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DRAINAGE MASTER PLAN

Prepared for:

City of Terrell, Texas

June 2020

Prepared by:

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06/11/2020

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TEXAS REGISTERED
ENGINEERING FIRM
F-2144

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VOLUME 1

METHODOLOGY AND OVERVIEW

EXECUTIVE SUMMARY

The City of Terrell (City) engaged Freese and Nichols, Inc. (FNI) to develop a Drainage Master Plan for the portion of the City between Kings Creek on the east and Bachelor Creek on the west. The Master Plan includes a City-Wide inventory and condition assessment of existing drainage infrastructure, delivered as a cloud-hosted spatial database through ArcGIS Online. The ArcGIS Online data is also visible through web-based interactive maps where data can be viewed, queried, and simple maps may be exported. By maintaining the database and potentially linking it to the work order system, the City may be able to more actively manage its stormwater assets. Maintaining high quality data will allow many future opportunities to save costs and begin programmatically replacing the infrastructure.

In addition to the inventory, FNI analyzed the existing infrastructure under two land use scenarios: existing conditions and ultimate conditions. Through these analyses and in discussions with City staff, locations were selected for the development of projects to accommodate the ultimate conditions flow and alleviate existing flooding. Twenty (20) separate projects were identified throughout the City, but generally the biggest flooding issues are on Kings Creek upstream of SH 34. Cost estimates were developed for each project, and the total cost is $65.5 million. Not included in that total are smaller projects the City could fund with Cash, called the “Small Projects”, a total of $1.3 million. Current drainage infrastructure within the City limits is estimated at $39 million, excluding depreciation.

FNI prioritized projects based on normalized scores for Life Safety (Road Flooding), Property Damage, Flooding Frequency, Project Cost, and Public Impact. As new projects are identified or current identified projects are completed, the City should keep the prioritization database updated.

FNI developed a funding strategy to demonstrate how reliance on the Stormwater Utility Fee to fund the large capital projects will require immediate and regular increases. Any opportunities for grants and low interest loans should be regularly pursued when grant requirements are in alignment with City goals. The City should promptly start to utilize the TIF Zone #1 revenues to fund the qualifying Large Projects before this resource expires. Specific Large Projects should be used in attempt to receive grant funding such as GLO CDBG-MIT or TWDB Flood Infrastructure Fund (FIF) as part of the State Flood Plan. Some grant funding opportunities require matching funds. TIF Zone #1 could be a potential source for matching funds.

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1.0 INTRODUCTION

In order quantify and reduce flood risk within the City Limits, the City of Terrell (City) engaged Freese and Nichols, Inc. (FNI) to develop a Drainage Master Plan for a specific portion of the City as shown in Figure 1.

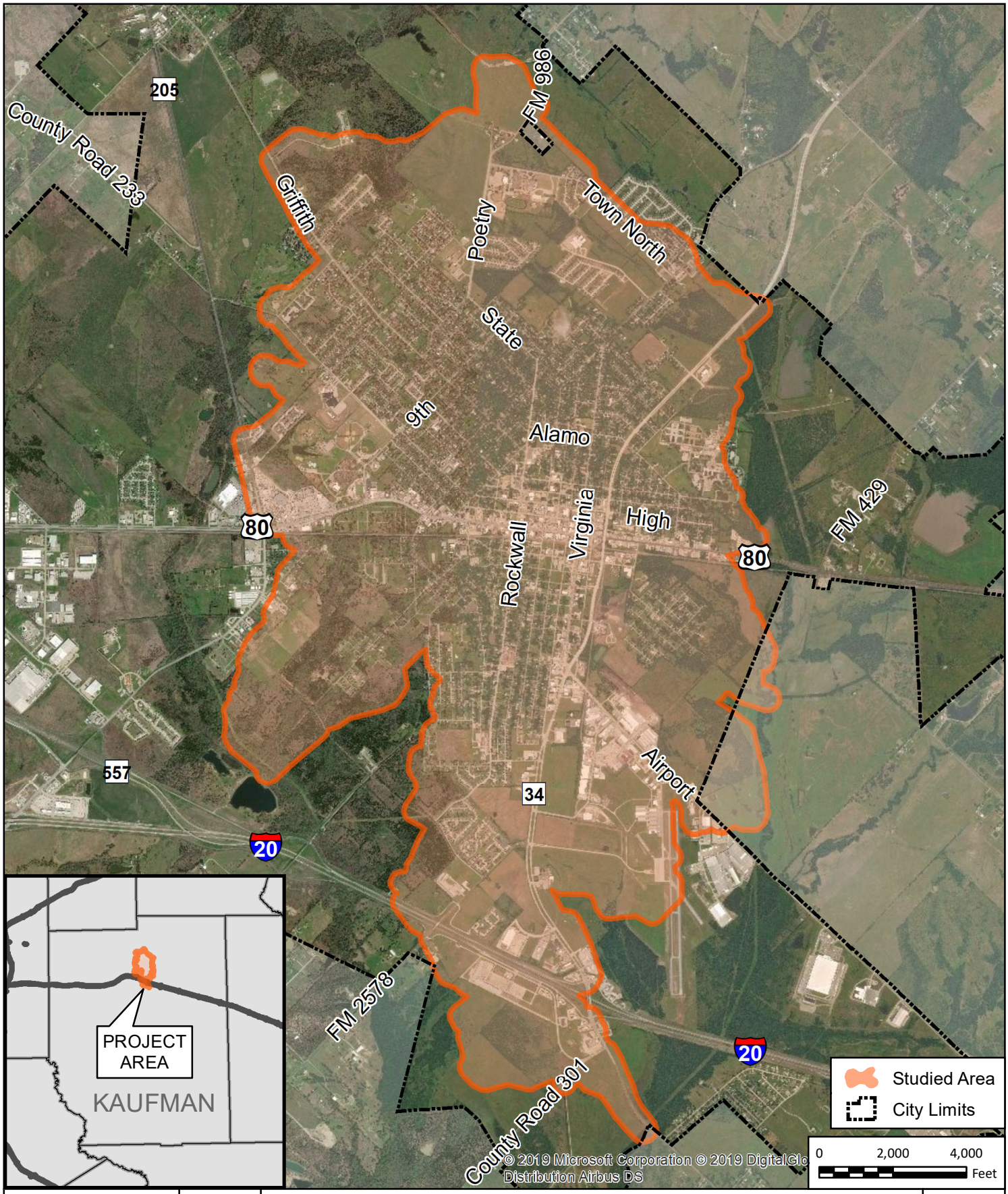
1.1 PURPOSE AND SCOPE OF STUDY

The purpose of the study was to evaluate the existing conditions of the study areas, identify deficiencies in the system, and compile a conceptual plan to improve the City's current drainage infrastructure and identify improvements needed to safely accommodate the design storm based on assumed future land use conditions. Key components of the Drainage Master Plan include:

- Data Collection – FNI staff performed site visits to all drainage facilities within the Study Area and FNI engaged Spooner Surveyors, Inc., to collect survey data in specific locations including creek cross sections as well as critical infrastructure spot elevations.
- GIS Inventory of Drainage System – FNI developed an ArcGIS Online (AGOL) collector application, web map, and editor application to manage spatial drainage data for the City.
- Existing Conditions Analysis – FNI developed new hydrology and hydraulics for the study area using HEC-HMS, HEC-RAS, and InfoWorks ICM.
- Project Development – FNI identified problem areas within the existing conditions analysis to develop projects that reduce flood risk.
- CIP Ranking – FNI worked with the City to implement a Pairwise ranking of the identified projects to determine which projects should be executed first.
- Public Meetings – FNI held a kickoff meeting at the beginning of the project for the citizens of Terrell to provide input into the process and help identify flood prone areas.

In addition to developing the Drainage Master Plan, several other tasks were undertaken within this contract. The interim deliverables relevant to this report are included in Volume 3. The full list of additional tasks is as follows:

- Criteria Manual review and update – FNI worked with the City to update the Drainage Criteria Manual to update to the latest and best information and include several new components.
- Maintenance Best Practices – FNI conducted a survey of peer cities regarding their maintenance practices and compiled a memorandum for documentation purposes.



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Overview of Studied Area

City of Terrell Drainage Master Plan

FIGURE 1

Path: H:\STORMWATER\Final Exhibits\01_REPORT\Figure_1.mxd

NAD 1983 StatePlane Texas North Central FIPS 4202 Feet

- State Street and Walnut Street Analysis – FNI analyzed the outfall of the Griffith Avenue Improvements to determine the impact of the changes to the drainage system from curb and gutters to a storm drain.
- Virginia Street Analysis – FNI analyzed the effect of the TxDOT SH34 and Virginia street projects in relation to flood depths along High Street.
- Railroad Crossing Analysis – FNI developed preliminary designs for Union Pacific Railroad (UPRR) railroad crossings that act as bottlenecks for drainage in the City.
- Funding Assessment – FNI provided research on multiple funding sources and developed strategies for maximizing the funding of drainage improvement projects within the City.

1.2 PREVIOUS STUDIES

The City provided several previous flood studies within the City for use in developing the master plan. These are shown in chronological order below:

- City of Terrell Storm Drainage System Study (Hogan and Rasor, August 1989) – A twenty-year look ahead for anticipated growth and requisite infrastructure. Inventory of existing drainage infrastructure and proposed new/improved infrastructure to meet anticipated growth.
- State Street/Walnut Street Drainage Study (Carter & Burgess, December 2003) – Analysis of a specific tributary to Kings Creek including open channel and closed-pipe analysis, plus a recommendation for improvements to achieve a 25-year capacity within the system.
- LOMR Tributaries KC1 and KC1B (Aqua Terra, April 2015) – Letter of Map Revision 15-06-227P-180416 to revise the FEMA regulatory floodplain of tributaries to Kings Creek, generally south and west of the Terrell Municipal Airport.
- LOMR for Bachelor Creek (Kimley-Horn, August 2015) – Letter of Map Revision 17-06-3844P-480416 to revise the FEMA regulatory floodplain of Bachelor Creek within the City Limits.
- LOMR Terry Creek and Tributaries (Kimley-Horn, July 2017) – Letter of Map Revision 17-06-3844P-480411 to revise the FEMA regulatory floodplain of Terry Creek and tributaries, generally west of the study area.
- Cedar Watershed, TX Base Level Engineering (AECOM, September 2017) – This study was accessed online. Automated techniques with manual adjustment using best-available data to determine an initial flood risk rating in majority FEMA-unstudied areas.

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2.0 DATA COLLECTION

2.1 SITE VISITS

Site visits were conducted by FNI on 12/07/17, 03/21/2018, 04/01/2018, and 04/11/2018 to collect data on the existing stormwater infrastructure. The level of detail includes approximate locations, measured dimensions, and a condition assessment. Storm drain entrances and outfalls were assessed when accessible via manholes or where a line connected to an open channel. The drainage infrastructure inventory provided by the City was also verified through multiple spot checks in each system section. When the data did not match, further data was collected for that section during the site visits.

2.2 GIS INVENTORY

The City provided FNI with the current storm drain inventory in an AutoCAD line-type format. The data was converted to GIS format. Layers were created for each infrastructure type: inlets, headwalls, storm drains, manholes, and channels. The attributes for each feature were populated based on the information included in the original data. The data was then updated using the provided as-built plans, site visits, and collected survey. The GIS inventory is accessible via desktop ArcGIS and ArcGIS Online (AGOL), Figure 2. This program will enable the City to update the inventory live while in the field. The desktop version of the data as delivered is available in Appendix C.

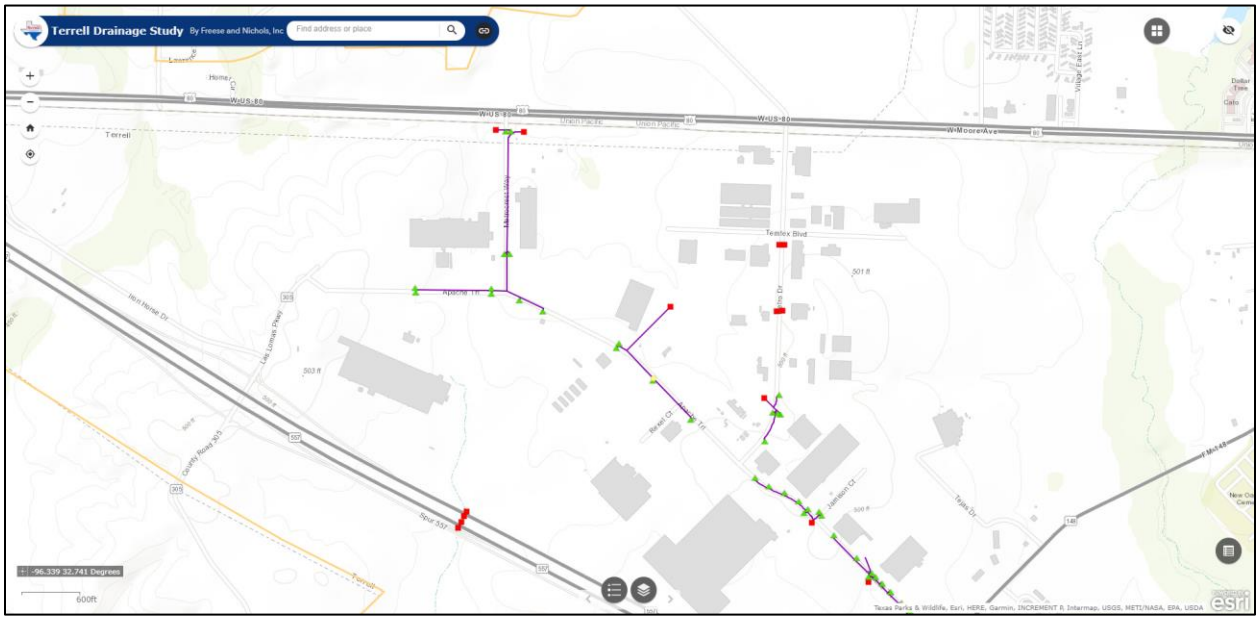

Figure 2: AGOL interface

2.3 RAIN-ON-MESH ANALYSIS

A preliminary rain-on-mesh (ROM) analysis was performed for the 100-year storm event. Full details for this process are included in section 4.1. The results from the ROM, Figure A1, show a broad but informative first look at potential flood prone areas and served as a useful screening tool early in the study process. These preliminary findings helped guide site visits and small projects determination. Many identified areas were later confirmed by the feedback received from the survey and public meeting.

2.4 PUBLIC INVOLVEMENT AND SURVEY

The City held a public meeting on April 4th, 2018 to inform the community about the ongoing Drainage Master Plan and facilitate feedback about problem areas in the city. FNI developed a survey for residents to complete that documented the drainage conditions near their home and also allowed them to document other known flooding issues throughout Terrell. This survey was also available for residents to access online for 50 days before and 34 days after the public meeting. A large map with the ROM results was on display for attendees to view and a separate large map of the city was available for attendees to mark problem areas with stickers.

The responses collected through the online survey and comments at the public meeting were compiled and returned the following results:

- There were multiple reports of flooding along June Street, including two structural flooding occurrences. The residents said it was due to multiple reasons and happens frequently.
- Several responses from the Lexington and Birdsong Streets community. Those on the border of the neighborhood reported no flooding issues, but those living in the center strip report flooding in their backyard area.
- A couple reports of flooding along Poetry Road whenever there is “measurable rain.”
- Several reports of flooding in the Redwood/Forest Creek community due to inadequate drainage for the area.
- A couple reports of significant flooding at the intersection of Highway 80 and 9th Street.
- Several reports of overbank flooding from residents along Kings Creek Drive.

The complete collection of responses is available in Appendix B. The survey responses and noted areas of flooding from the meeting are represented visually in Figure 3.

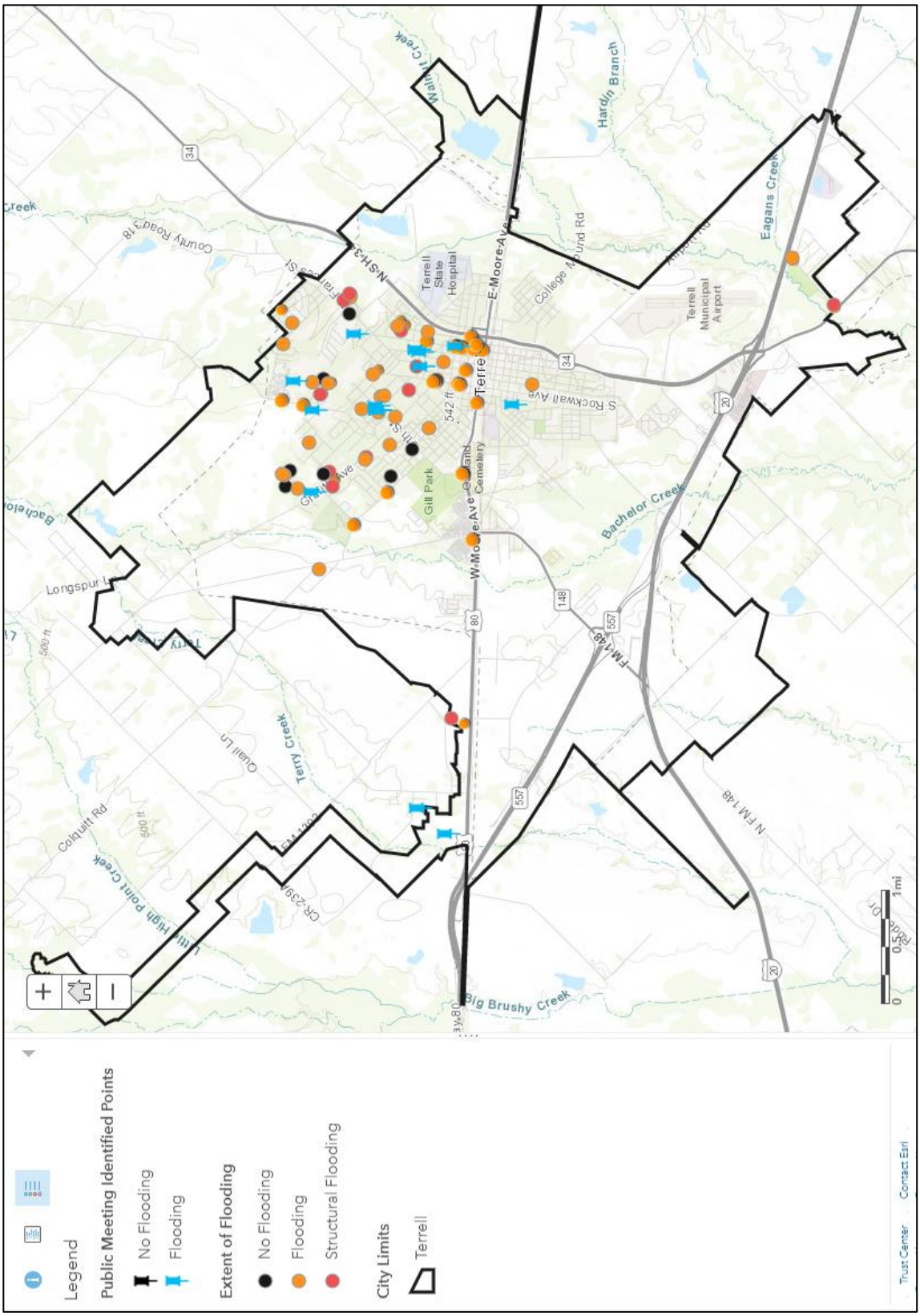

Figure 3: Community-reported flood data

2.5 DRAINAGE MAINTENANCE BEST PRACTICES

A peer review process was utilized to benchmark with City's current stormwater practices. Additional details are provided in the full memorandum in Volume 3. The key findings from the comparison of the City's drainage maintenance practices to that of its peers include the following:

- The number of City staff and field crews are consistent with other peer cities.
- Peer cities generally have an excavator, which was the only consistently missing piece of equipment for the City.
- The City can optimize the drainage maintenance program by leveraging the "condition" feature of the GIS dataset produced as part of the Drainage Master Plan project. The program can focus on areas that experience concentrated reports of poor and failed condition.

FNI noted that if the rate of drainage maintenance activities is insufficient to achieve the goals of the program, increasing the allocation of storm drainage maintenance activities as a percentage of the part time activities of city staff would be an immediate solution.

The long-term recommendation is to conduct an asset management benchmark evaluation as a best path forward for identifying future staffing, equipment, and approaches to maintain the City's storm system.

2.6 MEETINGS

FNI met with the City throughout the study to discuss findings and collaborate. The recorded meetings are shown in Table 1. The complete meeting minutes are included in Appendix B.

Table 1: FNI project meetings with City

Meeting	Date
Project Kickoff	10/26/2017
Update 1: Griffith, ArcGIS Online, Criteria, etc.	01/30/2018
Drainage Master Plan Meeting #2	05/10/2018
Phase 1 Wrap-Up	09/06/2018
Drainage Master Plan Phase 2 Meeting #1	12/10/2018
Drainage Master Plan Phase 2 Meeting #2	02/26/2019
Drainage Master Plan Alternatives, Funding, and Amendment	05/16/2019
Hydraulics and Alternatives Finalization	06/20/2019
Prioritization, Funding, and Report	08/13/2019

3.0 SMALL PROJECTS

FNI was tasked to develop a list of "small" drainage projects that the City could fund with cash. These small projects are maintenance focused and do not require detailed engineering or hydraulic modelling to make a recommendation and cost estimate. The locations of potential small projects noted during site visits were compared relative to completed work orders provided by the City, the results of the Rain-on-Mesh analysis of the 100-year storm event, and public comments received through the online survey and public meeting. These identified projects were also compared to the list of projects provided by the City. The combined list of projects was prioritized based on the following categories: road flooding, property damage, infrastructure damage, maintenance cost, and public impact. A few of the small projects were ultimately transferred to the large project category due to size, complexity, and cost. The final list and prioritization of the small projects can be seen in Table 2. Project #39, Skyline Drive, is under design at the time of this report. The complete memorandum, conceptual project exhibits, and OPCCs are located in Volume 3.

Table 2: Revised Small Projects List

Rank	*Project #*	*Location*	*Description*	*OPCC*
1	39	Skyline Drive	Realign 30" conduit	$106,000
2	8	Gill Park/Lions Club Lane	Ditch grading, small RCP	$167,400
3	28	Colquitt & Lovers	Repair headwalls, ditch grading	$38,600
4	9	Park/Moore	Grading, connect headwalls	$30,800
5	41	Elm & Roberts	Install small scale infrastructure	$168,800
6	1	Lexington Drive	Repair concrete lining	$182,100
7	14	Airport & SH34	Concrete channel repair	$228,800
8	26	Tanger Drive	Replace headwalls	$68,700
9	40	Rose St at N. Blanche Washout	Regrade channel	$75,400
10	12	Obstruction in channel	Relocate utility pole	$41,200
11	10	Cemetery	Channel grading	$138,300
12	35	Bachelor Creek crossing at Colquitt	Repair channel transition	$74,700
			Small Project Total	**$1,320,800**

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4.0 EXISTING INFRASTRUCTURE ANALYSIS METHODOLOGY

4.1 RAIN-ON-MESH ANALYSIS

A preliminary rain-on-mesh (ROM) analysis was performed using the HEC-RAS 2D modelling capabilities to simulate direct application of rainfall to the terrain. The 2009 LiDAR from NCTCOG was used as the terrain and the precipitation was derived the excess rainfall shown in the HEC-HMS model from a 100-year SCS storm under normal distribution. No storm drain infrastructure was included for this initial analysis, but large crossings were "burned" into the terrain. The results from the ROM analysis, Figure A1, showed a broad but informative first look at potential flood prone areas. The existing conditions analysis for watersheds KT3 and KT4 was based on the ROM results.

4.2 HYDROLOGY

4.2.1 Existing Hydrology

Watersheds were delineated based on the 2009 LiDAR shown in Figure A2 and labeled according to whether the system outfalls into Kings Creek (KC) or Bachelor Creek (BC). Figure A3 demonstrates the soils for the study area are primarily Group D. A review of dual soil groups showed a general correlation with proximity to floodplain areas and were therefore assumed to fall in the more conservative of the two classifications.

Existing land use was based on classifications performed by NCTCOG in 2015 and is shown in Figure A4. Hydrologic losses were calculated based on the SCS Curve Number Method by doing a weighted average of the iSWM land use categories for Groups B, C, and D soils shown in Table 3. The resulting curve number for each basin is shown in Figure A6.

Table 3: iSWM Runoff Curve Number

Land Use Description	*Soil Group*		
	B	*C*	*D*
High Density Residential	85	90	92
Medium Density Residential quarter	75	83	87
Medium Density Residential third	72	81	86
Low Density Residential 2 acres	65	77	82
Paved Driveways	98	98	98
Paved Streets and Roads	98	98	98
Gravel Streets and Roads	85	89	91
Open Space - Poor	79	86	89
Open Space - Fair	69	79	84
Open Space - Good	61	74	80
Commercial	92	94	95
Industrial	88	91	93
Brush - Fair	56	70	77

Basin flowpaths are also shown in Figure A6. The TR-55 method was used to calculate the time of concentration for each basin. At this point in the study the City was in a transition period between using iSWM and Atlas 14 precipitation data. The data for the 2-YR, 24-HR precipitation input used in the time of concentration calculations is similar between these two sources. The same regression equations are used so the time of concentration results would not differ. The iSWM data was applied to calculate the time of concentration values. The iSWM Technical Manual minimum and maximum values for time of concentration were applied along with an added undeveloped category shown in Table 4. Existing time of concentration results are included in Table A1.

Table 4: Minimum and Maximum Time of Concentration Values

Description	*Min (min)*	*Max (min)*
Residential	15	30
Commercial/Industrial	10	25
Central Business District	10	15
Undeveloped	15	35

The curve numbers from Figure A6, the lag times from Table A1, and the Atlas 14 data shown in Table 5 were used as inputs in a HEC-HMS version 4.2.1 model. The Atlas 14 data was applied for depths because it has been recently updated and there are significant differences when compared with the outdated depth data from TP-40. The 24-hour storm event depth was used and the SCS Type III distribution was

applied, per City request. The model was run at a one (1) minute interval. The Terrell Hydrologic Model can be accessed in Appendix C.

Table 5: Atlas 14 Precipitation Data

	Depth (in)					
Duration	*2-YR (50%)*	*5-YR (20%)*	*10-YR (10%)*	*25-YR (4%)*	*50-YR (2%)*	*100-YR (1%)*
24-hr	4.18	5.29	6.26	7.66	8.79	10.00

4.2.2 Ultimate Hydrology

The future land use was developed based on the City's future land plan as of 2017. The applied future land use is shown in Figure A5, the weighted curve number for each basin is shown in Figure A6 and the resulting time of concentrations are included in Table A2. An ultimate conditions basin file was made in the HEC-HMS model with the future land use updates and run with the same precipitation data to determine ultimate conditions flows. Some watersheds are almost completely built out and thus, do not show significant differences between the existing and ultimate conditions results. This study focused on reporting the ultimate flows so the long-term infrastructure planning would account for the future needs of the City. The mapped watersheds in this report show existing land use with ultimate flows.

4.3 HYDRAULICS

A combination of 1D and 2D hydraulic models were used to model the City's watersheds. Areas primarily consisting of open channel were modelled in 1D HEC-RAS. More complex areas and areas with significant storm drain infrastructure were modelled in 1D/2D Infoworks ICM models. The hydraulic model extents are shown in Figure A7. Figure A8 shows the 100-year depth results from existing conditions with ultimate flows. Detailed watershed descriptions and figures are provided for each watershed in Volume 2. All hydraulic models are included in Appendix C.

4.3.1 Open Channel Study Areas

Open channel study areas were generally extended to the point of confluence with the Kings Creek or Bachelor Creek floodplain. HEC-RAS version 5.0.5 was used to create six (6) steady-state, 1D hydraulic models. Modified Puls routing was used in an iterative process between the hydraulic and hydrologic models to create the existing and ultimate flow files. When boundary conditions were set to normal depth the average flowline slope was used as a guideline and verified with 100-year BFE data.

The KC1, KC5, KC6, and BC1 models were completely modelled by FNI. The KC3 and KC4 models started as working models provided by City and are based on flood study of the Creekside Development by McLendon Hydrology and Engineering. The models were updated by FNI. Detailed descriptions are included within each model.

The KC1 and KC5 models contain an Alternative plan which demonstrates the geometries and effects of the proposed CIP projects mentioned in Section 5.

4.3.2 Localized Study Areas

Localized study areas include areas with significant amounts of storm drain infrastructure, or complex flow scenarios, and were studied using InfoWorks ICM version 9.0. Seven (7) ICM models were developed and were named based on the area of focus within the watershed. Table 6 shows the watershed associated with each localized study area.

Table 6: Watershed location of ICM models

Watershed	*ICM model(s)*
KC1	Virginia, East
KC2	Griffith
KT1	Airport
KT2	Far South
BC1	West
BC5	Colquitt

Each model has a Base scenario representing the existing conditions. The storm drain network from the GIS inventory, subbasins, terrain, building footprints, roughness zones, and channel geometries were transferred from GIS to the base scenario in ICM. The time of concentration and weighted curve numbers from the hydrology calculations were also input.

The 24-hour Atlas 14 storm depth with Type 3 distribution was used for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events.

The Ultimate scenario for each model applies the calculated future land use curve numbers and time of concentrations. The West, Colquitt, Airport, Griffith, and Virginia models contain an Alternative scenario built from the Ultimate scenario and updated with the components of the proposed CIP projects mentioned in Section 5.

4.3.3 Alternatives and Large Project Identification

FNI analyzed the hydraulic results from all of the developed models and identified areas where significant flooding problems occurred. A list of 44 alternatives in total was established for the studied areas and discussed with the City. The City chose 12 (twelve) alternatives from this list to be modelled as Large Projects. Additionally, the conceptual solution provided in the Virginia Memorandum was expanded on, adding three (3) more Large Projects. Lastly, the proposed projects from the Railroad Memorandum were incorporated, bringing the total count to twenty (20) Large Projects. These Large Projects were modelled at a high level for the City's long-term planning purposes. More detailed design will be required when the time comes to implement the proposed projects.

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5.0 LARGE PROJECTS

Once identified, the Large Projects were prioritized in order to develop a Capital Improvement Plan (CIP). The ranking criteria and weight assigned to each criterion was developed through coordination with City staff. The five categories chosen were Life Safety/Road Flooding, Property Damage, Frequency of Flooding, Project Cost, and Public Impact. The ranking system was used to assess the relative severity of the drainage problems identified. A live database was utilized to compile the ranking system and other Large Project data to produce a concise One Page Report (OPR) for each identified project which are located in Volume 2.

5.1 RANKING CRITERIA

A pair-wise comparison table was developed by FNI that allowed the City to rank each of the criteria against each other. Each category was evaluated and given a score from one (1) to three (3) in comparison to each of the other four criteria. A score of 3 means the criterion being evaluated is more important than the one in which it is being compared to, a score of 2 means each of the criterion have equal importance, and a score of 1 means the criterion being evaluated is less important than the one it is being compared to. The sum of scores for each category is considered its “weight,” with weights ranging from a minimum of four (4) to a maximum of twelve (12). The final ranking of the criteria is shown in Table 7.

Table 7: Criteria Weighted Ranking

Criteria	Life Safety / Road Flooding	Property Damage	Frequency of Flooding	Project Cost	Public Impact	Sum	Rank	Weight
Life Safety / Road Flooding		3	3	3	3	12	1	0.30
Property Damage	1		1	3	3	8	3	0.20
Frequency of Flooding	1	3		3	2	9	2	0.23
Project Cost	1	1	1		1	4	5	0.10
Public Impact	1	1	2	3		7	4	0.18

FNI collaborated with the City to develop thorough descriptions for each category that would allow future projects to be scored consistently with those identified in this study. Each criterion was assigned a scoring range, ranging from a minimum score of zero (0) or one (1) to a maximum score of five (5). FNI developed quantifiable ranges for each criterion based on data produced from the 20 identified large projects. The data used to score each project was based on the project's area of influence. The following list provides descriptions for each category's ranking process and the scoring ranges developed for the criterion.

- Life Safety/Road Flooding: This criterion awards points for the life safety component of the project. Because most flood related fatalities involve motorists driving into floodwaters, this criterion is scored based on the depth of flow in or over the road during a 100-year storm event in the current conditions with ultimate flows. All roads within the project's area of influence were evaluated and the road with the highest depth was used for this criterion.

Table 8: Point Distribution for Life Safety/Road Flooding

Rating	Depth, ft	Score
Very High	3.0	5
High	2.5	4
Moderate	2.0	3
Low	1.5	2
Very Low	1.0	1
None	0.0	0

- Property Damage: This criterion awards points based on the existing potential for property damage due to flooding. Ranking is scored based on the number of structures that flood in existing conditions during a 100-year storm event. Finish Floor Elevations (FFE) were assumed to be one (1) foot above the LiDAR elevation for each structure. A building was considered flooded when the 100-year depth was greater than the FFE.

Table 9: Point Distribution for Property Damage

Rating	Count	Score
Very High	10	5
High	5	4
Moderate	3	3
Low	2	2
Very Low	1	1
None	0	0

- Frequency of Flooding: This criterion awards points based on the storm event in which significant flooding begins to occur. Ranking is scored based on the smallest storm that causes structural flooding.

Table 10: Point Distribution for Frequency of Flooding

Rating	Event	Score
Very High	2-YR	5
High	5-YR	4
Moderate	10-YR	3
Low	25-YR	2
Very Low	100-YR	1
None	None	0

- Project Cost: This criterion awards points for smaller projects which may be implemented with lesser impact on City budgets. The ranking is scored based on the estimated cost of the project.

Table 11: Point Distribution for Project Cost

Rating	OPCC	Score
Very High	$1,000,000	5
High	$2,000,000	4
Moderate	$4,000,000	3
Low	$8,000,000	2
Very Low	$11,000,000	1

- Public Impact: This criterion awards points for potential reduction of long-term maintenance costs associated with the project. The ranking is scored based on the historic frequency of work orders and drainage complaints associated with the project. The work orders and drainage complaints were weighted equally for this analysis.

Table 12: Point Distribution for Public Impact

Rating	Count	Score
Very High	10	5
High	6	4
Moderate	4	3
Low	2	2
Very Low	1	1

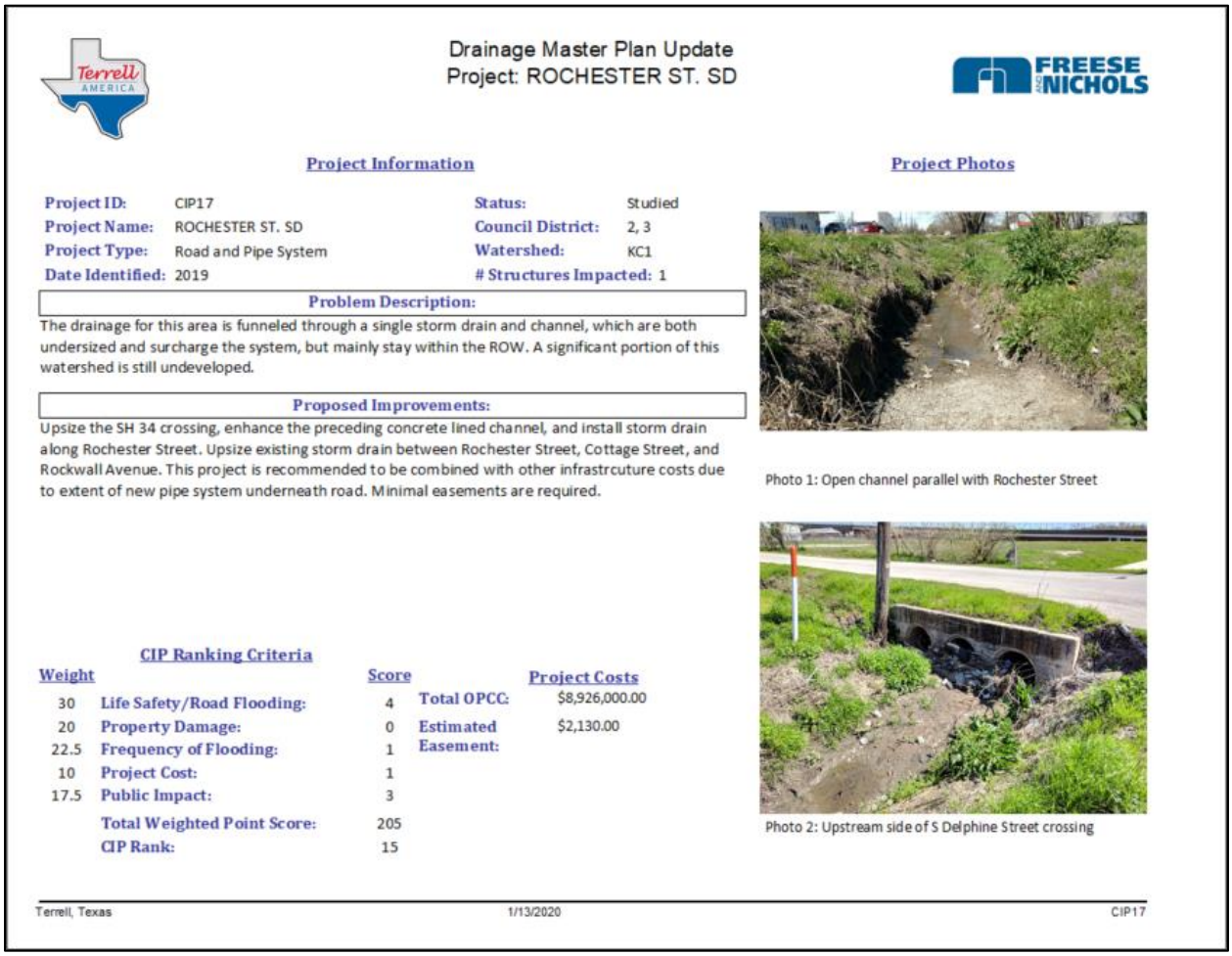
Each Large Project receives a score for each of the five criteria, and each score is multiplied by its weighted ranking. The sum of these weighted scores provides the Project's final prioritization score. The final project ranking is shown in Table 13. Table A3 provides additional detail about how the projects scored in each category.

Table 13: Large Project Ranking

Project	*Description*	*Rank*	*OPCC*
CIP09	Heath St. SD	1	$1,837,000
CIP07	KC2 Drainage Improvements	2	$11,021,000
CIP08	W. Alamo SD	3	$1,998,000
CIP13	Virginia St. SD Extension	4	$3,921,000
CIP19	Fuji Drainage Improvements	5	$4,182,000
CIP12	KC1 Upper Channel Improvements	6	$272,000
CIP11	KC1 Railroad Crossing (UPRR 182.12) and Channel Improvements	7	$1,536,000
CIP04	Cemetery Channel	8	$2,730,000
CIP03	BC1 Railroad Crossing (UPRR 183.74) and Channel Improvements	9	$1,258,000
CIP18	RR SPUR Culvert	10	$1,836,000
CIP14	College St. SD	11	$4,814,000
CIP10	N. Rockwall Channel & N. Morris Bypass	12	$8,978,000
CIP05	Stadium Channel	13	$1,791,000
CIP02	West End St. Culvert	14	$698,000
CIP17	Rochester St. SD	15	$9,600,000
CIP15	Brin St. SD	16	$3,466,000
CIP01	Brookhollow Channel and SD	17	$2,527,000
CIP16	Gardner St. Improvements	18	$1,889,000
CIP06	SWCC Railroad Crossing (UPRR 183.15) Improvements	19	$126,000
CIP20	Airport Lead	20	$2,018,000
	Large Project Total		**$66,498,000**

5.2 LARGE PROJECT DATABASE

A Microsoft Access database was created to house the Large Projects and the criteria that was input to determine the rankings. The current ranking does not necessarily mean the projects need to be completed in this order. It should be used as a tool to assist with annual budgeting and project implementation. The database is included in Appendix C and is a live document the City can use to verify project ranking in case criteria weight changes over time. An example of a project's one page report (OPR) from the database is shown in Figure 4. All of the OPRs are included in Volume 2 along with the Opinion of Probable Cost (OPCC) each Large Project.



Drainage Master Plan Update
Project: ROCHESTER ST. SD

Project Information

Project ID:	CIP17	**Status:**	Studied
Project Name:	ROCHESTER ST. SD	**Council District:**	2, 3
Project Type:	Road and Pipe System	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	1

Problem Description:

The drainage for this area is funneled through a single storm drain and channel, which are both undersized and surcharge the system, but mainly stay within the ROW. A significant portion of this watershed is still undeveloped.

Proposed Improvements:

Upsize the SH 34 crossing, enhance the preceding concrete lined channel, and install storm drain along Rochester Street. Upsize existing storm drain between Rochester Street, Cottage Street, and Rockwall Avenue. This project is recommended to be combined with other infrastrcuture costs due to extent of new pipe system underneath road. Minimal easements are required.

Project Photos

Photo 1: Open channel parallel with Rochester Street

Photo 2: Upstream side of S Delphine Street crossing

CIP Ranking Criteria

Weight		Score
30	Life Safety/Road Flooding:	4
20	Property Damage:	0
22.5	Frequency of Flooding:	1
10	Project Cost:	1
17.5	Public Impact:	3
	Total Weighted Point Score:	205
	CIP Rank:	15

Project Costs

Total OPCC:	$8,926,000.00
Estimated Easement:	$2,130.00

Terrell, Texas 1/13/2020 CIP17

Figure 4: Example of Access Database OPR

6.0 FUNDING STRATEGIES

The City contracted FNI to provide assistance with a funding evaluation for proposed stormwater management, including capital improvement projects (CIPs). This ongoing assistance includes project management and meetings, refining the planning level cost estimates, documenting the CIP ranking process, researching CIP funding options, and developing a recommended funding approach to address the City's identified stormwater management needs. The funding scenarios incorporate a selection of the evaluated alternative funding options and will factor the infrastructure, project costs, and prioritization rankings developed in the study.

