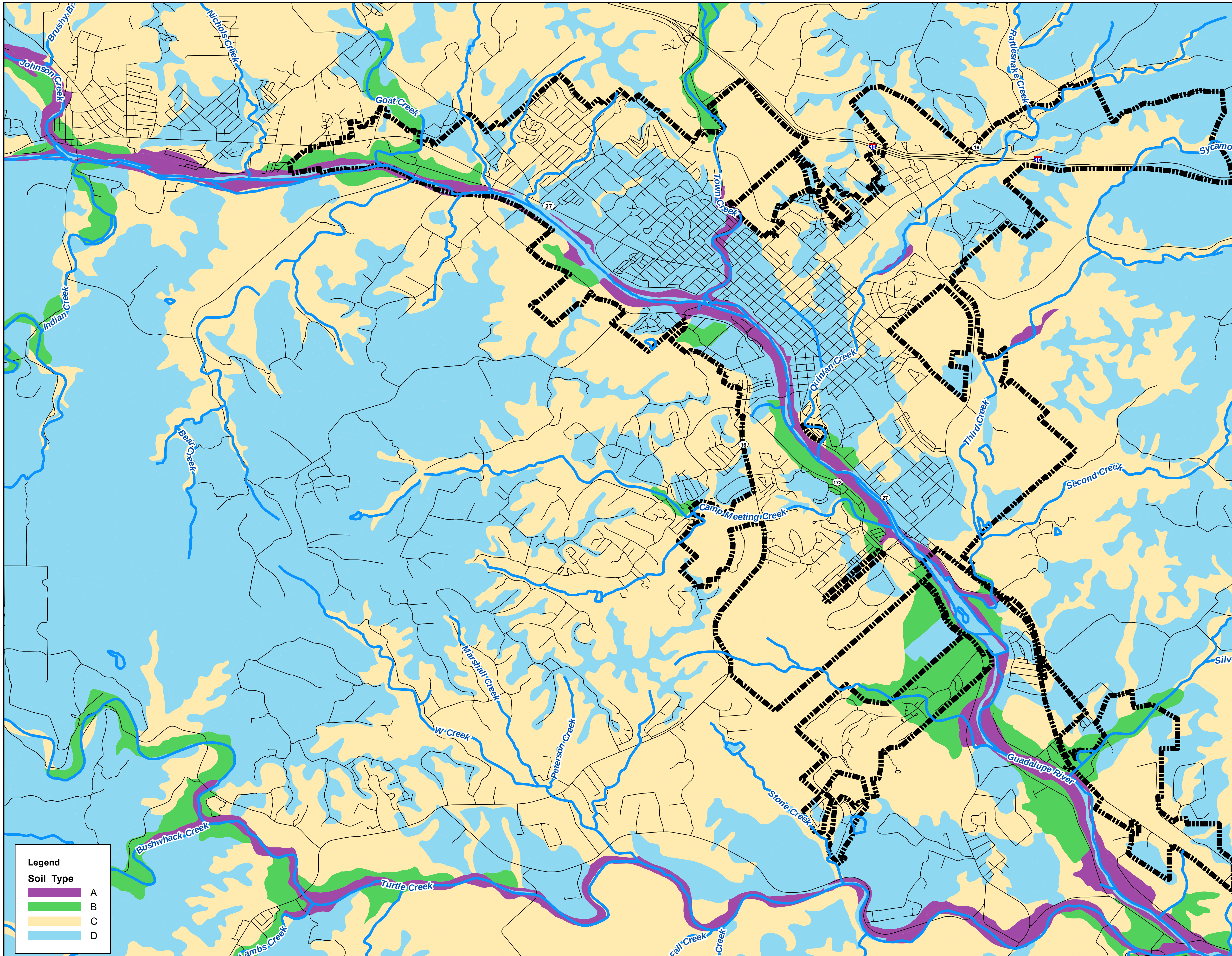
CITY OF KERRVILLE 1889 TEXAS

Path: \\SASTORAGE\share\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\xExhibit - Storm water network.mxd

Date: 7/23/2019

Exhibit 3 - NRCS Soil Types

City of Kerrville
Drainage Master Plan



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LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\xExhibit - Soils.mxd

Date: 5/9/2019

NOTES TO USERS

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NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

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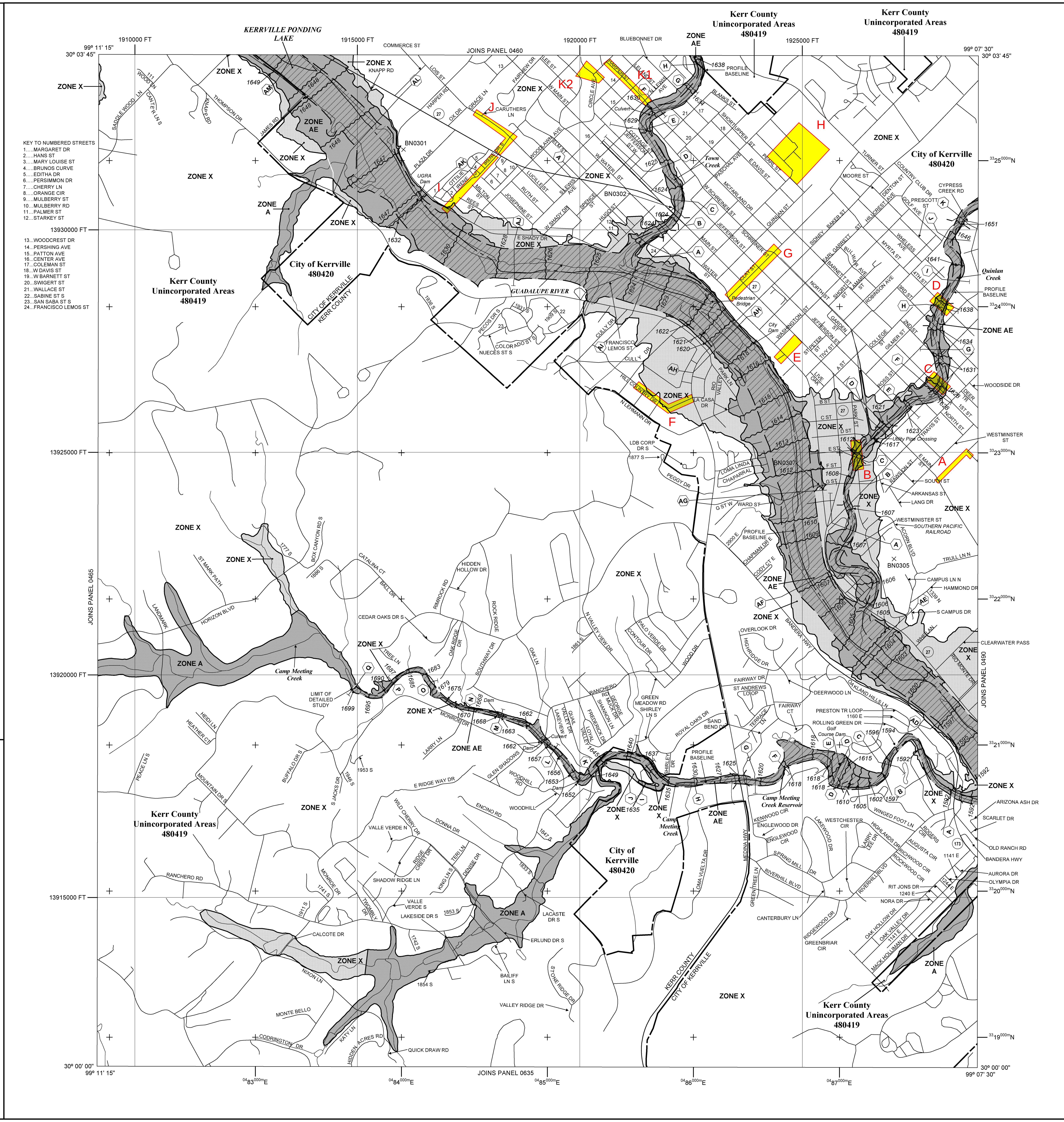

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
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ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
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FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain boundary
Floodway boundary
Zone D Boundary
CBRS and OPA Boundary
Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - 23	Transect line
97° 07' 30", 32° 22' 30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
4276000mE	1000-meter Universal Transverse Mercator grid values, zone 14
600000 FT	5000-foot grid ticks: Texas State Plane coordinate system, zone South Central (FIPSZONE 4204), Lambert Conformal Conic Projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

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EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP PANEL
JULY 19, 2000

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

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MAP SCALE 1" = 1000'

500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0470F

FIRM
FLOOD INSURANCE RATE MAP

KERR COUNTY, TEXAS
AND INCORPORATED AREAS

PANEL 470 OF 775

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
KERR COUNTY	480419	0470	F
CITY OF KERRVILLE	480420	0470	F

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
48265C0470F

MAP REVISED
MARCH 03, 2011

Federal Emergency Management Agency

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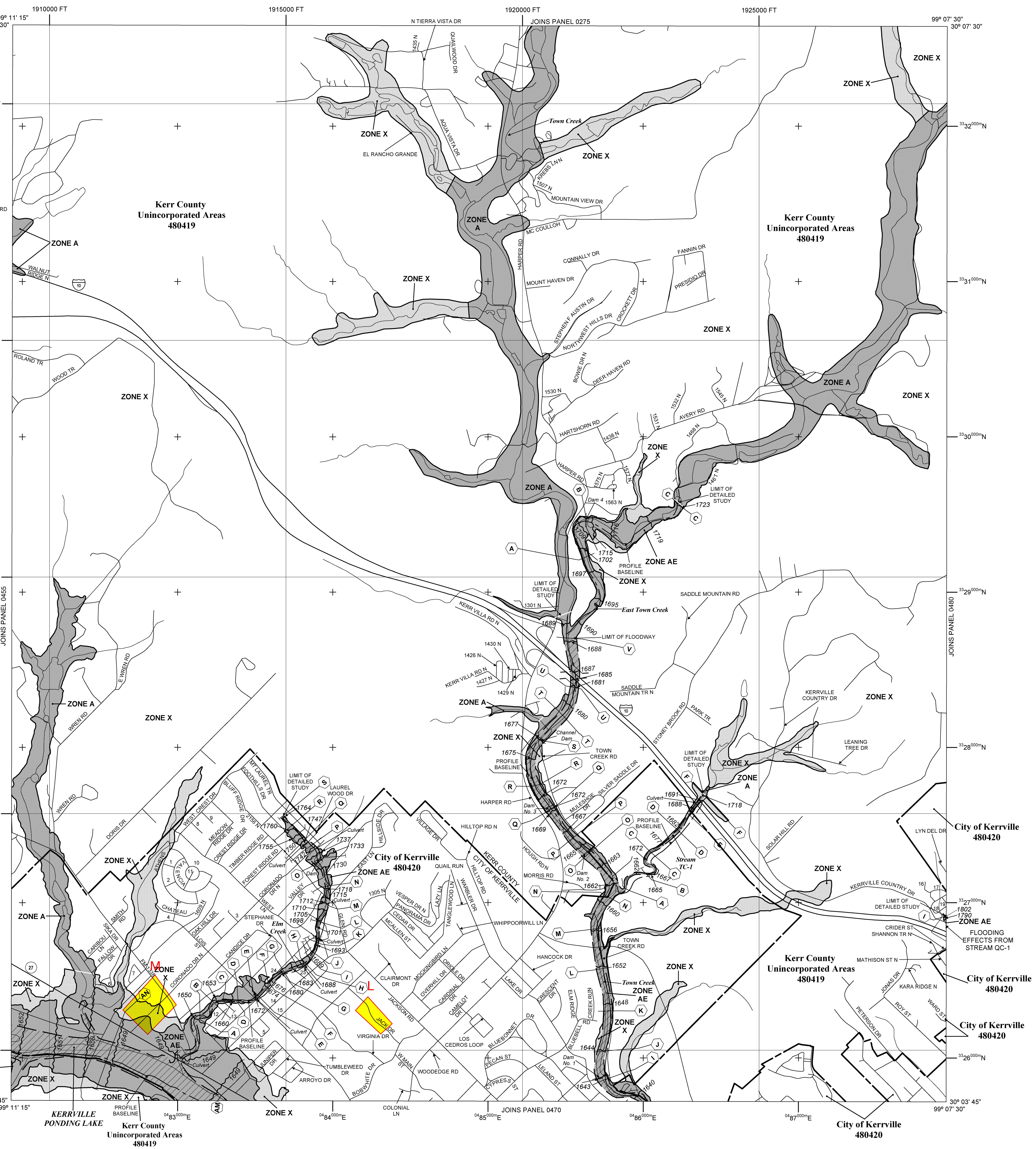
KEY TO NUMBERED STREETS
1.....SAN MARINO DR N
2.....GRANADA DR N
3.....WOODSTONE DR
4.....MERDIAN BLVD N
5.....CYNTHIA DR
6.....RABBIT RUN
7.....SUMMER LOOP
8.....TRAILWOOD CIR
9.....WESTRIDGE CIR
10.....VILLA
11.....VILLA DR N
12.....ERIN DR
13.....CRESTWOOD DR
14.....METHODIST ENCAMPMENT RD
15.....MANOR DR
16.....1489 N
17.....LESLIE DR
18.....1556 N
19.....1488 N
20.....KERR VILLA RD N
21.....1427 N
22.....1426 N
23.....1430 N
24...CRESTWOOD DR
25...ELMWOOD DR



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JULY 19, 2000

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NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0460F

FIRM
FLOOD INSURANCE RATE MAP
KERR COUNTY, TEXAS
AND INCORPORATED AREAS

PANEL 460 OF 775

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
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KERRVILLE, CITY OF	480420	460	F

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MAP NUMBER 48265C0460F

MAP REVISED MARCH 03, 2011

Federal Emergency Management Agency

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NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit their website at http://www.ngs.noaa.gov/.

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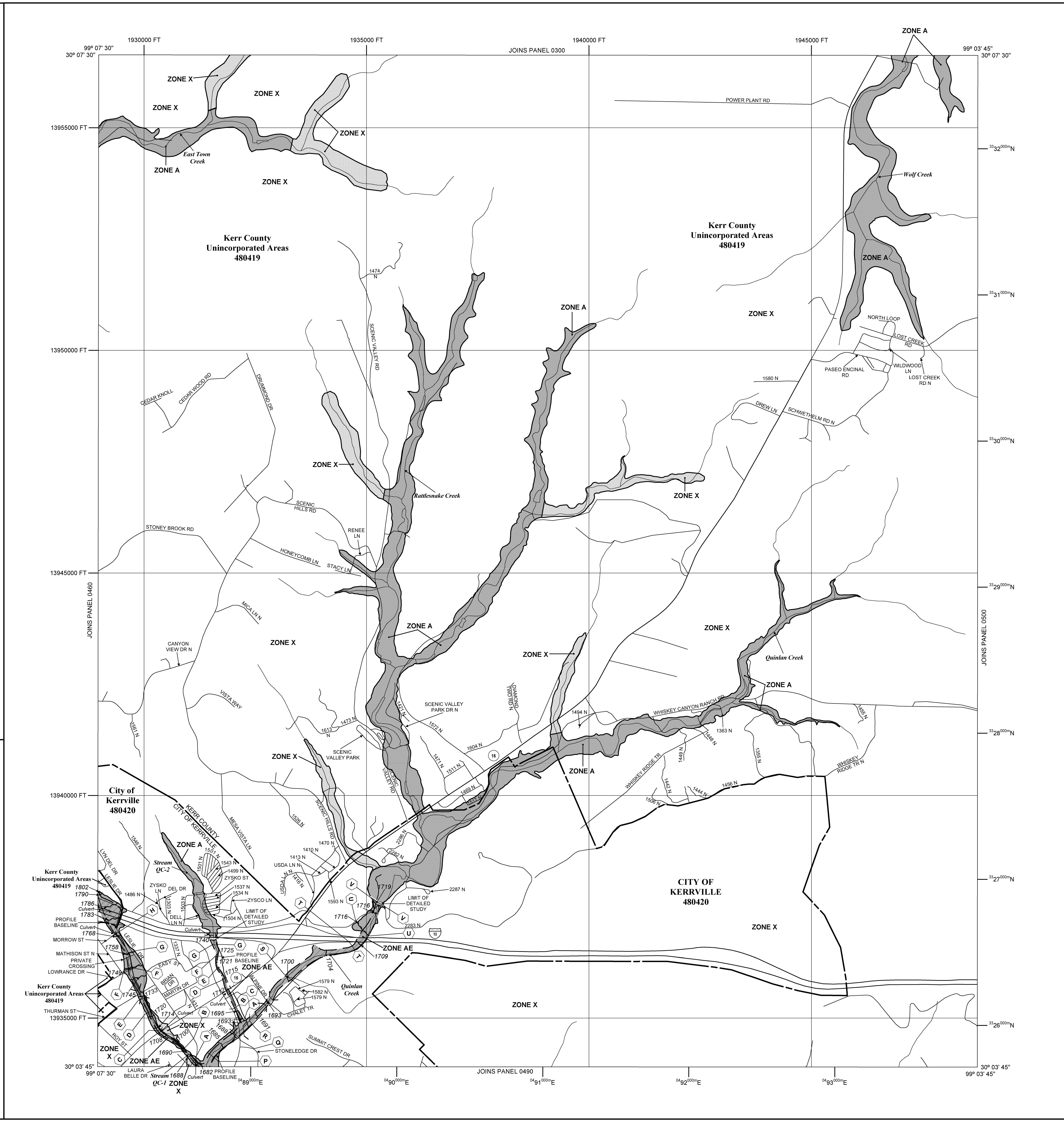

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	Floodplain boundary
	Floodway boundary
	Zone D Boundary
	CBRS and OPA Boundary
	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - 23	Transect line
97° 07' 30", 32° 22' 30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
$^{42}76^{000m}$E	1000-meter Universal Transverse Mercator grid values, zone 14
600000 FT	5000-foot grid ticks: Texas State Plane coordinate system, zone South Central (FIPSZONE 4204), Lambert Conformal Conic Projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index.

EFFECTIVE DATE OF COUNTYWIDE FLOOD
INSURANCE RATE MAP PANEL
JULY 19, 2000

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

March 3, 2011 - to update corporate limits, to change Base Flood Elevations and Special Flood Hazard Areas, to update map format, to update roads and road names, and to reflect updated topographic information

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MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0480F

FIRM
FLOOD INSURANCE RATE MAP

KERR COUNTY, TEXAS
AND INCORPORATED AREAS

PANEL 480 OF 775

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
KERR COUNTY	480419	0480	F
KERRVILLE, CITY OF	480420	0480	F

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
48265C0480F

MAP REVISED
MARCH 03, 2011

Federal Emergency Management Agency

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

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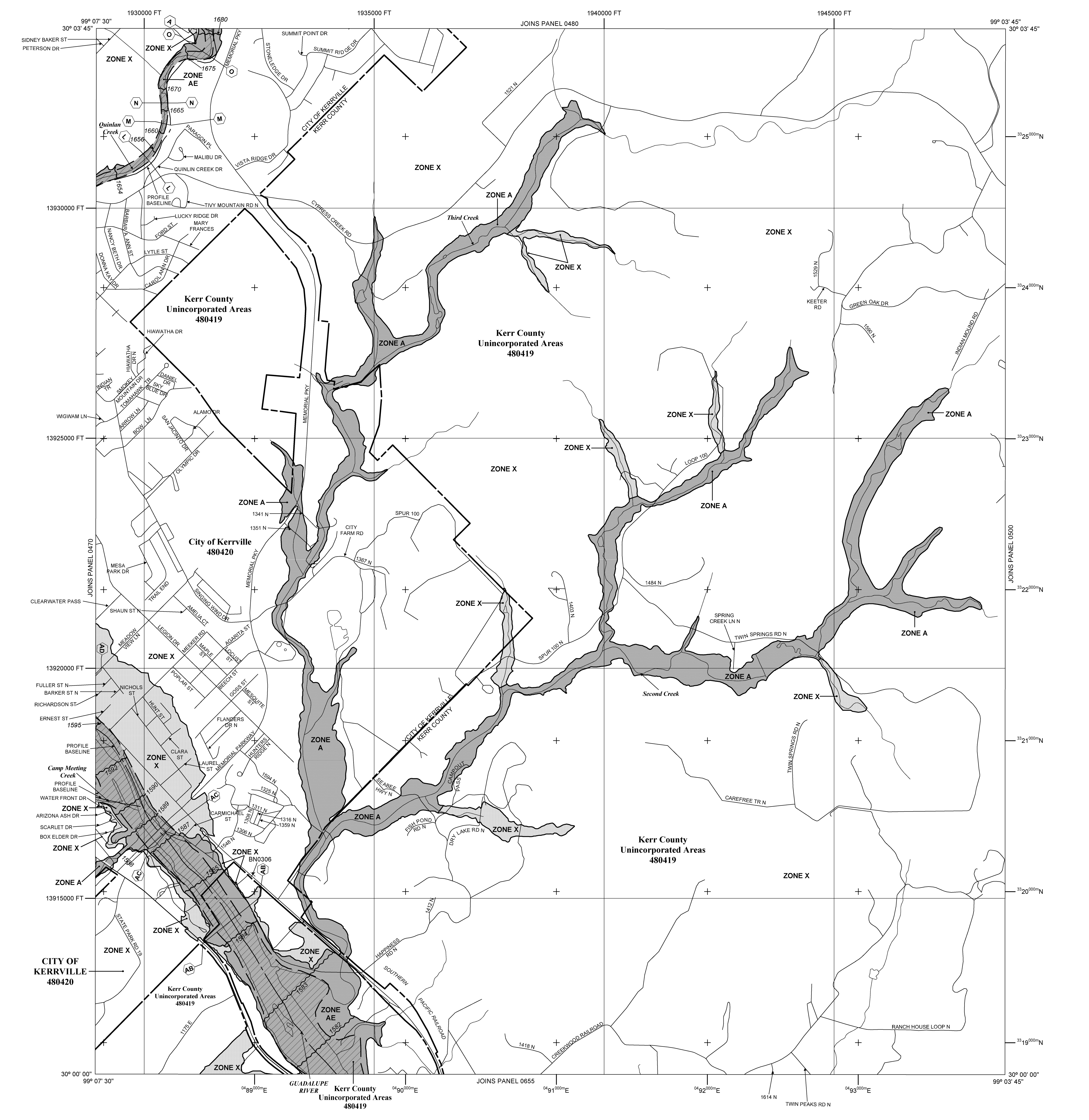

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300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0490F

FIRM

FLOOD INSURANCE RATE MAP

KERR COUNTY, TEXAS

AND INCORPORATED AREAS

PANEL 490 OF 775

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

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KERRVILLE, CITY OF	480420	0490	F

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MAP NUMBER 48265C0490F

MAP REVISED MARCH 03, 2011

Federal Emergency Management Agency

APPENDIX B - CITYWIDE DRAINAGE CIPS

APPENDIX B
TABLE OF CONTENTS

SUMMARY OF PROBABLE CONSTRUCTION COST

Stormwater Master Plan

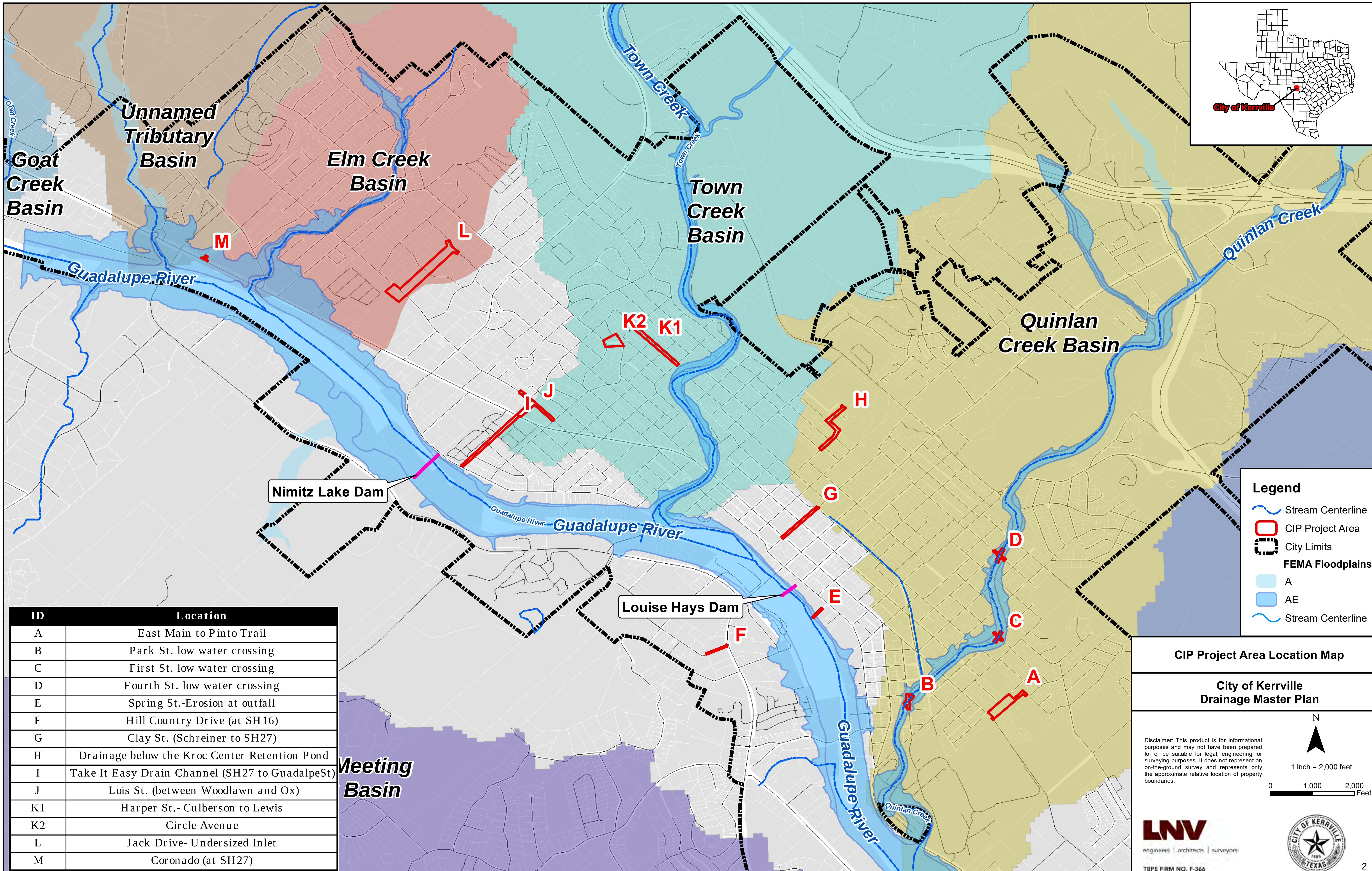
City of Kerrville

Date: 12/19/2019

ID	Project Priority Rank	Project Name	General	Roadway	Utilities	Drainage	Design, Permitting, Land Acquisition Costs	Total Project Cost[1]
A	5	East Main to Pinto Trail	$ 111,710	$ 210	$ 22,500	$ 565,237	$ 104,949	**$ 979,520**
B	11	Park St. Low Water Crossing	$ -	$ -	$ -	$ -	$ -	**$ 200,000**
C	11	First St. Low Water Crossing	$ -	$ -	$ -	$ -	$ -	**$ 200,000**
D	13	Fourth St. Low Water Crossing	$ -	$ -	$ -	$ -	$ -	**$ 200,000**
E	9	Spring St. - Erosion at Outfall	$ 83,370	$ -	$ -	$ 438,787	$ 91,377	**$ 744,073**
F1 & F2	3	Hill Country at SH16 Ph I	$ 32,001	$ 123,336	$ 7,500	$ 14,625	$ 27,729	**$ 249,557**
		Hill Country at SH16 Ph II	$ 280,803	$ 363,424	$ 16,800	$ 896,151	$ 233,577	**$ 2,180,050**
G & H	4	Kroc Center Detention Pond Clay St. (Schreiner to SH27)	$ 1,170,744	$ 1,093,620	$ 547,000	$ 3,680,945	$ 852,115	**$ 8,967,501**
I	1	Take It Easy Drainage Channel	$ 297,871	$ 118,320	$ -	$ 1,235,639	$ 227,127	**$ 2,291,913**
J	2	Lois St. (Woodlawn to Ox Dr.)	$ 24,460	$ 27,162	$ 46,940	$ 37,080	$ 20,346	**$ 189,899**
K1	10	Harper Street	$ 232,936	$ 332,090	$ 179,800	$ 505,310	$ 193,760	**$ 1,808,431**
K2	6	Circle Avenue	$ 23,684	$ 40,702	$ 3,900	$ 63,053	$ 24,626	**$ 188,800**
L	7	Jack Drive	$ 293,948	$ 128,901	$ 68,500	$ 1,138,724	$ 336,202	**$ 2,373,793**
M	7	Coronado at Junction Highway	$ 63,372	$ 53,485	$ 24,800	$ 209,770	$ 54,911	**$ 494,195**
Summary of Probable Cost			$ 3,744,163	$ 2,707,943	$ 1,088,440	$ 13,320,951	$ 4,148,777	**$ 21,067,733**

[1] Total project costs include all projected expenditures thru project completion

Notes: 2019 Dollars, assume 6% to 7% cost increase each year



ID	Location
A	East Main to Pinto Trail
B	Park St. low water crossing
C	First St. low water crossing
D	Fourth St. low water crossing
E	Spring St.-Erosion at outfall
F	Hill Country Drive (at SH16)
G	Clay St. (Schreiner to SH27)
H	Drainage below the Kroc Center Retention Pond
I	Take It Easy Drain Channel (SH27 to GuadalpeSt)
J	Lois St. (between Woodlawn and Ox)
K1	Harper St.- Culberson to Lewis
K2	Circle Avenue
L	Jack Drive- Undersized Inlet
M	Coronado (at SH27)

CIP Project Area Location Map

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

City of Kerrville Texas

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\xExhibit - Drainage Project Locations Overall .mxd

Date: 12/4/2019

LOCATION A - PINTO TRAIL CHANNEL

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	A
Project Name:	East Main to Pinto Trail Channel

Fiscal Year Plan								Total
								$979,520

Funding Source	
General Fund	0
Total	0

Problem Description:

Existing earthen Pinto Trail drainage channel is subject to high velocities resulting in erosion, destabilization of channel and overtopping flows. During large storm events, the channel is known to overtop and spill westward towards Westminster Street.

Proposed Improvement:

Construct a rectangular MSE channel with a concrete bottom from East Main Street to Pinto Trial.

Regrade existing downstream channel from Acorn Boulevard to East Main Street.

O & M Impact:

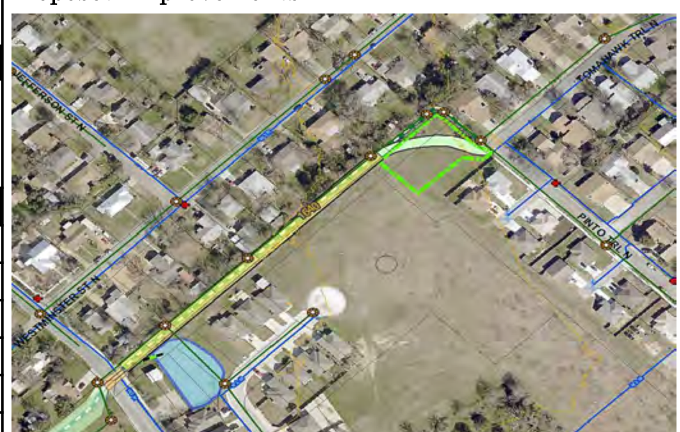
O & M will require periodic mowing and clean out of channel and culverts.

CIP Ranking Criteria	Score
Structural Flooding	45
Roadway Flooding	63
Roadway Emergency Service Access	18
Frequency of Flooding Damages	36
Erosion / Channel Stability	90
Level of Protection Benefit	90
Project Cost	36
Funding Source / Availability	24
Developmental Impacts	60
Permitting	40
Land / Easement Acquisition	12
Project Readiness	12
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	0
Total Weighted Point Score:	588
CIP Ranking:	5

Existing Conditions

Existing Earthen Drainage Channel (Facing D/S)

Proposed Improvements



Conceptual Drainage Improvement Layout

Notes:

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: A - East Main To Pinto Trail

Date: 12/19/2019

Solutions Today with a Vision for Tomorrow

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	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 64,674.22
	2	INSURANCE & BOND	LS	3%	1	$ 17,638.42
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 23,517.90
	4	SW3P	LS	1%	1	$ 5,879.47
Roadway	5	REMOVE CONCRETE CURB	LF	$ 6.00	35	$ 210.00
Utility	6	ADJUST EXISTING MANHOLES AND VALVE BOXES	EA	$ 2,000.00	3	$ 6,000.00
	7	ADJUST EXISTING WASTEWATER LATERAL	EA	$ 1,500.00	11	$ 16,500.00
Drainage	8	REMOVING CONC (RIPRAP)	SY	$ 18.00	319	$ 5,743.42
	9	CHANNEL EXCAVATION (150 CY < X < 5,000 CY)	CY	$ 25.00	3,010	$ 75,250.00
	10	CONCRETE RIPRAP (5")	SY	$ 90.00	2,150	$ 193,464.00
	11	CONCRETE STRUCTURE (BAFFLE BLOCKS / RETAINING WALL)	CY	$ 1,000.00	22	$ 22,000.00
	12	MSE RETAINING WALL, 3 FT	SF	$ 27.00	4,140	$ 111,780.00
	13	TOPSOIL (4")	SY	$ 9.00	8,000	$ 72,000.00
	14	BERMUDA SODDING	SY	$ 7.00	8,000	$ 56,000.00
	15	CHAIN LINK FENCE (REMOVE)	LF	$ 18.00	500	$ 9,000.00
	16	CHAIN LINK FENCE (4' HIGH)	LF	$ 40.00	500	$ 20,000.00
				Subtotal		$ 699,657.43
				Contingency	25%	$ 174,914.36
				Total Construction Cost		**$ 874,571.78**
				Engineering	12%	$ 104,948.61
				Total Project Cost		**$ 979,520.40**

A01 - Drainage Area Map
Pinto Trail

City of Kerrville
Drainage Master Plan

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LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

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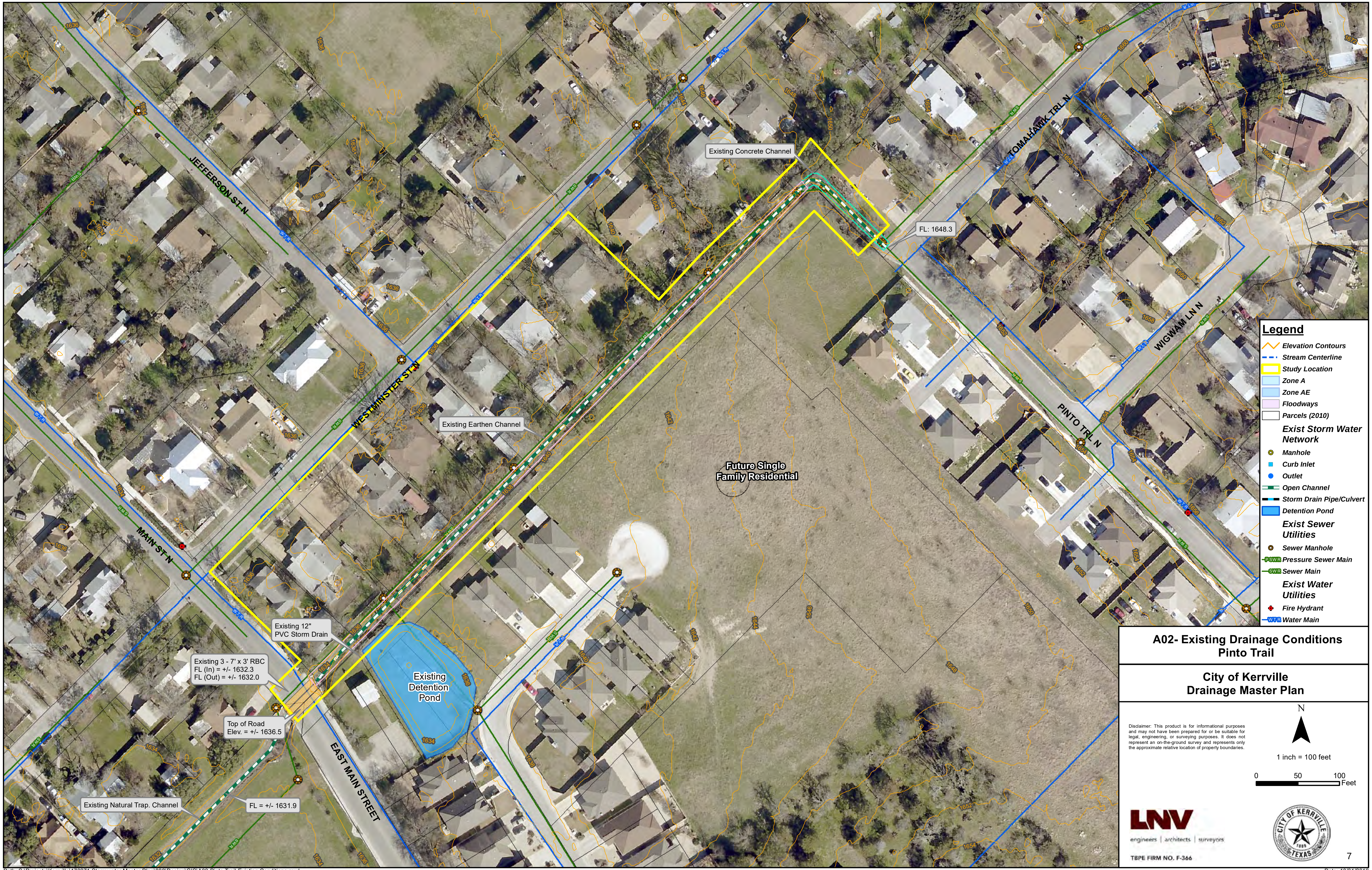
Date: 5/8/2019



A02- Existing Drainage Conditions Pinto Trail

City of Kerrville Drainage Master Plan

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TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\A02-Pinto Trail-Existing Conditions.mxd

Date: 10/31/2019

A03- Proposed Drainage Conditions Pinto Trail

City of Kerrville Drainage Master Plan

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TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\A03-Pinto Trail-Proposed Conditions (Updated 11.12.19).mxd

Date: 12/17/2019

LOCATION B, C, D – LOW WATER CROSSINGS

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	B
Project Name:	Park Street Low Water Crossing

Fiscal Year Plan								Total
								$200,000

Funding Source	
General Fund	0
Total	0

Problem Description:

Quinlan Creek at the Park Street low water crossing experiences overtopping flows resulting in frequent roadway closures due to insufficient capacity, hazardous flood flow conditions, erosion, and risk of property flooding.

Proposed Improvement:

Option 2:

Provide Automatic Flood Gates and warning signs to improve public safety.

O & M Impact:

Periodic maintenance of flood gate system.

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	36
Roadway Emergency Service Access	54
Frequency of Flooding Damages	90
Erosion / Channel Stability	18
Level of Protection Benefit	9
Project Cost	12
Funding Source / Availability	0
Developmental Impacts	30
Permitting	24
Land / Easement Acquisition	4
Project Readiness	4
Project Dependency	0
Water Quality Impacts	42
Riparian Impacts	0
Total Weighted Point Score:	413
CIP Ranking:	11

Existing Conditions

Existing 10'x3' Box Culvert (Facing U/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

Option 1 consists of major roadway and channel improvements that provide protection for up to the 5-year storm event.

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: B - Park Street Low Water Crossing

Date: 12/19/2019

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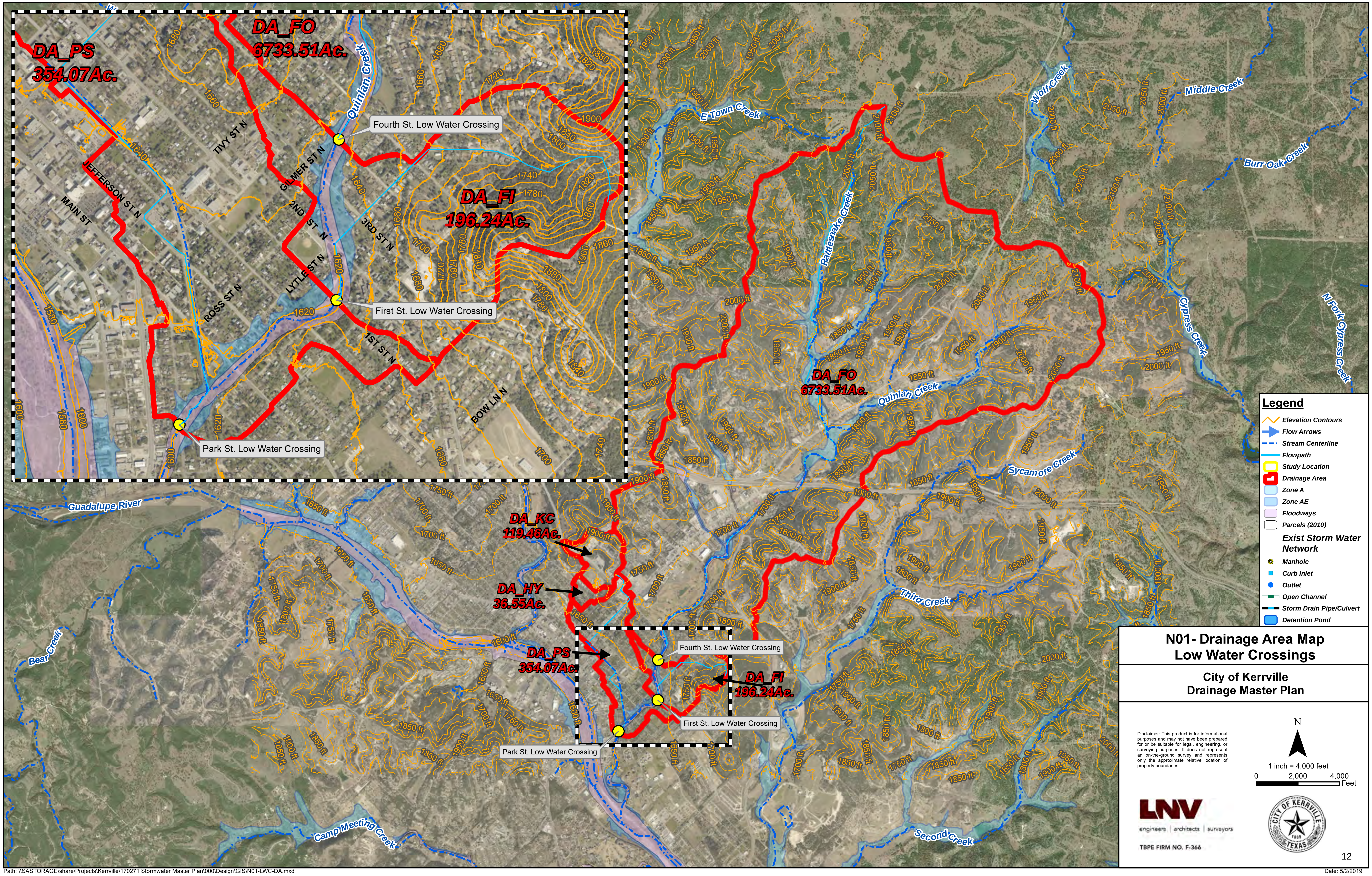
	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
		OPTION 1 (HIGH WATER DETECTION SYSTEM)				
	1	HIGH-WATER ALERT LIFESAVING TECHNOLOGY (HALT)	EA	100,000.00	2.00	$ 200,000.00
		OPTION 2 (BRIDGE REPLACEMENT AND CHANNEL IMPROVEMENT)				
General	1	MOBILIZATION	LS	11%	1	$ 188,749.82
General	2	INSURANCE & BOND	LS	3%	1	$ 51,477.22
General	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 68,636.30
General	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 51,477.22
General	5	SW3P	LS	1%	1	$ 17,159.07
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	940	$ 5,640.00
Roadway	7	EMBANKMENT (FINAL)(DENS CONT)(TY A)	CY	$ 18.00	2,637	$ 47,470.00
Roadway	8	TACK COAT	GAL	$ 5.00	181	$ 904.44
Roadway	9	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	2,022	$ 70,777.78
Roadway	10	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	1,809	$ 27,133.33
Roadway	11	CONCRETE CURB & GUTTER	LF	$ 20.00	940	$ 18,800.00
Roadway	12	CURB RAMP	EA	$ 1,500.00	4	$ 6,000.00
Utility	13	6" PVC WATER MAIN	LF	$ 50.00	550	$ 27,500.00
Drainage	14	CHANNEL EXCAVATION (5,000 CY < X < 70,000 CY)	CY	$ 20.00	35,670	$ 713,400.00
Drainage	15	BOX CULVERT EXCAVATION AND BACKFILL	CY	$ 15.00	2,315	$ 34,722.22
Drainage	16	CONCRETE STRUCTURE (HEADWALL, WINGWALL, AND TOEWALL)	CY	$ 1,000.00	150	$ 150,000.00
Drainage	17	PRECAST REINFORCED CONCRETE BOX CULVERT (12'X8')	CY	$ 800.00	480	$ 384,000.00
Drainage	18	GRAVEL SUBGRADE FILLER	CY	$ 42.00	167	$ 7,000.00
Drainage	19	CONCRETE RIPRAP (5" THICK)	SY	$ 90.00	420	$ 37,800.00
Drainage	20	TOPSOIL (4")	SY	$ 9.00	10,000	$ 90,000.00
Drainage	21	BERMUDA SODDING	SY	$ 7.00	10,000	$ 70,000.00
Drainage	22	TREE PLANTING AND PLACEMENT	EA	$ 500.00	20	$ 10,000.00
Drainage	23	MSE RETAINING WALL, (3 - 5 FT)	SF	$ 27.00	300	$ 8,100.00
Drainage	24	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	1,331	$ 3,993.00
Drainage	25	REMOVE CONC (HEADWALL)	CY	$ 480.00	6	$ 2,666.67
				Subtotal		$ 2,093,407.08
				Contingency	25%	$ 523,351.77
				Total Construction Cost		**$ 2,616,758.85**
				Land Acquisition	10%	$ 261,675.89
				Environmental Permitting	2%	$ 52,335.18
				Engineering	12%	$ 300,927.27
				Total Project Cost		**$ 3,231,697.18**



N01- Drainage Area Map
Low Water Crossings

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 4,000 feet

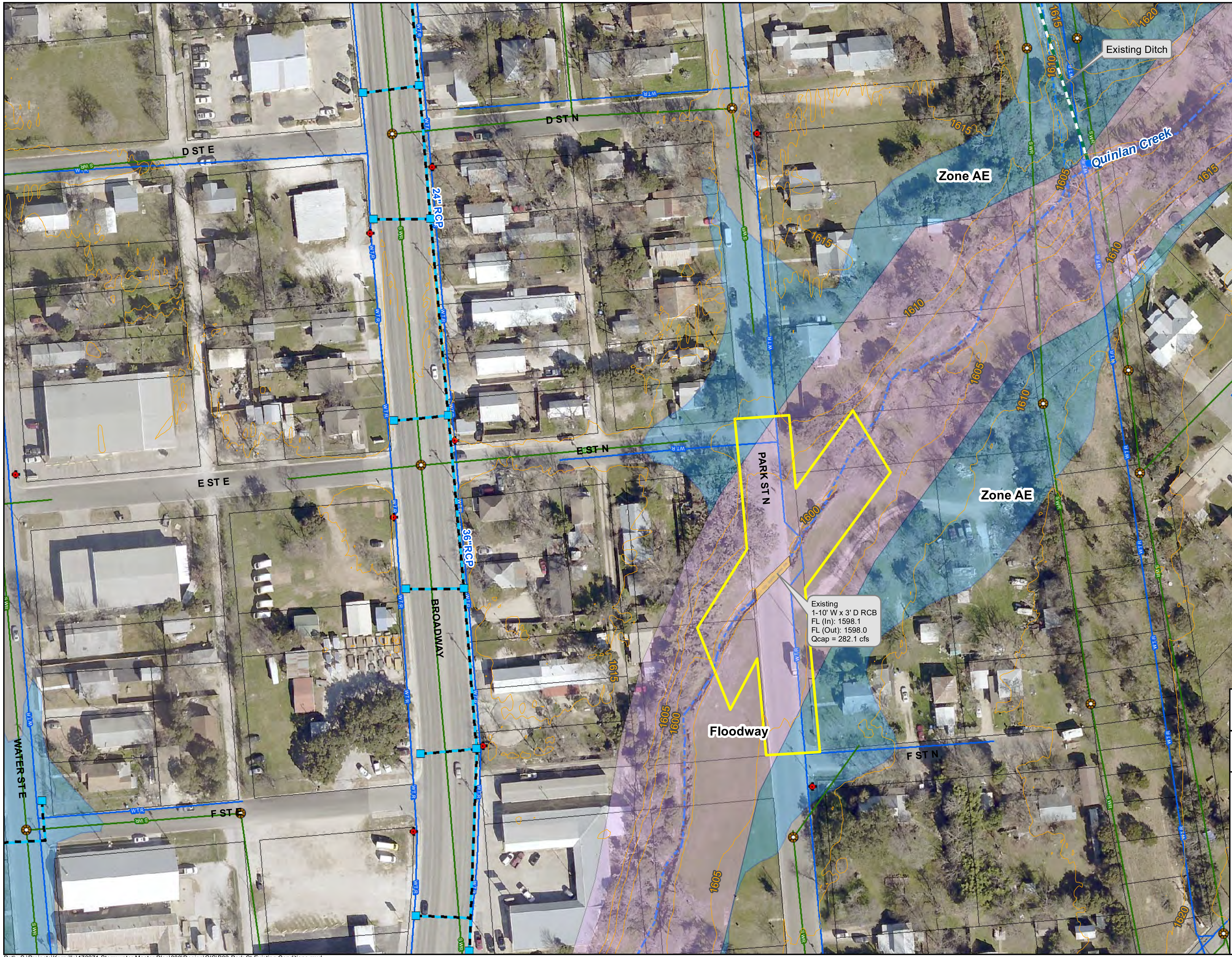
0 2,000 4,000 Feet

LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

Path: \\SASTORAGE\share\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\N01-LWC-DA.mxd

Date: 5/2/2019



Legend

- Elevation Contours
- Stream Centerline
- Study Location
- Zone A
- Zone AE
- Floodways
- Parcels (2010)

Exist Storm Water Network

- Manhole
- Curb Inlet
- Outlet
- Open Channel
- Storm Drain Pipe/Culvert
- Detention Pond

Exist Sewer Utilities

- Sewer Manhole
- Pressure Sewer Main
- Sewer Main

Exist Water Utilities

- Fire Hydrant
- Water Main

B02- Existing Drainage Conditions
Park Street

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 100 feet

0 50 100 Feet

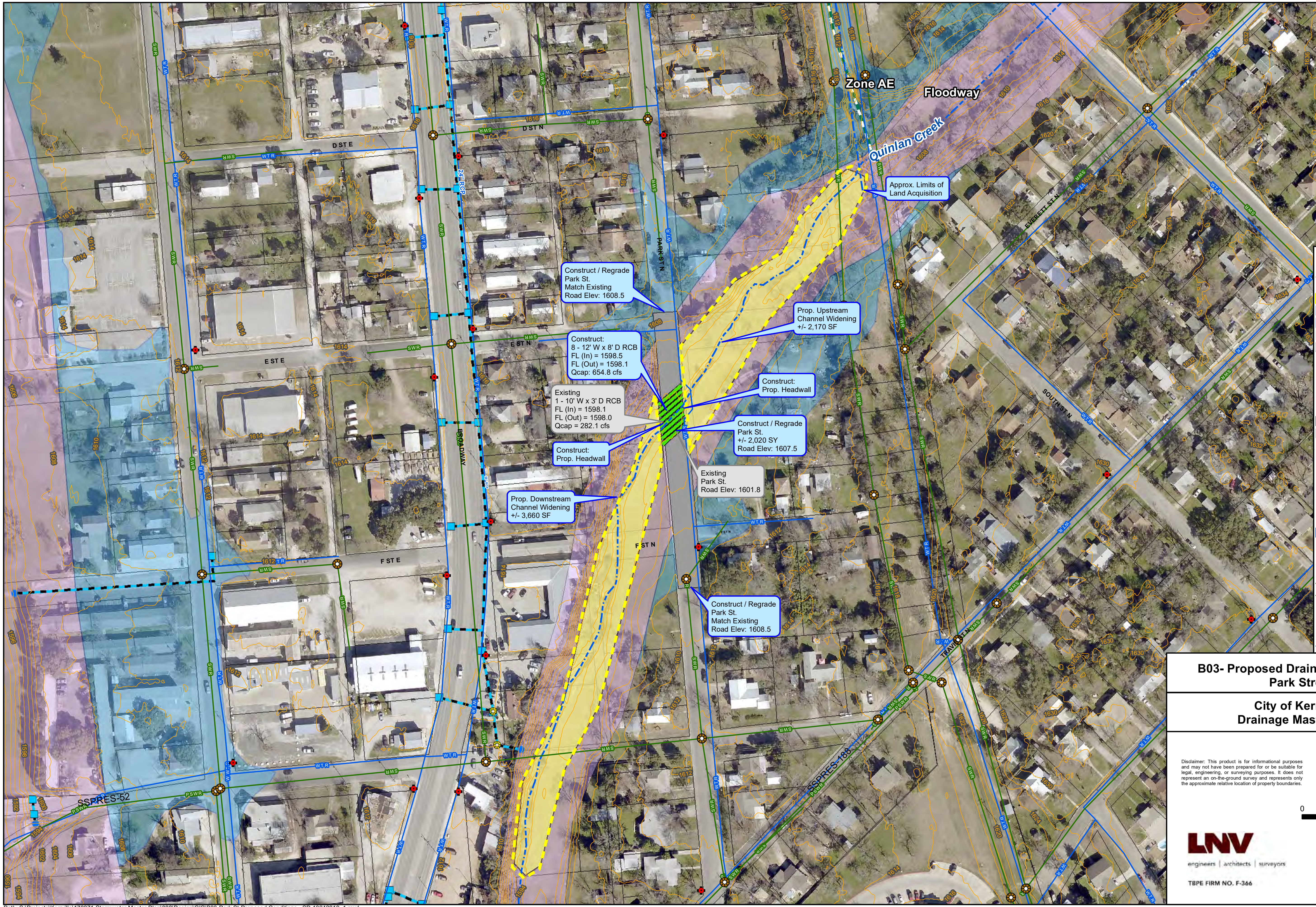
engineers | architects | surveyors

TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\B02-Park St-Existing Conditions.mxd

Date: 10/31/2019

B03- Proposed Drainage Conditions Park Street



Legend

- Elevation Contours
- Stream Centerline
- Study Location
- Zone A
- Zone AE
- Floodways
- Parcels (2010)

Proposed Storm Water Improvements
- Gurad Rail
- Box Culvert
- Channel Widening
- Road Grading

Exist Storm Water Network
- Manhole
- Curb Inlet
- Outlet
- Open Channel
- Storm Drain Pipe/Culvert
- Detention Pond

Exist Sewer Utilities
- Sewer Manhole
- Pressure Sewer Main
- Sewer Main

Exist Water Utilities
- Fire Hydrant
- Water Main

B03- Proposed Drainage Conditions Park Street

City of Kerrville Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 150 feet

0 75 150 Feet

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TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\B03-Park St-Proposed Conditions - SD 10242019_1.mxd

Date: 11/14/2019

City of Kerrville

Capital Improvements Project

Project Summary								
Project ID:		C						
Project Name:		First Street Low Water Crossing						
Fiscal Year Plan								Total
								$200,000

Funding Source	
General Fund	0
Total	0

Problem Description:

Quinlan Creek at the First Street low water crossing experiences overtopping flows resulting in frequent roadway closures due to insufficient capacity, hazardous flood flow conditions, erosion, and risk of property flooding.

Proposed Improvement:

Option 2:

Provide Automatic Flood Gates and warning signs to improve public safety.

O & M Impact:

Periodic maintenance of flood gate system.

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	36
Roadway Emergency Service Access	54
Frequency of Flooding Damages	90
Erosion / Channel Stability	18
Level of Protection Benefit	9
Project Cost	12
Funding Source / Availability	0
Developmental Impacts	30
Permitting	24
Land / Easement Acquisition	4
Project Readiness	4
Project Dependency	0
Water Quality Impacts	42
Riparian Impacts	0
Total Weighted Point Score:	413
CIP Ranking:	11

Existing Conditions

Existing 5 - 24" RCP Culvert (Facing U/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

Option 1 consists of major roadway and channel improvements that provide protection for up to the 5-year storm event.