The City has expressed in prior meetings the desire to fund more projects out of the Stormwater Utility Fee (SWUF), and certain preferences for cash, pay-as-you-go (PAYGO) and debt-based financing of CIPs. The funding memorandum discusses the development of a program to achieve these goals and the requisite changes to the SWUF as implemented, such that the stormwater infrastructure might stand on its own without additional support from the general fund.

In 2017, the rate was increased to $5.65 per equivalent residential unit (ERU), identified as Service Level 3 in the City's 2011 Stormwater Utility Report, which currently generates approximately $1,000,000 annually. This increased revenue enabled expanded storm system maintenance services, as well as capital improvements identified through an update to the City's stormwater master plan.

It appears the City's revenue could be at least $200,000 annually for each $1.00 assessed monthly per ERU based on a screening analysis of new commercial properties through development and annexation. The memorandum conservatively assumes a continued annual revenue rate of $180,000 per $1.00/ERU per month for the funding and rate scenario analyses in this document.

The identified small projects are to be funded from the SWUF using the PAYGO strategy over a three-year period. Three of the large projects are estimated to cost less than $1 million and are to be funded the same way as the small projects with a subsequent three-year timeline. There are 17 (seventeen) remaining large projects to be funded though the SWUF to fund debt service of GO bonds over a 30-year timeline. These large projects are recommended to be broken up into three (3) tranches to slowly build up the amount of funding required to service the debt. The timeline and required SWUF rate increases to implement this strategy is outlined in Table 14 and graphically represented in Figure 5.

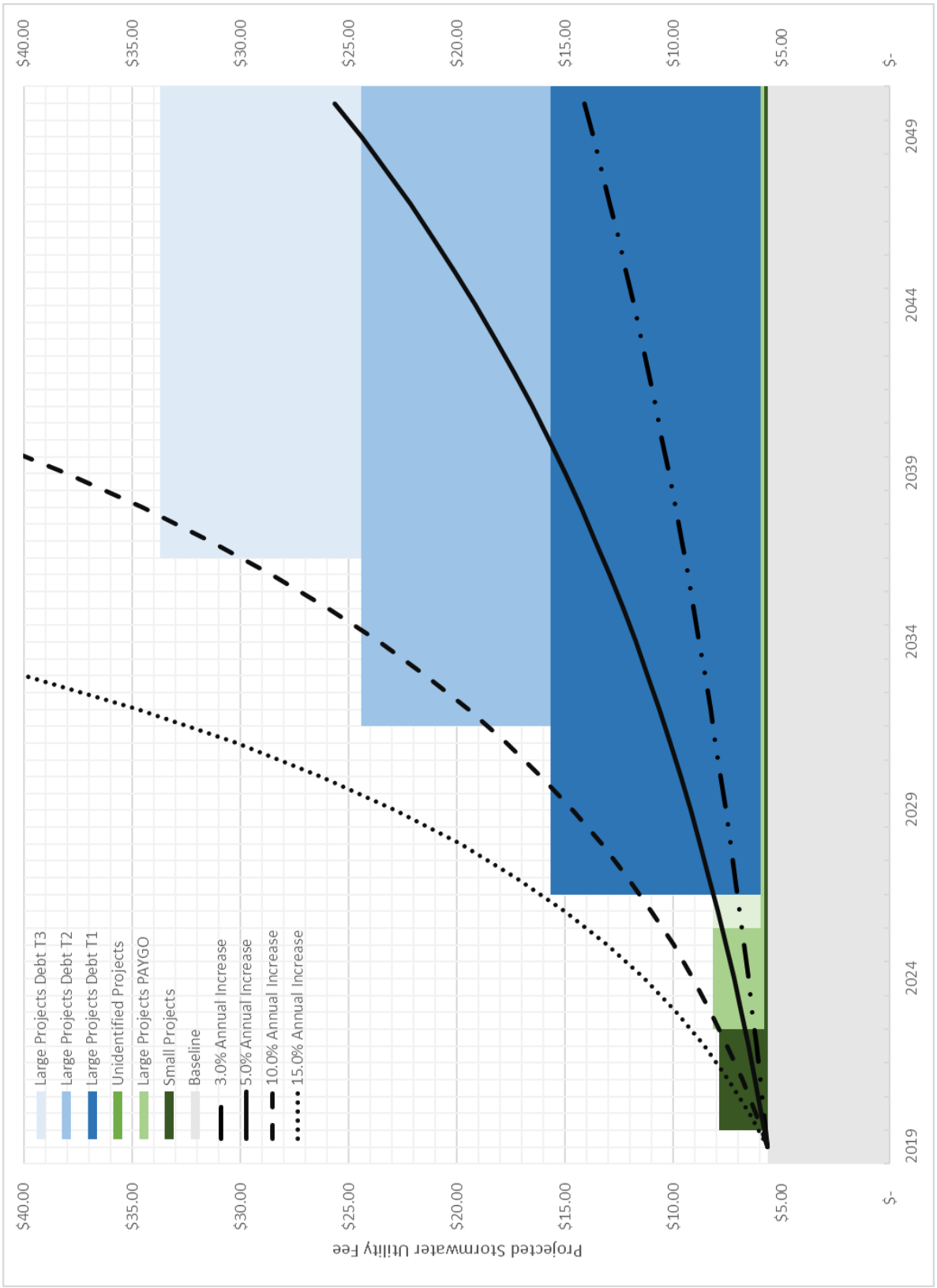


Figure 5: Timeline of Conceptual Stormwater Utility Fee

Table 14: Stormwater Utility Fee Schedule of Rates

Description	Start	Duration, years	Incremental Rate	Rate at Start	Rate at Completion	Net Rate
Baseline	2017	∞	$5.65	$5.65	$5.65	$5.65
Small Projects	2020	3	$2.24	$7.89	$0.16	$5.81
Large Projects PAYGO	2023	3	$2.36	$8.16	$0.16	$5.97
Large Projects Debt	2027	30	$9.70	$15.67	$4.51	$10.48
Large Projects Debt	2032	30	$8.74	$24.41	$4.07	$14.55
Large Projects Debt	2037	30	$9.28	$33.69	$4.32	$18.87
Replacement Fund	2050	∞	$22.41	$56.10	$22.41	$41.28

Based on the researched funding mechanisms and known project scopes, FNI created a scenario to fund the development of all the projects, which would make the utility fee for the City of Terrell among the highest in the State of Texas. The City is not alone in its current challenge to fund drainage infrastructure needs. Numerous municipalities in Texas and across the nation are facing similar circumstances. Further refinement of the baseline plan is described in the section below.

The Existing Infrastructure Liabilities will only continue to grow as time progresses. To avoid a drastic increase in the utility fee to account for these liabilities, the fee associated with these may be phased in over time, as politically expedient. Additional funding allows the City to take a more proactive rather than reactive approach to drainage maintenance and flood risk reduction projects. More extreme measures may be considered to replace unnecessary storm drains with open channels to reduce the cost burden, even if that means that structures must be bought out.

It is recommended that the City focus on the Small Projects initially because they fit within the existing funding capacity and can produce near term, tangible benefits to the community. The bonus is that the fee increase associated with the Small Projects may be counted towards other components when the projects are complete.

The Large Projects to be funded entirely with the utility fee may be delayed or broken up into smaller parts, but generally represent simple, straight-forward, and affordable projects. FNI recommends initiating these projects as soon as the Small Projects are completed, to maintain the positive momentum.

The Large Projects to be funded by debt, with debt service partially covered by the utility fee representing a tremendous increase in the utility fee. The utility fee could also be increased incrementally, as bonds or other debt issuance may be spaced out when politically expedient.

Specific Large Projects should be used in attempt to receive grant funding or low- to no- interest rate loans so that the total burden of the cost is not upon the City of Terrell. Some of the instances include:

The KC2 Channel Improvements, West Alamo Storm Drain, Heath Street Storm Drain, and North Rockwall Channel and North Morris Bypass projects ($23.8 million total) are good candidates to pursue a grant from the Texas Water Development Board (TWDB) as part of the state flood plan and represent most of the flood hazard within the City. The City should be prepared to provide as much information as possible to the TWDB as soon as the rules and procedures are known. Other grant opportunities for these projects should also be pursued such as the Flood Mitigation Assistance Grant Program sponsored by FEMA and the Watershed Protection and Flood Prevention Program sponsored by NRCS.

Multiple Large Projects are located within the Tax Incrementing Financing Reinvestment Zone #1 (TIF Zone #1) and they appear to meet the requirements for funding through TIF Zone #1 revenues. However, some project locations are specifically excluded from TIF Zone #1. If funds are needed for projects in the excluded areas, then the zone would need to be legally amended. TIF Zone #1 funding of approximately $14.0 million could be leveraged in the application for GLO CDBG-MIT funding of a combination or subset of CIP11, CIP12, CIP13, CIP14, and CIP15.

The complete funding memorandum can be found in Volume 3.

7.0 RECOMMENDATIONS

The preceding sections of this document describe the methodology used to collect data on and analyze the existing stormwater infrastructure, identify system deficiencies, develop projects to address those deficiencies, compare the projects and prioritize them, and describe a hypothetical approach to funding each of the projects in turn. Because the needs identified far exceed the capacity to fund the solutions in an acceptable time frame, a more realistic recommendation is as follows:

1. Increase the Stormwater Utility Fee as much and as often as possible

   As shown in the hypothetical funding scenario discussed in the Funding Memorandum, the Stormwater Utility Fee could be justifiably increased to be among the highest in the State, and still need to be increased to fund all of the identified needs. If the Utility Fee is not increased by at least the same amount as the cost escalation, no progress will be made in bringing in additional revenue to construct new projects.

2. Adopt an Asset Management strategy

   Now that the City has a spatial database of Stormwater infrastructure, it will be possible to leverage that asset data to increase efficiency in operations, identify counterproductive maintenance practices, and hopefully be able to estimate when infrastructure needs to be replaced to improve budgeting and minimize funding crises. The City should create a routine strategy to update and analyze the asset data so the Stormwater infrastructure is effectively managed.

3. Implement Small Projects and Large Projects under $1 Million

   As Utility Fee increases are achieved, and the small projects are addressed, one by one, momentum will build around the program and the completion of projects based on the previous rate increases will help justify the next round of rate increases. Because the significant projects will have already been identified, deviation from the known project list is not recommended unless the new project can score in the top half of the known problems based on the prioritization calculations. Once all small projects are complete, the City should do another survey or quick inventory of work orders to determine if any other small projects could be identified and addressed immediately. Following the small projects, the more affordable of the Large Projects should be implemented.

4. Utilize the TIF Zone #1 revenues to fund the Large Projects.

   The proposed projects that appear to meet the requirements of the existing TIF Zone #1 total to approximately $14.0 million. TIF Zone #1 was created in 2007 and has a limited life span, so this funding source is time sensitive. The funds from TIF Zone #1 could be leveraged for application of GLO CDBG-MIT to complete a combination or subset of CIP11, CIP12, CIP13, CIP14, and CIP15.

5. Pursue Grant Funding for Large Projects over $1 Million

   The Large Projects over $1 Million will take significant political effort to implement, as each project would represent the entire utility fee revenue for the year as it currently is. The political resistance can be smoothed if additional funding sources take the burden off the Citizens, especially through grant funding. There are some prerequisites to receive grant funding. The City should prepare to fund the development of items like a Multi-Hazard Mitigation Plan or Watershed Protection Plan, etc. either in-house or through a consultant so as funds become available, the City will be at the front of the line to receive the grants. More importantly, the City should be prepared to engage the Texas Water Development Board through the State Flood Planning process so the largest projects can be built into the plan and put on a schedule for implementation.

6. Manage expectations

   Though this study represents a significant investment by the City into its stormwater infrastructure, it is still a high-level document. The projects identified are largely conceptual in nature and will require additional design effort to fully determine the scope of each project. As such, there may be some limitations in the modeling approach such that an ancillary problem is not addressed by a proposed project, such as too little inlet capacity, but with an improved trunkline. Being conceptual, the projects have room to shrink or expand to meet the City's needs and an additional strategy the City might employ is to use a smaller design storm event to make a meaningful improvement in a severe problem area. If grant funding becomes available, the full design might be implemented, but in the short term, perhaps only the quick fix is affordable. Citizens will likely expect the problem to be solved when they see new infrastructure in the ground, but the onus will be on the City to communicate clearly this may not be the case.

A Drainage Master Plan serves best as a guideline that is updated as time goes on to incorporate changing circumstances. The GIS inventory, H&H models, CIP database, and funding strategies are all

tools the City should continue to update and use to study, plan, and improve the drainage infrastructure within the city limits.

APPENDIX A
H&H Exhibits

Table A1
Existing Time of Concentration Calculations

BASIN LAG TIME CALCULATION - EXISTING CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$ EXISTING MAX= 30						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$ EXISTING MAX= 1500 MIN 2 FPS						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$ EXISTING MAX= 1500 MIN 2 FPS						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
KT-2-050	Commercial/Industrial	10	25	35.56	0.0556	100	Short grass prairie	0.150	0.0101	3.72	11.93	Unpaved	16.1345	0.0209	723	2.33	5.17	Paved	20.3282	0.0169	461	2.65	2.90	Pipe	8.00	961	2.00	None			0.00	None			0.00	22.00	22.00	0.37	13.20	0.22
KT-2-040	Residential	15	30	85.88	0.1342	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0152	1410	2.00	11.75	None	0			0.00	0.00	Swale	3.00	834	4.63	Pipe	8.00	74	0.15	None			0.00	32.36	30.00	0.50	18.00	0.30
KT-2-030	Commercial/Industrial	10	25	69.70	0.1089	100	Short grass prairie	0.150	0.0128	3.72	10.87	Unpaved	16.1345	0.0123	1448	2.00	12.06	None	0			0.00	0.00	Channel	6.00	180	0.50	Pipe	8.00	68	0.14	None			0.00	23.58	23.58	0.39	14.15	0.24
KT-2-020	Commercial/Industrial	10	25	51.02	0.0797	100	Short grass prairie	0.150	0.0327	3.72	7.46	Unpaved	16.1345	0.0076	973	2.00	8.11	None	0			0.00	0.00	Swale	3.00	2361	13.12	Channel	6.00	294	0.82	None			0.00	29.50	25.00	0.42	15.00	0.25
KT-2-010	Commercial/Industrial	10	25	58.16	0.0909	101	Short grass prairie	0.150	0.0165	3.72	9.87	Unpaved	16.1345	0.0090	336	2.00	2.80	None	0			0.00	0.00	Swale	3.00	500	2.78	Pipe	8.00	310	0.65	Pipe	8.00	292	0.61	16.69	16.69	0.28	10.02	0.17
KT-1-120	Residential	15	30	76.79	0.1200	100	Short grass prairie	0.150	0.0150	3.72	10.22	Unpaved	16.1345	0.0116	1216	2.00	10.13	None	0			0.00	0.00	Pipe	8.00	53	0.11	Swale	3.00	311	1.73	Channel	6.00	717	1.99	24.18	24.18	0.40	14.51	0.24
KT-1-110	Residential	15	30	66.61	0.1041	100	Short grass prairie	0.150	0.0206	3.72	8.99	Unpaved	16.1345	0.0118	1502	2.00	12.51	None	0			0.00	0.00	Swale	3.00	319	1.77	Channel	6.00	40	0.11	Channel	6.00	63	0.18	23.56	23.56	0.39	14.14	0.24
KT-1-100	Commercial/Industrial	10	25	38.11	0.0595	49	Short grass prairie	0.150	0.0212	3.72	4.99	Gutter	36.144628	0.0094	960	3.50	4.57	None	0			0.00	0.00	Pipe	8.00	260	0.54	Channel	6.00	614	1.70	Pipe	8.00	825	1.72	13.53	13.53	0.23	8.12	0.14
KT-1-090	Commercial/Industrial	10	25	50.29	0.0786	100	Smooth Surfaces	0.011	0.0118	3.72	1.39	Paved	20.3282	0.0051	1305	2.00	10.88	Unpaved	16.1345	0.0026	197	2.00	1.64	Channel	6.00	849	2.36	Pipe	8.00	67	0.14	None			0.00	16.40	16.40	0.27	9.84	0.16
KT-1-085	Residential	15	30	8.91	0.0139	103	Short grass prairie	0.150	0.0063	3.72	14.75	Unpaved	16.1345	0.0112	346	2.00	2.89	Paved	20.3282	0.0114	348	2.17	2.68	Swale	3.00	419	2.33	None			0.00	None			0.00	22.64	22.64	0.38	13.58	0.23
KT-1-080	Commercial/Industrial	10	25	24.20	0.0378	100	Short grass prairie	0.150	0.0079	3.72	13.24	Gutter	36.144628	0.0025	668	2.00	5.56	None	0			0.00	0.00	Pipe	8.00	946	1.97	None			0.00	None			0.00	20.77	20.77	0.35	12.46	0.21
KT-1-075	Residential	15	30	30.19	0.0472	45	Short grass prairie	0.150	0.0122	3.72	5.86	Unpaved	16.1345	0.0099	1042	2.00	8.68	None	0			0.00	0.00	Swale	3.00	1002	5.57	None			0.00	None			0.00	20.11	20.11	0.34	12.07	0.20
KT-1-070	Residential	15	30	27.85	0.0435	100	Short grass prairie	0.150	0.0172	3.72	9.61	Unpaved	16.1345	0.0151	350	2.00	2.92	None	0			0.00	0.00	Swale	3.00	1523	8.46	Pipe	8.00	57	0.12	None			0.00	21.11	21.11	0.35	12.66	0.21
KT-1-060	Residential	15	30	27.10	0.0424	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0113	733	2.00	6.11	Paved	20.3282	0.0077	107	2.00	0.89	Pipe	8.00	899	1.87	Channel	6.00	27	0.07	None			0.00	24.77	24.77	0.41	14.86	0.25
KT-1-050	Residential	15	30	48.51	0.0758	100	Short grass prairie	0.150	0.0101	3.72	11.94	Unpaved	16.1345	0.0132	641	2.00	5.34	None	0			0.00	0.00	Channel	6.00	1035	2.88	Pipe	8.00	228	0.47	None			0.00	20.63	20.63	0.34	12.38	0.21
KT-1-040	Commercial/Industrial	10	25	95.46	0.1492	100	Short grass prairie	0.150	0.0117	3.72	11.27	Unpaved	16.1345	0.0109	357	2.00	2.97	None	0			0.00	0.00	Swale	3.00	1333	7.40	Channel	6.00	2078	5.77	Pipe	8.00	96	0.20	27.62	25.00	0.42	15.00	0.25
KT-1-030	Commercial/Industrial	10	25	49.13	0.0768	100	Short grass prairie	0.150	0.0096	3.72	12.17	Unpaved	16.1345	0.0026	1073	2.00	8.94	None	0			0.00	0.00	Pipe	8.00	64	0.13	Channel	6.00	40	0.11	None			0.00	21.36	21.36	0.36	12.82	0.21
KT-1-020	Undeveloped	15	35	65.13	0.1018	100	Short grass prairie	0.150	0.0173	3.72	9.63	Unpaved	16.1345	0.0098	725	2.00	6.04	None	0			0.00	0.00	Pipe	8.00	2224	4.63	None			0.00	None			0.00	20.30	20.30	0.34	12.18	0.20
KT-1-010	Undeveloped	15	35	99.76	0.1559	100	Short grass prairie	0.150	0.0096	3.72	12.20	Unpaved	16.1345	0.0208	676	2.33	4.84	None	0			0.00	0.00	Pipe	8.00	200	0.42	Channel	6.00	3405	9.46	None			0.00	26.92	26.92	0.45	16.15	0.27
KC-6-050	Commercial/Industrial	10	25	25.78	0.0403	100	Smooth Surfaces	0.011	0.0203	3.72	1.12	Paved	20.3282	0.0094	358	2.00	2.98	None	0			0.00	0.00	Pipe	8.00	490	1.02	None			0.00	None			0.00	5.12	10.00	0.17	6.00	0.10
KC-6-040	Undeveloped	15	35	46.81	0.0731	100	Short grass prairie	0.150	0.0266	3.72	8.11	Unpaved	16.1345	0.0233	617	2.46	4.18	Gutter	36.144628	0.0056	708	2.71	4.35	Pipe	8.00	97	0.20	Channel	6.00	647	1.80	None			0.00	18.64	18.64	0.31	11.18	0.19
KC-6-030	Undeveloped	15	35	70.33	0.1099	100	Short grass prairie	0.150	0.0072	3.72	13.70	Unpaved	16.1345	0.0175	1502	2.13	11.73	None	0			0.00	0.00	Swale	3.00	322	1.79	Channel	6.00	1407	3.91	Pipe	8.00	57	0.12	31.25	31.25	0.52	18.75	0.31
KC-6-020	Commercial/Industrial	10	25	29.28	0.0458	100	Smooth Surfaces	0.011	0.0123	3.72	1.36	Unpaved	16.1345	0.0194	1359	2.25	10.08	Unpaved	16.1345	0.0084	898	2.00	7.48	Pipe	8.00	103	0.22	Channel	6.00	110	0.30	None			0.00	19.44	19.44	0.32	11.67	0.19
KC-6-010	Undeveloped	15	35	21.66	0.0338	100	Short grass prairie	0.150	0.0540	3.72	6.11	Unpaved	16.1345	0.0189	755	2.22	5.68	None	0			0.00	0.00	Channel	6.00	1625	4.51	None			0.00	None			0.00	16.31	16.31	0.27	9.78	0.16
KC-5-110	Residential	15	30	22.67	0.0354	100	Short grass prairie	0.150	0.0153	3.72	10.11	Unpaved	16.1345	0.0202	306	2.29	2.23	None	0			0.00	0.00	Swale	3.00	856	4.75	Channel	6.00	225	0.63	None			0.00	17.72	17.72	0.30	10.63	0.18
KC-5-100	Residential	15	30	18.82	0.0294	105	Short grass prairie	0.150	0.0282	3.72	8.24	Unpaved	16.1345	0.0214	303	2.36	2.14	None	0			0.00	0.00	Channel	6.00	595	1.65	None			0.00	None			0.00	12.03	15.00	0.25	9.00	0.15
KC-5-090	Residential	15	30	20.75	0.0324	101	Short grass prairie	0.150	0.0587	3.72	5.96	Unpaved	16.1345	0.0253	243	2.57	1.58	None	0			0.00	0.00	Swale	3.00	1325	7.36	Pipe	8.00	26	0.06	Channel	6.00	284	0.79	15.74	15.74	0.26	9.44	0.16
KC-5-080	Residential	15	30	39.19	0.0612	105	Short grass prairie	0.150	0.0135	3.72	11.06	Unpaved	16.1345	0.0305	156	2.82	0.92	Paved	20.3282	0.0152	484	2.51	3.21	Channel	6.00	1302	3.62	Swale	3.00	413	2.29	Pipe	8.00	29	0.06	21.16	21.16	0.35	12.70	0.21
KC-5-070	Residential	15	30	51.03	0.0797	100	Short grass prairie	0.150	0.0077	3.72	13.32	Unpaved	16.1345	0.0233	528	2.46	3.58	Paved	20.3282	0.0140	877	2.41	6.07	Channel	6.00	465	1.29	Pipe	8.00	649	1.35	Channel	6.00	299	0.83	26.44	26.44	0.44	15.86	0.26
KC-5-060	Residential	15	30	25.15	0.0393	100	Short grass prairie	0.150	0.0292	3.72	7.82	Gutter	36.144628	0.0095	307	3.52	1.45	None	0			0.00	0.00	Swale	3.00	1169	6.49	Pipe	8.00	662	1.38	None			0.00	17.14	17.14	0.29	10.29	0.17
KC-5-050	Residential	15	30	33.85	0.0529	100	Short grass prairie	0.150	0.0141	3.72	10.44	Unpaved	16.1345	0.0173	145	2.12	1.14	None	0			0.00	0.00	Swale	3.00	2026	11.25	Pipe	8.00	289	0.60	None			0.00	23.44	23.44	0.39	14.06	0.23
KC-5-040	Residential	15	30	19.26	0.0301	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0194	175	2.24	1.30	None	0			0.00	0.00	Swale	3.00	839	4.66	Pipe	8.00	100	0.21	Channel	6.00	356	0.99	22.99	22.99	0.38	13.79	0.23
KC-5-030	Undeveloped	15	35	43.73	0.0683	100	Smooth Surfaces	0.011	0.0104	3.72	1.46	Unpaved	16.1345	0.0103	1129	2.00	9.41	None	0			0.00	0.00	Channel	6.00	1534	4.26	None			0.00	None			0.00	15.13	15.13	0.25	9.08	0.15
KC-5-020	Commercial/Industrial	10	25	83.82	0.1310	101	Short grass prairie	0.150	0.0073	3.72	13.69	Unpaved	16.1345	0.0088	1066	2.00	8.88	None	0			0.00	0.00	Channel	6.00	1560	4.33	None			0.00	None			0.00	26.91	25.00	0.42	15.00	0.25
KC-5-010	Undeveloped	15	35	73.09	0.1142	100	Short grass prairie	0.150	0.0084	3.72	12.83	Unpaved	16.1345	0.0202	788	2.30	5.72	None	0			0.00	0.00	Pipe	8.00	2857	5.95	None			0.00	None			0.00	24.50	24.50	0.41	14.70	0.25
KC-4-060	Undeveloped	15	35	45.70	0.0714	100	Short grass prairie	0.150	0.0112	3.72	11.48	Unpaved	16.1345	0.0114	1495	2.00	12.46	None	0			0.00	0.00	Swale	3.00	404	2.25	Pipe	8.00	62	0.13	None			0.00	26.32	26.32	0.44	15.79	0.26
KC-4-055	Undeveloped	15	35	37.33	0.0583	100	Short grass prairie	0.150	0.0234	3.72	8.54	Unpaved	16.1345	0.0258	1029	2.59	6.61	None	0			0.00	0.00	Swale	3.00	849	4.71	None			0.00	None			0.00	19.86	19.86	0.33	11.92	0.20
KC-4-050	Undeveloped	15	35	13.75	0.0215	100	Short grass prairie	0.150	0.0133	3.72	10.70	Unpaved	16.1345	0.0296	277	2.78	1.67	Gutter	36.144628	0.0173	881	4.75	3.09	Pipe	8.00	791	1.65	Pipe	8.00	656	1.37	None			0.00	18.47	18.47	0.31	11.08	0.18
KC-4-045	Residential	15	30	20.40	0.0319	92	Short grass prairie	0.150	0.0257	3.72	7.68	Gutter	36.144628	0.0079	684	3.22	3.54	None	0			0.00	0.00	Pipe	8.00	789	1.64	Channel	6.00	269	0.75	None			0.00	13.61	15.00	0.25	9.00	0.15
KC-4-040	Undeveloped	15	35	42.36	0.0662	100	Short grass prairie	0.150	0.0124	3.72	11.01	Unpaved	16.1345	0.0202	1529	2.29	11.10	None	0			0.00	0.00	Channel	6.00	285	0.79	None			0.00	None			0.00	22.90	22.90	0.38	13.74	0.23
KC-4-030	Residential	15	30	33.62	0.0525	100	Short grass prairie	0.150	0.0316	3.72	7.57	Unpaved	16.1345	0.0295	281	2.77	1.69	Gutter	36.144628	0.0071	599	3.06	3.27	Pipe	8.00	218	0.45	Channel	6.00	999	2.77	None			0.00	15.75	15.75	0.26	9.45	0.16
KC-4-020	Residential	15	30	85.69	0.1339	61	Short grass prairie	0.150	0.0133	3.72	7.19	Paved	20.3282	0.0076	1500	2.00	12.50	None	0			0.00	0.00	Channel	6.00	1492	4.14	Pipe	8.00	857	1.79	Channel	6.00	287	0.80	26.42	26.42	0.44	15.85	0.26

BASIN LAG TIME CALCULATION - EXISTING CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$				EXISTING MAX= 30		SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$				EXISTING MAX= 1500 MIN 2 FPS		SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$				EXISTING MAX= 1500 MIN 2 FPS		CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_C			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
KC-4-010	Undeveloped	15	35	54.63	0.0854	100	Short grass prairie	0.150	0.0244	3.72	8.39	Unpaved	16.1345	0.0297	325	2.78	1.95	Paved	20.3282	0.0051	271	2.00	2.26	None			0.00	Channel	6.00	2542	7.06	None			0.00	19.66	19.66	0.33	11.80	0.20
KC-3-070	Undeveloped	15	35	67.41	0.1053	100	Short grass prairie	0.150	0.0175	3.72	9.60	Unpaved	16.1345	0.0145	1500	2.00	12.50	None	0			0.00	0.00	Swale	3.00	421	2.34	Pipe	8.00	94	0.20	None			0.00	24.64	24.64	0.41	14.78	0.25
KC-3-060	Residential	15	30	56.59	0.0884	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Paved	20.3282	0.0071	148	2.00	1.23	Unpaved	16.1345	0.0104	1393	2.00	11.61	Channel	6.00	1133	3.15	Pipe	8.00	65	0.14	Channel	6.00	55	0.15	18.23	18.23	0.30	10.94	0.18
KC-3-050	Undeveloped	15	35	86.33	0.1349	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0219	1499	2.39	10.46	None	0			0.00	0.00	Swale	3.00	543	3.01	Channel	6.00	1242	3.45	None			0.00	32.75	32.75	0.55	19.65	0.33
KC-3-040	Undeveloped	15	35	34.85	0.0545	100	Short grass prairie	0.150	0.0173	3.72	9.64	Unpaved	16.1345	0.0171	1505	2.11	11.90	None	0			0.00	0.00	Swale	3.00	200	1.11	Channel	6.00	472	1.31	None			0.00	23.96	23.96	0.40	14.37	0.24
KC-3-030	Residential	15	30	59.69	0.0933	100	Short grass prairie	0.150	0.0118	3.72	11.22	Unpaved	16.1345	0.0099	629	2.00	5.24	None	0			0.00	0.00	Swale	3.00	750	4.16	Pipe	8.00	27	0.06	None			0.00	20.68	20.68	0.34	12.41	0.21
KC-3-020	Undeveloped	15	35	77.38	0.1209	100	Short grass prairie	0.150	0.0336	3.72	7.39	Paved	20.3282	0.0212	235	2.96	1.32	None	0			0.00	0.00	Swale	3.00	937	5.21	Pipe	8.00	48	0.10	None			0.00	14.02	15.00	0.25	9.00	0.15
KC-3-010	Undeveloped	15	35	14.26	0.0223	100	Smooth Surfaces	0.011	0.0116	3.72	1.40	Gutter	36.144628	0.0067	228	2.96	1.29	None	0			0.00	0.00	Pipe	8.00	548	1.14	Channel	6.00	993	2.76	None			0.00	6.59	15.00	0.25	9.00	0.15
KC-2-110	Residential	15	30	44.11	0.0689	100	Smooth Surfaces	0.011	0.0289	3.72	0.97	Paved	20.3282	0.0055	522	2.00	4.35	None	0			0.00	0.00	Pipe	8.00	608	1.27	Channel	6.00	648	1.80	Channel	6.00	666	1.85	10.24	15.00	0.25	9.00	0.15
KC-2-100	Residential	15	30	65.91	0.1030	100	Short Grass Prairie	0.150	0.0050	3.72	15.79	Paved	20.3282	0.0131	1084	2.33	7.76	None	0			0.00	0.00	Pipe	8.00	2055	4.28	None			0.00	None			0.00	27.83	27.83	0.46	16.70	0.28
KC-2-090	Residential	15	30	66.62	0.1041	102	Short Grass Prairie	0.150	0.0050	3.72	16.12	Paved	20.3282	0.0111	1482	2.14	11.54	None	0			0.00	0.00	Pipe	8.00	75	0.16	Channel	6.00	2325	6.46	Pipe	8.00	96	0.20	34.48	30.00	0.50	18.00	0.30
KC-2-080	Residential	15	30	68.06	0.1063	76	Smooth Surfaces	0.011	0.0380	3.72	0.70	Unpaved	16.1345	0.0126	1173	2.00	9.77	Paved	20.3282	0.0087	255	2.00	2.12	Pipe	8.00	1856	3.87	None			0.00	Pipe	8.00	71	0.15	16.61	16.61	0.28	9.97	0.17
KC-2-070	Residential	15	30	39.07	0.0610	100	Short Grass Prairie	0.150	0.0330	3.72	7.44	Unpaved	16.1345	0.0254	308	2.57	2.00	None	0			0.00	0.00	Channel	6.00	983	2.73	Pipe	8.00	280	0.58	None			0.00	12.75	15.00	0.25	9.00	0.15
KC-2-060	Residential	15	30	51.19	0.0800	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Gutter	36.144628	0.0140	408	4.27	1.59	None	0			0.00	0.00	Swale	3.00	681	3.78	Channel	6.00	48	0.13	None			0.00	7.46	15.00	0.25	9.00	0.15
KC-2-050	Residential	15	30	45.00	0.0703	100	Short Grass Prairie	0.150	0.0083	3.72	12.92	Unpaved	16.1345	0.0073	671	2.00	5.59	Paved	20.3282	0.0028	262	2.00	2.18	Channel	6.00	341	0.95	Pipe	8.00	955	1.99	None			0.00	23.63	23.63	0.39	14.18	0.24
KC-2-040	Residential	15	30	19.48	0.0304	100	Short grass prairie	0.150	0.0096	3.72	12.19	Unpaved	16.1345	0.0036	96	2.00	0.80	None	0			0.00	0.00	Swale	3.00	1023	5.68	Pipe	8.00	39	0.08	None			0.00	18.76	18.76	0.31	11.25	0.19
KC-2-030	Residential	15	30	32.40	0.0506	100	Short grass prairie	0.150	0.0379	3.72	7.06	Unpaved	16.1345	0.0132	939	2.00	7.83	None	0			0.00	0.00	Channel	6.00	320	0.89	Pipe	8.00	11	0.02	None			0.00	15.80	15.80	0.26	9.48	0.16
KC-2-020	Residential	15	30	78.17	0.1221	99	Short grass prairie	0.150	0.0105	3.72	11.69	Paved	20.3282	0.0059	694	2.00	5.78	Unpaved	16.1345	0.0052	614	2.00	5.12	Swale	3.00	200	1.11	None			0.00	None			0.00	23.70	23.70	0.40	14.22	0.24
KC-2-010	Residential	15	30	56.34	0.0880	99	Short grass prairie	0.150	0.0171	3.72	9.62	Unpaved	16.1345	0.0110	164	2.00	1.37	None	0			0.00	0.00	Pipe	8.00	2780	5.79	Channel	6.00	1434	3.98	None			0.00	20.76	20.76	0.35	12.46	0.21
KC-1-110	Residential	15	30	44.53	0.0696	100	Smooth Surfaces	0.011	0.0223	3.72	1.08	Paved	20.3282	0.0145	1079	2.45	7.35	Unpaved	16.1345	0.0177	422	2.15	3.27	Channel	6.00	1207	3.35	None			0.00	None			0.00	15.05	15.05	0.25	9.03	0.15
KC-1-100	Commercial/Industrial	10	25	20.62	0.0322	47	Short grass prairie	0.150	0.0684	3.72	3.02	Gutter	36.144628	0.0175	1316	4.78	4.59	None	0			0.00	0.00	None			0.00	None			0.00	None			0.00	7.60	10.00	0.17	6.00	0.10
KC-1-090	Residential	15	30	59.41	0.0928	50	Smooth Surfaces	0.011	0.0417	3.72	0.48	None	0		#N/A	0.00	0.00	Paved	20.3282	0.0140	1557	2.40	10.80	Channel	6.00	3752	10.42	None			0.00	Pipe	8.00	338	0.70	22.41	22.41	0.37	13.44	0.22
KC-1-080	Commercial/Industrial	10	25	72.19	0.1128	100	Smooth Surfaces	0.011	0.0141	3.72	1.29	Gutter	36.144628	0.0115	1501	3.87	6.46	None	0			0.00	0.00	Channel	6.00	1044	2.90	Pipe	8.00	66	0.14	None			0.00	10.79	10.79	0.18	6.47	0.11
KC-1-070	Commercial/Industrial	10	25	6.90	0.0108	87	Smooth Surfaces	0.011	0.0065	3.72	1.58	Unpaved	16.1345	0.0059	327	2.00	2.73	None	0			0.00	0.00	None			0.00	Swale	3.00	651	3.62	Pipe	8.00	702	1.46	9.39	10.00	0.17	6.00	0.10
KC-1-060	Residential	15	30	86.43	0.1351	99	Smooth Surfaces	0.011	0.0144	3.72	1.28	Paved	20.3282	0.0240	213	3.15	1.13	Unpaved	16.1345	0.0086	627	2.00	5.22	Swale	3.00	876	4.87	Pipe	8.00	2155	4.49	None			0.00	16.98	16.98	0.28	10.19	0.17
KC-1-050	Commercial/Industrial	10	25	37.82	0.0591	102	Short grass prairie	0.150	0.0240	3.72	8.59	Unpaved	16.1345	0.0141	161	2.00	1.34	None	0			0.00	0.00	Swale	3.00	1505	8.36	Channel	6.00	228	0.63	Pipe	8.00	219	0.46	19.39	19.39	0.32	11.63	0.19
KC-1-040	Commercial/Industrial	10	25	39.81	0.0622	101	Smooth Surfaces	0.011	0.0334	3.72	0.92	Paved	20.3282	0.0134	431	2.35	3.05	Gutter	36.144628	0.0134	1567	4.18	6.25	Channel	6.00	243	0.67	None			0.00	None			0.00	10.90	10.90	0.18	6.54	0.11
KC-1-030	Residential	15	30	16.08	0.0251	100	Short grass prairie	0.150	0.0195	3.72	9.20	Unpaved	16.1345	0.0138	639	2.00	5.33	Paved	20.3282	0.0078	88	2.00	0.73	Swale	3.00	856	4.75	Channel	6.00	427	1.19	None			0.00	21.20	21.20	0.35	12.72	0.21
KC-1-020	Undeveloped	15	35	42.92	0.0671	100	Short grass prairie	0.150	0.0256	3.72	8.23	Unpaved	16.1345	0.0424	240	3.32	1.21	None	0			0.00	0.00	Channel	6.00	1159	3.22	None			0.00	None			0.00	12.65	15.00	0.25	9.00	0.15
KC-1-010	Residential	15	30	99.19	0.1550	100	Short grass prairie	0.150	0.0122	3.72	11.09	Unpaved	16.1345	0.0156	1061	2.01	8.78	None	0			0.00	0.00	Channel	6.00	4238	11.77	None			0.00	None			0.00	31.64	30.00	0.50	18.00	0.30
BC-5-200	Undeveloped	15	35	40.89	0.0639	100	Short grass prairie	0.150	0.0303	3.72	7.70	Unpaved	16.1345	0.0096	1503	2.00	12.53	None	0			0.00	0.00	Swale	3.00	793	4.40	None			0.00	None			0.00	24.63	24.63	0.41	14.78	0.25
BC-5-130	Residential	15	30	22.92	0.0358	468	Short grass prairie	0.150	0.0471	3.72	22.19	Paved	20.3282	0.0170	1501	2.65	9.44	None	0			0.00	0.00	Channel	6.00	1137	3.16	None			0.00	None			0.00	34.78	30.00	0.50	18.00	0.30
BC-5-120	Residential	15	30	16.23	0.0254	100	Short grass prairie	0.150	0.0279	3.72	7.96	Gutter	36.144628	0.0105	737	3.71	3.31	Unpaved	16.1345	0.0190	349	2.23	2.61	Swale	3.00	1396	7.76	None			0.00	None			0.00	21.64	21.64	0.36	12.98	0.22
BC-5-110	Residential	15	30	24.45	0.0382	100	Short grass prairie	0.150	0.0337	3.72	7.38	Unpaved	16.1345	0.0141	1506	2.00	12.55	None	0			0.00	0.00	Swale	3.00	593	3.29	Channel	6.00	441	1.22	None			0.00	24.44	24.44	0.41	14.67	0.24
BC-5-100	Residential	15	30	13.37	0.0209	100	Smooth Surfaces	0.011	0.0079	3.72	1.63	Unpaved	16.1345	0.0134	889	2.00	7.41	None	0			0.00	0.00	Channel	6.00	201	0.56	None			0.00	None			0.00	9.60	15.00	0.25	9.00	0.15
BC-5-090	Residential	15	30	31.80	0.0497	72	Short grass prairie	0.150	0.0060	3.72	11.36	Paved	20.3282	0.0138	1187	2.39	8.27	None	0			0.00	0.00	None			0.00	None			0.00	None			0.00	19.63	19.63	0.33	11.78	0.20
BC-5-080	Residential	15	30	19.65	0.0307	100	Short grass prairie	0.150	0.0143	3.72	10.38	Unpaved	16.1345	0.0143	1147	2.00	9.56	Paved	20.3282	0.0136	350	2.37	2.46	Channel	6.00	912	2.53	Pipe	8.00	1343	2.80	None			0.00	27.73	27.73	0.46	16.64	0.28
BC-5-070	Residential	15	30	51.42	0.0803	100	Short grass prairie	0.150	0.0093	3.72	12.35	Unpaved	16.1345	0.0101	152	2.00	1.27	Paved	20.3282	0.0070	1057	2.00	8.81	Swale	3.00	1825	10.14	None			0.00	None			0.00	32.56	30.00	0.50	18.00	0.30
BC-5-060	Residential	15	30	20.43	0.0319	100	Short grass prairie	0.150	0.0187	3.72	9.34	Unpaved	16.1345	0.0075	850	2.00	7.09	Gutter	36.144628	0.0066	364	2.94	2.07	Channel	6.00	692	1.92	None			0.00	None			0.00	20.41	20.41	0.34	12.25	0.20
BC-5-050	Undeveloped	15	35	35.35	0.0552	41	Smooth Surfaces	0.011	0.0183	3.72	0.57	None	0		#N/A	0.00	0.00	Unpaved	16.1345	0.0121	1501	2.00	12.51	Swale	3.00	657	3.65	None			0.00	None			0.00	16.73	16.73	0.28	10.04	0.17
BC-5-040	Undeveloped	15	35	61.20	0.0956	100	Short grass prairie	0.150	0.0230	3.72	8.59	Unpaved	16.1345	0.0073	1501	2.00	12.51	None	0			0.00	0.00	Swale	3.00	304	1.69	Channel	6.00	555	1.54	None			0.00	24.33	24.33	0.41	14.60	0.24