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: C - First Street Low Water Crossing

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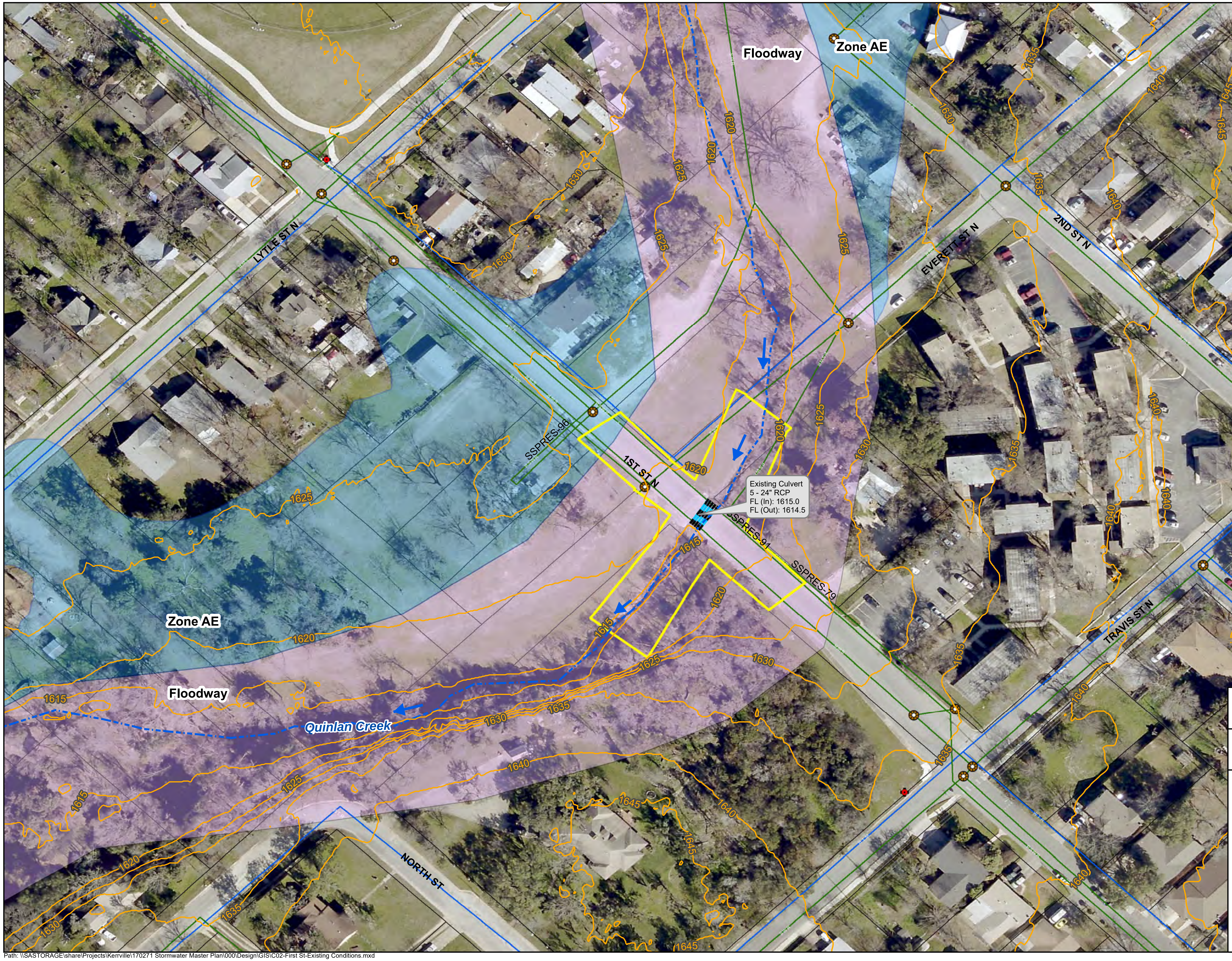
Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
		OPTION 1 (HIGH WATER DETECTION SYSTEM)				
	1	HIGH-WATER ALERT LIFESAVING TECHNOLOGY (HALT)	EA	$ 100,000.00	2.00	$ 200,000.00

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
		OPTION 2 (BRIDGE REPLACEMENT AND CHANNEL IMPROVEMENT)				
General	1	MOBILIZATION	LS	11%	1	$ 280,002.74
	2	INSURANCE & BOND	LS	3%	1	$ 76,364.38
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 101,819.18
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 76,364.38
	5	SW3P	LS	1%	1	$ 25,454.79
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	900	$ 5,400.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	1,077	$ 5,385.00
	8	EMBANKMENT (FINAL)(DENS CONT)(TY A)	CY	$ 18.00	942	$ 16,960.00
	9	TACK COAT	GAL	$ 5.00	120	$ 601.11
	10	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	1,400	$ 49,000.00
	11	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	1,202	$ 18,033.33
	12	CONCRETE CURB & GUTTER	LF	$ 20.00	900	$ 18,000.00
	13	CONCRETE SIDEWALKS	SY	$ 50.00	433	$ 21,666.67
	14	PORTLAND CEMENT CONCRETE DRIVEWAY	SY	$ 74.00	36	$ 2,631.11
Utility	15	ADJUST EXISTING MANHOLES AND VALVE BOXES	EA	$ 2,000.00	2	$ 4,000.00
	16	SANITARY SEWER MANHOLE (0' - 6')	EA	$ 6,500.00	2	$ 13,000.00
	17	SANITARY SEWER (6IN) (PVC) (SDR 26)	LF	$ 70.00	1,500	$ 105,000.00
Drainage	18	CHANNEL EXCAVATION (> 70,000 CY)	CY	$ 20.00	70,550	$ 1,411,000.00
	19	BOX CULVERT EXCAVATION AND BACKFILL	CY	$ 15.00	1,620	$ 24,305.56
	20	CONCRETE STRUCTURE (HEADWALL, WINGWALL, AND TOEWALL)	CY	$ 1,000.00	150	$ 150,000.00
	21	MSE RETAINING WALL, (3 - 5 FT)	SF	$ 27.00	800	$ 21,600.00
	22	PRECAST REINFORCED CONCRETE BOX CULVERT (12'X8')	CY	$ 800.00	512	$ 409,600.00
	23	GRAVEL SUBGRADE FILLER	CY	$ 42.00	117	$ 4,900.00
	24	CONCRETE RIPRAP (5" THICK)	SY	$ 90.00	420	$ 37,800.00
	25	TOPSOIL (4")	SY	$ 9.00	13,650	$ 122,850.00
	26	BERMUDA SODDING	SY	$ 7.00	13,650	$ 95,550.00
	27	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	60	$ 180.00
	28	REMOVE CONC (HEADWALL)	CY	$ 480.00	9	$ 4,266.67
	29	REMOVE STRUCTURE (PIPE) (24") (PIPE)	LF	$ 25.00	150	$ 3,750.00
				Subtotal		$ 3,105,484.92
				Contingency	25%	$ 776,371.23
				Total Construction Cost		**$ 3,881,856.15**
				Land Acquisition	14%	$ 543,459.86
				Environmental Permitting	2%	$ 77,637.12
				Engineering	11%	$ 427,004.18
				Total Project Cost		**$ 4,929,957.31**



C02- Existing Drainage Conditions
First Street

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 100 feet

0 50 100 Feet

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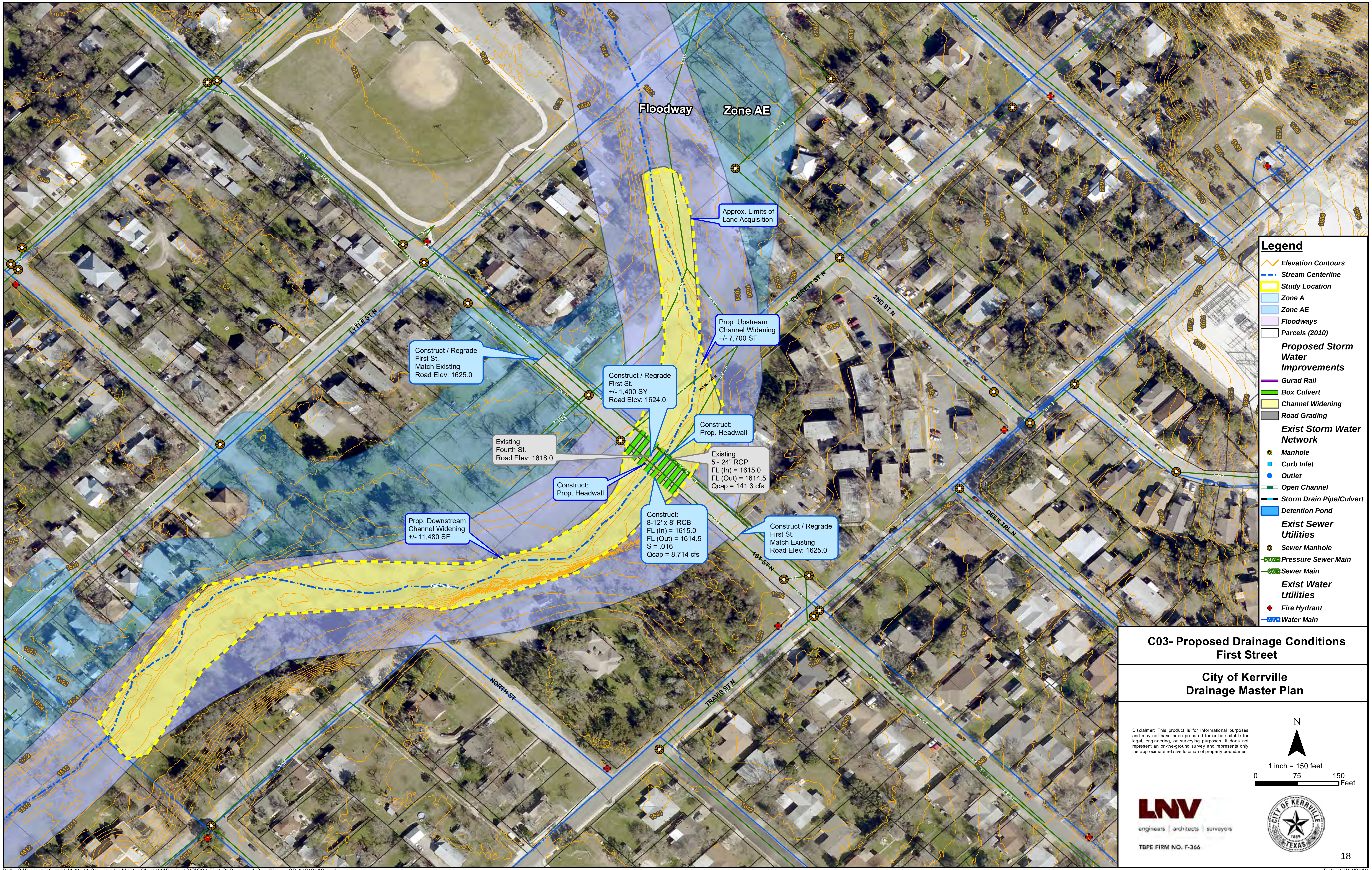
TBPE FIRM NO. F-366

Path: \\SASTORAGE\share\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\C02-First St-Existing Conditions.mxd

Date: 5/2/2019



C03- Proposed Drainage Conditions First Street

City of Kerrville Drainage Master Plan

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TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\C03-First St-Proposed Conditions - SD 10242019.mxd

Date: 12/17/2019

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	D
Project Name:	Fourth Street Low Water Crossing

Fiscal Year Plan								Total
								$200,000

Funding Source	
General Fund	0
Total	0

Problem Description:

Quinlan Creek at the Fourth Street low water crossing experiences overtopping flows resulting in frequent roadway closures due to insufficient capacity, hazardous flood flow conditions, erosion, and risk of property flooding.

Proposed Improvement:

Option 2:

Provide Automatic Flood Gates and warning signs to improve public safety.

O & M Impact:

Periodic maintenance of flood gate system.

CIP Ranking Criteria	Score
Structural Flooding	45
Roadway Flooding	36
Roadway Emergency Service Access	54
Frequency of Flooding Damages	90
Erosion / Channel Stability	18
Level of Protection Benefit	9
Project Cost	12
Funding Source / Availability	0
Developmental Impacts	30
Permitting	24
Land / Easement Acquisition	4
Project Readiness	4
Project Dependency	0
Water Quality Impacts	42
Riparian Impacts	0
Total Weighted Point Score:	368
CIP Ranking:	13

Existing Conditions

Existing 2 - 24" RCP Culvert (Facing D/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

Option 1 consists of major roadway and channel improvements that provide protection for up to the 2-year storm event.

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: D - Fourth Street Low Water Crossing

Solutions Today with a Vision for Tomorrow

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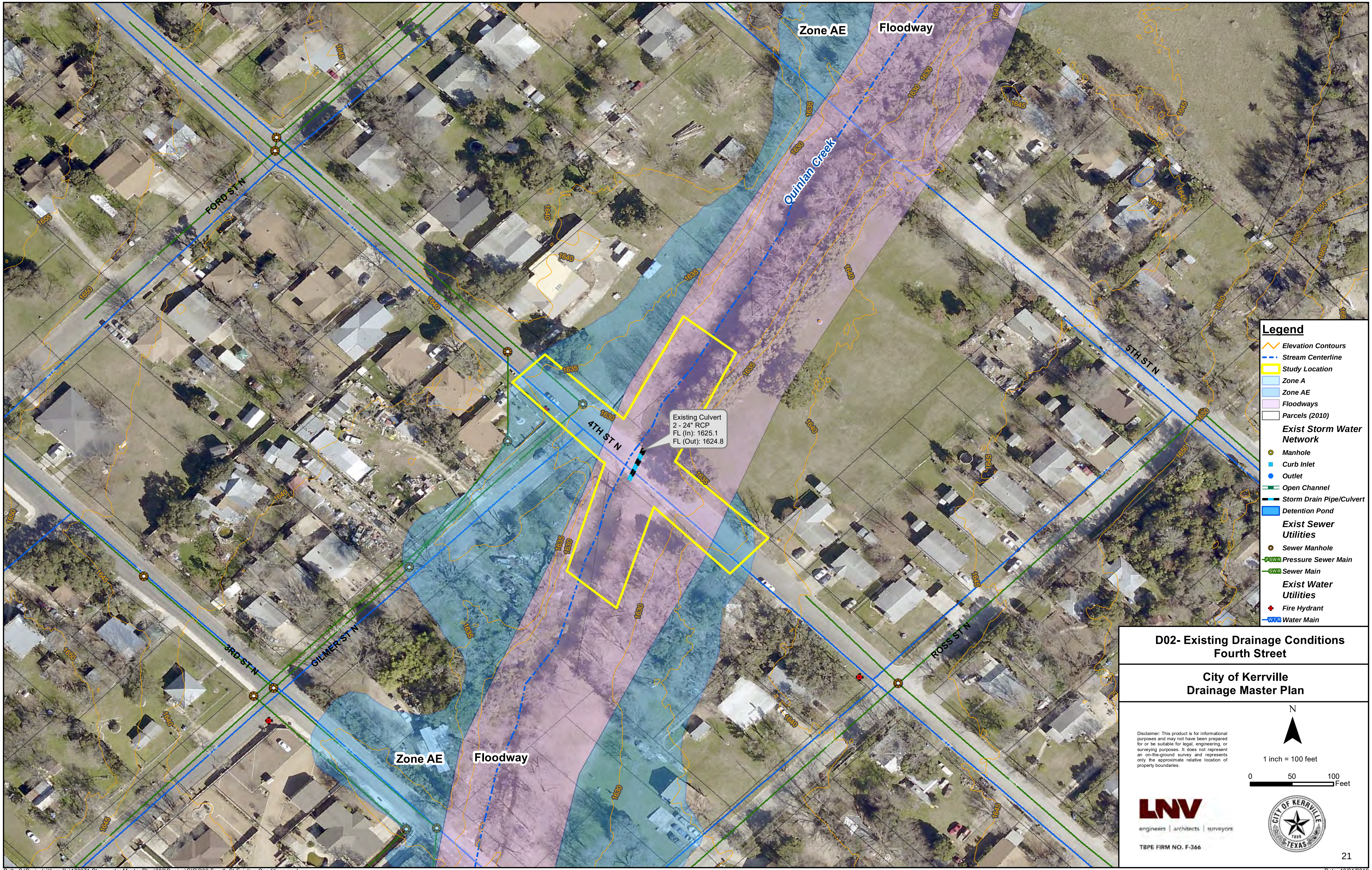
Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
		OPTION 1 (HIGH WATER DETECTION SYSTEM)				
	1	HIGH-WATER ALERT LIFESAVING TECHNOLOGY (HALT)	EA	$ 100,000.00	2.00	$ 200,000.00
		OPTION 2 (BRIDGE REPLACEMENT AND CHANNEL IMPROVEMENT)				
General	1	MOBILIZATION	LS	11%	1	$ 95,879.75
General	2	INSURANCE & BOND	LS	3%	1	$ 26,149.02
General	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 34,865.36
General	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 26,149.02
General	5	SW3P	LS	1%	1	$ 8,716.34
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	830	$ 4,980.00
Roadway	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	70	$ 350.00
Roadway	8	EMBANKMENT (FINAL)(DENS CONT)(TY A)	CY	$ 18.00	1,077	$ 19,379.33
Roadway	9	TACK COAT	GAL	$ 5.00	115	$ 572.50
Roadway	10	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	1,287	$ 45,052.78
Roadway	11	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	1,145	$ 17,175.00
Roadway	12	CURB RAMPS	EA	$ 1,500.00	2	$ 3,000.00
Roadway	13	CONCRETE CURB & GUTTER	LF	$ 20.00	830	$ 16,600.00
Roadway	14	PORTLAND CEMENT CONCRETE DRIVEWAY	SY	$ 74.00	70	$ 5,180.00
Utility	15	ADJUST EXISTING MANHOLES AND VALVE BOXES	EA	$ 2,000.00	1	$ 2,000.00
Utility	16	8" PVC WATER MAIN	LF	$ 60.00	320	$ 19,200.00
Drainage	17	CHANNEL EXCAVATION(5,000 CY < X < 70,000 CY)	CY	$ 20.00	7,130	$ 142,600.00
Drainage	18	BOX CULVERT EXCAVATION AND BACKFILL	CY	$ 15.00	1,348	$ 20,222.22
Drainage	19	CONCRETE STRUCTURE (HEADWALL, WINGWALL, AND TOEWALL)	CY	$ 1,000.00	117	$ 117,000.00
Drainage	20	PRECAST REINFORCED CONCRETE BOX CULVERT (12'X8')	CY	$ 800.00	390	$ 312,000.00
Drainage	21	GRAVEL SUBGRADE FILLER	CY	$ 42.00	148	$ 6,222.22
Drainage	22	CONCRETE RIPRAP (5" THICK)	SY	$ 90.00	340	$ 30,600.00
Drainage	23	TOPSOIL (4")	SY	$ 9.00	3,600	$ 32,400.00
Drainage	24	BERMUDA SODDING	SY	$ 7.00	3,600	$ 25,200.00
Drainage	25	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	100	$ 300.00
Drainage	26	MSE RETAINING WALL, (3 - 5 FT)	SF	$ 27.00	1,600	$ 43,200.00
Drainage	27	REMOVE CONC (HEADWALL)	CY	$ 480.00	13	$ 6,400.00
Drainage	28	REMOVE STRUCTURE (PIPE) (24") (PIPE)	LF	$ 25.00	80	$ 2,000.00
				Subtotal		$ 1,063,393.55
				Contingency	25%	$ 265,848.39
				Total Construction Cost		**$ 1,329,241.93**
				Land Acquisition	10%	$ 132,924.19
				Environmental Permitting	2%	$ 26,584.84
				Engineering	12%	$ 159,509.03
				Total Project Cost		**$ 1,648,260.00**



D02- Existing Drainage Conditions
Fourth Street

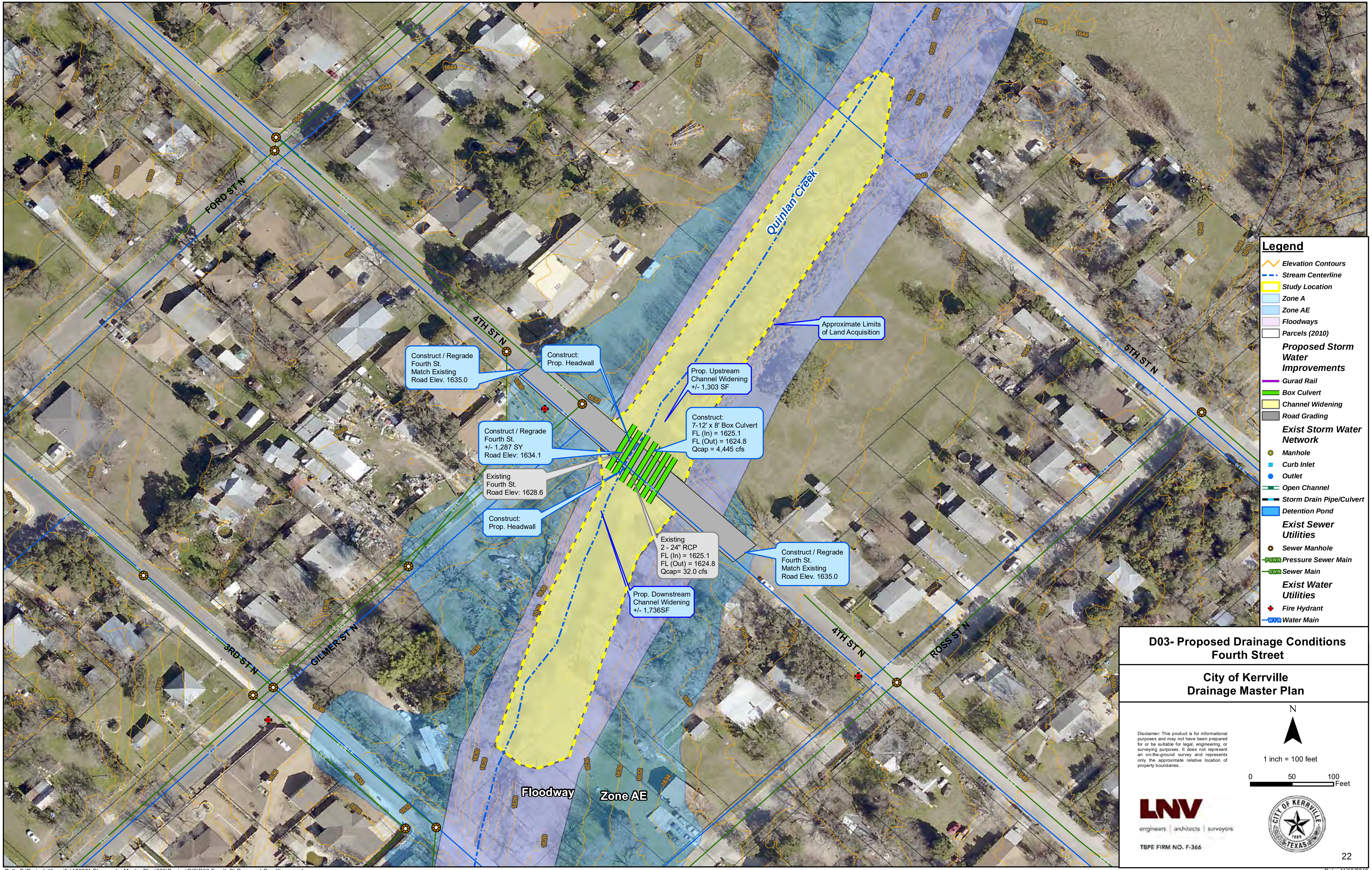
City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

LNV engineers | architects | surveyors
TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\D02-Fourth St-Existing Conditions.mxd

Date: 10/31/2019



D03- Proposed Drainage Conditions Fourth Street

City of Kerrville Drainage Master Plan

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TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\D03-Fourth St-Proposed Conditions.mxd

Date: 11/15/2019

LOCATION E – SPRING STREET CHANNEL

City of Kerrville

Capital Improvements Project

Project Summary								
Project ID:	E							
Project Name:	Spring Street							
Fiscal Year Plan								Total
								$744,073

Funding Source	
General Fund	0
Total	0

Existing Conditions

Existing Conditions of Gabion Lined Drainage Channel

Proposed Improvements

Conceptual Drainage Improvement Layout

Problem Description:

The existing gabion mattress has failed and the earthen channel bank extending into the Guadalupe River is at risk of further incising upstream if left in its present condition.

Proposed Improvement:

Extend the existing 54" storm drain further downstream and construct a concrete baffeled chute to convey flow down the steep embankment. Provide a stilling basin at the end of the chute to dissipate energy. Regrade the channel embankment as necessary.

O & M Impact:

CIP Ranking Criteria	Score
Structural Flooding	0
Roadway Flooding	0
Roadway Emergency Service Access	0
Frequency of Flooding Damages	90
Erosion / Channel Stability	90
Level of Protection Benefit	90
Project Cost	36
Funding Source / Availability	24
Developmental Impacts	30
Permitting	24
Land / Easement Acquisition	20
Project Readiness	20
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	528
CIP Ranking:	9

Notes:

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: E - Spring Street

Date: 12/19/2019

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	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 48,266.57
	2	INSURANCE & BOND	LS	3%	1	$ 13,163.61
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 17,551.48
	4	SW3P	LS	1%	1	$ 4,387.87
Drainage	5	EMBANKMENT (FINAL)(DENS CONT)(TY A)	CY	$ 60.00	3,320	$ 199,200.00
	6	REMOVE CONC (HEADWALL)	CY	$ 480.00	5	$ 2,400.00
	7	CONCRETE STRUCTURE RETAINING WALL, 5 FT HEIGHT	CY	$ 1,000.00	35	$ 35,000.00
	8	CONCRETE STRUCTURE (HEADWALLS OR OUTFALL STRUCTURES)	CY	$ 1,000.00	13	$ 13,000.00
	9	REINFORCED CONCRETE PIPE (CLASS III)(54" DIA)	LF	$ 400.00	100	$ 40,000.00
	10	CONCRETE STRUCTURE (CHUTE BOTTOM, AND BAFFLE BLOCKS)	CY	$ 1,000.00	117	$ 117,037.04
	11	TOPSOIL (4")	SY	$ 9.00	250	$ 2,250.00
	12	BERMUDA SODDING	SY	$ 7.00	250	$ 1,750.00
	13	ROCK RIPRAP (STONE PROTECTION)(18 IN)	CY	$ 170.00	120	$ 20,400.00
	14	GEOGRID REINFORCEMENT OF EMBANKMENT SLOPE	SY	$ 5.00	600	$ 3,000.00
	15	CL A CONC (COLLAR)	EA	$ 1,450.00	1	$ 1,450.00
	16	REMOVE STR (GABION)	LF	$ 22.00	150	$ 3,300.00
				Subtotal		$ 522,156.57
				Contingency	25%	$ 130,539.14
				Total Construction Cost		**$ 652,695.72**
				Environmental Permitting	2%	$ 13,053.91
				Engineering	12%	$ 78,323.49
				Total Project Cost		**$ 744,073.12**

E01 - Drainage Area Map
Spring St. Channel Erosion

City of Kerrville
Drainage Master Plan

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N

1 inch = 1,000 feet

0 500 1,000 Feet

LNV
engineers | architects | surveyors
TBPE FIRM NO. F-366

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\E01-Erosion at Spring Drive-DA.mxd

Date: 5/8/2019

E02- Existing Drainage Conditions
Spring Drive

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

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TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\E02-Erosion at Spring Drive-Existing Conditions.mxd

Date: 10/31/2019

E03- Proposed Drainage Conditions Spring Drive

City of Kerrville Drainage Master Plan

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Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\E03-Erosion at Spring Drive-Proposed Conditions.mxd

Date: 11/15/2019

LOCATION F – HILL COUNTRY DRIVE

City of Kerrville

Capital Improvements Project

Project Summary								
Project ID:		F						
Project Name:		Hill Country Drive						
Fiscal Year Plan								Total
								$2,429,607

Funding Source	
General Fund	0
Total	0

Problem Description:

The intersection experiences frequently property and street flooding due to Hill Country Drive's low lying roadway condition and due to two 36" CMP pipes with inverts set at the low point in the roadway resulting in the backup of water in the system.

Proposed Improvement:

• Phase I - Reconstruct / reprofile Hill Country Drive to improve the capture of runoff flowing towards the existing storm drain system.

• Phase II - replace existing 2 - 36" CMP with two 6' x 3' Reinforced Concrete Box Culverts from Hill Country Drive to the Downstream Channel

O & M Impact:

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	63
Roadway Emergency Service Access	90
Frequency of Flooding Damages	90
Erosion / Channel Stability	18
Level of Protection Benefit	54
Project Cost	12
Funding Source / Availability	24
Developmental Impacts	60
Permitting	40
Land / Easement Acquisition	20
Project Readiness	12
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	677
CIP Ranking:	3

Existing Conditions

Existing 2 - 36" CMP Culvert (Facing D/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

Phase II is located within TxDOT right-of-way and will require coordination and approval.

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: F.1 - Hill Country Dr. Phase - I

Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 16,000.71
	2	INSURANCE & BOND	LS	3%	1	$ 4,363.83
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 5,818.44
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 4,363.83
	5	SW3P	LS	1%	1	$ 1,454.61
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	600	$ 3,600.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	1,420	$ 7,100.00
	8	STREET EXCAVATION	CY	$ 31.00	144	$ 4,477.78
	9	EMBANKMENT (FINAL)(DENS CONT)(TY A)	CY	$ 18.00	72	$ 1,300.00
	10	LIME TREATED SUBGRADE (6" COMPACTED DEPTH)	SY	$ 6.00	867	$ 5,200.00
	11	FLEXIBLE BASE (6" COMPACTED DEPTH)	SY	$ 9.00	867	$ 7,800.00
	12	LIME	TON	$ 200.00	2	$ 416.00
	13	PRIME COAT	GAL	$ 5.00	87	$ 433.33
	14	REINFORCED CONCRETE PAVEMENT	SY	$ 80.00	867	$ 69,333.33
	15	CONCRETE CURB & GUTTER	LF	$ 20.00	600	$ 12,000.00
	16	PORTLAND CEMENT CONCRETE DRIVEWAY - COMMERCIAL	SY	$ 74.00	158	$ 11,675.56
Utility	17	8" PVC WATER MAIN	LF	$ 60.00	100	$ 6,000.00
	18	ADJUST EXISTING WASTEWATER LATERAL	EA	$ 1,500.00	1	$ 1,500.00
Drainage	19	REMOVE MISCELLANEOUS CONCRETE	SF	$ 5.00	175	$ 875.00
	20	CONCRETE RIPRAP (5" THICK)	SY	$ 250.00	19	$ 4,861.11
	21	TOPSOIL (4")	SY	$ 9.00	556	$ 5,000.00
	22	BERMUDA SODDING	SY	$ 7.00	556	$ 3,888.89
				Subtotal		$ 177,462.42
				Contingency	25%	$ 44,365.61
				Total Construction Cost		**$ 221,828.03**
				Engineering	13%	$ 27,728.50
				Total Project Cost		**$ 249,556.53**

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: F.2 - Hill Country Phase II

Date: 12/19/2019

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	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 140,401.33
	2	INSURANCE & BOND	LS	3%	1	$ 38,291.27
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 51,055.03
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 38,291.27
	5	SW3P	LS	1%	1	$ 12,763.76
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	2,300	$ 13,800.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	4,750	$ 23,750.00
	8	STREET EXCAVATION	CY	$ 31.00	192	$ 5,952.00
	9	EMBANKMENT (FINAL)(DENS CONT)(TY B)	CY	$ 20.00	301	$ 6,027.78
	10	TACK COAT	GAL	$ 5.00	386	$ 1,927.78
	11	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	3,856	$ 134,944.44
	12	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	3,856	$ 57,833.33
	13	CONCRETE CURB & GUTTER	LF	$ 20.00	2,300	$ 46,000.00
	14	CONCRETE SIDEWALKS	SY	$ 50.00	222	$ 11,111.11
	15	PORTLAND CEMENT CONCRETE DRIVEWAY - COMMERCIAL	SY	$ 74.00	839	$ 62,077.78
Utility	16	8" PVC WATER MAIN	LF	$ 60.00	280	$ 16,800.00
Drainage	17	REMOVE MISCELLANEOUS CONCRETE	SF	$ 5.00	4,760	$ 23,800.00
	18	BOX CULVERT EXCAVATION AND BACKFILL	CY	$ 15.00	2,596	$ 38,933.33
	19	STRUCTURAL EXCAVATION (100 < X < 500 CY)	CY	$ 85.00	117	$ 9,916.67
	20	CONCRETE STRUCTURE (RETAINING WALLS) (10 CY < X < 100 CY)	CY	$ 1,000.00	32	$ 32,222.22
	21	CONCRETE STRUCTURE (HEADWALLS OR OUTFALL STRUCTURES)	CY	$ 1,000.00	10	$ 10,370.37
	22	PRECAST REINFORCED CONCRETE BOX CULVERT (6'X3')	CY	$ 800.00	670	$ 536,000.00
	23	SPECIAL JUNCTION BOXES (COMPLETE) - 15'W X 15'L X 6'D	EA	$ 35,000.00	2	$ 70,000.00
	24	CONCRETE RIPRAP	SY	$ 90.00	511	$ 46,000.00
	25	TOPSOIL (4")	SY	$ 9.00	3,156	$ 28,400.00
	26	BERMUDA SODDING	SY	$ 10.00	3,156	$ 31,555.56
	27	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 7.00	760	$ 5,320.00
	28	TRENCH DRAIN (10'W X 30'L X 3'D)	EA	$ 25,000.00	1	$ 25,000.00
	29	REMOVE CONC (HEADWALL, WINGWALL)	CY	$ 480.00	4	$ 2,133.33
	30	REMOVE STRUCTURE (PIPE) (36") (PIPE)	LF	$ 25.00	1,460	$ 36,500.00
				Subtotal		$ 1,557,178.36
				Contingency	25%	$ 389,294.59
				Total Construction Cost		**$ 1,946,472.95**
				Engineering	12%	$ 233,576.75
				Total Project Cost		**$ 2,180,049.70**

F01 - Drainage Area Map
Hill Country Drive

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 250 feet

0 125 250 Feet

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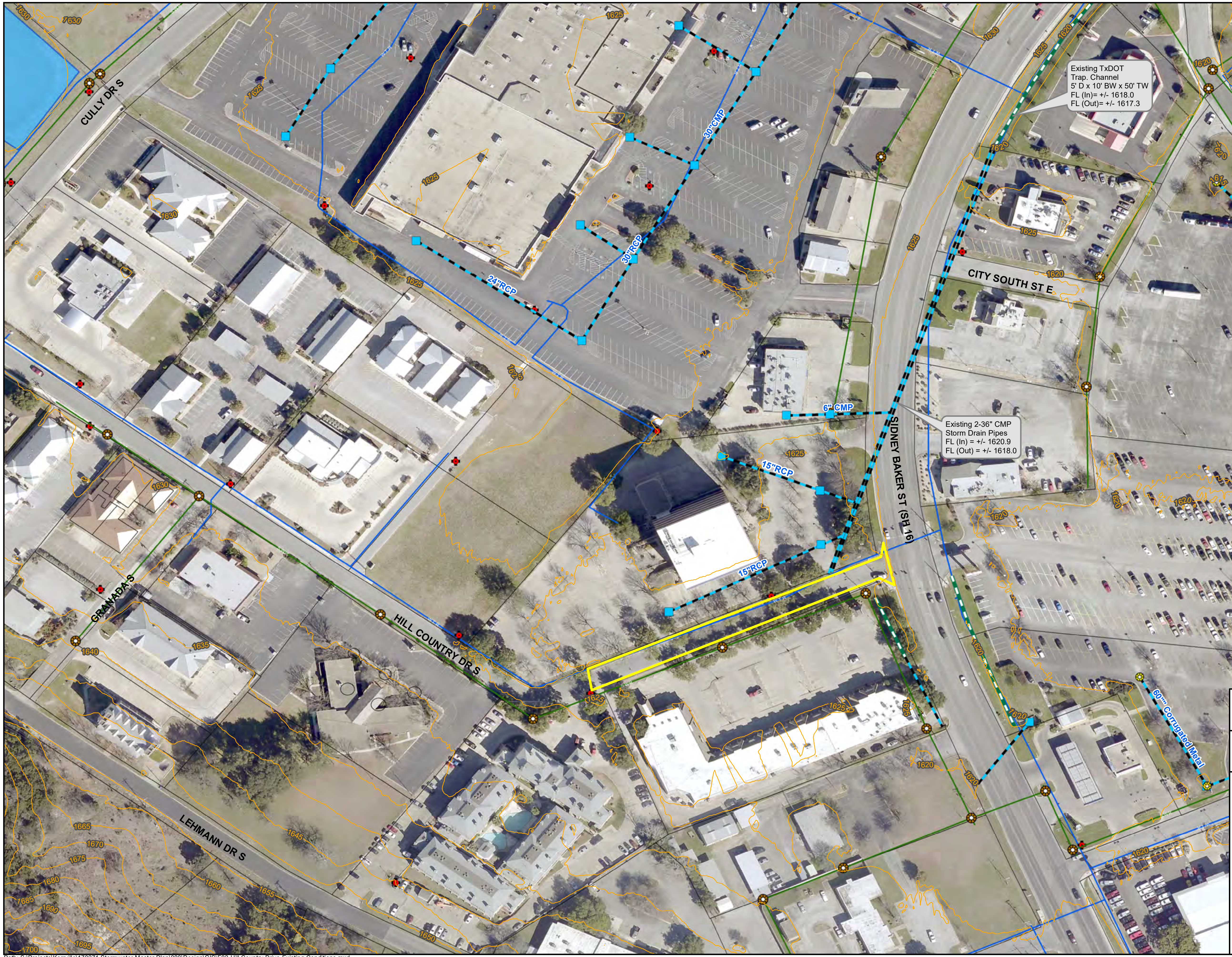
TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\F01-Hill Contry Drive -DA.mxd

Date: 12/4/2019



F02- Existing Drainage Conditions
Hill Country Drive

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 150 feet

0 75 150 Feet

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TBPE FIRM NO. F-366

CITY OF KERRVILLE TEXAS 1889

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\F02-Hill Country Drive-Existing Conditions.mxd

Date: 12/4/2019

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\F03-Hill Country Drive-Proposed Conditions (Const. Phase 1).mxd

Date: 12/4/2019

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\F03-Hill Country Drive-Proposed Conditions (Const. Phase 2).mxd

Date: 12/4/2019

LOCATION G & H – KROC CENTER & CLAY STREET

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	G & H
Project Name:	Kroc Center & Clay Street (Combined)

Fiscal Year Plan								Total
								$8,967,501

Funding Source	
General Fund	0
Total	0

Problem Description:

Prolonged discharge from existing 24" and 18" detention pond outfall structure results in excessive roadway flooding along George, Hays, McFarland and Clay Streets. In addition, the downstream system for Clay Street is undersized, resulting in localized flooding.

Proposed Improvement:

Reconfigure and reconstruct the existing Kroc Center detention pond outlet with a riser structure that connects directly to a new storm drain system beneath George Street and extending downstream along Miller, Quinlan, McFarland, and Clay Streets.

O & M Impact:

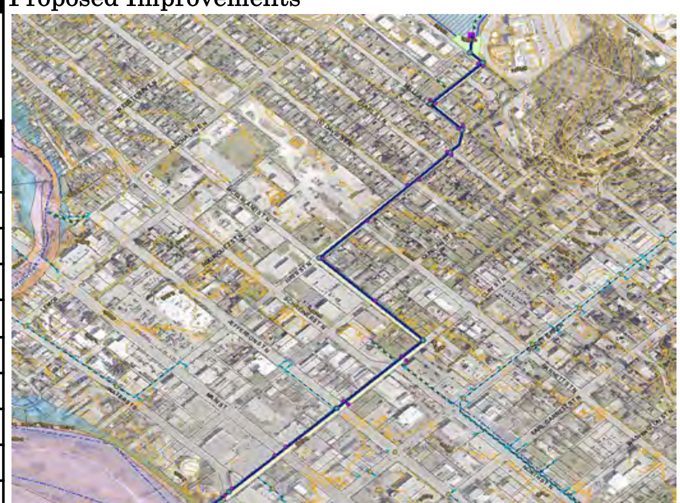
O & M will require periodic removal of debris that may block outflow of Kroc Center Detention Pond and proposed storm drain system.

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	90
Roadway Emergency Service Access	54
Frequency of Flooding Damages	90
Erosion / Channel Stability	0
Level of Protection Benefit	54
Project Cost	12
Funding Source / Availability	42
Developmental Impacts	60
Permitting	24
Land / Easement Acquisition	20
Project Readiness	4
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	644
CIP Ranking:	4

Existing Conditions

Existing Drainage Spillway - Facing Towards Kroc Center Pond

Proposed Improvements



Conceptual Drainage Improvement Layout

Notes:

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: G&H - Clay St. & Kroc Center

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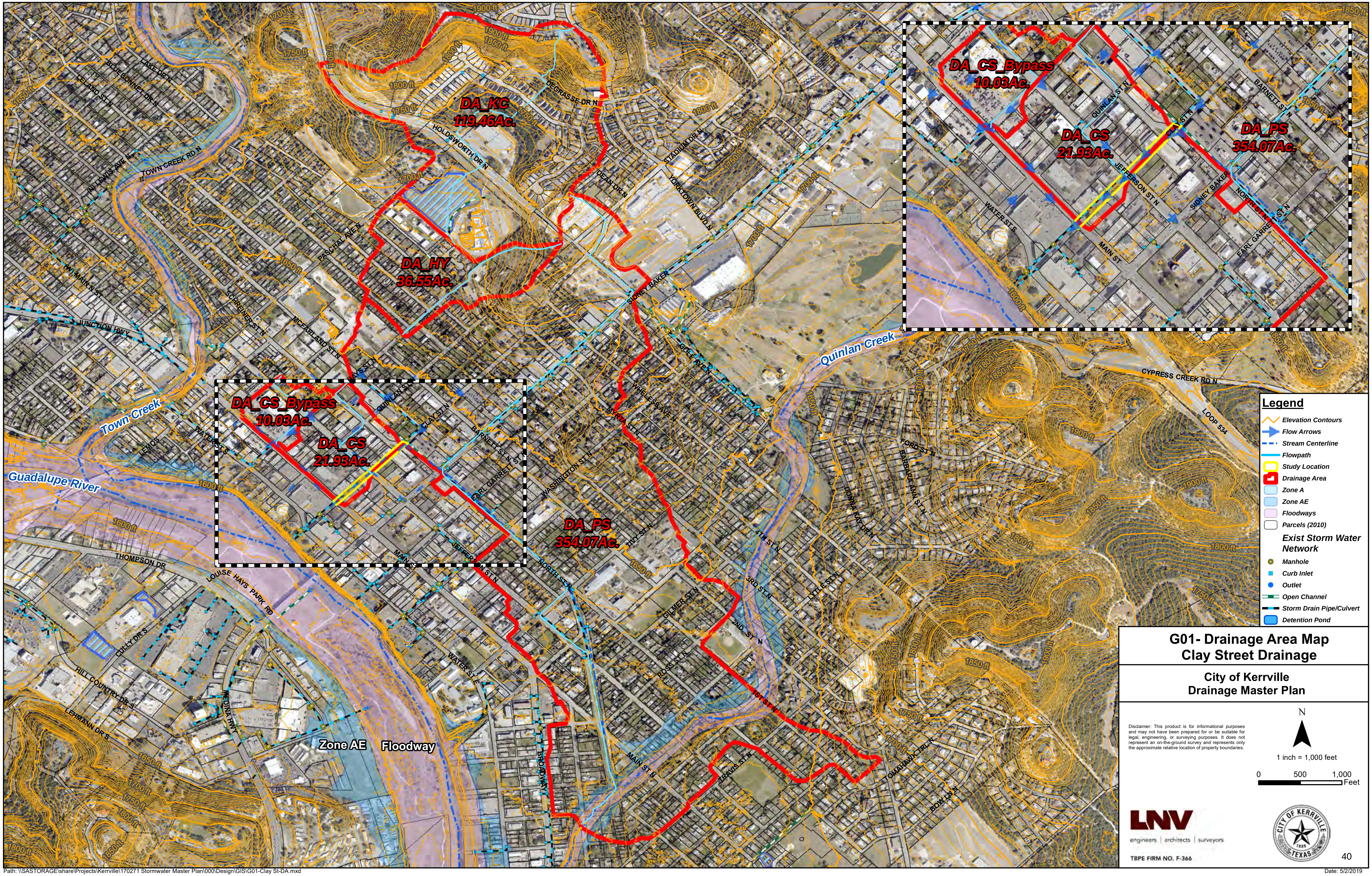
Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
	1	MOBILIZATION	LS	11%	1	$ 585,372.08
	2	INSURANCE & BOND	LS	3%	1	$ 159,646.93
General	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 212,862.58
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 159,646.93
	5	SW3P	LS	1%	1	$ 53,215.64
	6	REMOVE CONCRETE CURB	LF	$ 6.00	5,100	$ 30,600.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	11,600	$ 58,000.00
	8	STREET EXCAVATION	CY	$ 31.00	3,623	$ 112,309.56
	9	EMBANKMENT (FINAL)(DENS CONT)(TY A) @ Kroc Weir	CY	$ 18.00	107	$ 1,925.00
	10	TACK COAT	GAL	$ 5.00	1,700	$ 8,500.00
	11	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	7,933	$ 277,666.67
Roadway	12	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	17,000	$ 255,000.00
	13	CONCRETE STRUCTURE (MISCELLANEOUS)	CY	$ 1,000.00	29	$ 28,518.52
	14	CONCRETE CURB RAMPS	EA	$ 1,500.00	21	$ 31,500.00
	15	CONCRETE CURB & GUTTER	LF	$ 20.00	5,100	$ 102,000.00
	16	CONCRETE SIDEWALKS (One Side)	SY	$ 50.00	2,833	$ 141,666.67
	17	PORTLAND CEMENT CONCRETE DRIVEWAY - COMMERCIAL	SY	$ 74.00	567	$ 41,933.33
	18	RELOCATE TRAFFIC SIGNAL POLE ASSEMBLIES (STEEL)	EA	$ 2,000.00	2	$ 4,000.00
	19	ADJUST EXISTING MANHOLES AND VALVE BOXES	EA	$ 2,000.00	10	$ 20,000.00
	20	SANITARY SEWER (6IN) (PVC) (SDR 26)	LF	$ 70.00	1,300	$ 91,000.00
Utility	21	SANITARY SEWER (12IN) (PVC) (SDR 26)	LF	$ 100.00	1,000	$ 100,000.00
	22	SANITARY SEWER MANHOLE (0' - 6')	EA	$ 6,500.00	21	$ 136,500.00
	23	WATER SERVICE RPL AND RECONNECT	EA	$ 3,000.00	44	$ 132,000.00
	24	ADJUST EXISTING WASTEWATER LATERAL	EA	$ 1,500.00	45	$ 67,500.00
	25	REMOVE MISCELLANEOUS CONCRETE	SF	$ 5.00	1,430	$ 7,150.00
	26	POND OUTLET RISER	EA	$ 35,000.00	1	$ 35,000.00
	27	BOX CULVERT EXCAVATION AND BACKFILL	CY	$ 15.00	18,667	$ 280,000.00
	28	STRUCTURAL EXCAVATION (100 < X < 500 CY)	CY	$ 85.00	107	$ 9,090.28
	29	CONCRETE STRUCTURE (HEADWALL AND WINGWALL)	CY	$ 1,000.00	10	$ 10,370.37
	30	PRECAST REINFORCED CONCRETE BOX CULVERT (6'X4')	CY	$ 800.00	1,312	$ 1,049,920.00
	31	PRECAST REINFORCED CONCRETE BOX CULVERT (9'X4')	CY	$ 800.00	1,181	$ 944,480.00
	32	PRECAST REINFORCED CONCRETE BOX CULVERT (9'X5')	CY	$ 800.00	710	$ 568,160.00
	33	PRECAST REINFORCED CONCRETE BOX CULVERT (10'X5')	CY	$ 800.00	175	$ 140,024.00
	34	GRAVEL SUBGRADE FILLER	CY	$ 42.00	944	$ 39,666.67
	35	SPECIAL JUNCTION BOXES (COMPLETE) - 14W X 10L X 10D	EA	$ 21,200.00	1	$ 21,200.00
	36	SPECIAL JUNCTION BOXES (COMPLETE) - 12W X 12L X 8D	EA	$ 19,000.00	3	$ 57,000.00
Drainage	37	SPECIAL JUNCTION BOXES (COMPLETE) - 10W X 10L X 8D	EA	$ 15,000.00	5	$ 75,000.00
	38	INLET TYPE I (COMPLETE) (10 FT) (5' DEPTH)	EA	$ 6,000.00	10	$ 60,000.00
	39	INLET TYPE I (COMPLETE) (10 FT) (6' DEPTH)	EA	$ 6,500.00	7	$ 45,500.00
	40	INLET TYPE I (COMPLETE) (10 FT) (8' DEPTH)	EA	$ 7,000.00	5	$ 35,000.00
	41	INLET TYPE I (COMPLETE) (10 FT) (10' DEPTH)	EA	$ 7,500.00	2	$ 15,000.00
	42	MANHOLE VERTICAL STACK (SPECIAL MANHOLE RISER)	EA	$ 5,000.00	9	$ 45,000.00
	43	CONCRETE RIPRAP (5")	SY	$ 90.00	22	$ 2,000.00
	44	TOPSOIL (4")	SY	$ 9.00	2,833	$ 25,500.00
	45	BERMUDA SODDING	SY	$ 7.00	2,833	$ 19,833.33
	46	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	5,100	$ 15,300.00
	47	RELOCATE POWER POLE	EA	$ 5,000.00	26	$ 130,000.00
	48	REMOVE STRUCTURE (PIPE) (24") (PIPE)	LF	$ 25.00	900	$ 22,500.00
	49	REMOVE STRUCTURE (PIPE) (36") (PIPE)	LF	$ 25.00	1,130	$ 28,250.00
				Subtotal		$ 6,492,308.55
				Contingency	25%	$ 1,623,077.14
				Total Construction Cost		**$ 8,115,385.69**
				Engineering	11%	$ 852,115.50
				Total Project Cost		**$ 8,967,501.19**



Legend

- Elevation Contours
- Flow Arrows
- Stream Centerline
- Flowpath
- Study Location
- Drainage Area
- Zone A
- Zone AE
- Floodways
- Parcels (2010)

Exist Storm Water Network

- Manhole
- Curb Inlet
- Outlet
- Open Channel
- Storm Drain Pipe/Culvert
- Detention Pond

G01- Drainage Area Map
Clay Street Drainage

City of Kerrville
Drainage Master Plan

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N

1 inch = 1,000 feet

0 500 1,000 Feet

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TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

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Date: 5/2/2019

Path: \\SASTORAGE\share\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\H01-Kroc Center- DA.mxd

Date: 5/8/2019

Legend

- Elevation Contours
- Stream Centerline
- Study Location
- Zone A
- Zone AE
- Floodways
- Parcels (2010)

Exist Storm Water Network

- Manhole
- Curb Inlet
- Outlet
- Open Channel
- Storm Drain Pipe/Culvert
- Detention Pond

Exist Sewer Utilities

- Sewer Manhole
- Pressure Sewer Main
- Sewer Main

Exist Water Utilities

- Fire Hydrant
- Water Main

G&H02- Existing Drainage Conditions
Kroc Center and Clay Street

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 300 feet

0 150 300 Feet

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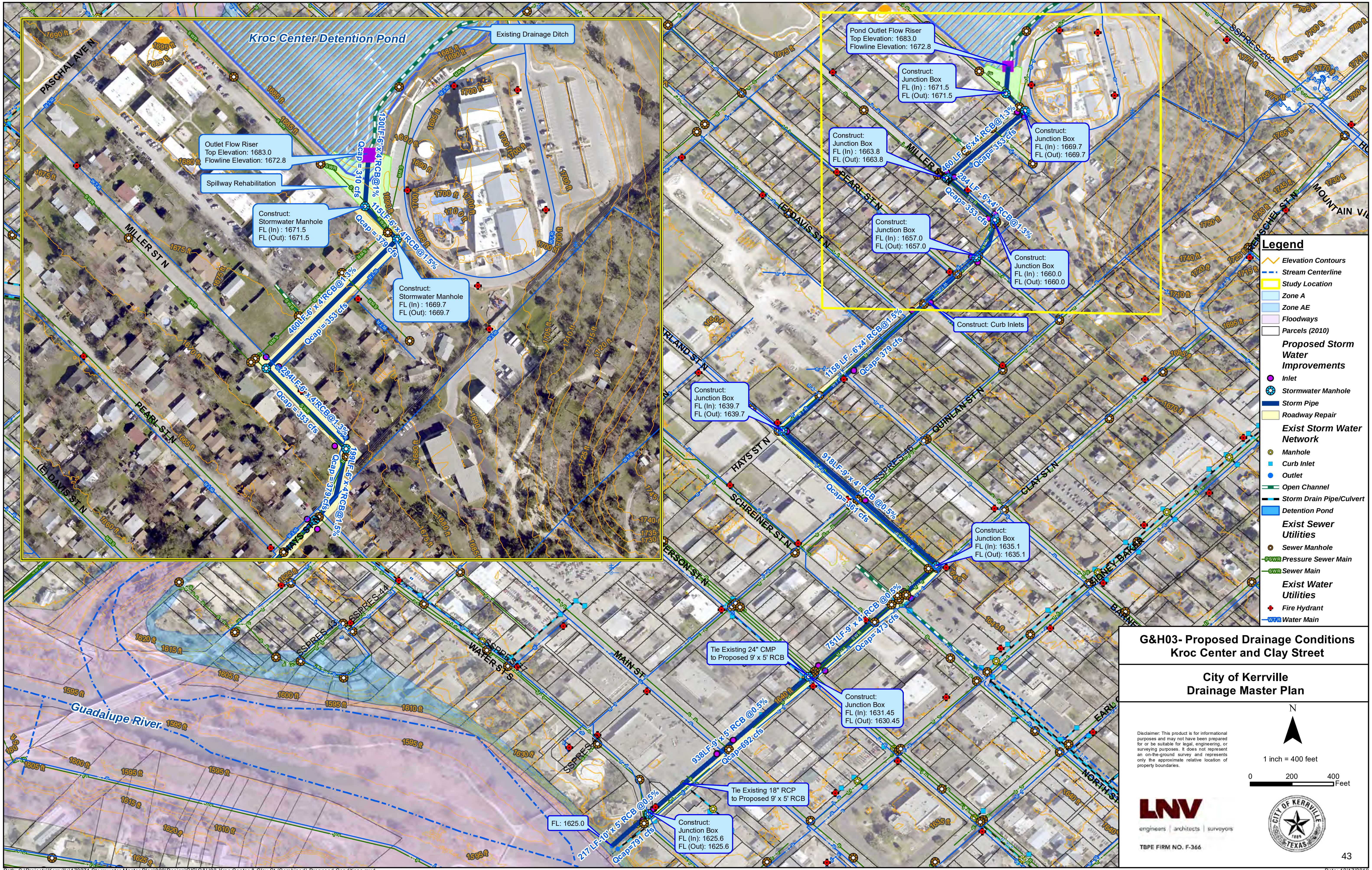
CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\G&H02-Kroc Center and Clay Street - Existing Conditions_Portrait.mxd

Date: 12/17/2019



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Date: 12/17/2019

LOCATION I – TAKE IT EASY CHANNEL

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	I
Project Name:	Take It Easy Drainage Channel

Fiscal Year Plan								Total
								$2,291,913

Funding Source	
General Fund	0
Total	0

Problem Description:

Steep channel banks have resulted in instabilities and slope failures due to the erosive velocity's in the channel.

Proposed Improvement:

Construct a 12' x 6' box culvert from the 66" CMP at Guadalupe Street for approximately 800 LF. Lower the profile of the channel to accommodate upsizing of the roadway culvert at Junction Highway. Reconstruct the remaining channel from the box culvert to Junction Highway with a rectangular section with 2:1 side slopes to existing grade.

O & M Impact:

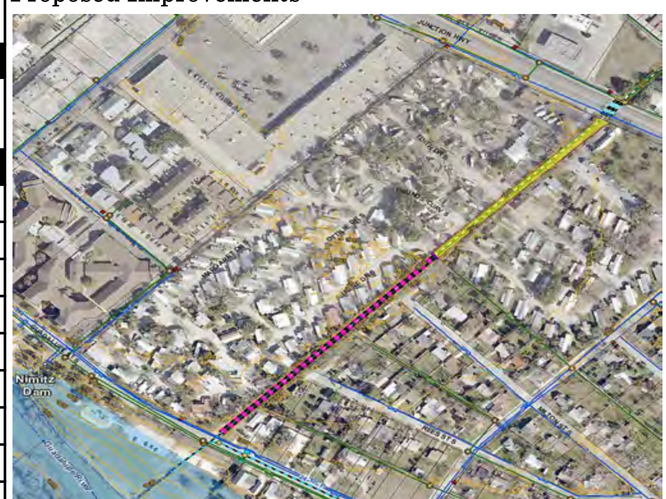
Periodic cleaning of culverts and channel after major storm events.

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	90
Roadway Emergency Service Access	54
Frequency of Flooding Damages	63
Erosion / Channel Stability	90
Level of Protection Benefit	90
Project Cost	12
Funding Source / Availability	42
Developmental Impacts	60
Permitting	24
Land / Easement Acquisition	20
Project Readiness	12
Project Dependency	40
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	771
CIP Ranking:	1

Existing Conditions

Existing Earthen Channel (Facing U/S)

Proposed Improvements



Conceptual Drainage Improvement Layout

Notes:

Take It Easy Channel Improvements should be constructed prior to improving Lois Street drainage conditions.