BASIN LAG TIME CALCULATION - EXISTING CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
									EXISTING MAX=	30				EXISTING MAX=	1500	MIN 2 FPS				EXISTING MAX=	1500	MIN 2 FPS																			
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
BC-5-030	Residential	15	30	40.34	0.0630	100	Short grass prairie	0.150	0.0072	3.72	13.65	Unpaved	16.1345	0.0120	1336	2.00	11.14	None	0			0.00	0.00	Channel	6.00	117	0.32	Pipe	8.00	89	0.18	None			0.00	25.30	25.30	0.42	15.18	0.25
BC-5-020	Residential	15	30	29.25	0.0457	100	Short grass prairie	0.150	0.0050	3.72	15.81	Unpaved	16.1345	0.0162	530	2.05	4.30	Gutter	36.144628	0.0072	709	3.06	3.86	Pipe	8.00	442	0.92	Swale	3.00	645	3.58	Channel	6.00	138	0.38	28.86	28.86	0.48	17.31	0.29
BC-5-010	Undeveloped	15	35	46.57	0.0728	100	Short grass prairie	0.150	0.0135	3.72	10.63	Unpaved	16.1345	0.0183	396	2.18	3.02	None	0			0.00	0.00	Channel	6.00	2856	7.93	None			0.00	None			0.00	21.58	21.58	0.36	12.95	0.22
BC-4-140	Residential	15	30	21.57	0.0337	100	Short grass prairie	0.150	0.0248	3.72	8.34	Unpaved	16.1345	0.0177	834	2.15	6.48	Gutter	36.144628	0.0078	621	3.19	3.25	Channel	6.00	703	1.95	None			0.00	None			0.00	20.01	20.01	0.33	12.01	0.20
BC-4-120	Residential	15	30	20.62	0.0322	100	Short grass prairie	0.150	0.0161	3.72	9.92	Unpaved	16.1345	0.0040	889	2.00	7.41	Gutter	36.144628	0.0042	608	2.33	4.35	Channel	6.00	386	1.07	Pipe	8.00	105	0.22	None			0.00	22.97	22.97	0.38	13.78	0.23
BC-4-110	Residential	15	30	27.94	0.0437	100	Short grass prairie	0.150	0.0083	3.72	12.90	Unpaved	16.1345	0.0106	273	2.00	2.27	Gutter	36.144628	0.0050	1226	2.55	8.00	Channel	6.00	389	1.08	None			0.00	None			0.00	24.26	24.26	0.40	14.55	0.24
BC-4-100	Residential	15	30	32.87	0.0514	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0115	1173	2.00	9.78	None	0			0.00	0.00	Pipe	8.00	150	0.31	Channel	6.00	790	2.20	None			0.00	28.11	28.11	0.47	16.87	0.28
BC-4-020	Residential	15	30	28.46	0.0445	100	Short grass prairie	0.150	0.0136	3.72	10.60	Unpaved	16.1345	0.0159	842	2.03	6.89	None	0			0.00	0.00	Swale	3.00	3708	20.60	None			0.00	None			0.00	38.09	30.00	0.50	18.00	0.30
BC-4-010	Residential	15	30	15.25	0.0238	100	Short grass prairie	0.150	0.0108	3.72	11.64	Unpaved	16.1345	0.0092	286	2.00	2.38	Paved	20.3282	0.0100	207	2.03	1.70	Swale	3.00	960	5.34	Pipe	8.00	121	0.25	Channel	6.00	157	0.44	21.74	21.74	0.36	13.04	0.22
BC-3-030	Residential	15	30	70.33	0.1099	100	Short grass prairie	0.150	0.0243	3.72	8.41	Unpaved	16.1345	0.0374	401	3.12	2.14	None	0			0.00	0.00	Swale	3.00	958	5.32	Pipe	8.00	617	1.29	None			0.00	17.16	17.16	0.29	10.30	0.17
BC-3-020	Residential	15	30	49.95	0.0781	100	Short grass prairie	0.150	0.0305	3.72	7.67	Unpaved	16.1345	0.0071	786	2.00	6.55	None	0			0.00	0.00	Swale	3.00	548	3.05	Channel	6.00	1078	3.00	None			0.00	20.27	20.27	0.34	12.16	0.20
BC-3-010	Residential	15	30	86.10	0.1345	100	Short grass prairie	0.150	0.0153	3.72	10.11	Unpaved	16.1345	0.0137	913	2.00	7.61	None	0			0.00	0.00	Channel	6.00	882	2.45	None			0.00	None			0.00	20.17	20.17	0.34	12.10	0.20
BC-2-010	Undeveloped	15	35	35.49	0.0555	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0115	1492	2.00	12.44	None	0			0.00	0.00	Swale	3.00	514	2.86	None			0.00	None			0.00	31.12	31.12	0.52	18.67	0.31
BC-1-140	Residential	15	30	46.97	0.0734	100	Short grass prairie	0.150	0.0161	3.72	9.91	Unpaved	16.1345	0.0323	334	2.90	1.92	Paved	20.3282	0.0172	578	2.67	3.61	Pipe	8.00	2039	4.25	None			0.00	None			0.00	19.70	19.70	0.33	11.82	0.20
BC-1-130	Residential	15	30	25.55	0.0399	100	Short grass prairie	0.150	0.0191	3.72	9.26	Paved	20.3282	0.0185	1149	2.77	6.92	None	0			0.00	0.00	Pipe	8.00	550	1.15	None			0.00	None			0.00	17.32	17.32	0.29	10.39	0.17
BC-1-120	Residential	15	30	23.08	0.0361	100	Short grass prairie	0.150	0.0237	3.72	8.50	Unpaved	16.1345	0.0065	1276	2.00	10.63	None	0			0.00	0.00	Pipe	8.00	116	0.24	None			0.00	None			0.00	19.37	19.37	0.32	11.62	0.19
BC-1-110	Residential	15	30	33.19	0.0519	98	Short grass prairie	0.150	0.0099	3.72	11.88	Unpaved	16.1345	0.0244	242	2.52	1.60	None	0			0.00	0.00	Swale	3.00	1053	5.85	Channel	6.00	677	1.88	None			0.00	21.21	21.21	0.35	12.72	0.21
BC-1-100	Commercial/Industrial	10	25	60.22	0.0941	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0151	174	2.00	1.45	None	0			0.00	0.00	Swale	3.00	273	1.52	Channel	6.00	1101	3.06	None			0.00	21.85	21.85	0.36	13.11	0.22
BC-1-090	Commercial/Industrial	10	25	30.97	0.0484	100	Short grass prairie	0.150	0.0160	3.72	9.94	Unpaved	16.1345	0.0126	709	2.00	5.91	None	0			0.00	0.00	Channel	6.00	920	2.56	Pipe	8.00	214	0.45	Channel	6.00	443	1.23	20.08	20.08	0.33	12.05	0.20
BC-1-080	Commercial/Industrial	10	25	46.64	0.0729	100	Short grass prairie	0.150	0.0147	3.72	10.27	Unpaved	16.1345	0.0208	950	2.33	6.80	None	0			0.00	0.00	Swale	3.00	1075	5.97	Channel	6.00	396	1.10	None			0.00	24.14	24.14	0.40	14.49	0.24
BC-1-070	Undeveloped	15	35	40.16	0.0627	85	Short grass prairie	0.150	0.0173	3.72	8.49	Unpaved	16.1345	0.0198	1802	2.27	13.24	None	0			0.00	0.00	Channel	6.00	542	1.51	None			0.00	None			0.00	23.23	23.23	0.39	13.94	0.23
BC-1-060	Undeveloped	15	35	61.91	0.0967	103	Short grass prairie	0.150	0.0162	3.72	10.10	Unpaved	16.1345	0.0110	925	2.00	7.71	None	0			0.00	0.00	Channel	6.00	1468	4.08	None			0.00	None			0.00	21.88	21.88	0.36	13.13	0.22
BC-1-050	Undeveloped	15	35	58.94	0.0921	100	Short grass prairie	0.150	0.0193	3.72	9.22	Unpaved	16.1345	0.0164	379	2.07	3.06	None	0			0.00	0.00	Swale	3.00	3344	18.58	Channel	6.00	373	1.03	None			0.00	31.89	31.89	0.53	19.13	0.32
BC-1-040	Undeveloped	15	35	47.57	0.0743	97	Short grass prairie	0.150	0.0147	3.72	10.03	Unpaved	16.1345	0.0141	1570	2.00	13.08	None	0			0.00	0.00	Channel	6.00	934	2.59	None			0.00	None			0.00	25.71	25.71	0.43	15.42	0.26
BC-1-030	Undeveloped	15	35	67.79	0.1059	105	Short grass prairie	0.150	0.0110	3.72	11.97	Unpaved	16.1345	0.0075	1500	2.00	12.50	None	0			0.00	0.00	Channel	6.00	2305	6.40	None			0.00	None			0.00	30.87	30.87	0.51	18.52	0.31
BC-1-021	Undeveloped	15	35	76.30	0.1192	97	Short grass prairie	0.150	0.0640	3.72	5.55	Unpaved	16.1345	0.0195	1355	2.25	10.03	Paved	20.3282	0.0104	155	2.08	1.24	Swale	3.00	1715	9.53	None			0.00	None			0.00	26.36	26.36	0.44	15.81	0.26
BC-1-020	Undeveloped	15	35	23.83	0.0372	100	Short grass prairie	0.150	0.0134	3.72	10.67	Unpaved	16.1345	0.0101	1500	2.00	12.50	None	0			0.00	0.00	Channel	6.00	621	1.73	None			0.00	None			0.00	24.90	24.90	0.42	14.94	0.25
BC-1-010	Undeveloped	15	35	28.93	0.0452	100	Short grass prairie	0.150	0.0076	3.72	13.42	Unpaved	16.1345	0.0206	576	2.32	4.14	None	0			0.00	0.00	Channel	6.00	1210	3.36	None			0.00	None			0.00	20.92	20.92	0.35	12.55	0.21
KT-1-090	Commercial/Industrial	10	25	50.29	0.0786	100	Smooth Surfaces	0.011	0.0118	3.72	1.39	Paved	20.3282	0.0051	1305	2.00	10.88	Unpaved	16.1345	0.0026	197	2.00	1.64	Channel	6.00	849	2.36	Pipe	8.00	67	0.14	None			0.00	16.40	16.40	0.27	9.84	0.16
KT-1-030	Commercial/Industrial	10	25	49.13	0.0768	100	Short grass prairie	0.150	0.0096	3.72	12.17	Unpaved	16.1345	0.0026	1073	2.00	8.94	None	0			0.00	0.00	Pipe	8.00	64	0.13	Channel	6.00	40	0.11	None			0.00	21.36	21.36	0.36	12.82	0.21
KT-1-110	Residential	15	30	66.61	0.1041	100	Short grass prairie	0.150	0.0206	3.72	8.99	Unpaved	16.1345	0.0118	1502	2.00	12.51	None	0			0.00	0.00	Swale	3.00	319	1.77	Channel	6.00	40	0.11	Channel	6.00	63	0.18	23.56	23.56	0.39	14.14	0.24
KT-1-060	Residential	15	30	27.10	0.0424	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0113	733	2.00	6.11	Paved	20.3282	0.0077	107	2.00	0.89	Pipe	8.00	899	1.87	Channel	6.00	27	0.07	None			0.00	24.77	24.77	0.41	14.86	0.25
KT-1-070	Residential	15	30	27.85	0.0435	100	Short grass prairie	0.150	0.0172	3.72	9.61	Unpaved	16.1345	0.0151	350	2.00	2.92	None	0			0.00	0.00	Swale	3.00	1523	8.46	Pipe	8.00	57	0.12	None			0.00	21.11	21.11	0.35	12.66	0.21
KT-1-085	Residential	15	30	8.91	0.0139	103	Short grass prairie	0.150	0.0063	3.72	14.75	Unpaved	16.1345	0.0112	346	2.00	2.89	Paved	20.3282	0.0114	348	2.17	2.68	Swale	3.00	419	2.33	None			0.00	None			0.00	22.64	22.64	0.38	13.58	0.23
KT-2-010	Commercial/Industrial	10	25	58.16	0.0909	101	Short grass prairie	0.150	0.0165	3.72	9.87	Unpaved	16.1345	0.0090	336	2.00	2.80	None	0			0.00	0.00	Swale	3.00	500	2.78	Pipe	8.00	310	0.65	Pipe	8.00	292	0.61	16.69	16.69	0.28	10.02	0.17
KT-2-020	Commercial/Industrial	10	25	51.02	0.0797	100	Short grass prairie	0.150	0.0327	3.72	7.46	Unpaved	16.1345	0.0076	973	2.00	8.11	None	0			0.00	0.00	Swale	3.00	2361	13.12	Channel	6.00	294	0.82	None			0.00	29.50	25.00	0.42	15.00	0.25
KT-2-030	Commercial/Industrial	10	25	69.70	0.1089	100	Short grass prairie	0.150	0.0128	3.72	10.87	Unpaved	16.1345	0.0123	1448	2.00	12.06	None	0			0.00	0.00	Channel	6.00	180	0.50	Pipe	8.00	68	0.14	None			0.00	23.58	23.58	0.39	14.15	0.24
KT-2-040	Residential	15	30	85.88	0.1342	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0152	1410	2.00	11.75	None	0			0.00	0.00	Swale	3.00	834	4.63	Pipe	8.00	74	0.15	None			0.00	32.36	30.00	0.50	18.00	0.30
KT-2-050	Commercial/Industrial	10	25	35.56	0.0556	100	Short grass prairie	0.150	0.0101	3.72	11.93	Unpaved	16.1345	0.0209	723	2.33	5.17	Paved	20.3282	0.0169	461	2.65	2.90	Pipe	8.00	961	2.00	None			0.00	None			0.00	22.00	22.00	0.37	13.20	0.22
KT-4-040	Residential	15	30	30.23	0.0472	100	Short grass prairie	0.150	0.0088	3.72	12.66	Unpaved	16.1345	0.0075	730	2.00	6.08	None	0			0.00	0.00	Swale	3.00	605	3.36	Pipe	8.00	917	1.91	None			0.00	24.01	24.01	0.40	14.41	0.24
KT-4-030	Undeveloped	15	35	62.32	0.0974	96	Industrial	0.090	0.0189	3.72	5.96	Unpaved	16.1345	0.0081	1481	2.00	12.34	None	0			0.00	0.00	Swale	3.00	600	3.34	None			0.00	None			0.00	21.64	21.64	0.36	12.98	0.22

BASIN LAG TIME CALCULATION - EXISTING CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$ EXISTING MAX= 30						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$ EXISTING MAX= 1500 MIN 2 FPS						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$ EXISTING MAX= 1500 MIN 2 FPS						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
KT-4-020	Undeveloped	15	35	62.32	0.0974	100	Short grass prairie	0.150	0.0093	3.72	12.30	Unpaved	16.1345	0.0108	1510	2.00	12.59	None	0			0.00	0.00	Swale	3.00	186	1.03	None			0.00	None			0.00	25.92	25.92	0.43	15.55	0.26
KT-4-010	Undeveloped	15	35	47.85	0.0748	100	Short grass prairie	0.150	0.0103	3.72	11.83	Unpaved	16.1345	0.0245	693	2.53	4.57	None	0			0.00	0.00	Swale	3.00	1901	10.56	None			0.00	None			0.00	26.96	26.96	0.45	16.18	0.27
KT-3-040	Residential	15	30	41.56	0.0649	100	Short grass prairie	0.150	0.0231	3.72	8.59	Unpaved	16.1345	0.0161	332	2.05	2.70	Paved	20.3282	0.0114	162	2.17	1.24	Swale	3.00	1362	7.57	None			0.00	None			0.00	20.09	20.09	0.33	12.05	0.20
KT-3-030	Residential	15	30	45.16	0.0706	100	Short grass prairie	0.150	0.0167	3.72	9.76	Unpaved	16.1345	0.0126	352	2.00	2.93	None	0			0.00	0.00	Swale	3.00	532	2.96	Pipe	8.00	1215	2.53	None			0.00	18.19	18.19	0.30	10.91	0.18
KT-3-020	Undeveloped	15	35	21.31	0.0333	100	Short grass prairie	0.150	0.0138	3.72	10.53	Unpaved	16.1345	0.0079	394	2.00	3.29	None	0			0.00	0.00	Swale	3.00	405	2.25	Channel	6.00	540	1.50	None			0.00	17.57	17.57	0.29	10.54	0.18
KT-3-010	Undeveloped	15	35	42.09	0.0658	100	Smooth Surfaces	0.011	0.0267	3.72	1.00	Paved	20.3282	0.0046	1207	2.00	10.06	Unpaved	16.1345	0.0004	299	2.00	2.49	Swale	3.00	497	2.76	Channel	6.00	1038	2.88	None			0.00	19.20	19.20	0.32	11.52	0.19

Table A2
Ultimate Time of Concentration Calculations

BASIN LAG TIME CALCULATION - ULTIMATE CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
									EXISTING MAX=	30				EXISTING MAX=	1500	MIN 2 FPS				EXISTING MAX=	1500	MIN 2 FPS																				
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
KT-2-050	Commercial/Industrial	10	25	35.56	0.0556	100	Short grass prairie	0.150	0.0101	3.72	11.93	Unpaved	16.1345	0.0209	723	2.33	5.17	Paved	20.3282	0.0169	461	2.65	2.90	Pipe	8.00	961	2.00	None			0.00	None			0.00	22.00	22.00	0.37	13.20	0.22
KT-2-040	Commercial/Industrial	10	25	85.88	0.1342	100	Smooth Surfaces	0.011	0.0037	3.72	2.20	Paved	20.3282	0.0152	1410	2.51	9.37	None	0			0.00	0.00	Swale	3.00	834	4.63	Pipe	8.00	74	0.15	None			0.00	16.35	16.35	0.27	9.81	0.16
KT-2-030	Commercial/Industrial	10	25	69.70	0.1089	100	Short grass prairie	0.150	0.0128	3.72	10.87	Unpaved	16.1345	0.0123	1448	2.00	12.06	None	0			0.00	0.00	Channel	6.00	180	0.50	Pipe	8.00	68	0.14	None			0.00	23.58	23.58	0.39	14.15	0.24
KT-2-020	Commercial/Industrial	10	25	51.02	0.0797	100	Short grass prairie	0.150	0.0327	3.72	7.46	Unpaved	16.1345	0.0076	973	2.00	8.11	None	0			0.00	0.00	Swale	3.00	2361	13.12	Channel	6.00	294	0.82	None			0.00	29.50	25.00	0.42	15.00	0.25
KT-2-010	Commercial/Industrial	10	25	58.16	0.0909	101	Short grass prairie	0.150	0.0165	3.72	9.87	Unpaved	16.1345	0.0090	336	2.00	2.80	None	0			0.00	0.00	Swale	3.00	500	2.78	Pipe	8.00	310	0.65	Pipe	8.00	292	0.61	16.69	16.69	0.28	10.02	0.17
KT-1-120	Residential	15	30	76.79	0.1200	100	Short grass prairie	0.150	0.0150	3.72	10.22	Unpaved	16.1345	0.0116	1216	2.00	10.13	None	0			0.00	0.00	Pipe	8.00	53	0.11	Swale	3.00	311	1.73	Channel	6.00	717	1.99	24.18	24.18	0.40	14.51	0.24
KT-1-110	Residential	15	30	66.61	0.1041	100	Short grass prairie	0.150	0.0206	3.72	8.99	Unpaved	16.1345	0.0118	1502	2.00	12.51	None	0			0.00	0.00	Swale	3.00	319	1.77	Channel	6.00	40	0.11	Channel	6.00	63	0.18	23.56	23.56	0.39	14.14	0.24
KT-1-100	Commercial/Industrial	10	25	38.11	0.0595	49	Short grass prairie	0.150	0.0212	3.72	4.99	Gutter	36.144628	0.0094	960	3.50	4.57	None	0			0.00	0.00	Pipe	8.00	260	0.54	Channel	6.00	614	1.70	Pipe	8.00	825	1.72	13.53	13.53	0.23	8.12	0.14
KT-1-090	Commercial/Industrial	10	25	50.29	0.0786	100	Smooth Surfaces	0.011	0.0118	3.72	1.39	Paved	20.3282	0.0051	1305	2.00	10.88	Unpaved	16.1345	0.0026	197	2.00	1.64	Channel	6.00	849	2.36	Pipe	8.00	67	0.14	None			0.00	16.40	16.40	0.27	9.84	0.16
KT-1-085	Residential	15	30	8.91	0.0139	103	Short grass prairie	0.150	0.0063	3.72	14.75	Unpaved	16.1345	0.0112	346	2.00	2.89	Paved	20.3282	0.0114	348	2.17	2.68	Swale	3.00	419	2.33	None			0.00	None			0.00	22.64	22.64	0.38	13.58	0.23
KT-1-080	Commercial/Industrial	10	25	24.20	0.0378	100	Short grass prairie	0.150	0.0079	3.72	13.24	Gutter	36.144628	0.0025	668	2.00	5.56	None	0			0.00	0.00	Pipe	8.00	946	1.97	None			0.00	None			0.00	20.77	20.77	0.35	12.46	0.21
KT-1-075	Residential	15	30	30.19	0.0472	45	Short grass prairie	0.150	0.0122	3.72	5.86	Unpaved	16.1345	0.0099	1042	2.00	8.68	None	0			0.00	0.00	Swale	3.00	1002	5.57	None			0.00	None			0.00	20.11	20.11	0.34	12.07	0.20
KT-1-070	Residential	15	30	27.85	0.0435	100	Short grass prairie	0.150	0.0172	3.72	9.61	Unpaved	16.1345	0.0151	350	2.00	2.92	None	0			0.00	0.00	Swale	3.00	1523	8.46	Pipe	8.00	57	0.12	None			0.00	21.11	21.11	0.35	12.66	0.21
KT-1-060	Residential	15	30	27.10	0.0424	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0113	733	2.00	6.11	Paved	20.3282	0.0077	107	2.00	0.89	Pipe	8.00	899	1.87	Channel	6.00	27	0.07	None			0.00	24.77	24.77	0.41	14.86	0.25
KT-1-050	Commercial/Industrial	10	25	48.51	0.0758	100	Smooth Surfaces	0.011	0.0101	3.72	1.48	Paved	20.3282	0.0132	641	2.33	4.58	None	0			0.00	0.00	Channel	6.00	1035	2.88	Pipe	8.00	228	0.47	None			0.00	9.41	10.00	0.17	6.00	0.10
KT-1-040	Commercial/Industrial	10	25	95.46	0.1492	100	Short grass prairie	0.150	0.0117	3.72	11.27	Unpaved	16.1345	0.0109	357	2.00	2.97	None	0			0.00	0.00	Swale	3.00	1333	7.40	Channel	6.00	2078	5.77	Pipe	8.00	96	0.20	27.62	25.00	0.42	15.00	0.25
KT-1-030	Commercial/Industrial	10	25	49.13	0.0768	100	Short grass prairie	0.150	0.0096	3.72	12.17	Unpaved	16.1345	0.0026	1073	2.00	8.94	None	0			0.00	0.00	Pipe	8.00	64	0.13	Channel	6.00	40	0.11	None			0.00	21.36	21.36	0.36	12.82	0.21
KT-1-020	Commercial/Industrial	10	25	65.13	0.1018	100	Smooth Surfaces	0.011	0.0173	3.72	1.19	Paved	20.3282	0.0098	725	2.01	6.01	None	0			0.00	0.00	Pipe	8.00	2224	4.63	None			0.00	None			0.00	11.84	11.84	0.20	7.10	0.12
KT-1-010	Commercial/Industrial	10	25	99.76	0.1559	100	Smooth Surfaces	0.011	0.0096	3.72	1.51	Paved	20.3282	0.0208	676	2.93	3.84	None	0			0.00	0.00	Pipe	8.00	200	0.42	Channel	6.00	3405	9.46	None			0.00	15.23	15.23	0.25	9.14	0.15
KC-6-050	Commercial/Industrial	10	25	25.78	0.0403	100	Smooth Surfaces	0.011	0.0203	3.72	1.12	Paved	20.3282	0.0094	358	2.00	2.98	None	0			0.00	0.00	Pipe	8.00	490	1.02	None			0.00	None			0.00	5.12	10.00	0.17	6.00	0.10
KC-6-040	Commercial/Industrial	10	25	46.81	0.0731	100	Smooth Surfaces	0.011	0.0266	3.72	1.00	Paved	20.3282	0.0233	617	3.10	3.32	Gutter	36.144628	0.0056	708	2.71	4.35	Pipe	8.00	97	0.20	Channel	6.00	647	1.80	None			0.00	10.67	10.67	0.18	6.40	0.11
KC-6-030	Commercial/Industrial	10	25	70.33	0.1099	100	Smooth Surfaces	0.011	0.0072	3.72	1.69	Paved	20.3282	0.0175	1502	2.69	9.31	None	0			0.00	0.00	Swale	3.00	322	1.79	Channel	6.00	1407	3.91	Pipe	8.00	57	0.12	16.82	16.82	0.28	10.09	0.17
KC-6-020	Commercial/Industrial	10	25	29.28	0.0458	100	Smooth Surfaces	0.011	0.0123	3.72	1.36	Unpaved	16.1345	0.0194	1359	2.25	10.08	Unpaved	16.1345	0.0084	898	2.00	7.48	Pipe	8.00	103	0.22	Channel	6.00	110	0.30	None			0.00	19.44	19.44	0.32	11.67	0.19
KC-6-010	Residential	15	30	21.66	0.0338	100	Smooth Surfaces	0.011	0.0540	3.72	0.76	Paved	20.3282	0.0189	755	2.79	4.51	None	0			0.00	0.00	Channel	6.00	1625	4.51	None			0.00	None			0.00	9.78	15.00	0.25	9.00	0.15
KC-5-110	Residential	15	30	22.67	0.0354	100	Short grass prairie	0.150	0.0153	3.72	10.11	Unpaved	16.1345	0.0202	306	2.29	2.23	None	0			0.00	0.00	Swale	3.00	856	4.75	Channel	6.00	225	0.63	None			0.00	17.72	17.72	0.30	10.63	0.18
KC-5-100	Residential	15	30	18.82	0.0294	105	Short grass prairie	0.150	0.0282	3.72	8.24	Unpaved	16.1345	0.0214	303	2.36	2.14	None	0			0.00	0.00	Channel	6.00	595	1.65	None			0.00	None			0.00	12.03	15.00	0.25	9.00	0.15
KC-5-090	Residential	15	30	20.75	0.0324	101	Short grass prairie	0.150	0.0587	3.72	5.96	Unpaved	16.1345	0.0253	243	2.57	1.58	None	0			0.00	0.00	Swale	3.00	1325	7.36	Pipe	8.00	26	0.06	Channel	6.00	284	0.79	15.74	15.74	0.26	9.44	0.16
KC-5-080	Residential	15	30	39.19	0.0612	105	Short grass prairie	0.150	0.0135	3.72	11.06	Unpaved	16.1345	0.0305	156	2.82	0.92	Paved	20.3282	0.0152	484	2.51	3.21	Channel	6.00	1302	3.62	Swale	3.00	413	2.29	Pipe	8.00	29	0.06	21.16	21.16	0.35	12.70	0.21
KC-5-070	Residential	15	30	51.03	0.0797	100	Short grass prairie	0.150	0.0077	3.72	13.32	Unpaved	16.1345	0.0233	528	2.46	3.58	Paved	20.3282	0.0140	877	2.41	6.07	Channel	6.00	465	1.29	Pipe	8.00	649	1.35	Channel	6.00	299	0.83	26.44	26.44	0.44	15.86	0.26
KC-5-060	Residential	15	30	25.15	0.0393	100	Short grass prairie	0.150	0.0292	3.72	7.82	Gutter	36.144628	0.0095	307	3.52	1.45	None	0			0.00	0.00	Swale	3.00	1169	6.49	Pipe	8.00	662	1.38	None			0.00	17.14	17.14	0.29	10.29	0.17
KC-5-050	Commercial/Industrial	10	25	33.85	0.0529	100	Smooth Surfaces	0.011	0.0141	3.72	1.29	Paved	20.3282	0.0173	145	2.67	0.90	None	0			0.00	0.00	Swale	3.00	2026	11.25	Pipe	8.00	289	0.60	None			0.00	14.05	14.05	0.23	8.43	0.14
KC-5-040	Commercial/Industrial	10	25	19.26	0.0301	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Paved	20.3282	0.0194	175	2.83	1.03	None	0			0.00	0.00	Swale	3.00	839	4.66	Pipe	8.00	100	0.21	Channel	6.00	356	0.99	8.85	10.00	0.17	6.00	0.10
KC-5-030	Commercial/Industrial	10	25	43.73	0.0683	100	Smooth Surfaces	0.011	0.0104	3.72	1.46	Paved	20.3282	0.0103	1129	2.07	9.10	None	0			0.00	0.00	Channel	6.00	1534	4.26	None			0.00	None			0.00	14.82	14.82	0.25	8.89	0.15
KC-5-020	Commercial/Industrial	10	25	83.82	0.1310	101	Short grass prairie	0.150	0.0073	3.72	13.69	Unpaved	16.1345	0.0088	1066	2.00	8.88	None	0			0.00	0.00	Channel	6.00	1560	4.33	None			0.00	None			0.00	26.91	25.00	0.42	15.00	0.25
KC-5-010	Commercial/Industrial	10	25	73.09	0.1142	100	Smooth Surfaces	0.011	0.0084	3.72	1.59	Paved	20.3282	0.0202	788	2.89	4.54	None	0			0.00	0.00	Pipe	8.00	2857	5.95	None			0.00	None			0.00	12.08	12.08	0.20	7.25	0.12
KC-4-060	Residential	15	30	45.70	0.0714	100	Smooth Surfaces	0.011	0.0112	3.72	1.42	Paved	20.3282	0.0114	1495	2.17	11.48	None	0			0.00	0.00	Swale	3.00	404	2.25	Pipe	8.00	62	0.13	None			0.00	15.28	15.28	0.25	9.17	0.15
KC-4-055	Residential	15	30	37.33	0.0583	100	Smooth Surfaces	0.011	0.0234	3.72	1.06	Paved	20.3282	0.0258	1029	3.27	5.25	None	0			0.00	0.00	Swale	3.00	849	4.71	None			0.00	None			0.00	11.02	15.00	0.25	9.00	0.15
KC-4-050	Residential	15	30	13.75	0.0215	100	Short grass prairie	0.150	0.0133	3.72	10.70	Paved	20.3282	0.0296	277	3.50	1.32	Gutter	36.144628	0.0173	881	4.75	3.09	Pipe	8.00	791	1.65	Pipe	8.00	656	1.37	None			0.00	18.13	18.13	0.30	10.88	0.18
KC-4-045	Residential	15	30	20.40	0.0319	92	Short grass prairie	0.150	0.0257	3.72	7.68	Gutter	36.144628	0.0079	684	3.22	3.54	None	0			0.00	0.00	Pipe	8.00	789	1.64	Channel	6.00	269	0.75	None			0.00	13.61	15.00	0.25	9.00	0.15

BASIN LAG TIME CALCULATION - ULTIMATE CONDITIONS

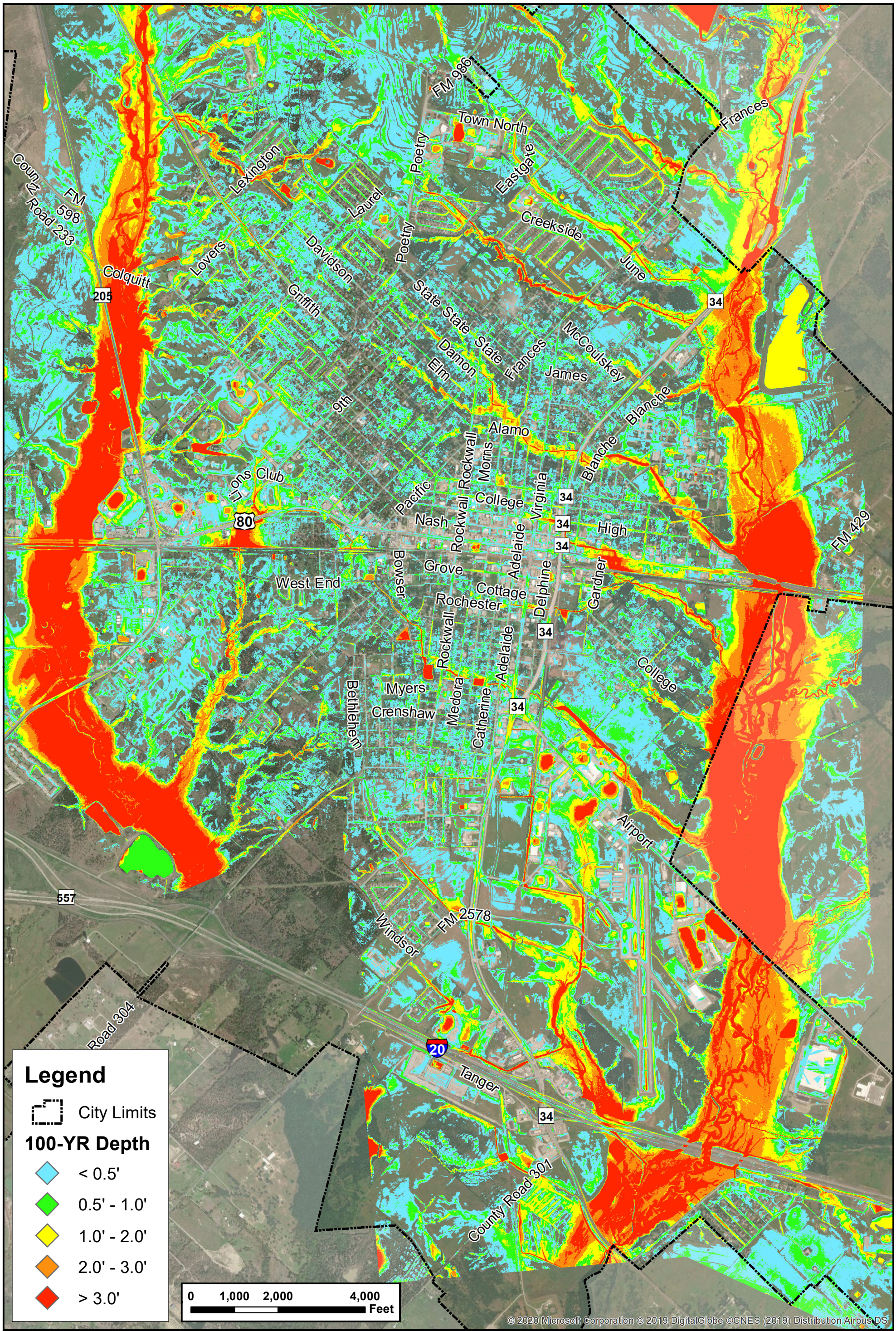
BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
										EXISTING					EXISTING					EXISTING																						
										MAX=	30				MAX=		1500	MIN 2 FPS		MAX=		1500	MIN 2 FPS																		
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
KC-4-040	Residential	15	30	42.36	0.0662	100	Smooth Surfaces	0.011	0.0124	3.72	1.36	Paved	20.3282	0.0202	1529	2.89	8.81	None	0			0.00	0.00	Channel	6.00	285	0.79	None			0.00	None			0.00	10.97	15.00	0.25	9.00	0.15
KC-4-030	Residential	15	30	33.62	0.0525	100	Short grass prairie	0.150	0.0316	3.72	7.57	Unpaved	16.1345	0.0295	281	2.77	1.69	Gutter	36.144628	0.0071	599	3.06	3.27	Pipe	8.00	218	0.45	Channel	6.00	999	2.77	None			0.00	15.75	15.75	0.26	9.45	0.16
KC-4-020	Residential	15	30	85.69	0.1339	61	Short grass prairie	0.150	0.0133	3.72	7.19	Paved	20.3282	0.0076	1500	2.00	12.50	None	0			0.00	0.00	Channel	6.00	1492	4.14	Pipe	8.00	857	1.79	Channel	6.00	287	0.80	26.42	26.42	0.44	15.85	0.26
KC-4-010	Residential	15	30	54.63	0.0854	100	Smooth Surfaces	0.011	0.0244	3.72	1.04	Paved	20.3282	0.0297	325	3.50	1.55	Paved	20.3282	0.0051	271	2.00	2.26	None			0.00	Channel	6.00	2542	7.06	None			0.00	11.91	15.00	0.25	9.00	0.15
KC-3-070	Residential	15	30	67.41	0.1053	100	Smooth Surfaces	0.011	0.0175	3.72	1.19	Paved	20.3282	0.0145	1500	2.45	10.22	None	0			0.00	0.00	Swale	3.00	421	2.34	Pipe	8.00	94	0.20	None			0.00	13.95	15.00	0.25	9.00	0.15
KC-3-060	Residential	15	30	56.59	0.0884	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Paved	20.3282	0.0071	148	2.00	1.23	Unpaved	16.1345	0.0104	1393	2.00	11.61	Channel	6.00	1133	3.15	Pipe	8.00	65	0.14	Channel	6.00	55	0.15	18.23	18.23	0.30	10.94	0.18
KC-3-050	Residential	15	30	86.33	0.1349	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Paved	20.3282	0.0219	1499	3.01	8.30	None	0			0.00	0.00	Swale	3.00	543	3.01	Channel	6.00	1242	3.45	None			0.00	16.73	16.73	0.28	10.04	0.17
KC-3-040	Residential	15	30	34.85	0.0545	100	Smooth Surfaces	0.011	0.0173	3.72	1.19	Paved	20.3282	0.0171	1505	2.66	9.44	None	0			0.00	0.00	Swale	3.00	200	1.11	Channel	6.00	472	1.31	None			0.00	13.06	15.00	0.25	9.00	0.15
KC-3-030	Residential	15	30	59.69	0.0933	100	Short grass prairie	0.150	0.0118	3.72	11.22	Unpaved	16.1345	0.0099	629	2.00	5.24	None	0			0.00	0.00	Swale	3.00	750	4.16	Pipe	8.00	27	0.06	None			0.00	20.68	20.68	0.34	12.41	0.21
KC-3-020	Residential	15	30	77.38	0.1209	100	Short grass prairie	0.150	0.0336	3.72	7.39	Paved	20.3282	0.0212	235	2.96	1.32	None	0			0.00	0.00	Swale	3.00	937	5.21	Pipe	8.00	48	0.10	None			0.00	14.02	15.00	0.25	9.00	0.15
KC-3-010	Residential	15	30	14.26	0.0223	100	Smooth Surfaces	0.011	0.0116	3.72	1.40	Gutter	36.144628	0.0067	228	2.96	1.29	None	0			0.00	0.00	Pipe	8.00	548	1.14	Channel	6.00	993	2.76	None			0.00	6.59	15.00	0.25	9.00	0.15
KC-2-110	Residential	15	30	44.11	0.0689	100	Smooth Surfaces	0.011	0.0289	3.72	0.97	Paved	20.3282	0.0055	522	2.00	4.35	None	0			0.00	0.00	Pipe	8.00	608	1.27	Channel	6.00	648	1.80	Channel	6.00	666	1.85	10.24	15.00	0.25	9.00	0.15
KC-2-100	Residential	15	30	65.91	0.1030	100	Short Grass Prairie	0.150	0.0050	3.72	15.79	Paved	20.3282	0.0131	1084	2.33	7.76	None	0			0.00	0.00	Pipe	8.00	2055	4.28	None			0.00	None			0.00	27.83	27.83	0.46	16.70	0.28
KC-2-090	Residential	15	30	66.62	0.1041	102	Short Grass Prairie	0.150	0.0050	3.72	16.12	Paved	20.3282	0.0111	1482	2.14	11.54	None	0			0.00	0.00	Pipe	8.00	75	0.16	Channel	6.00	2325	6.46	Pipe	8.00	96	0.20	34.48	30.00	0.50	18.00	0.30
KC-2-080	Residential	15	30	68.06	0.1063	76	Smooth Surfaces	0.011	0.0380	3.72	0.70	Unpaved	16.1345	0.0126	1173	2.00	9.77	Paved	20.3282	0.0087	255	2.00	2.12	Pipe	8.00	1856	3.87	None			0.00	Pipe	8.00	71	0.15	16.61	16.61	0.28	9.97	0.17
KC-2-070	Residential	15	30	39.07	0.0610	100	Short Grass Prairie	0.150	0.0330	3.72	7.44	Unpaved	16.1345	0.0254	308	2.57	2.00	None	0			0.00	0.00	Channel	6.00	983	2.73	Pipe	8.00	280	0.58	None			0.00	12.75	15.00	0.25	9.00	0.15
KC-2-060	Residential	15	30	51.19	0.0800	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Gutter	36.144628	0.0140	408	4.27	1.59	None	0			0.00	0.00	Swale	3.00	681	3.78	Channel	6.00	48	0.13	None			0.00	7.46	15.00	0.25	9.00	0.15
KC-2-050	Residential	15	30	45.00	0.0703	100	Short Grass Prairie	0.150	0.0083	3.72	12.92	Unpaved	16.1345	0.0073	671	2.00	5.59	Paved	20.3282	0.0028	262	2.00	2.18	Channel	6.00	341	0.95	Pipe	8.00	955	1.99	None			0.00	23.63	23.63	0.39	14.18	0.24
KC-2-040	Residential	15	30	19.48	0.0304	100	Short grass prairie	0.150	0.0096	3.72	12.19	Unpaved	16.1345	0.0036	96	2.00	0.80	None	0			0.00	0.00	Swale	3.00	1023	5.68	Pipe	8.00	39	0.08	None			0.00	18.76	18.76	0.31	11.25	0.19
KC-2-030	Residential	15	30	32.40	0.0506	100	Short grass prairie	0.150	0.0379	3.72	7.06	Unpaved	16.1345	0.0132	939	2.00	7.83	None	0			0.00	0.00	Channel	6.00	320	0.89	Pipe	8.00	11	0.02	None			0.00	15.80	15.80	0.26	9.48	0.16
KC-2-020	Residential	15	30	78.17	0.1221	99	Short grass prairie	0.150	0.0105	3.72	11.69	Paved	20.3282	0.0059	694	2.00	5.78	Unpaved	16.1345	0.0052	614	2.00	5.12	Swale	3.00	200	1.11	None			0.00	None			0.00	23.70	23.70	0.40	14.22	0.24
KC-2-010	Residential	15	30	56.34	0.0880	99	Short grass prairie	0.150	0.0171	3.72	9.62	Unpaved	16.1345	0.0110	164	2.00	1.37	None	0			0.00	0.00	Pipe	8.00	2780	5.79	Channel	6.00	1434	3.98	None			0.00	20.76	20.76	0.35	12.46	0.21
KC-1-110	Residential	15	30	44.53	0.0696	100	Smooth Surfaces	0.011	0.0223	3.72	1.08	Paved	20.3282	0.0145	1079	2.45	7.35	Unpaved	16.1345	0.0177	422	2.15	3.27	Channel	6.00	1207	3.35	None			0.00	None			0.00	15.05	15.05	0.25	9.03	0.15
KC-1-100	Commercial/Industrial	10	25	20.62	0.0322	47	Short grass prairie	0.150	0.0684	3.72	3.02	Gutter	36.144628	0.0175	1316	4.78	4.59	None	0			0.00	0.00	None			0.00	None			0.00	None			0.00	7.60	10.00	0.17	6.00	0.10
KC-1-090	Commercial/Industrial	10	25	59.41	0.0928	50	Smooth Surfaces	0.011	0.0417	3.72	0.48	None	0		#N/A	0.00	0.00	Paved	20.3282	0.0140	1557	2.40	10.80	Channel	6.00	3752	10.42	None			0.00	Pipe	8.00	338	0.70	22.41	22.41	0.37	13.44	0.22
KC-1-080	Commercial/Industrial	10	25	72.19	0.1128	100	Smooth Surfaces	0.011	0.0141	3.72	1.29	Gutter	36.144628	0.0115	1501	3.87	6.46	None	0			0.00	0.00	Channel	6.00	1044	2.90	Pipe	8.00	66	0.14	None			0.00	10.79	10.79	0.18	6.47	0.11
KC-1-070	Commercial/Industrial	10	25	6.90	0.0108	87	Smooth Surfaces	0.011	0.0065	3.72	1.58	Unpaved	16.1345	0.0059	327	2.00	2.73	None	0			0.00	0.00	None			0.00	Swale	3.00	651	3.62	Pipe	8.00	702	1.46	9.39	10.00	0.17	6.00	0.10
KC-1-060	Commercial/Industrial	10	25	86.43	0.1351	99	Smooth Surfaces	0.011	0.0144	3.72	1.28	Paved	20.3282	0.0240	213	3.15	1.13	Paved	20.3282	0.0086	627	2.00	5.22	Swale	3.00	876	4.87	Pipe	8.00	2155	4.49	None			0.00	16.98	16.98	0.28	10.19	0.17
KC-1-050	Commercial/Industrial	10	25	37.82	0.0591	102	Short grass prairie	0.150	0.0240	3.72	8.59	Unpaved	16.1345	0.0141	161	2.00	1.34	None	0			0.00	0.00	Swale	3.00	1505	8.36	Channel	6.00	228	0.63	Pipe	8.00	219	0.46	19.39	19.39	0.32	11.63	0.19
KC-1-040	Commercial/Industrial	10	25	39.81	0.0622	101	Smooth Surfaces	0.011	0.0334	3.72	0.92	Paved	20.3282	0.0134	431	2.35	3.05	Gutter	36.144628	0.0134	1567	4.18	6.25	Channel	6.00	243	0.67	None			0.00	None			0.00	10.90	10.90	0.18	6.54	0.11
KC-1-030	Residential	15	30	16.08	0.0251	100	Short grass prairie	0.150	0.0195	3.72	9.20	Unpaved	16.1345	0.0138	639	2.00	5.33	Paved	20.3282	0.0078	88	2.00	0.73	Swale	3.00	856	4.75	Channel	6.00	427	1.19	None			0.00	21.20	21.20	0.35	12.72	0.21
KC-1-020	Commercial/Industrial	10	25	42.92	0.0671	100	Smooth Surfaces	0.011	0.0256	3.72	1.02	Paved	20.3282	0.0424	240	4.18	0.96	None	0			0.00	0.00	Channel	6.00	1159	3.22	None			0.00	None			0.00	5.19	10.00	0.17	6.00	0.10
KC-1-010	Commercial/Industrial	10	25	99.19	0.1550	100	Smooth Surfaces	0.011	0.0122	3.72	1.37	Paved	20.3282	0.0156	1061	2.54	6.97	None	0			0.00	0.00	Channel	6.00	4238	11.77	None			0.00	None			0.00	20.11	20.11	0.34	12.07	0.20
BC-5-200	Residential	15	30	40.89	0.0639	100	Smooth Surfaces	0.011	0.0303	3.72	0.95	Paved	20.3282	0.0096	1503	2.00	12.53	None	0			0.00	0.00	Swale	3.00	793	4.40	None			0.00	None			0.00	17.88	17.88	0.30	10.73	0.18
BC-5-130	Residential	15	30	22.92	0.0358	468	Short grass prairie	0.150	0.0471	3.72	22.19	Paved	20.3282	0.0170	1501	2.65	9.44	None	0			0.00	0.00	Channel	6.00	1137	3.16	None			0.00	None			0.00	34.78	30.00	0.50	18.00	0.30
BC-5-120	Residential	15	30	16.23	0.0254	100	Short grass prairie	0.150	0.0279	3.72	7.96	Gutter	36.144628	0.0105	737	3.71	3.31	Unpaved	16.1345	0.0190	349	2.23	2.61	Swale	3.00	1396	7.76	None			0.00	None			0.00	21.64	21.64	0.36	12.98	0.22
BC-5-110	Residential	15	30	24.45	0.0382	100	Short grass prairie	0.150	0.0337	3.72	7.38	Unpaved	16.1345	0.0141	1506	2.00	12.55	None	0			0.00	0.00	Swale	3.00	593	3.29	Channel	6.00	441	1.22	None			0.00	24.44	24.44	0.41	14.67	0.24
BC-5-100	Residential	15	30	13.37	0.0209	100	Smooth Surfaces	0.011	0.0079	3.72	1.63	Unpaved	16.1345	0.0134	889	2.00	7.41	None	0			0.00	0.00	Channel	6.00	201	0.56	None			0.00	None			0.00	9.60	15.00	0.25	9.00	0.15
BC-5-090	Residential	15	30	31.80	0.0497	72	Short grass prairie	0.150	0.0060	3.72	11.36	Paved	20.3282	0.0138	1187	2.39	8.27	None	0			0.00	0.00	None			0.00	None			0.00	None			0.00	19.63	19.63	0.33	11.78	0.20

BASIN LAG TIME CALCULATION - ULTIMATE CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
									EXISTING					EXISTING					EXISTING																						
									MAX=	30				MAX=	1500	MIN 2 FPS			MAX=	1500	MIN 2 FPS																				
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
BC-5-080	Residential	15	30	19.65	0.0307	100	Short grass prairie	0.150	0.0143	3.72	10.38	Unpaved	16.1345	0.0143	1147	2.00	9.56	Paved	20.3282	0.0136	350	2.37	2.46	Channel	6.00	912	2.53	Pipe	8.00	1343	2.80	None			0.00	27.73	27.73	0.46	16.64	0.28
BC-5-070	Residential	15	30	51.42	0.0803	100	Short grass prairie	0.150	0.0093	3.72	12.35	Unpaved	16.1345	0.0101	152	2.00	1.27	Paved	20.3282	0.0070	1057	2.00	8.81	Swale	3.00	1825	10.14	None			0.00	None			0.00	32.56	30.00	0.50	18.00	0.30
BC-5-060	Residential	15	30	20.43	0.0319	100	Short grass prairie	0.150	0.0187	3.72	9.34	Unpaved	16.1345	0.0075	850	2.00	7.09	Gutter	36.144628	0.0066	364	2.94	2.07	Channel	6.00	692	1.92	None			0.00	None			0.00	20.41	20.41	0.34	12.25	0.20
BC-5-050	Residential	15	30	35.35	0.0552	41	Smooth Surfaces	0.011	0.0183	3.72	0.57	None	0		#N/A	0.00	0.00	Paved	20.3282	0.0121	1501	2.24	11.17	Swale	3.00	657	3.65	None			0.00	None			0.00	15.40	15.40	0.26	9.24	0.15
BC-5-040	Residential	15	30	61.20	0.0956	100	Smooth Surfaces	0.011	0.0230	3.72	1.06	Paved	20.3282	0.0073	1501	2.00	12.51	None	0			0.00	0.00	Swale	3.00	304	1.69	Channel	6.00	555	1.54	None			0.00	16.80	16.80	0.28	10.08	0.17
BC-5-030	Residential	15	30	40.34	0.0630	100	Short grass prairie	0.150	0.0072	3.72	13.65	Unpaved	16.1345	0.0120	1336	2.00	11.14	None	0			0.00	0.00	Channel	6.00	117	0.32	Pipe	8.00	89	0.18	None			0.00	25.30	25.30	0.42	15.18	0.25
BC-5-020	Residential	15	30	29.25	0.0457	100	Short grass prairie	0.150	0.0050	3.72	15.81	Unpaved	16.1345	0.0162	530	2.05	4.30	Gutter	36.144628	0.0072	709	3.06	3.86	Pipe	8.00	442	0.92	Swale	3.00	645	3.58	Channel	6.00	138	0.38	28.86	28.86	0.48	17.31	0.29
BC-5-010	Residential	15	30	46.57	0.0728	100	Smooth Surfaces	0.011	0.0135	3.72	1.31	Paved	20.3282	0.0183	396	2.75	2.40	None	0			0.00	0.00	Channel	6.00	2856	7.93	None			0.00	None			0.00	11.64	15.00	0.25	9.00	0.15
BC-4-140	Residential	15	30	21.57	0.0337	100	Short grass prairie	0.150	0.0248	3.72	8.34	Unpaved	16.1345	0.0177	834	2.15	6.48	Gutter	36.144628	0.0078	621	3.19	3.25	Channel	6.00	703	1.95	None			0.00	None			0.00	20.01	20.01	0.33	12.01	0.20
BC-4-120	Residential	15	30	20.62	0.0322	100	Short grass prairie	0.150	0.0161	3.72	9.92	Unpaved	16.1345	0.0040	889	2.00	7.41	Gutter	36.144628	0.0042	608	2.33	4.35	Channel	6.00	386	1.07	Pipe	8.00	105	0.22	None			0.00	22.97	22.97	0.38	13.78	0.23
BC-4-110	Residential	15	30	27.94	0.0437	100	Short grass prairie	0.150	0.0083	3.72	12.90	Unpaved	16.1345	0.0106	273	2.00	2.27	Gutter	36.144628	0.0050	1226	2.55	8.00	Channel	6.00	389	1.08	None			0.00	None			0.00	24.26	24.26	0.40	14.55	0.24
BC-4-100	Residential	15	30	32.87	0.0514	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0115	1173	2.00	9.78	None	0			0.00	0.00	Pipe	8.00	150	0.31	Channel	6.00	790	2.20	None			0.00	28.11	28.11	0.47	16.87	0.28
BC-4-020	Residential	15	30	28.46	0.0445	100	Short grass prairie	0.150	0.0136	3.72	10.60	Unpaved	16.1345	0.0159	842	2.03	6.89	None	0			0.00	0.00	Swale	3.00	3708	20.60	None			0.00	None			0.00	38.09	30.00	0.50	18.00	0.30
BC-4-010	Residential	15	30	15.25	0.0238	100	Short grass prairie	0.150	0.0108	3.72	11.64	Unpaved	16.1345	0.0092	286	2.00	2.38	Paved	20.3282	0.0100	207	2.03	1.70	Swale	3.00	960	5.34	Pipe	8.00	121	0.25	Channel	6.00	157	0.44	21.74	21.74	0.36	13.04	0.22
BC-3-030	Residential	15	30	70.33	0.1099	100	Short grass prairie	0.150	0.0243	3.72	8.41	Unpaved	16.1345	0.0374	401	3.12	2.14	None	0			0.00	0.00	Swale	3.00	958	5.32	Pipe	8.00	617	1.29	None			0.00	17.16	17.16	0.29	10.30	0.17
BC-3-020	Residential	15	30	49.95	0.0781	100	Short grass prairie	0.150	0.0305	3.72	7.67	Unpaved	16.1345	0.0071	786	2.00	6.55	None	0			0.00	0.00	Swale	3.00	548	3.05	Channel	6.00	1078	3.00	None			0.00	20.27	20.27	0.34	12.16	0.20
BC-3-010	Residential	15	30	86.10	0.1345	100	Short grass prairie	0.150	0.0153	3.72	10.11	Unpaved	16.1345	0.0137	913	2.00	7.61	None	0			0.00	0.00	Channel	6.00	882	2.45	None			0.00	None			0.00	20.17	20.17	0.34	12.10	0.20
BC-2-010	Residential	15	30	35.49	0.0555	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Paved	20.3282	0.0115	1492	2.18	11.40	None	0			0.00	0.00	Swale	3.00	514	2.86	None			0.00	None			0.00	16.22	16.22	0.27	9.73	0.16
BC-1-140	Residential	15	30	46.97	0.0734	100	Short grass prairie	0.150	0.0161	3.72	9.91	Unpaved	16.1345	0.0323	334	2.90	1.92	Paved	20.3282	0.0172	578	2.67	3.61	Pipe	8.00	2039	4.25	None			0.00	None			0.00	19.70	19.70	0.33	11.82	0.20
BC-1-130	Residential	15	30	25.55	0.0399	100	Short grass prairie	0.150	0.0191	3.72	9.26	Paved	20.3282	0.0185	1149	2.77	6.92	None	0			0.00	0.00	Pipe	8.00	550	1.15	None			0.00	None			0.00	17.32	17.32	0.29	10.39	0.17
BC-1-120	Residential	15	30	23.08	0.0361	100	Short grass prairie	0.150	0.0237	3.72	8.50	Unpaved	16.1345	0.0065	1276	2.00	10.63	None	0			0.00	0.00	Pipe	8.00	116	0.24	None			0.00	None			0.00	19.37	19.37	0.32	11.62	0.19
BC-1-110	Commercial/Industrial	10	25	33.19	0.0519	98	Smooth Surfaces	0.011	0.0099	3.72	1.47	Paved	20.3282	0.0244	242	3.18	1.27	None	0			0.00	0.00	Swale	3.00	1053	5.85	Channel	6.00	677	1.88	None			0.00	10.47	10.47	0.17	6.28	0.10
BC-1-100	Commercial/Industrial	10	25	60.22	0.0941	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0151	174	2.00	1.45	None	0			0.00	0.00	Swale	3.00	273	1.52	Channel	6.00	1101	3.06	None			0.00	21.85	21.85	0.36	13.11	0.22
BC-1-090	Commercial/Industrial	10	25	30.97	0.0484	100	Short grass prairie	0.150	0.0160	3.72	9.94	Unpaved	16.1345	0.0126	709	2.00	5.91	None	0			0.00	0.00	Channel	6.00	920	2.56	Pipe	8.00	214	0.45	Channel	6.00	443	1.23	20.08	20.08	0.33	12.05	0.20
BC-1-080	Commercial/Industrial	10	25	46.64	0.0729	100	Short grass prairie	0.150	0.0147	3.72	10.27	Unpaved	16.1345	0.0208	950	2.33	6.80	None	0			0.00	0.00	Swale	3.00	1075	5.97	Channel	6.00	396	1.10	None			0.00	24.14	24.14	0.40	14.49	0.24
BC-1-070	Residential	15	30	40.16	0.0627	85	Smooth Surfaces	0.011	0.0173	3.72	1.05	Paved	20.3282	0.0198	1802	2.86	10.51	None	0			0.00	0.00	Channel	6.00	542	1.51	None			0.00	None			0.00	13.06	15.00	0.25	9.00	0.15
BC-1-060	Residential	15	30	61.91	0.0967	103	Smooth Surfaces	0.011	0.0162	3.72	1.25	Paved	20.3282	0.0110	925	2.14	7.22	None	0			0.00	0.00	Channel	6.00	1468	4.08	None			0.00	None			0.00	12.54	15.00	0.25	9.00	0.15
BC-1-050	Residential	15	30	58.94	0.0921	100	Smooth Surfaces	0.011	0.0193	3.72	1.14	Paved	20.3282	0.0164	379	2.60	2.43	None	0			0.00	0.00	Swale	3.00	3344	18.58	Channel	6.00	373	1.03	None			0.00	23.18	23.18	0.39	13.91	0.23
BC-1-040	Residential	15	30	47.57	0.0743	97	Smooth Surfaces	0.011	0.0147	3.72	1.24	Paved	20.3282	0.0141	1570	2.41	10.85	None	0			0.00	0.00	Channel	6.00	934	2.59	None			0.00	None			0.00	14.68	15.00	0.25	9.00	0.15
BC-1-030	Undeveloped	15	35	67.79	0.1059	105	Short grass prairie	0.150	0.0110	3.72	11.97	Unpaved	16.1345	0.0075	1500	2.00	12.50	None	0			0.00	0.00	Channel	6.00	2305	6.40	None			0.00	None			0.00	30.87	30.87	0.51	18.52	0.31
BC-1-021	Residential	15	30	76.30	0.1192	97	Smooth Surfaces	0.011	0.0640	3.72	0.69	Paved	20.3282	0.0195	1355	2.84	7.96	Paved	20.3282	0.0104	155	2.08	1.24	Swale	3.00	1715	9.53	None			0.00	None			0.00	19.42	19.42	0.32	11.65	0.19
BC-1-020	Undeveloped	15	35	23.83	0.0372	100	Short grass prairie	0.150	0.0134	3.72	10.67	Unpaved	16.1345	0.0101	1500	2.00	12.50	None	0			0.00	0.00	Channel	6.00	621	1.73	None			0.00	None			0.00	24.90	24.90	0.42	14.94	0.25
BC-1-010	Undeveloped	15	35	28.93	0.0452	100	Short grass prairie	0.150	0.0076	3.72	13.42	Unpaved	16.1345	0.0206	576	2.32	4.14	None	0			0.00	0.00	Channel	6.00	1210	3.36	None			0.00	None			0.00	20.92	20.92	0.35	12.55	0.21
KT-1-090	Commercial/Industrial	10	25	50.29	0.0786	100	Smooth Surfaces	0.011	0.0118	3.72	1.39	Paved	20.3282	0.0051	1305	2.00	10.88	Unpaved	16.1345	0.0026	197	2.00	1.64	Channel	6.00	849	2.36	Pipe	8.00	67	0.14	None			0.00	16.40	16.40	0.27	9.84	0.16
KT-1-030	Commercial/Industrial	10	25	49.13	0.0768	100	Short grass prairie	0.150	0.0096	3.72	12.17	Unpaved	16.1345	0.0026	1073	2.00	8.94	None	0			0.00	0.00	Pipe	8.00	64	0.13	Channel	6.00	40	0.11	None			0.00	21.36	21.36	0.36	12.82	0.21
KT-1-110	Residential	15	30	66.61	0.1041	100	Short grass prairie	0.150	0.0206	3.72	8.99	Unpaved	16.1345	0.0118	1502	2.00	12.51	None	0			0.00	0.00	Swale	3.00	319	1.77	Channel	6.00	40	0.11	Channel	6.00	63	0.18	23.56	23.56	0.39	14.14	0.24
KT-1-060	Residential	15	30	27.10	0.0424	100	Short grass prairie	0.150	0.0050	3.72	15.83	Unpaved	16.1345	0.0113	733	2.00	6.11	Paved	20.3282	0.0077	107	2.00	0.89	Pipe	8.00	899	1.87	Channel	6.00	27	0.07	None			0.00	24.77	24.77	0.41	14.86	0.25
KT-1-070	Residential	15	30	27.85	0.0435	100	Short grass prairie	0.150	0.0172	3.72	9.61	Unpaved	16.1345	0.0151	350	2.00	2.92	None	0			0.00	0.00	Swale	3.00	1523	8.46	Pipe	8.00	57	0.12	None			0.00	21.11	21.11	0.35	12.66	0.21
KT-1-085	Residential	15	30	8.91	0.0139	103	Short grass prairie	0.150	0.0063	3.72	14.75	Unpaved	16.1345	0.0112	346	2.00	2.89	Paved	20.3282	0.0114	348	2.17	2.68	Swale	3.00	419	2.33	None			0.00	None			0.00	22.64	22.64	0.38	13.58	0.23

BASIN LAG TIME CALCULATION - ULTIMATE CONDITIONS

BASIN ID	BASIN DESCRIPTION	MINIMUM TC	MAXIMUM TC	BASIN AREA		SHEET FLOW $T_o = 0.42 * \frac{(n_o * L_o)^{0.8}}{P_2^{0.5} * S_o^{0.4}}$						SHALLOW CONCENTRATED FLOW #1 $V_{S1} = K * S_{S1}^{0.5}$ $T_{S1} = \frac{L_{S1}}{60 * V_{S1}}$						SHALLOW CONCENTRATED FLOW #2 $V_{S2} = K * S_{S2}^{0.5}$ $T_{S2} = \frac{L_{S2}}{60 * V_{S2}}$						CHANNELIZED FLOW #1 $T_{H1} = \frac{L_{H1}}{60 * V_{H1}}$				CHANNELIZED FLOW #2 $T_{H2} = \frac{L_{H2}}{60 * V_{H2}}$				CHANNELIZED FLOW #3 $T_{H3} = \frac{L_{H3}}{60 * V_{H3}}$				TIME OF CONCENTRATION $T_C = \sum T_i$			LAG TIME $T_L = 0.6 * T_C$	
									EXISTING					EXISTING			EXISTING																								
									MAX=		30			MAX=		1500	MIN 2 FPS	MAX=		1500	MIN 2 FPS																				
						L_o	LU1	n_o	S_o	P_2	T_o	Cond.	K	S_{S1}	L_{S1}	V_{S1}	T_{S1}	Cond.	K	S_{S2}	L_{S2}	V_{S2}	T_{S2}	Type	V_{H1}	L_{H1}	T_{H1}	Type	V_{H2}	L_{H2}	T_{H2}	Type	V_{H3}	L_{H3}	T_{H3}	T_c			T_L	
		min	min	ac	mi^2	ft	NA	NA	ft/ft	inches	min	NA	CONST	ft/ft	ft	fps	min	NA	CONST	ft/ft	ft	fps	min	NA	fps	ft	min	NA	fps	ft	min	NA	fps	ft	min	min	adj	hour	min	hour
KT-2-010	Commercial/Industrial	10	25	58.16	0.0909	100	Short grass prairie	0.150	0.0165	3.72	9.87	Unpaved	16.1345	0.0090	336	2.00	2.80	None	0			0.00	0.00	Swale	3.00	500	2.78	Pipe	8.00	310	0.65	Pipe	8.00	292	0.61	16.69	16.69	0.28	10.02	0.17
KT-2-020	Commercial/Industrial	10	25	51.02	0.0797	100	Short grass prairie	0.150	0.0327	3.72	7.46	Unpaved	16.1345	0.0076	973	2.00	8.11	None	0			0.00	0.00	Swale	3.00	2361	13.12	Channel	6.00	294	0.82	None			0.00	29.50	25.00	0.42	15.00	0.25
KT-2-030	Commercial/Industrial	10	25	69.70	0.1089	100	Short grass prairie	0.150	0.0128	3.72	10.87	Unpaved	16.1345	0.0123	1448	2.00	12.06	None	0			0.00	0.00	Channel	6.00	180	0.50	Pipe	8.00	68	0.14	None			0.00	23.58	23.58	0.39	14.15	0.24
KT-2-040	Commercial/Industrial	10	25	85.88	0.1342	100	Smooth Surfaces	0.011	0.0050	3.72	1.96	Paved	20.3282	0.0152	1410	2.51	9.37	None	0			0.00	0.00	Swale	3.00	834	4.63	Pipe	8.00	74	0.15	None			0.00	16.11	16.11	0.27	9.67	0.16
KT-2-050	Commercial/Industrial	10	25	35.56	0.0556	100	Short grass prairie	0.150	0.0101	3.72	11.93	Unpaved	16.1345	0.0209	723	2.33	5.17	Paved	20.3282	0.0169	461	2.65	2.90	Pipe	8.00	961	2.00	None			0.00	None			0.00	22.00	22.00	0.37	13.20	0.22
KT-4-040	Residential	15	30	30.23	0.0472	100	Short grass prairie	0.150	0.0088	3.72	12.66	Unpaved	16.1345	0.0075	730	2.00	6.08	None	0			0.00	0.00	Swale	3.00	605	3.36	Pipe	8.00	917	1.91	None			0.00	24.01	24.01	0.40	14.41	0.24
KT-4-030	Residential	15	30	62.32	0.0974	96	Smooth Surfaces	0.011	0.0189	3.72	1.11	Paved	20.3282	0.0081	1481	2.00	12.34	None	0			0.00	0.00	Pipe	8.00	600	1.25	None			0.00	None			0.00	14.70	15.00	0.25	9.00	0.15
KT-4-020	Residential	15	30	62.32	0.0974	100	Smooth Surfaces	0.011	0.0093	3.72	1.52	Paved	20.3282	0.0108	1510	2.12	11.89	None	0			0.00	0.00	Pipe	8.00	186	0.39	None			0.00	None			0.00	13.80	15.00	0.25	9.00	0.15
KT-4-010	Commercial/Industrial	10	25	47.85	0.0748	100	Smooth Surfaces	0.011	0.0103	3.72	1.46	Paved	20.3282	0.0245	693	3.18	3.63	None	0			0.00	0.00	Pipe	8.00	1901	3.96	None			0.00	None			0.00	9.05	10.00	0.17	6.00	0.10
KT-3-040	Residential	15	30	41.56	0.0649	100	Short grass prairie	0.150	0.0231	3.72	8.59	Unpaved	16.1345	0.0161	332	2.05	2.70	Paved	20.3282	0.0114	162	2.17	1.24	Swale	3.00	1362	7.57	None			0.00	None			0.00	20.09	20.09	0.33	12.05	0.20
KT-3-030	Residential	15	30	45.16	0.0706	100	Short grass prairie	0.150	0.0167	3.72	9.76	Unpaved	16.1345	0.0126	352	2.00	2.93	None	0			0.00	0.00	Swale	3.00	532	2.96	Pipe	8.00	1215	2.53	None			0.00	18.19	18.19	0.30	10.91	0.18
KT-3-020	Residential	15	30	21.31	0.0333	100	Smooth Surfaces	0.011	0.0138	3.72	1.30	Paved	20.3282	0.0079	394	2.00	3.29	None	0			0.00	0.00	Pipe	8.00	405	0.84	Channel	6.00	540	1.50	None			0.00	6.93	15.00	0.25	9.00	0.15
KT-3-010	Commercial/Industrial	10	25	42.09	0.0658	100	Smooth Surfaces	0.011	0.0267	3.72	1.00	Paved	20.3282	0.0046	1207	2.00	10.06	Paved	20.3282	0.0004	299	2.00	2.49	Pipe	8.00	497	1.03	Channel	6.00	1038	2.88	None			0.00	17.47	17.47	0.29	10.48	0.17



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Rain-on-Mesh (ROM)

City of Terrell, Texas

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FILE	A1_ROM
DATE	1/10/2020
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FIGURE A1

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Drainage Master Plan - Topography

City of Terrell, Texas

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Legend

- Basin
- City Limits

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FIGURE A2

0 500 1,000 2,000 Feet

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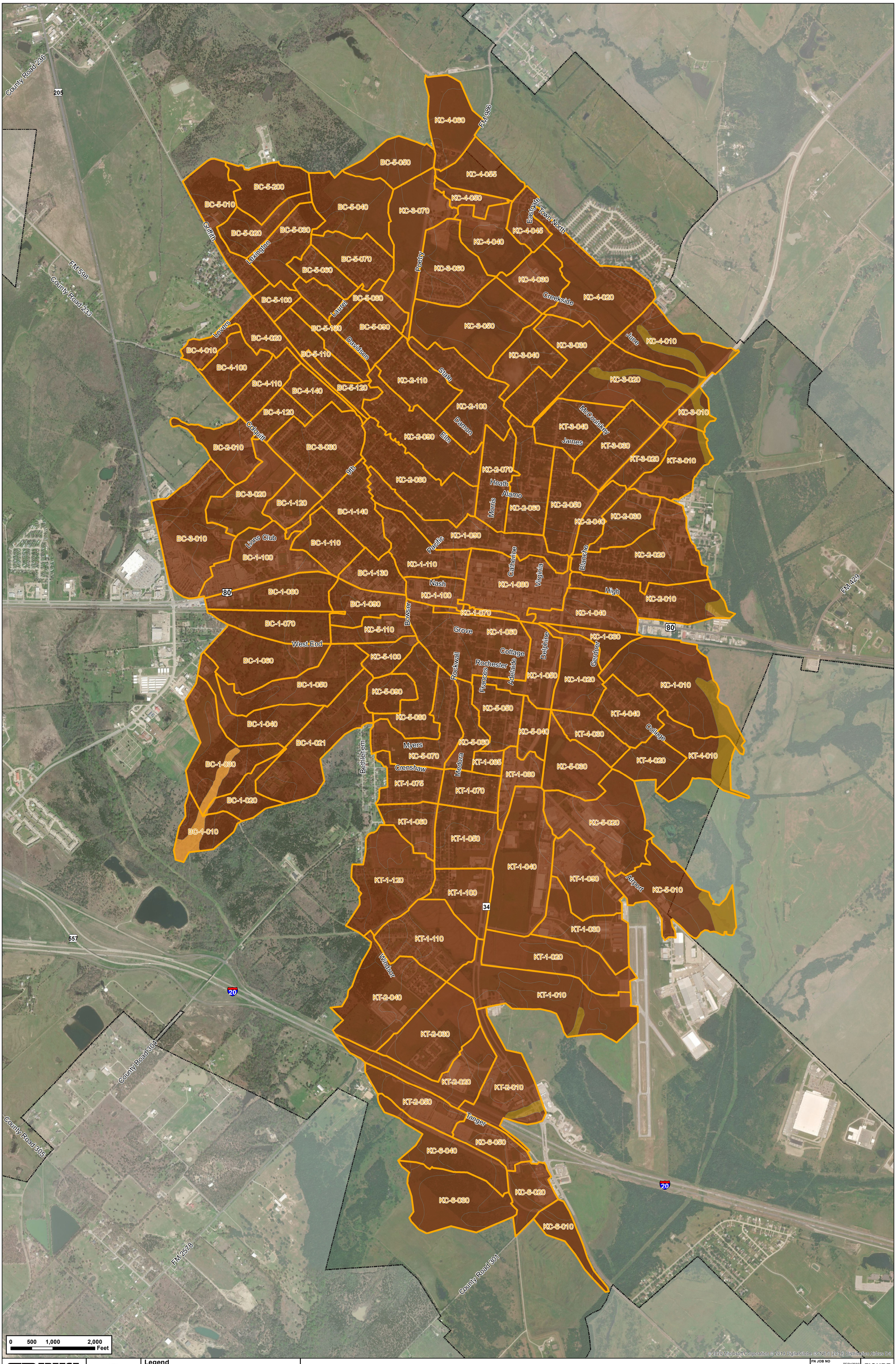

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Basin

City Limits

NRCS Soils

B

C

D

Drainage Master Plan - Soils

City of Terrell, Texas

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FIGURE A3

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Existing Land Use

- Commercial
- Industrial
- Medium Density Residential quarter
- Medium Density Residential third
- High Density Residential
- Brush - Fair
- Open Space - Poor
- Open Space - Fair
- Open Space - Good
- Paved Parking Lots
- Paved Streets and Roads
- Gravel Streets and Roads
- Water

0 500 1,000 2,000 Feet

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Drainage Master Plan - Existing Land Use

City of Terrell, Texas

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FILE	A4_ExistingLandUse
DATE	1/10/2020
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FIGURE A4

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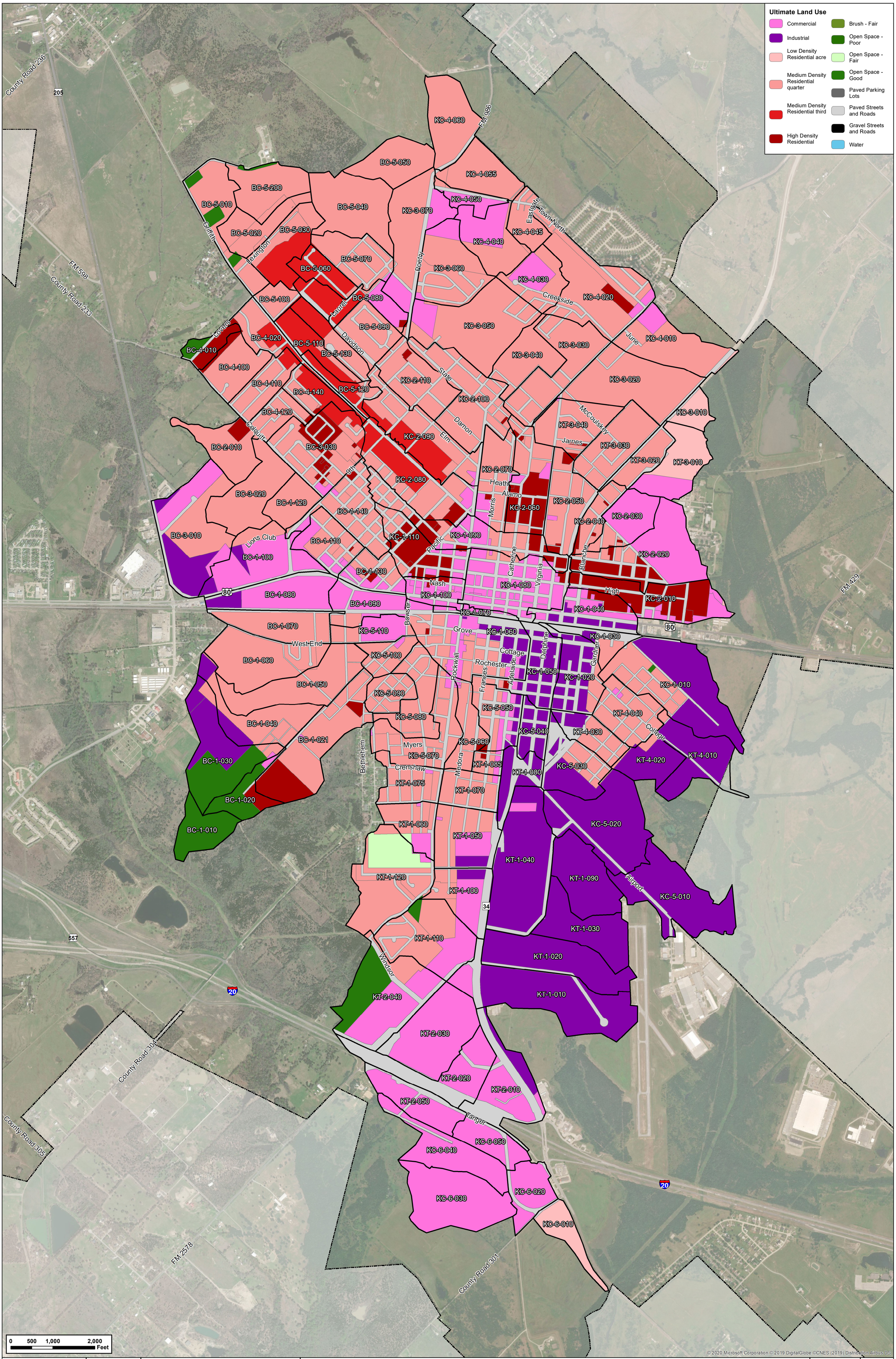

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Legend
- Basin
- City Limits

Drainage Master Plan - Ultimate Land Use

City of Terrell, Texas

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DATE	1/10/2020
SCALE	1:12,000
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FIGURE A5

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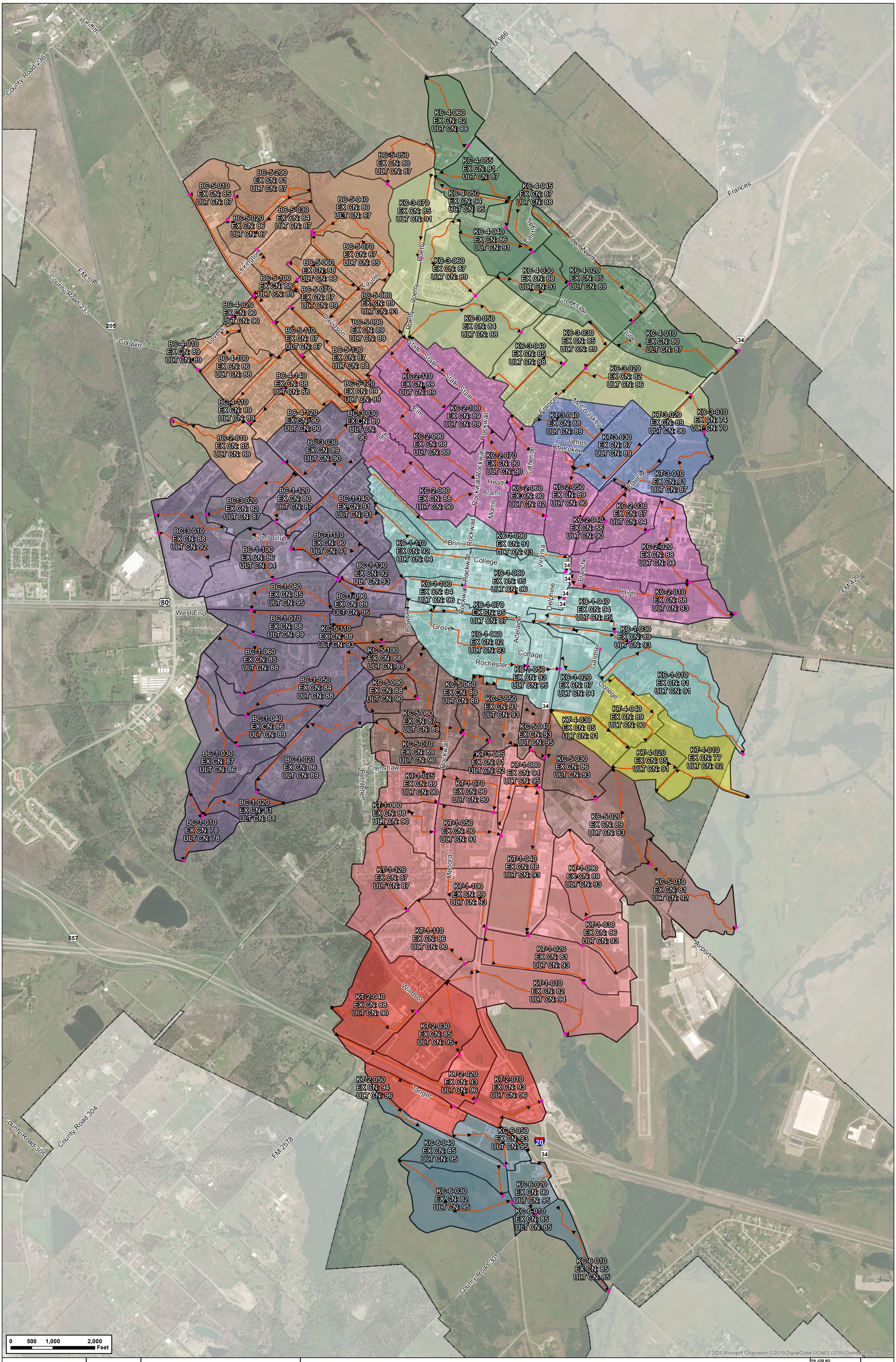