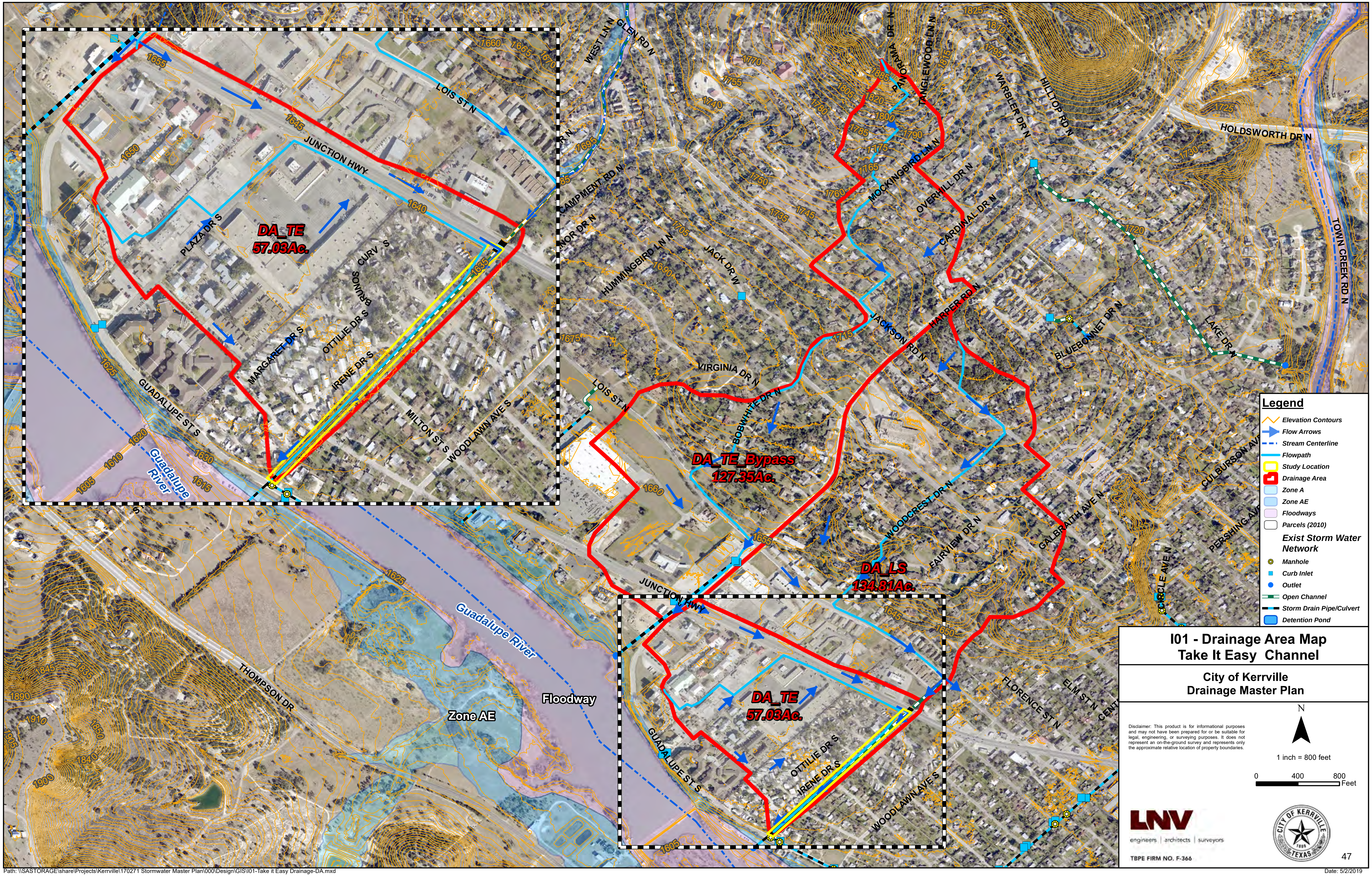
OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: I - Take It Easy Drainage Channel

Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 148,935.44
	2	INSURANCE & BOND	LS	3%	1	$ 40,618.76
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 54,158.34
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 40,618.76
	5	SW3P	LS	1%	1	$ 13,539.59
Roadway	6	CHAIN LINK FENCE (REMOVE)	LF	$ 18.00	665	$ 11,970.00
	7	CHAIN LINK FENCE (4' HIGH)	LF	$ 25.00	1,114	$ 27,850.00
	8	SIDEWALK PIPE RAILING (GALVANIZED)	LF	$ 100.00	700	$ 70,000.00
	9	MTL W-BEAM GD FEN (TIM POST)	LF	$ 85.00	100	$ 8,500.00
Drainage	10	REMOVE MISCELLANEOUS CONCRETE	SF	$ 7.00	1,060	$ 7,420.00
	11	REMOVE CONC (HEADWALL)	CY	$ 480.00	29	$ 14,155.62
	12	STRUCTURAL EXCAVATION (< 100 CY)	CY	$ 480.00	30	$ 14,222.22
	13	EMBANKMENT (FINAL)(DENS CONT)(TY A)	CY	$ 18.00	2,000	$ 36,000.00
	14	CHANNEL EXCAVATION(5,000 CY < X < 70,000 CY)	CY	$ 25.00	100	$ 2,500.00
	15	BOX CULVERT EXCAVATION AND BACKFILL	CY	$ 15.00	100	$ 1,500.00
	16	CONCRETE STRUCTURE (HEADWALLS OR OUTFALL STRUCTURES)	CY	$ 1,000.00	24	$ 24,296.30
	17	MULTI CONC BOX CULV (12 FT X 6 FT)	CY	$ 800.00	1,100	$ 880,000.00
	18	GRAVEL SUBGRADE FILLER	CY	$ 42.00	346	$ 14,544.44
	19	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	1,400	$ 4,200.00
	20	MSE RETAINING WALL, 6 FT	SF	$ 27.00	4,200	$ 113,400.00
	21	EROSION CONTROL BLANKET	SY	$ 13.00	1,800	$ 23,400.00
	22	TURF REINFORCED MATTING	SY	$ 20.00	5,000	$ 100,000.00
				Subtotal		$ 1,651,829.47
				Contingency	25%	$ 412,957.37
				Total Construction Cost		**$ 2,064,786.84**
				Engineering	11%	$ 227,126.55
				Total Project Cost		**$ 2,291,913.40**



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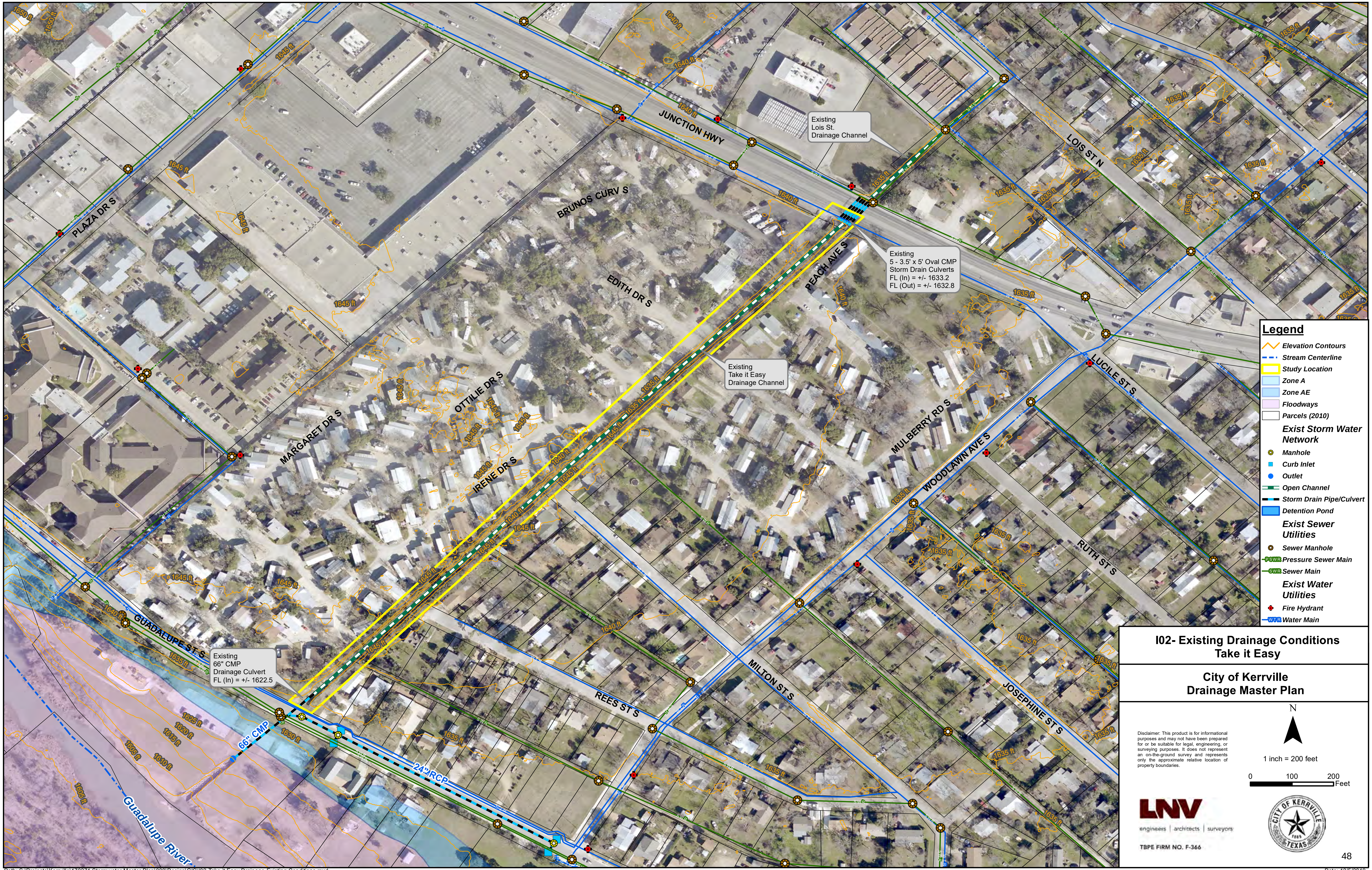
Date: 5/2/2019


JUNCTION HWY
PLAZA DR S
BRUNOS CURV S
EDITH DR S
PEACH AVE S
OTTILIE DR S
MARGARET DR S
IRENE DR S
MULBERRY RD S
WOODLAWN AVE S
LOIS ST N
LUCILE ST S
RUTH ST S
GUADALUPE ST S
REES ST S
MILTON ST S
JOSEPHINE ST S
Guadalupe River
Existing
Lois St.
Drainage Channel
Existing
5 - 3.5' x 5' Oval CMP
Storm Drain Culverts
FL (In) = +/- 1633.2
FL (Out) = +/- 1632.8
Existing
Take it Easy
Drainage Channel
Existing
66" CMP
Drainage Culvert
FL (In) = +/- 1622.5
66" CMP
24" RCP
1645 ft
1640 ft
1635 ft
1625 ft
1620 ft
Legend
Elevation Contours
Stream Centerline
Study Location
Zone A
Zone AE
Floodways
Parcels (2010)
Exist Storm Water Network
Manhole
Curb Inlet
Outlet
Open Channel
Storm Drain Pipe/Culvert
Detention Pond
Exist Sewer Utilities
Sewer Manhole
Pressure Sewer Main
Sewer Main
Exist Water Utilities
Fire Hydrant
Water Main
I02- Existing Drainage Conditions
Take it Easy
City of Kerrville
Drainage Master Plan
Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.
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1 inch = 200 feet
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engineers | architects | surveyors
TBPE FIRM NO. F-366
CITY OF KERRVILLE
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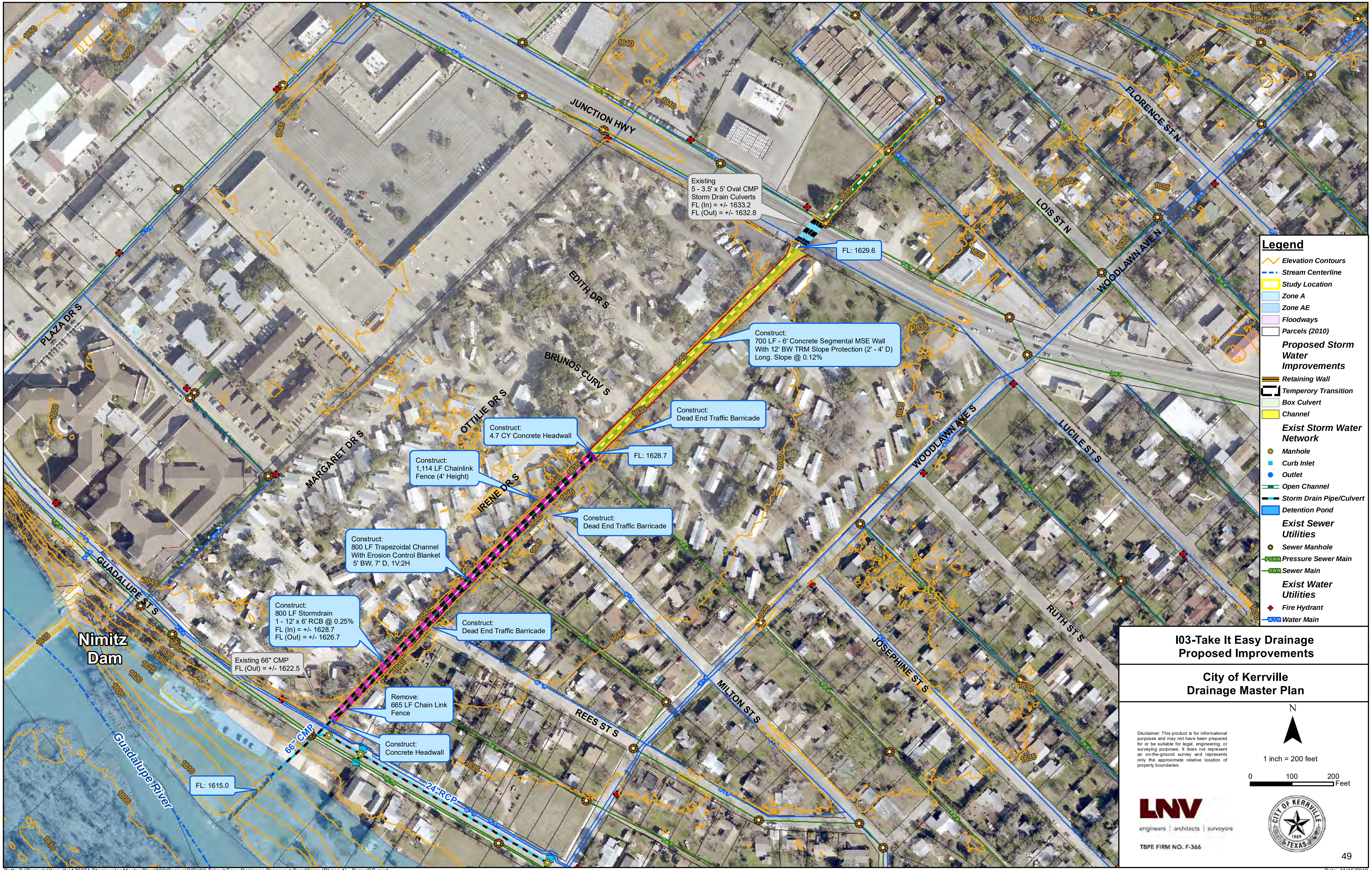

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Date: 11/15/2019

LOCATION J – LOIS STREET CHANNEL

City of Kerrville

Capital Improvements Project

Project Summary								
Project ID:		J						
Project Name:		Lois Street						
Fiscal Year Plan								Total
								$189,899

Funding Source	
General Fund	0
Total	0

Problem Description:

Frequent flooding occurs due to the backing up of water at the roadway culvert at Junction Highway and the shallow drainage channel which does no have sufficient capacity. The result is street, property and structural flooding.

Proposed Improvement:

Coordinate with TxDOT for Junction Highway culvert improvements.

Upsize the drainage channel from Lois Street to Junction Highway to improve flow conveyance.

O & M Impact:

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	90
Roadway Emergency Service Access	54
Frequency of Flooding Damages	90
Erosion / Channel Stability	18
Level of Protection Benefit	90
Project Cost	36
Funding Source / Availability	42
Developmental Impacts	60
Permitting	24
Land / Easement Acquisition	20
Project Readiness	20
Project Dependency	0
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	718
CIP Ranking:	2

Existing Conditions

Existing Concrete Drainage Channel (Facing D/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

This project is dependent on Take It Easy Channel downstream improvements occurring first, which include lowing the channel bottom to accommodate larger box culverts at Junction Highway.

OPINION OF PROBABLE CONSTRUCTION COST

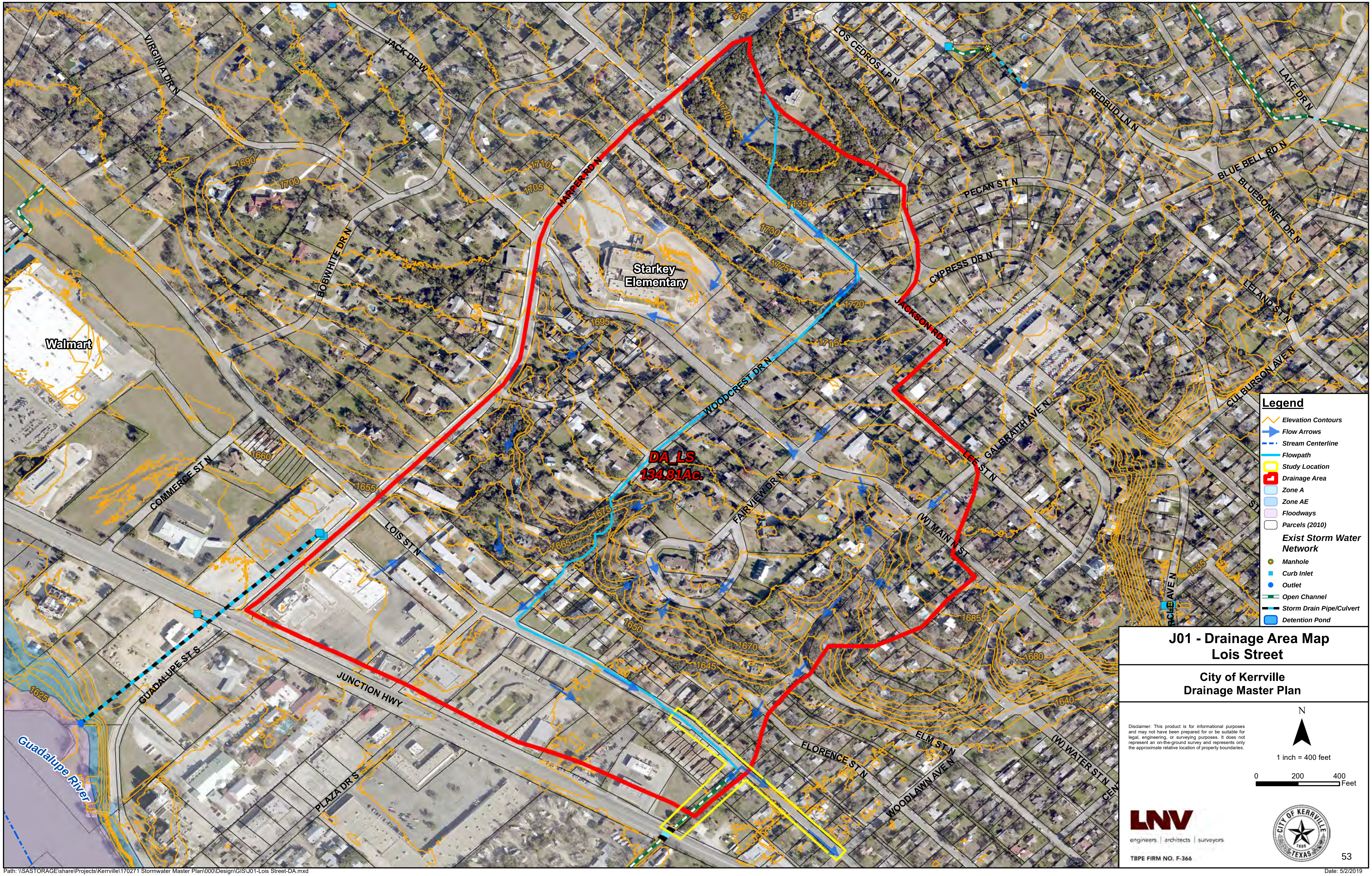
City of Kerrville Stormwater Master Plan

Project ID: J - Lois Street

Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 12,230.03
	2	INSURANCE & BOND	LS	3%	1	$ 3,335.46
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 4,447.28
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 3,335.46
	5	SW3P	LS	1%	1	$ 1,111.82
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	160	$ 960.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	400	$ 2,000.00
	8	STREET EXCAVATION	CY	$ 31.00	60	$ 1,846.22
	9	TACK COAT	GAL	$ 5.00	27	$ 133.33
	10	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	302	$ 10,577.78
	11	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	267	$ 4,000.00
	12	CONCRETE CURB & GUTTER	LF	$ 20.00	160	$ 3,200.00
	13	CONCRETE SIDEWALKS	SY	$ 50.00	89	$ 4,444.44
Utility	14	SANITARY SEWER MANHOLE (0' - 6')	EA	$ 6,500.00	2	$ 13,000.00
	15	8" PVC WATER MAIN	LF	$ 60.00	134	$ 8,040.00
	16	8" PVC SANITARY SEWER LINE (SDR-26) (ALL DEPTHS)	LF	$ 70.00	370	$ 25,900.00
Drainage	17	CHANNEL EXCAVATION (150 CY < X < 5,000 CY)	CY	$ 25.00	654	$ 16,361.11
	18	CONCRETE STRUCTURE (3' RETAINING WALL)	CY	$ 1,000.00	3	$ 2,592.59
	19	SIDEWALK DRAIN	EA	$ 3,000.00	1	$ 3,000.00
	20	CONCRETE RIPRAP (5" THICK)	SY	$ 90.00	168	$ 15,126.62
				Subtotal		$ 135,642.17
				Contingency	25%	$ 33,910.54
				Total Construction Cost		**$ 169,552.71**
				Engineering	12%	$ 20,346.32
				Total Project Cost		**$ 189,899.03**

* Replacement of TxDOT culverts at Junction Highway are to be coordinated and determined, not included in estimate



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Date: 5/2/2019

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\J02-Lois Street-Existing Conditions.mxd

Date: 10/31/2019

J03-Proposed Drainage Improvements
Lois Street

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

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1 inch = 100 feet

0 50 100 Feet

LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

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Date: 12/19/2019

LOCATION K1 AND K2 – HARPER STREET & CIRCLE AVENUE

City of Kerrville

Capital Improvements Project

Project Summary								
Project ID:	K1							
Project Name:	Harper Street							
Fiscal Year Plan								Total
								$1,808,431

Funding Source	
General Fund	0
Total	0

Problem Description:

Minor roadway flooding due to the relatively flat terrain and low-lying spots in the roadway resulting in frequent ponding and nuisance flooding

Proposed Improvement:

Construct a storm drain system from Town Creek to Culberson Avenue.

Perform minor roadway reconstruction by mill and overlay to eliminate low spots in the roadway and improve positive drainage.

O & M Impact:

CIP Ranking Criteria	Score
Structural Flooding	45
Roadway Flooding	36
Roadway Emergency Service Access	54
Frequency of Flooding Damages	63
Erosion / Channel Stability	0
Level of Protection Benefit	54
Project Cost	12
Funding Source / Availability	24
Developmental Impacts	60
Permitting	40
Land / Easement Acquisition	20
Project Readiness	12
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	524
CIP Ranking:	10

Existing Conditions

Existing Conditions at Harper Street (Facing U/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: K1 - Harper Street

Date: 12/19/2019

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	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 116,468.04
	2	INSURANCE & BOND	LS	3%	1	$ 31,764.01
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 42,352.02
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 31,764.01
	5	SW3P	LS	1%	1	$ 10,588.00
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	1,680	$ 10,080.00
	7	STREET EXCAVATION	CY	$ 31.00	263	$ 8,161.84
	8	SALVAGING, HAULING & STOCKPILING RECLAIMABLE ASPHALTIC PAVEMENT(2" DEPTH)	SY	$ 9.00	4,167	$ 37,500.00
	9	LIME TREATED SUBGRADE (6" COMPACTED DEPTH)	SY	$ 6.00	658	$ 3,949.28
	10	LIME	TON	$ 200.00	2	$ 315.94
	11	PRIME COAT	GAL	$ 5.00	450	$ 2,250.00
	12	TACK COAT	GAL	$ 5.00	417	$ 2,083.33
	13	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	4,500	$ 157,500.00
	14	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	4,167	$ 62,500.00
	15	CONCRETE CURB & GUTTER	LF	$ 20.00	1,680	$ 33,600.00
	16	CURB RAMP	EA	$ 1,500.00	8	$ 12,000.00
	17	CHAIN LINK FENCE (REMOVE)	LF	$ 18.00	50	$ 900.00
	18	CHAIN LINK FENCE (4' HIGH)	LF	$ 25.00	50	$ 1,250.00
Utility	19	ADJUST EXISTING MANHOLES AND VALVE BOXES	EA	$ 2,000.00	11	$ 22,000.00
	20	6" PVC WATER MAIN	LF	$ 50.00	40	$ 2,000.00
	21	ADJUST EXISTING WATER LATERAL	EA	$ 3,000.00	21	$ 63,000.00
	22	SANITARY SEWER (6IN) (PVC) (SDR 26)	LF	$ 70.00	190	$ 13,300.00
	23	SANITARY SEWER (12IN) (PVC) (SDR 26)	LF	$ 100.00	90	$ 9,000.00
	24	SANITARY SEWER MANHOLE (0' - 6')	EA	$ 6,500.00	6	$ 39,000.00
	25	ADJUST EXISTING WASTEWATER LATERAL	EA	$ 1,500.00	21	$ 31,500.00
Drainage	26	REINFORCED CONCRETE PIPE (CLASS III)(24" DIA)	LF	$ 130.00	320	$ 41,600.00
	27	REINFORCED CONCRETE PIPE (CLASS III)(36" DIA)	LF	$ 150.00	460	$ 69,000.00
	28	REINFORCED CONCRETE PIPE (CLASS III)(42" DIA)	LF	$ 228.00	1,000	$ 228,000.00
	29	CONCRETE STRUCTURE (HEADWALLS OR OUTFALL STRUCTURES)	CY	$ 1,000.00	8	$ 8,000.00
	30	CL A CONC (COLLAR)	EA	$ 1,450.00	1	$ 1,450.00
	31	RIPRAP (STONE PROTECTION)(18 IN)	CY	$ 170.00	8	$ 1,360.00
	32	JUNCTION BOX (COMPLETE) 6'X6'X6'	EA	$ 7,500.00	4	$ 30,000.00
	33	INLET TYPE I (COMPLETE) (10 FT) (10' DEPTH)	EA	$ 7,500.00	16	$ 120,000.00
	34	INLET EXTENSIONS (10 FT.)	EA	$ 4,000.00	4	$ 16,000.00
	35	CONCRETE RETAINING WALLS-(SIDEWALK/ DRIVEWAYS)	CY	$ 1,000.00	27	$ 27,000.00
	36	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	1,500	$ 4,500.00
				Subtotal		$ 1,291,736.48
				Contingency	25%	$ 322,934.12
				Total Construction Cost		**$ 1,614,670.60**
				Engineering	12%	$ 193,760.47
				Total Project Cost		**$ 1,808,431.07**

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	K2
Project Name:	Circle Avenue

Fiscal Year Plan								Total
								$188,800

Funding Source	
General Fund	0
Total	0

Problem Description:

Runoff received from Jackson Drive travels down a steep earthen slope towards Circle Drive resulting in erosion and the accumulation of sediment within the roadway.

Proposed Improvements:

Construct a concrete lined channel with energy dissipation controls from Jackson Drive to Circle Avenue.

Direct runoff at the downstream outlet parallel with Circle Avenue to prevent flows from discharging across the roadway and into private property.

O & M Impact:

Periodic cleaning of the concrete channel and outlet.

CIP Ranking Criteria	Score
Structural Flooding	0
Roadway Flooding	36
Roadway Emergency Service Access	18
Frequency of Flooding Damages	63
Erosion / Channel Stability	90
Level of Protection Benefit	90
Project Cost	60
Funding Source / Availability	24
Developmental Impacts	30
Permitting	40
Land / Easement Acquisition	12
Project Readiness	20
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	587
CIP Ranking:	6

Existing Conditions

Existing Earthen Channel Outfall Location (Facing U/S)

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: K2 - Circle Avenue

Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 11,842.05
	2	INSURANCE & BOND	LS	3%	1	$ 3,229.65
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 4,306.20
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 3,229.65
	5	SW3P	LS	1%	1	$ 1,076.55
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	242	$ 1,452.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	560	$ 2,800.00
	8	STREET EXCAVATION	CY	$ 31.00	231	$ 7,147.41
	9	TACK COAT	GAL	$ 5.00	36	$ 181.21
	10	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	407	$ 14,240.57
	11	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	362	$ 5,436.43
	12	CONCRETE CURB & GUTTER	LF	$ 20.00	242	$ 4,840.00
	13	PORTLAND CEMENT CONCRETE DRIVEWAY	SY	$ 74.00	62	$ 4,604.44
Utility	14	8" PVC WATER MAIN	LF	$ 60.00	65	$ 3,900.00
Drainage	15	CHANNEL EXCAVATION (< 150 CY)	CY	$ 20.00	147	$ 2,940.74
	16	CONCRETE STRUCTURE (BAFFLE BLOCKS)	CY	$ 1,000.00	1	$ 888.89
	17	CONCRETE RIPRAP (5" THICK) (100 SY < X < 4000 SY)	SY	$ 90.00	406	$ 36,500.00
	18	TOPSOIL (4")	SY	$ 9.00	733	$ 6,600.00
	19	BERMUDA SODDING	SY	$ 7.00	733	$ 5,133.33
	20	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	330	$ 990.00
	21	CONCRETE BOLLARDS	EA	$ 5,000.00	2	$ 10,000.00
				Subtotal		$ 131,339.14
				Contingency	25%	$ 32,834.78
				Total Construction Cost		**$ 164,173.92**
				Engineering	15%	$ 24,626.09
				Total Project Cost		**$ 188,800.01**

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Date: 5/8/2019

Legend

- Elevation Contours
- Stream Centerline
- Study Location
- Zone A
- Zone AE
- Floodways
- Parcels (2010)

Exist Storm Water Network

- Manhole
- Curb Inlet
- Outlet
- Open Channel
- Storm Drain Pipe/Culvert
- Detention Pond

Exist Sewer Utilities

- Sewer Manhole
- Pressure Sewer Main
- Sewer Main

Exist Water Utilities

- Fire Hydrant
- Water Main

K1-02, K2-02 - Existing Drainage Conditions
Harper Street & Circle A Ave

City of Kerrville
Drainage Master Plan

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1 inch = 200 feet

0 100 200 Feet

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CITY OF KERRVILLE TEXAS 1889

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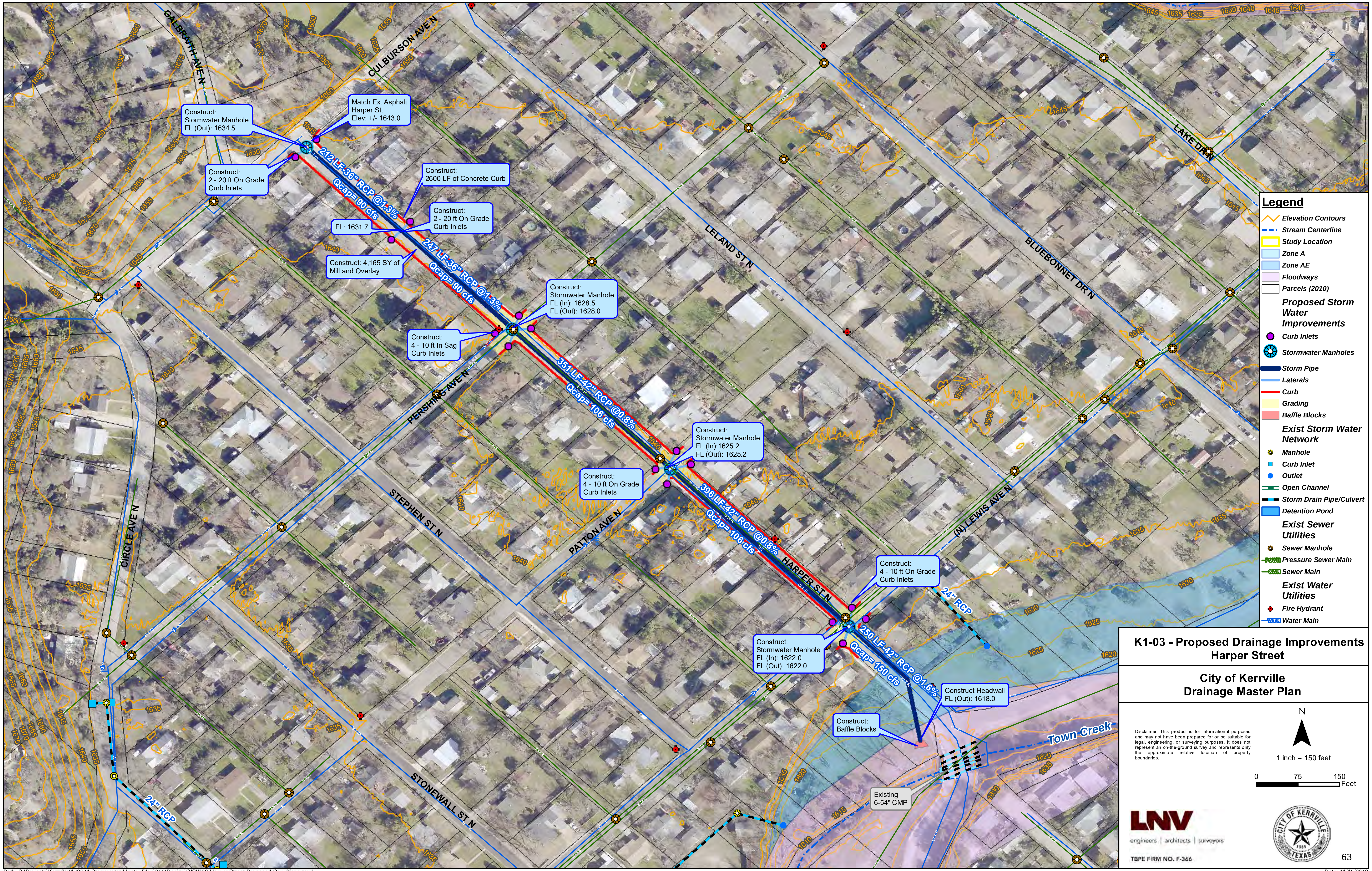
Date: 10/31/2019



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Date: 11/15/2019

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Date: 11/14/2019

LOCATION L – JACK DRIVE

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	L
Project Name:	Jack Drive

Fiscal Year Plan							Total
							$2,373,793

Funding Source	
General Fund	0
Total	0

Problem Description:

Significant runoff that accumulates at Jack Drive has no storm drain system to be collected into which results in flood flows traveling across residential properties and places structures at risk of damage.

Proposed Improvement:

Construct a storm drain pipe system from Jack Drive to Lois Street intended to capture runoff and convey it within available easements and within proposed easements, as needed. Jack and bore storm drain pipe in areas where there are significant structures, trees or high risk of property damage due to construction.

O & M Impact:

CIP Ranking Criteria	Score
Structural Flooding	90
Roadway Flooding	36
Roadway Emergency Service Access	18
Frequency of Flooding Damages	90
Erosion / Channel Stability	0
Level of Protection Benefit	54
Project Cost	12
Funding Source / Availability	24
Developmental Impacts	60
Permitting	40
Land / Easement Acquisition	12
Project Readiness	12
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	552
CIP Ranking:	7

Existing Conditions

Existing Undersized Drainage Network at Jack Drive

Proposed Improvements

Conceptual Drainage Improvement Layout

Notes:

OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: L - Jack Drive

Date: 12/19/2019

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	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 146,973.77
	2	INSURANCE & BOND	LS	3%	1	$ 40,083.75
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 53,445.01
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 40,083.75
	5	SW3P	LS	1%	1	$ 13,361.25
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	260	$ 1,560.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	1,070	$ 5,350.00
	8	STREET EXCAVATION	CY	$ 31.00	669	$ 20,741.87
	9	TACK COAT	GAL	$ 5.00	143	$ 712.50
	10	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	1,618	$ 56,641.67
	11	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	1,425	$ 21,375.00
	12	CONCRETE CURB & GUTTER	LF	$ 20.00	670	$ 13,400.00
	13	CONCRETE SIDEWALKS	SY	$ 50.00	72	$ 3,611.11
	14	PORTLAND CEMENT CONCRETE DRIVEWAY	SY	$ 74.00	74	$ 5,508.89
Utility	15	ADJUST EXISTING MANHOLES AND VALVE BOXES	EA	$ 2,000.00	1	$ 2,000.00
	16	SANITARY SEWER MANHOLE (0' - 6')	EA	$ 6,500.00	6	$ 39,000.00
	17	8" PVC WATER MAIN	LF	$ 60.00	60	$ 3,600.00
	18	SANITARY SEWER (6IN) (PVC) (SDR 26)	LF	$ 70.00	270	$ 18,900.00
	19	SANITARY SEWER (12IN) (PVC) (SDR 26)	LF	$ 100.00	50	$ 5,000.00
Drainage	20	CHANNEL EXCAVATION (150 CY < X < 5,000 CY)	CY	$ 25.00	554	$ 13,851.85
	21	STRUCTURAL EXCAVATION DRVY RET WALLS	CY	$ 85.00	2	$ 204.63
	22	CONCRETE STRUCTURE(RETAINING WALLS) (< 10 CY)	CY	$ 1,000.00	2	$ 2,407.41
	23	CONCRETE STRUCTURE (HEADWALLS OR OUTFALL STRUCTURES)	CY	$ 1,000.00	3	$ 2,888.89
	24	REINFORCED CONCRETE PIPE (CLASS III)(42" DIA)	LF	$ 228.00	1,230	$ 280,440.00
	25	REINFORCED CONCRETE PIPE (CLASS III)(48" DIA)	LF	$ 390.00	426	$ 166,140.00
	26	JUNCTION BOX (COMPLETE) 6'X6'X6'	EA	$ 7,500.00	4	$ 30,000.00
	27	INLET TYPE I (COMPLETE) (10 FT) (5' DEPTH)	EA	$ 6,000.00	6	$ 36,000.00
	28	MANHOLE VERTICAL STACK (SPECIAL MANHOLE RISER)	EA	$ 3,000.00	4	$ 12,000.00
	29	CHAIN LINK WIRE FENCE (6' HIGH)	LF	$ 40.00	520	$ 20,800.00
	30	TOPSOIL (4")	SY	$ 9.00	1,222	$ 11,000.00
	31	BERMUDA SODDING	SY	$ 7.00	1,222	$ 8,555.56
	32	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	1,886	$ 5,658.00
	33	RIPRAP (STONE PROTECTION)(18 IN)	CY	$ 170.00	2	$ 377.78
	34	GRATE INLET (COMPL) (TY W-3)	EA	$ 6,000.00	1	$ 6,000.00
	35	REMOVE STRUCTURE (INLET)	EA	$ 1,200.00	2	$ 2,400.00
	36	JACK BORE (48" RCP)	LF	$ 900.00	600	$ 540,000.00
				Subtotal		$ 1,630,072.68
				Contingency	25%	$ 407,518.17
				Total Construction Cost		**$ 2,037,590.85**
				Land Acquisition	5%	$ 101,879.54
				Engineering	12%	$ 234,322.95
				Total Project Cost		**$ 2,373,793.34**

L01 - Drainage Area Map
Jack Drive

City of Kerrville
Drainage Master Plan

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LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\L01-JackDrive-DA.mxd

Date: 12/5/2019

L02- Existing Drainage Conditions
Jack Drive

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\L02-JackDrive-Existing Conditions.mxd

Date: 12/5/2019

L03-Proposed Drainage Conditions
Jack Drive

City of Kerrville
Drainage Master Plan

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N

1 inch = 200 feet

0 100 200 Feet

LNV
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TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\L03-JackDrive-Proposed Conditions (Option 2) - SD Copy.mxd

Date: 1/9/2020

LOCATION M – CORONADO DRIVE

City of Kerrville

Capital Improvements Project

Project Summary	
Project ID:	M
Project Name:	Coronado Drive North at SH27 (Junction Highway)

Fiscal Year Plan								Total
								$494,195

Funding Source	
General Fund	0
Total	0

Problem Description:

Junction Highway is higher than Coronado Drive resulting in runoff traveling from Coronado to backup and pond in the system due to lack of positive drainage which results in street flooding and roadway closures during storm events.

Proposed Improvements:

Construct a trench drain or inlet system at Coronado Drive and convey runoff thru a storm pipe across Junction Highway that discharges into the Guadalupe River.

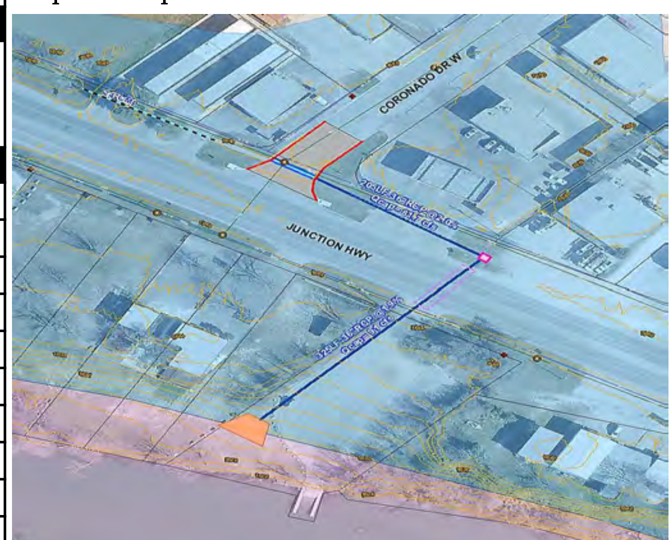
O & M Impact:

CIP Ranking Criteria	Score
Structural Flooding	0
Roadway Flooding	63
Roadway Emergency Service Access	54
Frequency of Flooding Damages	63
Erosion / Channel Stability	0
Level of Protection Benefit	54
Project Cost	60
Funding Source / Availability	60
Developmental Impacts	30
Permitting	24
Land / Easement Acquisition	20
Project Readiness	20
Project Dependency	20
Water Quality Impacts	42
Riparian Impacts	42
Total Weighted Point Score:	552
CIP Ranking:	7

Existing Conditions

Existing Drainage Conditions at Coronado St.

Proposed Improvements



Conceptual Drainage Improvement Layout

Notes:

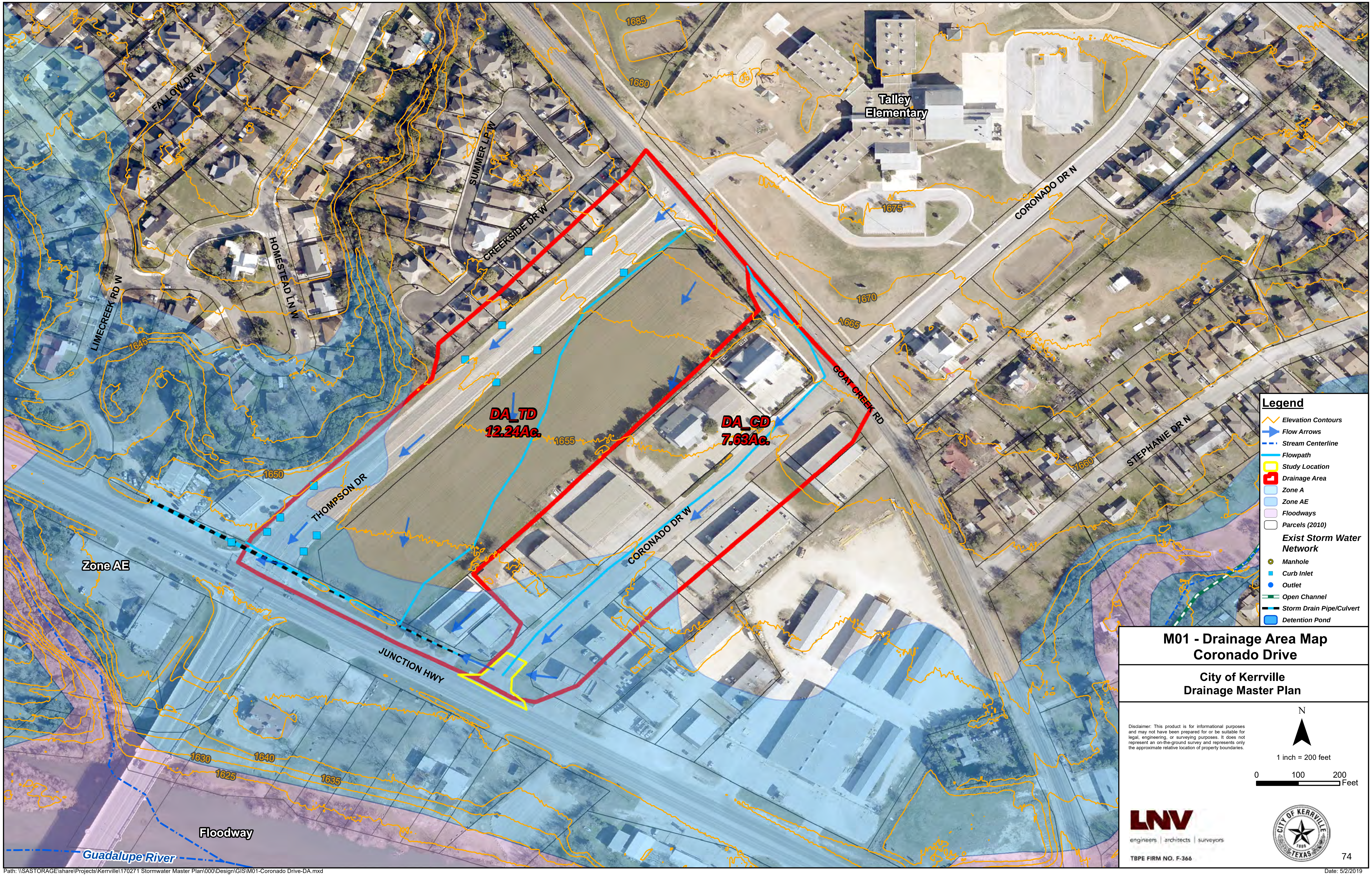
OPINION OF PROBABLE CONSTRUCTION COST

City of Kerrville Stormwater Master Plan

Project ID: M - Coronado Drive

Date: 12/19/2019

	ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
General	1	MOBILIZATION	LS	11%	1	$ 31,686.10
	2	INSURANCE & BOND	LS	3%	1	$ 8,641.66
	3	PREPARING RIGHT OF WAY	LS	4%	1	$ 11,522.22
	4	TRAFFIC CONTROL PLAN	LS	3%	1	$ 8,641.66
	5	SW3P	LS	1%	1	$ 2,880.55
Roadway	6	REMOVE CONCRETE CURB	LF	$ 6.00	210	$ 1,260.00
	7	REMOVE CONCRETE SIDEWALKS & DRIVEWAYS	SF	$ 5.00	1,025	$ 5,125.00
	8	STREET EXCAVATION	CY	$ 31.00	227	$ 7,026.67
	9	TACK COAT	GAL	$ 5.00	49	$ 245.56
	10	HOT MIX ASPHALTIC PAVEMENT TYPE B (6" COMP. DEPTH)	SY	$ 35.00	567	$ 19,833.33
	11	HOT MIX ASPHALTIC PAVEMENT TYPE D (2" COMP. DEPTH)	SY	$ 15.00	491	$ 7,366.67
	12	CONCRETE CURB & GUTTER	LF	$ 20.00	210	$ 4,200.00
	13	PORTLAND CEMENT CONCRETE DRIVEWAY - COMMERCIAL	SY	$ 74.00	114	$ 8,427.78
Utility	14	SANITARY SEWER MANHOLE (0' - 6')	EA	$ 6,500.00	3	$ 19,500.00
	15	8" PVC WATER MAIN	LF	$ 60.00	30	$ 1,800.00
	16	8" PVC SANITARY SEWER LINE (SDR-26) (ALL DEPTHS)	LF	$ 70.00	50	$ 3,500.00
Drainage	17	GRATE INLET (COMPL) (TRAFFIC) (TY X-1) (5' X 5')	EA	$ 5,000.00	1	$ 5,000.00
	18	REMOVE MISCELLANEOUS CONCRETE	SF	$ 5.00	880	$ 4,400.00
	19	STRUCTURAL EXCAVATION (100 < X < 500 CY)	CY	$ 85.00	61	$ 5,194.44
	20	REINFORCED CONCRETE PIPE (CLASS III)(36" DIA)	LF	$ 155.00	530	$ 82,150.00
	21	SAFETY END TREATMENT (TYPE 1) (36" DIA)	EA	$ 3,000.00	1	$ 3,000.00
	22	JUNCTION BOX (COMPLETE) 5'X5'X5'	EA	$ 5,820.00	1	$ 5,820.00
	23	CONCRETE RIPRAP (5" THICK)	SY	$ 90.00	102	$ 9,175.00
	24	TRENCH EXCAVATION SAFETY PROTECTION	LF	$ 3.00	677	$ 2,031.00
	25	JACK BORE (36" RCP)	LF	$ 900.00	85	$ 76,500.00
	26	TRENCH DRAIN (3.5'W X 30'L X 5'D)	EA	$ 16,500.00	1	$ 16,500.00
				Subtotal		$ 351,427.64
				Contingency	25%	$ 87,856.91
			Total Construction Cost			$ 439,284.55
				Engineering	13%	$ 54,910.57
			Total Project Cost			$ 494,195.12



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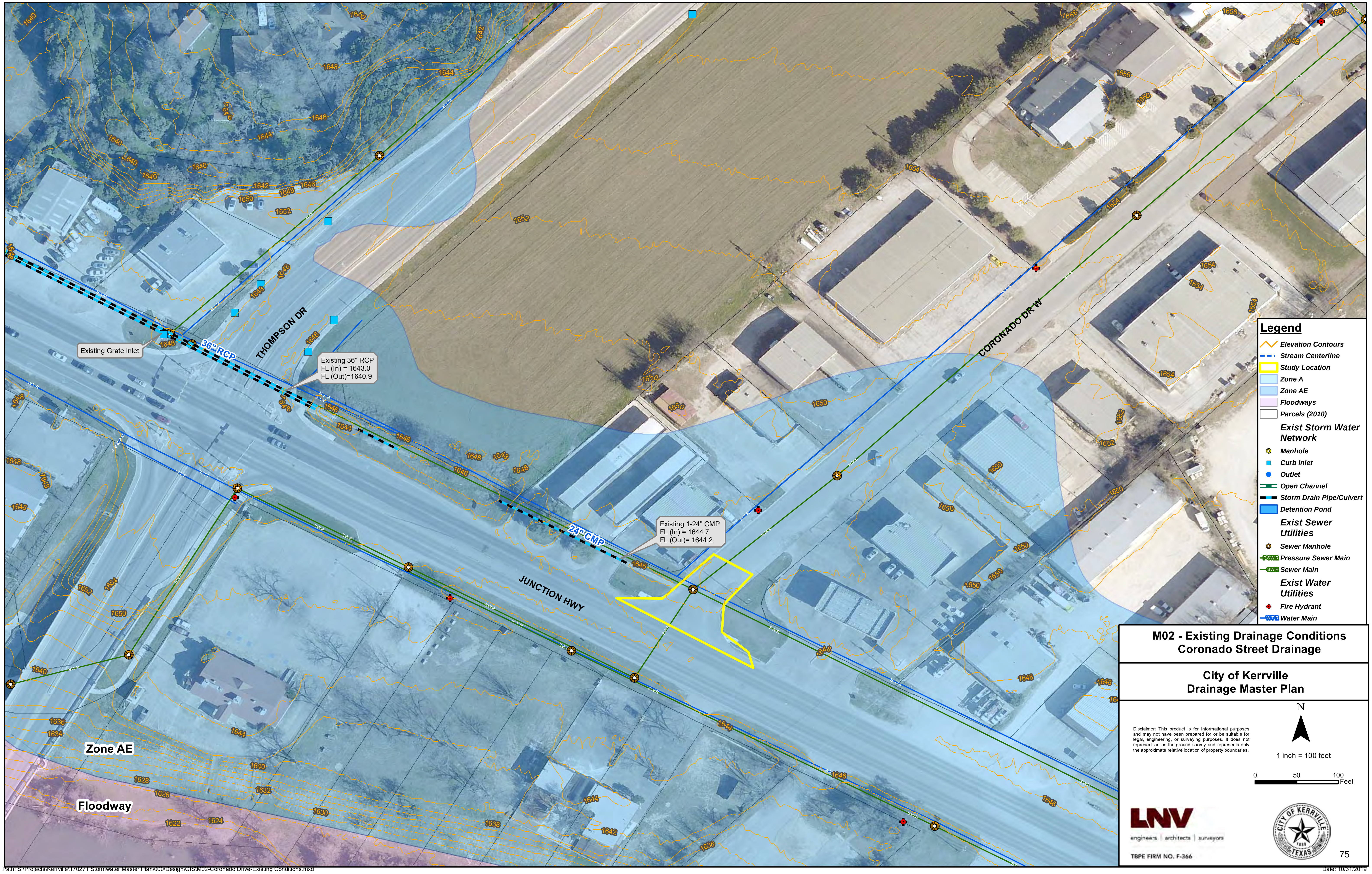
Date: 5/2/2019



M02 - Existing Drainage Conditions
Coronado Street Drainage

City of Kerrville
Drainage Master Plan

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. It does not represent an on-the-ground survey and represents only the approximate relative location of property boundaries.

N

1 inch = 100 feet

0 50 100 Feet

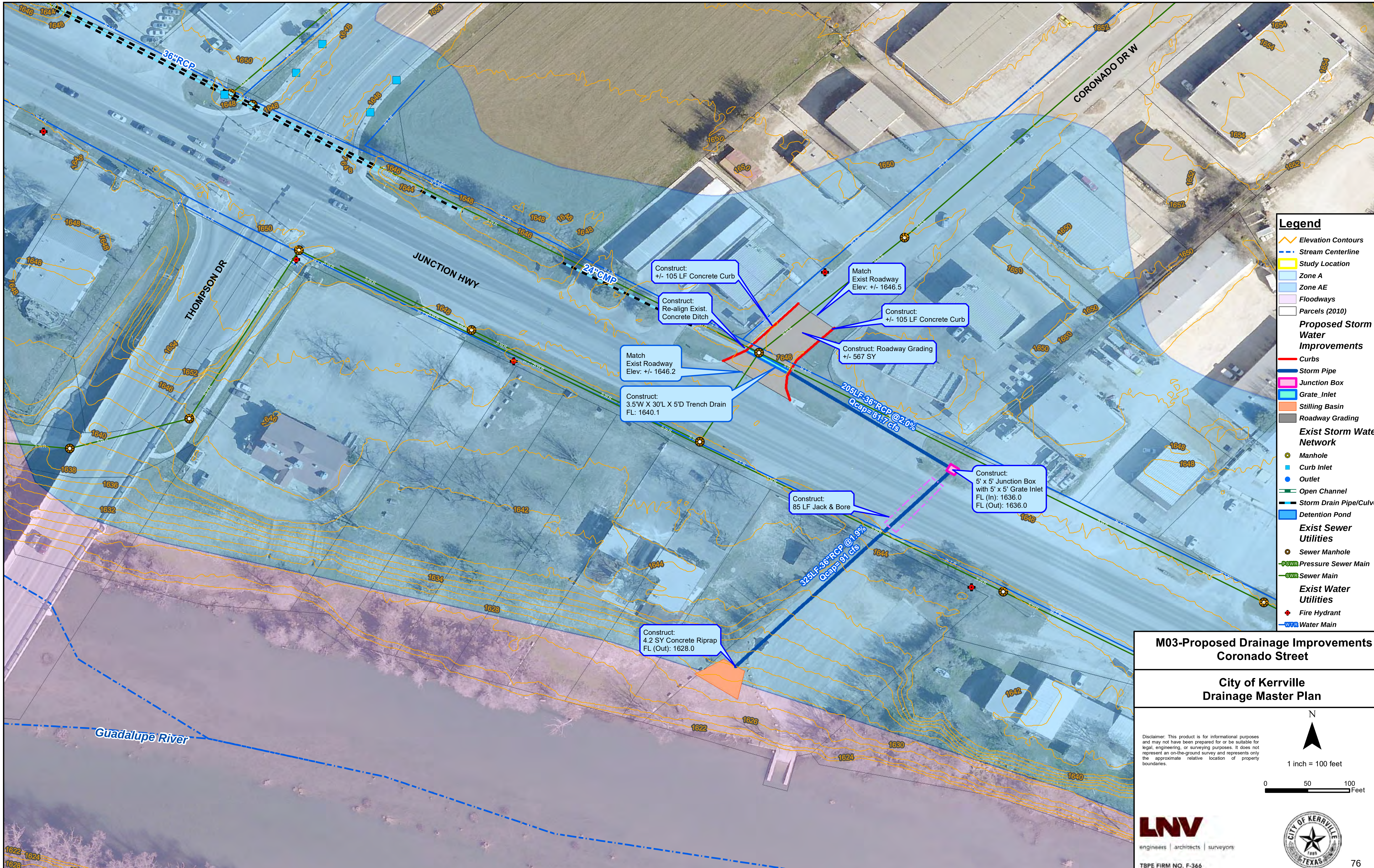
LNV engineers | architects | surveyors

TBPE FIRM NO. F-366

CITY OF KERRVILLE TEXAS 1889

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\M02-Coronado Drive-Existing Conditions.mxd

Date: 10/31/2019



M03-Proposed Drainage Improvements Coronado Street

City of Kerrville Drainage Master Plan

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TBPE FIRM NO. F-366

CITY OF KERRVILLE 1889 TEXAS

Path: S:\Projects\Kerrville\170271 Stormwater Master Plan\000\Design\GIS\M03-Coronado Drive-Proposed Conditions (Option 2).mxd

Date: 11/20/2019

APPENDIX C – DRAINAGE POLICY AND CRITERIA REVIEW

SECTION 54 FLOODS

ARTICLE	ORDINANCE	RECOMMENDATION
I	IN GENERAL	No change.
II	FLOODPLAIN MANAGEMENT	
31 – Purpose and Methods	(a) *Purpose.* This article is adopted for the purpose of promoting the public health, safety and general welfare and to minimize public and private losses due to flood conditions in specific areas by provisions designed to: (1) Protect human life and health; (2) Minimize expenditure of public money for costly flood control projects; (3) Minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public; (4) Minimize prolonged business interruptions; (5) Minimize damage to public facilities and utilities such as water and gas mains, electric, telephone and sewer lines, streets and bridges located in floodplains; (6) Help maintain a stable tax base by providing for the sound use and development of floodprone areas in such a manner as to minimize future flood blight areas; and (7) Ensure that potential buyers are notified that property is in a flood area.	ADD PROVISIONS: (a) *Purpose.* (8) To minimize public and private property losses due to flooding; (9) To preserve the natural floodplains where at all possible;
	(b) *Methods of reducing flood losses.* In order to accomplish the purposes set forth in subsection (a) of this section, this article uses the following methods: (1) Restrict or prohibit uses that are dangerous to health, safety or property in times of flood, or which cause excessive increases in flood heights or velocities; (2) Require that uses vulnerable to floods, including facilities which serve such uses, be protected against flood damage at the time of initial construction; (3) Control the alteration of natural floodplains, stream channels, and natural protective barriers, which are involved in the accommodation of floodwaters; (4) Control filling, grading, dredging and other development which may increase flood damage; (5) Prevent or regulate the construction of flood barriers which will unnaturally divert floodwaters or which may increase flood hazards to other lands.	(6) Controlling development which would cause greater erosion or potential flood damage such as grading, dredging, excavation, and filling. (7) Imposing a regulatory 1% annual chance floodplain that requires using the ultimate development of the watershed to determine the 1% annual chance water surface elevations. New developments must be constructed above this elevation.

ARTICLE	ORDINANCE	RECOMMENDATION
32 – Definition and Interpretation	*Definitions.* Unless specifically defined in this section, words or phrases used in this article shall be interpreted to give them the meaning they have in common usage and to give this article its most reasonable application: *Actual start* for purposes of determining the "start of construction" as defined in this section, means: (1) The first placement of permanent construction of a structure on a site; (2) The placement of a manufactured home on a foundation; or (3) In the case of a substantial improvement, the first alteration of any wall, ceiling, floor, or other structural part of a building, whether or not that alteration affects the external dimensions of the building. *Alluvial fan flooding* means flooding occurring on the surface of an alluvial fan or similar land form which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and, unpredictable flow paths. *Alluvial stream* means a stream that has formed its channel by the process of aggradation. The sediment in the stream is similar to the material in the bed and banks. *Apex* means a point on an alluvial fan or similar land form below which the flow path of the major stream that formed the fan becomes unpredictable and alluvial fan flooding can occur. *Appeal* means a request for a review of the floodplain administrator's interpretation of any provision of this article or a request for a variance. *Area of shallow flooding* means a designated AO, AH, AR/AO, AR/AH, or VO zone on a community's flood insurance rate map (FIRM) with a one percent or greater annual chance of flooding to an average depth of one to three feet where a clearly defined channel does not exist, where the path of flooding is unpredictable, and where velocity flow may be evident. Such flooding is characterized by ponding or sheet flow. *Area of special flood hazard* means the land in the floodplain within the city subject to a one percent or greater chance of flooding in any given year. Prior to completion of detailed ratemaking in preparation of publication of a FIRM, such area may be designated as zone A on the flood hazard boundary map. After the completion of detailed ratemaking in preparation for publication of a FIRM, such area may be designated as zones A, AE, AH, AO, A1-99, VO, V1-30, VE or V. *Base flood* means the flood having a one percent chance of being equaled or exceeded in any given year. *Base flood elevation (BFE)* means the water surface elevation associated with the base flood as defined in the flood insurance study approved by FEMA dated March	**ADD PROVISIONS:** *Definitions*. *1% annual chance floodplain* (formerly 100-year floodplain) is the land within a community subject to a one (1) percent or greater chance of flooding in any given year. These areas are typically designated as a Federal Emergency Management Agency (FEMA) Zone A, AE, AH, or AO on FEMA Flood Insurance Rate Maps (FIRM Panels). *Appurtenant structure* means a structure which is on the same parcel of property as the principal structure to be insured and the use of which is incidental to the use of the principal structure. *Area of flood inundation* refers to sites that are subject to flooding as a result of water ponding in the controlled storage areas of dams, detention and retention ponds. *Area of future flood conditions* means the land area that would be inundated by the 1% annual chance (100-year) flood based on future conditions hydrology.

ARTICLE	ORDINANCE	RECOMMENDATION
	3, 2011, any amendments approved by FEMA to such flood insurance study, or such other flood insurance study as may be later adopted and/or amended by FEMA. *Basement* means any area of the building having its floor subgrade (below ground level) on all sides. *CFR* means the Code of Federal Regulations. *Competent engineering study* means hydrologic and/or hydraulic analysis performed in accordance with standard engineering practices required by FEMA. *Critical feature* means an integral and readily identifiable part of a flood protection system, without which the flood protection provided by the entire system would be compromised. *Cross section* means a vertical profile of the ground surface taken perpendicular to the direction of flood flow. The profile is defined by coordinates of ground elevation and horizontal distance (station). *Development* means any manmade change in improved and unimproved real estate, including but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials. *Development permit* means any authorization required by the city prior to development in the floodplain. The term "development permit" includes, but is not limited to, a subdivision plat, site plan, building permit, grading permit or construction permit. *Director* means the director of engineering of the city. *Elevated building* means a nonbasement building which, for insurance purposes, has its lowest elevated floor raised above ground level by foundation walls, shear walls, posts, piers, pilings, or columns. *Existing construction* and *existing structures* mean for the purpose of determining rates, structures for which the "start of construction" commenced before the effective date of the FIRM or before January 1, 1975, for FIRM's effective before that date. *Existing manufactured home park or subdivision* means a manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before October 1, 1998. *Expansion to an existing manufactured home park or subdivision* means the preparation of additional sites by the construction of facilities for servicing the lots on which manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads).	*CLOMR* means a Conditional Letter of Map Revision. A CLOMR will be submitted for FEMA approval for all proposed physical changes to the floodplain that will result in a change to the floodplain boundary. **MODIFY PROVISIONS:** **Definitions - Elevated Building Definition.** *Elevated building* means a non-basement building (i) built, in the case of a building in Zones AE, A, A99, AO, AH, X, and D, to have the top of the elevated floor, elevated above the ground level by means of pilings, columns (posts and piers), or shear walls parallel to the floor of the water and (ii) adequately anchored so as not to impair the structural integrity of the building during a flood of up to the magnitude of the base flood. In the case of Zones AE, A, A99, AO, AH, X, D, "elevated building" also includes a building elevated by means of fill or solid foundation perimeter walls with openings sufficient to facilitate the unimpeded movement of floodwaters.

ARTICLE	ORDINANCE	RECOMMENDATION

FEMA means the Federal Emergency Management Agency.

First placement of permanent construction means the initial step of constructing a permanent structure in a site including, but not limited to:

(1) The pouring of slab or footings;

(2) The installation of piles;

(3) The construction of columns; or

(4) Any work beyond the stage of excavation.

For purpose of this definition the term "permanent construction" does not include land preparation, such as clearing, grading and filling, installation of streets and/or walkways, excavation for basement, footings, piers or foundations or the erection of temporary forms, or the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure.

Flood and *flooding* mean:

(1) A general and temporary condition of partial or complete inundation of normally dry land areas from:

a. The overflow of inland or tidal waters;

b. The unusual and rapid accumulation or runoff of surface waters from any source; or

c. Mudslides which are proximately caused by flooding as defined in subsection (1)b of this definition and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when earth is carried by a current of water and deposited along the path of the current; and

(2) The collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as flash flood or an abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding as defined in subsection (1)a of this definition.

Flood elevation determination means a determination by the administrator of FEMA of the water surface elevation of the base flood.

Flood elevation study and *flood insurance study* mean an examination, evaluation, and determination of (i) flood hazards and, if appropriate, corresponding water surface elevations; or (ii) mudslides (i.e. mudflow) and/or flood-related erosion hazards.

ARTICLE	ORDINANCE	RECOMMENDATION
	Flood insurance rate map (FIRM) means an official map of the areas of the incorporated limits of the city on which FEMA has delineated both the areas of special flood hazards and the risk premium zones applicable to property located within the city.	**ADD PROVISIONS:** *Flood Insurance Study (FIS)* is the official report provided by the Federal Emergency Management Agency. The report contains flood profiles, water surface elevation or the base flood, as well as the flood boundary map. Also see Flood Elevation Study.
	Flood protection system means those physical structural works for which funds have been authorized, appropriated, and expended and which have been constructed in conformance with sound engineering standards specifically to modify flooding in order to reduce the extent of the areas within the city subject to a "special flood hazard" and the extent of the depths of associated flooding, including, but not limited to, dams, reservoirs, levees or dikes.	*Flood-prone area* means any land area susceptible to being inundated by water from any source (see definition of flooding).
	Floodplain and *floodprone area* mean the land lying between the channel of the Guadalupe River and/or its tributaries and the outer boundary of the 100-year flood, as delineated on the FIRM. The term "floodplain" includes land within the regulatory floodways and land within the flood fringe.	*Floodplain management* means the operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works and floodplain management regulations.
	Floodplain development permit means the city authorization required by this article to allow a property owner to obtain preliminary or final approval of an application for development of land within the floodplain issued alone or concurrently with a building permit pursuant to chapter 26, article II, of this Code.	*Floodplain management regulations* means zoning ordinances, subdivision regulations, building codes, health regulations, special purpose ordinances (such as a floodplain ordinance, grading ordinance and erosion control ordinance) and other applications of police power. The term describes such state or local regulations, in any combination thereof, which provide standards for the purpose of flood damage prevention and reduction.
	Floodproofing means any combination of structural and nonstructural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents.	
	Floodway and *regulatory floodway* mean the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.	
	Floodway fringe means the area between the floodway boundary and the 100-year floodplain boundary.	
	Functionally dependent use means a use which cannot perform its intended purpose unless it is located or carried out in close proximity to water. The term "functionally dependent use" includes only docking facilities, port facilities that are necessary for the loading and unloading of cargo or passengers, and shipbuilding and ship repair facilities, but does not include longterm storage or related manufacturing facilities.	
	Habitable floor means any floor, other than a floor used for storage purposes only, which is usable for one or more of the following purposes: (1) Working; (2) Sleeping; (3) Eating; (4) Cooking; or	*Habitable structure* means a structure that has facilities to accommodate people for an overnight stay. These include, but are not limited to, residential homes, apartments, condominiums, hotels, motels, and manufactured homes. Recreational vehicles are not included in this definition.

ARTICLE	ORDINANCE	RECOMMENDATION
	(5) Recreation. *Highest adjacent grade* means the highest natural elevation of the ground surface prior to construction next to the proposed walls of a structure. *Historic structure* means any structure that is: (1) Listed individually in the National Register of Historic Places (a listing maintained by the United States Department of Interior) or preliminarily determined by the Secretary of the Interior as meeting the requirements for individual listing on the National Register; (2) Certified or preliminarily determined by the Secretary of the Interior as contributing to the historical significance of a registered historic district or a district preliminarily determined by the Secretary to qualify as a registered historic district; (3) Individually listed on a state inventory of historic places in states with historic preservation programs which have been approved by the Secretary of the Interior; or (4) Individually listed on a local inventory of historic places in communities with historic preservation programs that have been certified either: a. By an approved state program as determined by the Secretary of the Interior; or b. Directly by the Secretary of the Interior in states without approved programs. *Levee* means a manmade structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding. *Levee system* means a flood protection system which consists of a levee, or levees, and associated structures, such as closure and drainage devices, which are constructed and operated in accordance with sound engineering practices. *Lowest floor* means the lowest floor of the lowest enclosed area (including basement). An unfinished or flood resistant enclosure, usable solely for parking of vehicles, building access or storage in an area other than a basement area is not considered a building's lowest floor; provided that such enclosure is not built so as to render the structure in violation of the applicable nonelevation design requirement of Section 60.3 of the National Flood Insurance Program regulations (44 CFR 60.3). *Manufactured home* means a structure transportable in one or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when connected to the required utilities. For floodplain management purposes, the term "manufactured home" also includes park trailers, travel trailers, and other similar recreational vehicles or trailers placed on a site for greater than 30 consecutive days. For insurance purposes, the term "manufactured home" does	**ADD PROVISIONS:** *LOMR* means a letter of map revision. A LOMR will be submitted for FEMA approval for all changes to the floodplain boundary that are delineated on the current Flood Insurance Rate Maps.

ARTICLE	ORDINANCE	RECOMMENDATION
	not include park trailers, travel trailers, and other similar recreational vehicles or trailers. *Manufactured home park or subdivision* means a parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale. *Mean sea level* means for purposes of the National Flood Insurance Program, the National Geodetic Vertical Datum (NGVD) of 1929 or other datum, to which base flood elevations shown on the FIRM are referenced. *New construction* means, for floodplain management purposes, structures for which the "start of construction" commenced on or after the effective date of a floodplain management regulation adopted by the city and includes any subsequent improvements to such structures. *New manufactured home park or subdivision* means a manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after the effective date of the ordinance from which this article is derived or any amendment to this article. *100-year flood* means the flood that has a one percent chance of being equaled or exceeded once every year; equivalent to the one percent annual chance flood. *Recreational vehicle* means a vehicle which is: (1) Built on a single chassis; (2) Four hundred square feet or less when measured at the largest horizontal projection; (3) Designed to be self-propelled or permanently towable by a light duty truck; and (4) Designed primarily not for use as a permanent dwelling but as temporary living quarters for recreational, camping, travel, or seasonal use. *Standard Fire Prevention Code* means the Standard Fire Prevention Code of 1994, promulgated by the Southern Building Code Congress International, Inc., as incorporated and amended by section 50-6. *Start of construction* means other than new construction or substantial improvements performed under the Coastal Barrier Resources Act (PL 97-348), the date the building permit was issued for new construction or substantial improvements to an existing structure, provided the actual start of construction, repair, reconstruction, rehabilitation, addition, placement or other improvement was within 180 days of the permit date. *Structure* means a walled and roofed building, including a gas or liquid storage tank, that is principally above ground, or a manufactured home.	ADD PROVISIONS: *Natural state* means the topography that exists at the time information is gathered for flood insurance rate maps or any subsequent approved revisions to those maps. *Regulatory floodplain* is the land within the community subject to a one (1) percent or greater chance of flooding in any given year assuming all future development has occurred throughout the watershed. The regulatory floodplain is delineated on the currently effective FEMA Flood Insurance Rate Maps (FIRM Panels). NOTE: As the city's floodplain ordinance (this Appendix F of the Unified Development Code) is approved by FEMA as a condition of participation in the National Flood Insurance Program (NFIP), the city's regulatory floodplain is considered FEMA's future base flood. *Regulatory floodway* means the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. The floodway is congruent with the regulatory 1% annual chance floodplain in the City of Kerrville and its Extra Territorial Jurisdiction. *Repetitive loss* means flood-related damages sustained by a structure on two (2) separate occasions during a ten-year period for which the cost of repairs at the time of each such flood event, on the average, equals or exceeds twenty-five (25) percent of the market value of the structure before the damage occurred. *Riverine* means relating to, formed by, or resembling a river (including tributaries), stream, brook, etc. *Special flood hazard area* see Area of Special Flood Hazard.

ARTICLE	ORDINANCE	RECOMMENDATION
	Substantial damage means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred. *Substantial improvement* means any reconstruction, rehabilitation, addition, or other improvement of a structure, including structures which have incurred substantial damage regardless of the actual repair work performed, the cost of which alone or in combination with the cost of all other reconstruction, rehabilitation, or improvements performed on the structure within the five years prior to the start of construction equals or exceeds 50 percent of the market value of the structure either before the start of construction, or, in the case where the structure has received substantial damage, the market value before the damage occurred. The term "substantial improvement" does not include: (1) Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which haven't been identified by city officials and which are solely necessary to assure safe living conditions; or (2) Any alteration of a historic structure listed on the National Register of Historic Places or a state inventory of historic places. *Variance* means a grant of relief by the city from the provisions of this article in accordance with Section 60.6 of the National Flood Insurance Program regulations (44 CFR 60.6) when specific enforcement would result in unnecessary hardship, which relief would allow construction or development in a manner otherwise prohibited by this article. *Violation* means the failure of a structure or other development to be fully compliant with this article and other floodplain management regulations. A structure or other development without the elevation certificate, other certifications, or other evidence of compliance required in 44 CFR 60.3(b)(5), (c)(4), (c)(10), (d)(3), (e)(2), (e)(4), or (e)(5) is presumed to be in violation until such time as that documentation is provided. *Water surface elevation* means the height, in relation to the National Geodetic Vertical Datum (NGVD) of 1929 (or other datum, where specified), of floods of various magnitudes and frequencies in the floodplains of the Guadalupe River and its tributaries.	

33 General Provisions	(a) *Lands to which this article applies.* This article applies to all areas of special flood hazard within the incorporated limits of the city. (b) *Basis for establishing the areas of special flood hazard.* The areas of special flood hazard identified and defined in the following documents prepared by FEMA are hereby adopted by reference and incorporated as part of this article: (1) A scientific and engineering report entitled, *The Flood Insurance Study for Kerr County, Texas and Incorporated Areas* , effective March 3, 2011; (2) Flood Insurance Rate Map Nos. 48265C0455F, 48265C0460F, 48265C0480F, 48265C0470F, 48265C0490F, 48265C0635F, effective on March 3, [2011]. (c) *Compliance.* No structure or land shall hereafter be located, altered, or have its use changed without full compliance with this article and other applicable regulations. (d) *Abrogation and greater restrictions.* This article is not intended to repeal, abrogate, or impair any existing easements, covenants, or deed restrictions; however, to the extent that this article and other ordinances conflict or overlap, whichever imposes the more stringent restrictions shall prevail. (e) *Interpretation.* In the interpretation and application of this article, all provisions shall be: (1) Considered as minimum requirements; (2) Liberally construed in favor of the city in light of the purposes set forth in section 54-31; and (3) Deemed neither to limit nor repeal any other powers granted under state law. (f) *Warning and disclaimer of liability.* The degree of flood protection required by this article is considered reasonable for regulatory purposes and is based on scientific and engineering considerations. On rare occasions greater floods can and will occur and flood heights may be increased by manmade or natural causes. This article does not imply that land outside the areas of special flood hazards or uses permitted within such areas will be free from flooding or flood damages. This article shall not create liability on the part of the city or any official or employee thereof for any flood damages that result from reliance on this article or any administrative decision lawfully made under this article.	MODIFY PROVISION: (a) Lands to which this article applies. This article applies to all areas of special flood hazard within the incorporated limits of the city <u>and where applicable in its area of extraterritorial jurisdiction</u>. ADD PROVISION: (b)(3) {*Include latest FEMA Letter of Map Revisions*}

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34 Administration	(a) *Designation of the floodplain administrator.* The director of engineering or designee is hereby appointed the floodplain administrator to administer and implement the provisions of this article and other appropriate sections of Part 44 of the Code of Federal Regulations (National Flood Insurance Program Regulations) pertaining to floodplain management.	**MODIFY PROVISION:**
	(b) *Duties and responsibilities of the floodplain administrator.* Duties and responsibilities of the floodplain administrator shall include, but not be limited to, the following:	
	(1) Maintain and hold open for public inspection all records pertaining to the provisions of this article, including records related to floodplain development permits issued or denied pursuant to section 54-35;	
	(2) Review permit applications to determine whether proposed building sites will be reasonably safe from flooding;	
	(3) Review, approve or deny all applications for floodplain development permits required by this article;	
	(4) Review proposed development to assure that all necessary permits have been received from those governmental agencies from which approval is required by federal or state law, including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 USC 1334;	
	5) Where interpretation is needed as to the exact location of the boundaries of the areas of special flood hazards (for example, where there appears to be a conflict between a mapped boundary and actual field conditions) the floodplain administrator shall make the necessary interpretation;	
	(6) Notify, in riverine situations, adjacent communities and the state natural resource conservation commission, prior to any alteration or relocation of a watercourse, and submit evidence of such notification to the Federal Emergency Management Agency;	(6) Notify <u>(as applicable)</u> in riverine situations adjacent communities<u>, the Texas Water Development Board (TWDB) and the Texas Commission on Environmental Quality (TCEQ), prior to any alteration or relocation of a watercourse, and submit evidence of such notification to the Federal Emergency Management Agency;</u>
	(7) Assure that the flood carrying capacity within the altered or relocated portion of any watercourse is maintained;	
	(8) When base flood elevation data has not been provided in accordance with section 54-33(b), the floodplain administrator shall obtain, review and reasonably utilize any base flood elevation data and floodway data available from a federal, state or other source pending receipt of data from the FEMA administrator in order to administer the provisions of section 54-35; provided, however, the floodplain administrator may require that such information be provided by an applicant with respect to property which is the subject of a floodplain development permit application;	
	(9) If a regulatory floodway has not been designated for a particular waterway, the floodplain administrator must require that no new construction, substantial improvements, or other development (including fill) shall be permitted within zones A1-30 and AE on the city's FIRM,	

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unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the city;

(10) Maintain a record of all variance actions, including justification for their issuance, and report such variances to FEMA upon request or as otherwise required by law or regulation.

(c) *Floodplain development permits.* In order to ensure compliance with this article, a floodplain development permit is required for all development in the areas of special flood hazard, the issuance of which shall be in accordance with the following procedures:

(1) *Application.* An application for a floodplain development permit shall be made in writing, alone or in conjunction with the issuance of a building permit pursuant to chapter 26, article II, of this Code, on forms provided by the public works department and filed with the floodplain administrator, which application must contain at least the following information and documentation:

a. The name, address, and phone number of the applicant;

b. If different than the applicant, the name, address, and phone number of the record owner of the property according to the real property records of the county;

c. If the applicant and/or owner are not individuals, the name, address, and phone number of the person or people authorized to act on behalf of the applicant and/or owner in all matters relating to the application;

d. The complete lot and block or metes and bounds description of the property for which the application is made and, if available, the street address of the property;

e. If the applicant is not the owner of the property described in the application, a sworn statement from the owner or legal representative of the owner that the applicant has been authorized to make an application for a floodplain development permit with respect to the property;

f. A detailed description of the existing and/or proposed use of the property;

g. Plans, in duplicate, drawn to scale and sealed and signed by a licensed professional engineer or licensed professional surveyor showing:

1. The location, dimensions, and elevation of:
   i. Proposed landscape alterations;

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ii. Existing and proposed structures;
iii. Floodplain and floodway boundaries;
2. The location of the items listed in subsection (c)(1)g.1 of this section in relation to areas of special flood hazard;
3. Elevation (in relation to mean sea level) of the lowest floor (including basement) of all new and substantially improved structures; and
4. Elevation in relation to mean sea level to which any nonresidential structure shall be floodproofed;

h. If the development includes the placement of fill in the floodplain, a grading plan certified by a professional engineer predevelopment and post-development grades and elevations, which plan shows the location of the floodplain and/or floodway boundaries with dimensions and proposed structures;

i. A certificate from a registered professional engineer that any nonresidential floodproofed structure shall meet the floodproofing criteria of section 54-35(b)(2);

j. A description of the extent to which any watercourse or natural drainage will be altered or relocated as a result of proposed development;

k. The nonrefundable application fee established by the city council for floodplain development permit application.

(2) *Only completed applications considered.* No application for a floodplain development permit shall be deemed to be completed until all information and documentation set forth in subsection (c)(1) of this section have been delivered to the floodplain administrator and the required application fee paid. If upon review of a floodplain development permit application the floodplain administrator determines that the application is not complete, the floodplain administrator shall notify the applicant of that fact and indicate which information and/or documents are required in order for the application to be considered complete. The floodplain administrator shall have no duty to consider an incomplete application.

(3) *Review criteria of application.* Upon receipt of a completed floodplain development application, the floodplain administrator shall review the application based on all of the provisions of this article and the following relevant factors:

a. The danger to life and property due to flooding or erosion damage;

b. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the individual owner;

c. The danger that materials may be swept onto other lands to the injury of others;

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d. The compatibility of the proposed use with existing and anticipated development;

e. The safety of access to the property in times of flood for ordinary and emergency vehicles;

f. The costs of providing governmental services during and after flood conditions including maintenance and repair of streets and bridges, and public utilities and facilities such as sewer, gas, electrical and water systems;

g. The expected heights, velocity, duration, rate of rise and sediment transport of the floodwaters and the effects of wave action, if applicable, expected at the site;

h. The necessity to the facility of a waterfront location, where applicable;

i. The availability of alternative locations, not subject to flooding or erosion damage, for the proposed use;

j. The relationship of the proposed use to the comprehensive plan for that area.

(4) *Approval or denial of application.* Not later than 60 days after an application for a floodplain development permit is received and deemed complete by the floodplain administrator, the floodplain administrator shall grant or deny the issuance of a floodplain development permit based on the requirements of this article and the factors set forth in subsection (c)(3) of this section. If the floodplain administrator denies the issuance of a floodplain development permit, the floodplain administrator must provide to the applicant written notice of the denial setting forth in detail the basis for the denial.

(5) *Application which also requires variance.* Notwithstanding subsection (c)(4) of this section, if an applicant for a floodplain development permit is also requesting a variance to the provisions of this article with respect to the development of the same property, the floodplain administrator shall not be required to take action on the floodplain development permit application until 15 days following the city council decision regarding the application for the variance.

(6) *Appeal from decision of floodplain administrator.* The city council shall hear and decide appeals that allege an error in any requirement, decision, or interpretation made by the floodplain administrator in the interpretation or enforcement of this article with respect to the denial of a floodplain development permit, which appeal shall be in accordance with the following procedures:

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	a. *Who may appeal.* Any person aggrieved by the decision of the floodplain administrator may appeal the decision to the city council. b. *Form of appeal.* To be effective, the appeal must be made in writing and must contain at least the following: 1. A citation to the specific statute and/or ordinance which is the subject of the appeal; 2. The date on which the floodplain administrator rendered the denial which is the subject of the appeal to the appellant; 3. A copy of the denial notice prepared by the floodplain administrator which is the basis for the appeal; 4. The specific grounds upon which the appeal is based; 5. A description of the property affected by the floodplain administrator's decision sufficient to identify the location and the boundaries of the property; 6. The reason the person filing the appeal should be considered a person aggrieved by the decision; 7. The signature of the person filing the appeal; and 8. Eight copies of the site plan drawing submitted with the floodplain development permit application. c. *Perfection of appeal.* An appeal pursuant to this subsection (c)(6) shall be deemed timely filed and perfected only if the notice of appeal: 1. Is filed not later than 30 calendar days after the date on which the decision of the floodplain administrator was received by the appellant with; i. The city clerk; ii. The floodplain administrator; 2. Is accompanied by the filing fee established by the city council; and 3. Contains all the information set forth in subsection (c)(6)b of this section. d. *Preparation of record.* Upon receiving the notice of appeal, the floodplain administrator must immediately forward to the city clerk all of the papers constituting the record of the action that is appealed. e. *Date of public hearing.* Unless a later date is set upon written request of the appellant, the city council shall hold a public hearing on an appeal under this subsection (c)(6) not later than 30 days after the filing and perfection of the notice of appeal. f. *Decision of the city council.* After receiving all evidence and hearing all argument, the city council shall: 1. Affirm the decision of the floodplain administrator; or 2. Upon a finding that the floodplain administrator made an error in any requirement, decision, or determination in denying the application:	

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i. Reverse the decision of the floodplain administrator and issue the floodplain development permit; or

ii. Remand the matter application to the floodplain administrator for reconsideration with specific directions of matters to be reconsidered.

g. *Required vote.* The concurring vote of 75 percent of the membership of the city council is required to modify or reverse the decision or determination of the floodplain administrator.

(7) *Termination of permits.* A floodplain development permit shall terminate and become null and void if actual start of construction of the new construction or substantial improvements described in the application does not commence within six months after issuance of the permit.

(d) *Variances.* The city council may grant a variance to the regulations of this article in accordance with the following procedures:

(1) *Application.* An application for a variance shall be made in writing on forms provided by the public works department and filed with the floodplain administrator. An application for a variance shall be deemed complete when all information on the application form is provided and the application is accompanied by the following:

a. All fees established by the city council for such matters;

b. A description of the property to which the variance would apply sufficient to identify the location and the boundaries of the property;

c. The reason the person is requesting the variance;

d. The signature, acknowledged by a notary public of:

1. The owner of the property; and
2. If different than the owner, the signature of the person requesting the variance; and

e. Eight copies of a site plan drawn to scale showing existing and proposed development of the property in question.

(2) *When application to be considered.* Upon filing of an application for a variance, the floodplain administrator shall request the city manager place the application for request for variance on the next regular city council agenda following 20 days after the filing of a completed application for variance with the floodplain administrator. An application for variance shall not be deemed complete unless and until all items and fees required by subsection (d)(1) of this section have been delivered.

(3) *Grounds applicable to grant of any variance.* Except as authorized by subsection (d)(8) of this section, no variance shall be granted by the city council until it makes the following findings:

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	a. Considering the flood hazard, the requested variance is the minimum necessary to afford relief; b. The applicant has shown good and sufficient cause for the granting of the variance; c. Failure to grant the variance would result in exceptional hardship to the applicant; and d. Granting of a variance will not result in: 1. Increased flood heights; 2. Additional threats to public safety, 3. Extraordinary public expense; 4. The creation of nuisances; 5. Causing a fraud on or victimization of the public; or 6. A conflict with other existing local laws or ordinances. (4) *Form of variance granted.* Upon consideration of the factors noted in subsection (d)(3) of this section, and the purpose of this article as set forth in section 54-31(a), the city council may grant or deny a request for a variance. If granted, all variances shall be approved by ordinance of the city council. In adopting an ordinance granting a variance, the city council may include such conditions to the grant as it deems necessary to further the purpose and objectives of this article. (5) *Variances issued for certain new construction or substantial improvements.* Variances may be issued for new construction and substantial improvements to be erected on a lot of one-half acre or less in size contiguous to and surrounded by lots with existing structures constructed below the base flood level, providing the relevant factors in subsection (c)(3) of this section have been fully considered. As the lot size increases beyond the one-half acre, the technical justification required for issuing the variance increases. (6) *Variances for functionally dependent use.* Variances may be issued by the city council for new construction and substantial improvements and for other development necessary for the conduct of a functionally dependent use provided that: a. The city council makes the findings required by subsection (d)(3) of this section; and b. The structure or other development is protected by methods that minimize flood damages during the base flood and create no additional threats to public safety. (7) *Variances in floodway generally prohibited.* Notwithstanding anything to the contrary in this section, variances shall not be issued within any designated floodway if any increase in flood levels during the base flood discharge would result.	

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	(8) *Exception for variances regarding historic places.* Variances may be issued for the repair or rehabilitation of structures listed on the National Register of Historic Places or the state inventory of historic places, without regard to the procedures set forth in this article, provided: a. The proposed repair or rehabilitation will not preclude the structure's continued designation as a historic structure; and b. The variance is the minimum necessary to preserve the historic character and design of the structure. (9) *Notice issued with grant of variance.* Any applicant to whom a variance is granted shall be given written notice by the floodplain administrator that: a. The issuance of a variance to construct a structure below the base flood elevation will result in increased premium rates for flood insurance up to amounts as high as $25.00 for each $100.00 of insurance coverage; and b. Such construction below the base flood elevation increases risks to life and property. Such notice shall be maintained with the record of all variances granted by the city council. (e) *False information or statements.* It shall be unlawful for a person to intentionally, knowingly, or recklessly make a false statement or provide false information in an application for a floodplain development permit or a variance from this article.	
35 Provisions for flood hazard reduction.	(a) *General standards.* In all areas of special flood hazards, the following provisions are required for all new construction and substantial improvements: (1) *Anchoring.* All new construction or substantial improvements shall be designed (or modified) and adequately anchored to prevent flotation, collapse or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy. (2) *Methods and practices of construction.* All new construction or substantial improvements shall be constructed by methods and practices that minimize flood damage. (3) *Use of flood resistant materials.* All new construction or substantial improvements shall be constructed with materials resistant to flood damage. (4) *Floodproofing of mechanical systems.* All new construction or substantial improvements shall be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.	**MODIFY PROVISION:** (1) *Anchoring.* All new construction or substantial improvements shall be designed (or modified) and adequately anchored to prevent flotation, collapse or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy (see U.S. Corps of Engineers Flood Proofing Regulations). (2) Methods and practices of construction. All new construction or substantial improvements shall be constructed by methods and practices that minimize flood damage (see U.S. Corps of Engineers Flood Proofing Regulations).

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	(5) *Water supply systems.* All new and replacement water supply systems shall be designed to minimize or eliminate infiltration of floodwaters into the system. (6) *Sanitary sewer systems.* New and replacement sanitary sewage systems shall be designed to minimize or eliminate infiltration of floodwaters into the system and discharge from the systems into floodwaters. (7) *On-site waste disposal systems.* Installation of on-site waste disposal systems shall be prohibited within areas of special flood hazard. (b) *Specific standards.* In all areas of the floodplain where base flood elevation data has been provided as set forth in sections 54-33(b), 54-34(b)(8) or subsection (c)(4) of this section, the following additional construction standards apply to new construction or substantial improvements within the floodplain: (1) *Residential construction.* New construction and substantial improvement of any residential structure must be constructed with the lowest floor (including basement) elevated to at least one foot above the base flood elevation. In addition to such other requirements as may be set forth in chapter 26, article II, of this Code, construction of a residential structure to which this subsection (b) applies shall not proceed beyond completion of the finished slab until a registered public land surveyor has certified on a form approved by and filed with the floodplain administrator that the lowest floor (including basement) is in fact elevated to or above the base flood elevation for the property. (2) *Nonresidential construction.* New construction and substantial improvements of any commercial, industrial or other nonresidential structure shall either: a. Have the lowest floor (including basement) elevated to at least one foot above the base flood elevation; or b. Be designed so that the portion of the structure below the base flood elevation, together with attendant utility and sanitary sewer facilities, is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy. A registered professional engineer shall develop and/or review structural design, specifications, and plans for the construction, and shall certify to the floodplain administrator that the design and methods of construction are in accordance with accepted standards of practice as outlined in this subsection. A record of such certification, which includes the specific elevation in relation to mean sea level to which such structures are floodproofed, shall be provided to and maintained by the floodplain administrator on forms prescribed by the floodplain administrator.	(1) *Residential construction.* New construction and substantial improvement of any residential structure must be constructed with the lowest floor (including basement) elevated to at least <u>two feet</u> above the base flood elevation and <u>two feet above the adjacent street or curb</u>. In addition to such other requirements as may be set forth in chapter 26, article II, of this Code, construction of a residential structure to which this subsection (b) applies shall not proceed beyond completion of the finished slab until a registered public land surveyor has certified on a form approved by and filed with the floodplain administrator that the lowest floor (including basement) is in fact elevated to or above the base flood elevation for the property. *{NOAA Atlas 14: New precipitation data is anticipated to impact the regulatory floodplain. Until the floodplain maps are restudied and remapped, the City of Kerrville should require new developments to be 2 feet above the existing and ultimate conditions base flood elevation.}*

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	(3) *Enclosures.* New construction and substantial improvements, with fully enclosed areas below the lowest floor that are usable solely for the parking of vehicles, building access, or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement shall be certified by either a registered professional engineer or architect or meet or exceed the following minimum criteria: a. A minimum of two openings on separate walls having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. b. The bottom of all openings shall be no higher than one foot above grade. c. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters. (4) *Manufactured homes located in zone A.* All manufactured homes to be placed within zone A on the city's FIRM shall be installed in accordance with the following regulations: a. Generally, the manufactured home must be installed using methods and practices which minimize flood damage; b. The manufactured home must be elevated to resist flotation, collapse, or lateral movement, which elevation must, as a minimum, be in accordance with section 54-35(b)(1); c. In addition to applicable state and local anchoring requirements for resisting wind forces, the manufactured home must be anchored using methods which resist flotation, collapse, or lateral movement, including, but not limited to, use of over-the-top or frame ties to ground anchors. (5) *Manufactured homes located in zones A1-30, AE or AH.* All manufactured homes to be placed or substantially improved within zones A1-30, AH, or AE on the city's FIRM must be constructed in accordance with the following regulations: a. The manufactured home must be elevated on a permanent foundation such that the lowest floor of the manufactured home is at or above the base flood elevation and otherwise securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement if the manufactured home is located: 1. Outside of a manufactured home park; 2. In a new manufactured home park or subdivision; 3. In an expansion to a new manufactured home park or subdivision; or	**MODIFY PROVISION:** (5) *Manufactured homes located in zones A1-30, aE, or AH.* a. The manufactured home must be elevated on a permanent foundation such that the lowest floor of the manufactured home is <u>two feet above</u> the base flood elevation and otherwise securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement if the manufactured home is located: OR a. <u>Construction/Installation of manufactured homes within the regulatory floodlain (base flood) is not allowed.</u>

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	4. In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as a result of a flood. b. If the manufactured homes are being placed or substantially improved on sites within an existing manufactured home park or subdivision and are not otherwise subject to the provisions of subsection (b)(5)a of this section, the manufactured home must be elevated so that either:	**MODIFY PROVISION:**
	1. The lowest floor of the manufactured home is at or above the base flood elevation; or	1. The lowest floor of the manufactured home is two feet above the base flood elevation; or
	2. The manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement.	**ADD PROVISION:** (7) *Recreational Vehicles*. Require that recreational vehicles placed on sites within Zones A1-30, AH, and AE on the community's FIRM either (i) be on the site for fewer than one hundred eighty (180) consecutive days, or (ii) be fully licensed and ready for highway use, or (iii) meet the permit requirements of Article 4, Section C(1), and the elevation and anchoring requirements for "manufactured homes" in paragraph (4) of this section. A recreational vehicle is ready for highway use if it is on its wheels or jacking system, is attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.
	(6) *Compliance with zoning code.* To the extent of any conflict between the development standards for manufactured housing set forth in this article and the development standards set forth in title 11, chapter I, of the former Code of Ordinances: a. The most restrictive standards shall apply; and b. Whenever title 11, chapter I of the former Code of Ordinances requires that a manufactured home be attached to the real property by a permanent foundation, such requirement shall apply, notwithstanding a lesser anchoring regulation allowed by this article.	
	(c) *Standards for placement of fill in floodplain.* The placement of fill in the floodplain pursuant to a floodplain development permit shall be in accordance with the following minimum specifications: (1) The fill must be placed in a manner to obtain a minimum of 90 percent of the maximum soil compaction as determined by the standard proctor test in order to reduce settlement. (2) Fill material must be soil or rock, and must be free of wood or construction debris. (3) Fill material shall not contain organic material which may result in decomposition and settlement. (4) Side slopes which are not stabilized in accordance with standard engineering practices shall not exceed a grade of three feet horizontal to one foot vertical. (5) No portion of the fill material shall be placed in the regulatory floodway.	

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	(6) Provisions must be made to prevent fill from eroding or moving laterally into the regulatory floodway. (d) *Standards for proposed subdivisions.* In addition to the regulations set forth in chapter IV of title 10 of the former Code of Ordinances regarding the subdivision of land within the city, the following regulations shall apply to the subdivision of land which is regulated by this article: (1) *Consideration of purposes of this article.* In addition to the intent and purposes set forth in Article 10-IV-1(A) of the former Code of Ordinances, the approval by the planning and zoning commission of a plat for the subdivision of land (including, but not limited to, a manufactured home subdivision), and, as required by Article 11-I-10(d)(3) of the former Code of Ordinances, the approval of a development site plan for a manufactured home rental community by the city council shall be consistent with section 54-31 if part of the land being subdivided and/or developed is located within a special flood hazard zone. (2) *Location of floodplain and floodway.* No preliminary plat and/or final plat indicating a proposed subdivision of property which is in whole or in part located within a floodplain and/or floodway may be approved in accordance with title 10, chapter IV of the former Code of Ordinances until the preliminary plat and/or final plat drawing contains: a. The horizontal location of the floodplain with sufficient detail to determine the area of the proposed subdivision, including, but not limited to, any proposed lot, which is located in whole or in part within the floodplain; and b. The horizontal location of the floodway with sufficient dimensions to locate the floodway on all platted lots. (3) *Base flood elevation indicated on plat.* In addition to the requirements set forth in chapter IV of title 10 of the former Code of Ordinances, before the planning and zoning commission may approve a final plat of property, all or part of which is located in a special flood hazard zone, the base flood elevation for each lot of the proposed subdivision or each manufactured home site located in a manufactured home rental community which is located in a special flood hazard zone must be determined and indicated on the final plat or development site plan, whichever is required. If the BFE for the property has not been established in accordance with section 54-33(b), the owner or developer of the proposed subdivision or manufactured home rental community shall generate sufficient data for the floodplain administrator to determine the BFE for such property in accordance with section 54-34(b)(8). (4) *Drainage requirements.* All proposed subdivisions and manufactured home rental communities shall have adequate drainage provided to reduce exposure to flood hazards.	ADD PROVISION: (7) Filling or the disposal of any materials which will diminish the water flow capacity of any waterway or floodplain defined by this ordinance must be compensated with remedial action. An equal amount of storage volume must be created in another location of the same SFHA to compensate for the storage capacity lost. {See Allowable Development Within the Regulatory Floodplain section below} (8) All proposed subdivisions must be contiguous to high ground that is not subject to flooding (the base flood, ultimate development 100-year or the twenty-five-year ultimate development flood, whichever is higher) that is in excess of one (1) foot flow depth, i.e., no "island" will be considered for platting; unless adequate connecting structures capable of passing the base flood, ultimate development 100-year or twenty-five-year ultimate development flood (whichever is higher) are provided to high ground (not subject to the controlling flood of the same floodplain), and an additional one (1) foot of free board is provided to all minimum floor slab elevations. (9) All proposed subdivisions traversed by an area of special flood hazard where the "buildable" portion of the subdivision is severed by the floodplain shall be provided with adequate access. Adequate access shall be a structure that will pass the control flood (ultimate development 100-year) without overtopping the structure. Upstream property must not be affected by backwater, and velocities in the vicinity of the structure must be controlled to prevent scour, erosion or structural damage. Proposed subdivisions that involve the platting of streets shall have at least one (1) access to an unflooded portion of existing dedicated street or roadway.

ARTICLE	ORDINANCE	RECOMMENDATION
	(5) *Location of public utilities.* All proposed subdivisions and manufactured home rental communities must locate all public utilities and facilities such as sanitary sewer, natural gas, electrical and water systems in such a manner as to minimize or eliminate flood damage. (e) *Standards for areas in the 100-year floodplain with no base flood elevation determined (zone A).* No building permit shall be issued for construction of property located within a special flood hazard zone until the proper detailed methods have been applied by a professional engineer to determine the BFE for the property and a letter of map revision or letter of map amendment has been obtained from FEMA. (f) *Floodways.* Encroachment into a regulatory floodway with fill, new construction, substantial improvements or other development is prohibited unless: (1) A registered professional engineer, based on a competent engineering study certified by the engineer, demonstrates through hydrologic and hydraulic analysis performed in accordance with standard engineering practice to the satisfaction of the floodplain administrator that the proposed encroachment will not result in any increase in flood levels within the city during the occurrence of the base flood discharge; or (2) The city or the person wishing to place the encroachment in the floodway has applied for a conditional FIRM and floodway revision from FEMA and has received consent from FEMA to allow encroachments within the floodway. If an encroachment into a regulatory floodway is permitted in accordance with subsection (f)(1) of this section, the new construction or substantial improvements placed within the floodway shall comply with all applicable flood hazard reduction provisions of this article.	(10) Proposed subdivisions that do not involve the platting of streets shall have access to an existing dedicated street that is not subject to flood depths of over one (1) foot. (11) Existing channels shall not be increased or decreased from their natural state until engineering data meeting the requirements of section 54-XX, Stormwater Management, has been approved by the city engineer. Floodplain engineering and procedures requirements for subdivision within FEMA or United States Corps of Engineers official flood prone areas shall conform to the engineering criteria as set out in section 54-XX, Stormwater Management.
36 Nuisances within a special flood hazard area	(a) *Certain nuisances defined.* Notwithstanding anything to the contrary set forth in this Code, the following activities occurring within a special flood hazard area constitute a danger to the health, safety, and welfare of the residents of the city, are hereby defined as public nuisances, and are prohibited within any special flood hazard area: (1) The manufacture, processing, blending, mixing, refining, or distribution of the following products as defined in the Standard Fire Prevention Code: a. Explosives; b. Blasting agents; c. Flammable or combustible gases, solids or liquids, hazardous chemicals, liquified petroleum gases, and petroleum products such as gasoline and diesel; and d. Road construction materials containing petroleum products;	

ARTICLE	ORDINANCE	RECOMMENDATION
	(2) Storage of the products listed in subsection (a)(1) of this section; except that the indoor storage of incidental cleaning products, or the retail sale of packaged products off-the-shelf at normal retail sales outlets, is allowed; (3) The construction and operation of on-site sewage disposal systems. (b) *Defense; prior use of property.* It shall be a defense to prosecution pursuant to subsection (a) of this section if: (1) Property located within a special flood hazard zone was being used for a purpose defined as a nuisance in subsection (a) of this section, before January 26, 1996, has been continuously used for such purpose thereafter, and such use was: a. A permitted use pursuant to the city Code as January 26, 1996; or b. Constituted a lawful nonconforming use under the city's zoning code on January 26, 1996; and (2) Property which becomes located within a special flood hazard area as the result of an amendment to the city's FIRM was being used for a purpose defined as a nuisance in subsection (a) of this section, before the effective date of the amended FIRM, has been continuously used for such purpose thereafter, and such use was: a. A permitted use pursuant to the city's zoning code as of the effective date of the FIRM; or b. Constituted a lawful nonconforming use under the city's zoning code on the effective date of the FIRM.	
37 Penalties	(a) *Criminal penalties.* The penalty for violation of this article shall be in accordance with the general penalty provisions contained in section 1-7. (b) *Civil remedies.* In addition to any other criminal or civil remedies that may be available to the city, the city may seek and obtain an injunction against the owner or owner's representative with control over the property in accordance with V.T.C.A., Local Government Code ch. 54.	

CHAPTER 118 WATERWAYS

ARTICLE	ORDINANCE	RECOMMENDATION
I	**IN GENERAL**	
II	**CITY WATER IMPOUNDMENT REGULATIONS**	
31 Scope	This article shall apply to: (1) The waters of the Guadalupe River impounded behind the city impoundment dam and for a distance of 1.8 miles upstream of the dam; and (2) The lands and easements owned by the city adjacent to and beneath the waters impounded by the dam.	
32 Definitions	The following words, terms and phrases, when used in this article, shall have the meanings ascribed to them in this section, except where the context clearly indicates a different meaning: *City impoundment dam* and *dam* mean the dam constructed within the Guadalupe River and located adjacent to the west line of the Walter Fosgate Survey No. 138, Kerr County, Texas, the centerline of such dam being south 40° east 2470 feet, more of less, from the southwest corner of such survey, within the incorporated limits of the city. *Habitable structure* means a structure designed primarily for human occupancy and are potential locations for shelter from storms. Typically included within this category are residences, hotels and restaurants. Additionally, a habitable structure includes improvements, attached or otherwise, including but not limited to porches and gazebos, and excludes sidewalks, swimming pools, and other surface level improvements. *Impounded waters* means the waters of the Guadalupe River impounded by the city behind the dam pursuant to the authority of TCEQ up to the level of 1622 feet above mean sea level. *Jugline* means a free-floating main fishing line tied to a free-floating device. *Lake* means that body of water impounded behind the dam for a distance of 1.8 miles upstream of the centerline of the dam. *Lakebed* means those lands outside of the main Guadalupe River channel covered by the impounded waters when the water elevation at the dam is 1622 feet above mean sea level. *TCEO* means the Texas Commission on Environmental Quality or its successor agency. *Throwline* means a main fishing line with one end attached to a fixed anchor. *Trotline* means a main fishing line with both ends free-floating and anchored in any manner.	**MODIFY PROVISION:** *City impoundment dam definition* - {Reference dam by name and National Inventory Dam identification number} *Habitable Structure* – Refer to Section 54 32- Definitions Habitable Structures *TCEQ* means the Texas Commission on Environmental Quality or its successor agency.

Water treatment plant means the water treatment plant owned by the city and located on the south shore of the Guadalupe River adjacent to the dam.

Watercraft means any vessel, other than a seaplane, used or capable of being used for transportation on water regardless of the means of propulsion.

33 Prohibited Activities.

No person shall:

(1) Operate an internal combustion engine of a watercraft on the lake;

(2) Construct or maintain a dock, wharf, or habitable structure fixed into, resting upon, or located over the lakebed or fixed into, resting upon, or located over any other property owned by the city;

(3) Construct or maintain a dock, wharf, or habitable structure fixed into, resting upon, or located over any flood easement owned by the city that is upstream of the dam;

(4) Place, operate, or maintain a houseboat on the lake;

(5) Place, use, or maintain a trotline, throwline, or jugline at any location within the lake; or

(6) Swim, fish, or operate a watercraft within a distance of 200 feet from the raw water intake of the water treatment plant.

34 Defenses.

It shall be a defense to section 118-33(1) if the person who is operating a watercraft equipped with an internal combustion engine is engaged in:

(1) A law enforcement activity;

(2) An effort to prevent the personal injury or death of a person in eminent danger of injury or death;

(3) Operation, maintenance, and/or monitoring of the water treatment plant, dam, or impoundment and the person is an employee, agent, or contractor of the city; or

(4) Is engaged in an activity that has been authorized by resolution of the city council.

35 Penalties

Conviction of a violation of this article shall constitute a misdemeanor punishable in accordance section 1-8.

RECOMMENDED SECTIONS FOR ADDITION TO SECTION 54

38 Enforcement

ADD PROVISIONS FOR ENFORCEMENT:

No structure or land shall hereafter be constructed, located, extended, converted, or altered without full compliance with the terms of this ordinance and other applicable regulations. Violation of the provisions of this court order by failure to comply with any of its requirements (including violations of conditions and safeguards established in connection with conditions) shall constitute a misdemeanor. Any person who violates this court order or fails to comply with any of its requirements shall upon conviction thereof be fined not more than five hundred dollars ($500.00) for each violation, and in addition shall pay all costs and expenses involved in the case. Nothing herein contained shall prevent City of Kerrville from taking such other lawful action as is necessary to prevent or remedy any violation.

(a) Notice of Violation
(b) Remediation
(c) Options
(d) Reporting Violations, Other Remedies

39 Allowable Development Within the Regulatory Floodplain.

ADD PROVISIONS FOR DEFINING ALLOWABLE DEVELOPMENT WITHIN THE REGULATORY FLOODPLAIN

This ordinance shall only apply to areas of special flood hazard within the jurisdiction of the city and where applicable in its area of extraterritorial jurisdiction.

(a) Reserved.

(b) Reserved.

(c) An increase in water surface elevation is permitted solely when all the following conditions are met:

1. Property owner owns both sides of the floodplain.
2. The increase in the regulatory floodplain is contained in a dedicated drainage easement or right-of-way as required per subsection XXX.
3. Increase in water surface elevation for the 1% annual chance floodplain does not exceed six (6) inches.
4. No increase in water surface elevations or velocities upstream and downstream outside of the owner's property limits.

(d) Account for increase in discharge due to loss of storage in all reclamation analyses.

(e) Demonstrate that the development will not increase the regulatory 1% annual chance floodplain velocities above six (6) fps. No increase in velocity will be permitted if predevelopment velocities in the floodplain exceed six (6) fps unless proven that the existing channel/creek is stable (i.e., rocky bottom channel/creek) and no signs of erosion or scour are occurring in predevelopment conditions.

(f) The following development may be allowed in the regulatory 1% annual chance and will require a floodplain development permit (see section 54 34-C for permit requirements):

(1) All-weather street crossings that meet the requirements of subsection XX-XX.

(2) Utility construction.

(3) Parks.

(4) Greenways.

(5) Recreational facilities and golf courses.

(6) Hike and bike trails.

(7) Drainage improvements that mitigate existing or anticipated flood hazards.

(8) Publicly funded capital improvement projects that reduce flooding to protect the public safety.

(9) Maintenance activities necessary to maintain the stormwater conveyance of the floodplain.

(10) Drainage infrastructure repair.

(11) Floodplain restoration.

(12) Wetland reestablishment, mitigation, or environmentally friendly design criteria (i.e. Natural channel design, Low-Impact Development, etc., set forth by the City of Kerrville, Upper Guadalupe Blanco River Authority and/or U.S. Army Corps of Engineers).

(13) Habitat re-establishment.

(14) Installation of flood monitoring controls - rain gages, early flood warning systems, high water detection systems, etc.

(15) Installations of emergency devices necessary to warn alarm and protect citizens at flood hazards.

(16) Improvements to a structure that do not fall under the definition of substantial improvement.

(17) Elevating and/or floodproofing structures in the floodplain.

(18) 1% annual chance floodplain reclamation where the watershed drainage area is less than three hundred twenty (320) acres when the floodplain storage volume lost due to fill is offset by comparable excavation within the same floodplain (see subsections 54-39(d) and 54-39(f)(27). In addition, all federal, state, or local permits shall be obtained, including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. 1334 (see subsections 54-XX).

(19) Parking lot construction where water depths do not exceed six (6) inches during a future 1% annual chance storm event.

(20) 1% annual chance floodplain reclamation in areas of ineffective flow where floodplain storage volume lost to reclamation is offset by comparable excavation within the same creek floodplain. (See subsections 54-39(d) and 54-39(f)(27).)

(21) 1% annual chance floodplain reclamation in overbank areas subject to extensive shallow (0'—3') flooding where velocities in the overbank area are less than three (3) fps and where floodplain storage volume lost to reclamation is offset by comparable excavation within the same creek floodplain (see subsections 54-39(d) and 54-39(f)(27).) Where a maximum amount of fill allowed in the overbank areas is no more than three (3) feet with engineered slope stability calculations.

(22) Historic structure reconstruction, rehabilitation or restoration.

(23) Development in the low risk flood area, as defined by appendix A or subject to the requirements of section 54-XX.

(24) Reclamation between the 1% annual chance floodplain and the regulatory 1% annual chance floodplain.

(25) Reserved.

(26) Nonresidential construction. The following restrictions will be placed on nonresidential construction in the floodplain:

A. Demonstrate that no alternative sites are available for development within the property that is out of the floodplain.
B. Meet all the requirements of subsection 54-39(b), Nonresidential construction.
C. Ensure the lowest finished floor elevation and/or the height to which the building must be floodproofed is no lower than the higher elevation of the energy grade line or the water surface elevation plus one (1) foot of the regulatory 1% annual chance floodplain.
D. An increase in water surface elevation may be permitted on the developer's property if the floodplain is contained in a dedicated drainage easement or right-of-way. If all the requirements of 54-39(c) are met.
E. Reserved.

F. Demonstrate that the development will not increase the 1% annual chance floodplain post-development velocities above six (6) fps. No increase in velocity will be permitted if predevelopment velocities exceed six (6) fps.
G. Demonstrate that the development will not be subject to damage from hydrostatic or hydrodynamic forces, debris impact, soaking, sediments and contaminants.
H. Provide, operate and maintain an early flood warning system for the development. Warning systems will be subject to periodic inspection by the City of Kerrville to ensure they are maintained and operated as intended as per floodplain administrator's direction.
I. Complete the Letter of Map Revision process for the development.
J. The owner shall indemnify the City of Kerrville against damages resulting from flooding on the owner's site.
K. Other site-specific restrictions and/or requirements deemed appropriate by the floodplain administrator.

(27) Construction in areas of flood inundation must meet the requirements of section 54-XX, General Standards. Structures associated with park and recreation development (fences, open construction type bleachers, concession stands etc.) may be permitted in areas of flood inundation. Keep this construction out of the flood conveyance section of the floodplain. Compensate for loss of storage. Secure structures to minimize damage from hydrostatic or hydrodynamic forces (including buoyancy) and debris impact.

40 Prohibited Development Within the Regulatory Floodplain.

ADD PROVISION FOR PROHIBITED DEVELOPMENT WITHIN THE REGULATORY FLOODPLAIN.

(a) The following development will not be allowed in the regulatory floodplain:

(1) Development without first obtaining a floodplain development permit.

(2) Habitable structures.

(3) Street or access construction that does not meet the requirements of subsection XX.

(4) Activity prohibited by Chapter XX, Article XX of the City Code "Aquifer Recharge Zone and Watershed Protection."

(5) 1% annual chance floodplain reclamation where the watershed drainage area exceeds three hundred twenty (320) acres except as provided in section A.

(6) 1% annual chance floodplain reclamation in over bank areas that are subject to flood depths greater than three (3) feet.

(7) 1% annual chance floodplain reclamation in over bank areas where flood velocities are greater than three (3) fps.

(8) No development will be permitted that has a significant adverse impact to other properties - refer to subsection XX-XX.

ART. 10-IV-1 PROCEDURE FOR PLAT APPROVAL

SECTION (B) PLATS		RECOMMENDATION
2. d.	(4) Storm drainage facilities as currently required by this or other applicable ordinances, and; (5) Easements or rights-of-way as may be currently required by this or other applicable ordinance for the installation of any of the above stated improvements;	No change.

ART. 10-IV-2 PROCEDURE FOR PLAT APPROVAL

SECTION (A) PRELIMINARY PLAT		RECOMMENDATION
1.	General The applicant shall present to City staff a concept plan prior to the submission of the preliminary plat. The staff shall present the concept plan to the Commission for review and comment. The objective of the concept plan presentation is a clarify city regulations and the comprehensive plan-land use strategy guidelines, as they apply to the parcel of land in question and its proposed subdivision. The concept plan shall include the following information: a. The property's legal description, zoning, and location identifying the site in relation to natural water courses, public rights-of-way, and significant landmarks which are located within five hundred feet (500.0') of the boundary of the proposed subdivision; b. Proposed uses, lot layouts, and general land features, to include significant trees or tree stands, major grade changes, flood plains, ridge lines, and drainage courses; c. Existing and proposed utilities, streets and drainage facilities or courses. When the proposed subdivision constitutes a unit of a large tract owned by the developer or in which the developer has interest, the Commission may require that the concept plan identify and include the entire area which is intended to be subsequently subdivided. The presentation, including portions of the larger tract, shall be required to include, at a minimum, the same information as required for the concept plan, except that individual lots need not be shown so long as the anticipated land uses and development density is presented. The latter shall be used to determine compatibility with zoning, street layout, and utility and drainage facility capacities. The preliminary plat as approved will be the basis for the preparation of construction plans for improvements. The preliminary plat may be given final approval in phases, but if so, each phase given final approval shall conform to the approved preliminary plat.	No change.