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Legend

- Junction Point
- Drainage Flow Path
- Basin
- City Limits

Drainage Master Plan - Hydrology

City of Terrell, Texas

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FILE	A6_Hydrology
DATE	1/10/2020
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FIGURE **A6**

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FEMA Layers

- 1% ANNUAL CHANCE FLOOD HAZARD
- FLOODWAY
- 0.2% ANNUAL CHANCE FLOOD HAZARD

Colquitt

West

Griffith

Virginia

East

Airport

Far South

KC1

KC3

KC4

KC5

KC6

BC1

0 500 1,000 2,000 Feet

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Legend

- 1D River Reach
- Cross Section
- ICM 2D Zone
- Inlet
- Headwall
- Conduit
- City Limits

Drainage Master Plan - Hydraulic Workmap

City of Terrell, Texas

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FILE	A7_ HydraulicWorkmap
DATE	1/10/2020
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FIGURE A7

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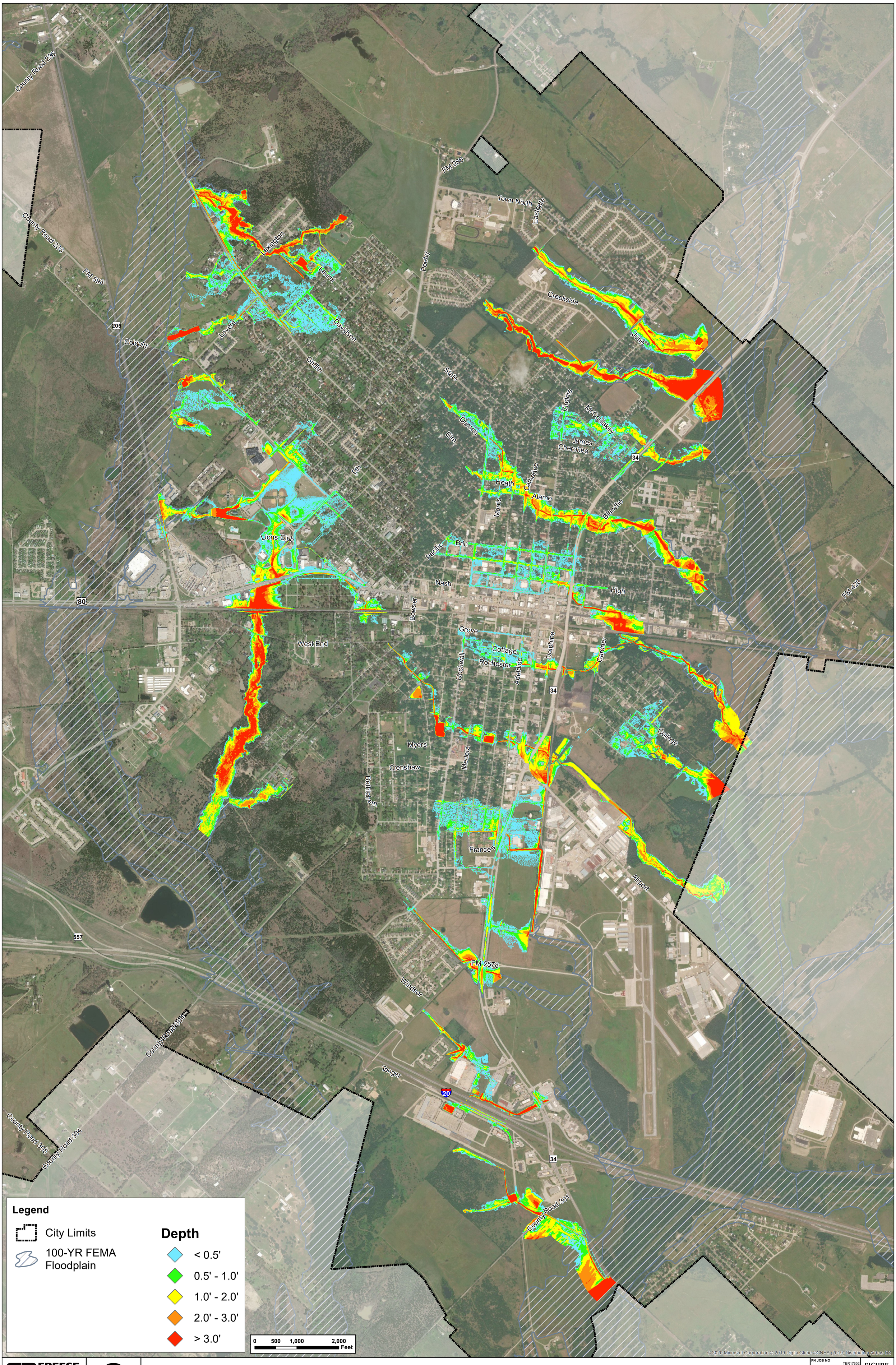

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Drainage Master Plan - 100-Year Ultimate Depth

City of Terrell, Texas

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DATE	1/13/2020
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FIGURE A8

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Table A3: Large Project Scoring and Ranking										
Project	Description	Watershed	Individual Category Scores					Prioritization Score	Rank	Cost
			Life Safety / Road Flooding	Property Damage	Frequency of Flooding	Cost	Public Impact			
CIP09	Heath St. SD	KC2	5	5	5	4	4	473	1	$ 1,837,000
CIP07	KC2 Channel Improvements	KC2	5	5	5	1	4	443	2	$ 11,021,000
CIP08	W. Alamo SD	KC2	5	4	5	4	2	418	3	$ 1,998,000
CIP13	Virginia St. SD Extension	KC1	4	4	5	3	4	413	4	$ 3,921,000
CIP19	Fuji Drainage Improvements	KT1	3	4	5	3	5	400	5	$ 4,182,000
CIP12	KC1 Upper Channel Improvements	KC1	5	4	5	5	0	393	6	$ 272,000
CIP11	KC1 Railroad Crossing (UPRR 182.12) and Channel Improvements	KC1	5	4	5	4	0	383	7	$ 1,536,000
CIP04	Cemetery Channel	BC1	4	3	2	3	4	325	8	$ 2,730,000
CIP03	BC2 Railroad Crossing (UPRR 183.74) and Channel Improvements	BC1	4	3	3	4	0	288	9	$ 1,258,000
CIP18	RR SPUR Culvert	KC5	5	2	2	4	0	275	10	$ 1,836,000
CIP14	College St. SD	KC1	3	2	3	2	3	270	11	$ 4,814,000
CIP10	N. Rockwall Channel & N. Morris Bypass	KC2	2	3	2	1	5	263	12	$ 8,978,000
CIP05	Stadium Channel	BC1	2	2	2	4	4	255	13	$ 1,791,000
CIP02	West End St. Culvert	BC1	1	3	3	5	0	208	14	$ 698,000
CIP17	Rochester St. Channel	KC1	4	0	1	1	3	205	15	$ 9,600,000
CIP15	Brin St. SD	KC1	2	2	0	3	3	183	16	$ 3,466,000
CIP01	Brookhollow Channel and SD	BC5	2	0	0	3	4	160	17	$ 2,527,000
CIP16	Gardner St. Improvements	KC1	2	2	0	4	0	140	18	$ 1,889,000
CIP06	SWCC Railroad Crossing (UPRR 183.15) Improvements	BC1	0	2	0	5	0	90	19	$ 126,000
CIP20	Airport Lead	KT1	0	0	0	3	0	30	20	$ 2,018,000

APPENDIX B
Data Collection Exhibits

Exhibit B1
Public Survey Reponses

Terrell Drainage Master Plan

What is the address where you live?

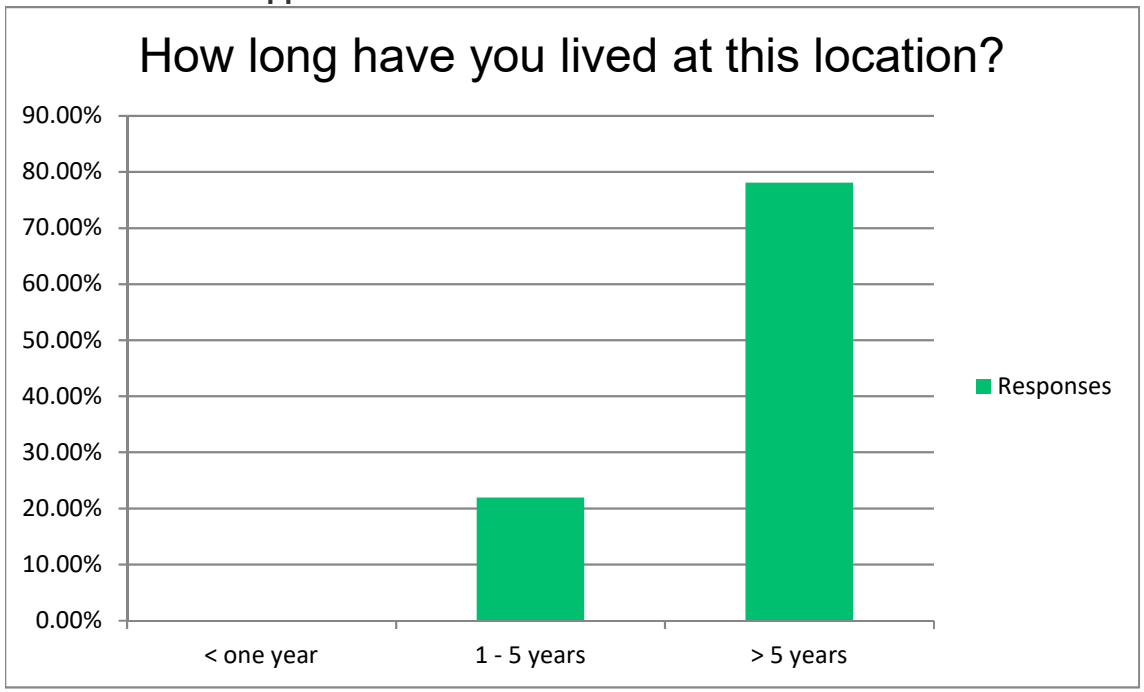
Answered	**42**
Skipped	**0**

Respondents	Response Date	Responses	Categories
1	Mar 20 2018 08:47 AM	4496 US Highway 80	
2	Mar 17 2018 02:06 PM	206 Grace Lane	
3	Mar 17 2018 10:17 AM	111 Roberts ave	
4	Mar 16 2018 09:24 PM	1103 Griffith Ave.	
5	Mar 12 2018 06:16 PM	112 Forrest creek lane	
6	Mar 10 2018 05:18 PM	101 june st	
7	Mar 10 2018 05:03 PM	109 June St Terrell	
8	Mar 10 2018 12:34 PM	108 DENALI CT	
9	Mar 06 2018 10:05 PM	411 kingscreek	
10	Mar 06 2018 02:41 PM	207 Grace Lane	
11	Mar 06 2018 10:10 AM	145 Lexington Dr.	
12	Mar 02 2018 06:15 AM	404 Main Street	
13	Feb 27 2018 10:57 PM	319 James st	
14	Feb 27 2018 10:36 PM	610 Griffith ave	
15	Feb 27 2018 10:29 PM	1015 Ross St	
16	Feb 27 2018 09:16 PM	413 Town North dr	
17	Feb 27 2018 09:11 PM	511 n catherine st	
18	Feb 27 2018 09:07 PM	402 Gant St	
19	Feb 27 2018 03:09 PM	140 Redwood Lane	
20	Feb 27 2018 11:15 AM	1015 state hwy 205 terrell texas	
21	Feb 27 2018 09:58 AM	1808 Willowbrook Dr Terrell Texas 75160	
22	Feb 27 2018 07:15 AM	132 Redwood, Terrell,Tx75160	
23	Feb 27 2018 05:43 AM	115 Oak Dr	
24	Feb 26 2018 11:40 PM	104 Brookhollow	
25	Feb 26 2018 10:50 PM	109 Brookhollow	
26	Feb 26 2018 10:45 PM	106 Cherokee Street	
27	Feb 26 2018 10:04 PM	204 Heath	
28	Feb 26 2018 10:01 PM	104 Kings Creek Dr	
29	Feb 26 2018 09:56 PM	129 Birdsong Lane	
30	Feb 26 2018 09:53 PM	111 Stonebriar Way	
31	Feb 26 2018 09:43 PM	831 griffith	
32	Feb 26 2018 09:38 PM	402 E. Alamo St.	
33	Feb 26 2018 09:21 PM	105 Paloma Circle	
34	Feb 26 2018 09:14 PM	9 Griffith Ct	
35	Feb 26 2018 09:05 PM	1620 Harrisee	
36	Feb 26 2018 08:41 PM	827 Griffith	
37	Feb 26 2018 08:31 PM	1609 N. Frances	
38	Feb 20 2018 03:51 PM	717 s.medora	
39	Feb 17 2018 05:11 PM	Lexington Dr.	
40	Feb 15 2018 11:42 AM	141 Lexington Drive	
41	Feb 15 2018 09:47 AM	1105 Main Street, Terrell, Texas	
42	Feb 15 2018 09:09 AM	400 Elm Drive	

Terrell Drainage Master Plan

How long have you lived at this location?

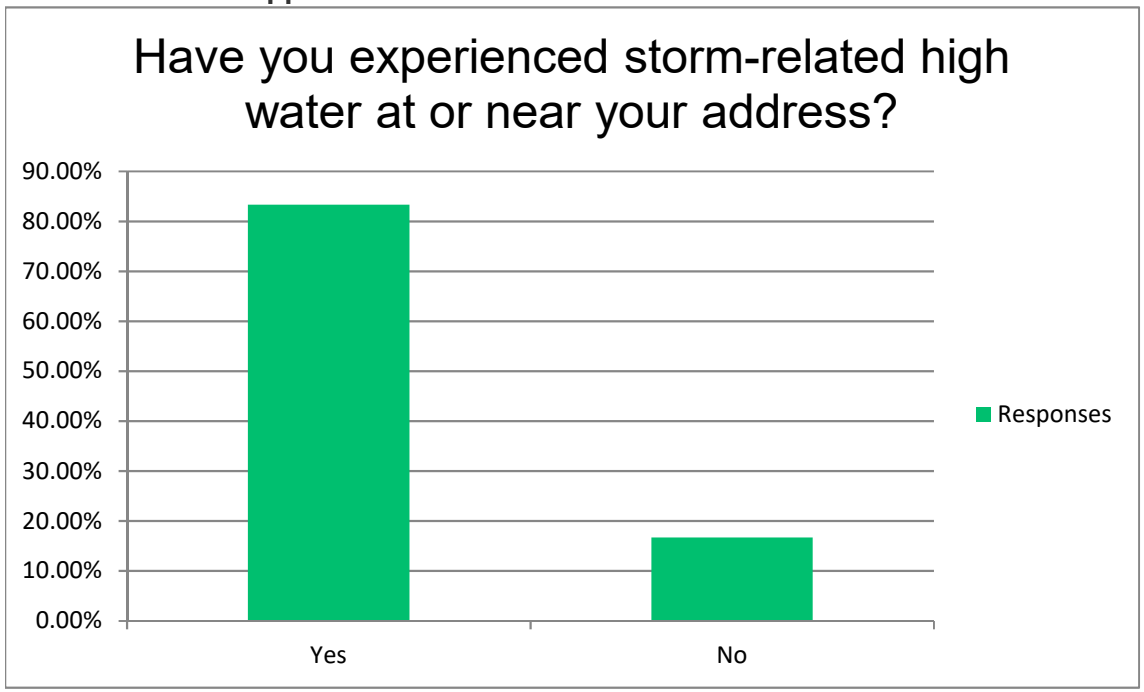
Answer Choices	Responses	
< one year	0.00%	0
1 - 5 years	21.95%	9
> 5 years	78.05%	32
	Answered	**41**
	Skipped	**1**



Terrell Drainage Master Plan

Have you experienced storm-related high water at or near your address?

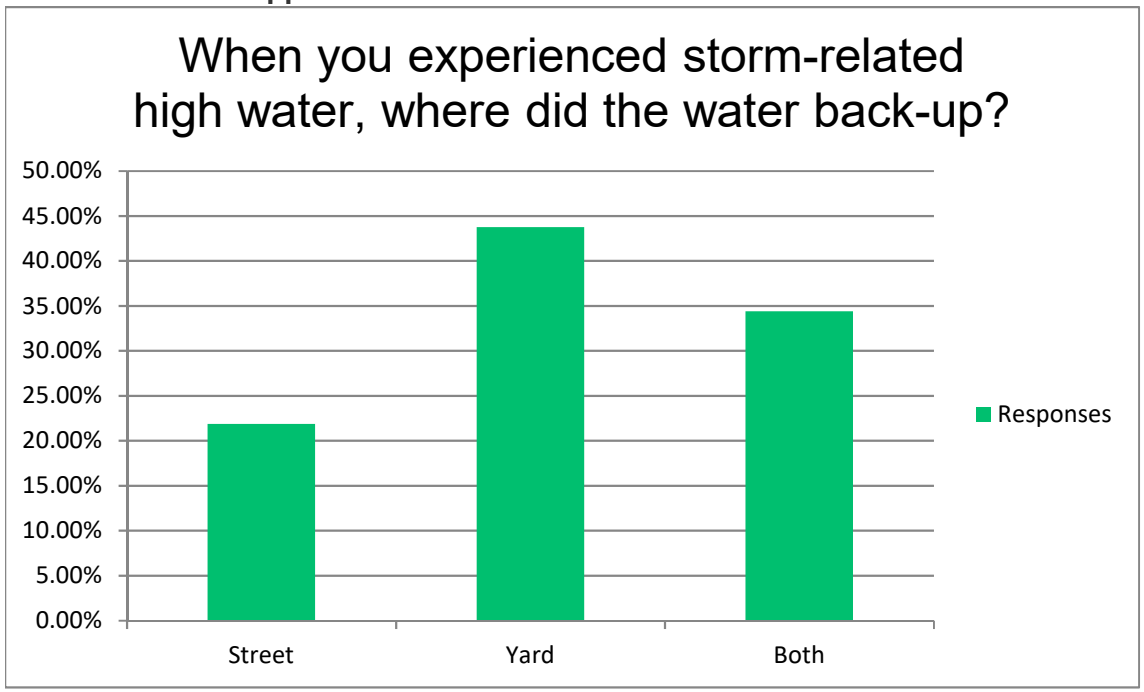
Answer Choices	Responses	
Yes	83.33%	35
No	16.67%	7
	Answered	**42**
	Skipped	**0**



Terrell Drainage Master Plan

When you experienced storm-related high water, where did the water back-up?

Answer Choices	Responses	
Street	21.88%	7
Yard	43.75%	14
Both	34.38%	11
Answered		**32**
Skipped		**10**



Terrell Drainage Master Plan

If near your address, please provide the location.

Answered	**27**
Skipped	**15**

Respondents	Response Date	Responses	Categories
1	Mar 20 2018 08:49 AM	Creek	
2	Mar 17 2018 02:15 PM	206 Grace Lane	
3	Mar 16 2018 09:41 PM	Griffith Ave. and Brookhollow	
4	Mar 12 2018 06:19 PM	Back fence line between homes I forrest creek and redwood	
5	Mar 10 2018 05:21 PM	101 june	
6	Mar 10 2018 05:08 PM	front of the house back of the house both yards creek backs up the creek and street needs to be cleaned out	
7	Mar 06 2018 10:07 PM	The storm drain and field next to me.	
8	Mar 02 2018 06:17 AM	Right in front of our house	
9	Feb 27 2018 10:59 PM	Corner of James & San Jacinto	
10	Feb 27 2018 10:37 PM	610 Griffith Avenue	
11	Feb 27 2018 10:31 PM	1015 Ross St Terrell Tx 75160	
12	Feb 27 2018 09:18 PM	No	
13	Feb 27 2018 09:09 PM	Rockwall street and my house	
14	Feb 27 2018 09:58 AM	Francis	
15	Feb 27 2018 07:18 AM	Backyard at 132 Redwood	
16	Feb 27 2018 05:44 AM	115 Oak Dr	
17	Feb 26 2018 11:47 PM	Ditch next to 104 Brookhollow	
18	Feb 26 2018 10:47 PM	Next door and on LaRoe	
19	Feb 26 2018 10:05 PM	204 Heath	
20	Feb 26 2018 10:02 PM	100 Kings creek Dr	
21	Feb 26 2018 09:39 PM	E. Alamo and San Jacinto, San Jacinto south	
22	Feb 26 2018 09:15 PM	Griffith St.	
23	Feb 26 2018 09:06 PM	The end of June street	
24	Feb 20 2018 03:53 PM	717 s.medora	
25	Feb 17 2018 05:12 PM	117 Lexington Dr.	
26	Feb 15 2018 11:43 AM	behind our house along the easement - comes way up into the yard	
27	Feb 15 2018 09:10 AM	9th & Griffith	

Terrell Drainage Master Plan

Please give approximate date(s) of the high water.

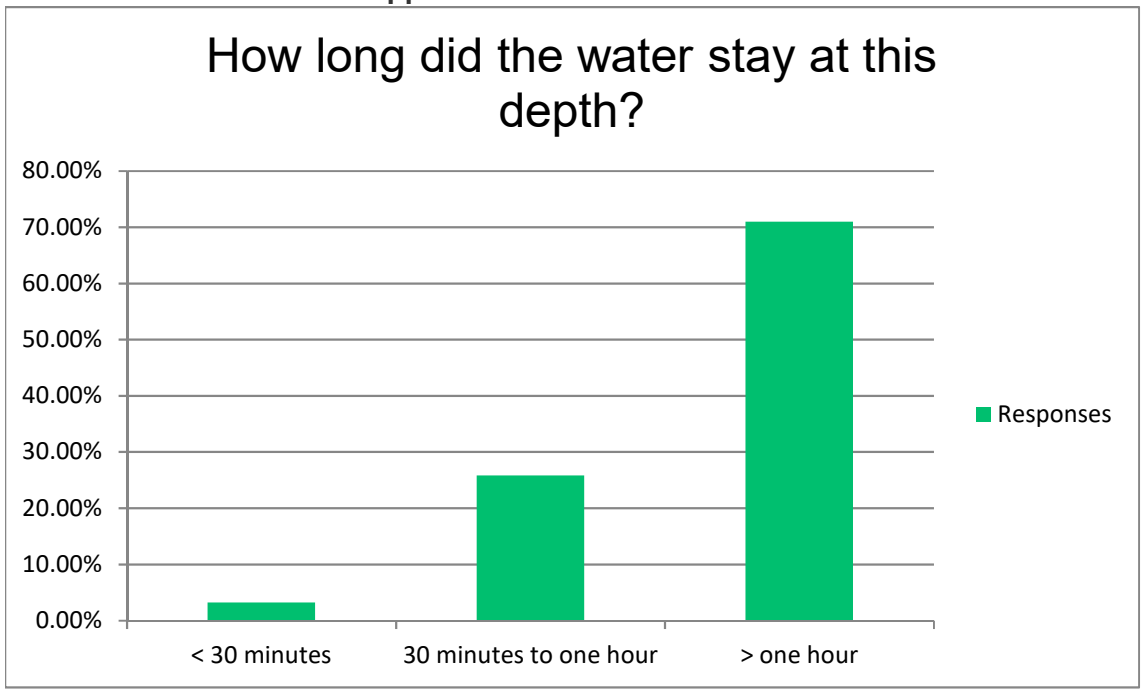
Answered	**30**
Skipped	**12**

Respondents	Response Date	Responses	Categories
1	Mar 20 2018 08:49 AM	Anytime their is heavy rainfall	
2	Mar 17 2018 02:15 PM	Heavy rain in excess of 2-3 inches	
3	Mar 17 2018 10:20 AM	June 4, 2017	
4	Mar 16 2018 09:41 PM	Mid 2017 and during Huffman's Council term	
5	Mar 12 2018 06:19 PM	Every time it rains any significant amount. Ie last week	
6	Mar 10 2018 05:21 PM	Everytime it rains	
7	Mar 10 2018 05:08 PM	Every time it rains, water stands in front of the house, i have pictures	
8	Mar 10 2018 12:36 PM	EVERY TIME WE HAVE A REASONABLE AMOUNT OF RAIN	
9	Mar 06 2018 10:07 PM	2/23-2/28	
10	Mar 06 2018 10:12 AM	2015-2018	
11	Mar 02 2018 06:17 AM	Every time it rains	
12	Feb 27 2018 10:59 PM	Feb 22, 23 & 24	
13	Feb 27 2018 10:31 PM	Anytime we have lots of rain in short time	
14	Feb 27 2018 09:18 PM	Any time is rains heavily	
15	Feb 27 2018 09:09 PM	2-20–18	
16	Feb 27 2018 11:16 AM	Spring Time	
17	Feb 27 2018 09:58 AM	Everytime it rains	
18	Feb 27 2018 07:18 AM	Anytime we get heavy rain	
19	Feb 27 2018 05:44 AM	All last week! Any heavy rain!	
20	Feb 26 2018 11:47 PM	When it rains	
21	Feb 26 2018 10:47 PM	2/22 - 2/23	
22	Feb 26 2018 10:05 PM	2017	
23	Feb 26 2018 10:02 PM	Feb-Mar 2017	
24	Feb 26 2018 09:39 PM	Since I have lived here	
25	Feb 26 2018 09:15 PM	Every time we have heavy rainfall.	
26	Feb 26 2018 09:06 PM	Now	
27	Feb 26 2018 08:43 PM	2-23	
28	Feb 17 2018 05:12 PM	Everytime there is a hard fast rain	
29	Feb 15 2018 11:43 AM	anytime it rains	
30	Feb 15 2018 09:10 AM	water standing non road	

Terrell Drainage Master Plan

How long did the water stay at this depth?

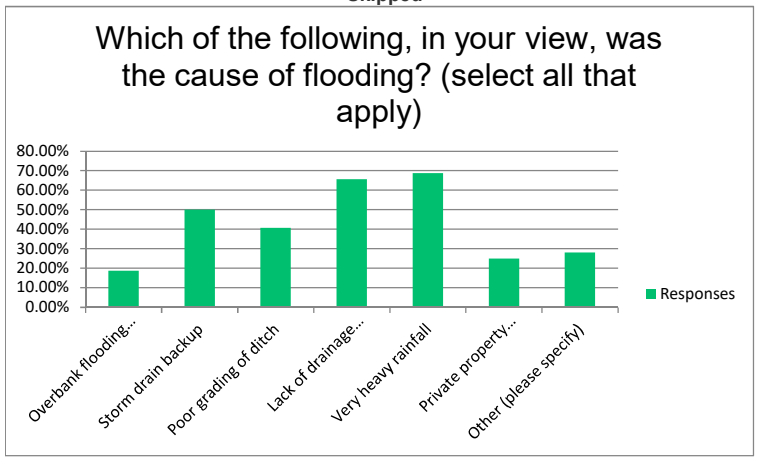
Answer Choices	Responses	
< 30 minutes	3.23%	1
30 minutes to one hour	25.81%	8
> one hour	70.97%	22
	Answered	**31**
	Skipped	**11**



Terrell Drainage Master Plan

Which of the following, in your view, was the cause of flooding? (select all that apply)

Answer Choices		Responses
Overbank flooding from creek	18.75%	6
Storm drain backup	50.00%	16
Poor grading of ditch	40.63%	13
Lack of drainage infrastructure	65.63%	21
Very heavy rainfall	68.75%	22
Private property drainage problems	25.00%	8
Other (please specify)	28.13%	9
Answered		**32**
Skipped		**10**

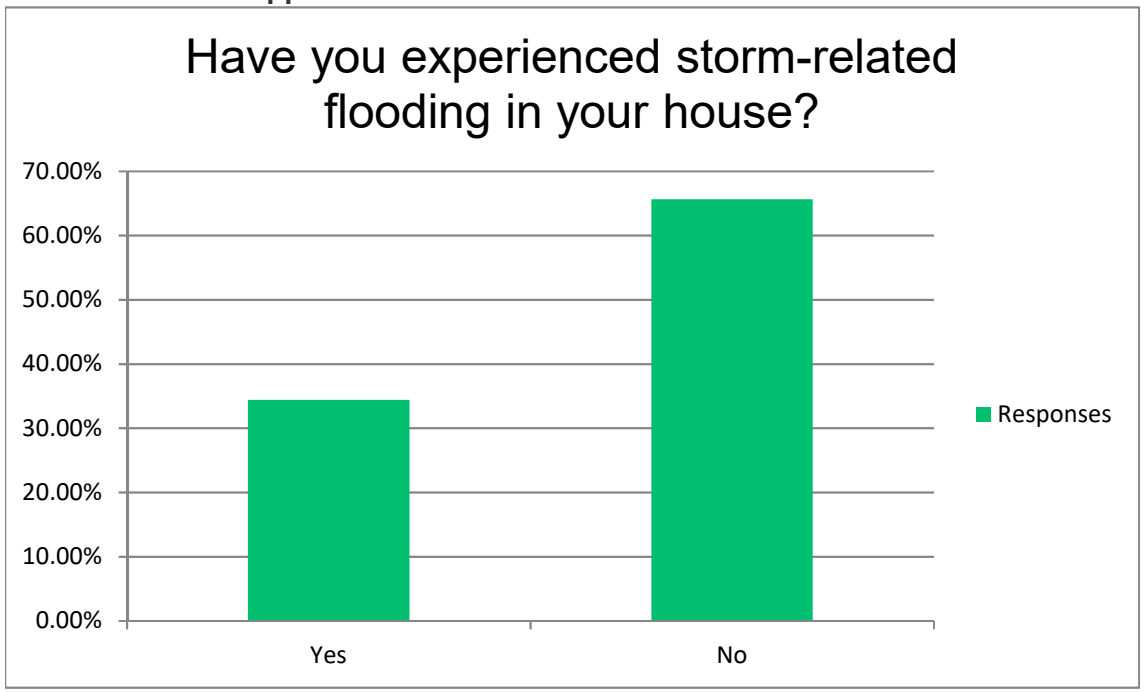


Respondents	Response Date	Other (please specify)	Categories
1	Mar 17 2018 02:15 PM	Drainage pipe at alley obstructed.	
2	Mar 12 2018 06:19 PM	Developer inadequately designed drainage for Forrest Creek subdivision	
3	Mar 10 2018 05:21 PM	The creek is blocked from new construction above us and the mud from water breaks have the end of the streetblocked	
4	Mar 10 2018 05:08 PM	clean out the front street and the debris that has the creek blocked	
5	Mar 10 2018 12:36 PM	Runoff from field behind my property causes a small river to flow through my yard and my neighbor's yard.	
6	Mar 02 2018 06:17 AM	Poor grade of Street	
7	Feb 27 2018 09:18 PM	There’s two storm drain for the entire town north street	
8	Feb 27 2018 07:18 AM	Water draining into creek	
9	Feb 26 2018 09:06 PM	No ditches	

Terrell Drainage Master Plan

Have you experienced storm-related flooding in your house?

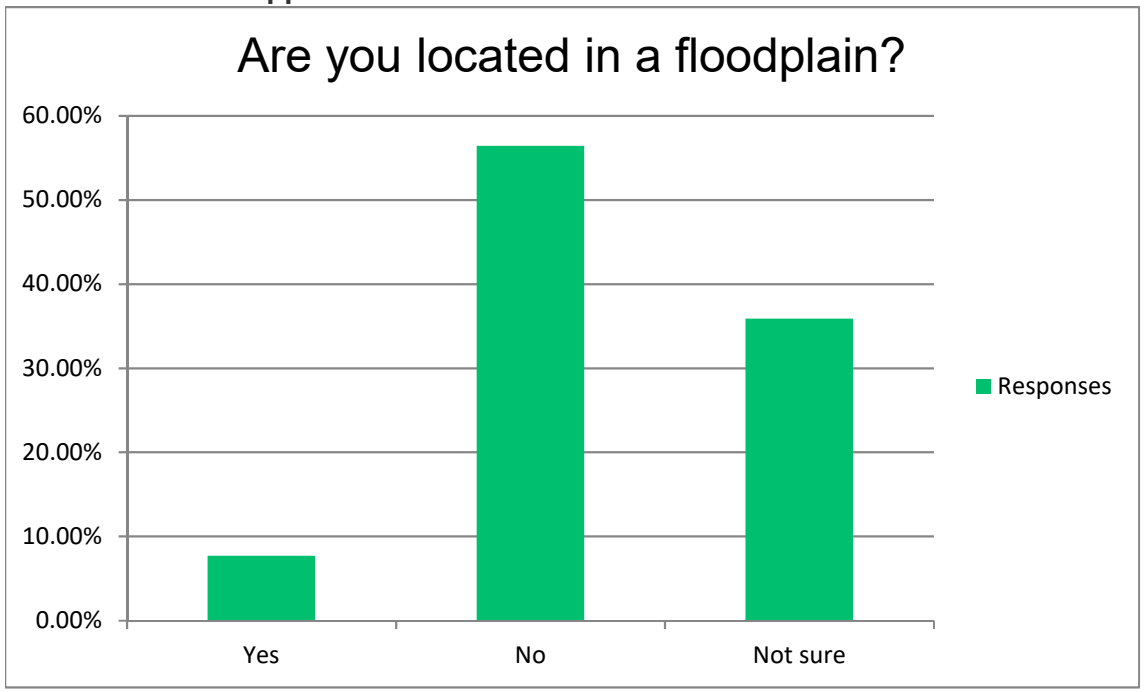
Answer Choices	Responses	
Yes	34.38%	11
No	65.63%	21
	Answered	**32**
	Skipped	**10**



Terrell Drainage Master Plan

Are you located in a floodplain?

Answer Choices	Responses	
Yes	7.69%	3
No	56.41%	22
Not sure	35.90%	14
	Answered	**39**
	Skipped	**3**



Terrell Drainage Master Plan

Are there other areas of high water during rain events that you encounter while you drive around town? Please list the location(s) and approximate date(s).

Answer Choices		Responses
Location	100.00%	28
Approximate Date (month/year acceptable)	78.57%	22
Answered		**28**
Skipped		**14**

Respondents	Response Date	Location	Categories	Approximate Date (month/year acceptable)	Categories
1	Mar 20 2018 08:50 AM	Several residences and businesses along hwy 80		Ongoing problem	
2	Mar 17 2018 10:22 AM	Griffith Ave; Rockwall st		every time it rains...	
3	Mar 12 2018 06:19 PM	By Terrell HS poetry road entrance		March 2018	
4	Mar 10 2018 05:24 PM	All of june st. Getting ready to collect the sewage water i seen and mosquitos for the state health department ii seen sewage running down harrissee		Jan feb march 2018	
5	Mar 10 2018 05:08 PM	Virginia Street			
6	Mar 10 2018 12:37 PM	Poetry Road from State to High School		Every time we have measurable rain	
7	Mar 02 2018 06:18 AM	Moore Ave east and west of downtown; intersection at McGinty's			
8	Feb 27 2018 11:00 PM	Virginia St & Brin; Virginia St & college		Any time you have rain	
9	Feb 27 2018 10:31 PM	Rockwall st and Griffith st			
10	Feb 27 2018 09:18 PM	Ni			
11	Feb 27 2018 09:10 PM	Nash st I believe behind Baylor		2-2018	
12	Feb 27 2018 03:10 PM	Griffith, Rockwall		Jan 2018	
13	Feb 27 2018 11:18 AM	corner of moore ave and 9th, colquitt, griffith, moore ave near taco bell, virginia,		Spring time mainly	
14	Feb 27 2018 07:18 AM	Rockwall St			
15	Feb 26 2018 10:51 PM	Bridge at Colquitte and Lovers		2017	
16	Feb 26 2018 10:49 PM	In front of the Baylor Health Center, on the dip in Rockwall Street in front of La Azteca.		All	
17	Feb 26 2018 10:03 PM	Virginia ave, hwy 34 near old Terrell tribune bdlg		Feb, 2018, Feb Mar 2017	
18	Feb 26 2018 09:57 PM	Cvs		2/25/18	
19	Feb 26 2018 09:54 PM	Colquitt, Charles Lane		When it rains	
20	Feb 26 2018 09:40 PM	Westbound East Alamo toward Virginia		Since I have lived here. Water still there right now	
21	Feb 26 2018 09:22 PM	Rockwall and College		4/17	
22	Feb 26 2018 09:15 PM	Rockwall to Virginia at the "dips" north of 80		Every time we have significant rainfall	
23	Feb 26 2018 09:08 PM	Virginia street, from Creek Side to Moore		With any rain	
24	Feb 26 2018 08:33 PM	Brin and N. Virginia		Every time it rains	
25	Feb 20 2018 03:55 PM	allmost any were in the southern sector of town			
26	Feb 17 2018 05:13 PM	100 Griffith Ave		Everytime there is a hard fast rain	
27	Feb 15 2018 09:48 AM	Ninth Street @ Moore Avenue		5/17	
28	Feb 15 2018 09:11 AM	North Rockwall Street		2017	

Exhibit B2
Meeting Minutes

MEETING MINUTES

Innovative approaches
Practical results
Outstanding service

NAME OF MEETING:	Project Kick-Off Meeting
PROJECT:	TER17602 – Drainage Master Plan
RECORDED BY:	Kristina McLaren
DATE:	October 26, 2017
LOCATION:	City of Terrell City Hall
DATE SENT FOR APPROVAL:	October 30, 2017
DATE FINALIZED:	November 7, 2017
ATTENDEES:	Scott Hubley, FNI Jeremy Dixon, FNI Kristina McLaren, FNI Scott Maughn, FNI Daniel Huffines, FNI Steve Rogers, COT Mike Mikeska, COT Kris Walker, COT Mike Kochanek, FNI

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION
1.	Key personnel and project roles were reviewed. Steve and Mike are to be the points of contact for the City of Terrell (City). Scott and Jeremy will be points of contact for FNI.

2.	Scope Review
	- Public involvement
	  ○ The public meeting will include an online survey for feedback form residents in the study area. FNI will set up the survey. Duration will be approx. 1 month and will last for 1 week beyond the public meeting. The City will advertise via water bill insert. FNI will provide draft language.
	- Meetings
	  ○ Progress phone call meetings will be held on an ad hoc basis.
	- GIS system inventory
	  ○ The City will share their current GIS files via FNI managed FTP.
	- Field data collection
	  ○ FNI will notify the City 2-3 weeks in advance of a field visit that will require City assistance to access site or perform maintenance/cleaning if necessary.
	  ○ FNI will split the site visits into waves based on prioritization of sites.
	- Data design and implementation
	  ○ Steve mentioned there is a private development occurring near the identified Tributaries 3 and 4 on Kings Creek which might affect current survey data. This site a part of Phase 2 of this project.
	- Criteria Manual and Best Management Practices
	  ○ The City has sent FNI the most recent word version of their Criteria Manual. FNI will track their changes as they edit it.

	- Local systems
	  o The additional survey performed for the existing conditions analysis of local systems will be determined from FNI H&H modelling and the identified locations will be approved by the City prior to survey.
	- Virginia Street analysis
	  o FNI will focus on modelling the identified drainage problem at the corner of Virginia Street and then include the remainder of the reach later on.
	- Small project development
	  o FNI will provide a pairwise comparison for the Small Project List.

3.	Schedule Review - The DMP public meeting will be pushed back 2-4 weeks in coordination with the FNI Utilities team and the City depending on when the Griffith Avenue public meeting is held. - The Virginia Street modelling will be performed in January as soon as the GIS data is ready and the TxDOT and field data have been received. - City noted that budgeting for the next fiscal year begins around April and the Small Projects list needs to be delivered shortly thereafter.
4.	Technical Discussion - The City has had no Severe Repetitive Loss Areas that they are aware of according to FEMA standards. - The City is currently updating their Comprehensive Plan. These updates include Master Thoroughfare Plan and Zoning, which will be available as of December 2017. - The City has no dual use parks. - The storm drain record drawings are in GIS and mostly complete. As more information is added, files will be updated on the FTP.
5.	Project communications were discussed. FNI and the City will meet again before the calendar year is over. In addition to monthly reports, other communication via email and phone will be performed as needed.

ACTION ITEMS

WHAT	WHO	WHEN	STATUS
1. City to share GIS data and maps via FNI managed FTP. See attached Data Request Memo.	City	ASAP	Complete
2. FNI to revise Schedule	FNI	ASAP	Complete
3. FNI to set up survey crew	FNI	ASAP	Complete
4. City to send PO number for project.	City	Next Week	Complete
5. FNI to start working on editing the Technical memorandum for Criteria and BMPs.	FNI	This Month	Complete
6. FNI will send data request to TxDOT for pre-2014 for Virginia Street Survey and Analysis.	FNI	This Month	Complete
7. City to send pre-TxDOT project study to FNI for Virginia Street Analysis.	City	Next Month	Complete

WHAT	WHO	WHEN	STATUS
8. FNI to send instructions to the City on how to request FEMA data for models	FNI	Next Month	Complete
9. FNI to send instructions to the City on how to request FEMA data for a list of repetitive loss areas.	FNI	Next Month	Complete
10. FNI to continue data collection.	FNI	Ongoing	Complete

MEETING MINUTES

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

PROJECT:	TER17602 – Terrell Drainage Master Plan	
NAME OF MEETING:	Update 1: Griffith, ArcGIS Online, Criteria, etc.	
RECORDED BY:	Jeremy Dixon	
DATE:	January 30, 2018	
LOCATION:	Terrell City Hall	
DATE SENT FOR APPROVAL:	January 31, 2018	
DATE FINALIZED:	February 7, 2018	
ATTENDEES:	Steve Rogers	Scott Hubley
	Mike Mikeska	Kristina McLaren
	Kelly Dillard	Jeremy Dixon

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	Overall project status • Provided update on current tasks. • Provided updated schedule. • Survey set to resume with Phase 1 creek cross sections and bridge/culvert survey. Additional storm drain system survey will be collected once GIS data is fully processed.	Scott

2.	Griffith Avenue Impact Analysis
	• Reviewed highlights of the memo.
	• Proposed 20' channel is too expensive. Pursue other alternatives that may not meet criteria for the tailwater elevation including:
	  ○ Minimal grading to fit outfall (essentially the "do nothing" alternative, Terrell will not meet criteria)
	  ○ A reasonably sized channel that slightly improves conveyance
	  ○ Extend the box culvert further downstream and minimal grading
	  ○ Split the flow to Roberts Ave
	• Discussed problem area at Griffith Ave and 3rd St. Flow through neighbors' backyard into another. Need to show improvement at this location as well. 50' max stub out plus inlets on 3rd and near the existing driveway that drains to the road.
	• Stub-outs will be provided at 1st and 3rd, but likely will not be needed at 9th.
		Jeremy

3.	ArcGIS Online Draft Web Map • Demonstrated the process to get from City data to "final product data." • Kris will get access to the data through our AGOL setup and will have 1-2 weeks for review of collected features and	Kristina

ITEM	DESCRIPTION	PRESENTER
	fields. Any additional data that needs to be collected must be determined at this point. Modifying the data fields beyond this point is not desirable. • We will schedule a 2-hr GIS handoff meeting and do some field training outside of City Hall. The City intends to collect additional water/wastewater data using the mobile application and will include the appropriate staff in the training meeting.	
4.	Preparation for Public Meeting • Confirmed March 28 at City Hall Council Chambers, 7:00 PM. • City will handle advertising the meeting in newspaper, City website, and social media. • Format will be Open House style. • The original Council presentation will be rolling on loop in the background on the projector. • Multiple stations with maps and exhibits at each corner of the room. • All exhibits/maps for display will be sent to Steve for approval prior to the meeting. • Exhibits/maps to be plotted on foam boards on easels. • Possibly set up ArcGIS Online Webmap for documenting complaints.	All
5.	Small Project Development • FNI will keep track of potential locations with known issues identified during site visits. List will be developed from these, plus list from maintenance. • Preference is given to projects that enhance health and safety. • Interim or phase 1 of multiple phase solutions may be a part of the small project list. • Ballpark costs will be helpful in identifying which projects qualify as "small." • Generally, projects less than $250k will be small, but Steve will determine that once we have the list.	All
6.	Virginia Street Analysis • City's main concern are the removal of valley gutters along Virginia at College and Brin Street. TxDOT project in 2014 removed the dips but left the signs in place (FNI will include photos of signs in memo). Removal of the dips changed the flow patterns in the area and cause flooding all along High Street, where water formerly was spread along College and Brin. • The only comparison needed is for the 2014 TxDOT Project. • The storms on June 4th flash-flooded a fire truck at High Street between Delphine and New SH 34. Steve will send flood records to FNI that we can include in memo.	All

ITEM	DESCRIPTION	PRESENTER
	• Need to be prepared with our analysis for a meeting with Jason Verner at TxDOT to demonstrate the impact. • Memo will provide clear, simple language to describe the impact, and include lots of photos and exhibits for documentation.	
7.	Criteria Review • Added Downstream Assessment, Detention Design, and Erosion Hazard Zone sections. Updated tables, figures, and removed nomographs. • The City has a floodplain permit form that can be added to appendix. • Downstream Assessment – trigger is good at 1-acre, but also may be required as needed by City Engineer. • Downstream Assessment – City prefers "Proportional Share" approach. • Downstream Assessment – No increases in WSE or Flow (remove 0.01 ft and 0.1 cfs language). • Detention Design – Volume calculation by Modified Rational Method acceptable. Hydrograph Analysis acceptable. Study for 1-year, 10-year, and 100-year. Do not use detention rate. • Detention Design – 25-year minimum for overflow spillway elevation. • Detention Design – Remove fire lane restriction for parking lot detention. • Detention Design – Property Owner signs affidavit of compliance with federal, state, and local regulations at the time of drainage plan submittal. • Detention Design – Add a detail for Retention and Wet Pond within the manual • Detention Design – Add wet-bottom detention requirements including aeration, and available storage. No need to include make-up water. • Change preliminary plat to preliminary/construction plat. • Update Street Typical Sections based on Thoroughfare Plan Update • Change Culvert design to 1 foot of freeboard (from 2 feet) • Rip Rap design – FNI will send documents on Gregory Method for sizing Rip Rap • Rip Rap design – City prefers Rip Rap size of 12 inches or less, but typically 6 to 8 inches. If calcs do not support it, City prefers to grout. • Rip Rap design – 2-foot minimum toe wall unless directed by City Engineer.	Kelly

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Provide login username for Kris to access and review ArcGIS Online Webmap	City	ASAP	Complete
2. Setup drainage@cityofterrell.org email address	City	ASAP	Complete
3. Send backup on rainfall data (TxDOT vs Atlas 14)	Jeremy	2 weeks	Complete
4. Send coincident peak analysis table	Jeremy	2 weeks	Complete
5. Send example construction plan checklist files	Scott	2 weeks	Complete
6. Send Gregory Method for Rip Rap Design	Kelly	2 weeks	Complete

MEETING MINUTES

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

PROJECT:	TER17602 – Terrell Drainage Master Plan	
NAME OF MEETING:	Drainage Master Plan Meeting #2	
RECORDED BY:	Jeremy Dixon	
DATE:	May 10, 2018	
LOCATION:	Terrell City Hall	
DATE SENT FOR APPROVAL:	May 17, 2018	
DATE FINALIZED:		
ATTENDEES:	Steve Rogers	Scott Hubley
	Mike Mikeska	Jeremy Dixon

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER

1.	**Virginia Street Analysis**
	• Reviewed results of analysis and alternatives
	  ○ Extend 8'x5' RCB to Virginia Street from Callie Street and use inlets along the way to maximize use of capacity.
	• Discussed meeting with TxDOT
	  ○ The goal of our Technical Memorandum is to convince TxDOT that we have a feasible solution to the problems their design caused.
	  ○ We will attend the meeting with TxDOT and be there to field the Technical questions.
	  ○ Steve will handle financial negotiations with TxDOT.
	• Provide final draft of Memo to City within 2 weeks.
		Jeremy

2.	**Small Projects List**
	• Reviewed Big Map of all 38 projects.
	• Reviewed individual small projects list.
	  ○ The TxDOT list is a separate list of projects.
	  ○ Steve to provide his list of ±10 projects.
	  ○ In general, the FNI list of small projects was sufficient to complete scope
	• Provide Technical Memorandum documenting the prioritized Small Projects list within 1 month.
		All

3.	**Management Best Practices**
	• Reviewed List of Cities
	  ○ Replace Bryan with Greenville (1st Preference) or Forney
	  ○ Interview Glenn for Terrell's current practices
	  ○ List: Fort Worth, Weatherford, Waxahachie, Ennis, Greenville (or Forney), Mansfield, Red Oak, Terrell
	• Reviewed List of Questions
	  ○ Add two questions:
		Scott

	1. Do you have a Stormwater Utility Fee? 2. What is your current rate? • Provide summary in Technical Memorandum within 2-3 months. This is important.	

4.	**Outstanding Action Items**
	• Need data on:
	  ○ Grove Street drainage (probably not available)
	  ○ Builder's First Source (available)
	  ○ Excel Center on Colquitt Rd. (available)
	  ○ Poetry Rd. Drainage (probably not available)
	  ○ St. Luke St. / Park St. Drainage Improvements (available)
	• FNI to send updated TCSS once details are complete.
	  ○ Provide very conservative detail for turndowns and toe ditches.
	  ○ Riprap, concrete riprap, and grouted riprap details will be provided.
	  ○ This task is not urgent, as final update will require Atlas 14 data (expected to be available in December), but FNI will provide updated draft version by the end of June.
	• FNI to review Griffith Downstream Assessment Memo considering recent changes to Griffith Avenue project outfall.
	  ○ Sign and seal the memo once final. City has no more comments.
		All

5.	**Project Financials / Status**
	• To study Virginia Alternative, GIS handoff and training meeting can be pushed to Phase 2.
	  ○ Railroad analysis can likely be pushed to begin in early Phase 2.
	  ○ Steve to review and provide comments before proceeding with scope change.
	• Steve has a flood study on two of the Phase 2 creeks.
	• There is a need to show more progress on the project.
	  ○ FNI will provide bullet list of to-date accomplishments and completed tasks.
	• Bill complete by Mid-September, all Phase 1 work products should follow shortly thereafter
		All

6.	**Coordination on Griffith Avenue Project** • Reviewed OPCC for alternatives packages for the Griffith Avenue Project. Steve was concerned of discrepancy in individual alternative cost increase vs combined alternatives cost increase.	Steve

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Summary of complete tasks	FNI	5/16/2018	Complete
2. Final draft of Virginia Memo to City	FNI	5/24/2018	Complete
3. City small projects list	City	ASAP	Complete
4. Final small projects Memo	FNI	6/7/2018	Complete
5. Maintenance Best Practices Memo	FNI	Mid-July	Complete
6. Provide requested plans	City	ASAP	Complete
7. Sealed Griffith Memo	FNI	ASAP	Complete
8. Send link to ArcGIS Online map to Kris	FNI	5/18/2018	Complete
9. Updated draft TCSS	FNI	6/29/2018	Complete

MEETING MINUTES

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

PROJECT:	Drainage Master Plan	
NAME OF MEETING:	Phase 1 Wrap-Up Meeting	
RECORDED BY:	Jeremy Dixon	
DATE:	09/06/2018	
LOCATION:	Terrell City Hall	
DATE SENT FOR APPROVAL:	09/11/2018	
DATE FINALIZED:	09/18/2018	
ATTENDEES:	Steve Rogers	Trey Shanks
	Scott Hubley	
	Jeremy Dixon	

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	Review Drainage Maintenance Best Practices Memo • Reviewed key features and findings of Memo • Add a street sweeper as a possible equipment addition • Add general statements such as the $5.65/ERU SWUF provides approx. $1M per year • Steve to provide additional comments • Phase 2 Funding Memo to address original SWUF, and deviation from original schedule/deployment, with the goal to help identify shortfalls and potential filler from other sources. Finish by April.	All
2.	Hydrology and Hydraulics • Reviewed basin delineations, curve numbers • Reviewed hydraulic model extents between 1D and 2D • Reviewed preliminary hydraulic results • Final hydraulic results will be provided with updated mapping and structural inundation estimates • Will not report 500-year mapping	Jeremy

3.	TCSS Update and Standard Details Discussion
	• Atlas 14 will be available at the end of September
	• Final TCSS will be update with Atlas 14 data availability
	• Reviewed sample of standard details
	  ○ Concrete Riprap
	  ○ Turn downs
	  ○ Riprap connections to Concrete
	• FNI will provide standard details
		All

4.	Phase 2 Discussion • Contract at Council 9/13 • McLendon Hydrology has taken over the Creekside Drainage Study – New models will be available	All

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Provide final comments on Best Practices Memo	Steve	9/14/18	Complete
2. Provide final Best Practices Memo	FNI	9/28/18	Complete
3. Provide final Phase 1 Hydraulic Results	FNI	9/21/18	Complete
4. Provide Final TCSS update	FNI	10/12/18	Complete
5. Provide Standard Details	FNI	9/21/18	Complete
6. Steve to schedule meeting with TxDOT	Steve	ASAP	Superseded

MEETING MINUTES

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

PROJECT:	Drainage Master Plan	
NAME OF MEETING:	Drainage Master Plan Phase 2 Meeting #1	
RECORDED BY:	Jeremy Dixon	
DATE:	December 10, 2018	
LOCATION:	Terrell City Hall	
DATE SENT FOR APPROVAL:	December 11, 2018	
DATE FINALIZED:	December 18, 2018	
ATTENDEES:	Steve Rogers	Scott Hubley
	Mike Mikeska	Jeremy Dixon

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	**Project Status** • No issues with the 11/29 schedule at this time	Scott

2.	**Phase 1 Outstanding Items**
	• Criteria Manual – Reviewed Atlas 14 information. No changes needed.
	• Standard details for Concrete Riprap – reviewed drawing. Received comments to address.
	  ○ Note 2: Clarify what is meant by transverse joints at weephole locations
	  ○ Section A: replace Grade 1 with Nominal 6-8”
	• Maintenance Best Practices Memo. No changes needed.
	• GIS Handoff & Training – will occur when survey is complete
	• Meeting with TxDOT for Virginia – may not occur due to new circumstances
	• Small Projects List: City does not have the final version.
		All

3.	**Railroad Analysis Results and Memo** • Memo needs to note cost and benefit for each proposed change • City needs time to review and provide comments	Jeremy

4.	**Phase 1 Concept Alternatives**
	• Discussed alternatives for Phase 1 areas to identify preferred locations of study:
	• South Side / KC5
	  ○ Railroad Spur Culvert
	• East Side / KC1
	  ○ UPRR Improvements
	  ○ Channel Improvements DS of RR and Gardner St
	• West Side / BC1
	  ○ UPRR Improvements
	  ○ Channel Improvements in Park and near Cemetery
		All

ITEM	DESCRIPTION	PRESENTER

	• N Rockwall / KC2
	  ○ Open channel improvements and associated buyouts
	  ○ Parallel system on Heath St and Alamo St
	  ○ Morris St bypass
	• Need survey of specific locations:
	  ○ Mineral Wells St Culverts
	  ○ Ninth St SD line and Junction Boxes near Stadium
	  ○ Railroad Spur Culvert	

5.	**Phase 2 Approaches** • Funding Memo Split – Approach is acceptable. FNI will proceed as planned. • Use of Creekside Models – City to provide when available.	Jeremy

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Update notes on Concrete Riprap Detail	FNI	12/21/18	Complete
2. Provide final Maintenance Best Practices Memo	FNI	12/14/18	Complete
3. Provide Finalized Small Projects List	FNI	12/14/18	Complete
4. Provide Additional Comments on Railroad Memo	City	1/2/19	Complete
5. Provide Creekside Models	City	TBD	Complete
6. Provide Oldcastle Plans	City	1/2/19	Complete

MEETING MINUTES

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

PROJECT:	Drainage Master Plan	
NAME OF MEETING:	Drainage Master Plan Phase 2 Meeting #2	
RECORDED BY:	Jeremy Dixon	
DATE:	February 26, 2019	
LOCATION:	Terrell City Hall	
DATE SENT FOR APPROVAL:	February 28, 2019	
DATE FINALIZED:	March 8, 2019	
ATTENDEES:	Steve Rogers	Scott Hubley
	Mike Mikeska	Jeremy Dixon
		Kristina McLaren

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	**Project Status** • Overall project is on schedule	Jeremy

2.	**Phase 1 Outstanding Items**
	• GIS Handoff & Training
	  ○ Additional survey from Phase 2 has been incorporated
	  ○ Alternatives may require additional survey
	• Meeting with TxDOT for Virginia
	  ○ Probably not going to occur
	  ○ City is going to pursue a Community Development Block Grant with improvements to extend past problem area on Virginia to relieve SD system
	  ○ City requests FNI to include this project in the Alternatives and look in more detail at the Virginia Recommended design through Virginia and Brin intersection
		All

3.	**Phase 2 Status and Results Review**
	• Discussed the Phase 2 H&H results and City provided current information for these areas:
	  ○ Two areas not included in delineated watershed on east side of City
	  ○ Visual and detail markups
	• KC6
	• Airport/KC5
	  ○ Development occurring near British Flying School Rd.
	  ○ City identified “Airport Lead” as a potential alternative
	• Colquitt
	• BC3/West
		Jeremy

ITEM	DESCRIPTION	PRESENTER
	○ Halff is designing a project that puts in a bridge on 205 north of the crossing flows • Additional Area #1 – KT-1 ○ City approved Tanger to QT area as an additional local area to be analyzed • Creekside Models Pending ○ Steve to send Creekside models to FNI this week/as available	
4.	**Phase 1 Alternatives Review** • Discussed the current results for alternatives analysis for Phase 1 areas: • KC5 Railroad Spur and Channel Improvements ○ Models updated with Old Castle plans ○ Alternative slightly reduced magnitude of floodplain near railroad • State and Walnut ○ The Carter & Burgess study was based on Rational Method ○ Recommended improvements were applied to ICM model and would not solve all the drainage problems in this area – original cost estimate would equal approx. $7M today • State and Walnut Improved ○ FNI determined a scenario that would improve upstream drainage and create net-zero effect on downstream through a combination of a bypass pipe, upsizing crossings, associated buyouts, and implementing a natural channel design • Other Alternatives ○ West – channel improvements in Gill/Lions Club Park ○ West – cemetery channel improvements	Jeremy
5.	**Additional Items** • Grace Lane North of Griffith ○ Add as Small Project • Griffith – Third St. Extension Design ○ Discussed conceptual design and ultimate conditions ○ Discussed Improved Griffith design • Funding Memo – On schedule • "Airport Lead" ○ Identified as area for alternative analysis • Steve presented Moore Ave at Chamber of Commerce alternate concept	All

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Complete Phase 1 Alternatives Analysis - include Virginia more detailed analysis	FNI	3/15/19	Complete
2. Compile Phase 2 Alternative List	FNI	3/8/19	Complete
3. Analyze Tanger to QT as local area	FNI	3/22/19	Complete
4. Add Grace Lane to Small Projects	FNI	3/8/19	Complete
5. Determine effort for two gaps in watershed delineation on east side of City	FNI	3/8/19	Complete
6. Provide P&P and associated costs for Third Street extension	FNI	3/1/19	Complete
7. Provide separate summary of Griffith Improvements recommendation	FNI	3/1/19	Complete
8. Request info from Kyle Dickey on floodplain reclamation in Kings Creek Trib 1 & 1B at SH34.	FNI	3/1/19	Complete
9. Provide Additional Comments on State and Walnut Alternative	City	3/5/19	Complete
10. Provide Creekside Models	City	3/1/19	Complete
11. Provide plans for design project on 205.	City	3/5/2019	Superseded
12. Provide plans from 2013 utilities project on Third Street	City	2/26/19	Complete

MEETING MINUTES

Innovative approaches
Practical results
Outstanding service

PROJECT:	Drainage Master Plan
NAME OF MEETING:	Hydraulics and Alternatives Finalization
RECORDED BY:	Jeremy Dixon
DATE:	June 20, 2019
LOCATION:	Terrell City Hall
DATE SENT FOR APPROVAL:	June 24, 2019
DATE FINALIZED:	July 01, 2019
ATTENDEES:	Steve Rogers, Jeremy Dixon, Mike Mikeska, Chris Johnson, Scott Hubley, Kristina McLaren

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	**Project Status** • Overall project is on schedule – models approved in amendment are about to enter QC • Entering CIP/Ranking stage	Jeremy
2.	**Hydraulic Analysis Updates** • FNI contacted McClendon and confirmed that "Creekside South" model, KC3 system, is preliminary • Discussed labeling watersheds with a better system than what was used in original scope • Reviewed Capital Project sample map and City provided comments to improve visuals and understanding • Draft of properties directly effected by capital projects was reviewed ○ Easements to be added to list • Sample project OPCC and CIP summary OPCC exhibits were reviewed	Jeremy

3.	**Alternatives Updates**
	• Reviewed modelled concepts for alternatives approved in Amendment: Downtown (Brin, College, Virginia), Airport, Brookhollow, and Rochester
	  ○ Airport Drainage Improvements to be called Fuji Drainage Improvements
	  ○ Drainage ditches to be removed from Fuji alternative and replaced with storm drain
	• Need exhibits to have better comparison of existing and proposed infrastructure in alternatives
	• City noted a development planned downstream of Brookhollow alternative and requested existing flow rate from QC'd model
		Jeremy

	• City satisfied with modelled infrastructure aside from above comments	

4.	**Ranking Criteria and Process**
	• Reviewed ranking criteria
	  ○ City satisfied with main five criteria listed
	  ○ Identified optional criteria (Link to other City projects, Project Readiness, Complexity/Acceptance, Land Acquisition, ROW Availability) to be called Additional Considerations and addressed separately from main ranking in CIP summary sheets
	• City requests FNI to work on and present a first draft of weighted ranking in lieu of using polling method
	• Sequence table of projects will be added to each watershed map
	• City expressed expectations for funding memo
		All

5.	**Report Outline** • City chose Option 2 – DMP Ending	Jeremy

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Brookhollow EX flow rate and ROM exhibit	FNI	6/26/19	Complete
2. Provide examples of labeling options	FNI	6/28/19	Complete
3. Choose labeling method	City	7/5/2019	Complete
4. Provide new work orders	City	6/28/19	Complete
5. Update Exhibits • Design for 11x17 print • Address specific visual comments	FNI	7/22/2019	Complete
6. Create Infrastructure Maps	FNI	7/22/2019	Complete
7. Update property list and add required easements	FNI	7/22/2019	Complete
8. Complete OPCCs	FNI	7/22/2019	Complete
9. QC remaining Alternative models	FNI	6/28/2019	Complete
10. Prepare CIP Criteria Ranking	FNI	8/2/2019	Complete
11. Update Funding Memo	FNI	8/2/2019	Complete
12. Check Small Project Ranking	FNI	6/24/2019	Complete
13. Next Meeting: August 13 @ 10:30am	All	6/20/2019	Complete

MEETING MINUTES

Innovative approaches
Practical results
Outstanding service

PROJECT:	Drainage Master Plan	
NAME OF MEETING:	Prioritization, Funding, and Report	
RECORDED BY:	Jeremy Dixon	
DATE:	August 13, 2019	
LOCATION:	Terrell City Hall	
DATE SENT FOR APPROVAL:	August 19, 2019	
DATE FINALIZED:	August 27, 2019	
ATTENDEES:	Steve Rogers	Scott Hubley
	Mike Mikeska	Jeremy Dixon
		Kristina McLaren

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	**Project Status** • Still working towards Finalized DMP Report deadline on 9/20/2019	Jeremy
2.	**Hydraulics and Alternatives Analysis Complete** • Updated City depth results exhibit ○ Includes areas added in amendment: Stallings Addition and SH 34 North • Streams will not be relabeled • Remove NFHL on legend – classify as FEMA	Jeremy
3.	**Pairwise Criteria and Process Refresher** • Criteria updated with ranges applicable for project ○ City noted "count" term needs to be made clearer	All
4.	**Prioritization Results** • KC1/Downtown and KC2/State & Walnut/Griffith should be at the top of the priority list.	All

5.	**Sample Report Text**
	• KC1/Downtown watershed example write up discussed
	• Watershed maps shown and City provided comments
	  ○ NFHL (FEMA) layer needs more description and to be more visually distinct from study results
	• Downtown Area, CIPs 04, 05, 06, need to be broken down differently to incorporate more near-term phases that will improve area and show "success"
	  ○ Virginia Analysis Memo to be revisited and incorporated
	  ○ Think about opportunities presented by the sewer project along CIP-04
	• When costs are exorbitant, consider benefit of reduced criteria
		Jeremy

	• Build momentum with projects by generating a list of successes	
6.	**Funding Memo Assumptions** • Draft memo presented, along with assumptions used • City requests break point of $2 million projects be reduced to $1 million • City requests additional recommendation to memo based on what fee their peers are implementing • Noted that current ERU count is what's used for funding calculations • Memo will highlight TWDB and GLO/CDBG funding opportunities • Dedicate more money to projects	All

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. Update CIP IDs to apply watershed and be sequential within watershed	FNI	8/23/2019	Complete
2. Update KC1/Downtown phasing, specifically CIP04, 05, 06	FNI	8/27/2019	Complete
3. Update funding memo	FNI	8/30/2019	Complete
4. Complete draft for remaining watershed reports, exhibits, and CIP one page reports	FNI	8/30/2019	Complete
5. Next meeting: TBD	All	8/14/2019	Complete

MEETING MINUTES

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

PROJECT:	TER17602: Terrell Drainage Master Plan
NAME OF MEETING:	Draft Report and Council Presentation Discussion
RECORDED BY:	Jeremy Dixon
DATE:	November 12, 2019
LOCATION:	Terrell City Hall
DATE SENT FOR APPROVAL:	November 25, 2019
DATE FINALIZED:	December 2, 2019
ATTENDEES:	Steve Rogers Scott Hubley Mike Mikeska

The following reflects our understanding of the items discussed during the subject meeting. If you do not notify us within five working days, we will assume that you are in agreement with our understanding.

ITEM	DESCRIPTION	PRESENTER
1.	Presented first draft of report. • Add tabs and individual Table of Contents for both Volume 2 and Volume 3. • Add overall map of all watersheds at the beginning of Volume 2. • Update all maps with latest City Limits. • Update Funding Memo to include discussion on TIF. • City to provide additional comments.	Jeremy/Scott
2.	Presented draft council presentation. • January 24-ish • Expecting a 2-hour presentation, build in some repetition • City will lead presentation, FNI provide additional detail and support • Do an ArcGIS Online demo • Discuss updated TCSS • Need more detail on analysis and flood hazards • Need more detail on high-ranked projects	Jeremy/Scott

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
1. City to review draft report and provide additional comments	City	Wk 2 December	Complete
2. FNI to revise council presentation	FNI	Wk 2 December	Complete

ACTION ITEMS			
WHAT	**WHO**	**WHEN**	**STATUS**
3. City to provide information on previous grant applications for KC2 (State and Walnut)	City	ASAP	Complete
4. Schedule ArcGIS Online Handoff	FNI/City	TBD	Complete

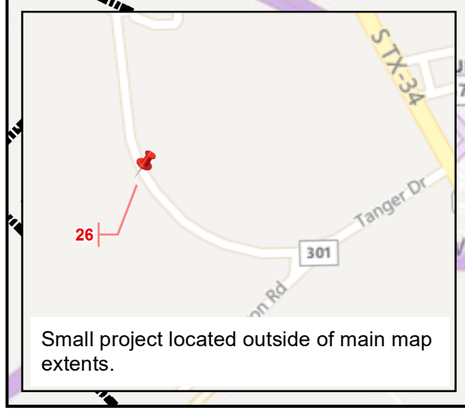
APPENDIX C
Digital Data

VOLUME 2

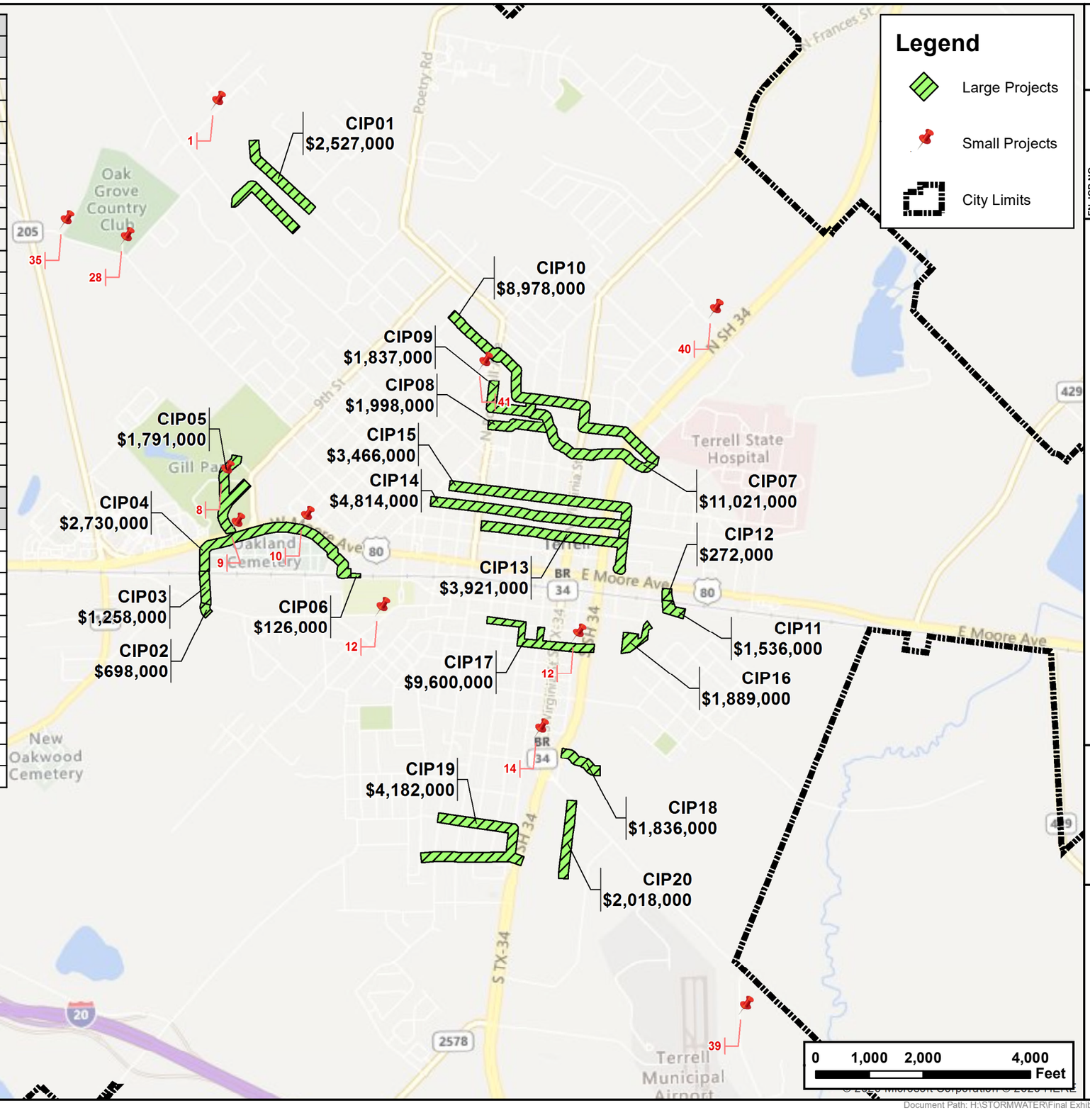
STUDY AREAS

Large Projects		
ID	Location	OPCC
CIP01	Brookhollow Channel and SD	$ 2,527,000
CIP02	West End St. Culvert	$ 698,000
CIP03	BC2 Railroad Crossing and Channel Improvements	$ 1,258,000
CIP04	Cemetery Channel	$ 2,730,000
CIP05	Stadium Channel	$ 1,791,000
CIP06	SWCC Railroad Crossing Improvements	$ 126,000
CIP07	KC2 Channel Improvements	$11,021,000
CIP08	W. Alamo SD	$ 1,998,000
CIP09	Heath St. SD	$ 1,837,000
CIP10	N. Rockwall Channel & N. Morris Bypass	$ 8,978,000
CIP11	KC1 Railroad Crossing and Channel Improvements	$ 1,536,000
CIP12	KC1 Upper Channel Improvements	$ 272,000
CIP13	Virginia St. SD Extension	$ 3,921,000
CIP14	College St. SD	$ 4,814,000
CIP15	Brin St. SD	$ 3,466,000
CIP16	Gardner St. Improvements	$ 1,889,000
CIP17	Rochester St. Channel	$ 9,600,000
CIP18	RR SPUR Culvert	$ 1,836,000
CIP19	Fuji Drainage Improvements	$ 4,182,000
CIP20	Airport Lead	$ 2,018,000

Small Projects		
ID	Location	OPCC
1	Lexington Drive	$182,000
8	Gill Park/Lions Club Lane	$167,400
9	Park/Moore	$30,800
10	Cemetery	$138,300
12	Obstruction in channel	$41,200
14	Airport & SH34	$228,800
26	Tanger Drive	$68,700
28	Colquitt & Lovers	$38,600
35	Bachelor Creek crossing at Colquitt	$74,700
39	Skyline Drive	$106,000
40	Rose St at N Blanche Washout	$75,400
41	Elm & Roberts	$168,800



Small project located outside of main map extents.



Legend

- Large Projects
- Small Projects
- City Limits

FIGURE A

FN JOB NO	TER17602
FILE	CIP
DATE	6/11/2020
SCALE	1:24,000
DRAFTED	02730

CIP Projects

City of Terrell Drainage Master Plan

FREESE AND NICHOLS
2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

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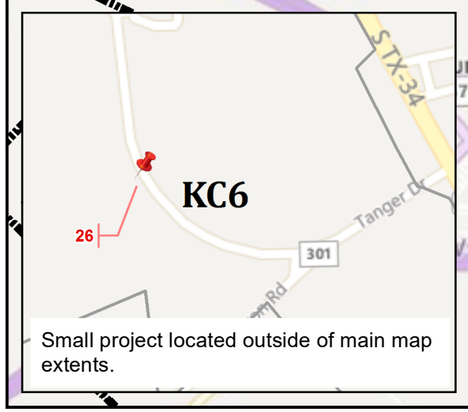
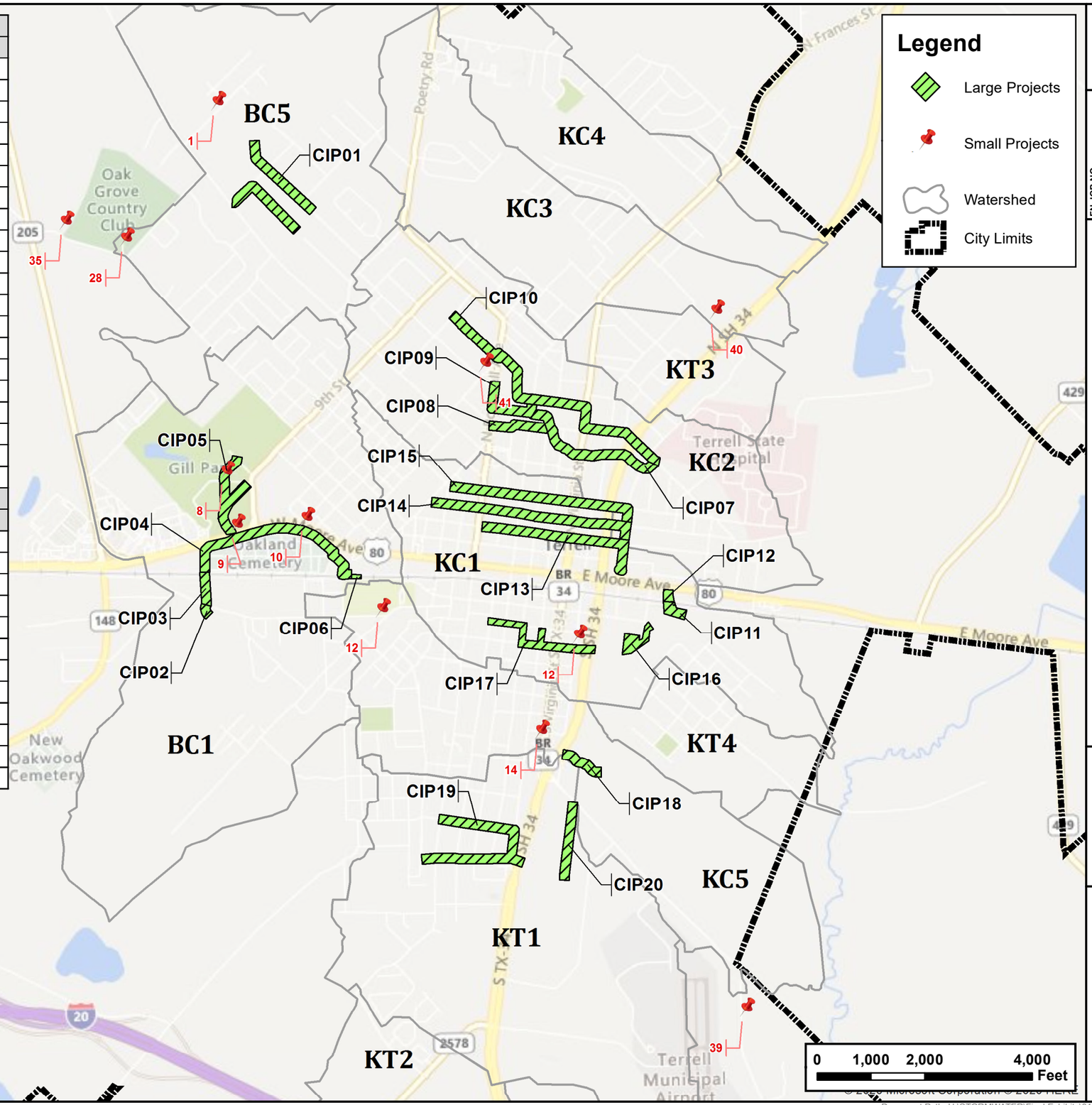
Document Path: H:\STORMWATER\Final Exhibits\01_REPORT\CIP.mxd

Large Projects		
ID	Location	Page #
CIP01	Brookhollow Channel and SD	BC5 — 5
CIP02	West End St. Culvert	BC1 — 5
CIP03	BC2 Railroad Crossing and Channel Improvements	BC1 — 6
CIP04	Cemetery Channel	BC1 — 6
CIP05	Stadium Channel	BC1 — 6
CIP06	SWCC Railroad Crossing Improvements	BC1 — 6
CIP07	KC2 Channel Improvements	KC2 — 5
CIP08	W. Alamo SD	KC2 — 6
CIP09	Heath St. SD	KC2 — 6
CIP10	N. Rockwall Channel & N. Morris Bypass	KC2 — 7
CIP11	KC1 Railroad Crossing and Channel Improvements	KC1 — 5
CIP12	KC1 Upper Channel Improvements	KC1 — 5
CIP13	Virginia St. SD Extension	KC1 — 6
CIP14	College St. SD	KC1 — 6
CIP15	Brin St. SD	KC1 — 6
CIP16	Gardner St. Improvements	KC1 — 6
CIP17	Rochester St. Channel	KC1 — 7
CIP18	RR SPUR Culvert	KC5 — 4
CIP19	Fuji Drainage Improvements	KT1 — 5
CIP20	Airport Lead	KT1 — 5

Small Projects		
ID	Location	Page #
1	Lexington Drive	BC5 — 6
8	Gill Park/Lions Club Lane	BC1 — 7
9	Park/Moore	BC1 — 7
10	Cemetery	BC1 — 7
12	Obstruction in channel	KC1 — 8
14	Airport & SH34	KT1 — 6
26	Tanger Drive	KC6 — 3
28	Colquitt & Lovers	BC5 — 6
35	Bachelor Creek crossing at Colquitt	n/a
39	Skyline Drive	n/a
40	Rose St at N Blanche Washout	KT3 — 3
41	Elm & Roberts	KC2 — 6



Small project located outside of main map extents.



Legend

- Large Projects
- Small Projects
- Watershed
- City Limits

Key Map

City of Terrell Drainage Master Plan

FIGURE B

FN JOB NO	TER17602
FILE	Key Map
DATE	6/10/2020
SCALE	1:24,000
DRAFTED	02730

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1.0 INTRODUCTION

This portion of the report compiles all of the study findings and provides a comprehensive account for each studied watershed. Existing infrastructure and hydraulic results are discussed at a watershed level. The identified Large Projects are described and accompanied by a conceptual OPCC. Lastly, the proposed Small and Large Projects within the study area are prioritized in both tabular and mapped formats.

Four (4) types of maps are presented. The watersheds without proposed Large Projects only display the first two types of maps:

1. Existing Conditions – This map shows the results of the 100-year ultimate flows on the existing geometries. The map also displays the extents of the hydraulic models that were developed for the watershed.
2. Infrastructure – This map displays the existing infrastructure according to the inventory compiled during the study and also shows the proposed infrastructure from the Large Projects recommended for the watershed.
3. 100-YR Floodplain – This map shows the effect of the proposed Large Projects on the 100-year ultimate flow local floodplain. The FEMA delineated National Flood Hazard Layer is the effective 100-year floodplain. This data has been included to demonstrate how the local floodplains tie into the effective. This map also shows how the previously inundated structures are impacted by the proposed projects.
4. Conceptual Phasing – This map displays the Large Projects within the watershed along with the conceptual phasing that could be used to carry out the Master Drainage Plan.

The prepared OPCCs are based off of 2019 unit costs. There is also a cost shown for the project if it is implemented five (5) years from the time of this study. This future cost is based on an assumed 3% annual inflation. Other general assumptions used to prepare the OPCCs are included in the notes on the individual reports.

KC1

STUDY AREA: KC1

BACKGROUND

KC1 is generally bounded on the north by Brin Street, the south by Rochester Street, the west by Pacific Avenue, and the east by Kings Creek. The upstream end of reach KC1 Upper starts on just south of the SH34 and High Street intersection. The upstream end of reach KC1-A begins near the intersection of Adelaide Street and Rochester Street. The confluence of the tributaries occurs just east of the Gardner Street crossing and flows between the railroad tracks and the Stalling's Addition subdivision.

Existing storm drain systems are present between on High Street, Nash Street, SH 34 north of US 80, Rockwall Avenue, Cottage Street, Rochester Street, SH 34 just south of Grove Street, between College Street and High Street, and between US 80 and Nash Street. The existing storm drain systems vary in age and condition, though are generally in fair or better condition.