	RECOMMENDATION
3. **Form and Content** a. Natural Features (1) The location of existing water courses, dry creek beds, caves, springs, wells, sinkholes and other similar drainage features including existing drainage structures; (2) The limit of the "100-year" flood hazard area boundary and the floodway, as determined by the most current map published by the Federal Emergency Management Agency (FEMA). If neither encroaches upon the subject property, a note to that effect must be placed upon the drawing. (3) Topographic data drawn according to "The Manual of Practice for Land Surveying in the Sate of Texas," Category 6, except that where each tract or lot created is equal to or greater than 25 acres in size, data compiled from United States Geologic Survey (USGS) map or an aerial photograph may be substituted. Contour intervals shall be: (a) Where the slope is less than five percent ; 2 feet. (b) Where the slope is five percent or greater but less than ten percent; 5 feet. (c) Where the slope is ten percent or greater but less than fifteen percent; 10 feet. (d) Where the slope is fifteen percent or greater; 20 feet The contoured area shall extend outward in all directions along the entire length of the subdivision boundary line for a distance equal to 25% of the distance across the tract, but not less than 50 feet nor more than 200 feet in any one direction; provided, however, in the event the developer, his contractors or agents, are unable to gain access to property adjacent to the proposed subdivision for the purpose of obtaining the above-required topographical data as the result of an inability to obtain the consent of the property owner or a the likelihood of injury to persons or property who might go on to such adjacent property, the inability to obtain such data, and the reason for such inability shall be certified to in writing by the developer and delivered to the Planning Director. The Planning Director or his designee shall provide reasonable assistance to the developer in gaining access to the adjacent property; provided however, such assistance shall not require the City to obtain any easements or commit the expenditures of any City funds. If access to the adjacent property cannot be obtained with ten (10) working days after receipt by the Planning Director of the certified statement, the requirement to extend the contoured area beyond the perimeter of the proposed subdivision shall be waived.	No change.

RECOMMENDATION

SECTION (B) FINAL PLAT

3. **A. Natural Features**

(1) The location of center lines of all waterways intended to convey water from or to adjacent private land owners;

(2) The boundaries of all drainage easements and the one hundred (100) year flood plain and designated flood way. If the subdivision or a portion thereof is in a flood-prone area, the developer will be required to comply with provisions of the City's floodplain management ordinances. This information must be certified by a Registered Professional Engineer with the following statement:

> *"The fully developed, concentrated storm water runoff resulting from the one hundred (100) year frequency storm is contained within the drainage easements shown and/or public rights-of-way dedicated by this plat"*

On each buildable lot in said flood plain the required base flood elevation (BFE) shall be indicated. Vertical bench marks tied to USGS Vertical datum of 1929 or the City of Kerrville's Coordinate System, shall be shown on the plat with a maximum horizontal separation of 1,000 feet between benchmarks.

5. <u>Minor Subdivision Approval</u>

(5) all water, sanitary sewer, and drainage facilities that are otherwise required to be constructed pursuant to this chapter are already in place and meet the regulations then in effect for construction of such improvements; however, the subdivision may be considered and approved as a minor subdivision if no storm water drainage study has been submitted or the required storm drainage facilities constructed, provided the plat contains the following note:

> *A drainage study conforming to the applicable drainage specifications shall be submitted to, and approved by, the city engineer before a building permit is issued for any lot in the subdivision. Drainage improvements which adequately address the findings of the study shall be made part of the building permit application, and shall be constructed concurrently with the development of the site.*

ART. 10-IV-3 MINIMUM DESIGN STANDARDS

		RECOMMENDATION
SECTION (C)	PARKS, OPEN SPACES, PUBLIC EASEMENTS AND PRESERVATION OF NATURAL FEATURES	

1. Parkland Dedication All subdivision plat which are to be approved by the Planning and Zoning Commission shall note the method of Parkland Dedication, which has been chosen by the developer and approved by the City as provided in Ordinance No. 91-10.
2. Easements for Public Utilities The City Planning Commission may require easements for poles, wires, conduits, storm and sanitary sewers, gas, water or other utility lines, along any necessary lot lines. Easements shall be a minimum of fourteen (14) feet in width. Easements of the same or greater width may be required along the lines of or across lots, where necessary for the extension of existing or planned utilities.
3. Preservation of Natural Features Natural features such as large trees, water courses, historic spots, and similar community assets which, if preserved, will add attractiveness and value to the property. Nature features shall be identified on a site plan prior to plat approval. If considered to be of significant value to the property, or the neighborhood, or the community, the Commission may require the preservation of some or all of these natural features.

SECTION (D) DEVELOPMENT OF SENSITIVE LANDS: FLOOD HAZARDS

Land subject to flooding as identified in the Federal Insurance Administration's report entitled "The Flood Insurance Study for the City of Kerrville, dated January 19, 1982, with accompanying flood hazard maps shall serve as the basis for identifying those lands susceptible to flood conditions. The developer and/or his agent at the pre-application conference stage of preparing the preliminary plat shall establish floodway elevations. Lands that are to be platted for development which are susceptible to flooding shall be in accordance with current city code requirements in which finished flood elevations shall be established a minimum of one (1) foot above the established flood criteria and/or in accordance with alternatives identified by the Federal Insurance Administration.

The City Planning Commission shall not approve the subdivision of land if from adequate investigations conducted by all public agencies concerned, it has been determined that in the best interest of the public, the site is not suitable for platting and development purposes of the kind proposed.

ART. 10-IV-4 DEVELOPMENT PROCEDURES

	RECOMMENDATION
SECTION (A) MINIMUM DEVELOPMENT IMPROVEMENTS	
1. General	
h. Drainage Facilities Drainage facilities shall be designed and provided to meet the approval of the City Engineer and shall be designed and constructed in accordance with the City's *Design Manual for Storm Drainage Facilities* and City construction standards and specifications	REVISE PROVISION: Drainage Facilities ~~Drainage facilities shall be designed and provided to meet the approval of the City Engineer and shall be designed and constructed in accordance with the City's *Design Manual for Storm Drainage Facilities* and City construction standards and specifications.~~ h. The minimum configuration of any stormwater facility shall accommodate potential runoff from the entire upstream drainage area under developed conditions and shall be designed to prevent overloading the capacity of the downstream drainage system as determined by the City Engineer and in accordance with Flood Control Requirements and the City's adopted Design Manual for Storm Drainage Facilities and City construction standards and specifications. i. The City may require the phasing of development, the use of control methods such as retention or detention, the construction of off-site drainage improvements, and/or payment of stormwater connection fees in order to mitigate the impacts of the proposed development.

	RECOMMENDATION
ADDED SECTION	STORMWATER COLLECTION AND DRAINAGE SYSTEMS

FLOOD CONTROL REQUIREMENTS

A. Flood Damage Prevention Ordinance. Developments and improvements in or near a FEMA floodplain shall meet the requirements of the Chapter 39 of the City's Code of Ordinances.

B. Site Stormwater Management. The following two items should be considered during the design process:

1. Diversion of storm water away from the natural watercourse will not be allowed, except within the property boundaries controlled by the developer under the following conditions:
   a. The storm water is returned to its natural flowing watercourse prior to leaving the developer's property,
   b. For watersheds greater than twenty (20) acres, a timing analysis of the existing and diverted hydrograph must be performed to confirm that the peak flow rate has not been increased at the point that it reenters the watercourse, as a result of the diversion.
2. All developments shall provide adequate drainage outfall at the lower end of the site into an existing street, alley, drainage, easements or right-of-way, or to the centerline of an existing natural drain. Where a proposed street, storm drain, or open channel does not discharge into a natural low or into an existing adequate drainage easement, then facilities and drainage easements of adequate width — to contain the design discharge — shall be constructed and dedicated.
3. Developments cannot increase the water surface elevation off-site unless contained within a dedicated drainage easement or right-of-way.

C. Responsibility to Accept Storm Water. The owner or developer of property to be developed shall be responsible for the conveyance of all storm water flowing through the property. This responsibility includes the storm water flowing onto the property by any other developed property as well as the drainage naturally flowing through the property by reason of topography.

D. Design Based on Maximum Build-Out Configuration. Drainage improvements shall accommodate runoff from the upstream drainage area in its anticipated maximum "build-out" condition, and shall be designed to prevent overloading the capacity of the downstream drainage system. The City may require the phasing of development, the use of control methods such as retention or detention, or the construction of off-site drainage improvements in order to mitigate the impact of the proposed development.

E. Design Storm Event. All drainage facilities (including streets, curbs, gutters, storm drains, ditches, creeks, detention ponds, etc.) shall be designed to intercept and transport runoff from a twenty five (25) year frequency storm. The drainage system shall be designed to convey those flows greater than a twenty five (25) year frequency, up to and including a one hundred (100) year frequency storm within defined rights-of-way or drainage easements.

F. Detention or Retention Required. Drainage facilities shall be designed and constructed so that the rate of runoff from a site after construction shall be equal to or less than the runoff prior to construction for the two (2), ten (10), twenty five (25), and one hundred (100) year storm frequencies.

1. The timing of the hydrograph released from the detention facility must be checked against the timing of the flow rate in the first open watercourse to prevent any increase in the peak flow rate in the receiving watercourse. For detention basins constructed in-line on an existing watercourse, the creation of the basin shall not increase flood elevations in the channel upstream of the new development boundaries.
2. Computation of the rate of runoff shall be based on an assumption of a contributing drainage area or watershed fully developed in accordance with the Stormwater Technical Manual.
3. Low impact development practices can be used to reduce peak flow rates to reduce or eliminate detention requirements when designed in accordance with the Stormwater Technical Manual criteria.

RECOMMENDATION

4. Detention pond bottoms must be vegetated.

G. Waiver of Detention/Retention.

1. Detention/retention may be waived for non-residential small site permits if no adverse impacts are demonstrated through drainage analysis and a payment-in-lieu is made into the stormwater management fund in accordance with Section 6.1.1.3.
2. Detention/Retention may be waived in High Intensity Zones if no adverse impacts are demonstrated through drainage analysis and a payment-in-lieu is made into the stormwater management fund in accordance with Section 6.1.1.3.

H. Street Drainage. Except for inverted crown thoroughfares, no lowering of the standard height of street crown shall be allowed for the purposes of obtaining additional hydraulic capacity. Bridges and culverts in residential streets, shall be designed for the runoff from the one hundred (100) year frequency flow based on a fully developed watershed. shall not produce a headwater depth at the roadway greater than either twelve (12) inches above the roadway crown or any top of upstream curb elevation, whichever is lower. For bridges and culverts in streets other than residential areas, the one hundred (100) year headwater depth is limited to six (6) inches. Storm drain system shall be designed to meet the criteria listed in the Stormwater Technical Manual.

I. Minimize Cut and Fill. The layout of the street network, lots and building sites shall minimize the amount of cut and fill on slopes in accordance with the standards for cut and fill set forth in Section 6.1.2.2.

J. Permit Required. No person, individual, partnership, firm or corporation shall deepen, widen, fill, reclaim, reroute or change the course or location of any existing ditch, channel, stream or drainage without first obtaining a site plan permit and permits from applicable agencies (such as FEMA or the U.S. Army Corps of Engineers) having jurisdiction. The Responsible Official may, at his or her discretion, require preparation and submission of a FEMA or flood study for a proposed development if there are concerns regarding storm drainage on the subject property or upstream or downstream from the subject property. The costs of such study, if required, shall be borne by the developer.

K. Conformance with the City's Stormwater Technical Manual. All stormwater facilities, including those for low impact development, detention, retention or water quality, shall be designed by a licensed professional engineer in accordance with the City's Stormwater Technical Manual, including requirements for location, screening and fencing not inconsistent with this Chapter and applicable ordinances. All plans submitted to the Responsible Official for approval shall include a layout of the stormwater management system together with supporting calculations for the design of the system.

ADDED SECTION

Impervious Cover Calculation and Limitations

Paved roads, sidewalks, parking areas, parking lots, buildings and other impermeable construction covering the natural land surface shall be considered impervious cover. The methods to be used to calculate the percent of impervious cover created by the development of a parcel or tract of land are described in the City Stormwater Technical Manual. Note that the area of impervious cover for a surface may be reduced based on data acceptable to the Responsible Official showing that the surface has a significant degree of permeability.

ADDED SECTION

Drainage Requirements During Construction

During construction, on-site drainage shall be maintained so that water surfaces are not increased upstream or downstream of the site when compared to pre-project conditions unless fully contained within a drainage easement or designated right-of-way.

ADDED SECTION

Drainage Improvement Responsibility

A. Drainage improvements required by this Article shall be provided at the sole expense of the owner of the property to be developed, unless otherwise expressly provided to the contrary in a subdivision improvements agreement.

B. Drainage easements shall be provided to the public by the owner of property to be developed for the purposes of drainage master planning of all drainage improvements, open or enclosed, and all storm water flows to the limits of the one hundred (100) year

RECOMMENDATION

floodplain as determined in accordance with anticipated fully-developed contributing area land use conditions and allowing continuous access for inspection, operation, maintenance and rehabilitation of all drainage improvements.

C. At the discretion of the Responsible Official, the owner of the property to be developed shall dedicate drainage improvements to the public in a right-of-way rather than a drainage easement.

D. In determining whether drainage improvements should be dedicated to the public, the Responsible Official shall take the following factors into consideration:
1. Drainage improvements associated with a single development shall remain private; and
2. Drainage improvements that serve streets or other public property or may serve multiple developments or provide regional detention/treatment shall be dedicated to the public.

E. Drainage easement and right-of-way widths shall be specified by the City as necessary for inspection and maintenance of facilities as well as to accommodate areas anticipated to be inundated by stormwater.

F. Full detention basin design may be deferred until the site development permit stage if the property owner submits a "request for detention deferral" demonstrating an understanding of the implications of such design deferral AND the following notes are placed on the subdivision plat AND supporting documentation is provided.
1. "Stormwater detention is required for this property. The engineer of record for this subdivision plat has estimated that an area of approximately ____________ acres and a volume of approximately ____________ acre feet will be required for this use. This is an estimate only and detailed analysis may reveal different requirements."
2. "No building permit shall be issued for this platted property until a stormwater detention system design has been approved by the City of Kerrville or applicable county if in the ETJ."

Drainage Improvements Maintenance Responsibility

A. Drainage improvements constructed or installed under this Article shall be maintained in accordance with the following:
1. Drainage improvements located in public rights- of-way that have been accepted by the City shall be maintained by the appropriate jurisdiction.
2. Drainage improvements located on private property with publicly dedicated easements shall be maintained by the property owner.

ART. 10-IV-5 CONSTRUCTION PLANS

RECOMMENDATION

SECTION (A) MINIMUM DEVELOPMENT IMPROVEMENTS

3. **Form and Content**

g. **Plan of Storm Drainage System**

(1) Developer shall present a topographic map showing existing drainage conditions and submit a drainage plan which meets approval of the City Engineer prior to approval of submission. An adequate drainage system, including necessary open ditches, pipes, culverts, intersection drains, drop inlets, bridges, etc., shall be provided for the proper drainage of all surface water. The 100-year flood plain shall be delineated based upon condition of the projected ultimate development of the subdivision.

	RECOMMENDATION
(2) Where a subdivision is traversed by a water course, drainage way, natural channel or stream, there shall be provided an “easement” or “right-of-way” conforming substantially to the limit of such water course, plus additional width to accommodate future needs. Drainage easements shall be approved by the City Engineer both as to location and width.	

2013

CITY OF KERRVILLE

KERR COUNTY

TEXAS

DRAINAGE DESIGN MANUAL

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1.0 GENERAL

This manual contains the minimum storm drainage design criteria to be followed in the design of storm drainage facilities in the City of Kerrville (City). If an item is not covered in this manual other criteria as approved by the City Engineer may be applied.

2.0 DESIGN STORM FREQUENCY

The 1% storm frequency (100–year storm) for fully developed watershed conditions shall be used in all storm sewer designs in the City, unless specified otherwise in this manual. Alternative approaches are only permitted with the approval of the City Engineer or designee.

3.0 DETERMINATION OF DESIGN DISCHARGE

The Rational Method for computing storm water runoff is to be used for hydraulic design of facilities serving a drainage area of less than 150 acres with no significant flood storage. For drainage areas greater than 150 acres, a Unit Hydrograph method shall be utilized to compute the storm water runoff (i.e., Snyder's Unit Hydrograph, Soil Conservation Service Unit Hydrograph (SCS), or Clark's Unit Hydrograph). If a hydrologic modeling system computer program is utilized to compute the storm water runoff, the model must be compatible with the Army Corps of Engineers HEC-HMS software. A copy of the digital model must be submitted to the Engineering Department with the plan review submittal. In all cases, the detailed calculations utilized to determine the storm water design discharges and a summary of the results must be included within the civil construction plans.

3.1 RATIONAL METHOD

The Rational Method can be used to estimate storm water runoff peak flows for the design of gutter flows, drainage inlets, storm sewer pipe, culverts and small ditches. It is most applicable to small, highly impervious areas. The maximum drainage area that is allowed to be used with the Rational Method is 150-acres.

The Rational Formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area (A), runoff coefficient (C), and the mean rainfall intensity (I) for a duration equal to the time of concentration (T_c).

The Rational Formula is expressed as follows:

$$Q = C \times I \times A \tag{3.1}$$

where: Q = maximum rate of runoff (cfs)
C = runoff coefficient representing a ratio of runoff to rainfall (unitless)
I = average rainfall intensity for a duration equal to the T_c (in/hr)
A = drainage area contributing to the design location (acres)

3.1.1 Time of Concentration

The time of concentration (T_c) can be defined as the time required for water to flow from the most hydraulically remote point in a drainage basin to the point being analyzed. The most hydraulically remote drainage point refers to the route requiring the longest drainage travel time and not necessarily the greatest linear distance. Use of the Rational Formula requires the time of concentration for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I). Overland (sheet) flow, shallow concentrated flow and channel flows are components that need to be considered in the calculation of time of concentration. The ~~following~~ NRCS TR-55 method~~s are~~ is ~~recommended~~ preferred method for calculating ~~for~~ time of concentration calculation. The minimum time of concentration for any drainage area shall be 5 minutes. Additionally, the minimum slope used for calculation of sheet and shallow flow travel time components should be 0.005 feet per foot (0.5%).

3.1.1.1 Overland flow – ~~flow over plane surfaces: For each drainage area, the distance is determined from the design point to the most hydraulically remote point in the tributary area. From a topographic map, the average slope is determined for the same distance. The runoff coefficient (C) is determined by the procedure described in a subsequent section of this chapter. Overland flow distance should not exceed 300 feet. The overland flow time can be determined by the following formula (Equation 3.2) or by the Seelye Chart for Overland Flow Time (Figure A, Appendix A). Note that for overland sheet flow the minimum time is 5 minutes and the maximum overland flow time shall be 20 minutes.~~

$$\cancel{T_{overland} = \frac{1.8(1.1 - C)L^{1/2}}{S^{1/3}}} \qquad (3.2)$$

Commented [AS1]: Formula used here is the FAA Method for calculating time of concentration which is mixing up methodologies between FAA and NRCS TR-55. Recommend using TR-55 Method. Revised formulate provided below.

~~where: *C* = runoff coefficient determined from Table 3.2~~
~~*L* = over land flow length in feet (ft)~~
~~*S* = average overland slope in percent (%)~~

Sheet flow is shallow flow over land surfaces, which usually occurs in the headwaters of streams. The engineer should realize that sheet flow occurs for only very short distances, especially in urbanized conditions. Sheet flow for both natural (undeveloped) and developed conditions should be limited to a maximum of 100 feet. Sheet flow for developed conditions should be based on the actual pavement or grass conditions for areas that are already developed and should be representative of the anticipated land use within the headwater area in the case of currently undeveloped areas. In a typical residential subdivision, sheet flow may be the distance from one end of the lot to the other or from the house to the edge of the lot. In some heavily urbanized drainage areas, sheet flow may not exist in the headwater area. The NRCS method employs equation 5.4.1, which is a modified form kinematic wave equation, for the calculation of the sheet flow travel time.

- TR-55 "Urban Hydrology for Small Watersheds," SCS 1986 may be used, please consider the maximum (20 min.) and minimum (5 min.) when defining the flow length (L).

(Equation 5.4.1)

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}\, s^{0.4}}$$

T_t = travel time (hr.)
n = Manning's roughness coefficient
L = flow length (ft.)
P_2 = 2-year, 24-hour rainfall*
s = slope of hydraulic grade line (land slope, ft/ft)

3.1.1.2. Shallow concentrated flow – overland flow usually becomes shallow concentrated flow after a maximum of ~~300~~ 100 feet, and before the flow enters a defined channel or drainage system, the flow is considered shallow concentrated flow. Travel time for shallow concentrated flow is calculated as follows:

$$T_{shallow} = \frac{L}{V_{shallow}(60)} \tag{3.3}$$

where: T = time (minutes)

L = shallow concentrated flow length in feet (ft)
$V_{shallow}$ = shallow concentrated flow velocity in feet per second (fps)
$S_{decimal}$ = average water course slope in decimal

$$V_{shallow} = 16.1345\sqrt{S_{decimal}} \quad \text{[for unpaved areas]} \tag{3.4}$$

$$V_{shallow} = 20.3282\sqrt{S_{decimal}} \quad \text{[for paved areas]} \tag{3.5}$$

3.1.1.3 Channel Flow – Velocity in channels should be calculated from the Manning's equation. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity for travel time calculations is usually determined for bank-full elevation assuming low vegetation winter conditions. When actual cross section information is not available, non-floodplain channel velocities for ultimate watershed development should not be less than 6 fps for estimating time of concentration.

$$T_{channel} = \frac{L}{V_{channel}(60)} \tag{3.6}$$

where: T= time (minutes)
$V_{channel}$ = channel flow average velocity (fps)
L = Length of reach along the flow path (ft)

The Channel Velocity is calculated using Manning's Formula as follows:

$$V_{channel} = \frac{1.486\left(R^{2/3}\right)\left(S^{1/2}\right)}{n} \tag{3.7}$$

$$R = \frac{A}{P_w} \tag{3.8}$$

To obtain the total time of concentration, the overland, shallow concentrated, and channel flow times must be added together. For example, if the flow time in a channel is 15 minutes and the overland flow time from a ridge line to the channel is 10 minutes, then the total time of concentration is 25 minutes.

3.1.2 Rainfall Intensity (I)

The rainfall intensity (I) is the average rainfall rate in in/hr for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the drainage area, the rainfall intensity can be determined from Rainfall-Intensity-Duration data given in Table 3.1. Note that the data represented in this table were derived from the NOAA Atlas 14 ~~Dodson Method~~ as follows:

$$\cancel{I = \frac{b}{(T+d)^e}} \tag{3.9}$$

~~where: *I* = rainfall intensity (in/hr)~~
~~*T* = rainfall duration (minutes)~~

~~*b, d, e* = coefficients based upon precipitation data~~

3.1.3 Runoff Coefficient (C)

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the design engineer. While engineering judgment will always be required in the selection of runoff coefficients, typical coefficients represent the integrated effects of many drainage basin parameters. Table 3.2 gives the recommended runoff coefficients for the Rational Method.

It should be remembered that the Rational Method assumes that all land uses within a drainage area are uniformly distributed throughout the area. If it is important to locate a specific land use within the drainage area, then another hydrologic method may be used where hydrographs can be generated and routed through the drainage system. If a hydrograph is used, the results should be compared to the Rational Method and the more conservative results utilized in the design.

It may be that using only the impervious area from a highly impervious site (and the corresponding high C factor and shorter time of concentration) will yield a higher peak runoff value than by using the whole site. **This should be checked** particularly in areas where the overland portion is grassy (yielding a long T_c) to avoid underestimating peak runoff.

Table 3.1 Rain-Intensity-Duration Data for Kerr County

Hours	Minutes	2	5	10	25	50	100
Coefficients		Return Period (Years)					
e		0.789	0.765	0.764	0.763	0.766	0.768
b		49	58	69	80	91	104
d		8.4	8	8	8	8	8.4
Hours	Minutes	Rainfall Intensity (inches per hour)					
0.083	5	6.32	8.15	9.72	11.30	12.76	14.17
	6	5.97	7.70	9.19	10.68	12.05	13.41
	7	5.67	7.31	8.72	10.13	11.43	12.74
	8	5.39	6.95	8.30	9.65	10.88	12.13
	9	5.15	6.64	7.92	9.21	10.39	11.60
	10	4.92	6.36	7.58	8.82	9.94	11.11
	11	4.72	6.10	7.28	8.46	9.54	10.67
	12	4.54	5.86	7.00	8.14	9.17	10.26
	13	4.37	5.65	6.74	7.84	8.84	9.89
	14	4.22	5.45	6.50	7.57	8.53	9.55
0.25	15	4.07	5.27	6.29	7.31	8.24	9.24
	16	3.94	5.10	6.09	7.08	7.98	8.94
	17	3.82	4.94	5.90	6.86	7.73	8.67
	18	3.70	4.80	5.73	6.66	7.50	8.42
	19	3.60	4.66	5.56	6.47	7.29	8.18
	20	3.50	4.53	5.41	6.29	7.09	7.96
	21	3.40	4.41	5.27	6.13	6.90	7.75
	22	3.31	4.30	5.13	5.97	6.72	7.55
	23	3.23	4.19	5.01	5.82	6.56	7.37
	24	3.15	4.09	4.89	5.68	6.40	7.19
	25	3.08	4.00	4.77	5.55	6.25	7.03
	26	3.01	3.91	4.66	5.43	6.11	6.87
	27	2.94	3.82	4.56	5.31	5.97	6.72
	28	2.87	3.74	4.47	5.20	5.85	6.58
	29	2.81	3.66	4.37	5.09	5.73	6.44
0.5	30	2.76	3.59	4.28	4.99	5.61	6.31
	31	2.70	3.52	4.20	4.89	5.50	6.19
	32	2.65	3.45	4.12	4.79	5.39	6.07
	33	2.60	3.39	4.04	4.70	5.29	5.96
	34	2.55	3.32	3.97	4.62	5.20	5.85
	35	2.50	3.26	3.90	4.54	5.10	5.75
	36	2.46	3.21	3.83	4.46	5.01	5.65
	37	2.41	3.15	3.77	4.38	4.93	5.55
	38	2.37	3.10	3.70	4.31	4.85	5.46
	39	2.33	3.05	3.64	4.24	4.77	5.37
	40	2.30	3.00	3.58	4.17	4.69	5.29
	41	2.26	2.95	3.53	4.11	4.62	5.20
	42	2.22	2.91	3.47	4.04	4.55	5.12
	43	2.19	2.87	3.42	3.98	4.48	5.05
	44	2.16	2.82	3.37	3.92	4.41	4.97
0.75	45	2.12	2.78	3.32	3.87	4.35	4.90
	46	2.09	2.74	3.28	3.81	4.29	4.83
	47	2.06	2.70	3.23	3.76	4.23	4.76
	48	2.03	2.67	3.19	3.71	4.17	4.70
	49	2.01	2.63	3.14	3.66	4.11	4.64
	50	1.98	2.60	3.10	3.61	4.06	4.58
	51	1.95	2.56	3.06	3.56	4.00	4.52
	52	1.93	2.53	3.02	3.52	3.95	4.46
	53	1.90	2.50	2.98	3.47	3.90	4.40
	54	1.88	2.47	2.95	3.43	3.86	4.35
	55	1.86	2.44	2.91	3.39	3.81	4.30
	56	1.83	2.41	2.88	3.35	3.76	4.24
	57	1.81	2.38	2.84	3.31	3.72	4.19
	58	1.79	2.35	2.81	3.27	3.68	4.15
	59	1.77	2.33	2.78	3.23	3.63	4.10
1	60	1.75	2.30	2.75	3.20	3.59	4.05
2	120	1.06	1.42	1.69	1.97	2.21	2.50
3	180	0.79	1.06	1.26	1.47	1.65	1.86
6	360	0.46	0.63	0.76	0.88	0.99	1.11
12	720	0.27	0.37	0.45	0.52	0.58	0.66
24	1440	0.16	0.22	0.27	0.31	0.35	0.39

Commented [AS2]: Revise table to adopt NOAA Atlas 14, Volume 11 precipitation frequency estimates. Convert Atlas 14 precipitation estimates to Intensity-Duration-Frequency (IDF) and Depth-Duration-Frequency (DDF) tables.

Commented [AS2]: Revise table to adopt NOAA Atlas 14, Volume 11 precipitation frequency estimates. Convert Atlas 14 precipitation estimates to Intensity-Duration-Frequency (IDF) and Depth-Duration-Frequency (DDF) tables.

Table 3.2 Rational Method Runoff Coefficients	
Description of Area	**Runoff Coefficient (C)**
Developed:	
Asphalt	0.95
Concrete	0.97
Grass Areas (Lawns, Parks, etc.):	
Poor Condition (Grass Cover < 50% of Area)	
Flat, 0-2%	0.47
Average, 2-7%	0.53
Steep, over 7%	0.55
Fair Condition (Grass Cover between 50% & 75% of Area)	
Flat, 0-2%	0.41
Average, 2-7%	0.49
Steep, over 7%	0.53
Good Condition (Grass Cover > 75% of Area)	
Flat, 0-2%	0.36
Average, 2-7%	0.46
Steep, over 7%	0.51
Undeveloped:	
Cultivated	
Flat, 0-2%	0.47
Average, 2-7%	0.51
Steep, over 7%	0.54
Pasture/Range	
Flat, 0-2%	0.41
Average, 2-7%	0.49
Steep, over 7%	0.53
Forest/Woodlands	
Flat, 0-2%	0.39
Average, 2-7%	0.47
Steep, over 7%	0.52
Land Use	
Single Family Residential (40% Impervious Cover)	
Flat, 0-2%	0.60
Average, 2-7%	0.66
Steep, over 7%	0.69
Multifamily Residential (65% Impervious Cover)	
Flat, 0-2%	0.76
Average, 2-7%	0.79
Steep, over 7%	0.81
Retail/Office/Light Commercial (80% Impervious Cover)	
Flat, 0-2%	0.85
Average, 2-7%	0.87
Steep, over 7%	0.88
Regional Commercial/Industrial (95% Impervious Cover)	
Flat, 0-2%	0.94
Average, 2-7%	0.95
Steep, over 7%	0.96

Adapted from: 1. iSWM Design Manual for Development/Redevelopment, 2006
2. City of Austin, Drainage Criteria Manual, 2007

3.2 UNIT HYDROGRAPHS

For drainage areas greater than 150 acres, a Unit Hydrograph method shall be utilized to compute the storm water runoff (i.e., Snyder's Unit Hydrograph, Soil Conservation Service Unit Hydrograph (SCS), or Clark's Unit Hydrograph). If the Army Corps of Engineers HEC-HMS software is utilized to compute the storm water runoff, a copy of the digital model must be submitted to the Engineering Department with the plan review submittal. Additionally, the detailed calculations utilized to determine the storm water design discharges must be included in the civil construction plans.

The methodologies specified and approved by the US Army Corps of Engineers manual for the Snyder's Unity Hydrograph, Soil Conservation Service Unit Hydrograph (SCS) and the Clark's Unit Hydrograph are hereby adopted by this manual and included by reference. The recommended methodology is the SCS Method.

3.2.1 LOSS METHOD

Commented [AS3]: Provide description summary for methods, acceptable values and reference to formulas.

3.2.1.1 SCS CURVE NUMBER LOSS

3.2.1.2

{INSERT SCS CURVE NUMBER BY SOIL TYPE TABLE}

{INSERT TABLE FOR PERCENT IMPERVIOUS COVER BY LAND USE}

3.2.2 TRANSFORM METHOD

3.2.2.1 SCS UNIT HYDROGRAPH

3.2.2.2 SNYDER UNIT HYDROGRAPH METHOD

3.2.2.3 CLARK UNITY HYDROGRAPH METHOD

3.2.3 REACH ROUTING

Commented [AS4]: Provide explanation of acceptable reach routing methods including Muskingum, Muskingum-Cunge 8-Point , Modified Puls, Kinematic Wave

4.0 STREET DRAINAGE

The design flow of water in a street is related to its interference with traffic, public safety, parking, ADA requirements & pedestrian access and the chance of flood damage to surrounding properties. Interference with traffic is regulated by design limits of the spread of water into or through traffic lanes. Flooding of surrounding properties is regulated by limiting the depth of flow at the curb and by containment of the 100-year design storm flow within the street right of way. The following subsections specify the capacity limitations allowed in the City of Kerrville streets.

4.1 PERFORMANCE STANDARDS & LIMITATIONS

4.1.1 Flow Velocity

The maximum velocity of street flow shall not exceed 10 feet/second. At street "T" intersections, the flow velocity must be checked on the stem of the "T" to ensure that flow will not traverse the crown and opposing curb of the crossing street and enter onto private property.

4.1.2 Flow Depth

The flow depth shall be limited to the top of curb for the 4% chance (25-year) storm event.

The 1% (100-year) storm event shall be confined to be within the limits of the street rights-of-

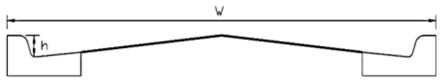
ways.
Streets draining a watershed greater than one hundred (100) acres must be designed for the 100-year ultimate design frequency storm. Street width shall not be widened beyond the width as determined by the street classification for drainage purposes.

For 100-year storm event flow depth shall not exceed 10 inches. In street right-of-way the product of water depth (ft.) x velocity (fps) should not be more than 6.5.

Once capacity has been reached, flows shall be conveyed via a public drainage system. In general, the flows listed in Table 4.1 shall not be exceeded without substantiating computations satisfactorily demonstrating that adverse impacts will be eliminated.

Table 4.1 – Street Capacity Table for Standard Parabolic Curb & Gutter Asphalt Streets

Manning's n = 0.018
h=0.54



Street Slope (%)	City Standard Curbed & Guttered Street Width (feet)					
	30		36		42	
	Q (cfs)	V(fps)	Q (cfs)	V(fps)	Q (cfs)	V(fps)
0.40	17.2	2.1	20.8	2.1	24.3	2.1
0.45	18.3	2.3	22.0	2.3	25.8	2.3
0.50	19.3	2.4	23.2	2.4	27.2	2.4
0.55	20.2	2.5	24.4	2.5	28.5	2.5
0.60	21.1	2.6	25.5	2.6	29.8	2.6
0.65	22.0	2.7	26.5	2.7	31.0	2.7
0.70	22.8	2.8	27.5	2.8	32.2	2.8
0.75	23.6	2.9	28.5	2.9	33.3	2.9
0.80	24.4	3.0	29.4	3.0	34.4	3.0
0.85	25.1	3.1	30.3	3.1	35.4	3.1
0.90	25.9	3.2	31.2	3.2	36.5	3.2
0.95	26.6	3.3	32.0	3.3	37.5	3.3
1.00	27.3	3.4	32.9	3.4	38.4	3.4
1.50	33.4	4.1	40.2	4.1	47.1	4.2
2.00	38.6	4.8	46.5	4.8	54.4	4.8
2.50	43.1	5.3	52.0	5.3	60.8	5.4
3.00	47.2	5.8	56.9	5.9	66.6	5.9
3.50	51.0	6.3	61.5	6.3	71.9	6.3
4.00	54.5	6.7	65.7	6.8	76.9	6.8
4.50	57.9	7.1	69.7	7.2	81.6	7.2
5.00	61.0	7.5	73.5	7.6	86.0	7.6
5.50	64.0	7.9	77.1	7.9	90.2	8.0
6.00	66.8	8.2	80.5	8.3	94.2	8.3
6.50	69.5	8.6	83.8	8.6	98.0	8.6
7.00	72.2	8.9	86.9	8.9	101.7	9.0
7.50	74.7	9.2	90.0	9.3	105.3	9.3
8.00	77.1	9.5	92.9	9.6	108.7	9.6
8.50	79.5	9.8	95.8	9.9	112.1	9.9
9.00	79.7	10.0	95.1	10.0	110.5	10.0
9.50	76.5	10.0	91.2	10.0	106.0	10.0
10.00	73.5	10.0	87.7	10.0	101.9	10.0
10.50	70.8	10.0	84.5	10.0	98.2	10.0
11.00	68.3	10.0	81.5	10.0	94.7	10.0
11.50	66.0	10.0	78.7	10.0	91.6	10.0
12.00	63.8	10.0	76.2	10.0	88.6	10.0

4.2 ALLOWABLE FLOW SPREAD

4.2.1 Residential Streets

Runoff in a residential street from the 4% design frequency flows shall not exceed a depth of the lowest top of curb. Stormwater shall be removed from the streets by inlets or openings into

Commented [AS5]: Revise table calculations to reflect adopted street classifications per the Kerrville 2050 Comprehensive Plan.

Check Q and V values.

adjacent public drainage systems. They shall generally be placed at low points and as frequently as necessary to avoid exceeding water spread & depth criteria.

4.2.2 Collector Streets

Based upon the 4% storm event, Flow Spread shall be designed to provide at least one (1) open 12-foot traffic lane at the center of the street. For divided collectors, the flow spread shall be designed to provide one (1) open travel lane in each direction. Wherever possible, a collector street shall not be crossed with surface drainage unless approved by the City Engineer.

4.2.3 Major and Minor Arterials

Based upon the 1% design frequency flows, Flow Spread shall be designed to not exceed one (1) travel lane in each direction. Bypass from upstream inlets in excess of 5-cfs is not allowed into major or minor arterial intersections.

4.2.4 Alleys

The 1% design frequency flows shall not exceed the capacity of the paved alley section. Alley capacities must be checked at all alley turns and intersections to determine if curbing is needed or if grades should be flattened. Curbing must be required for at least 10-feet on either side of an inlet in an alley and on the other side of the alley so that the top of the inlet is even with the high edge of the alley pavement.

In residential areas where the standard 10-foot wide alley section capacity is exceeded, a wider alley may be used to provide more drainage capacity. Curbs shall not be added to alleys to increase the capacity. Where a particular width alley is required, such as a 12-foot width, a wider alley, such as a 16-foot width, may be required for greater capacity. Approximate increases in right-of-way widths will be necessary.

4.3 INTERSECTIONS

Inlet placement and storm sewer size shall ensure that design storm flows are intercepted along street legs entering the intersection in advance of the curb returns connecting the streets based on the criteria provided in this manual. In no case shall inlets be placed in the curved portion of curbs connecting intersecting streets. Where storm flow is allowed to pass through an intersection, valley gutter design must provide for smooth, uninterrupted traffic flow.

Intersection Pair	Intercept	Valley Gutter Criteria
Arterial - Arterial	All legs	No valley gutters
Arterial - Collector	All legs	No valley gutters
Arterial - Residential	All legs	No valley gutters
Collector - Collector	All legs	No valley gutters
Collector - Residential	Residential legs	Valley gutters can parallel Collector
Residential - Residential	Two legs preferred	Valley gutters acceptable

5.0 ROADWAY DITCH REQUIREMENTS

When roadway ditches are used in-lieu of city standard curb & gutter, the following standards shall apply. If any of the below requirements cannot be achieved, an alternative to mitigate the deficiency shall be submitted for review and approval by the City.

1. The ditch shall not be less than 24 inches in depth.
2. The side slopes shall not be steeper than ~~3H~~4H:1V.
3. Provisions for armoring and/or vegetation for erosion control on the side slopes and bottom shall be shown on the plans.
4. The ditch shall convey the flows generated by the 1% storm event.
5. The flow velocity in an unarmed ditch shall generally not exceed 6 feet per second. Reference Table 6.1a for further velocity control information.

6.0 OPEN CHANNELS, CULVERTS, AND BRIDGES

6.1 GENERAL DESIGN CONSIDERATIONS

- Stormwater systems should be planned and designed so as to generally conform to natural drainage patterns and discharge to natural drainage pathways within a drainage basin. These natural drainage pathways should only be modified as a last resort to contain and safely convey the peak flows generated by the development.

- Runoff must be discharged in a manner that will not cause adverse impacts on downstream properties or stormwater systems. In general, runoff from development sites within a drainage basin should be discharged at the existing natural drainage outlet or outlets. If the developer wishes to change discharge points he or she must demonstrate that the change will not have any adverse impacts on downstream properties or stormwater (minor) systems.

- It is important to ensure that the combined on-site flood control system and major stormwater system can handle blockages and flows in excess of the design capacity to minimize the likelihood of nuisance flooding or damage to private properties. If failure of minor stormwater systems and/or major stormwater structures occurs during these periods, the risk to life and property could be significantly increased.

- In establishing the layout of stormwater systems, it is essential to ensure that flows are not diverted onto private property during flows up to the major stormwater system design capacity.

6.2 OPEN CHANNELS

Natural or lined open channels shall be designed to convey the flood peak flows while at the same time be designed in such a way to minimize erosion and maintain the stability of the stream banks. Concrete lined channels are generally discouraged by the City. **Bioengineering** techniques may be used in natural channels with side slopes no steeper than 3H:1V. Construction of a low-flow channel, where possible, is another recommended option. Low-flow channels should be sized using the channel forming discharge or the 2-year storm. The design engineer is reminded that it may be extremely difficult to obtain the proper permits from the State and Federal authorities for concrete channel designs. In addition, developers are responsible for acquisition of all regulatory agency permits.

- Open channels provide opportunities for reduction of flow peaks and pollution loads. They may be designed as wet or dry enhanced swales or grass channels.

- Channels can be designed with natural meanders improving both aesthetics and pollution removal through increased contact time.

- Grass channels generally provide better habitat than hardened channel sections, though studies have shown that riprap interstices provide significant habitat as well. Velocities should be carefully checked at design flows and the outer banks at bends should be specifically designed for increased shear stress and superelevation.

- Compound sections can be developed to carry the annual flow in the lower section and higher flows above them. Figure 6.1 illustrates a compound section that carries the 50% design frequency flows (2-year storm event) and 1% design frequency flows within banks. This reduces channel erosion at lower flows, and meandering, self-forming low flow channels that attack banks. The shelf in the compound section should have a minimum 1V:12H slope to ensure drainage.

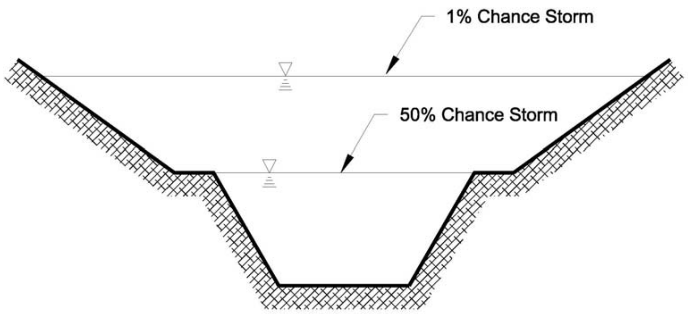


Figure 6.1 Compound Channel Section

6.2.1 Open Channel Lining Types

The three main classifications of open channel linings are vegetated, flexible, and rigid. Vegetated linings include grass with mulch, sod, and bioengineering techniques. Stone riprap and some forms of flexible man-made linings or gabions are examples of flexible linings, while rigid linings are generally concrete or rigid block.

Vegetative Linings – Vegetation, where practical, is the most desirable lining for an artificial channel. It stabilizes the channel body, consolidates the soil mass of the bed, checks erosion on the channel surface, provides habitat, and provides water quality benefits (see Appendix B-References, *iSWM Technical Manual* for more details on using enhanced swales and grass channels for water quality purposes).

Conditions under which vegetation only linings may not be acceptable include but are not limited to:

- High velocities
- Standing or continuously flowing water
- Lack of regular maintenance necessary to prevent growth of taller or woody vegetation
- Lack of nutrients and inadequate topsoil
- Excessive shade

Proper seeding, mulching, and soil preparation are required during construction to assure establishment of healthy vegetation.

If low flows are prevalent, a hard lined pilot channel may be needed, and it should be wide enough to accommodate maintenance equipment.

Flexible Linings – Rock riprap, including rubble and gabion baskets, is the most common type of flexible lining for channels. It presents a rough surface that can dissipate energy and mitigate increases in erosive velocity. These linings are usually less expensive than rigid linings and have self-healing qualities that reduce maintenance. However, they may require the use of a filter fabric depending on the underlying soils, and the growth of grass, weeds, and trees may present maintenance problems.

Rigid Linings – Rigid linings are generally constructed of concrete and used where high flow capacity is required. Higher velocities, however, create the potential for scour at channel lining transitions and channel headcutting.

6.2.2 Uniform Flow Calculations

Manning's Equation
Manning's Equation, presented in three forms below, is recommended for evaluating uniform flow conditions in open channels:

$$v = \frac{1.486}{n} R^{\frac{2}{3}} \sqrt{s} \qquad (6.1)$$

$$Q = \frac{1.486}{n} A R^{\frac{2}{3}} \sqrt{s} \qquad (6.2)$$

$$s = \left(\frac{Q\,n}{1.486\,A\,R^{\frac{2}{3}}}\right)^2 \qquad (6.3)$$

where: v = average channel velocity (ft/s)
Q = discharge rate for design conditions (cfs)
n = Manning's roughness coefficient
A = wetted cross sectional area or cross sectional area of flow (ft^2)
R = hydraulic radius A/P (ft) [see equation 3.8]
s = slope of the channel or channel bed (ft/ft)

Note that when solving for *S* in Equation 6.3, *S* represents the energy gradient, which is the head loss per length of flow path. When *S* is less than 0.1%, the energy gradient is approximately the bed slope.

Manning's n Values

The Manning's n value is an important variable in open channel flow computations. Variation in this variable can significantly affect discharge, depth, and velocity estimates. Since Manning's n values depend on many different physical characteristics of natural and man-made channels, care and good engineering judgment must be exercised in the selection process.

Recommended Manning's n values for natural channels are given in Table 6.1 For natural channels, Manning's n values should be estimated using experienced judgment and information presented in publications such as the *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains*, FHWA-TS-84-204, 1984, FHWA HEC-15, 1988, or Chow, 1959. Recommended Manning’s n values for various artificial channels are provided in Table 6.2.

Table 6.1
Roughness Coefficients (Manning's n) and Allowable Velocities for Natural Channels

Channel Description	**Manning's n**	**Maximum Permissible Channel Velocity (ft/s)**
MINOR NATURAL STREAMS		
Fairly regular section		
1. Some grass and weeds; little or no brush	0.030 – 0.035	***6**
2. Dense growth of weeds, depth of flow materially greater than weed height	0.035	***6**
3. Some weeds, light brush on banks	0.035	***6**
4. Some weeds, heavy brush on banks	0.050	***6**
5. Some weeds, dense willows on banks	0.060	***6**
• For trees within channels with branches submerged at high stage, increase above values by	+0.010	***6**
• Irregular section with pools, slight channel meander, increase above values by	+0.010	***6**
Floodplain – Pasture		***6**
1. Short grass	0.030	***6**
2. Tall grass	0.035	***6**
Floodplain – Cultivated Areas		***6**
1. No crop	0.030	***6**
2. Mature row crops	0.035	***6**
3. Mature field crops	0.040	***6**
Floodplain – Uncleared		***6**
1. Heavy weeds scattered brush	0.050	***6**
2. Wooded	0.120	***6**
MAJOR NATURAL STREAMS		***6**
Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of "n" for larger streams of mostly regular sections, with no boulders or brush	Range from 0.028 to 0.060	***6**
UNLINED VEGETATED CHANNELS		***6**
Clays (Bermuda Grass)	0.030	***6**
Sandy and Silty Soils (Bermuda Grass)	0.030	***6**
UNLINED NON-VEGETATED CHANNELS		
Sandy Soils	0.030	2.5
Silts	0.030	1.5
Sandy Silts	0.030	3
Clays	0.030	5
Coarse Gravels	0.030	6
Shale	0.030	8
Rock	0.025	15

(Adapted from: iSWM Technical Manual, 2010)

***Reference Table 6.1a Velocity Control**

Table 6.1a Velocity Control				
Velocity (fps)	Type of Facility Required	Hydraulic Radius	Correction Factor	Maximum Permissible Velocity (fps)
1 to 6 (maximum average velocity = 6 fps)	Vegetated Earthen Channel	0-1 1-3 3-5 5-8 8-10 Over 10	0.83 0.92 1.05 1.15 1.225 1.25	5 5.5 6.3 6.9 7.35 7.5
6 to 8	Concrete Retards	NA	NA	NA
>8	Concrete Lining or Drop Structures	NA	NA	NA

Table 6.2 Manning's Roughness Coefficients (n) for Artificial Channels				
		Depth Range		
Category	***Lining Type***	**0-0.5 ft**	**0.5-2.0 ft**	**>2.0 ft**
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Temporary*	Woven Paper Net	0.016	0.015	0.015
	Jute Net	0.028	0.022	0.019
	Fiberglass Roving	0.028	0.022	0.019
	Straw with Net	0.065	0.033	0.025
	Curled Wood Mat	0.066	0.035	0.028
	Synthetic Mat	0.036	0.025	0.021
Gravel Riprap	1-inch D50	0.044	0.033	0.030
	2-inch D50	0.066	0.041	0.034
Rock Riprap	6-inch D50	0.104	0.069	0.035
	12-inch D50	–	0.078	0.040
Note: Values listed are representative values for the respective depth ranges. Manning's roughness coefficients, n, vary with the flow depth. *Some "temporary" linings become permanent when buried.				

(Source: HEC-15, 1988; iSWM TM, 2010)

6.2.3 Critical Flow Calculations

In the design of open channels, it is important to calculate the critical depth in order to determine if the flow in the channel will be subcritical or supercritical. If the flow is subcritical it is relatively easy to handle the flow through channel transitions because the flows are tranquil and wave action is minimal. In subcritical flow, the depth at any point is influenced by a downstream control, which may be either the critical depth or the water surface elevation in a pond or larger downstream channel. In supercritical flow, the depth of flow at any point is influenced by a control upstream, usually critical depth. In addition, the flows have relatively shallow depths and high velocities. Hydraulic jumps are possible under these conditions and consideration should be given to stabilizing the channel.

Critical depth depends only on the discharge rate and channel geometry. The general equation for determining critical depth is expressed as:

$$\frac{Q^2}{g} = \frac{A_C^3}{T} \tag{6.4}$$

where: Q = discharge rate for design conditions (cfs)
g = acceleration due to gravity (32.2 ft/sec^2)
A_c = critical depth cross-sectional area (ft^2)
T = top width of water surface (ft)

Note: A trial and error procedure is needed to solve Equation 6.4. The cross-sectional area is a function of the critical depth and can be factored out depending upon the geometry of the channel section. For a rectangular channel:

$$d_c = \frac{A_C}{T} \quad \text{[rectangular]} \tag{6.5}$$

where: d_c = critical depth

Therefore, Equation 6.4 can be rewritten as:

$$d_C^3 = \frac{Q^2}{g} \quad \text{[rectangular]} \tag{6.6}$$

6.2.4 Semi-Empirical Calculations

Semi-empirical equations (as presented in Table 6.3) or section factors (as presented in Figure 6.2) can be used to simplify trial and error critical depth calculations. The following equation is used to determine critical depth with the critical flow section factor, Z:

$$Z = \frac{Q}{\sqrt{g}} \tag{6.7}$$

where: Z = critical flow section factor

Q = discharge rate for design conditions (cfs)
g = acceleration due to gravity (32.2 ft/sec2)

The following guidelines are given for evaluating critical flow conditions of open channel flow:

- A normal depth of uniform flow within about 10% of critical depth is unstable and should be avoided in design, if possible.
- If the velocity head is less than one-half the mean depth of flow, the flow is subcritical.
- If the velocity head is equal to one-half the mean depth of flow, the flow is critical.
- If the velocity head is greater than one-half the mean depth of flow, the flow is supercritical.

Note: The head is the height of water above any point, plane, or datum of reference. The velocity head in flowing water is calculated as the velocity squared divided by 2 times the gravitational constant ($V^2/2g$).

The Froude number, Fr, calculated by the following equation, is useful for evaluating the type of flow conditions in an open channel:

$$\mathrm{Fr} = \frac{v}{T} \qquad (6.8)$$

where: Fr = Froude number (dimensionless)
v = velocity of flow (ft/s)

g = acceleration of gravity (32.2 ft/sec^2)
A = cross-sectional area of flow (ft^2)
T = top width of flow (ft)
Q= discharge rate for design conditions (cfs)
d = depth corresponding to velocity v (ft)

If Fr is greater than 1.0, flow is supercritical; if it is under 1.0, flow is subcritical. Fr is 1.0 for critical flow conditions.

Table 6.3 Critical Depth Equations for Uniform Flow in Selected Channel Cross Sections

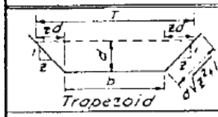
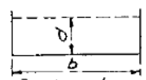
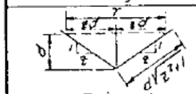
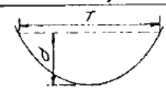
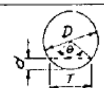
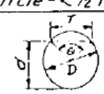
Channel Type[1]	Semi-Empirical Equations[2] for Estimating Critical Depth	Range of Applicability
1. Rectangular[3]	$d_c = [Q^2/(gb^2)]^{1/3}$	N/A
2. Trapezoidal[3]	$d_c = 0.81[Q^2/(gz^{0.75}b^{1.25})]^{0.27} - b/30z$	$0.1 < 0.5522\ Q/b^{2.5} < 0.4$ *For* $0.5522\ Q/b^{2.5} < 0.1$, *use rectangular channel equation*
3. Triangular[3]	$d_c = [(2Q^2)/(gz^2)]^{1/5}$	N/A
4. Circular[4]	$d_c = 0.325(Q/D)^{2/3} + 0.083D$	$0.3 < d_c/D < 0.9$
5. General[5]	$(A^3/T) = (Q^2/g)$	N/A

where:
d_c = critical depth (ft)
Q = design discharge (cfs)
g = acceleration due to gravity (32.2 ft/s^2)
b = bottom width of channel (ft)
z = side slopes of a channel (horizontal to vertical)
D = diameter of circular conduit (ft)
A = cross-sectional area of flow (ft^2)
T = top width of water surface (ft)

[1] See Figure 6.2 for channel sketches
[2] Assumes uniform flow with the kinetic energy coefficient equal to 1.0
[3] Reference: French (1985)
[4] Reference: USDOT, FHWA, HDS-4 (1965)
[5] Reference: Brater and King (1976)

(Source: iSWM TM, 2010)

If the water surface profile in a channel transitions from supercritical flow to subcritical flow, a hydraulic jump must occur. The location of the hydraulic jump and its sequent depth are critical to proper design of free flow conveyances. To determine the location of a hydraulic jump, the standard step method is used to compute the water surface profile and specific force (momentum principle) and specific energy relationships are used. For computational methods refer to Chow, 1959, TxDOT, 2002, and Mays, 1999. The HEC-RAS computer program can be used to compute water surface profiles for both subcritical and supercritical flow regimes.

Section	Area A	Wetted Perimeter P	Hydraulic Radius R	Top Width T	Critical Depth Factor, Z
 Trapezoid	$bd+zd^2$	$b+2d\sqrt{z^2+1}$	$\frac{bd+zd^2}{b+2d\sqrt{z^2+1}}$	$b+2zd$	$\frac{[(b+zd)d]^{1.5}}{\sqrt{b+2zd}}$
 Rectangle	bd	$b+2d$	$\frac{bd}{b+2d}$	b	$bd^{1.5}$
 Triangle	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$2zd$	$\frac{\sqrt{2}}{2}zd^{2.5}$
 Parabola	$\frac{2}{3}dT$	$T+\frac{8d^2}{3T}$ [1]	$\frac{2dT^2}{3T^2+8d^2}$ [1]	$\frac{3a}{2d}$	$\frac{2}{9}\sqrt{6}\,Td^{1.5}$
 Circle - < ½ full [2]	$\frac{D^2}{8}\left(\frac{\pi\theta}{180}-\sin\theta\right)$	$\frac{\pi D\theta}{360}$	$\frac{45D}{\pi\theta}\left(\frac{\pi\theta}{180}-\sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$	$a\sqrt{\frac{a}{D\sin\frac{\theta}{2}}}$
 Circle - > ½ full [3]	$\frac{D^2}{8}\left(2\pi-\frac{\pi\theta}{180}+\sin\theta\right)$	$\frac{\pi D(360-\theta)}{360}$	$\frac{45D}{\pi(360-\theta)}\left(2\pi-\frac{\pi\theta}{180}+\sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$	$a\sqrt{\frac{a}{D\sin\frac{\theta}{2}}}$

[1] Satisfactory approximation for the interval $0 < \frac{d}{T} \leq 0.25$
When $d/T > 0.25$, use $p = \frac{1}{2}\sqrt{16d^2+T^2} + \frac{T^2}{8d}\sinh^{-1}\frac{4d}{T}$

[2] $\theta = 4\sin^{-1}\sqrt{d/D}$
[3] $\theta = 4\cos^{-1}\sqrt{d/D}$
} Insert θ in degrees in above equations

Note: Small z = Side Slope Horizontal Distance
Large Z = Critical Depth Section Factor

Figure 6.2 Open Channel Geometric Relationships for Various Cross Sections
(Source: USDA, SCS, NEH-5 1956; iSWM TM, 2010)

6.2.5 Flow Considerations

- Channel capacity shall be determined to accommodate the discharge from a 4% design storm event (25-year) assuming ultimate ~~build-out~~ conditions for all of the contributing drainage area. In addition, the channel shall be designed to convey the 1% storm event flows generated from the developed on-site conditions and the existing off-site conditions.
- Where supercritical flow is encountered, allowances shall be made in the design for the proper handling of the water.
- Velocity of flow shall not be less than 2.5 fps for the 4% storm event.
- Maximum velocities for the design flow shall be less than the values given in Table 6.1 for the type of surface treatment(s) specified.
- Where the minimum velocities cannot be maintained or when low flows are expected on a regular basis, a concrete pilot channel or approved equal shall be constructed to convey the 50% (2-year) storm event.
- Channels shall be designed to convey the 1% storm without overtopping the channel and shall be designed with a minimum freeboard equal to one foot above the 4% chance storm design depth or 20% of the design depth, whichever is less.
- A driveable access way shall be provided in floodplain easements for the length of the easement when regular maintenance of the floodplain is required.

6.2.6 Physical Considerations

- The maximum side slope for a non-armored or reinforced open channel shall be 3H:1V unless proposed erosion control data and slope stability calculations are submitted and approved by the City Engineer.
- The minimum velocity for earthen or vegetative lined channels shall be 2.5 fps ~~longitudinal slope shall be 1% (100H:1V) for earthen or vegetative lined channels~~ to prevent formation of standing water. The slope may be reduced to less than 0.5% if a concrete pilot channel or city approved alterative is provided to convey the 5-year storm event.
- Special channel linings and energy dissipation features must be used to compensate for high velocities and hydraulic jumps associated with supercritical flow. The channel must contain the hydraulic jump throughout the extent of the supercritical profile.
- The maximum allowable deflection angle for bends in designed channels shall be 30 degrees. The outside of horizontal curves shall provide additional channel bank height and surface treatment as necessary to fully contain the design flow and prevent erosion and overtopping. Allowance for extra freeboard shall be made when the centerline radius of the channel is less than three (3) times the bottom width. Where sharp bends or high velocities are involved, the designer shall account for extra freeboard requirements using the following formula as a minimum:

$$d_2 - d_1 = \frac{V^2(T+b)}{2gR} \qquad (6.9)$$

where: d_1 = depth of flow at the inside of the bend (ft) d_2 = depth of flow at the outside of the bend (ft) b = bottom width of

channel (ft)
V = average approach velocity in the channel (ft/sec)
T = width of flow at the water surface (ft)
g = acceleration of gravity (32.2 ft/sec^2)
R = center line radius of the turn or bend (ft)

- A fifteen (15) foot access road on one side of the extreme limits of the channels is required when channels do not parallel and adjoin an alley or roadway. Where utilities are installed in the access road of the channel, the access road will be widen to seventeen (17) feet. "Extreme Limits" of the channel shall mean the side slope intercept with the natural ground or proposed finished ground elevation. Where designed channel bottoms exceed one hundred (100) feet in width, the fifteen-foot access road shall be provided on both sides of the channel. The access road will slope toward the channel with a maximum cross slope of one (1) inch per foot. Additionally, the top of utility manholes within the access road to match the finish ground surface.
- Earthen channels shall be vegetated.
- Fencing will be required adjacent to the channel where channel vertical wall heights exceed two (2) feet. Fencing will also be required adjacent to the channel where channel side slopes exceed two to one (2:1) and the channel depth is greater than two (2) feet. The fencing must not cause sight distance problems for motorists.

Interceptor Channel
Interceptor channels for proper conveyance of upstream storm water sheet flow shall be required on all subdivision plats where upstream contributing area exceeds the criteria indicated below. Interceptor channels shall be constructed prior to the issuing of building permits on any lot that would intercept natural drainage.

A. Interceptor channels shall be provided for residential subdivisions where the drainage area to the back of platted lots exceeds the depth of two (2) average residential lots with equivalent zoning.
B. Interceptor channels shall be required on nonresidential subdivision plats where the off-site drainage area contributing to the proposed development exceeds three (3) acres.

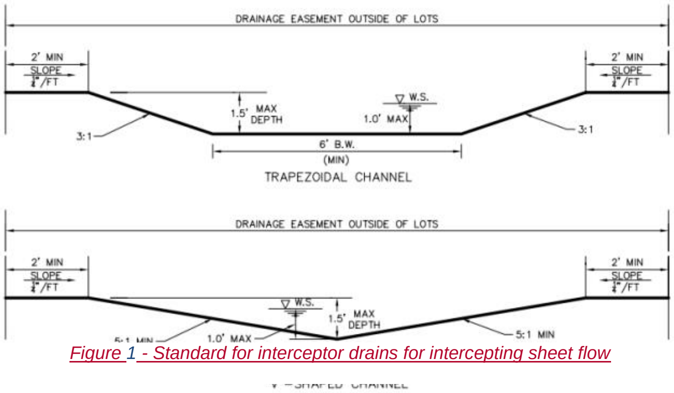


Figure 1 - Standard for interceptor drains for intercepting sheet flow

Freeboard

Drainage Freeboard for Concrete Lined and Earth Channels for Twenty-Five-Year

Design Depth of Flow	Required Freeboard
0 to 5 feet	0.5 foot
5 to 10 feet	10% of design depth
10 feet and over	1.0 foot

Maintenance Considerations

A. Access - A drivable access way shall be provided in drainage easements for the length of the easement when regular maintenance of the floodplain is required.

   Maintenance Access Right-of-Way. An unobstructed access right-of-way connecting the drainage easement with an alley or roadway parallel to or near the easement shall be provided at a minimum spacing of one (1) access right-of-way at approximately one thousand-foot intervals. The access right-of-way shall be a minimum of fifteen (15) feet in width and shall be maintained clear of obstructions that would limit maintenance vehicular access. If the flow line of the designed channel incorporates grade control structures or vehicular bridges that would prevent maintenance equipment from accessing that portion of the channel, additional access points may be required. Channel design, earthen or concrete, shall have ramps in the side slopes near the access points that would allow maintenance equipment to descend to the floor level of the channel. The maximum allowable ramp slope for vehicular access is seven to one (H7:V1). Access points adjacent to roadways or alleys shall be provided with a post and cable feature with padlock to prevent unauthorized use.

B. Schedule

   Design of new channels or alterations to existing channels shall consider future maintenance requirements. A maintenance schedule for any private channel shall be submitted to and approved by the City Engineer prior to approval of construction plans. Maintenance requirements of concrete channels consist of de-silting activities, prevention of vegetation establishment in construction joints, and repair of concrete as necessary. Maintenance of earthen channels includes regular observation and repair, as necessary, of erosion, scouring, and removal of silt deposits, as necessary to maintain design parameters. Developers shall be responsible for maintaining newly planted channels until coverage is established throughout eighty-five (85) percent of the area.

This area shall include slopes, floor, and any attendant maintenance easement. New earthen channels shall be planted with grass species. Mowing frequencies vary with the vegetation growth rates, but is required when the grass exceeds the design roughness coefficient of the channel.

6.3 CULVERTS & BRIDGES

6.3.1 General Overview

A culvert is a hydraulically short conduit, open on both ends, generally used to convey stormwater runoff through a roadway or an embankment and typically constructed without manholes, inlets, or catch basins. For economy and hydraulic efficiency, culverts are typically designed to operate with the inlet submerged during the design storm event. Bridges, on the other hand, are not covered with embankment or designed to take advantage of submergence to increase hydraulic capacity, even though some are designed to be inundated under flood conditions. According to FHWA standards, a culvert with a clear opening of more than 20-feet, measured along the center of the roadway between inside of end walls, is considered a bridge.

6.3.2 Design Considerations

The design engineer shall keep head losses and velocities within the guidelines specified in this manual and where not included shall be within generally acceptable engineering practices. This normally requires selecting a structure which creates a slight headwater (1.2 times the culvert height) and has a flow velocity at or below the allowed maximum. Velocities in culverts are normally limited to the maximum allowed in the downstream channel unless there is some form of energy dissipation at the outfall.

6.3.3 Flow Control

In the hydraulic design of culverts, an investigation must be made into the type of flow condition through the culvert. The flow will be controlled, or limited, either at the culvert entrance or the outlet, and is designated either inlet or outlet control, respectively.

Inlet Control – Inlet control occurs when the barrel capacity exceeds the culvert inlet capacity and the tailwater elevations is too low to control. In other words, the headwater depth entrance geometry at the inlet will control the amount of water entering the barrel. The roughness, length of culvert barrel, and outlet conditions do not affect capacity for culverts with inlet control.

Outlet Control – Outlet control occurs when the culvert inlet capacity exceeds the barrel capacity or the tailwater elevation causes backwater effect through the culvert. In this case, the tailwater elevation, slope, length and roughness of the culvert barrel will determine the hydraulic capacity of the culvert even though the entrance conditions are such that a larger flow could be conveyed.

Proper culvert design should include an analysis to determine whether the inlet is outlet or inlet controlled. For more information on inlet and outlet control, see TxDOT's Hydraulic Design Manual, 2011 or latest edition.

6.3.4 Design Frequency & Freeboard

The culvert(s) should be designed for the ultimate twenty-five (25) year storm if the drainage area to the culvert crossing is less than one hundred (100) acres. If the drainage area to the culvert(s) is more than one hundred (100) acres, the system should be designed for the ultimate one hundred (100) year storm. Channels upstream and downstream of culverts must contain the design storm and freeboard.

~~Freeboard, the vertical clearance between the design water surface and the lowest point of the roadway at the culvert, is included as a safety factor in the event of clogging of the culvert. One~~

~~foot (1') of freeboard above the 1% chance water surface elevation is required. Bridges shall be designed to pass the 1% storm event, fully developed watershed conditions, peak flow with two feet (2') of clearance below the lowest part of the open span of the bridge, commonly called the low chord.~~

Freeboard at a bridge is the vertical distance between the design water surface elevation and the low-chord of the bridge. The bridge low-chord is the lowest portion of the bridge deck superstructure. The purpose of freeboard is to provide room for the passage of floating debris, extra area for conveyance in the event that debris build-up on the piers reduces hydraulic capacity of the bridge, and a factor of safety against the occurrence of waves or floods larger than the design flood. The minimum freeboard is one (1) foot for the ultimate one hundred (100) year storm. For drainage areas less than one hundred (100) acres, the ultimate twenty-five (25) year storm freeboard will range from 6" to 1 ft depending on channel depth

Roadway Overtopping
Avoid overtopping of the bridge deck from a design storm. If overtopping of the bridge is possible, the design engineer should check the bridge for floatation and provide proper anchorage of the deck and super structure components.

Bridge Railing

The bridge railing should be traffic rated.

If overtopping of the bridge from a design storm is possible, the bridge railing should be design to minimize obstruction to the storm overtopping.

Should a bridge railing be on the exterior of the bridge with a sidewalk adjacent to the railing, a hand rail may be needed on top of the bridge railing.

6.3.5 Headwalls & Entrance Conditions

1. Headwalls are structural appurtenances located at the ends of a culvert that are typically formed of cast-in-place concrete. The purpose of these structures are:

    a. To retain the fill material and reduce erosion of embankment slopes.
    b. To improve hydraulic efficiency.
    c. To provide structural stability to the culvert ends and serve as a counterweight to offset buoyant or uplift forces.

2. Headwalls shall be designed to fit the conditions of the site, and constructed according to the City of Kerrville Standard Details, or the Texas Department of Highways and Public Transportation Details, unless approved otherwise by the City Engineer.

6.3.6 Outlet Velocity

The velocity in the culvert is likely to be higher than that in the channel because the culvert usually constricts the available channel area. This increased velocity can cause streambed scour and bank erosion in the vicinity of the culvert outlet. There may also be eddies resulting from flow expansion. It is important to control the amount of scour at the culvert outlet because of the possibility of undermining of the headwall and loss of support of the culvert itself. Bank erosion may threaten nearby structures and may also disrupt the stability of the channel itself.

At many locations, use of a simple outlet treatment (e.g., cutoff walls, concrete aprons, rock rubble rip-rap, other) may provide adequate protection against scour. At other locations, adjustment of the barrel slope may be sufficient to prevent damage from scour.

When the outlet velocity exceeds the erosive velocity in the downstream channel, considerations should be given to energy dissipation devices (e.g., dissipation blocks, stilling basins, rip-rap basins, etc).

7.0 INLET DESIGN

All storm sewer inlets shall be designed to capture the fully developed flows and located to comply with Section 4.0 of this manual. Figures A through O may be used to determine the capacity of specific inlets under various conditions.

The following is a list of guidelines for inlet placement:

1. The maximum length of inlets at one location along a street shall not exceed 20 feet.
2. Placing several inlets at a single location is permitted in areas with steep grades in order to reduce bypass and avoid exceeding street capacities in flatter reaches downstream.
3. To minimize water draining through an intersection, inlets should be placed upgrade from an intersection.
4. Inlets should also be located in alleys upgrade of intersections and where necessary to prevent water from entering intersections in amounts exceeding the allowed street capacity.
5. Inlets should be placed upstream from right angle turns.
6. Any discharge of concentrated flow into streets and alleys requires a hydraulic analysis of street and alley capacities.
7. Inlet boxes designed more than 4.5’ deep require a special design.
8. All “Y’ inlets and inlets 10-feet or greater shall have a minimum 21-inch lateral. All smaller inlets shall have a minimum lateral of 18-inches.
9. Inlets at a sag point require a minimum of 10-feet of opening, unless approved otherwise by

the City Engineer.
10. The end of recessed inlet boxes shall be at least 10-feet from a curb return for an intersection or driveway. The inlet shall be located to minimize interference with the use of adjacent property. Inlets shall not be located across from median openings where a future drive approach may be added.
11. Data shown at each inlet shall include storm drain stationing, size of inlet, type of inlet, top of curb elevation, throat of inlet opening, and flowline of inlet.
12. Inlet box depth shall not be less than 4-feet.
13. Interconnecting inlets on lateral shall be avoided.
14. Grate type inlets, except for combination inlets, shall be avoided.

7.1 POSITIVE OVERFLOW

The approved storm sewer system shall provide positive overflow at all Low Points. The term "Positive Overflow" means that when inlets do not function properly due to clogging or when the design capacity of the conduit is exceeded, the excess flow can be conveyed overland along an improved/armored course.

8.0 CLOSED CONDUIT SYSTEMS

All enclosed drainage systems shall be hydraulically designed using Manning's Equation:

$$Q = \frac{1.486}{n} A R^{\frac{2}{3}} \sqrt{s} \qquad (8.1)$$

where: Q = discharge rate for design conditions (cfs)
n = Manning's roughness coefficient
A = inside cross-sectional area of conduit (ft2)
R = hydraulic radius A/P (ft) [see equation 3.8]
s = slope of the energy grade line (ft/ft)

Table 8.1 provides recommended Manning's n values for different types of closed conduit materials.

Alignments of proposed storm sewer systems shall utilize existing easements and rights-of-ways where possible. No other utility parallel with the storm sewer system shall be located within 5-feet horizontally. Storm drainage systems shall be designed so that the necessary trenching will not undermine existing surface structures, utilities or trees. The minimum bury depth for storm drain systems shall be three feet (3'). Storm sewer junction structures with manhole access shall be provided as follows:

- For underground systems consisting of pipe diameters less than 48-inches shall be spaced a maximum of 500-feet apart.
- For underground systems consisting of pipe diameters 48-inches and larger shall be spaced a maximum of 1000-feet apart.

Horizontal and vertical curve design for storm sewer systems shall take into account joint closure. Half tongue exposure is the maximum opening permitted with tongue and groove pipe. Where vertical and/or horizontal alignment require greater deflection, radius pipe on curved alignment shall be used.

The minimum pipe size allowed in the City of Kerrville is 18-inches in diameter.

Table 8.1 Manning's n Values for Closed Conduits

Type of Conduit	Wall & Joint Description	Manning's n
Concrete Pipe	Good joints, smooth walls	0.012
	Good joints, rough walls	0.016
	Poor joints, rough walls	0.017
Concrete Box	Good joints, smooth finished walls	0.012
	Poor joints, rough, unfinished walls	0.018
Corrugated Metal Pipes and Boxes Annular Corrugations	2 2/3- by ½-inch corrugations	0.024
	6- by 1-inch corrugations	0.025
	5- by 1-inch corrugations	0.026
	3- by 1-inch corrugations	0.028
	6-by 2-inch structural plate	0.035
	9-by 2-1/2 inch structural plate	0.035
Corrugated Metal Pipes, Helical Corrugations, Full Circular Flow	2 2/3-by ½-inch corrugated 24-inch plate width	0.012
Spiral Rib Metal Pipe	3/4 by 3/4 in recesses at 12 inch spacing, good joints	0.013
High Density Polyethylene (HDPE)	Corrugated Smooth Liner	0.015
	Corrugated	0.020
Polyvinyl Chloride (PVC)		0.011

Source: HDS No. 5, 2001; iSWM TM, 2010

Note: For further information concerning Manning n values for selected conduits consult Hydraulic Design of Highway Culverts, Federal Highway Administration, 2001, HDS No. 5, pages 201 - 208.

8.1 HYDRAULIC GRADIENT OF CONDUITS

After computing the runoff rate to each inlet, the size and gradient of pipe required to carry the design storm must be determined. The City of Kerrville requires that all hydraulic gradient calculations begin at the outfall of the system. The following are criteria for the starting elevation of the hydraulic gradient:

1. Starting hydraulic grade at an outfall into a creek, channel or pond shall be the 1% chance storm event water surface elevation.
2. In lieu of a known or calculated 1% chance storm event water surface elevation, the starting hydraulic gradient shall not be below the top of pipe.

Calculations of the 1% storm event hydraulic grade line shall be provided on all storm sewer profiles and begin from the downstream starting hydraulic grade line elevation and progress upstream using Manning’s formula. Adjustments are made in the hydraulic grade line whenever the velocity in the line changes due to conduit size changes or discharge changes.

Hydraulic grade line "losses" or "gains" for connections, pipe size changes, and other velocity changes must be accounted for and can be calculated by the following formulas:

VELOCITY DIFFERENCE	
$V_1 < V_2$	$V_1 > V_2$
$h_j = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$ (8.2)	$h_j = \frac{V_2^2}{4g} - \frac{V_1^2}{4g}$ (8.3)

where: h_j = Head loss (Hydraulic Jump) in feet
V_1 = Upstream Velocity in fps
V_2 = Downstream Velocity in fps
g = the acceleration of gravity (32.2 ft/sec^2)

In determining the hydraulic gradient for a lateral, begin with the hydraulic grade of the trunk line at the junction plus the h_j due to the velocity change. Where the lateral is in full flow, the hydraulic grade is projected along the friction slope calculated using Manning's equation (see Equation 6.3).

Head losses at structures, such as manholes, wye branches, bends, junction boxes and inlets, shall be calculated as shown in Figures 8.1 & 8.2. The minimum head loss used at any structure shall be 0.1 feet.

The basic equation takes the form as set forth below with the various conditions of the coefficient "K_j" shown in Table 8.2.

$$h_j = \frac{V_2^2}{2g} - K_j \frac{V_1^2}{2g} \tag{8.4}$$

where: h_j = Junction or structure head loss in feet
v_1 = Velocity in upstream pipe in fps
v_2 = Velocity in downstream pipe in fps
K_j = Junction or structure coefficient of loss.

In the case where the manhole is at the very beginning of a line or the line is laid with bends or on a curve, the equation becomes the following without any velocity of approach.

$$h_j = K_j \frac{V_2^2}{2g} \tag{8.5}$$

TABLE 8.2 Junction or Structure Coefficient of Loss			
Case No.	**Reference Figure**	**Description of Condition**	**Coefficient K_j**
I	13-1	Inlet on Main Line	0.50
II	13-1	Inlet on Main Line with Branch Lateral	0.25
III	13-1	Manhole on Main Line with 45° Branch Lateral	0.50
IV	13-1	Manhole on Main Line with 90° Branch Lateral	0.25

V	13-2	45° Wye Connection or cut-in	0.75
VI	13-2	Inlet or Manhole at Beginning of Line	1.25

VII	13-2	Conduit on Curves for 90° * Curve radius = diameter Curve radius = 2 to 8 x diameter Curve radius = 8 to 20 x diameter	 0.50 0.25 0.10
VIII	13-2	Bends where radius is equal to diameter 90° Bend 60° Bend 45° Bend 22.5° Bend Manhole on line with 60° Lateral Manhole on line with 22.5° Lateral	 0.50 0.43 0.35 0.20 0.35 0.75
* Where bends or other than 90° bend coefficient can be used with the following percentage factor applied: 60° Bend = 85%, 45° Bend = 70%, 22.5° Bend = 40%			

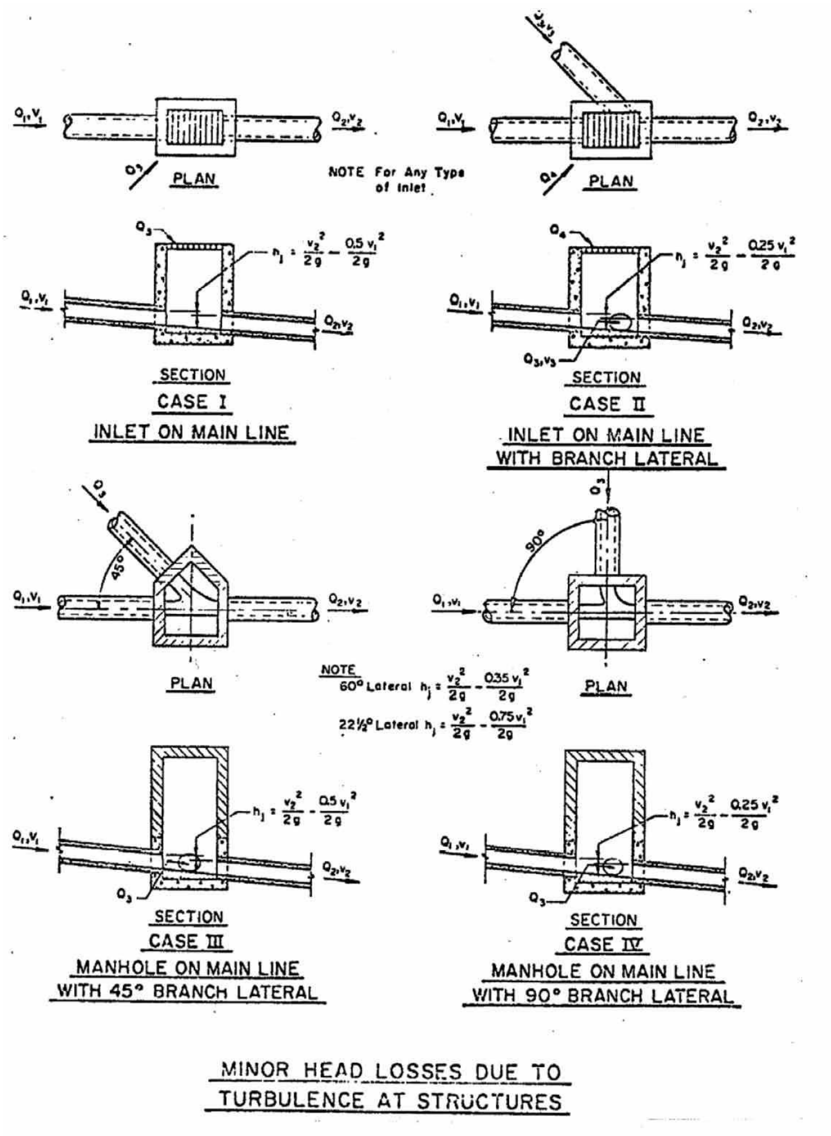

NOTE For Any Type of Inlet
PLAN
PLAN
SECTION
CASE I
INLET ON MAIN LINE
SECTION
CASE II
INLET ON MAIN LINE WITH BRANCH LATERAL
PLAN
PLAN
NOTE
60° Lateral $h_j = \frac{v_2^2}{2g} - \frac{0.35 v_1^2}{2g}$
22½° Lateral $h_j = \frac{v_2^2}{2g} - \frac{0.75 v_1^2}{2g}$
SECTION
CASE III
MANHOLE ON MAIN LINE WITH 45° BRANCH LATERAL
SECTION
CASE IV
MANHOLE ON MAIN LINE WITH 90° BRANCH LATERAL
MINOR HEAD LOSSES DUE TO TURBULENCE AT STRUCTURES

FIGURE 8.1

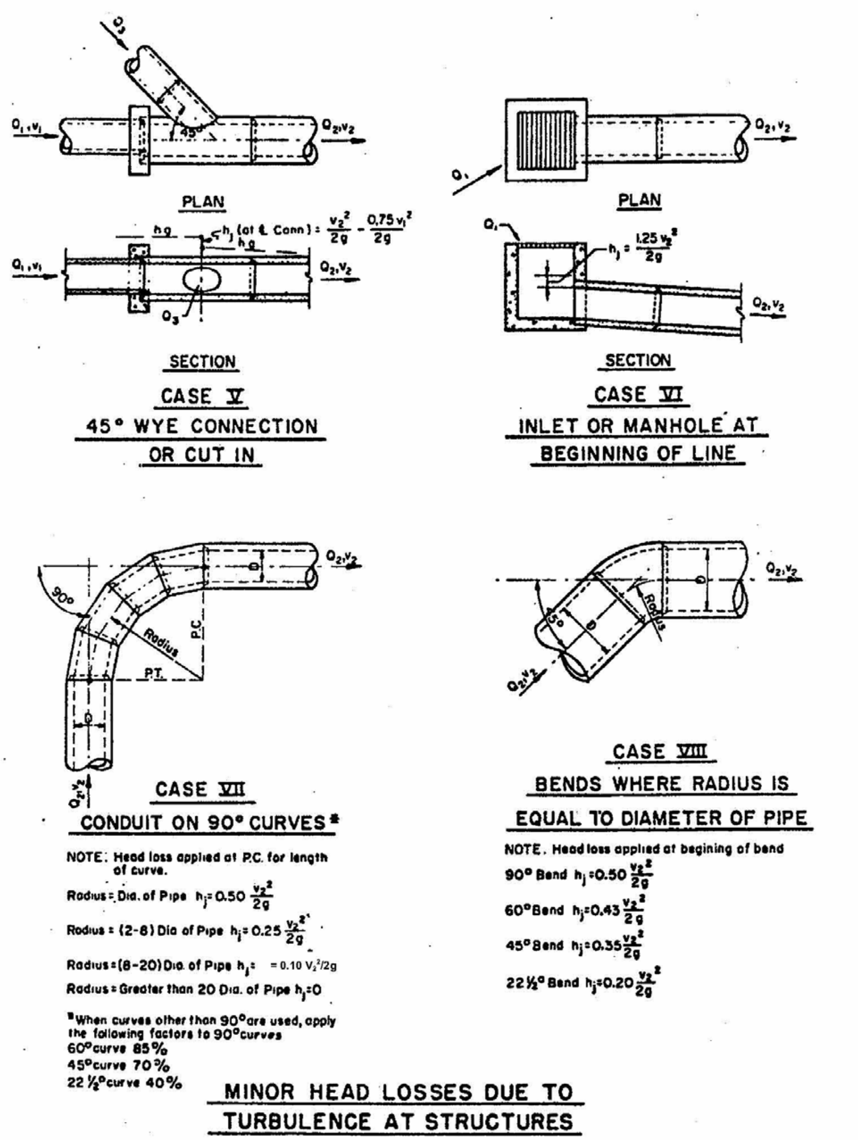

PLAN
SECTION
CASE V
45° WYE CONNECTION OR CUT IN
PLAN
SECTION
CASE VI
INLET OR MANHOLE AT BEGINNING OF LINE
CASE VII
CONDUIT ON 90° CURVES*
NOTE: Head loss applied at P.C. for length of curve.
Radius = Dia. of Pipe $h_j = 0.50 \frac{v_2^2}{2g}$
Radius = (2-8) Dia of Pipe $h_j = 0.25 \frac{v_2^2}{2g}$
Radius = (8-20) Dia. of Pipe $h_j = 0.10 V_2^2/2g$
Radius = Greater than 20 Dia. of Pipe $h_j = 0$
*When curves other than 90° are used, apply the following factors to 90° curves
60° curve 85%
45° curve 70%
22 ½° curve 40%
CASE VIII
BENDS WHERE RADIUS IS EQUAL TO DIAMETER OF PIPE
NOTE. Head loss applied at begining of bend
90° Bend $h_j = 0.50 \frac{v_2^2}{2g}$
60° Bend $h_j = 0.43 \frac{v_2^2}{2g}$
45° Bend $h_j = 0.35 \frac{v_2^2}{2g}$
22½° Bend $h_j = 0.20 \frac{v_2^2}{2g}$
MINOR HEAD LOSSES DUE TO TURBULENCE AT STRUCTURES

FIGURE 8.2

8.2 VELOCITIES AND GRADES

Storm sewer systems should operate with velocities of flow sufficient to prevent clogging. The controlling velocity is near the bottom of the conduit and considerably less than the mean velocity of the sewer. Storm drains shall be designed to have a minimum mean velocity flowing full of 2.5 fps.

The maximum velocities in storm sewer systems are important mainly due to the possibility of excessive erosion on the pipe material. To reduce this erosive potential, the City of Kerrville requires that the maximum velocity in a storm sewer system be 15 fps.

Storm sewer system discharging into an open channel or ditch shall not exceed a velocity of 6 fps without armoring and/or dissipation devices installed at the outfall.

8.X VELOCITY PROTECTION AND CONTROL DEVICES

Commented [AS6]: Recommend adding a section on velocity control devices and methods for preventing scour with energy dissipators. Reference FHWA HEC-14.

8.3 MATERIALS

Reinforced concrete pipe is the preferred pipe material for public storm sewer systems in the City of Kerrville; however, alternatives may be acceptable on a case-by case basis if approved by the City Engineer.

9.0 STORM WATER DETENTION

Storm water detention shall be provided to mitigate increased peak flows in the City of Kerrville. The purpose of the mitigation is to minimize downstream flooding impacts from upstream development. Storm water detention basins shall be categorized as (On-Site" or "Regional", where On-Site basins are those which are located off-channel and provide stormwater management for a particular project or development, and Regional basjns are designed to provide stormwater management in conjunction with other improvements on a watershed-wide basis. These categories are further subdivided into "Small" and "Large", depending on tributary area impounded volume. Small On-Site basins have drainage areas less than 25 acres, and Large On-Site basins have drainage areas between 25 and 64 acres. Small Regional basins impound up to 150 ac-ft, and Large Regional basins impound more than 150 ac-ft, with any Regional basin having an embankment over 15' categorized as large. The following criteria shall be applied in the design of storm water detention facilities:

1. A fee may be assessed by the City of Kerrville in-lieu of constructing on-site detention if there are existing facilities in place or that are proposed in the near future that would account for the increase runoff from the proposed development improvements.
2. On-site storm water detention shall be provided to control post-development runoff down to pre-development conditions. The proposed cumulative storm water discharges from a development site shall not exceed the calculated discharges under existing conditions.
3. An existing conditions drainage area map shall be provided with the civil construction plans and include the detailed calculations used to determine the existing conditions flow rate. In calculating the existing conditions flow rate, the designer shall also calculate the existing conditions travel time and plot the drainage path on the map. Reference Section 3.1 in this manual for information on calculating time of concentration.
4. Storm water detention facilities for watersheds of up to 150 acres in size shall be designed using the "Modified Rational Method" (see example below).
5. Storm water detention facilities for watersheds over 150 acres shall be designed using a detailed Unit Hydrograph method (i.e., Snyder's or SCS).

~~6.~~ A summary of the detailed detention calculations shall be provided on the construction plans. If a unit hydrograph is used to size the detention for watersheds over 150 acres, a separate report summarizing the detailed calculations shall be provided to the City for review and referenced on the construction plans. Additionally, if a HEC-HMS unit hydrograph computer model is utilized, a digital copy in HEC-HMS format shall also be provided~~.~~

6.
~~8.~~7. Stage-storage-discharge values shall be tabulated and flow calculations for discharge structures shall also be shown on the construction plans. The stage-storage-discharge values shall be provided in a table format and include stages at a maximum of 1 foot increments.
~~9.~~8. Storm water detention facilities shall be designed for the 50% (2-year), 20% (5-year), 4% (25-year), and 1% (100-year) storm events ultimate conditions.
~~10.~~9. Off-site areas draining through the proposed development site shall not be allowed to pass through the proposed on-site storm water detention facility unless the off-site area is released through the proposed detention facility at pre-development conditions and the actual travel time is considered. Otherwise, the off-site flows shall be conveyed via a separate drainage system and bypass the proposed detention facility.
10. L~~arge On-Site and Regional Storm water detention basins shall be designed with a maintenance access wide enough for a 10' wide tracked backhoe to maneuver. This generally requires a minimum of a 12' wide maintenance access be provided in all detention basins. The maximum cross slope shall not exceed 2.0% and the longitudinal slope shall not exceed 6H:1V. Basins with permanent storage (retention basins) must include dewatering facilities to provide for maintenance.~~ An unobstructed fifteen (15)-foot access easement around the periphery of the flooded area shall be dedicated as a drainage easement for facilities that require regular mowing or other ongoing maintenance, at the discretion of the Director of TCI. An unobstructed fifteen (15)-foot access right-of-way shall be established; this will connect the drainage easement adjacent to the storage facility to a road or alley.

    Access ramps with a maximum slope of seven to one (7:1), with a maximum cross slope of 2%, will be provided for access to the flow line of all storage facilities.
11. When an earthen embankment is proposed for detention, a typical embankment section and specifications for fill shall be included in the construction plans. No earthen embankment shall exceed a slope greater than 3H:1V.
12. An armored emergency spillway shall be provided above the 1% storm water surface elevation and have sufficient capacity to convey the 1% storm with the following minimum freeboard to top of embankment. The spillway design calculations shall be included in the construction plans.

DETENTION BASIN CLASS	MINIMUM FREEBOARD
On-Site Small	0.5'
On-Site Large	1.0'
Regional: Small	2.0'
Regional: Large	*

*Design storm event and required freeboard for Large Regional ponds shall be determined by a dam breach analysis based on the principles outlined in Chapter 299 of the Texas Administrative Code. The dam breach analysis shall be submitted to the City Engineer for approval.

13. Minimum crest widths for earthen embankments shall be as follows:

EMBANKMENT HEIGHT	MINIMUM CREST WIDTH
Up to 4'	3'
>4' to 6'	4'

>6’	As recommended by geotechnical engineer

14. Storm runoff may be detained within parking lots. However, the engineer should be aware of the inconvenience to both pedestrians and traffic. The location of ponding areas in a parking lot should be planned so that this condition is minimized. Stormwater ponding depths (for the 100-year storm) in parking lots are limited to an average height of ~~eight~~ four (~~8~~4) inches with a maximum of ~~twelve~~ six (~~12~~6) inches.
15. All detention basins shall be stabilized to prevent erosion. For earthen detention basins, stabilization shall be defined as the uniform establishment of perennial vegetative cover with a density of at least 70% of the native background for all unpaved areas and areas not covered by permanent structures, or equivalent permanent stabilization measures (such as the use of riprap, gabions or geotextiles) have been employed.

16. State rules and regulations regarding impoundments and dams shall be observed in the design and maintenance of storm water detention facilities.
17. Outflow structures for storm water detention facilities shall be designed so that discharge flows at a non-erosive rate.
18. An outlet control structure such as an orifice or weir placed at the inlet end of the outfall pipe is to provide an integrated stage-discharge such that a wide range of storms can be effectively controlled. Emergency overflow structures and paved positive overflow channels shall be included with the design of detention systems.
19. Whenever possible, detention basins shall fit in the natural contour of the land, be aesthetically pleasing and be free draining. A grading plan with 1-foot intervals shall be placed on the construction plans. Maintenance access shall be provided for each basin. The bottom slope shall be a minimum of 1% towards the outfall structure. Detention basins shall be designed with short and long term erosion control.
20. A detention basin maintenance plan must be submitted to the City Engineer prior to final acceptance. A sample detention basin maintenance plan is included on the following page of this manual.
21. Detention basins shall be enclosed within a detention easement and the filed easement document shall be provided to the City Engineer prior to final acceptance

DETENTION BASIN MAINTENANCE PLAN
City of Kerrville Project No.
(**Project Name**)

The following are guidelines for the overall maintenance of the detention basin.

- *Inspections*. The detention system should be inspected to assure proper operation at least 4 times annually. One of these inspections should occur during or immediately following wet weather.

- *Sediment Removal*. Remove sediment from outlet weir structure, and downstream of the outlet at least 2 times annually, or when depth reaches 3 inches. When sediment accumulation in other areas of the basin, fills the basin by 10% of the basin volume, all sediment should be removed and disposed of properly.

- *Mowing*. The side slopes, and embankment of a detention basin must be mowed regularly to discourage woody growth and control weeds. Grass areas in and around basins must be mowed at least four times annually to limit vegetation height to 12 inches. More frequent mowing to maintain aesthetic appeal may be necessary in landscaped areas. When mowing is performed, a mulching mower should be used, or grass clippings should be caught and removed.

- *Debris and Litter Removal*. Debris and litter will accumulate near the outfall weir and should be removed during regular mowing operations and inspections. Particular attention should be paid to floating debris that can eventually clog the outfall weir.

- *Erosion Control*. The pond side slopes and embankment may periodically suffer from slumping and erosion, although this should not occur often if the soils are properly compacted during construction. Regrading and revegetation may be required to correct the problems.

- *Nuisance Control*. Standing water or soggy conditions in the detention basin can create nuisance conditions for nearby residents. Odors, mosquitoes, weeds, and litter are all occasionally perceived to be problems. Most of these problems are generally a sign that regular inspections and maintenance are not being performed (e.g., mowing and debris removal).

I agree to perform the above maintenance items on the Detention Basin.

____
OWNER (Please print name)

____
DATE

____
SIGNATURE

MODIFIED RATIONAL METHOD
DETENTION BASIN DESIGN (EXAMPLE)

Given: A 10-acre site, currently pasture land with on an average slope of 5% percent, is to be developed into a single family residential subdivision (typical lot will have 60-70% impervious cover). The entire area is proposed to drain into a proposed detention basin. The existing time of concentration (Tc) has been determined to be 21 minutes and the proposed 15 minutes.

Determine: Maximum release rate and required detention storage for the 1% storm event.

Solution:

1. Determine 1% storm event's peak runoff rate prior to site development. This is the maximum allowable release rate from the site after development.
2. Determine the inflow hydrograph for storms of various durations in order to determine maximum volume required with the release rate determined in Step 1 below.
   Note: Incrementally increase durations (1-minute normally & 5-minutes maximum) to determine maximum required storage volume. The duration with a peak inflow less than maximum release rate, or where required storage is less than storage for the prior duration, is the last increment.

Step 1:
<u>Present Conditions</u> $Q = C \times I \times A$

C = 0.51
Tc = 21 min
I = 7.75 in/hr
Q = (0.51) (7.75) (10.0) = 39.5 cfs (Max allowable release rate)

Step 2:
<u>Future Conditions</u> (Single family Residential 65% Impervious Cover)

C = 0.79
Tc = 15 min
I = 9.24 in/hr
Q = (0.79) (9.24) (10.0) = 73.0 cfs

Step 3:
Check various duration storms

10 min	I = 11.11	Q= 0.79 x 11.11 x 10 = 87.8
15 min	I = 9.24	Q= 0.79 x 9.24 x 10 = 73.0
20 min	I = 7.96	Q= 0.79 x 7.96 x 10 = 62.9
25 min	I = 7.03	Q= 0.79 x 7.03 x 10 = 55.5
30 min	I = 6.31	Q= 0.79 x 6.31 x 10 = 49.9
35 min	I = 5.57	Q= 0.79 x 5.57 x 10 = 45.4
40 min	I = 5.29	Q= 0.79 x 5.29 x 10 = 41.8

Maximun Storage Volume is determined by deducting the volume of runoff released during the time of inflow from the total inflow for each duration.

Inflow = (Storm Duration) X (Respective Peak Discharge) X (60 sec/min)
Outflow = (Half of the respective inflow duration) X (control release discharge) X (60 sec/min)

10 min. Storm	Inflow 10 x 87.8 x 60 sec/min	=	52,654 cf
	Outflow 0.5 x 25 x 39.5 x 60 sec. /min	=	29,644 cf
	Storage	=	**23,010 cf**
15 min. Storm	Inflow 15 x 73.0 x 60 sec /min.	=	65,667 cf
	Outflow 0.5 x 30 x 39.5 x 60 sec. /min	=	35,573 cf
	Storage	=	**30,094 cf**
20 min. Storm	Inflow 20 x 62.9 x 60 sec /min.	=	75,456 cf
	Outflow 0.5 x 35 x 39.5 x 60 sec. /min	=	41,501 cf
	Storage	=	**33,955 cf**
25 min. Storm	Inflow 25 x 55.5 x 60 sec /min.	=	83,275 cf
	Outflow 0.5 x 40 x 39.5 x 60 sec. /min	=	47,430 cf
	Storage	=	**35,845 cf**
30 min. Storm	Inflow 30 x 49.9 x 60 sec /min.	=	89,777 cf
	Outflow 0.5 x 45 x 39.5 x 60 sec. /min	=	53,359 cf
	Storage	=	**36,419 cf**
35 min. Storm	Inflow 35 x 45.4 x 60 sec /min.	=	95,343 cf
	Outflow 0.5 x 50 x 39.5 x 60 sec. /min	=	59,288 cf
	Storage	=	**36,055 cf**
40 min. Storm	Inflow 40 x 41.8 x 60 sec /min.	=	100,210 cf
	Outflow 0.5 x 55 x 39.5 x 60 sec. /min	=	65,216 cf
	Storage	=	**34,994 cf**

Maximun Volume required is 36,419 cf at 30 min. storm duration.

10.0 MINIMUM LOT AND FLOOR ELEVATIONS

Minimum lot and floor elevations shall be established as follows:

(1) Lots abutting a natural or excavated channel shall have a minimum elevation for the buildable area of the lot at least one-foot higher than the top of channel bank or 1% storm event water surface elevation, whichever is higher.
(2) Any habitable structure on property in or abutting a floodplain shall conform to the City's Floodplain Management Ordinance. All structures must be located at least one (1) foot above the 1% storm floodplain.
(3) Where lots do not join a natural or excavated channel, minimum floor elevations shall be a minimum of one (1) foot above the street curb or edge of alley, whichever is higher. Where the intent of the development is to preserve the natural condition of the site (Tree Preservation), the finished floor elevation may be lower if approved by the City Engineer. Such approval will require special design parameters to ensure runoff from the street or alley does not flow into or across the lot.

11.0 DRAINAGE EASEMENTS

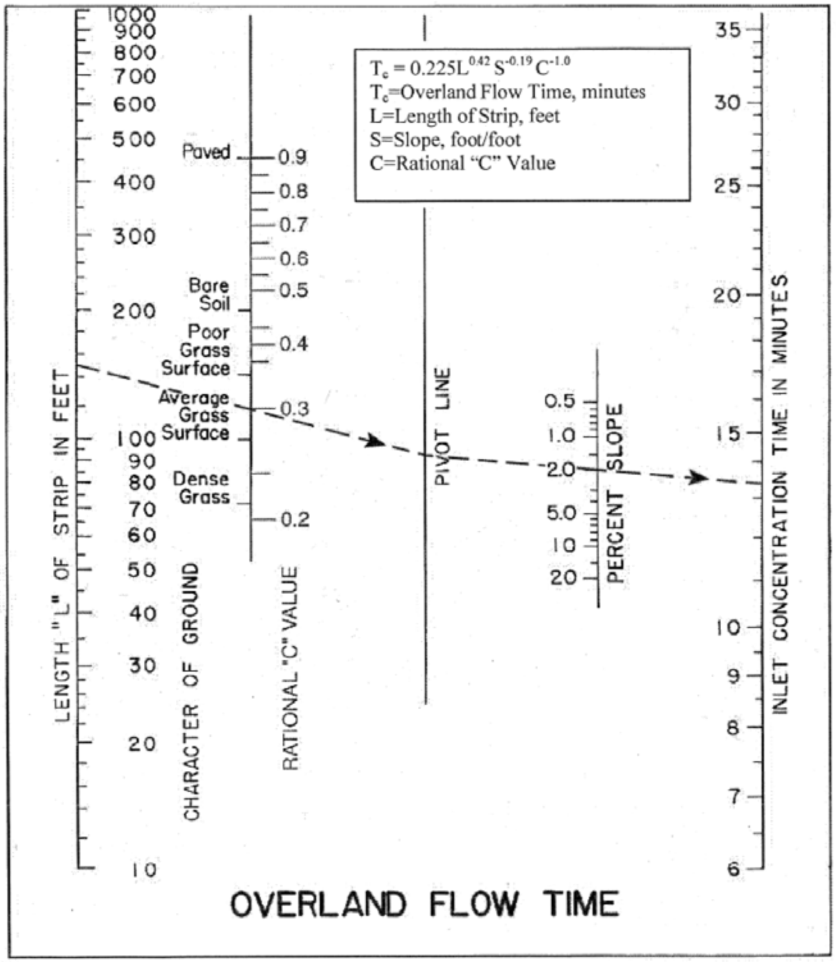
Commented [AS7]: Revisit these requirements and verify that any replatting or plats require the dedication of public drainage easements for significant waterways.

Drainage Easements shall be provided for all storm sewer systems conveying runoff from one property to another. Drainage Easements for storm sewer pipe shall not be less than 15 feet, and easement widths for open channels shall be at least 20 feet wider than the top of the channel, 15 feet of which shall be on one side to serve as an access for maintenance purposes. Where easements are proposed parallel with property lot lines, the easements shall not be allowed to straddle lot lines; instead, the easement must be located on one side of each lot.

APPENDIX A - FIGURES

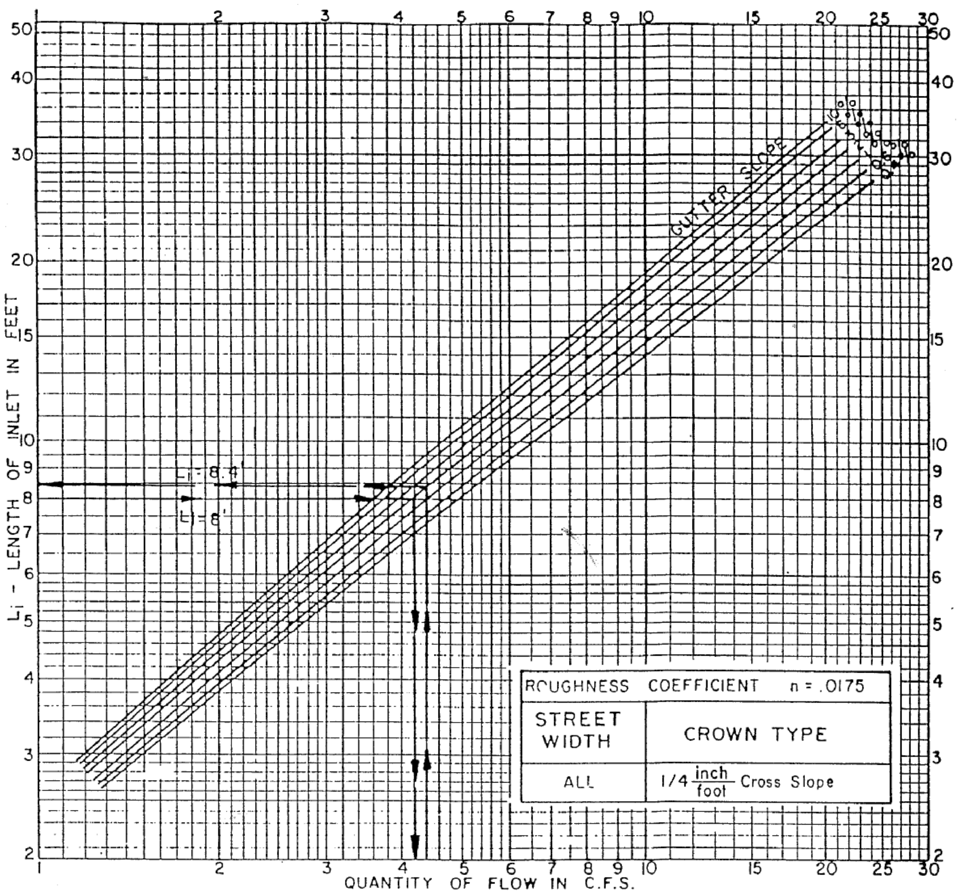
DRAINAGE DESIGN MANUAL

CITY OF KERRVILLE
KERR COUNTY
TEXAS



(Source: Data Book for Civil Engineers, Vol. I – Design, 1951)

Figure A



EXAMPLE

Known:
Pavement Width = 24'
Gutter Slope = 2.0 %
Pavement Cross Slope = 1/4" / 1'
Gutter Flow = 4.4 cfs

Find:
Length of Inlet Required (L_i)

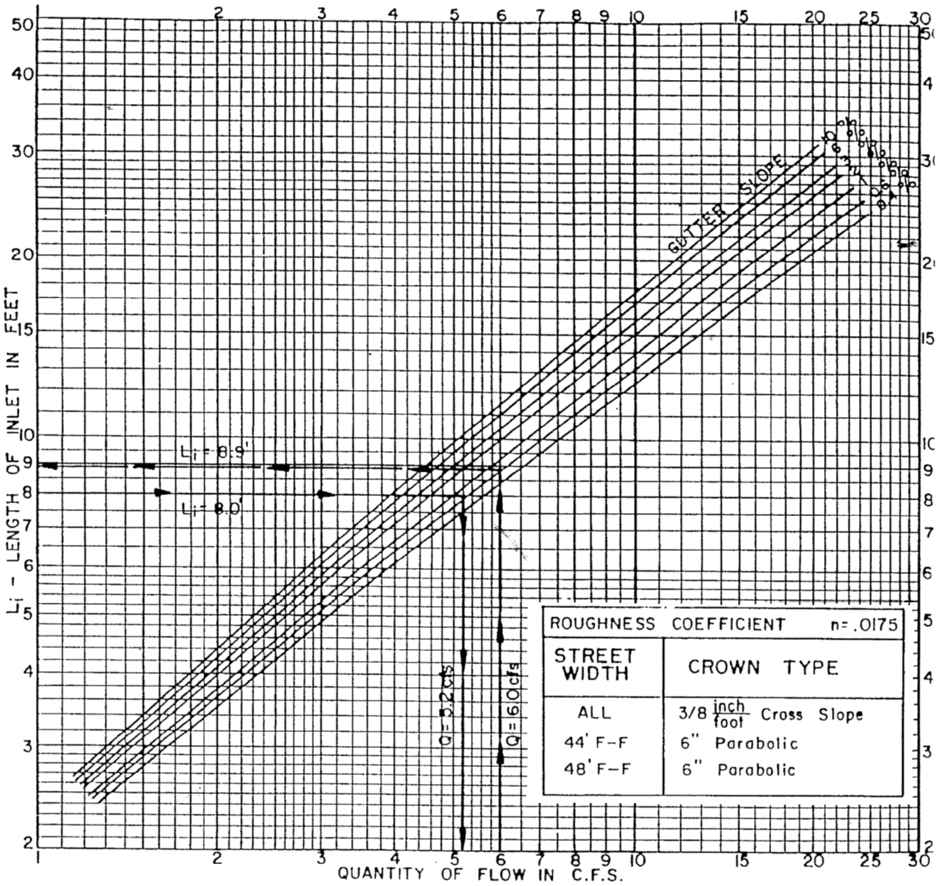
Solution:
Enter Graph at 4.4 cfs
Intersect Slope = 2.0 %
Read L_i = 8.4'

Decision:
1 Use 10' Inlet
No Flow Remains in Gutter
2 Use 8' Inlet
Intercept Only Part of Flow

Use 8' Inlet
Enter Graph at L_i = 8'
Intersect Slope = 2.0%
Read Q = 4.2 cfs
Remaining Gutter Flow =
4.4 cfs – 4.2 cfs = 0.2 cfs

RECESSED AND STANDARD CURB OPENING INLET CAPACITY CURVES ON GRADE

Figure B



EXAMPLE

Known:
- Pavement Width = 44'
- Gutter Slope = 0.6 %
- 6" Parabolic Crown
- Gutter Flow = 6.0 cfs

Find:
- Length of Inlet Required (L_i)

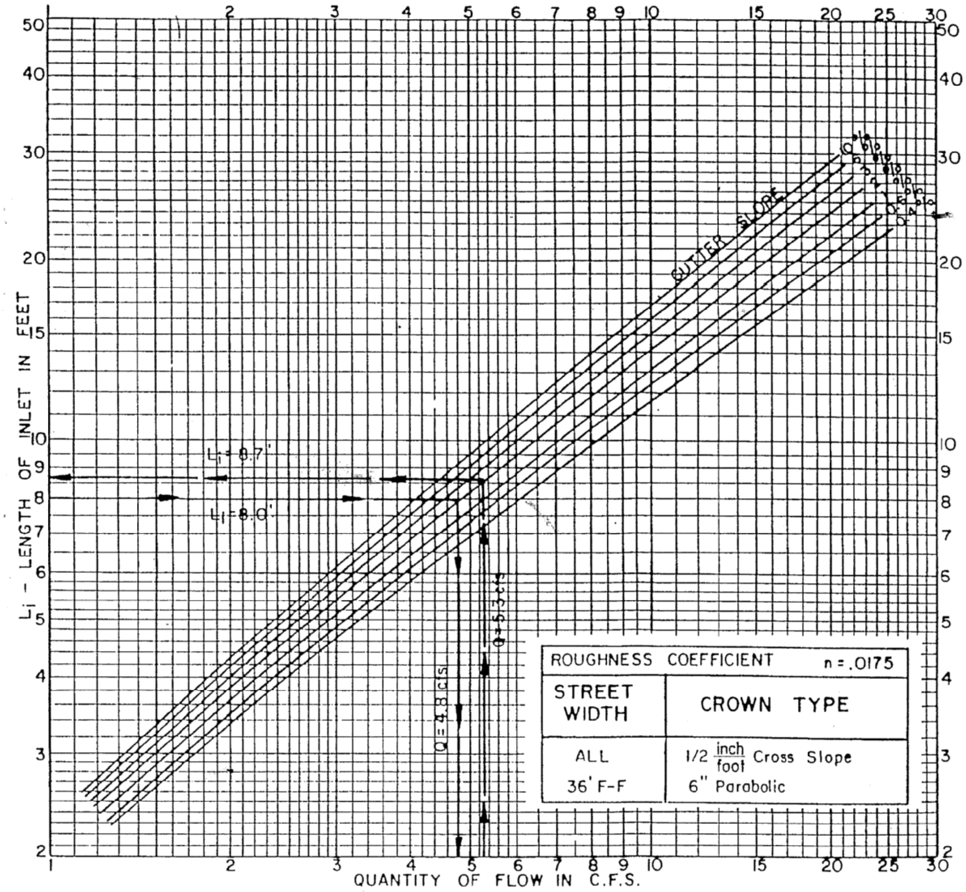
Solution:
- Enter Graph at 6.0 cfs
- Intersect Slope = 0.6 %
- Read L_i = 8.9'

Decision:
1. Use 10' Inlet
   No Flow Remains in Gutter
2. Use 8' Inlet
   Intercept Only Part of Flow

Use 8' Inlet
Enter Graph at L_i = 8'
Intersect Slope = 0.6 %
Read Q = 5.2 cfs
Remaining Gutter Flow =
6.0 cfs – 5.2 cfs = 0.8 cfs

RECESSED AND STANDARD
CURB OPENING INLET
CAPACITY CURVES
ON GRADE

Figure C



EXAMPLE

Known:
Pavement Width = 36'
Gutter Slope = 2%
6" Parabolic Crown
Gutter Flow = 5.3 cfs

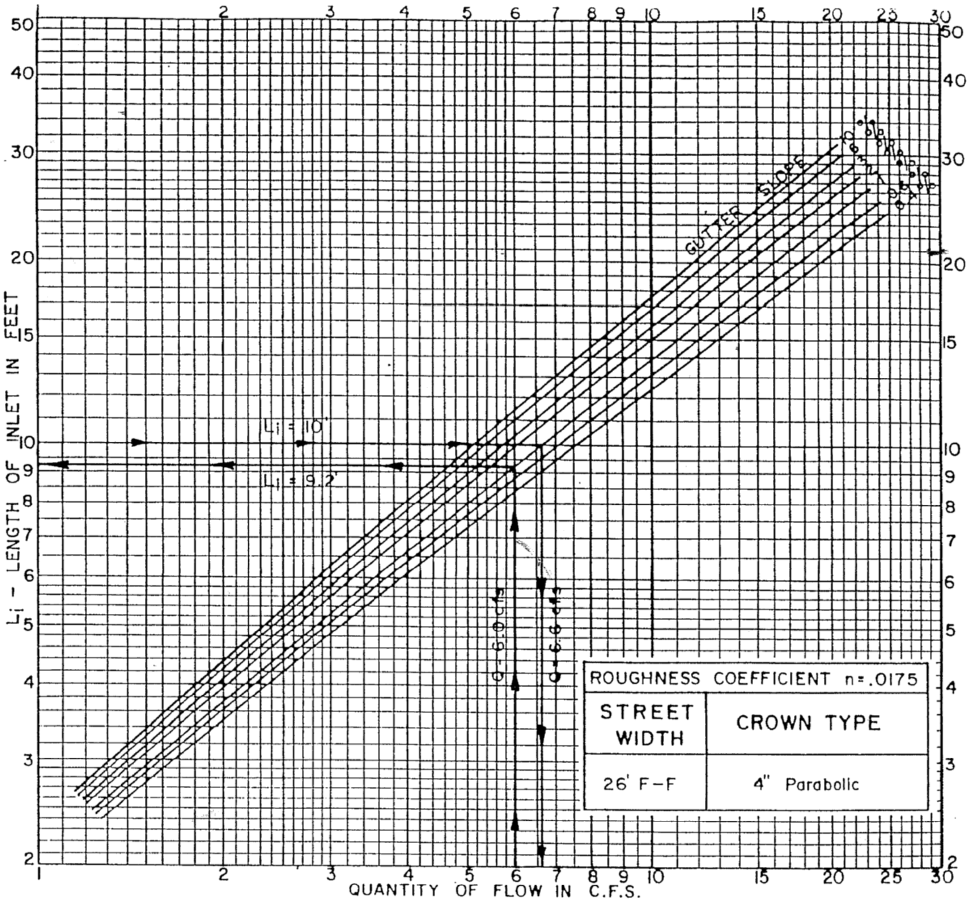
Find:
Length of Inlet Required (L_i)