Rain-on-mesh analysis shows storm drain systems exist and there are few areas where flood depths are significant outside the Right-of-Way (ROW). In some instances, the depths in the ROW are significant.

DATA COLLECTED

The 1989 Drainage Master Plan identified a project called Line "G" with multiple phases and branches for a total of $3,760,000 (1989 dollars). The proposed project from that study is shown in Figure 1.

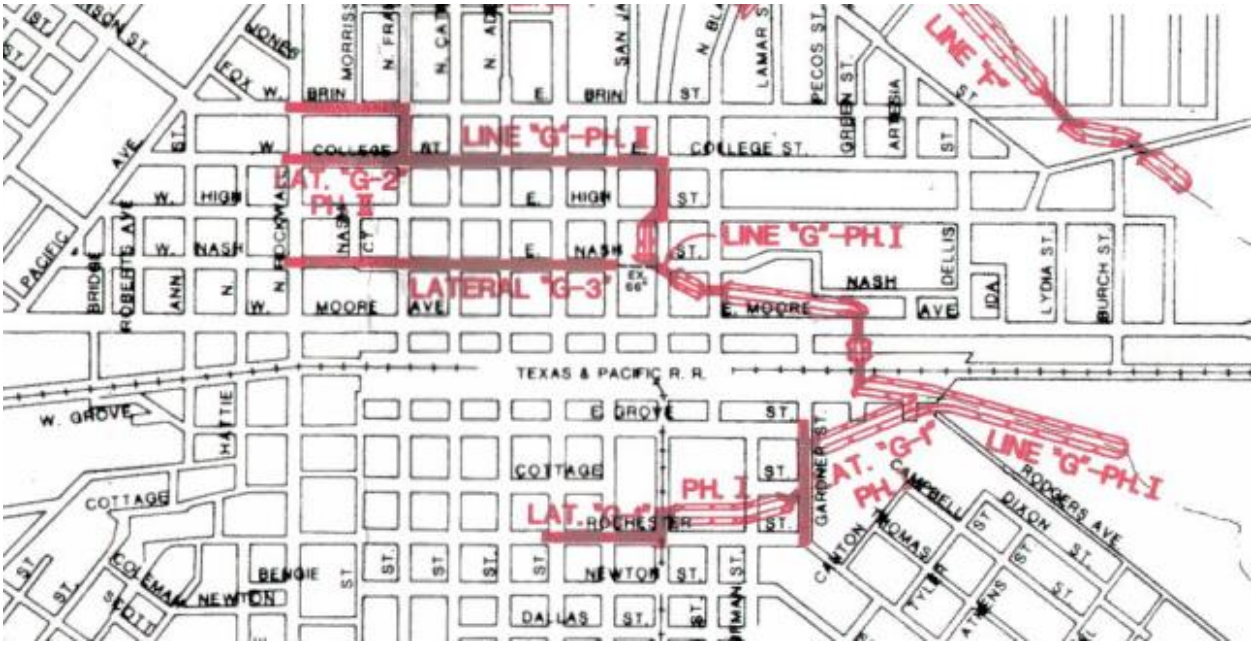
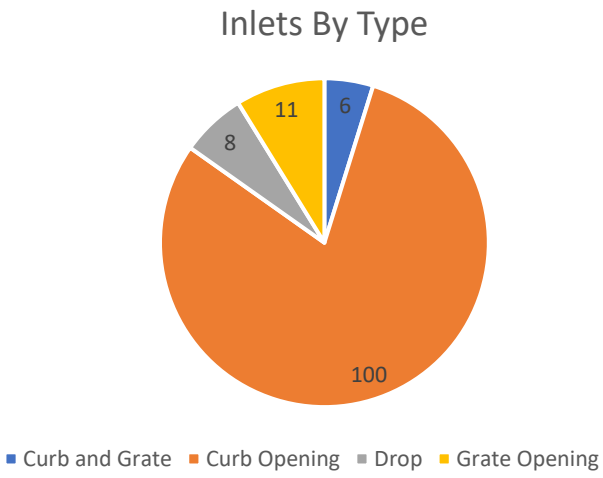
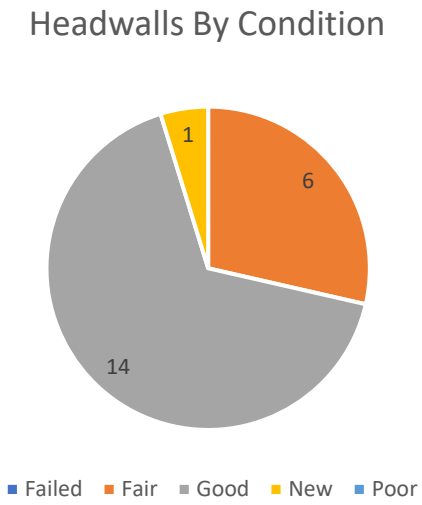


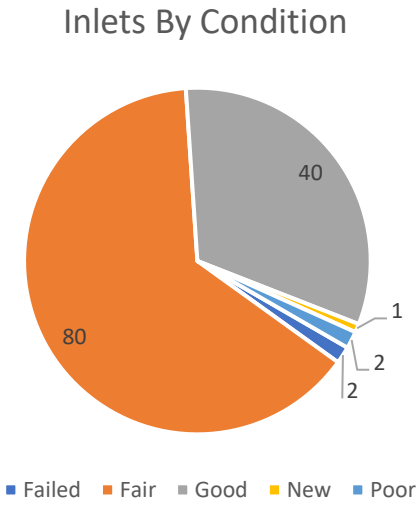
Figure 1: Proposed structures from 1989 Drainage Master Plan.

Part of the previously identified project has been completed; the concrete lining of the drainage channel from Blanche Street to just downstream of US 80. The City indicated the reason for the lining of the channel was for maintenance reasons, not for hydraulic capacity concerns.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 125 inlets, 21 headwalls, and 5.2 miles of conduit within this watershed. A summary of inlets, headwalls and pipe length within the watershed is provided in the graphics in Figure 2.







Conduit by Width	
Conduit Width	Total Length (ft)
1'	594
2'	12,615
3'	5,413
4'	2,193
5'	2,309
6'	468
8'	141
10'	509
<Null>	3,228

Figure 2: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the KC1 HEC-RAS model, and the Virginia and East ICM models.

Upper watershed storm drains were modeled using InfoWorks ICM, with separate models north and south of US 80, called “Virginia” and “East”, respectively. Lower watershed open channels were modeled using HEC-HMS and HEC-RAS to the confluence with Kings Creek. A map depicting the area of study for each component is shown in Exhibit KC1-01.

Results of the data collection and modeling show:

- 121 flooded roadway block segments with a maximum depth of 4.0 feet in the 100-year storm
- 125 properties experience flooding during the 100-year storm
- The first structure is flooded in the 2-year storm
- The public noted flooding in 18 areas and there were 16 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

There are several different flood prone zones identified within the study area that have separate solutions:

Valley Gutters on Rockwall Avenue — Valley gutters convey a significant amount of flow within the ROW across Rockwall Avenue, but are a hazard to vehicular traffic in the area with many scrape marks visible at each location. All flow is in the surface; however, this is a large source of the flood risk given that there are multiple pathways for flow to take to get to the sump on High Street at SH 34.

High Street Sump at SH 34 — A significant sump exists on High Street at SH 34, which was exacerbated by the TxDOT project CSJ 0173-04-025. A Fire Truck Engine was damaged by flood waters at the sump during a storm in June 2016. TxDOT constructed an 8’x5’ RCB stub-out for expanding the storm drain in the future, however there are cover limitations for what can be connected to the stub-out.

Railroad Crossing — The railroad crossing is significantly undersized and backs up flood waters onto US 80, with the potential to flood multiple businesses between N Blanche Street and Dellis Street and has been previously identified for improvements by FNI in a separate memo.

Rochester Street SD and Channel — The drainage for this area is funneled through a single storm drain and channel, which are both undersized and surcharge the system, but mainly stay within the ROW.

Gardner Street Culvert and Channel — The channel parallel to Gardner Street is encroached by a structure and makes two 90-degree turns before the Gardner Street culvert crossing. Further, the culvert crossing is severely undersized, overtopping in the 1-year event.

PROPOSED IMPROVEMENTS

Similar to what was identified in the 1989 plan, new storm drains are needed on Brin Street, College Street, Rochester Street, and Gardner Street, though with some slight differences in alignments and extents of storm drains. The proposed infrastructure improvements are shown in Exhibit KC1-02.

An additional drainage crossing of SH 34 is recommended at High Street in order to avoid the bottleneck effect of the current infrastructure underneath the highway. The recommended interim condition that provides significant results requires additional storm drain to start at the Blanche Street crossing, extend north towards High Street, and then continue until the intersection of High Street and Delphine Street. This interim condition will provide increased capacity that results in a slight reduction in depth at the High Street sag point during the 100-year storm and a significant reduction during the 2-year storm. The interim condition is compatible with the proposed plan for this area, which includes upsizing the storm drain along High Street through the intersection with Rockwell Avenue.

New storm drain on Brin Street and College Street allows removal of the valley gutters and the hazard it poses to vehicles. Flow will be contained from Rockwall Avenue all the way to the outfall in the main channel, just downstream of Blanche Street. A new crossing of SH 34 is required as the stub-out left by TxDOT is both undersized and of insufficient cover to make a meaningful connection. It is assumed that inlet pairs will be placed at every intersection to capture additional runoff along the alignment.

Upsizing the Railroad Crossing and improving the channel adjacent reduces flood hazard and will lessen the probability of the railroad being overtopped.

Improvements to the Rochester Street Storm Drain and Channel will allow the existing storm drain on Rockwall Avenue to function as designed, without a bottleneck for drainage. Further, the Rochester Channel will need less drainage maintenance in the future.

The Gardner Street Culvert and Channel will remove the severe overtopping of Gardner Street and improve the efficiency of flow through the area. The detention pond is included in the project to mitigate the increased flow rates.

The combined effect of the proposed improvements results in the improved 100-year floodplain shown in Exhibit KC1-03. The overtopping across US 80 is significantly reduced and the flooding is better contained to the ROW in the Rochester, Downtown, and Gardner Street areas.

The combined improvements in this watershed are expected to increase discharges downstream, however; these flows are discharged to an engineered channel that has additional capacity. The area downstream of the engineered channel is generally undeveloped land in existing conditions.

Cost Estimates were prepared for each project. In total the cost for the projects within the watershed is approximately $25.5 million to meet current City criteria, with more detail shown in the OPCCs.

IMPLEMENTATION

The costs for all the improvements in the study area exceed what can feasibly be financed from the City's current revenue streams without significant modification. FNI recommends breaking the projects into discrete segments based on ability to fund each. Projects should be implemented from downstream to upstream to achieve optimal drainage conditions, as seen in the conceptual phasing outlined in Exhibit KC1-04. The sequencing explained below takes ranking, feasibility, and coordination into consideration. Phased costs are estimated based on the tabulated OPCC for each full CIP.

CIP11: KC1 Railroad Crossing and Channel Improvements and CIP12: KC1 Upper Channel

These improvements can be implemented in three segments. CIP11 Phase 1 would be the downstream channel enhancements for approximately $50,000. CIP11 Phase 2 would upsize the railroad crossing for about $1.5 million. CIP12 Phase 1 would be the final segment of this sequence and apply the upstream channel improvements for around $272,000. Upsizing the railroad crossing will require coordination with UPRR. FNI performed an analysis of the railroad crossing and included a draft version of the application forms that UPRR requires for submittal. UPRR is a potential funding source for the proposed improvements. When this project is implemented, the impacts to the downstream area will need to be

revisited as flow restrictions are removed and the floodplain is slightly increased through an undeveloped area.

CIP13: Virginia St. SD Extension, CIP14: College St. SD, & CIP15: Brin St. SD

These three projects consist of installing a significant amount of large storm drain in the downtown area. The proposed infrastructure sequence should start with the interim condition of CIP13 Phases 1 and 2. CIP13 Phase 1 begins with the upsized crossing at Blanche Street as well as a portion of the proposed storm drain along Blanche Street. The final component of this Phase, installing storm drain along High Street through the west side of SH 34, will require coordination with TxDOT and cost an estimated $1.9 million. Next, CIP13 Phase 2 would be constructed along with the currently proposed utilities project planned for Delphine Street for approximately $1.2 million.

CIP14 Phase 1 continues the storm drain north along Blanche Street up through the intersection with Brin Street then runs along Brin Street between the intersections with Virginia and Blanche. CIP15 Phase 1 similarly runs along College Street between the intersections of Virginia Street and Blanche Street. These two sections should be implemented simultaneously to optimize TxDOT coordination and traffic impacts along SH 34. The combined cost of doing these two sections together is estimated to be about $3.5 million.

After the SH 34 infrastructure has been completed, CIP15 Phase 2 would finish the Brin Street storm drain installation through to Pacific Avenue for about $2.2 million. Then CIP14 Phase 2 would complete the proposed storm drain on College Street between Virginia Street and Pacific Avenue for approximately $2.6 million. Lastly, CIP13 Phase 3 will complete the storm drain along High Street through to the intersection with Rockwall Avenue for about $800,000. These three segments are equally valuable and should be implemented along with other roadway projects to optimize funds.

The implementation of these three projects would alleviate the flooding noted by residents in several locations in the downtown area. The proposed infrastructure would provide conveyance directly for High Street, Virginia Street, College Street, and Brin Street, which would also improve conditions on Nash Street and US 80.

Coordination with TxDOT will be required for these projects due to the connection the existing system and the two proposed crossings of SH 34.

CIP16: Gardner St. Improvements

There are two logical phases for these improvements: CIP16 Phase 1 would install the proposed storm drain for around $1.4 million. CIP16 Phase 2 would involve the installation of the proposed storage and channel grading for an estimated cost of $535,000.

CIP17: Rochester St. SD

It is recommended these capital improvements be implemented in three phases. CIP17 Phase 1 would include the upsized crossing of SH 34 and the concrete channel enhancements for an approximate cost of $6.5 million. CIP17 Phase 2 would be the installation of the proposed infrastructure along Rochester Street from Delphine Street to Catherine Street for about $2.3 million. CIP17 Phase 3 would complete the proposed infrastructure from the intersection of Catherine Street and Rochester Street to the west end of Cottage Road for about $800,000. TxDOT coordination will be required for the state highway crossing and may be a source of funding for that portion of the project. It is recommended to couple the storm drain installation with other roadway projects.

Small Projects

The following small projects are within this watershed:

- Obstruction in Channel — One of the noted obstructions in a channel is located at E. Rochester Street and Delphine Street. FNI recommends relocating the telephone pole and stabilizing the channel.

A summary of the projects and the suggested implementation order is located in Table 1. Costs have been conservatively rounded up during the estimating process and will need to be refined as part of the future design process.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Obstruction in Channel	$ 41,200
		Total Small Project Cost	**$ 41,200**
Large Projects	2	CIP13 Phase 1	$ 1,900,000
	3	CIP13 Phase 2	$ 1,200,000
	4	CIP14 Phase 1	$ 2,600,000
	5	CIP15 Phase 1	$ 900,000
	6	CIP13 Phase 3	$ 800,000
	7	CIP14 Phase 2	$ 2,600,000
	8	CIP15 Phase 2	$ 2,200,000
	9	CIP16 Phase 1	$ 1,400,000
	10	CIP16 Phase 2	$ 535,000
	11	CIP17 Phase 1	$ 6,500,000
	12	CIP17 Phase 2	$ 2,300,000
	13	CIP11 Phase 1	$ 50,000
	14	CIP11 Phase 2	$ 1,500,000
	15	CIP12 Phase 1	$ 272,000
	16	CIP17 Phase 3	$ 800,000
		Total Large Project Cost	**$ 25,557,000**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Inundated Buildings

- 25-YR Inundation (11)
- 100-YR Inundation (9)

Depth

- < 0.5'
- 0.5' - 1.0'
- 1.0' - 2.0'
- 2.0' - 3.0'
- > 3.0'

- 2D Model Extent
- 1D Model Extent
- 100-YR FEMA Floodplain

Valley Gutters on Rockwall Avenue

High Street Sump at SH 34

Railroad Crossing

Rochester Street SD and Channel

Gardner Street Culvert and Channel

KC1 KC2 KC5 KT1 KT4 BC1

Elm, 9th, Griffith, Colquitt, Heath, Alamo, Morris, Brin, Pacific, Catherine, Adelaide, Nash, Bowser, Frances, Virginia, Blanche, High, State, Grove, Rockwall, Medora, Cottage, Rochester, Delphine, Gardner, College, West End, Bethlehem, Myers, Crenshaw

80, 34

0 400 800 1,600 Feet

FIGURE KC1-01

FN JOB NO	TER17602
FILE	KC1-01
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Existing Conditions - KC1

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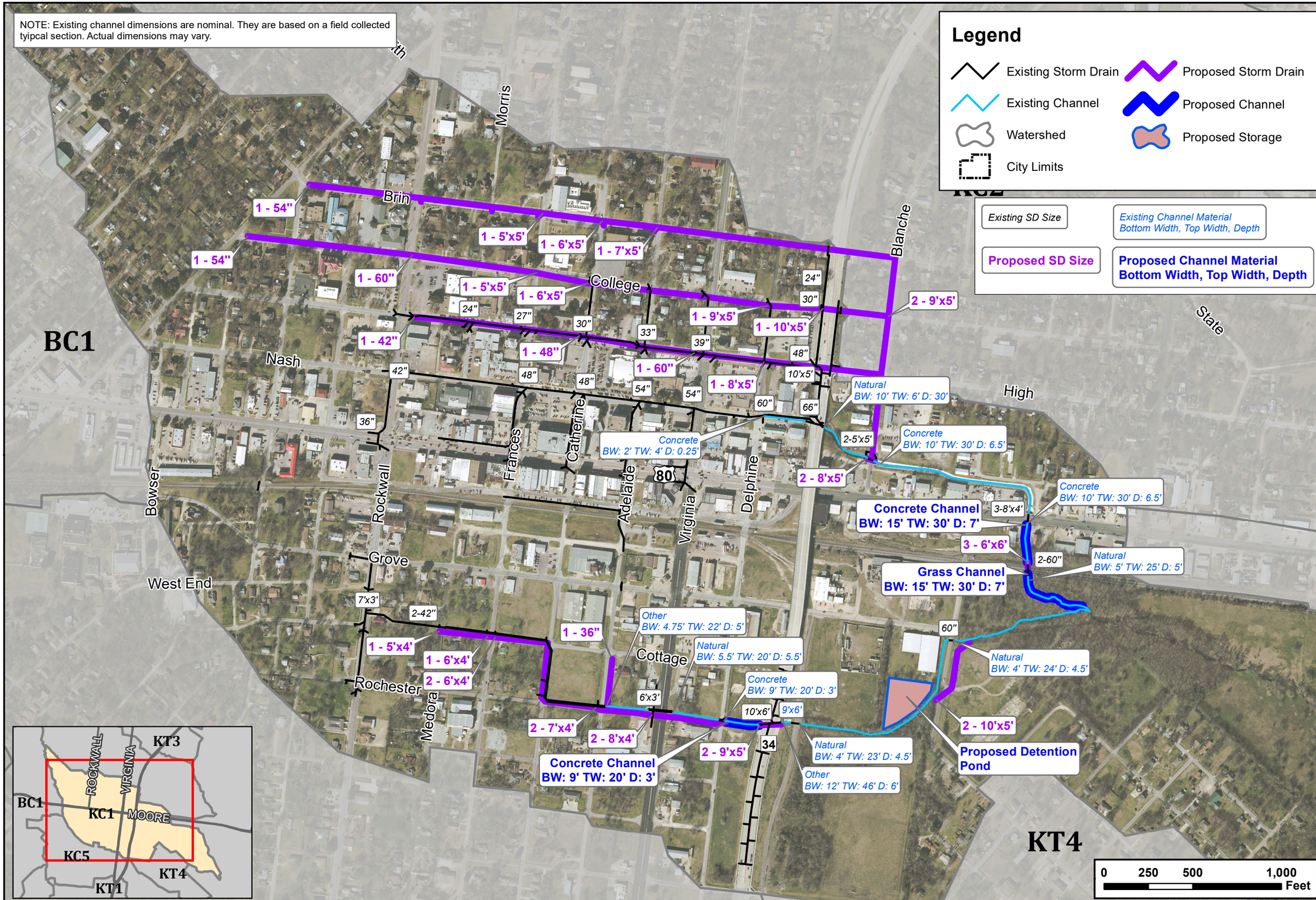

FIGURE KC1-02

FN JOB NO	TER17602
FILE	KC1-02
DATE	6/10/2020
SCALE	1:6,000
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Infrastructure - KC1

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NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Buildings Impacted

- Protected - 25YR (10)
- Protected - 100YR (8)
- 25-YR Inundation (1)
- 100-YR Inundation (1)
- Buyout (0)

- Existing 100-YR Floodplain
- Proposed 100-YR Floodplain
- 100-YR FEMA Floodplain

Valley Gutters on Rockwall Avenue

High Street Sump at SH 34

Railroad Crossing

Rochester Street SD and Channel

Gardner Street Culvert and Channel

KC2

BC1

KC5

KT4

KT1

Elm
9th
Griffith
Colquitt
Heath
Alamo
Morris
Brin
Pacific
Nash
Catherine
Adelaide
Virginia
Frances
Bowser
High
Grove
Rockwall
Cottage
Rochester
Delphine
Gardner
West End
Medora
College
Bethlehem
Myers
Crenshaw
80
34

0 400 800 1,600 Feet

FIGURE	KC1-03
FN JOB NO	TER17602
FILE	KC1-03
DATE	1/9/2020
SCALE	1:9,600
DRAFTED	02730

100-YR Floodplain - KC1

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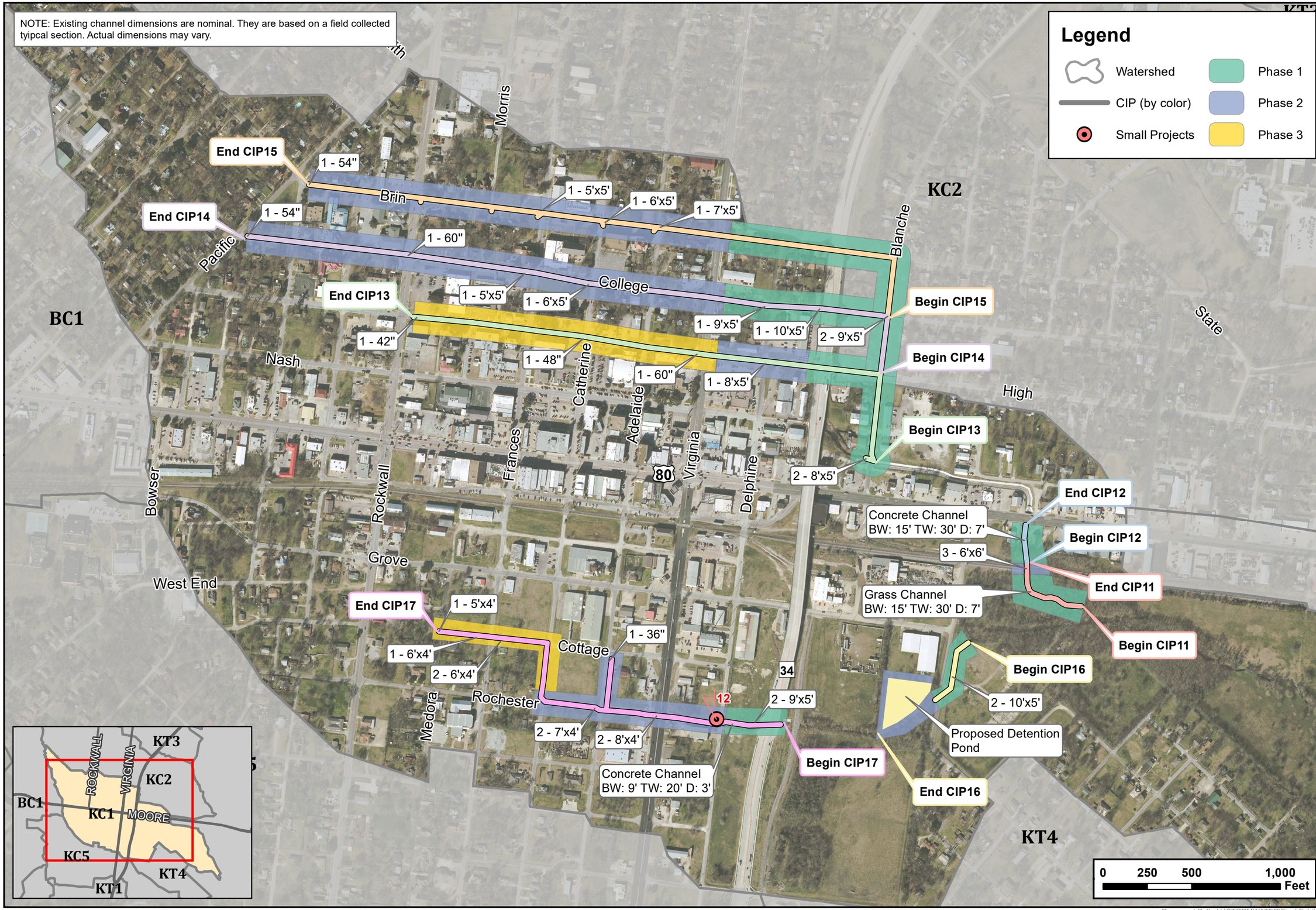

FIGURE KC1-04

FN JOB NO TER17602
FILE KC1-04
DATE 6/10/2020
SCALE 1:6,000
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Conceptual Phasing - KC1

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Drainage Master Plan Update
Project: KC1 RAILROAD CROSSING & CHANNEL IMPROVEMENTS

Project Information

Project ID:	CIP11	**Status:**	Studied
Project Name:	KC1 RAILROAD CROSSING & CHANNEL IMPROVEMENTS	**Council District:**	3
Project Type:	N/A	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	7

Problem Description:

The railroad crossing (182.12) is significantly undersized and backs up flood waters onto Moore Avenue, with the potential to flood multiple businesses between N Blanche Street and Dellis Street. This area has been previously identified for improvements by FNI in a separate memorandum.

Proposed Improvements:

Upsize the railroad crossing and improve the channel downstream to reduce flood hazard and lessen the risk of the railroad being overtopped.

Project Photos



Photo 1: Upstream side of railroad crossing



Photo 2: Open channel on downstream side of railroad crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	5
20	**Property Damage:**	3
22.5	**Frequency of Flooding:**	5
10	**Project Cost:**	4
17.5	**Public Impact:**	0
	Total Weighted Point Score:	362.5
	CIP Rank:	7

Project Costs

Total OPCC:	$1,536,000.00
Estimated Easement:	$1,040.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #11: KC1 RAILROAD CROSSING (UPRR 182.12) AND CHANNEL IMPROVEMENTS					
1	REMOVAL OF EXISTING CULVERT (60")	106	LF	$ 75	$ 7,950
2	REMOVAL OF EXISTING HEADWALL	5	CY	$ 200	$ 1,000
3	EXCAVATION AND HAUL	210	CY	$ 20	$ 4,200
4	INSTALL 8'X5' RCB	159	LF	$ 630	$ 100,170
5	HEADWALL (SMALL)	2	EA	$ 10,000	$ 20,000
6	BORE CULVERT (8'X5')	159	LF	$ 4,300	$ 683,700
7	SHORING	1,500	SF	$ 25	$ 37,500
8	GRADING	156	SY	$ 15	$ 2,340
9	CLEARING/GRUBBING	2	AC	$ 2,500	$ 5,000
10	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
11	SWPPP	1	LF	$ 5,000	$ 5,000
12					
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 1,040	$ 1,040

SUBTOTAL		$	882,900
ASSOC INFRASTRUCTURE	20%	$	176,580
SUBTOTAL		$	1,059,480
OH&P	15%	$	158,922
SUBTOTAL		$	1,218,402
MOBILIZATION	5%	$	60,920
SUBTOTAL		$	1,279,322
CONTINGENCY	20%	$	255,864
PROJECT TOTAL (2019 COSTS)		**$**	**1,536,000**
COST ESCALATION FACTOR	2.9%	$	236,000
PROJECT TOTAL (2024 COSTS)		**$**	**1,772,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.

2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.

Drainage Master Plan Update
Project: KC1 UPPER CHANNEL IMPROVEMENTS

Project Information

Project ID:	CIP12	**Status:**	Studied
Project Name:	KC1 UPPER CHANNEL IMPROVEMENTS	**Council District:**	3
Project Type:	Channel	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	7

Problem Description:

The channel slope is limiting the conveyance of this portion of the system and the typical section does not meet the demand of this fully developed contributing area.

Proposed Improvements:

Adjust channel flowline to match flowlines with the proposed upsized railroad culvert crossing. Implement new typical section to achieve maximum efficiency from this part of the system and provide a smooth transition from the nearby Highway 80 crossing upstream.

Project Photos



Photo 1: Downstream side of Highway 80 crossing



Photo 2: Open channel downstream of Highway 80 crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	5
20	**Property Damage:**	4
22.5	**Frequency of Flooding:**	5
10	**Project Cost:**	5
17.5	**Public Impact:**	0
	Total Weighted Point Score:	392.5
	CIP Rank:	6

Project Costs

Total OPCC:	$272,000.00
Estimated Easement:	$290.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #12: KC1 UPPER CHANNEL IMPROVEMENTS					
1	REMOVE CONCRETE CHANNEL	500	SY	$ 20	$ 10,000
2	CONCRETE LINING	885	SY	$ 100	$ 88,500
3	GRADING	1,600	SY	$ 15	$ 24,000
4	TRENCH SAFETY	320	LF	$ 5	$ 1,600
5	SEED/SOD	300	SY	$ 5	$ 1,500
6	CLEARING/GRUBBING	1	AC	$ 2,500	$ 2,500
7	EXCAVATION AND HAUL	400	CY	$ 20	$ 8,000
8	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
9	SWPPP	1	EA	$ 5,000	$ 5,000
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 290	$ 290

SUBTOTAL		$	156,390
ASSOC INFRASTRUCTURE	20%	$	31,278
SUBTOTAL		$	187,668
OH&P	15%	$	28,150
SUBTOTAL		$	215,818
MOBILIZATION	5%	$	10,791
SUBTOTAL		$	226,609
CONTINGENCY	20%	$	45,322
PROJECT TOTAL (2019 COSTS)		**$**	**272,000**
COST ESCALATION FACTOR	2.9%	$	42,000
PROJECT TOTAL (2024 COSTS)		**$**	**314,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.

2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.

Drainage Master Plan Update
Project: VIRGINIA ST. SD EXTENSION

Project Information

Project ID:	CIP13	**Status:**	Studied
Project Name:	VIRGINIA ST. SD EXTENSION	**Council District:**	3, 5
Project Type:	Pipe System / Road Crossing	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	10

Problem Description:

A significant sump exists on High Street at SH 34, which was exacerbated by the TxDOT project CSJ 0173-04-025. A Fire Truck Engine was damaged by flood waters at the sump during a storm in June 2016. TxDOT constructed an 8'x5' RCB stub-out for expanding the storm drain in the future, however there are cover limitations for what can be connected to the stub-out.

Proposed Improvements:

Repurpose the stub-out left by TxDOT in High Street by reorienting and lowering the flowline to create an effective system. Add new strom drain, including a new crossing of SH 34 to reduce significant ponding depths that occur at sag on High Street. Tie new line in downstream of Blanche Street culvert crossing. Continue to upsize infrastructure on High Street. Combine portion of upsize extension with Delphine utilities project. New storm drain will enable the Ciy to remove the hazardous valley gutters present in the downtown area. Carry upsized storm drain on High Street through to Rockwall Avenue. Place inlet pairs at every intersection to capture additional runoff along the alignment.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	4
20	**Property Damage:**	4
22.5	**Frequency of Flooding:**	5
10	**Project Cost:**	3
17.5	**Public Impact:**	4
	Total Weighted Point Score:	412.5
	CIP Rank:	4

Project Costs

Total OPCC:	$3,921,000.00
Estimated Easement:	$0.00

Project Photos



Photo 1: Sag on High Street to the west of existing inlets



Photo 2: Inlet on High Street not located at sag

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #13: VIRGINIA ST. SD EXTENSION					
1	INSTALL 42" RCP	939	LF	$ 201	$ 188,739
2	INSTALL 48" RCP	656	LF	$ 232	$ 152,192
3	INSTALL 60" RCP	395	LF	$ 314	$ 124,030
4	INSTALL 8'x5' RCB	779	LF	$ 630	$ 490,770
5	INSTALL 9'x5' RCB	984	LF	$ 900	$ 885,600
6	TRENCH SAFETY	3,214	LF	$ 5	$ 16,070
7	EXCAVATION AND HAUL	3,722	CY	$ 20	$ 74,440
8	ROAD EXCAVATION	1,702	CY	$ 27	$ 45,954
9	ASPHALT PAVEMENT REPLACEMENT	3,267	SY	$ 80	$ 261,360
10	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
11	UTILITY RELOCATION	1	LS	$ 92,067	$ 92,067
12	SWPPP	1	EA	$ 6,600	$ 6,600
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ -	$ -

SUBTOTAL		$	2,352,822
ASSOC INFRASTRUCTURE	20%	$	470,564
SUBTOTAL		$	2,823,386
OH&P	15%	$	423,508
SUBTOTAL		$	3,246,894
MOBILIZATION	5%	$	162,345
SUBTOTAL		$	3,409,239
CONTINGENCY	15%	$	511,386
PROJECT TOTAL (2019 COSTS)		**$**	**3,921,000**
COST ESCALATION FACTOR	2.9%	$	602,000
PROJECT TOTAL (2024 COSTS)		**$**	**4,523,000**

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NOTES:

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Drainage Master Plan Update
Project: COLLEGE ST. SD

Project Information

Project ID:	CIP14	**Status:**	Studied
Project Name:	COLLEGE ST. SD	**Council District:**	3, 5
Project Type:	Pipe System / Road Crossing	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	10

Problem Description:

Valley gutters convey a significant amount of flow within the ROW across Rockwall Avenue, however, are a hazard to vehicular traffic in the area, with many scrape marks visible at each location. All flow is in the surface; however, this is a large source of the flood risk given that there are multiple pathways for flow to take to get to the sump on High Street at SH 34.

Proposed Improvements:

New storm drain on College Street allows removal of the valley gutters and the hazard it poses to vehicles. Flow will be contained from Rockwall Avenue all the way to the outfall in the main channel, just downstream of Blanche Street. A new crossing of SH 34 is required as the stub-out left by TxDOT is both undersized and of insufficient cover to make a meaningful connection. Place inlet pairs at every intersection to capture additional runoff along the alignment.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	3
20	**Property Damage:**	2
22.5	**Frequency of Flooding:**	3
10	**Project Cost:**	2
17.5	**Public Impact:**	3
	Total Weighted Point Score:	270
	CIP Rank:	11

Project Costs

Total OPCC:	$4,814,000.00
Estimated Easement:	$0.00

Project Photos



Photo 1: Valley gutter located at intersection of College Street and Rockwall Avenue



Photo 2: Inlet on College Street

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #14: COLLEGE ST. SD					
1	INSTALL 54" RCP	935	LF	$ 278	$ 259,930
2	INSTALL 5'x5' RCB	1,003	LF	$ 340	$ 341,020
3	INSTALL 6'X5' RCB	1,023	LF	$ 460	$ 470,580
4	INSTALL 9'X5' RCB	831	LF	$ 900	$ 747,900
5	INSTALL 10'X5' RCB	373	LF	$ 830	$ 309,590
6	TRENCH SAFETY	3,643	LF	$ 5	$ 18,215
7	EXCAVATION AND HAUL	3,682	CY	$ 20	$ 73,640
8	ROAD EXCAVATION	1,621	CY	$ 27	$ 43,767
9	ASPHALT PAVEMENT REPLACEMENT	3,240	SY	$ 80	$ 259,200
10	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
11	UTILITY RELOCATION	1	LS	$ 106,451	$ 106,451
12	SWPPP	1	EA	$ 12,000	$ 12,000
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ -	$ -

SUBTOTAL		$	2,657,293
ASSOC INFRASTRUCTURE	20%	$	531,459
SUBTOTAL		$	3,188,752
OH&P	15%	$	478,313
SUBTOTAL		$	3,667,064
MOBILIZATION	5%	$	183,353
SUBTOTAL		$	3,850,418
CONTINGENCY	25%	$	962,604
PROJECT TOTAL (2019 COSTS)		**$**	**4,814,000**
COST ESCALATION FACTOR	2.9%	$	740,000
PROJECT TOTAL (2024 COSTS)		**$**	**5,554,000**

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Drainage Master Plan Update
Project: BRIN ST. SD

Project Information

Project ID:	CIP15	**Status:**	Studied
Project Name:	BRIN ST. SD	**Council District:**	3, 5
Project Type:	Pipe System / Road Crossing	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	10

Problem Description:

Valley gutters convey a significant amount of flow within the ROW across Rockwall Avenue, however, are a hazard to vehicular traffic in the area, with many scrape marks visible at each location. All flow is in the surface; however, this is a large source of the flood risk given that there are multiple pathways for flow to take to get to the sump on High Street at SH 34.

Proposed Improvements:

New storm drain on Brin Street allows removal of the valley gutters and the hazard it poses to vehicles. Flow will be contained from Rockwall Avenue all the way to the outfall in the main channel, just downstream of Blanche Street. A new crossing of SH 34 to reduce demand on infrastructure on High Street that results in high depths within the ROW. Place inlet pairs at every intersection to capture additional runoff along the alignment.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	2
20	**Property Damage:**	2
22.5	**Frequency of Flooding:**	0
10	**Project Cost:**	3
17.5	**Public Impact:**	3
	Total Weighted Point Score:	182.5
	CIP Rank:	16

Project Costs

Total OPCC:	$3,466,000.00
Estimated Easement:	$240.00

Project Photos



Photo 1: Valley gutter located at intersection of Brin Street and Rockwall Avenue



Photo 2: Brin Street intersection without curb inlets

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #15: BRIN ST. SD					
1	INSTALL 5'x5' RCB	338	LF	$ 340	$ 114,920
2	INSTALL 6'X5' RCB	314	LF	$ 460	$ 144,440
3	INSTALL 7'X5' RCB	1,684	LF	$ 550	$ 926,200
4	INSTALL 36" RCP	135	LF	$ 170	$ 22,950
5	INSTALL 54" RCP	1,325	LF	$ 278	$ 368,350
6	TRENCH SAFETY	3,796	LF	$ 5	$ 18,980
7	EXCAVATION AND HAUL	3,661	CY	$ 20	$ 73,220
8	ROAD EXCAVATION	1,610	CY	$ 27	$ 43,470
9	ASPHALT PAVEMENT REPLACEMENT	3,258	SY	$ 80	$ 260,640
10	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
11	UTILITY RELOCATION	1	LS	$ 78,843	$ 78,843
12	SWPPP	1	EA	$ 12,500	$ 12,500
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 240	$ 240

SUBTOTAL		$	2,079,753
ASSOC INFRASTRUCTURE	20%	$	415,951
SUBTOTAL		$	2,495,704
OH&P	15%	$	374,356
SUBTOTAL		$	2,870,059
MOBILIZATION	5%	$	143,503
SUBTOTAL		$	3,013,562
CONTINGENCY	15%	$	452,034
PROJECT TOTAL (2019 COSTS)		**$**	**3,466,000**
COST ESCALATION FACTOR	2.9%	$	100,514
PROJECT TOTAL (2024 COSTS)		**$**	**3,567,000**

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Drainage Master Plan Update
Project: GARDNER ST. IMPROVEMENTS

Project Information

Project ID:	CIP16	**Status:**	Studied
Project Name:	GARDNER ST. IMPROVEMENTS	**Council District:**	3
Project Type:	Pipe System / Channel	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	0

Problem Description:

The channel parallel to Gardner Street is encroached by a structure and makes two 90-degree turns before crossing Gardner Street. Further, the culvert crossing of Gardner Street is severely undersized, overtopping in the 1-year event.

Proposed Improvements:

Add culverts at a separate Gardner Street crossing to increase crossing capacity. Also install a detention pond to mitigate increased flow rates. Adjacent channel will need minor regrading to match detention pond inlet and outlet elevations. Minimal easements will be required as most of this project already resides within the ROW.