Solution:
Enter Graph at 5.3 cfs
Intersect Slope = 2%
Read L_i = 8.7'

Decision:
1 Use 10' Inlet
No Flow Remains in Gutter
2. Use 8' Inlet
Intercept Only Part of Flow
Use 8' Inlet
Enter Graph at L_i = 8'
Intersect Slope = 2%
Read Q = 4.8 cfs
Remaining Gutter Flow =
5.3 cfs – 4.8 cfs = 0.5 cfs

RECESSED AND STANDARD CURB OPENING INLET CAPACITY CURVES ON GRADE

Figure D



ROUGHNESS COEFFICIENT n=.0175	
STREET WIDTH	CROWN TYPE
26' F-F	4" Parabolic

EXAMPLE

Known:
Pavement Width = 26'
Gutter Slope = 1%
4" Parabolic Crown
Gutter Flow = 6.0 cfs

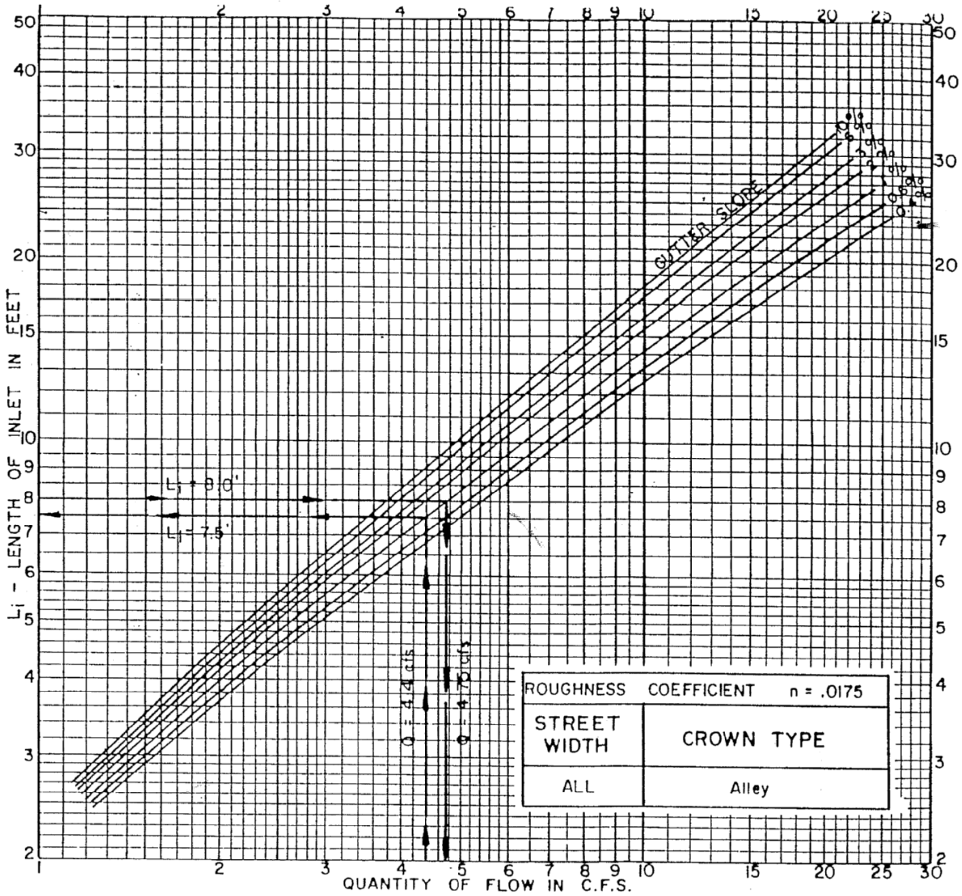
Find:
Length of Inlet Required (L_i)

Solution:
Enter Graph at 6.0 cfs
Intersect Slope = 1%
Read L_i = 9.2'

Decision:
1. Use 10' Inlet
No Flow Remains in Gutter
2. Use 8' Inlet
Intercept Only Part of Flow
Use 10' Inlet
Enter Graph at L_i = 10'
Intersect Slope = 1%
Read Q = 6.6 cfs
No Flow Remains in Gutter

RECESSED AND STANDARD CURB OPENING INLET CAPACITY CURVES ON GRADE

Figure E



ROUGHNESS COEFFICIENT n = .0175	
STREET WIDTH	CROWN TYPE
ALL	Alley

EXAMPLE

Known:
Pavement Width = 16'
Gutter Slope = 1%
Pavement Cross Slope = 1/4"/1'
Gutter Flow = 4.4 cfs

Find:
Length of Inlet Required (L_i)

Solution:
Enter Graph at 4.4 cfs
Intersect Slope = 1%
Read L_i = 7.5'

Decision:
1. Use 8' Inlet
No Flow Remains in Gutter
2. Use 6' Inlet
Intercept Only Part of Flow

Use 8' Inlet
Enter Graph at L_i = 8'
Intersect Slope = 1%
Read Q = 4.75 cfs
No Flow Remains in Gutter

RECESSED AND STANDARD
CURB OPENING INLET
CAPACITY CURVES
ON GRADE

FIGURE F

EXAMPLE

Known:

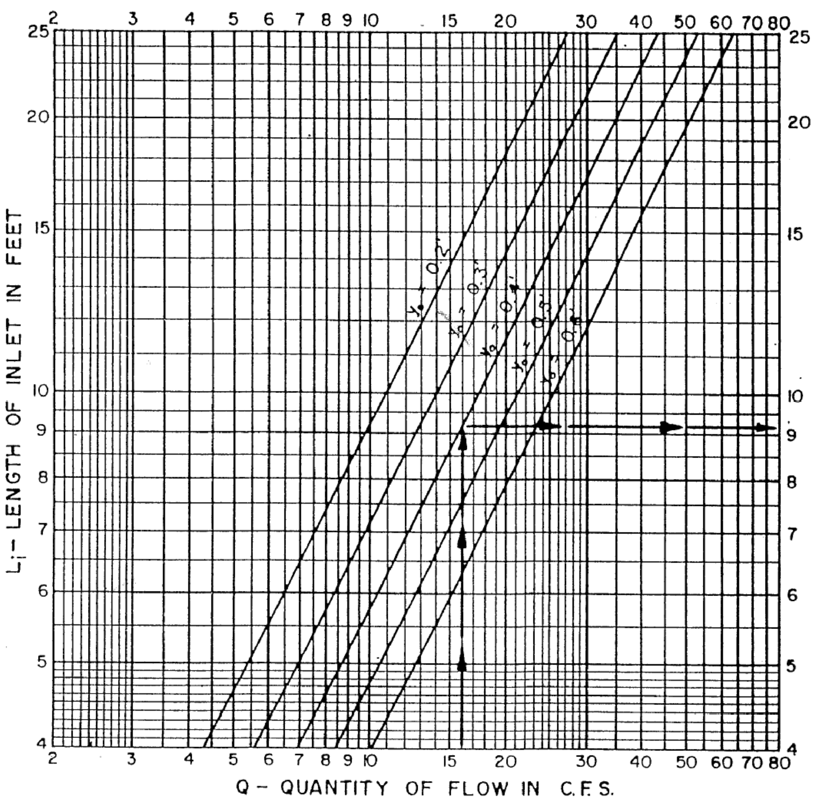
Quantity of Flow = 16.0 c.f.s.
Maximum Depth of Flow Desired in Gutter At Low Point (y_o) = 0.4'

Find:

Length of Inlet Required (L_i)

Solution:

Enter Graph at 16.0 c.f.s.
Intersect y_o = 0.4'
Read L_i = 9.2'
Use 10' Inlet



ROUGHNESS COEFFICIENT n = .0175	
STREET WIDTH	CROWN TYPE
ALL	Straight and Parabolic

RECESSED AND STANDARD CURB OPENING INLET CAPACITY CURVES AT LOW POINT

FIGURE G

EXAMPLE

Known:

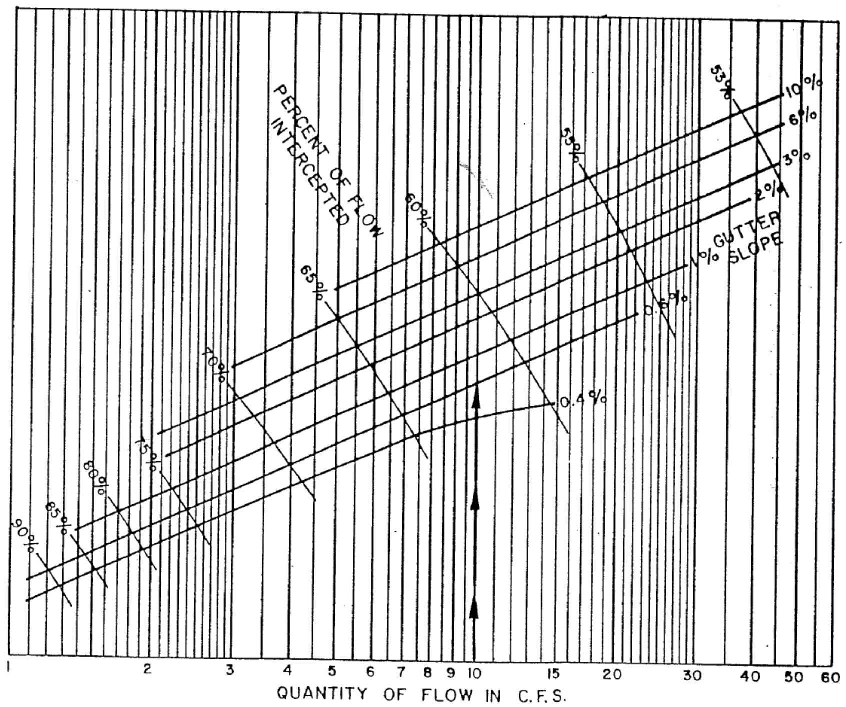
Quantity of Flow = 10.0 c.f.s.
Gutter Slope = 0.6 %

Find:

Capacity of Two Grate Combination Inlet

Solution:

Enter Graph at 10.0 c.f.s.
Intersect Slope = 0.6 %
Read Percent of Flow Intercepted = 62 %
62 % of 10.0 c.f.s. = 6.2 c.f.s. as Capacity of Two Grate Combination Inlet
Remaining Gutter Flow = 10.0 c.f.s – 6.2 c.f.s. = 3.8 c.f.s.



TWO GRATE COMBINATION INLET
CAPACITY CURVES
ON GRADE

FIGURE H

EXAMPLE

Known:

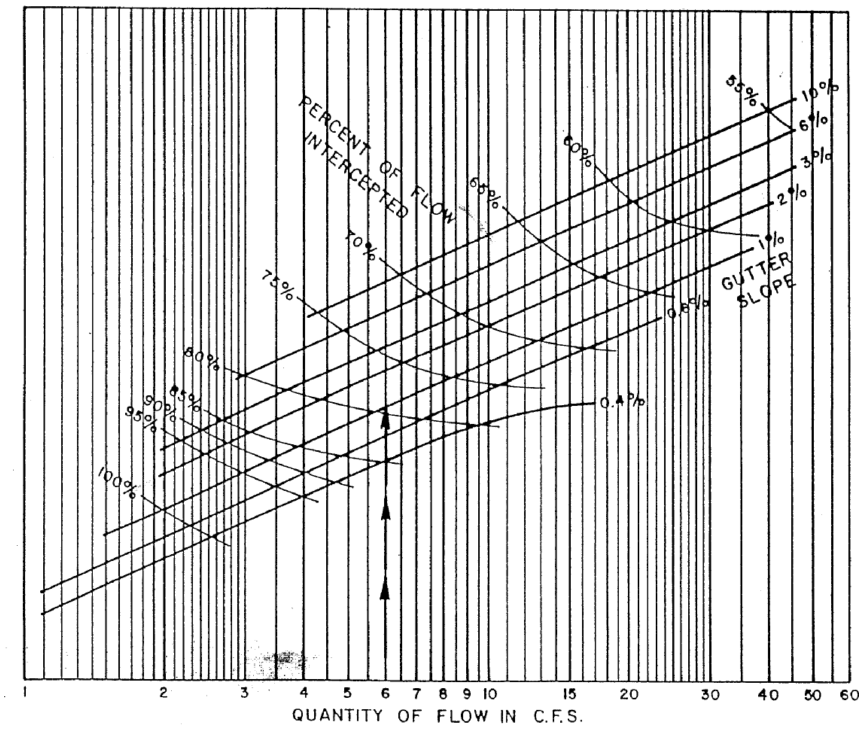
Quantity of Flow = 6.0 c.f.s.
Gutter Slope = 1.0 %

Find:

Capacity of Four Grate Combination Inlet

Solution:

Enter Graph at 6.0 c.f.s.
Intersect Slope = 1.0 %
Read Percent of Flow Intercepted = 79 %
79 % of 6.0 c.f.s. = 4.7 c.f.s. as Capacity of Four Grate Combination Inlet
Remaining Gutter Flow = 6.0 c.f.s. – 4.7 c.f.s. = 1.3 c.f.s.



FOUR GRATE COMBINATION INLET CAPACITY CURVES ON GRADE

FIGURE I

EXAMPLE

Known:

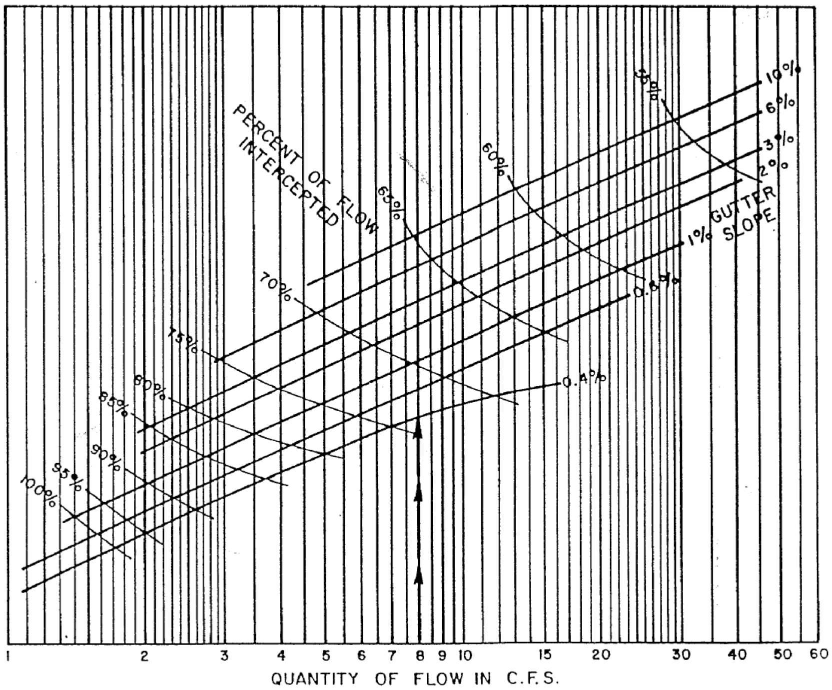
Quantity of Flow = 8.0 c.f.s.
Gutter Slope = 0.4%

Find:

Capacity of Three Grate Inlet

Solution:

Enter Graph at 8.0 c.f.s.
Intersect Slope = 0.4%
Read Percent of Flow Intercepted = 74%
74% of 8.0 c.f.s. = 5.9 c.f.s. as Capacity of Three Grate Inlet
Remaining Gutter Flow = 8.0 c.f.s. – 5.9 c.f.s. = 2.1 c.f.s.



THREE GRATE INLET AND
THREE GRATE COMBINATION INLET
CAPACITY CURVES
ON GRADE

FIGURE J

EXAMPLE

Known:

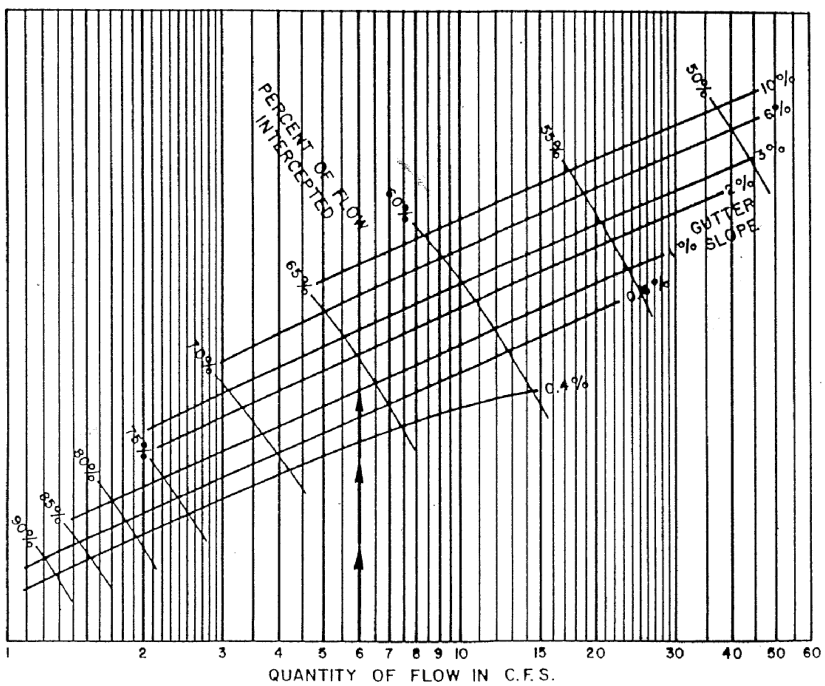
Quantity of Flow = 6.0 c.f.s.
Gutter Slope = 1.0%

Find:

Capacity of Two Grate Inlet

Solution:

Enter Graph at 6.0 c.f.s.
Intersect Slope = 1.0%
Read Percent of Flow
Intercepted = 66%
66% of 6.0 c.f.s. = 4.0 c.f.s.
as Capacity of Two Grate Inlet
Remaining Gutter Flow =
6.0 c.f.s. – 4.0 c.f.s. = 2.0 c.f.s.



TWO GRATE INLET
CAPACITY CURVES
ON GRADE

FIGURE K

EXAMPLE

Known:

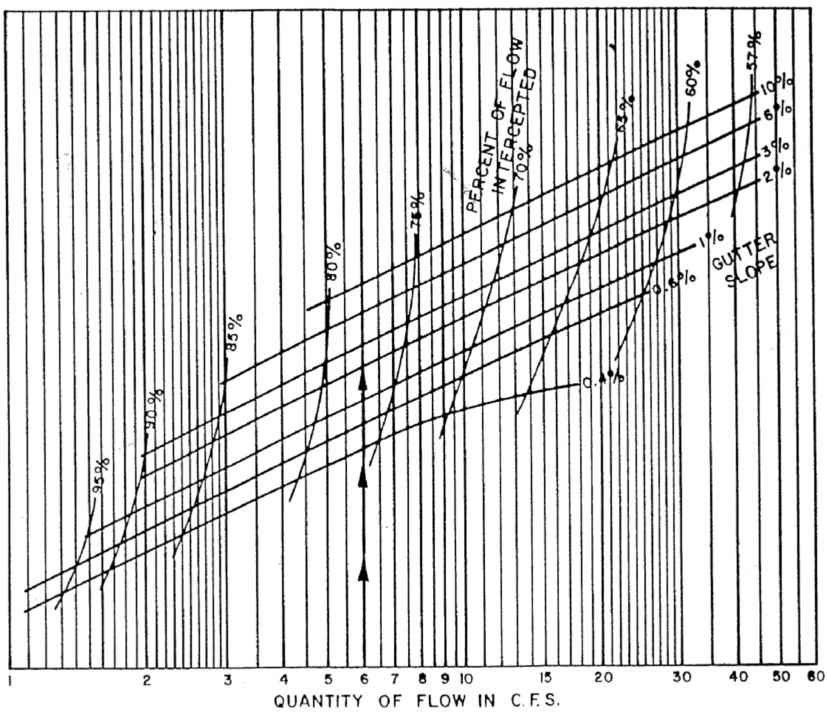
Quantity of Flow = 6.0 c.f.s.
Gutter Slope = 1.0%

Find:

Capacity of Four Grate Inlet

Solution:

Enter Graph at 6.0 c.f.s.
Intersect Slope = 1.0%
Read Percent of Flow
Intercepted = 77%
77% of 6.0 c.f.s. = 4.6 c.f.s.
as Capacity of Four Grate Inlet
Remaining Gutter Flow =
6.0 c.f.s. – 4.6 c.f.s. = 1.4 c.f.s.



FOUR GRATE INLET
CAPACITY CURVES
ON GRADE

FIGURE L

EXAMPLE

Known:

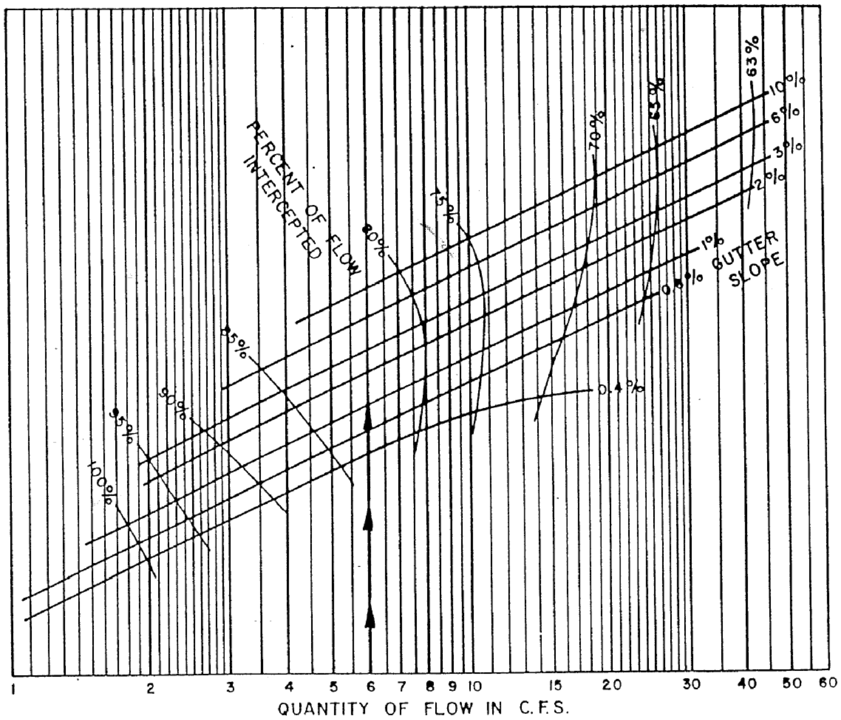
Quantity of Flow = 6.0 c.f.s.
Gutter Slope = 1.0%

Find:

Capacity of Six Grate Inlet

Solution:

Enter Graph at 6.0 c.f.s.
Intersect Slope = 1.0%
Read Percent of Flow
Intercepted = 82%
82% of 6.0 c.f.s. = 4.9 c.f.s.
as Capacity of Six Grate Inlet
Remaining Gutter Flow =
6.0 c.f.s. – 4.9 c.f.s. = 1.1 c.f.s.



SIX GRATE INLET
CAPACITY CURVES
ON GRADE

FIGURE M

EXAMPLE

Known:

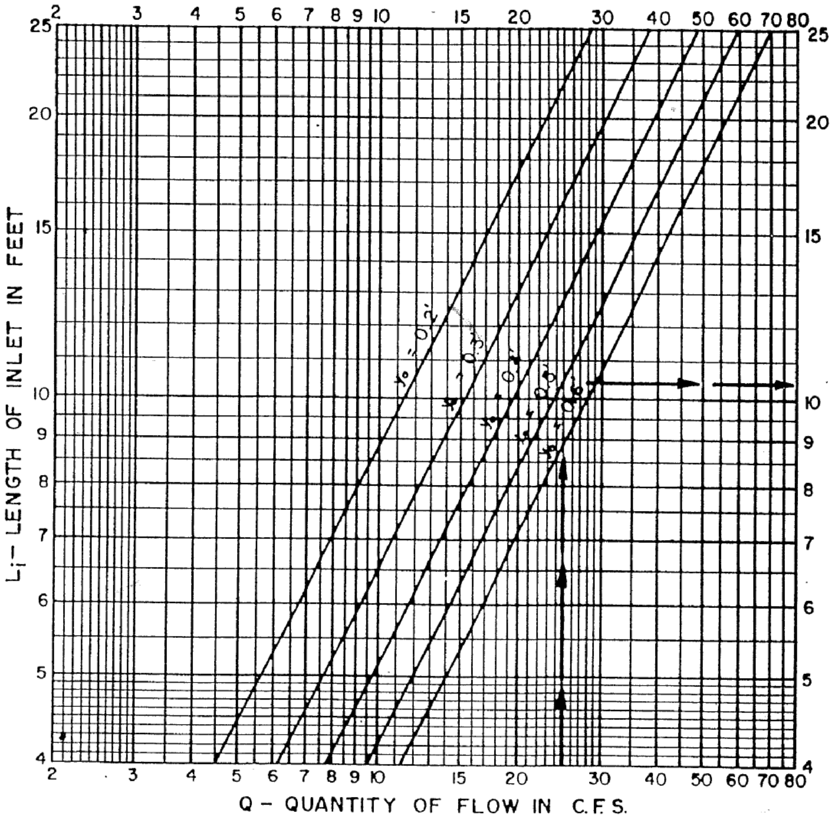
Quantity of Flow = 25.0 c.f.s.
Maximum Depth of Flow Desired
At Low Point (y_o) = 0.5'

Find:

Length of Inlet Required (L_i)

Solution:

Enter Graph at 25.0 c.f.s.
Intersect y_o = 0.5'
Read L_i = 10.4'
Use 12' Inlet



ROUGHNESS COEFFICIENT n = .0175	
STREET WIDTH	CROWN TYPE
ALL	Straight and Parabolic

COMBINATION INLET CAPACITY CURVES AT LOW POINT

FIGURE N

EXAMPLE

Known:

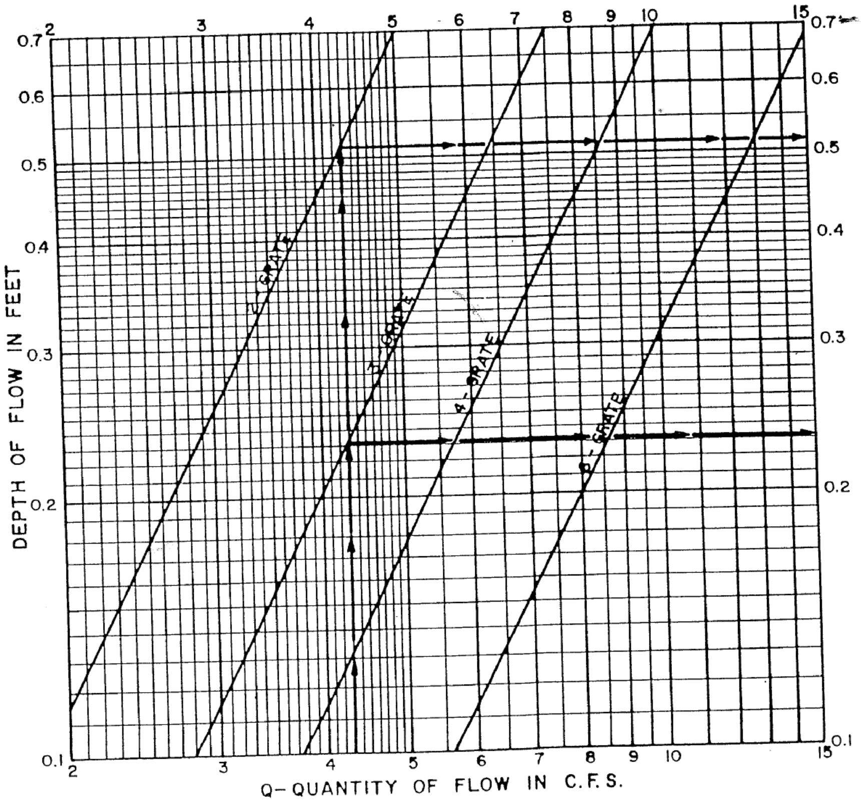
Quantity of Flow = 4.3 c.f.s.
Maximum Depth of Flow Desired at Low Point = 0.3'

Find:

Inlet Required

Solution:

Enter Graph at 4.3 c.f.s.
Intersect 3 - Grate at 0.23'
Intersect 2 - Grate at 0.51'
Use 3 - Grate



GRATE INLET
CAPACITY CURVES
AT LOW POINT

FIGURE O

EXAMPLE

Known:

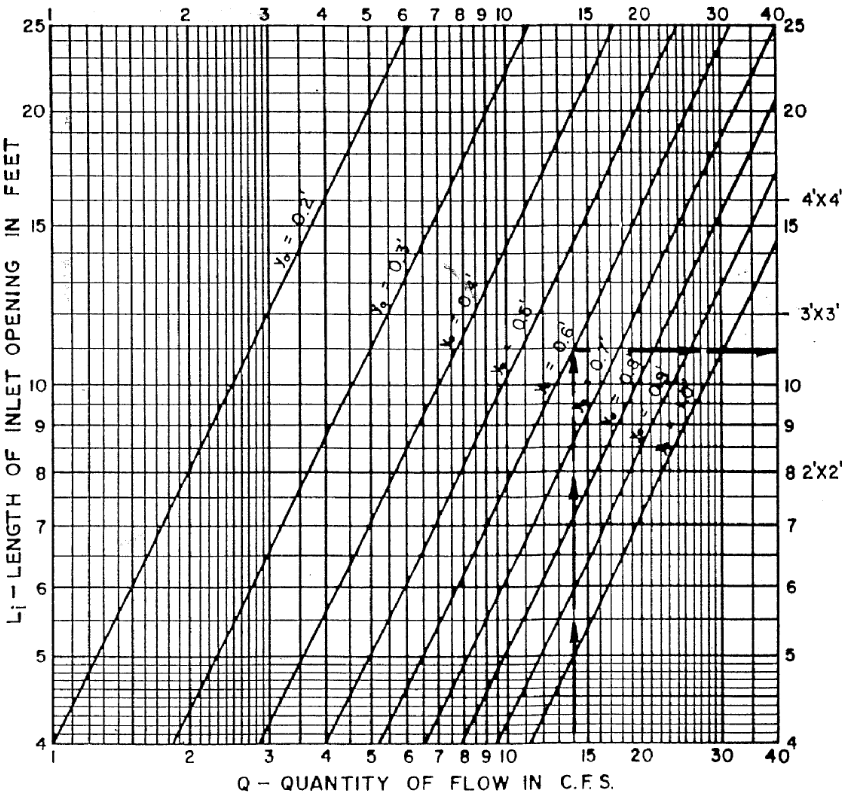
Quantity of Flow = 14.0 c.f.s.
Maximum Depth of Flow Desired (y_o) = 0.6'

Find:

Length of Inlet Opening Required (L_i)

Solution:

Enter Graph at 14.0 c.f.s.
Intersect y_o = 0.6'
Read L_i = 10.9'
Use 12' of Inlet ; 3'X 3'



Standard Drop Inlet Sizes:
2'X 2' ; Li = 8'
3'X 3' ; Li = 12'
4'X 4' ; Li = 16'

DROP INLET
CAPACITY CURVES
AT LOW POINT

FIGURE P

APPENDIX B - REFERENCES

DRAINAGE DESIGN MANUAL

CITY OF KERRVILLE
KERR COUNTY
TEXAS

APPENDIX B – REFERENCES

Commented [AS8]: Update references.

The following sources were references were consulted directly or indirectly by reference in the development of this manual:

North Central Texas Council of Governments (NCTCOG), Draft integrated Storm Water Management (iSWM) Design Manual for Development/Redevelopment, 2004.

North Central Texas Council of Governments (NCTCOG), integrated Storm Water Management (iSWM) Technical Manual, 2010.

U.S. Geological Survey (USGS) & Texas Department of Transportation (TxDOT), Study of Depth-Duration Frequency of Precipitation for Texas, 1998.

Texas Department of Transportation (TxDOT), Hydraulic Design Manual, 2011.

City of Austin, Texas, Drainage Criteria Manual, 2007.

City of Dallas, Texas, Drainage Design Manual, 1993.

City of San Antonio, Texas, Unified Development Code, 2005.

U.S. Army Corps of Engineers (USACE), Hydrologic Modeling System HEC-HMS Technical Reference Manual, 2000.

City of Bryan, City of College Station, Texas, Unified Stormwater Design Guidelines, 2009.

City of Kerrville, Texas, Draft Drainage Design Manual, 2011.

Federal Highway Administration (FHWA), Hydraulic Design of Highway Culverts, Hydraulic Design Series Number 5, 2005.

APPENDIX D - TECHNICAL SUPPORT DATA – PART 1

Methodology for Drainage Analysis for City of Kerrville Stormwater Masterplan

1) Hydrologic Analysis

The hydrologic analysis performed in this study is approximate and intended for planning purposes only to determine peak flows at problem areas and determining the feasible design alternatives to mitigate the flooding occurring, occasional street ponding, and to upgrade existing storm drain network in the City of Kerrville, Tx.

The hydrologic analysis was primarily performed using rational peak flow analysis except for Kroc Center and Clay Street drainage calculation. In the drainage analysis, contributing drainage basin areas range from 6.36 acres to 6734 acres. Considering terrain diversity at problem locations, drainage design approaches vary according to the contributing drainage area at study location, and existing drainage structures located within the drainage basin. Preferably, for drainage areas less than 150 acres, rational method is used to determine peak flow contributed by the basin at the outlet. Rational method focuses on runoff coefficient, rainfall intensities, and drainage areas.

$$Q = C \times I \times A$$

Where,
Q: Peak Discharge (cfs)
C: Runoff Coefficient
I: Rainfall Intensity (inch/hour)
A: Drainage Area (Acres)

Travel time was calculated for each basin considering sheet, shallow and channel flows types. Manning roughness values and terrain slope is considered to determine Time of Concentration (TC) as depicted in TR-55 manual. Basin Lag Times were derived based on 0.6 multiplied by the calculated Time of Concentration. Time of concentration calculations were performed for both existing and proposed situations. Considering future developments in the study region, drainage calculations use TC values for ultimate conditions.

No previous existing conditions hydrologic models were available for the Quinlan Creek, Town Creek, and Guadalupe River. Therefore, a cursory hydrologic analysis was performed using the United States Army Corps of Engineers (USACE) HEC-HMS and XpStorm software for Kroc Center and Clay Street. Hydrologic model parameters were developed using the best available data obtained from previous studies, aerial imagery, various topographic mapping sources such as Texas Natural Resources Information System (TNRIS).

Stormwater discharges for Kroc Center and Clay Street were computed using the Soil Conservation Services (SCS) Unit Hydrograph method. The SCS Runoff Curve Numbers (CN) were calculated using the National Resource Conservation Services (NRCS) soil type data in conjunction with the CN values outlined in Table 2-2a of the U.S. Department of Agriculture Technical Release No. 55, Urban Hydrology for Small Watersheds (TR-55) and the City of Cibolo's Stormwater Design Guidelines Manual Table C-7. See the following section for the table of values utilized by this study. Composite Curve Numbers for each sub-basin were computed using hydrologic soil types and existing land use conditions for the watershed under AMC II conditions. The existing land use was determined using the aerial imagery. Primarily, the study area consists of hydrologic soil types C and D. Hydrologic soil types were delineated based on the USDA-NRCS Soil Survey Division's Soil Map for Kerr County.

SCS runoff method considers the initial abstraction for each basin to determine excess runoff. The initial abstraction defines the amount of precipitation that must fall before surface excess results and is only applied to the previous portion of the basin if the percent impervious is specified. The initial abstraction was calculated as 0.2 times the potential retention, which is based on the Curve Number value. The methodology is outlined in the U.S. Department of Agriculture, Technical Release No. 55, Urban Hydrology for Small Watersheds.

Preliminary XpStorm model was created to analyze the Kroc Center detention pond and evaluate the downstream drainage conditions due to continuous discharge from the pond outlet. Surface runoff from 18" and 24" outlet structure was modeled for 25- and 100-year storm event. XpStorm model was further extended to determine adverse effects on Clay Street drainage conditions.

No hydrologic analysis was performed for low water crossing, instead, the hydraulic model was developed using HEC-RAS software and FEMA FIS flows to analysis flooding situations at First Street, Fourth Street, and Park Street low water crossings. See Hydraulic Analysis section for more information.

Runoff Coefficient (C) Calculations									
		Existing Conditions				Ultimate Conditions			
Drainage ID	Street Name	Landuse (Existing)	Area (Acres)	Runoff Coe.	Weighted Runoff (Existing)	Landuse (Ultimate)	Area (Acres)	Runoff Coe.	Weighted Runoff (Ultimate)
DA_CS	Coronado St.	Poor Condition Grass Area	0.4	0.53	0.93	Average Regional Commercial	0.4	0.95	0.95
		Average Regional Commercial	7.23	0.95		Average Regional Commercial	7.5	0.95	
DA_TD	Thompson Dr. (Coronado)	Flat Single Family Residential	0.9	0.6	0.64	Flat Single Family Residential	0.9	0.6	0.92
		Flat Cultivated	7.2	0.47		Flat Regional Commercial	7.2	0.94	
		Flat Regional Commercial	4.24	0.94		Flat Regional Commercial	4.24	0.94	
DA_HS	Harper St.	Average Single Family Residential	13.11	0.66	0.66	Average Single Family Residential	13.11	0.66	0.66
DA_CA	Harper St. - Circle Ave.	Average Single Family Residential	14.33	0.66	0.66	Average Single Family Residential	14.33	0.66	0.69
		Average Retail/Office/Light Commercial	3.47	0.87		Average Retail/Office/Light Commercial	3.47	0.87	
		Average Fair Condition Grass	4.78	0.49		Average Single Family Residential	4.78	0.66	
DA_HC	Hill Country	Steep Single Family Residential	0	0.69	0.84	Steep Single Family Residential	0	0.69	0.89
		Steep Good Condition Grass	5.61	0.51		Steep Single Family Residential	5.61	0.69	
		Average Regional Commercial	17.66	0.95		Average Regional Commercial	17.66	0.95	
DA_HC1	Hill Country	Steep Single Family Residential	0	0.69	0.95	Steep Single Family Residential	0	0.69	0.95
		Steep Good Condition Grass	0	0.51		Steep Single Family Residential	0	0.69	
		Average Regional Commercial	4.56	0.95		Average Regional Commercial	4.56	0.95	
DA_TE	Easy Drain Channel	Flat Regional Commercial	16.43	0.94	0.83	Flat Regional Commercial	16.43	0.94	0.83
		Average Multifamily Residential	40.6	0.79		Average Multifamily Residential	40.6	0.79	
	Easy Drain Channel Bypass	Average Single Family Residential	95.4	0.66	0.69	Average Single Family Residential	95.4	0.66	0.73
		Average Good Condition Grass	10.85	0.46		Average Regional Commercial	10.85	0.95	
		Average Regional Commercial	21.1	0.95		Average Regional Commercial	21.1	0.95	
DA_LS	Lois St.	Average Single Family Residential	100.55	0.66	0.69	Average Single Family Residential	100.55	0.66	0.73
		Average Good Condition Grass	10.91	0.46		Average Regional Commercial	10.91	0.95	
		Average Regional Commercial	23.35	0.95		Average Regional Commercial	23.35	0.95	
DA_LS1	Lois St.	Average Single Family Residential	6.36	0.66	0.66	Average Single Family Residential	6.36	0.66	0.66

Runoff Coefficient (C) Calculations									
		Existing Conditions				Ultimate Conditions			
Drainage ID	Street Name	Landuse (Existing)	Area (Acres)	Runoff Coe.	Weighted Runoff (Existing)	Landuse (Ultimate)	Area (Acres)	Runoff Coe.	Weighted Runoff (Ultimate)
DA_JD	Jack Drive	Average Single Family Residential	16.52	0.66	0.59	Average Single Family Residential	16.52	0.66	0.66
		Average Fair Condition Grass	10.76	0.49		Average Single Family Residential	10.76	0.66	
DA_KC	Kroc Center	Average Single Family Residential	33.62	0.66	0.62	Average Single Family Residential	62.39	0.66	0.76
		Flat Good Condition Grass	9.28	0.36		Flat Good Condition Grass	9.28	0.36	
		Average Good Condition Grass	43.71	0.46		Average Retail/Office/Light Commercial	51.49	0.87	
		Average Retail/Office/Light Commercial	32.84	0.87		Average Retail/Office/Light Commercial	32.84	0.87	
DA_HY	Kroc Center	Average Single Family Residential	28.77	0.66	0.62	Average Single Family Residential	28.77	0.66	0.66
		Average Good Condition Grass	7.78	0.46		Average Single Family Residential	7.78	0.66	
DA_PT	East Main to Pinto Trail (Channel Begin)	Average Single Family Residential	51.98	0.66	0.61	Average Single Family Residential	51.98	0.66	0.66
		Average Good Condition Grass	15.43	0.46		Average Single Family Residential	15.43	0.66	
	East Main to Pinto Trail (Channel End)	Flat Single Family Residential	11.8	0.6	0.53	Flat Single Family Residential	11.8	0.6	0.60
		Flat Pasture/Range	6.62	0.41		Flat Single Family Residential	6.62	0.6	
DA_FO	Fourth St. Low Water Crossing	Flat Forest Woodlands	5596	0.39	0.43	Flat Single Family Residential	5596	0.6	0.60
		Flat Single Family Residential	1137.51	0.6		Flat Single Family Residential	1137.51	0.6	
DA_FI	First St. Low Water Crossing	Average Forest Woodlands	73.75	0.47	0.59	Average Single Family Residential	73.75	0.66	0.66
		Average Single Family Residential	122.49	0.66		Average Single Family Residential	122.49	0.66	
DA_PS	Park St. Low Water Crossing	Flat Single Family Residential	218.5	0.6	0.64	Flat Single Family Residential	218.5	0.6	0.70
		Flat Retail/Office/Light Commercial	93.43	0.85		Flat Retail/Office/Light Commercial	93.43	0.85	
		Flat Fair Condition Grass	42.14	0.41		Flat Retail/Office/Light Commercial	42.14	0.85	
DA_SS	Spring St. Erosion Outfall	Flat Regional Commercial	34.78	0.94	0.94	Flat Regional Commercial	34.78	0.94	0.94
DA_CS	Clay St.	Flat Regional Commercial	24.04	0.94	0.94	Flat Regional Commercial	24.04	0.94	0.94
	Clay St. (Bypass)	Flat Regional Commercial	10.03	0.94	0.94	Flat Regional Commercial	10.03	0.94	0.94

Curve Number (CN) Value Calculation									
Drainage ID	Street Name	Existing Conditions				Ultimate Conditions			
		Landuse (Existing)	Area (Acres)	CN	Weighted CN (Existing)	Landuse (Ultimate)	Area (Acres)	CN	Weighted CN (Ultimate)
DA_CS	Coronado St.	Fair Condition Open Space	0.4	79	93.2	Commercial and Business	0.4	94	94.0
		Commercial and Business	7.23	94		Commercial and Business	7.5	94	
DA_TD	Thompson Dr. (Coronado)	1/4 Acre Residential District	0.9	83	81.5	1/4 Acre Residential District	0.9	83	93.2
		Good Condition Open Space	7.2	74		Commercial and Business	7.2	94	
		Commercial and Business	4.24	94		Commercial and Business	4.24	94	
DA_HS	Harper St.	1/4 Acre Residential District	13.11	87	87.0	1/4 Acre Residential District	13.11	87	87.0
DA_CA	Harper St. - Circle Ave.	1/4 Acre Residential District	14.33	87	87.6	1/4 Acre Residential District	14.33	87	88.2
		Commercial and Business	3.47	95		Commercial and Business	3.47	95	
		Fair Condition Open Space	4.78	84		1/4 Acre Residential District	4.78	87	
DA_HC	Hill Country	1/4 Acre Residential District	0	83	89.9	1/4 Acre Residential District	0	83	92.1
		Good Condition Open Space	5.61	74		1/4 Acre Residential District	5.61	83	
		Commercial and Business	17.66	95		Commercial and Business	17.66	95	
DA_HC1	Hill Country	1/4 Acre Residential District	0	83	95.0	1/4 Acre Residential District	0	83	95.0
		Good Condition Open Space	0	74		1/4 Acre Residential District	0	83	
		Commercial and Business	4.56	95		Commercial and Business	4.56	95	
DA_TE	Easy Drain Channel	Commercial and Business	16.43	95	85.7	Commercial and Business	16.43	95	85.7
		2 Acre Residential Destrict	40.6	82		2 Acre Residential Destrict	40.6	82	
	Easy Drain Channel Bypass	1/4 Acre Residential District	95.4	87	87.7	1/4 Acre Residential District	95.4	87	89.0
		Good Condition Open Space	10.85	80		Commercial and Business	10.85	95	
		Commercial and Business	21.1	95		Commercial and Business	21.1	95	

Curve Number (CN) Value Calculation									
Drainage ID	Street Name	Existing Conditions				Ultimate Conditions			
		Landuse (Existing)	Area (Acres)	CN	Weighted CN (Existing)	Landuse (Ultimate)	Area (Acres)	CN	Weighted CN (Ultimate)
DA_LS	Lois St.	1/4 Acre Residential District	100.55	87	87.8	1/4 Acre Residential District	100.55	87	89.0
		Good Condition Open Space	10.91	80		Commercial and Business	10.91	95	
		Commercial and Business	23.35	95		Commercial and Business	23.35	95	
DA_LS1	Lois St.	1/4 Acre Residential District	6.36	87	87.0	1/4 Acre Residential District	6.36	87	87.0
DA_JD	Jack Drive	1/4 Acre Residential District	16.52	87	85.8	1/4 Acre Residential District	16.52	87	87.0
		Fair Condition Open Space	10.76	84		1/4 Acre Residential District	10.76	87	
DA_KC	Kroc Center	1/4 Acre Residential District	33.62	83	83.9	1/4 Acre Residential District	62.39	83	88.4
		Good Condition Open Space	9.28	74		Good Condition Open Space	9.28	74	
		Fair Condition Open Space	43.71	79		Commercial and Business	51.49	94	
		Commercial and Business	32.84	94		Commercial and Business	32.84	94	
DA_HY	Kroc Center	1/4 Acre Residential District	28.77	83	81.1	1/4 Acre Residential District	28.77	83	83.0
		Good Condition Open Space	7.78	74		1/4 Acre Residential District	7.78	83	
DA_PT	East Main to Pinto Trail (Channel Begin)	1/4 Acre Residential District	51.98	87	85.4	1/4 Acre Residential District	51.98	87	87.0
		Good Condition Open Space	15.43	80		1/4 Acre Residential District	15.43	87	
	East Main to Pinto Trail (Channel End)	1/4 Acre Residential District	11.8	87	84.5	1/4 Acre Residential District	11.8	87	87.0
		Good Condition Open Space	6.62	80		1/4 Acre Residential District	6.62	87	

Curve Number (CN) Value Calculation									
Drainage ID	Street Name	Existing Conditions				Ultimate Conditions			
		Landuse (Existing)	Area (Acres)	CN	Weighted CN (Existing)	Landuse (Ultimate)	Area (Acres)	CN	Weighted CN (Ultimate)
DA_FO	Fourth St. Low Water Crossing	Woods Grass Combination (Good)	5596	79	80.4	1/4 Acre Residential District	5596	87	87.0
		1/4 Acre Residential District	1137.51	87		1/4 Acre Residential District	1137.51	87	
DA_FI	First St. Low Water Crossing	Woods Grass Combination (Good)	73.75	72	78.9	1/4 Acre Residential District	73.75	83	83.0
		1/4 Acre Residential District	122.49	83		1/4 Acre Residential District	122.49	83	
DA_PS	Park St. Low Water Crossing	1/4 Acre Residential District	218.5	87	88.3	1/4 Acre Residential District	218.5	87	90.1
		Commercial and Business	93.43	95		Commercial and Business	93.43	95	
		Good Condition Open Space	42.14	80		Commercial and Business	42.14	95	
DA_SS	Spring St. Erosion Outfall	Commercial and Business	34.78	95	95.0	Commercial and Business	34.78	95	95.0
DA_CS	Clay St.	Commercial and Business	24.04	95	95.0	Commercial and Business	24.04	95	95.0
	Clay St. (Bypass)	Commercial and Business	10.03	95	95.0	Commercial and Business	10.03	95	95.0

Time of Concentration Calculations (Existing Conditions)

Overland/ Sheet Flow: $T_o = 0.42 \cdot \dfrac{(n_0 \cdot L_0)^{0.8}}{P_2^{\,0.5} \cdot S_o^{\,0.4}}$

Shallow Concentrated Flow: $V_s = Fig.3.1$ $\quad T_s = \dfrac{L_s}{60 \cdot V_s}$

Channelized Flow: $T_h = \dfrac{L_h}{60 \cdot V_h}$

Time of Concentration: $T_c = T_o + T_s + T_h$

Lag Time: $T_L = 0.6 \cdot T_c$

Location	Basin ID	Basin Area (Ac)	Basin Area (sq.mi.)	Overland/ Sheet Flow: Lo ft	So %	So ft/ft	C N/A	P2 Inches	Mannings N NA	To minutes	To (15 min max)	Shallow Concentrated Flow: 1=Paved 2=Unpaved	Ls ft	Ss ft/ft	Vs fps	Ts minutes	Channelized Flow: Flow Type	Vh fps	Lh ft	Th minutes	Time of Concentration: Tc minutes	Tc hours	Lag Time: TL minutes	TL hours
Coronado Dr.	DA_CD	7.63	0.012	100	2.000	0.020	0.930	3.920	0.011	1.09	1.09	1	100.00	0.016	2.56	0.65	Pipe				4.59	0.08	2.75	0.05
																	Channel	5.00						
																	Gutter	6.43	1096.54	2.84				
Thompson Drive - Downstream of Coronado Dr.	DA_TD	12.24	0.019	100	5.000	0.050	0.640	3.920	0.240	8.94	8.94	2	1059.10	0.016	2.04	8.67	Pipe	7.81	180.00	0.38	18.64	0.31	11.18	0.19
																	Channel	5.00	195.65	0.65				
																	Gutter	5.00						
Harper Street	DA_HS	13.11	0.020	100	5.000	0.050	0.660	3.920	0.150	6.14	6.14	2	884.00	0.031	2.84	5.19	Pipe				13.77	0.23	8.26	0.14
																	Channel	5.00						
																	Gutter	5.19	759.56	2.44				
Harper Street (Bypass) Culberson to Circle Ave	DA_CA	22.58	0.035	100	2.000	0.020	0.660	3.920	0.011	1.09	1.09	1	100.00	0.035	3.80	0.44	Pipe				4.35	0.07	2.61	0.04
																	Channel	10.60	371.84	0.58				
																	Gutter	8.43	1126.45	2.23				
Jack Drive	DA_JD	27.28	0.043	100	2.000	0.020	0.590	3.920	0.150	8.85	8.85	2	1495.79	0.043	3.34	7.45	Pipe				17.67	0.29	10.60	0.18
																	Channel	5.00						
																	Gutter	5.00	410.00	1.37				
Hill Country Drive	DA_HC	23.27	0.036	100	19.320	0.193	0.840	3.920	0.240	5.20	5.20	2	965.00	0.214	7.48	2.15	Pipe				9.58	0.16	5.75	0.10
																	Channel	5.00						
																	Gutter	9.00	1198.83	2.22				
Hill Country Drive	DA_HC1	4.56	0.007	100	1.000	0.010	0.950	3.920	0.240	17.01	15.00	1	899.99	0.003	1.10	13.67	Pipe				28.67	0.48	17.20	0.29
																	Channel	5.00						
																	Gutter	6.43						
Clay St	DA_CS	21.93	0.034	100	0.500	0.005	0.940	3.920	0.011	1.91	1.91	1	106.00	0.010	2.02	0.88	Pipe				7.25	0.12	4.35	0.07
																	Channel	5.00						
																	Gutter	4.70	1259.21	4.47				
Clay St Bypass	DA_CS_BYPASS	10.03	0.016	100	0.600	0.006	0.940	3.920	0.011	1.77	1.77	1	100.00	0.003	1.10	1.52	Pipe				9.06	0.15	5.44	0.09
																	Channel	5.00						
																	Gutter	2.68	927.50	5.77				
Lois Street	DA_LS	134.81	0.211	100	1.000	0.010	0.690	3.920	0.240	17.01	15.00	2	362.92	0.020	2.28	2.66	Pipe				25.20	0.42	15.12	0.25
																	Channel	5.00						
																	Gutter	8.88	4017.89	7.54				
Lois Street	DA_LS1	6.36	0.010	100	0.400	0.004	0.660	3.920	0.240	24.54	15.00	2	478.00	0.005	1.14	7.01	Pipe				22.69	0.38	13.61	0.23
																	Channel	5.00						
																	Gutter	4.50	183.15	0.68				
Fourth St. Low Water Crossing	DA_FO	6733.51	10.521	100	2.000	0.020	0.390	3.920	0.240	12.89	12.89	2	1792.00	0.040	3.23	9.26	Pipe				130.22	2.17	78.13	1.30
																	Channel	5.00	32421.00	108.07				
																	Gutter							
First St. Low Water Crossing	DA_FI	196.24	0.307	100	4.000	0.040	0.500	3.920	0.240	9.77	9.77	2	1128.00	0.130	5.82	3.23	Pipe				27.09	0.45	16.25	0.27
																	Channel	4.50	3805.00	14.09				
																	Gutter							
Park St. Low Water Crossing	DA_PS	354.07	0.553	100	8.000	0.080	0.600	3.920	0.011	0.63	0.63						Pipe				32.93	0.55	19.76	0.33
																	Channel	5.00	9689.06	32.30				
																	Gutter							
Spring St. - Erosion at Outfall	DA_SS	34.78	0.054	100	4.000	0.040	0.940	3.920	0.011	0.83	0.83	1	100.00	0.001	0.63	2.65	Pipe				16.56	0.28	9.94	0.17
																	Channel	5.00						
																	Gutter	3.75	2943.91	13.08				

Time of Concentration Calculations (Existing Conditions)																								
Location	Basin ID	Basin Area (Ac)	Basin Area (sq.mi.)	Overland/ Sheet Flow:								Shallow Concentrated Flow:					Channelized Flow:				Time of Concentration:		Lag Time:	
				$T_o = 0.42 \cdot \frac{(n_0 \cdot L_0)^{0.8}}{P_2^{0.5} \cdot S_o^{0.4}}$								$V_s = Fig.3.1$			$T_s = \frac{L_s}{60 \cdot V_s}$		$T_h = \frac{L_h}{60 \cdot V_h}$				$T_c = T_o + T_s + T_h$		$T_L = 0.6 \cdot T_c$	
				Lo	So	So	C	P2	Mannings N	To	To	1=Paved	Ls	Ss	Vs	Ts	Flow Type	Vh	Lh	Th	Tc		TL	
				ft	%	ft/ft	N/A	Inches	NA	minutes	(15 min max)	2=Unpaved	ft	ft/ft	fps	minutes		fps	ft	minutes	minutes	hours	minutes	hours
Kroc Center Detention Pond	DA_KC	119.46	0.187	100	1.000	0.010	0.620	3.920	0.011	1.44	1.44	2	375.00	0.200	7.23	0.86	Pipe				9.34	0.16	5.60	0.09
																	Channel	8.00	3374.86	7.03				
																	Gutter							
Kroc Center Detention Pond - Hays Street	DA_HY	36.55	0.057	100	3.000	0.030	0.620	3.920	0.240	10.96	10.96	2	1466.86	0.070	4.27	5.73	Pipe				17.77	0.30	10.66	0.18
																	Channel	5.00						
																	Gutter	8.20	530.73	1.08				
East Main to Pinto Trail (Channel Begin)	DA_PT_BEGIN	65.21	0.102	100	4.000	0.040	0.610	3.920	0.240	9.77	9.77	2	872.28	0.180	6.86	2.12	Pipe				14.61	0.24	8.77	0.15
																	Channel							
																	Gutter	12.02	1960.38	2.72				
East Main to Pinto Trail (Channel End)	DA_PT_END	18.42	0.029	100	2.000	0.020	0.530	3.920	0.240	12.89	12.89	2	942.00	0.017	2.10	7.48	Pipe				22.48	0.37	13.49	0.22
																	Channel	5.00						
																	Gutter	4.14	523.00	2.11				
Easy Drain Channel	DA_TE	57.03	0.089	100	3.000	0.030	0.830	3.920	0.011	0.93	0.93	1	690.00	0.004	1.27	9.06	Pipe				20.09	0.33	12.05	0.20
																	Channel	5.26	2701.42	8.56				
																	Gutter	6.12	564.00	1.54				
Easy Drain Channel - Bypass	DA_TE_BYPASS	127.35	0.199	103.29	6.000	0.060	0.690	3.920	0.150	5.85	5.85	2	746.00	0.118	5.55	2.24	Pipe				19.50	0.33	11.70	0.20
																	Channel							
																	Gutter	9.12	6243.33	11.41				

Time of Concentration Calculations (Ultimate Conditions)

Location	Basin ID	Basin Area (Ac)	Basin Area (sq.mi.)	Overland/ Sheet Flow:								Shallow Concentrated Flow:					Channelized Flow:				Time of Concentration:		Lag Time:	
				$T_o = 0.42 \cdot \frac{(n_0 \cdot L_0)^{0.8}}{P_2^{\,0.5} \cdot S_o^{\,0.4}}$								$V_s = Fig.3.1$ $T_s = \frac{L_s}{60 \cdot V_s}$					$T_h = \frac{L_h}{60 \cdot V_h}$				$T_c = T_o + T_s + T_h$		$T_L = 0.6 \cdot T_c$	
				Lo	So	So	C	P2	No	To	To	1=Paved	Ls	Ss	Vs	Ts	Flow Type	Vh	Lh	Th	Tc		TL	
				ft	%	ft/ft	N/A	in		minutes	(15 min max)	2=Unpaved	ft	ft/ft	fps	minutes		fps	ft	minutes	minutes	hours	minutes	hours
Coronado Dr.	DA_CD	7.63	0.012	100	2.000	0.020	0.950	3.920	0.011	1.09	1.09	1	100.00	0.016	2.56	0.65	Pipe				4.59	0.08	2.75	0.05
																	Channel	5.00						
																	Gutter	6.43	1096.54	2.84				
Thompson Drive - Downstream of Coronado Dr.	DA_TD	12.24	0.019	100	5.000	0.050	0.920	3.920	0.011	0.76	0.76	1	1059.10	0.016	2.56	6.90	Pipe	7.81	180.00	0.38	8.69	0.14	5.22	0.09
																	Channel	5.00	195.65	0.65				
																	Gutter	5.00						
Harper Street	DA_HS	13.11	0.020	100	5.000	0.050	0.660	3.920	0.150	6.14	6.14	2	884.00	0.031	2.84	5.19	Pipe				13.77	0.23	8.26	0.14
																	Channel	5.00						
																	Gutter	5.19	759.56	2.44				
Harper Street (Bypass) Culberson to Circle Ave	DA_CA	22.58	0.035	100	2.000	0.020	0.690	3.920	0.011	1.09	1.09	1	100.00	0.035	3.80	0.44	Pipe				4.35	0.07	2.61	0.04
																	Channel	10.60	371.84	0.58				
																	Gutter	8.43	1126.45	2.23				
Jack Drive	DA_JD	27.28	0.043	100	2.000	0.020	0.660	3.920	0.150	8.85	8.85	1	1495.79	0.043	4.22	5.91	Pipe				16.13	0.27	9.68	0.16
																	Channel	5.00						
																	Gutter	5.00	410.00	1.37				
Hill Country Drive	DA_HC	23.27	0.036	100	19.320	0.193	0.890	3.920	0.240	5.20	5.20	2	965.00	0.214	7.48	2.15	Pipe				9.58	0.16	5.75	0.10
																	Channel	5.00						
																	Gutter	9.00	1198.83	2.22				
Hill Country Drive	DA_HC1	4.56	0.007	100	1.000	0.010	0.950	3.920	0.240	17.01	15.00	1	899.99	0.003	1.10	13.67	Pipe				28.67	0.48	17.20	0.29
																	Channel	5.00						
																	Gutter	6.43						
Clay St	DA_CS	21.93	0.034	100	0.500	0.005	0.940	3.920	0.011	1.91	1.91	1	106.00	0.010	2.02	0.88	Pipe				7.25	0.12	4.35	0.07
																	Channel	5.00						
																	Gutter	4.70	1259.21	4.47				
Clay St Bypass	DA_CS_BYPASS	10.03	0.016	100	0.600	0.006	0.940	3.920	0.011	1.77	1.77	1	100.00	0.003	1.10	1.52	Pipe				9.06	0.15	5.44	0.09
																	Channel	5.00						
																	Gutter	2.68	927.50	5.77				
Lois Street	DA_LS	134.81	0.211	100	1.000	0.010	0.730	3.920	0.150	11.68	11.68	2	362.92	0.020	2.28	2.66	Pipe				21.88	0.36	13.13	0.22
																	Channel	5.00						
																	Gutter	8.88	4017.89	7.54				
Lois Street	DA_LS1	6.36	0.010	100	0.400	0.004	0.660	3.920	0.150	16.85	15.00	2	478.00	0.005	1.14	7.01	Pipe				22.69	0.38	13.61	0.23
																	Channel	5.00						
																	Gutter	4.50	183.15	0.68				
Fourth St. Low Water Crossing	DA_FO	6733.51	10.521	100	2.000	0.020	0.390	3.920	0.150	8.85	8.85	2	1792.00	0.040	3.23	9.26	Pipe				126.18	2.10	75.71	1.26
																	Channel	5.00	32421.00	108.07				
																	Gutter							
First St. Low Water Crossing	DA_FI	196.24	0.307	100	4.000	0.040	0.500	3.920	0.150	6.71	6.71	2	1128.00	0.130	5.82	3.23	Pipe				24.03	0.40	14.42	0.24
																	Channel	4.50	3805.00	14.09				
																	Gutter							
Park St. Low Water Crossing	DA_PS	354.07	0.553	100	8.000	0.080	0.600	3.920	0.011	0.63	0.63						Pipe				32.93	0.55	19.76	0.33
																	Channel	5.00	9689.06	32.30				
																	Gutter							
Spring St. - Erosion at Outfall	DA_SS	34.78	0.054	100	4.000	0.040	0.940	3.920	0.011	0.83	0.83	1	100.00	0.001	0.63	2.65	Pipe				16.56	0.28	9.94	0.17
																	Channel	5.00						
																	Gutter	3.75	2943.91	13.08				

Time of Concentration Calculations (Ultimate Conditions)																								
Location	Basin ID	Basin Area (Ac)	Basin Area (sq.mi.)	Overland/ Sheet Flow:								Shallow Concentrated Flow:					Channelized Flow:				Time of Concentration:		Lag Time:	
				$T_o = 0.42 \cdot \frac{(n_0 \cdot L_0)^{0.8}}{P_2^{0.5} \cdot S_o^{0.4}}$								$V_s = Fig.3.1$			$T_s = \frac{L_s}{60 \cdot V_s}$		$T_h = \frac{L_h}{60 \cdot V_h}$				$T_c = T_o + T_s + T_h$		$T_L = 0.6 \cdot T_c$	
				Lo	So	So	C	P2	No	To	To	1=Paved	Ls	Ss	Vs	Ts	Flow Type	Vh	Lh	Th	Tc		TL	
				ft	%	ft/ft	N/A	in		minutes	(15 min max)	2=Unpaved	ft	ft/ft	fps	minutes		fps	ft	minutes	minutes	hours	minutes	hours
Kroc Center Detention Pond	DA_KC	119.46	0.187	100	1.000	0.010	0.760	3.920	0.011	1.44	1.44	2	375.00	0.200	7.23	0.86	Pipe				9.34	0.16	5.60	0.09
																	Channel	8.00	3374.86	7.03				
																	Gutter							
Kroc Center Detention Pond - Hays Street	DA_HY	36.55	0.057	100	3.000	0.030	0.660	3.920	0.150	7.53	7.53	2	1466.86	0.070	4.27	5.73	Pipe				14.33	0.24	8.60	0.14
																	Channel	5.00						
																	Gutter	8.20	530.73	1.08				
East Main to Pinto Trail (Channel Begin)	DA_PT_BEGIN	65.21	0.102	100	4.000	0.040	0.660	3.920	0.150	6.71	6.71	2	872.28	0.180	6.86	2.12	Pipe				11.55	0.19	6.93	0.12
																	Channel							
																	Gutter	12.02	1960.38	2.72				
East Main to Pinto Trail (Channel End)	DA_PT_END	18.42	0.029	100	2.000	0.020	0.600	3.920	0.150	8.85	8.85	2	942.00	0.017	2.10	7.48	Pipe				18.43	0.31	11.06	0.18
																	Channel	5.00						
																	Gutter	4.14	523.00	2.11				
Easy Drain Channel	DA_TE	57.03	0.089	100	3.000	0.030	0.830	3.920	0.011	0.93	0.93	1	690.00	0.004	1.27	9.06	Pipe				20.09	0.33	12.05	0.20
																	Channel	5.26	2701.42	8.56				
																	Gutter	6.12	564.00	1.54				
Easy Drain Channel - Bypass	DA_TE_BYPASS	127.35	0.199	103.29	6.000	0.060	0.730	3.920	0.150	5.85	5.85	2	746.00	0.118	5.55	2.24	Pipe				19.50	0.33	11.70	0.20
																	Channel							
																	Gutter	9.12	6243.33	11.41				

Peak Flow Value Calculations For Each Basin

Runoff Estimates Using Atlas 14 Values (Existing Conditions)

Drainage Area ID	Drainage ID	Area (A) Acres	Area (Sq. Miles)	Tc (min) TR-55	Runoff Coefficient (C)	Q1yr (cfs)	Q2yr (cfs)	Q5yr (cfs)	Q10yr (cfs)	Q25yr (cfs)	Q50yr (cfs)	Q100yr (cfs)
Spring St. - Erosion at Outfall	DA_SS	34.78	0.05	14.64	0.94	108.96	129.21	161.17	188.66	228.20	260.10	293.60
Hill Country Drive	DA_HC	23.27	0.04	9.58	0.84	82.48	98.39	123.33	144.54	175.17	200.31	226.43
Hill Country Drive	DA_HC1	4.56	0.01	28.67	0.95	10.87	12.87	15.94	18.67	22.48	25.56	28.81
Clay St	DA_CS	21.93	0.03	7.25	0.94	96.44	114.97	143.73	168.65	204.59	233.20	263.59
Kroc Center Detention Pond	DA_KC	119.46	0.19	9.34	0.62	314.56	375.70	469.92	551.23	669.14	764.36	865.06
Easy Drain Channel	DA_TE	57.03	0.09	20.09	0.83	146.87	174.06	217.06	253.89	307.00	349.68	394.57
Lois Street (10)	DA_LS	134.81	0.21	25.20	0.69	256.35	303.51	378.30	441.89	534.04	607.55	685.11
Harper Street	DA_HS	13.11	0.02	13.77	0.66	31.17	37.05	46.26	54.20	65.63	74.88	84.61
Jack Drive	DA_JD	27.28	0.04	17.67	0.59	52.67	62.45	77.89	91.16	110.25	125.64	141.81
Coronado Dr.	DA_CD	7.63	0.01	4.59	0.93	36.46	43.40	54.24	63.65	77.18	87.80	99.13
East Main to Pinto Trail (Channel Begin)	DA_PT_BEGIN	65.21	0.10	14.61	0.61	139.85	165.98	207.12	242.56	293.54	334.74	378.01
East Main to Pinto Trail (Channel End)	DA_PT_END	18.42	0.03	23.05	0.53	28.66	33.95	42.33	49.48	59.82	68.10	76.82
Lois Street (10A)	DA_LS1	6.36	0.01	20.63	0.66	12.22	14.48	18.05	21.10	25.51	29.04	32.76
Harper Street (Bypass) Culberson to Circle Ave	DA_CA	22.58	0.04	4.35	0.66	76.32	90.84	113.51	133.22	161.53	183.75	207.46
Thompson Drive - Downstream of Coronado Dr.	DA_TD	12.24	0.02	18.64	0.64	25.03	29.67	37.00	43.30	52.36	59.66	67.32
Clay St Bypass	DA_CS_BYPASS	10.03	0.02	9.06	0.94	40.52	48.38	60.51	70.98	86.16	98.39	111.33
Kroc Center Detention Pond - Hays Street	DA_HY	36.55	0.06	17.77	0.62	73.34	86.95	108.46	126.92	153.51	174.93	197.43
Easy Drain Channel - Bypass	DA_TE_BYPASS	127.35	0.20	19.50	0.69	275.50	326.53	407.22	476.38	576.08	656.23	740.53
Park Street LWC	DA_PS	354.07	0.55	32.93	0.64	527.53	623.91	777.45	906.94	1095.62	1245.06	1403.13
First Street LWC	DA_FI	196.24	0.31	27.09	0.59	302.17	357.61	445.62	520.22	628.55	714.69	805.69
Fourth Street LWC	DA_FO	6733.51	10.52	130.22	0.43	2619.09	3210.23	4073.77	4859.83	6012.42	6991.29	8061.96

Note: These calculations are for each basin. To get the cumulative discharge at a computation point, peak flow runoff for each basin draining to the computation point should be considered.

Runoff Estimates Using Atlas 14 Values (Ultimate Conditions)

Drainage Area ID	Drainage ID	Area (A) Acres	Area (Sq. Miles)	Tc (min) TR-55	Runoff Coefficient (C)	Q1yr (cfs)	Q2yr (cfs)	Q5yr (cfs)	Q10yr (cfs)	Q25yr (cfs)	Q50yr (cfs)	Q100yr (cfs)
Spring St. - Erosion at Outfall	DA_SS	34.78	0.05	14.64	0.94	108.96	129.21	161.17	188.66	228.20	260.10	293.60
Hill Country Drive	DA_HC	23.27	0.04	9.58	0.89	86.72	103.45	129.67	151.97	184.18	210.61	238.07
Hill Country Drive	DA_HC1	4.56	0.01	28.67	0.95	10.87	12.87	15.94	18.67	22.48	25.56	28.81
Clay St	DA_CS	21.93	0.03	7.25	0.94	96.44	114.97	143.73	168.65	204.59	233.20	263.59
Kroc Center Detention Pond	DA_KC	119.46	0.19	9.34	0.76	382.63	456.99	571.60	670.51	813.94	929.76	1052.26
Easy Drain Channel	DA_TE	57.03	0.09	20.09	0.83	146.87	174.06	217.06	253.89	307.00	349.68	394.57
Lois Street (10)	DA_LS	134.81	0.21	21.88	0.73	293.54	347.77	433.62	506.97	612.92	697.86	787.28
Harper Street	DA_HS	13.11	0.02	13.77	0.66	31.17	37.05	46.26	54.20	65.63	74.88	84.61
Jack Drive	DA_JD	27.28	0.04	16.13	0.66	60.54	71.79	89.55	104.84	126.81	144.55	163.17
Coronado Dr.	DA_CD	7.63	0.01	4.59	0.95	37.33	44.43	55.52	65.16	79.01	89.88	101.48
East Main to Pinto Trail (Channel Begin)	DA_PT_BEGIN	65.21	0.10	11.55	0.66	167.67	199.97	249.97	293.06	355.48	406.08	459.43
East Main to Pinto Trail (Channel End)	DA_PT_END	18.42	0.03	19.01	0.60	35.42	41.98	52.36	61.27	74.10	84.43	95.28
Lois Street (10A)	DA_LS1	6.36	0.01	20.63	0.66	12.22	14.48	18.05	21.10	25.51	29.04	32.76
Harper Street (Bypass)Culberson to Circle Ave	DA_CA	22.58	0.04	4.35	0.69	80.50	95.82	119.74	140.53	170.38	193.83	218.84
Thompson Drive - Downstream of Coronado Dr.	DA_TD	12.24	0.02	8.69	0.92	49.00	58.49	73.14	85.81	104.14	118.87	134.48
Clay St Bypass	DA_CS_BYPASS	10.03	0.02	9.06	0.94	40.52	48.38	60.51	70.98	86.16	98.39	111.33
Kroc Center Detention Pond - Hays Street	DA_HY	36.55	0.06	14.33	0.66	85.11	101.07	126.14	147.74	178.83	203.97	230.38
Easy Drain Channel - Bypass	DA_TE_BYPASS	127.35	0.20	19.50	0.73	292.14	346.26	431.82	505.16	610.88	695.88	785.27
Park Street LWC	DA_PS	354.07	0.55	32.93	0.64	527.53	623.91	777.45	906.94	1095.62	1245.06	1403.13
First Street LWC	DA_FI	196.24	0.31	24.03	0.59	326.50	386.66	481.99	563.20	680.75	774.69	873.72
Fourth Street LWC	DA_FO	6733.51	10.52	126.18	0.43	2668.80	3268.91	4145.91	4941.71	6107.95	7100.47	8182.83

Note: These calculations are for each basin. To get the cumulative discharge at a computation point, peak flow runoff for each basin draining to the computation point should be considered.

2) Hydraulic Analysis

The project's hydraulic analysis consisted of calculating capacity, velocity and depths for existing roadways, drainage structures, and channels to evaluate the water surface elevations and resulting localized flooding issues experienced at First, Fourth and Park Street low water crossings. Floodplain hydraulics were analyzed using the USACE HEC-RAS software version 5.0.5. All modeling simulations are one-dimensional steady-state runs.

A HEC-RAS hydraulic model was generated for Quinlan Creek using 2011 TNRIS 1/16 USGS Quad DEM bare earth terrain data at a 1-meter resolution, and field investigations. A field survey was conducted as part of this analysis for approximate invert elevations and road profiles. However, a detailed field survey will be required during the drainage design phase.

The hydraulic analysis was performed for the 1-, 2-, 5-, 10-, 25-, 50- and 100-year effective conditions storm events. Cross-sections along the streamlines were placed to capture the geometry of the channel and stream characteristics and to capture data for hydraulically significant structures such as bridges, culverts, and roads. The maps of the cross-sections modeled as part of this study are included in the sections below. All cross-sections are modeled from left to right looking downstream. Further refinement of the model with field survey data is required to enhance the accuracy and to further define the extent of the flooding and the corresponding benefits of the proposed improvements.

Hydraulic model parameter estimations include Manning's roughness coefficient (n) values, contraction and expansion coefficients, and ineffective flow limits. For Quinlan Creek, the drainage channel typically has an irregular channel geometry with heavy brush vegetation and trees within the channel banks and pasture and brushland within the overbank areas.

Overbank manning's values were typically defined as having n values of 0.04 to 0.06 for pasture and brush areas. Each of the values follows the recommendations provided by the HEC-RAS Reference Manual and by Table 5-7 of the Floodplain Modeling Using HEC-RAS (Haestad 147).

Contraction and expansion coefficients are applied upstream and downstream, respectively, of culverts and bridges to represent the contraction of flow as water enters the drainage structure and expands outward as it exits the structure. In this study, contraction and expansion coefficients of cross-sections bounding bridges are 0.1 and 0.3, respectively.

Ineffective flow limits are added to cross-sections to accurately model any given section's inability to convey flow, such as cross-sections that bound bridges and culverts. Ineffective limits were also set at the top of channel banks to account for storage in over banks that do not contribute to channel conveyance. Blocked obstructions are placed in areas where the conveyance is not expected to occur or in areas that should not be included as storage.

No hydrologic peak flow calculations were performed for low water crossings. Instead, effective FEMA FIS flows are considered for the following scenarios:

1) Existing Conditions
2) Proposed Conditions with Channel Modification
3) Proposed Conditions with Channel Modification and Culvert Replacement
4) Proposed Conditions with Channel Modification, Culvert Replacement, and 3 Feet Railing.

Iterative approximate hydraulic calculations were performed using various parameters such as channel modification slope, channel bottom width, culvert height, and span. Considering the large volume of surface runoff in Quinlan Creek and existing structural restrains, drainage structures were designed barely for 10 years for Park Street and First Street. 2-year storm capacity was able to achieve for Fourth Street low water crossing.

Following table shows the effective flows used for hydraulic analysis. FIS FEMA study report is used to extract discharge values for 10-, 50-, 100- and 500-years at low water crossings. A linear relationship between surface runoff from ATLAS 14 precipitation and FIS discharge is used to estimate flows for 1-, 2-, 5-, 25-years.

Atlas 14 Peak Flows (Rational Method) - Ultimate									
Name	Area	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR	500 YR
Park Street LWC	7,450.00	3,463.04	4,213.63	5,325.64	6,323.17	7,781.47	9,008.88	10,339.18	N/A
First Street LWC	6,929.75	2,995.30	3,655.57	4,627.90	5,504.91	6,788.70	7,875.16	9,056.55	N/A
Fourth Street LWC	6,733.51	2,668.80	3,268.91	4,145.91	4,941.71	6,107.95	7,100.47	8,182.83	N/A
FIS FEMA Effective Flows									
Name	Area	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR	500 YR
Type		Estimated	Estimated	Estimated	FIS FEMA	Estimated	FIS FEMA	FIS FEMA	FIS FEMA
Park Street LWC	7,494.40	3,149.13	3,831.68	4,842.90	5,750.00	8,076.11	9,350.00	10,830.00	14,140.00
First Street LWC	7,232.00	3,025.27	3,692.15	4,674.21	5,560.00	7,741.12	8,980.00	10,400.00	13,660.00
Fourth Street LWC	6,643.20	2,759.69	3,380.23	4,287.10	5,110.00	6,950.56	8,080.00	9,350.00	12,520.00

Hydraulic summary of low water crossings is given below:

1) Fourth Street Low Water Crossing Analysis

Proposed Improvements:

- **Channel Modification**
  Limits: RS 130 to RS 1055 (Approx. 925 ft)
  Bottom Width: 80 feet
  Bottom Width Near Culvert: 100 feet
  Side Slope: 3H:1V
- **Culvert Replacement**
  7 – 12' X 8'
  FL (In): 1625.1 ft
  FL (Out): 1624.8 ft
- **Roadway Regrading**
  Existing Road Elevation: 1628.5 ft
  Proposed Roadway Elevation Over Culvert: 1634.1 ft
  Proposed Roadway Elevation at Tie End: 1635.0 ft
  Max. Road Raise: 5.6 ft

Hydraulic Analysis Result for Fourth Street:

Existing Conditions

Existing Conditions (With No Improvements) at Fourth Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,639.41	1,628.59	25.63	12,609.57	4.08	4.08	10.82
100 YR	1,637.97	1,628.59	25.27	9,525.54	4.02	4.02	9.38
50 YR	1,637.29	1,628.59	24.87	8,289.40	3.96	3.96	8.70
25 YR	1,636.60	1,628.59	24.00	7,076.67	3.82	3.82	8.01
10 YR	1,635.35	1,628.59	22.20	4,975.94	3.53	3.53	6.76
5 YR	1,634.63	1,628.59	21.03	4,158.44	3.35	3.35	6.04
2 YR	1,633.73	1,628.59	22.71	3,397.13	3.61	3.61	5.14
1 YR	1,633.05	1,628.59	21.99	2,692.35	3.50	3.50	4.46

Proposed Channel Modification with Existing Culvert

Proposed Conditions With Channel Modification Only at Fourth Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,638.97	1,628.59	25.63	12,282.01	4.08	4.08	10.38
100 YR	1,637.54	1,628.59	25.27	9,333.31	4.02	4.02	8.95
50 YR	1,636.86	1,628.59	24.87	7,951.32	3.96	3.96	8.27
25 YR	1,636.17	1,628.59	24.00	6,711.35	3.82	3.82	7.58
10 YR	1,634.90	1,628.59	24.11	4,992.89	3.84	3.84	6.31
5 YR	1,634.19	1,628.59	25.12	4,375.27	4.00	4.00	5.60
2 YR	1,633.27	1,628.59	24.82	3,444.01	3.95	3.95	4.68
1 YR	1,632.61	1,628.59	24.58	2,747.74	3.91	3.91	4.02

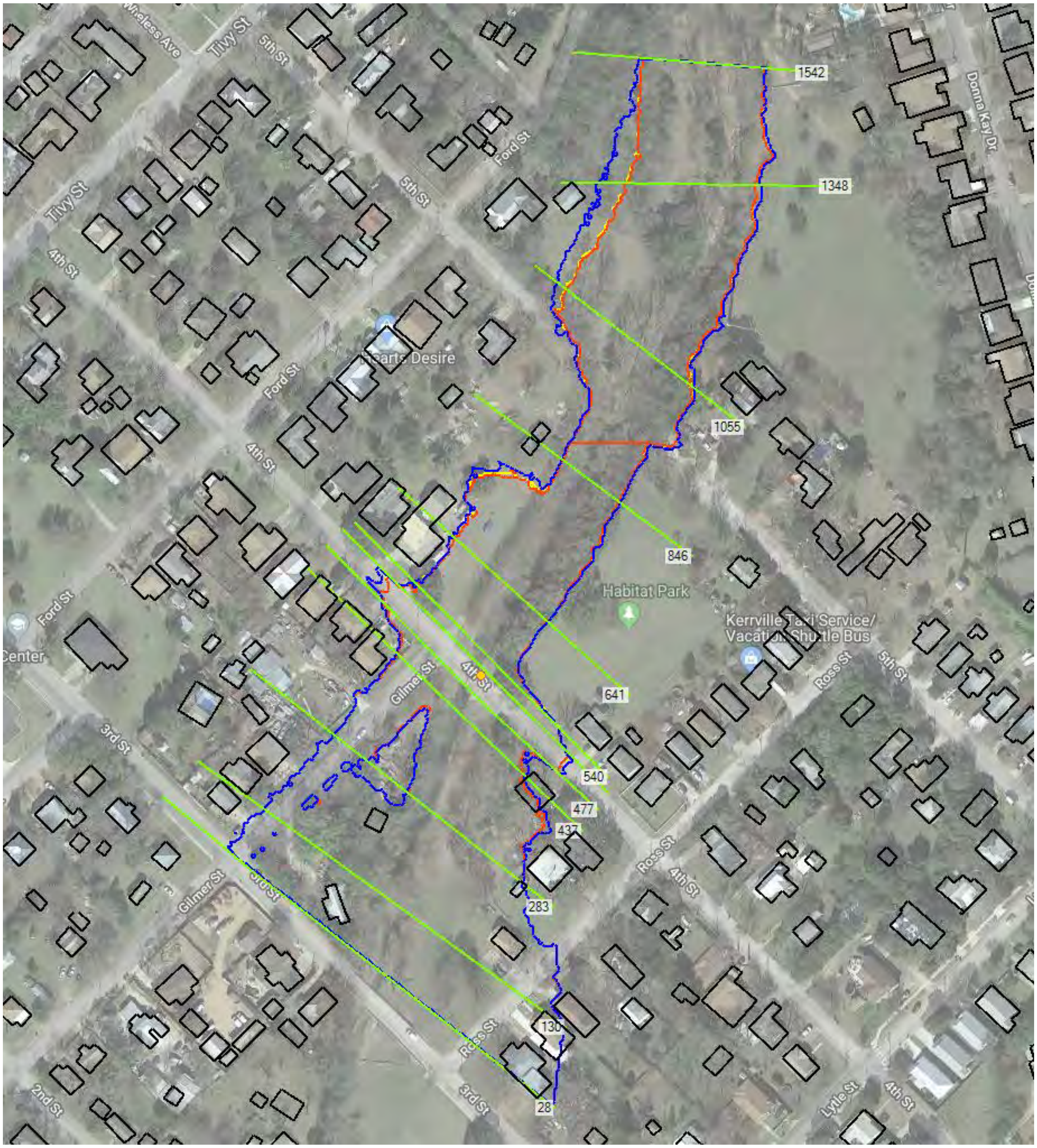
Proposed Channel Modification with Proposed Culvert

Proposed Channel Modification and Culvert Replacement at Fourth Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,639.02	1,634.01	2,931.27	9,588.73	4.36	4.36	5.01
100 YR	1,637.67	1,634.01	3,547.33	5,802.67	5.28	5.28	3.66
50 YR	1,637.08	1,634.01	3,747.22	4,332.78	5.58	5.58	3.07
25 YR	1,636.50	1,634.01	3,870.71	3,079.29	5.76	5.76	2.49
10 YR	1,635.37	1,634.01	3,986.71	1,123.30	5.93	5.93	1.36
5 YR	1,634.52	1,634.01	4,033.72	253.38	6.00	6.00	0.51
2 YR	1,633.35	1,634.01	3,380.23		5.06	5.03	0.00
1 YR	1,632.60	1,634.01	2,759.69		4.50	4.31	0.00

Proposed Channel Modification with Proposed Culvert and 3ft Railing

Proposed Channel Modification + Culvert Replacement + 3 ft Rail							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,639.17	1,634.01	3,955.07	8,564.94	5.89	5.89	5.16
100 YR	1,638.04	1,634.01	4,445.85	4,904.15	6.62	6.62	4.03
50 YR	1,637.47	1,634.01	4,542.39	3,537.61	6.76	6.76	3.46
25 YR	1,636.85	1,634.01	4,576.02	2,373.98	6.81	6.81	2.84
10 YR	1,635.54	1,634.01	4,340.02	769.98	6.46	6.46	1.53
5 YR	1,634.58	1,634.01	4,171.33	115.77	6.21	6.21	0.57
2 YR	1,633.35	1,634.01	3,380.23		5.06	5.03	0.00
1 YR	1,632.60	1,634.01	2,759.69		4.50	4.31	0.00

Inundation Map for Fourth Street Low Water Crossing



Blue – Existing Conditions

Orange – Proposed Conditions with Channel Modification Only

Yellow – Proposed Conditions with Channel Modification and Culvert Replacement

2) First Street Low Water Crossing Analysis

Proposed Improvements:

- **Channel Modification**
  Limits: RS 476 to RS 2070 (Approx. 1594 ft)
  Bottom Width: 100 feet
  Bottom Width Near Culvert: 110 feet
  Side Slope: 3H:1V
- **Culvert Replacement**
  8 – 12' X 8'
  FL (In): 1615 ft
  FL (Out): 1614.5 ft
- **Roadway Regrading**
  Existing Road Elevation: 1618.025 ft
  Proposed Roadway Elevation Over Culvert: 1624 ft
  Proposed Roadway Elevation at Tie End: 1625 ft
  Max. Road Raise: 6 ft

Hydraulic Analysis Result for First Street:

Existing Conditions

Existing Conditions (With No Improvements) at First Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,629.44	1,618.21	47.17	13,595.47	3.00	3.00	11.23
100 YR	1,627.73	1,618.21	49.08	10,278.71	3.12	3.12	9.52
50 YR	1,627.09	1,618.21	49.81	9,170.05	3.17	3.17	8.88
25 YR	1,626.09	1,618.21	49.59	7,686.73	3.16	3.16	7.88
10 YR	1,624.59	1,618.21	49.52	5,567.44	3.15	3.15	6.38
5 YR	1,623.73	1,618.21	44.66	4,629.34	2.84	2.84	5.52
2 YR	1,622.90	1,618.21	49.18	3,642.82	3.13	3.13	4.69
1 YR	1,622.38	1,618.21	54.35	2,970.65	3.46	3.46	4.17

Proposed Channel Modification with Existing Culvert

Proposed Conditions With Channel Modification Only							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,625.37	1,618.28	170.18	13,498.35	10.83	10.83	7.09
100 YR	1624.8	1618.28	172.78	10229.9	11	11	6.52
50 YR	1,624.48	1,618.28	174.56	8,803.25	11.11	11.11	6.20
10 YR	1,623.45	1,618.28	195.95	5,366.99	12.47	12.47	5.17
25 YR	1,624.16	1,618.28	180.63	7,565.63	11.50	11.50	5.88
5 YR	1,623.09	1,618.28	206.21	4,470.04	13.13	13.13	4.81
2 YR	1,622.63	1,618.28	199.73	3,493.89	12.72	12.72	4.35
1 YR	1,622.31	1,618.28	202.27	2,822.73	12.88	12.88	4.03

Proposed Channel Modification with Proposed Culvert

Proposed Conditions With Channel Modification and Culvert Replacement							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,625.89	1,624.01	9,048.18	4,611.82	11.78	11.78	1.88
100 YR	1,624.99	1,624.01	8,523.23	1,876.77	14.19	11.36	0.98
50 YR	1,624.48	1,624.01	8,137.30	842.70	13.97	11.46	0.47
25 YR	1,624.29	1,624.01	7,310.43	430.57	13.48	16.56	0.28
10 YR	1,622.57	1,624.01	5,560.00		12.31	15.40	0
5 YR	1,621.71	1,624.01	4,674.00		11.61	14.72	0
2 YR	1,620.69	1,624.01	3,692.00		10.74	13.85	0
1 YR	1,619.97	1,624.01	3,025.00		10.05	13.17	0

Proposed Channel Modification with Proposed Culvert and 3 ft Railing

Proposed Conditions With Channel Mod + Culvert Replacement + Railing							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,626.20	1,624.01	9,885.72	3,774.28	12.87	12.87	2.19
100 YR	1,625.42	1,624.01	8,714.38	1,685.63	14.29	11.62	1.41
50 YR	1,624.76	1,624.01	8,275.04	704.97	14.05	11.65	0.75
25 YR	1,624.45	1,624.01	7,450.47	290.54	13.57	16.64	0.44
10 YR	1,622.57	1,624.01	5,560.00		12.31	15.40	0
5 YR	1,621.71	1,624.01	4,674.00		11.61	14.72	0
2 YR	1,620.69	1,624.01	3,692.00		10.74	13.85	0
1 YR	1,619.97	1,624.01	3,025.00		10.05	13.17	0

Inundation Map for First Street Low Water Crossing

Blue – Existing Conditions

Orange – Proposed Conditions with Channel Modification Only

Yellow – Proposed Conditions with Channel Modification and Culvert Replacement

3) Park Street Low Water Crossing Analysis

Proposed Improvements:

- **Channel Modification**
  Limits: RS 388 to RS 1801
  Bottom Width: 50 feet
  Bottom Width Near Culvert: 120 feet
  Side Slope: 3H:1V
  Channel alignment is provided to the River Station (RS) 388, 488 and 795.
  Channel is aligned approximately 60' – 70' to the left to avoid structural impacts.
- **Culvert Replacement**
  8 – 12' X 8'
  FL (In): 1598.5 ft
  FL (Out): 1598.1 ft
- **Roadway Regrading**
  Existing Road Elevation: 1601.8 ft
  Proposed Roadway Elevation Over Culvert: 1607.5 ft
  Proposed Roadway Elevation at Tie End: 1608.5 ft
  Max. Road Raise: 5.7 ft

Hydraulic Analysis Result for Park Street:

Existing Conditions

Existing Conditions (With No Improvements) at Park Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,613.66	1,601.84	69.37	13,353.89	2.31	2.31	11.82
100 YR	1,611.94	1,601.84	72.76	10,742.14	2.43	2.43	10.10
50 YR	1,611.06	1,601.84	70.13	8,997.62	2.34	2.34	9.22
25 YR	1,610.22	1,601.84	74.45	8,131.01	2.48	2.48	8.38
10 YR	1,608.21	1,601.84	39.39	5,710.61	1.31	1.31	6.37
5 YR	1,607.45	1,601.84	81.71	4,761.29	2.72	2.72	5.61
2 YR	1,606.43	1,601.84	81.39	3,802.39	2.71	2.71	4.59
1 YR	1,605.64	1,601.84	71.46	3,077.54	2.38	2.38	3.80

Proposed Channel Modification with Existing Culvert

Proposed Channel Modification at Park Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,611.76	1,601.84	95.00	14,450.22	3.17	3.17	9.92
100 YR	1,610.31	1,601.84	96.45	10,971.92	3.22	3.22	8.47
50 YR	1,609.49	1,601.84	98.75	9,285.09	3.29	3.29	7.65
25 YR	1,608.75	1,601.84	111.14	7,964.86	3.70	3.70	6.91
10 YR	1,606.71	1,601.84	133.52	5,616.48	4.45	4.45	4.87
5 YR	1,606.31	1,601.84	166.19	4,676.81	5.54	5.54	4.47
2 YR	1,605.87	1,601.84	201.17	3,630.83	6.71	6.71	4.03
1 YR	1,605.48	1,601.84	255.15	2,893.86	8.50	8.50	3.64

Proposed Channel Modification with Proposed Culvert

Proposed Channel Modification and Culvert Replacement at Park Street							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,611.82	1,607.51	3,149.14	10,990.86	4.1	4.1	4.31
100 YR	1,610.55	1,607.51	3,799.29	7,030.72	4.95	4.95	3.04
50 YR	1,609.98	1,607.51	4,399.25	4,950.75	5.73	5.73	2.47
25 YR	1,609.42	1,607.51	4,836.99	3,239.01	6.3	6.3	1.91
10 YR	1,607.56	1,607.51	5,644.34	105.66	7.35	7.35	0.05
5 YR	1,606.43	1,607.51	4,843.00		6.91	6.49	0
2 YR	1,605.34	1,607.51	3,832.00		6.2	5.78	0
1 YR	1,604.59	1,607.51	3,149.00		5.6	5.19	0

Proposed Channel Modification with Proposed Culvert and 3ft Railing

Proposed Channel Modification + Culvert Replacement + 3 ft Rail							
Profile	W.S. US.	Min El Weir Flow	Q Culv Group	Q Weir	Culv Vel US	Culv Vel DS	Depth of Water Over Culvert (ft)
	(ft)	(ft)	(cfs)	(cfs)	(ft/s)	(ft/s)	
500 YR	1,611.91	1,607.51	3,638.19	10,501.81	4.74	4.74	4.40
100 YR	1,610.85	1,607.51	4,581.90	6,248.10	5.97	5.97	3.34
50 YR	1,610.26	1,607.51	5,058.81	4,291.19	6.59	6.59	2.75
25 YR	1,609.66	1,607.51	5,351.21	2,724.80	6.97	6.97	2.15
10 YR	1,607.59	1,607.51	5,714.35	35.65	7.44	7.44	0.08
5 YR	1,606.43	1,607.51	4,843.00		6.91	6.49	0
2 YR	1,605.34	1,607.51	3,832.00		6.2	5.78	0
1 YR	1,604.59	1,607.51	3,149.00		5.6	5.19	0

Inundation Map for Park Street Low Water Crossing

Blue – Existing Conditions

Orange – Proposed Conditions with Channel Modification Only

Yellow – Proposed Conditions with Channel Modification and Culvert Replacement

Methodology for Ranking Criteria and Scoring for City of Kerrville Stormwater Masterplan

Prioritization ranking performed in this study was intended to be modified to fit the City of Kerrville's needs and considerations. The goal was to effectively rank projects by a system which would produce consistent results based on project-specific characteristics such as potential hazards, project cost, and economic factors. Project rankings will support city officials in recommending potential project implementation. Ranking for future projects will also be able to follow this process as the City of Kerrville continues to develop.

1) Project Prioritization

Each proposed project has been prioritized by a ranking system identifying four major Categories: Public Safety, Economic Effect(s), Project Timing and Environmental. Each category contains subcategories that relate to each project individually and can be graded based on severity. Each project is intended to be graded individually producing a score and effectively ranking each project. After each project was graded on each subcategory, the next step was to weigh each category based on relative importance to one another.

2) Category Ranking Criteria

Categories are given a weighted value based on importance over another using a "Pairwise" process. This process is operated through a simple, customizable table which can be restructured and utilized in different ranking conditions. The goal was to create a ranking process in which will yield consistent results considering the different aspects of the projects. A scale of 1 to 3 is used to score each categories importance, and by scoring each category against another, we can determine which category is considered most to least important. A score of 1 being of least importance and a score of 3 being most important, a higher weighted value is assigned to the most important category and a lower weighted value to the lest important.

LNV's intent was to tailor the method of rankings based on the city of Kerrville's specific needs and considerations; by allowing the city officials to prioritize each category, this ranking process will ultimately be utilized directly for and directly based by the city of Kerrville representatives.

Criteria	Public Safety	Economic	Project Timing	Environment	CATEGORY WEIGHT	RANK
Public Safety		3	3	3	9	1
Economic	1		3	2	6	2
Project Timing	1	1		2	4	4
Environment	1	2	3		6	2

3) Criteria Identification

After LNV's and city of Kerrville's cooperative efforts, project ranking and prioritizations were evaluated by the following principles:

- **Public Safety** (53%) – This principal considers overall public safety during major rainfall events. Risk of structural flooding, roadway flooding, emergency services access, frequency of flood damages and erosion/channel stability concerns are measured by individual severity to the general public's safety. Post-project level of protection is also weighted in this category. Infrastructure damage, at risk velocity and emergency access during large rain events, is highly weighed in this category.

Category	Category Weight	Sub Category	Point Value Range Description	Point Value
Public Safety	9	Structural Flooding for 100-year (1% AEP), estimated (Pre-Project Conditions)	Low Risk (0 structures flooded)	0
			Moderate Risk (1-10 structures flooded)	5
			High Risk (10+ structures flooded or critical facility effected)	10
		Roadway Flooding for 100-Year (1% AEP) (Pre-Project Conditions)	No road overtopping	0
			Local road overtopping	4
			Collector road overtopping	7
			Arterial road overtopping	10
		Roadway Emergency Services Access for 25-year (4% AEP) storm-event (Pre-Project Conditions)	Access not impacted	0
			Access minimally impacted	2
			Alternative route required / limited access (duration 0 ≤ x ≤ 1 hour)	6
			No access or alternative route available (duration x ≥ 1 hour)	10
		Frequency of Flood Damages (Pre-Project Conditions)	Minimal (100-year < X)	1
			Moderate (25-year < X ≤ 100-year)	4
			High (1-year < X ≤ 25-year)	7
			Very High (X ≤ 1-year)	10
		Erosion / Channel Stability	No Erosion	0
			Stable (minimal erosion)	2
			Unstable (risk of property loss)	6
			Highly unstable (risk of structure damage or accelerated property loss)	10
		Drainage Service (Post-Project Protection)	≤10 Year (10% AEP)	1
			10 Year (10% AEP) - 25-Year (4% AEP)	4
			25 Year (4% AEP) - 100-Year (1% AEP)	6
			≥100-Year (1% AEP)	10

- **Economic** (18%) – This principal considers the cost-effectiveness of each proposed project. It is important for the city to acknowledge that each project will vary in scale and in price. Project cost, funding sources/availability, and the potential for development/redevelopment are considered to account for the overall economic stability of the city and potential growth the city may encounter when improvements are complete.

Category	Category Weight	Sub Category	Point Value Range Description	Point Value
Economic	6	Project Cost	High Cost ($2 million < X)	2
			Moderate Cost ($1 million < X ≤ $2 million)	6
			Low Cost (≥ $1 million)	10
		Funding Source / Availability	Unidentified funding sources	0
			General Fund	4
			Future Municipal Bonds (2020-? Bond Program)	7
			Cost-Share Potential (Federal or State grants, Inter-local agreements)	10
		Development/Redevelopment Post-Project (residential and commercial)	Negative impact (reduced development and/or business potential)	0
			No significant impact (no change to development and/or business potential)	5
			Positive impact (development potential, improved land value, sales, etc.)	10

- **Project Timing** (11%) – Permitting, land/easement acquisition needs, project readiness, and project depencency for implementation are accounted for to understand the overall difficulty for the project to effectively be ready for groundbreaking. State and Federal permitting may prove to have lengthy application scenarios and, in some cases, can add substantial costs and fees to a project.

Category	Category Weight	Sub Category	Point Value Range Description	Point Value
Project Timing	4	Permitting	Significant Permitting & Mitigation	0
			Federal permitting (Section 404 IP, other)	2
			Limited permitting local/state/federal (Nationwide, TCEQ WPAP)	6
			Local permitting only	10
		Land/Easement Acquisition	Condemnation/buy-outs may be required	1
			Limited easement/land acquisition needs (no impact to structures)	3
			No additional easements or property acquisition anticipated	5
		Project Readiness (est. time until completion)	Long Range (X > 2 years)	1
			Mid-Range (1-year < X ≤ 2 year)	3
			Short-Range (X ≤ 1 year)	5
		Project Dependency	Project is dependent on other upstream/downstream improvements occuring before this project to mitigate flooding issues	0
			Project is independent of any upstream/downstream improvements to mitigate flooding issues	5
			Project must be constructed before other related projects to solve flooding issues in basin	10

- **Environment** (18%) – Environmental properties such as water quality impacts and riparian habitat impacts are also considered to weigh each project's potential for significantly changing natural habitat and/or ability to create or change water quality characteristics in the future.

Category	Category Weight	Sub Category	Point Value Range Description	Point Value
Environment	6	Water Quality Impacts Post-Project	Negative impact (WQ reduced due to increased impervious cover, etc.)	0
			No significant impact	7
			Positive impact (WQ enhanced with LID/BMP features)	15
		Riparian Impacts Post-Project (habitat, natural waterways, trees, wetlands, etc.)	Negative impacts (loss of natural riparian areas)	0
			No impacts (no significant change to natural riparian areas)	7
			Positive impacts (preserves or creates natural riparian areas)	15

Ranking order should not be relied upon to determine the exact order of project implementation but rather be utilized as a useful guide with a system that ensures consistent results. Point values, ranges and subcategories are also interchangeable and can be substituted for qualities or quantities city officials see fit. It is important to note if modifications are made, they are made with similar considerations described in this methodology.

Full CIP ranking criteria and project scoring are available in this appendix.

City of Kerrville Stormwater Master Plan - CIP Ranking Criteria

Category	Category Weight	Sub Category	Point Value Range Description	Point Value	1 A. Pinto Trail Project Score	1 A. Pinto Trail Weighted Score	2 B. Park Street Project Score	2 B. Park Street Weighted Score	3 C. First Street Project Score	3 C. First Street Weighted Score	4 D. Fourth Street Project Score	4 D. Fourth Street Weighted Score	5 E. Spring Drive Project Score	5 E. Spring Drive Weighted Score
Public Safety	9	Structural Flooding/Losses for 100-year (1% AEP), estimated (Pre-Project Conditions)	Low Risk (0 structures damaged) Moderate Risk (1-10 structures damaged) High Risk (10+ structures damaged or critical facility effected)	0 5 10	5	45	10	90	10	90	5	45	0	0
		Roadway Flooding for 100-Year (1% AEP) (Pre-Project Conditions)	No road overtopping Local road overtopping Collector road overtopping Arterial road overtopping	0 4 7 10	7	63	4	36	4	36	4	36	0	0
		Roadway Emergency Services Access for 25-year (4% AEP) storm-event (Pre-Project Conditions)	Access not impacted Access minimally impacted Alternative route required / limited access (duration 0 ≤ x ≤ 1 hour) No access or alternative route available (duration x ≥ 1 hour)	0 2 6 10	2	18	6	54	6	54	6	54	0	0
		Frequency of Flood Damages (Pre-Project Conditions)	Minimal (100-year < X) Moderate (25-year < X ≤ 100-year) High (1-year < X ≤ 25-year) Very High (X ≤ 1-year)	1 4 7 10	4	36	10	90	10	90	10	90	10	90
		Erosion / Channel Stability	No Erosion Stable (minimal erosion) Unstable (risk of property loss) Highly unstable (risk of structure damage or accelerated property loss)	0 2 6 10	10	90	2	18	2	18	2	18	10	90
		Level of Protection Benefit (Post-Project Protection)	≤10 Year (10% AEP) 10 Year (10% AEP) - 25-Year (4% AEP) 25 Year (4% AEP) - 100-Year (1% AEP) ≥100-Year (1% AEP)	1 4 6 10	10	90	1	9	1	9	1	9	10	90
Economic	6	Project Cost	High Cost ($2 million < X) Moderate Cost ($1 million < X ≤ $2 million) Low Cost ($1 million ≥ X)	2 6 10	6	36	2	12	2	12	2	12	6	36
		Funding Source / Availability	Unidentified funding sources General Fund Future Municipal Bonds (2020-? Bond Program) Cost-Share Potential (Federal or State grants, Inter-local agreements)	0 4 7 10	4	24	0	0	0	0	0	0	4	24
		Development/Redevelopment Post-Project (residential and commercial)	Negative impact (reduced development and/or business potential) No significant impact (no change to development and/or business potential) Positive impact (development potential, improved land value, sales, etc.)	0 5 10	10	60	5	30	5	30	5	30	5	30
Project Timing	4	Permitting	Significant Permitting & Mitigation Federal permitting (Section 404 IP, other) Limited permitting local/state/federal (Nationwide, TCEQ WPAP, FEMA) Local permitting only	0 2 6 10	10	40	6	24	6	24	6	24	6	24
		Land/Easement Acquisition	Condemnation/buy-outs may be required Limited easement/land acquisition needs (no impact to structures) No additional easements or property acquisition anticipated	1 3 5	3	12	1	4	1	4	1	4	5	20
		Project Readiness (est. time until completion)	Long Range (X > 2 years) Mid-Range (1-year < X ≤ 2 year) Short-Range (X ≤ 1 year)	1 3 5	3	12	1	4	1	4	1	4	5	20
		Project Dependency	Project is dependent on other upstream/downstream improvements occurring before this project to mitigate flooding issues Project is independent of any upstream/downstream improvements to mitigate flooding issues Project must be constructed before other related projects to solve flooding issues in basin	0 5 10	5	20	0	0	0	0	0	0	5	20
Environment	6	Water Quality Impacts Post-Project	Negative impact (WQ reduced due to increased impervious cover, etc.) No significant impact Positive impact (WQ enhanced with LID/BMP features)	0 7 15	7	42	7	42	7	42	7	42	7	42
		Riparian Impacts Post-Project (habitat, natural waterways, trees, wetlands, etc.)	Negative impacts (loss of natural riparian areas) No impacts (no significant change to natural riparian areas) Positive impacts (preserves or creates natural riparian areas)	0 7 15	0	0	0	0	0	0	0	0	7	42
				Public Safety Score (Max = 540)		342		297		297		252		270
				Economic Score (Max = 180)		120		42		42		42		90
				Project Timing Score (Max = 120)		84		32		32		32		84
				Environment Score (Max = 180)		42		42		42		42		84
				Total Score (Max = 1020)		588		413		413		368		528
				Rank		5		11		11		13		9

* AEP = Annual Exceedance Probability

City of Kerrville Stormwater Master Plan - CIP Ranking Criteria

Category	Category Weight	Sub Category	Point Value Range Description	Point Value	6 F. Hill Country Drive Project Score	6 F. Hill Country Drive Weighted Score	7 & 8 GH. Kroc & Clay Project Score	7 & 8 GH. Kroc & Clay Weighted Score	9 I. Take It Easy Project Score	9 I. Take It Easy Weighted Score	10 J. Lois Street Project Score	10 J. Lois Street Weighted Score
Public Safety	9	Structural Flooding/Losses for 100-year (1% AEP), estimated (Pre-Project Conditions)	Low Risk (0 structures damaged) Moderate Risk (1-10 structures damaged) High Risk (10+ structures damaged or critical facility effected)	0 5 10	10	90	10	90	10	90	10	90
		Roadway Flooding for 100-Year (1% AEP) (Pre-Project Conditions)	No road overtopping Local road overtopping Collector road overtopping Arterial road overtopping	0 4 7 10	7	63	10	90	10	90	10	90
		Roadway Emergency Services Access for 25-year (4% AEP) storm-event (Pre-Project Conditions)	Access not impacted Access minimally impacted Alternative route required / limited access (duration 0 ≤ x ≤ 1 hour) No access or alternative route available (duration x ≥ 1 hour)	0 2 6 10	10	90	6	54	6	54	6	54
		Frequency of Flood Damages (Pre-Project Conditions)	Minimal (100-year < X) Moderate (25-year < X ≤ 100-year) High (1-year < X ≤ 25-year) Very High (X ≤ 1-year)	1 4 7 10	10	90	10	90	7	63	10	90
		Erosion / Channel Stability	No Erosion Stable (minimal erosion) Unstable (risk of property loss) Highly unstable (risk of structure damage or accelerated property loss)	0 2 6 10	2	18	0	0	10	90	2	18
		Level of Protection Benefit (Post-Project Protection)	≤10 Year (10% AEP) 10 Year (10% AEP) - 25-Year (4% AEP) 25 Year (4% AEP) - 100-Year (1% AEP) ≥100-Year (1% AEP)	1 4 6 10	6	54	6	54	10	90	10	90
Economic	6	Project Cost	High Cost ($2 million < X) Moderate Cost ($1 million < X ≤ $2 million) Low Cost ($1 million ≥ X)	2 6 10	2	12	2	12	2	12	6	36
		Funding Source / Availability	Unidentified funding sources General Fund Future Municipal Bonds (2020-? Bond Program) Cost-Share Potential (Federal or State grants, Inter-local agreements)	0 4 7 10	4	24	7	42	7	42	7	42
		Development/Redevelopment Post-Project (residential and commercial)	Negative impact (reduced development and/or business potential) No significant impact (no change to development and/or business potential) Positive impact (development potential, improved land value, sales, etc.)	0 5 10	10	60	10	60	10	60	10	60
Project Timing	4	Permitting	Significant Permitting & Mitigation Federal permitting (Section 404 IP, other) Limited permitting local/state/federal (Nationwide, TCEQ WPAP, FEMA) Local permitting only	0 2 6 10	10	40	6	24	6	24	6	24
		Land/Easement Acquisition	Condemnation/buy-outs may be required Limited easement/land acquisition needs (no impact to structures) No additional easements or property acquisition anticipated	1 3 5	5	20	5	20	5	20	5	20
		Project Readiness (est. time until completion)	Long Range (X > 2 years) Mid-Range (1-year < X ≤ 2 year) Short-Range (X ≤ 1 year)	1 3 5	3	12	1	4	3	12	5	20
		Project Dependency	Project is dependent on other upstream/downstream improvements occurring before this project to mitigate flooding issues Project is independent of any upstream/downstream improvements to mitigate flooding issues Project must be constructed before other related projects to solve flooding issues in basin	0 5 10	5	20	5	20	10	40	0	0
Environment	6	Water Quality Impacts Post-Project	Negative impact (WQ reduced due to increased impervious cover, etc.) No significant impact Positive impact (WQ enhanced with LID/BMP features)	0 7 15	7	42	7	42	7	42	7	42
		Riparian Impacts Post-Project (habitat, natural waterways, trees, wetlands, etc.)	Negative impacts (loss of natural riparian areas) No impacts (no significant change to natural riparian areas) Positive impacts (preserves or creates natural riparian areas)	0 7 15	7	42	7	42	7	42	7	42
				Public Safety Score (Max = 540)		405		378		477		432
				Economic Score (Max = 180)		96		114		114		138
				Project Timing Score (Max = 120)		92		68		96		64
				Environment Score (Max = 180)		84		84		84		84
				Total Score (Max = 1020)		677		644		771		718
				Rank		3		4		1		2

* AEP = Annual Exceedance Probability

		City of Kerrville Stormwater Master Plan - CIP Ranking Criteria			11 K1. Harper Street		11a K2. Circle Avenue		12 L. Jack Drive		13 M. Coronado Drive	
Category	Category Weight	Sub Category	Point Value Range Description	Point Value	Project Score	Weighted Score	Project Score	Weighted Score	Project Score	Weighted Score	Project Score	Weighted Score
Public Safety	9	Structural Flooding/Losses for 100-year (1% AEP), estimated (Pre-Project Conditions)	Low Risk (0 structures damaged) Moderate Risk (1-10 structures damaged) High Risk (10+ structures damaged or critical facility effected)	0 5 10	5	**45**	0	**0**	10	**90**	0	**0**
		Roadway Flooding for 100-Year (1% AEP) (Pre-Project Conditions)	No road overtopping Local road overtopping Collector road overtopping Arterial road overtopping	0 4 7 10	4	**36**	4	**36**	4	**36**	7	**63**
		Roadway Emergency Services Access for 25-year (4% AEP) storm-event (Pre-Project Conditions)	Access not impacted Access minimally impacted Alternative route required / limited access (duration 0 ≤ x ≤ 1 hour) No access or alternative route available (duration x ≥ 1 hour)	0 2 6 10	6	**54**	2	**18**	2	**18**	6	**54**
		Frequency of Flood Damages (Pre-Project Conditions)	Minimal (100-year < X) Moderate (25-year < X ≤ 100-year) High (1-year < X ≤ 25-year) Very High (X ≤ 1-year)	1 4 7 10	7	**63**	7	**63**	10	**90**	7	**63**
		Erosion / Channel Stability	No Erosion Stable (minimal erosion) Unstable (risk of property loss) Highly unstable (risk of structure damage or accelerated property loss)	0 2 6 10	0	**0**	10	**90**	0	**0**	0	**0**
		Level of Protection Benefit (Post-Project Protection)	≤10 Year (10% AEP) 10 Year (10% AEP) - 25-Year (4% AEP) 25 Year (4% AEP) - 100-Year (1% AEP) ≥100-Year (1% AEP)	1 4 6 10	6	**54**	10	**90**	6	**54**	6	**54**
Economic	6	Project Cost	High Cost ($2 million < X) Moderate Cost ($1 million < X ≤ $2 million) Low Cost ($1 million ≥ X)	2 6 10	2	**12**	10	**60**	2	**12**	10	**60**
		Funding Source / Availability	Unidentified funding sources General Fund Future Municipal Bonds (2020-? Bond Program) Cost-Share Potential (Federal or State grants, Inter-local agreements)	0 4 7 10	4	**24**	4	**24**	4	**24**	10	**60**
		Development/Redevelopment Post-Project (residential and commercial)	Negative impact (reduced development and/or business potential) No significant impact (no change to development and/or business potential) Positive impact (development potential, improved land value, sales, etc.)	0 5 10	10	**60**	5	**30**	10	**60**	5	**30**
Project Timing	4	Permitting	Significant Permitting & Mitigation Federal permitting (Section 404 IP, other) Limited permitting local/state/federal (Nationwide, TCEQ WPAP, FEMA) Local permitting only	0 2 6 10	10	**40**	10	**40**	10	**40**	6	**24**
		Land/Easement Acquisition	Condemnation/buy-outs may be required Limited easement/land acquisition needs (no impact to structures) No additional easements or property acquisition anticipated	1 3 5	5	**20**	3	**12**	3	**12**	5	**20**
		Project Readiness (est. time until completion)	Long Range (X > 2 years) Mid-Range (1-year < X ≤ 2 year) Short-Range (X ≤ 1 year)	1 3 5	3	**12**	5	**20**	3	**12**	5	**20**
		Project Dependency	Project is dependent on other upstream/downstream improvements occurring before this project to mitigate flooding issues Project is independent of any upstream/downstream improvements to mitigate flooding issues Project must be constructed before other related projects to solve flooding issues in basin	0 5 10	5	**20**	5	**20**	5	**20**	5	**20**
Environment	6	Water Quality Impacts Post-Project	Negative impact (WQ reduced due to increased impervious cover, etc.) No significant impact Positive impact (WQ enhanced with LID/BMP features)	0 7 15	7	**42**	7	**42**	7	**42**	7	**42**
		Riparian Impacts Post-Project (habitat, natural waterways, trees, wetlands, etc.)	Negative impacts (loss of natural riparian areas) No impacts (no significant change to natural riparian areas) Positive impacts (preserves or creates natural riparian areas)	0 7 15	7	**42**	7	**42**	7	**42**	7	**42**
				Public Safety Score (Max = 540)		252		297		288		234
				Economic Score (Max = 180)		96		114		96		150
				Project Timing Score (Max = 120)		92		92		84		84
				Environment Score (Max = 180)		84		84		84		84
				Total Score (Max = 1020)		**524**		**587**		**552**		**552**
				Rank		**10**		**6**		**7**		**7**

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