Project Photos



Photo 1: Open channel upstream of Gardner Road crossing



Photo 2: Downstream side of Gardner Road crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	2
20	**Property Damage:**	2
22.5	**Frequency of Flooding:**	0
10	**Project Cost:**	4
17.5	**Public Impact:**	0
	Total Weighted Point Score:	140
	CIP Rank:	18

Project Costs

Total OPCC:	$1,889,000.00
Estimated Easement:	$14,070.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #16: GARDNER ST. IMPROVEMENTS					
1	INSTALL 10'x5' RCB	700	LF	$ 830	$ 581,000
2	HEADWALL (LARGE)	2	EA	$ 20,000	$ 40,000
3	SEED/SOD	770	SY	$ 5	$ 3,850
4	INSTALL 12" ROCK RIP RAP	30	CY	$ 65	$ 1,950
5	CLEARING/GRUBBING	2	AC	$ 2,500	$ 5,000
6	EXCAVATION AND HAUL	12,590	CY	$ 20	$ 251,800
7	GARDNER OUTLET STRUCTURE	1	EA	$ 10,000	$ 10,000
8	GRADING	6,400	SY	$ 15	$ 96,000
9	TRENCH SAFETY	350	LF	$ 5	$ 1,750
10	ROAD EXCAVATION	1,180	CY	$ 27	$ 31,860
11	BACKFILL	260	CY	$ 100	$ 26,000
12	RAISE GARDNER ST.	1	LS	$ 30,300	$ 30,300
13	UTILITY RELOCATION	1	LS	$ 14,525	$ 14,525
14	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
15	SWPPP	1	EA	$ 10,000	$ 10,000
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 14,070	$ 14,070

SUBTOTAL		$	1,133,105
ASSOC INFRASTRUCTURE	20%	$	226,621
SUBTOTAL		$	1,359,726
OH&P	15%	$	203,959
SUBTOTAL		$	1,563,685
MOBILIZATION	5%	$	78,184
SUBTOTAL		$	1,641,869
CONTINGENCY	15%	$	246,280
PROJECT TOTAL (2019 COSTS)		**$**	**1,889,000**
COST ESCALATION FACTOR	2.9%	$	290,000
PROJECT TOTAL (2024 COSTS)		**$**	**2,179,000**

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Drainage Master Plan Update
Project: ROCHESTER ST. SD

Project Information

Project ID:	CIP17	**Status:**	Studied
Project Name:	ROCHESTER ST. SD	**Council District:**	2, 3
Project Type:	Road and Pipe System	**Watershed:**	KC1
Date Identified:	2019	**# Structures Impacted:**	1

Problem Description:

The drainage for this area is funneled through a single storm drain and channel, which are both undersized and surcharge the system, but mainly stay within the ROW. A significant portion of this watershed is still undeveloped.

Proposed Improvements:

Upsize the SH 34 crossing, enhance the preceding concrete lined channel, and install storm drain along Rochester Street. Upsize existing storm drain between Rochester Street, Cottage Street, and Rockwall Avenue. This project is recommended to be combined with other infrastrcuture costs due to extent of new pipe system underneath road. Minimal easements are required.

Project Photos



Photo 1: Open channel parallel with Rochester Street



Photo 2: Upstream side of S Delphine Street crossing

CIP Ranking Criteria

Weight		Score
30	Life Safety/Road Flooding:	4
20	Property Damage:	0
22.5	Frequency of Flooding:	1
10	Project Cost:	1
17.5	Public Impact:	3
	Total Weighted Point Score:	205
	CIP Rank:	15

Project Costs

Total OPCC:	$9,600,000.00
Estimated Easement:	$2,130.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #17: ROCHESTER ST. SD					
1	REMOVAL OF EXISTING CULVERT (10'X6')	136	LF	$ 300	$ 40,800
2	REMOVAL OF EXISTING CULVERT (6'X3')	300	LF	$ 100	$ 30,000
3	REMOVAL OF EXISTING CULVERT (36")	120	LF	$ 45	$ 5,400
4	REMOVAL OF EXISTING CULVERT (42")	2,610	LF	$ 50	$ 130,500
5	REMOVE CONCRETE CHANNEL	687	SY	$ 20	$ 13,740
6	GRADING	687	SY	$ 15	$ 10,305
7	INSTALL 9'x5' RCB	272	LF	$ 900	$ 244,800
8	INSTALL 8'x4' RCB	852	LF	$ 610	$ 519,720
9	INSTALL 7'x4' RCB	636	LF	$ 530	$ 337,080
10	INSTALL 6'x4' RCB	1,898	LF	$ 450	$ 854,100
11	INSTALL 5'x4' RCB	273	LF	$ 330	$ 90,090
12	INSTALL 36" RCP	292	LF	$ 170	$ 49,640
13	HEADWALL (MEDIUM)	2	EA	$ 15,000	$ 30,000
14	CONCRETE LINING	687	SY	$ 100	$ 68,700
15	TRENCH SAFETY	2,280	LF	$ 5	$ 11,400
16	EXCAVATION AND HAUL	4,185	CY	$ 20	$ 83,700
17	ROAD EXCAVATION	1,845	CY	$ 27	$ 49,815
18	ASPHALT PAVEMENT REPLACEMENT	3,273	SY	$ 80	$ 261,840
19	BORE CULVERT (9'X5')	272	LF	$ 8,800	$ 2,393,600
20	CLEARING/GRUBBING	1	AC	$ 2,500	$ 2,500
21	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
22	UTILITY RELOCATION	1	LS	$ 46,266	$ 46,266
23	SWPPP	1	EA	$ 8,600	$ 8,600
24	EASEMENTS	1	LS	$ 2,130	$ 2,130
		SUBTOTAL			$ 5,299,726
		ASSOC INFRASTRUCTURE		20%	$ 1,059,945
		SUBTOTAL			$ 6,359,671
		OH&P		15%	$ 953,951
		SUBTOTAL			$ 7,313,622
		MOBILIZATION		5%	$ 365,681
		SUBTOTAL			$ 7,679,303
		CONTINGENCY		15%	$ 1,151,895
PROJECT TOTAL (2019 COSTS)					**$ 8,832,000**
COST ESCALATION FACTOR				2.9%	$ 1,357,000
PROJECT TOTAL (2024 COSTS)					**$ 10,189,000**

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KC2

STUDY AREA: KC2

BACKGROUND

The KC2 watershed is generally north of Downtown and drains from west to east, through the Terrell State Hospital before it outfalls to Kings Creek. The watershed is almost entirely developed. There are three tributaries to the main channel of KC2, that have been channelized through storm drains to varying degrees. The confluence of the tributaries occurs between Morris Street and Frances Street.

Existing storm drain systems are present on State Street, N Rockwall Avenue, Damon Street, Alamo Street, Heath Street, SH 34 north of US 80, San Jacinto street, and a portion of the main KC2 channel on the Terrell State Hospital property. The existing storm drain systems vary in age and condition, though are generally in fair or worse condition.

Rain-on-mesh analysis shows that though storm drain systems exist, there are widespread areas where flood depths are significant outside the Right-of-Way (ROW), particularly between N Rockwall Avenue and E State Street.

DATA COLLECTED

The 1989 Drainage Master Plan identified projects called Line “F” and Lateral “F-1” for a total of $2,645,000 (1989 dollars). The proposed project from that study is shown in Figure 1.



Figure 1: Proposed structures from 1989 Drainage Master Plan.

In 2003, the State and Walnut drainage study, recommended roughly tripling the size of the existing infrastructure in the watershed to achieve a 100-year level of protection. Only the costs for culverts were identified, approximately $295,000 (2003 dollars). Additional improvements from the study are shown in Figure 2.

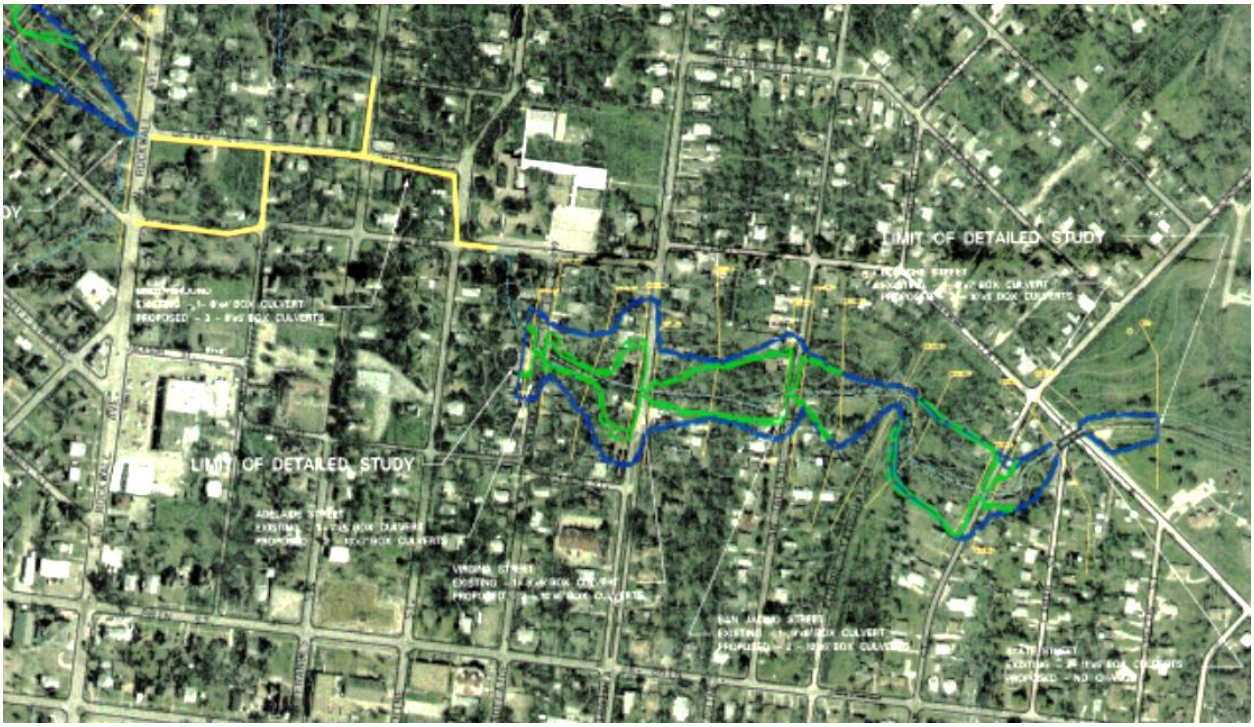
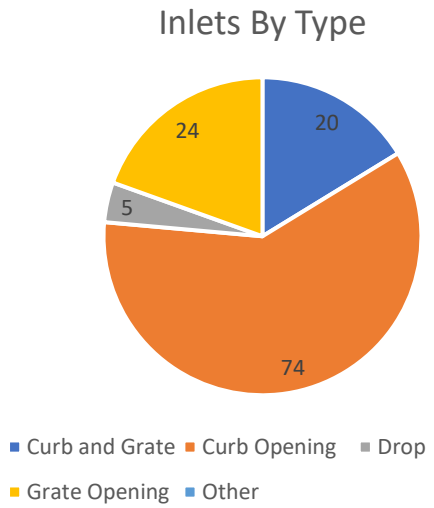
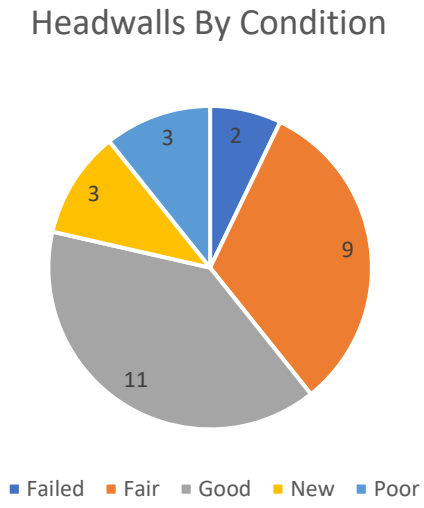
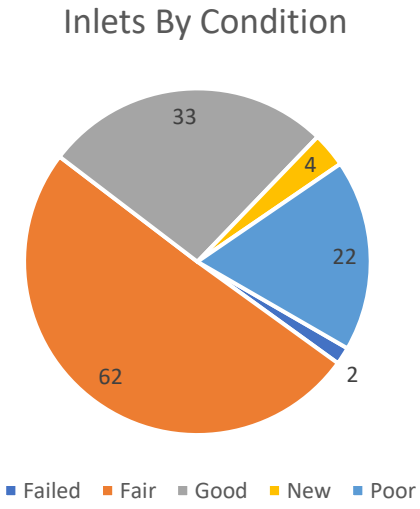


Figure 2: Proposed structures from State Street / Walnut Street Study (2003)

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 123 inlets, 28 headwalls, and 5.1 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 3.







Conduit by Width	
Conduit Width	Total Length (ft)
1'	826
2'	14,769
3'	4,263
4'	1,837
5'	656
6'	1,092
7'	398
8'	657
10'	181
13'	161
<Null>	1,957

Figure 3: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the Griffith ICM model.

The entire watershed was modeled using ICM because the upper and lower watersheds have complex storm drain hydraulics. A map depicting the area of study for each component is shown in Exhibit KC2-01.

Results of the data collection and modeling show:

- 63 flooded roadway block segments with a maximum depth of 4.6 feet in the 100-year storm
- 147 properties experience flooding during the 100-year storm
- The first structure is flooded in the 2-year storm
- The public noted flooding in 30 areas and there were 26 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

There are several different flood prone zones identified within the study area that have separate solutions. In general, there are two primary drivers for the causes of flooding within the watershed:

Limited Floodplain Storage — Within the watershed, original creeks have been channelized, put into storm drains, and encroached with buildings. The encroachment has removed what floodplain storage existed before the watershed became developed.

Limited Conveyance Capacity — The channelization of the watershed occurred, but to a much lower design storm standard. Coupled with the lack of floodplain storage, the lack of capacity provides no buffer or delay in timing for storm events that exceed the pipe capacity, and results in deep, widespread flooding for relatively frequent events.

PROPOSED IMPROVEMENTS

Similar to what was identified in the 1989 plan and also the 2003 study, new and/or upsized storm drains are needed on Damon Street, N Rockwall Avenue, Heath Street, Alamo Street, and Frances Street, though with some slight differences in alignments and extents of storm drains. A key addition to the plan is a bypass system along property lines, Virginia Street, and Alamo Street, which allows for optionality in the final design. The proposed infrastructure improvements are shown in Exhibit KC2-02.

New and/or upsized storm drain throughout the watershed enables safe conveyance of the design flood and reduces the flood hazard significantly.

Channel improvements from N Rockwall Avenue to Frances Street are focused on increasing the conveyance.

Channel improvements from Catherine Street at Alamo Street to E State Street are focused on increasing both conveyance and storage volume. The improvements will make the infrastructure work as a system to keep daily flows contained to the main channel and attempt to mimic a natural floodplain by allowing for significant storage depths during larger storm events. Culverts will be upsized between channel sections at Catherine Street, Adelaide Street, Virginia Street, San Jacinto Street, N Blanche Street, and E State Street. Though the drainage area increases between each street, there are only nominal increases in the proposed culvert size at each cross section, which allows the existing culvert at SH 34 to remain without modification. Further study will be needed to refine the channel dimensions that will produce a stable morphology and overall reduce maintenance, and such an action may provide an opportunity to bank mitigation credits for some of the other projects in the City. Further, having a linear trail with an enhanced riparian corridor may be an opportunity to diffuse the infrastructure costs among other City budget categories, such as parks.

The combined effect of the proposed improvements results in the improved 100-year floodplain shown in Exhibit KC2-03. The overtopping across all roads is significantly reduced and the flooding is better contained to the ROW.

The combined improvements in this watershed are not expected to increase peak discharges downstream. The additional floodplain storage provided by the proposed riparian corridor is essential to containing peak flows.

Cost Estimates were prepared for each project. In total the cost for the projects within the watershed is approximately $23.8 million to meet current City criteria with more detail shown in the OPCCs.

IMPLEMENTATION

The costs for all the improvements in the study area exceed what can feasibly be financed from the City's current revenue streams without significant modification. FNI recommends breaking the projects into discrete segments based on ability to fund each. Projects should be implemented from downstream to upstream to achieve optimal drainage conditions, as seen in the conceptual phasing outlined in Exhibit KC2-04. One key exception to the rule is for a geomorphic channel, which should be constructed from upstream to downstream, so that washouts are not experienced. The sequencing explained below takes ranking, feasibility, and coordination into consideration. Phased costs are estimated based on the tabulated OPCC for each full CIP.

CIP07: KC2 Channel Improvements

These improvements can be implemented in three phases. CIP07 Phase 1 would be the buyouts, demolition, and storage volume excavation for approximately $7.8 million. If any properties are classified as Repetitive Loss or Severe Repetitive Loss, FEMA may provide some matching funds to alleviate the cost of this Phase. Additionally, the mass grading should be entirely above the ordinary high water mark of the channel and should therefore be exempt from Section 404 permitting. Further, by strategically buying out properties that are subject to regular flooding, the City is taking action to limit future losses and potential emergency responses, which may improve the situation enough to slow down the process of proceeding with Phase 2 and 3.

CIP07 Phase 2 would be culvert improvements and channel improvements for about $1.1 million. This could be further broken down into smaller reaches as necessary to fit into available budgets.

CIP07 Phase 3 would be the upsizing of the primary storm drain conveyance on the upstream side of this project for around $2.3 million. This section will run from the Alamo/Catherine Street intersection to the Frances Heath Street intersection.

CIP08: W Alamo SD

CIP08 includes upsizing some existing storm drain and adding new storm drain from the outfall of the Griffith Avenue Improvements currently under construction to the confluence with the main stem at Alamo Street/Catherine Street at a cost of approximately $2.0 million. CIP08 can begin as soon as CIP07 Phase 2 is complete because it will require the increased outfall depth and mitigation.

This proposed project will enable the infrastructure from the Griffith Avenue Improvements project that is under construction at the time of this report to be fully utilized. The combination of these projects should address the public survey responses that mentioned property and street flooding on Griffith Avenue and Rockwall Avenue, as well as any overflow that influenced the comment from Roberts Avenue.

Coordination with TxDOT will be required for changes to the storm drain along Rockwall Avenue.

CIP09: Heath St. SD

CIP09 upsizes and adds new storm drain along Heath Street and N Rockwall Avenue for an estimated cost of $1.8 million. It also provides a balancing connection between the CIP10 bypass and the main system.

The upsized infrastructure of this proposed project will address the flooding causes mentioned in the public survey comments located on Heath Street and Roberts Avenue.

Coordination with TxDOT will be required for changes to the storm drain along Rockwall Avenue.

CIP10: N Rockwall Avenue Channel and N Morris Bypass

FNI recommends CIP10 be split into phases due to the high cost. There are three (3) key components, the upsize of Damon Street storm drain, upsize of existing channel from N Rockwall Avenue to E Elm Street, and a new bypass from E Elm Street to the current KC2 crossing at E State Street.

CIP10 Phase 1 should be the open channel component, which provides some drainage relief by lowering the tailwater on the Damon Street storm drain. The open channel work is estimated at approximately $650,000 and will require easements from adjacent property owners to contain the full corridor.

CIP10 Phase 2 should be the upsized storm drain along Damon Street, which would eliminate the widespread flooding along Damon Street and N Rockwall Avenue. The cost for this storm drain is approximately $1.7 million.

CIP10 Phase 3 should be the bypass portion of the project, but being so expensive, this project should either be the last project in the watershed or among the first. It will have a significant impact of flooding either way but doing this Phase last is what provides the freeboard for the rest of the system. Otherwise there will likely still be some minor road overtopping at the main road crossings. Total cost for this Phase is approximately $6.9 million.

The bypass storm drain would directly alleviate areas along Alamo Drive where there were multiple public survey responses that mentioned yard and street flooding. The additional infrastructure will also improve the overall storm drain network's ability to efficiently convey the runoff within this watershed. The upsized structures that carry on upstream of N Rockwall Avenue will also address the public survey responses from Grace Lane and 9th Street that mentioned property flooding.

Small Projects

The following small projects are within this watershed:

- Elm Street and Roberts Street – A combination of culverts, drainage ditches, and storm drains to address a local drainage issue.

A summary of the projects and the suggested implementation order is located in Table 1. Costs have been conservatively rounded up during the estimating process and will need to be refined as part of the future design process.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Elm St. and Roberts St.	$ 168,800
		Total Small Project Cost	**$ 168,800**
Large Projects	2	CIP07 Phase 1	$ 7,800,000
	3	CIP07 Phase 2	$ 1,100,000
	4	CIP07 Phase 3	$ 2,300,000
	5	CIP08	$ 1,998,000
	6	CIP09	$ 1,837,000
	7	CIP10 Phase 1	$ 650,000
	8	CIP10 Phase 2	$ 1,700,000
	9	CIP10 Phase 3	$ 6,920,000
		Total Large Project Cost	**$ 24,305,000**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

Watershed

Inundated Buildings

25-YR Inundation (54)

100-YR Inundation (13)

Depth

< 0.5'

0.5' - 1.0'

1.0' - 2.0'

2.0' - 3.0'

> 3.0'

2D Model Extent

1D Model Extent

100-YR FEMA Floodplain

North Rockwall Channel and Storm Drain

Morris Bypass

Heath Street Storm Drain

West Alamo Storm Drain

Upper KC2 Drainage

KT3

BC1

KC1

9th

Damon

Elm

Griffith

Rockwall

Frances

Heath

Alamo

James

San Jacinto

Blanche

Virginia

Morris

Catherine

State

Brin

Pacific

College

Adelaide

Nash

Delphine

High

Bowser

34

80

0 300 600 1,200 Feet

FIGURE KC2-01

FN JOB NO	TER17602
FILE	KC2-01
DATE	1/13/2020
SCALE	1:7,200
DRAFTED	02730

Existing Conditions - KC2

City of Terrell Drainage Master Plan

FREESE NICHOLS
2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

KC3

KT3

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

9th
Natural
BW: 4' TW: 15' D: 1'
Concrete
BW: 3' TW: 10' D: 1.5'
State
1 - 7'x4'
36"
Damon
33"
27"
Rockwall
42"
Grass Channel
BW: 4' TW: 17' D: 2'
2 - 5'x4'
1 - 5'x4'
Natural
BW: 4' TW: 17' D: 5.5'
1 - 8'x4'
Elm
Natural
BW: 3' TW: 20' D: 3'
Grass Channel
BW: 5' TW: 45' D: 4.5'
Natural
BW: 4' TW: 15' D: 4'
18"
1 - 24"
1-3'x2'
4'x2.3'
1 - 36"
Grass Channel
BW: 4' TW: 14' D: 4'
Frances
Catherine
Virginia
James
Cherokee
San Jacinto
Blanche
48"
1 - 9'x6'
4'x4'
1 - 5'x5'
1 - 10'x6'
Elm
2-5'x3'
8'x4'
8'x4'
Heath
Griffith
1 - 7'x5'
1 - 8'x5'
1 - 11'x5'
Natural
BW: 6' TW: 24' D: 6'
Concrete
BW: 6' TW: 16' D: 3.5'
2-27"
Alamo
6.5'x4.5'
Natural
BW: 6' TW: 22' D: 5.5'
34
8'x2.5'
1 - 7'x5'
1 - 8'x5'
Grass Channel
BW: 13' TW: 27' D: 2.5'
Natural
BW: 9' TW: 25' D: 6'
Concrete
BW: 15' TW: 16' D: 6'
Natural
BW: 12' TW: 20' D: 9'
Natural
BW: 10' TW: 70' D: 4'
6.5'x5'
1 - 7'x5'
8'x5'
6'x9'
2-8'x5'
1 - 8'x6'
State
10'x6'
Morris
Grass Channel
BW: 12' TW: 27' D: 2.5'
1 - 7'x5'
1 - 8'x5'
Grass Channel
BW: 12' TW: 27' D: 2.5'
Grass Channel
BW: 12' TW: 27' D: 2.5'
Natural
BW: 7' TW: 30' D: 6.5'
8'x7'
Grass Channel
BW: 12' TW: 27' D: 3'
Grass Channel
BW: 12' TW: 27' D: 3'
Rockwall
Adelaide
Blanche
Brin

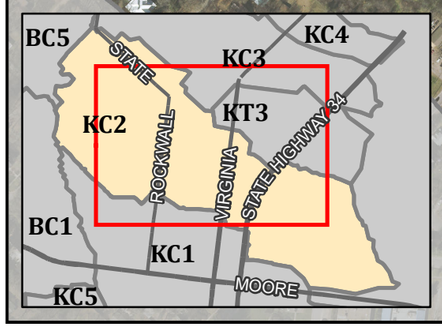


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FIGURE KC2-02

FN JOB NO	TER17602
FILE	KC2-02
DATE	6/10/2020
SCALE	1:4,800
DRAFTED	02730

Infrastructure - KC2

City of Terrell Drainage Master Plan

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2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Buildings Impacted

- Protected - 25YR (32)
- Protected - 100YR (9)
- 25-YR Inundation (0)
- 100-YR Inundation (0)
- Buyout (27)

- Existing 100-YR Floodplain
- Watershed
- Proposed 100-YR Floodplain
- 100-YR FEMA Floodplain

KC3

KT3

KC1

BC1

North Rockwall Channel and Storm Drain

Morris Bypass

Heath Street Storm Drain

West Alamo Storm Drain

Upper KC2 Drainage

9th

Elm

Griffith

Rockwall

Damon

Frances

Heath

Alamo

James

Blanche

Virginia

Morris

Catherine

State

Pacific

Brin

College

Adelaide

Nash

Delphine

High

Bowser

34

80

0 300 600 1,200 Feet

FIGURE KC2-03

100-YR Floodplain - KC2

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	KC2-03
DATE	1/10/2020
SCALE	1:7,200
DRAFTED	02730

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Watershed
- CIP (by color)
- Small Projects
- City Limits
- Phase 1
- Phase 2
- Phase 3

KC3

KT3

KC1

9th

State

End CIP10

1 - 7'x4'

Damon

2 - 5'x4'

Grass Channel
BW: 4' TW: 17' D: 2'

1 - 8'x4'

Elm

Frances

Grass Channel
BW: 5' TW: 45' D: 4.5'

End CIP09

41

1 - 24"

1 - 36"

Rockwall

Grass Channel
BW: 4' TW: 14' D: 4'

1 - 9'x6'

1 - 10'x6'

1 - 8'x5'

1 - 5'x5'

1 - 7'x5'

End CIP07

Heath

Griffith

Begin CIP09

1 - 11'x5'

1 - 7'x5'

End CIP08

1 - 8'x5'

Morris

Begin CIP08

Alamo

Grass Channel
BW: 13' TW: 27' D: 2.5'

1 - 7'x5'

Grass Channel
BW: 12' TW: 27' D: 2.5'

Catherine

Grass Channel
BW: 12' TW: 27' D: 2.5'

1 - 7'x5'

1 - 8'x5'

Adelaide

Grass Channel
BW: 12' TW: 27' D: 2.5'

Grass Channel
BW: 12' TW: 27' D: 3'

1 - 8'x6'

Blanche

Begin CIP10

State

Begin CIP07

Virginia

James

Cherokee

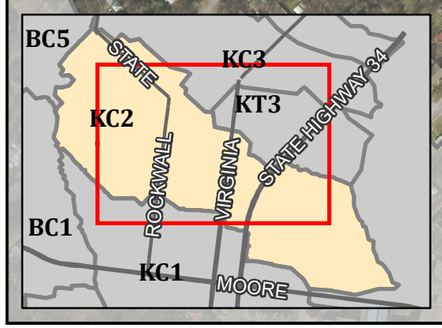
McCoulskey

40

34

Brin

0 200 400 800 Feet



Conceptual Phasing - KC2

City of Terrell Drainage Master Plan

FIGURE KC2-04

FN JOB NO	TER17602
FILE	KC2-04
DATE	6/10/2020
SCALE	1:4,800
DRAFTED	02730

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Drainage Master Plan Update
Project: KC2 CHANNEL IMPROVEMENTS

Project Information

Project ID:	CIP07	**Status:**	Studied
Project Name:	KC2 CHANNEL IMPROVEMENTS	**Council District:**	3, 4
Project Type:	Channel & Road Crossing	**Watershed:**	KC2
Date Identified:	2019	**# Structures Impacted:**	50

Problem Description:

The undersized culvert crossings and significant amount of runoff from the completely developed watershed upstream results in wide flooplains that effect numerous private properties. There are also multiple instances of roads overtopping. The system is limited by downstream conditions and is under capacity for the amount of developed area it is responsible to drain.

Proposed Improvements:

Increase culvert crossings to meet ultimate flow demand. Buyout properties adjacent to the channel and use the area to increase the floodplain storage. Implement geomorphic channels that are sized for smaller, reocurring events. Overbank floodplains should be designed to drain back into the channel. Acquired properties can also be utilized as green space.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	5
20	**Property Damage:**	5
22.5	**Frequency of Flooding:**	5
10	**Project Cost:**	1
17.5	**Public Impact:**	4
	Total Weighted Point Score:	442.5
	CIP Rank:	2

Project Costs

Total OPCC:	$11,021,000.00
Estimated Easement:	$1,596,420.00

Project Photos



Photo 1: Large pool at downstream side of San Jacinto Street crossing



Photo 2: Downstream of crossing at E State Street

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC2	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #07: KC2 CHANNEL IMPROVEMENTS					
1	REMOVAL OF EXISTING CULVERT (6.5'X5')	347	LF	$ 100	$ 34,700
2	REMOVAL OF EXISTING CULVERT (6'X9')	53	LF	$ 100	$ 5,300
3	REMOVAL OF EXISTING CULVERT (8'X4')	714	LF	$ 175	$ 124,950
4	REMOVAL OF EXISTING CULVERT (8'X5')	34	LF	$ 180	$ 6,120
5	REMOVAL OF EXISTING CULVERT (8'X7')	42	LF	$ 190	$ 7,980
6	REMOVAL OF EXISTING HEADWALL	53	CY	$ 200	$ 10,667
7	INSTALL 7'x5' RCB	90	LF	$ 550	$ 49,500
8	INSTALL 8'x5' RCB	144	LF	$ 630	$ 90,720
9	INSTALL 8'x6' RCB	42	LF	$ 690	$ 28,980
10	INSTALL 11'x5' RCB	553	LF	$ 2,000	$ 1,106,000
11	HEADWALL (MEDIUM)	20	EA	$ 15,000	$ 300,000
12	GRADING	26,168	SY	$ 15	$ 392,520
13	SEED/SOD	181,138	SY	$ 5	$ 905,690
14	UTILITY RELOCATION	1	LS	$ 63,760	$ 63,760
15	TRENCH SAFETY	829	LF	$ 5	$ 4,145
16	EXCAVATION AND HAUL	60,682	CY	$ 20	$ 1,213,640
17	ROAD EXCAVATION	607	CY	$ 27	$ 16,389
18	ASPHALT PAVEMENT REPLACEMENT	1,095	SY	$ 80	$ 87,600
19	CLEARING/GRUBBING	6	AC	$ 2,500	$ 15,000
20	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
21	SWPPP	1	EA	$ 9,200	$ 9,200
22	EASEMENTS	1	LS	$ 1,596,420	$ 1,596,420
	SUBTOTAL				$ 6,084,281
	ASSOC INFRASTRUCTURE			20%	$ 1,216,856
	SUBTOTAL				$ 7,301,137
	OH&P			15%	$ 1,095,171
	SUBTOTAL				$ 8,396,307
	MOBILIZATION			5%	$ 419,815
	SUBTOTAL				$ 8,816,123
	CONTINGENCY			25%	$ 2,204,031

PROJECT TOTAL (2019 COSTS)		**$ 11,021,000**
COST ESCALATION FACTOR	2.9%	$ 1,693,000
PROJECT TOTAL (2024 COSTS)		**$ 12,714,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.
2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.

Drainage Master Plan Update
Project: W. ALAMO SD

Project Information

Project ID:	CIP08	**Status:**	Studied
Project Name:	W. ALAMO SD	**Council District:**	4
Project Type:	Pipe System	**Watershed:**	KC2
Date Identified:	2019	**# Structures Impacted:**	11

Problem Description:

The downstream portion of the conduit is in poor condition. This portion of the system is undersized and creates a tailwater controlling effect for flows coming from the Griffith area.

Proposed Improvements:

Upsize the storm drain to improve the local drainage and reduce the amount of flow contained in the ROW. Replace the inconsistently sized storm drain with a system that increases in capacity as it goes downstream. Upsize Rockwall Avenue crossing as well to achieve the full funtion of the new Griffith Avenue storm drain system.

Project Photos



Photo 1: Inlet at corner of Rockwall Avenue and Alamo Street



Photo 2: Downstream side of Rockwall Avenue crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	5
20	**Property Damage:**	4
22.5	**Frequency of Flooding:**	5
10	**Project Cost:**	4
17.5	**Public Impact:**	2
	Total Weighted Point Score:	417.5
	CIP Rank:	3

Project Costs

Total OPCC:	$1,998,000.00
Estimated Easement:	$42,330.00

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC2	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #08: W. ALAMO SD					
1	REMOVAL OF EXISTING CULVERT (5'X3')	195	LF	$ 100	$ 19,500
2	REMOVAL OF EXISTING CULVERT (27")	712	LF	$ 45	$ 32,040
3	REMOVAL OF EXISTING HEADWALL	16	CY	$ 200	$ 3,200
4	INSTALL 7'x5' RCB	421	LF	$ 550	$ 231,550
5	INSTALL 8'x5' RCB	804	LF	$ 630	$ 506,520
6	HEADWALL (MEDIUM)	3	EA	$ 15,000	$ 45,000
7	GRADING	70	SY	$ 15	$ 1,050
8	UTILITY RELOCATION	1	LS	$ 36,904	$ 36,904
9	TRENCH SAFETY	1,225	LF	$ 5	$ 6,125
10	EXCAVATION AND HAUL	1,737	CY	$ 20	$ 34,740
11	ROAD EXCAVATION	695	CY	$ 27	$ 18,765
12	ASPHALT PAVEMENT REPLACEMENT	1,314	SY	$ 80	$ 105,120
13	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
14	SWPPP	1	EA	$ 5,000	$ 5,000
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 42,330	$ 42,330

SUBTOTAL		$	1,102,844
ASSOC INFRASTRUCTURE	20%	$	220,569
SUBTOTAL		$	1,323,413
OH&P	15%	$	198,512
SUBTOTAL		$	1,521,925
MOBILIZATION	5%	$	76,096
SUBTOTAL		$	1,598,021
CONTINGENCY	25%	$	399,505
PROJECT TOTAL (2019 COSTS)		**$**	**1,998,000**
COST ESCALATION FACTOR	2.9%	$	307,000
PROJECT TOTAL (2024 COSTS)		**$**	**2,305,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.
2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.

Drainage Master Plan Update
Project: HEATH ST. SD

Project Information

Project ID:	CIP09	**Status:**	Studied
Project Name:	HEATH ST. SD	**Council District:**	4
Project Type:	Pipe System	**Watershed:**	KC2
Date Identified:	2019	**# Structures Impacted:**	26

Problem Description:

The existing storm drain in this part of the system is difficult to access and undersized based on available records. It is currently the single, undersized line for a large, fully developed drainage area.

Proposed Improvements:

Upsize the storm drain on Rockwall Avenue and Heath Street, add additional inlets on Heath Street, and also add a connector between this line of the system and the proposed bypass line. This will equalize the demand on the overall system and also serve as partial redundancy in case of a failure on one side.

Project Photos



Photo 1: Storm drain outlet near intersection of W Alamo Street and N Catherine Street



Photo 2: Storm drain outlet and downstream open channel

CIP Ranking Criteria

Weight		Score
30	Life Safety/Road Flooding:	5
20	Property Damage:	5
22.5	Frequency of Flooding:	5
10	Project Cost:	4
17.5	Public Impact:	4
	Total Weighted Point Score:	472.5
	CIP Rank:	1

Project Costs

Total OPCC:	$1,837,000.00
Estimated Easement:	$12,550.00

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC2	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #09: HEATH ST. SD					
1	REMOVAL OF EXISTING CULVERT (18")	130	LF	$ 45	$ 5,850
2	REMOVAL OF EXISTING CULVERT (48")	679	LF	$ 50	$ 33,950
3	REMOVAL OF EXISTING CULVERT (3'x2')	365	LF	$ 45	$ 16,425
4	REMOVAL OF EXISTING CULVERT (4'X4')	242	LF	$ 60	$ 14,520
5	REMOVAL OF EXISTING CULVERT (5'X3')	102	LF	$ 100	$ 10,200
6	REMOVAL OF EXISTING CULVERT (8'X4')	56	LF	$ 175	$ 9,800
7	REMOVAL OF EXISTING HEADWALL	11	CY	$ 200	$ 2,222
8	INSTALL 5'x5' RCB	242	LF	$ 340	$ 82,280
9	INSTALL 7'x5' RCB	407	LF	$ 550	$ 223,850
10	INSTALL 8'x5' RCB	318	LF	$ 630	$ 200,340
11	INSTALL 11'x5' RCB	56	LF	$ 2,000	$ 112,000
12	INSTALL 24" RCP	130	LF	$ 125	$ 16,250
13	INSTALL 36" RCP	364	LF	$ 170	$ 61,880
14	UTILITY RELOCATION	1	LS	$ 34,830	$ 34,830
15	TRENCH SAFETY	1,517	LF	$ 5	$ 7,585
16	EXCAVATION AND HAUL	1,447	CY	$ 20	$ 28,940
17	ROAD EXCAVATION	635	CY	$ 27	$ 17,145
18	ASPHALT PAVEMENT REPLACEMENT	1,289	SY	$ 80	$ 103,120
19	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
20	SWPPP	1	EA	$ 5,000	$ 5,000
21	EASEMENTS	1	LS	$ 12,550	$ 12,550
	SUBTOTAL				$ 1,013,737
	ASSOC INFRASTRUCTURE			20%	$ 202,747
	SUBTOTAL				$ 1,216,485
	OH&P			15%	$ 182,473
	SUBTOTAL				$ 1,398,957
	MOBILIZATION			5%	$ 69,948
	SUBTOTAL				$ 1,468,905
	CONTINGENCY			25%	$ 367,226
PROJECT TOTAL (2019 COSTS)					**$ 1,837,000**
COST ESCALATION FACTOR				2.9%	$ 282,000
PROJECT TOTAL (2024 COSTS)					**$ 2,119,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.
2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.

Drainage Master Plan Update
Project: N. ROCKWALL CHANNEL & N. MORRIS BYPASS

Project Information

Project ID:	CIP10	**Status:**	Studied
Project Name:	N. ROCKWALL CHANNEL & N. MORRIS BYPASS	**Council District:**	3, 4, 5
Project Type:	Pipe System / Channel	**Watershed:**	KC2
Date Identified:	2019	**# Structures Impacted:**	5

Problem Description:

The existing system in the KC2 watershed is grossly undersized for the runoff it recieves. There are multiple constraining factors for this system and to generalize, it needs more infrastructure capacity to meet the current City criteria in this area that is practically fully developed. Road overtoppings and structure inundation are present throughout the system.

Proposed Improvements:

Apply a bypass storm drain that will signficantly assist this system. Install a large conduit that ties in at the E State Street crossing. This will provide relief for the system as needed. Implementing the majority of this bypass within the ROW minimizes the need for easements, but does increase the cost of the project. Accompany this project with other roadway projects as possible to reduce overall cost. Also, increase the typical channel section for the channel between Rockwall Avenue and Frances Street.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	2
20	**Property Damage:**	3
22.5	**Frequency of Flooding:**	2
10	**Project Cost:**	1
17.5	**Public Impact:**	5
	Total Weighted Point Score:	262.5
	CIP Rank:	12

Project Costs

Total OPCC:	$8,978,000.00
Estimated Easement:	$148,010.00

Project Photos



Photo 1: Headwall at intersection of N Frances Street and Elm Drive



Photo 2: Downstream side of Rockwall Avenue crossing near W Damon Street

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC2	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #10: N. ROCKWALL CHANNEL & N. MORRIS BYPASS					
1	REMOVAL OF EXISTING CULVERT (36")	1,221	LF	$ 45	$ 54,945
2	REMOVAL OF EXISTING HEADWALL	32	CY	$ 200	$ 6,400
3	INSTALL 5'x4' RCB	81	LF	$ 330	$ 26,730
4	INSTALL 7'x4' RCB	1,122	LF	$ 530	$ 594,660
5	INSTALL 8'x4' RCB	100	LF	$ 610	$ 61,000
6	INSTALL 9'x6' RCB	467	LF	$ 940	$ 438,980
7	INSTALL 10'x6' RCB	2,537	LF	$ 1,000	$ 2,537,000
8	GRADING	6,955	SY	$ 15	$ 104,325
9	HEADWALL (MEDIUM)	3	EA	$ 15,000	$ 45,000
10	SEED/SOD	6,955	SY	$ 5	$ 34,775
11	UTILITY RELOCATION	1	LS	$ 182,919	$ 182,919
12	TRENCH SAFETY	5,070	LF	$ 5	$ 25,350
13	EXCAVATION AND HAUL	7,914	CY	$ 20	$ 158,280
14	ROAD EXCAVATION	2,862	CY	$ 27	$ 77,274
15	ASPHALT PAVEMENT REPLACEMENT	5,250	SY	$ 80	$ 420,000
16	CLEARING/GRUBBING	3	AC	$ 2,500	$ 7,500
17	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
18	SWPPP	1	EA	$ 18,100	$ 18,100
19					
20	EASEMENTS	1	LS	$ 148,010	$ 148,010

SUBTOTAL		$	4,956,248
ASSOC INFRASTRUCTURE	20%	$	991,250
SUBTOTAL		$	5,947,497
OH&P	15%	$	892,125
SUBTOTAL		$	6,839,622
MOBILIZATION	5%	$	341,981
SUBTOTAL		$	7,181,603
CONTINGENCY	25%	$	1,795,401

PROJECT TOTAL (2019 COSTS)		**$**	**8,978,000**

COST ESCALATION FACTOR	2.9%	$	1,380,000
PROJECT TOTAL (2024 COSTS)		**$**	**10,358,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.
2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.

KC3

STUDY AREA: KC3

BACKGROUND

KC3 drainage area begins just west of Poetry Road and drains southeast to its confluence with Kings Creek just downstream of SH 34. The watershed is mostly undeveloped but has been developing quickly in recent years. The City expects developers to address relevant drainage issues as part of ongoing development activities. There is only one primary channel in the watershed, which becomes defined just downstream of Poetry Road.

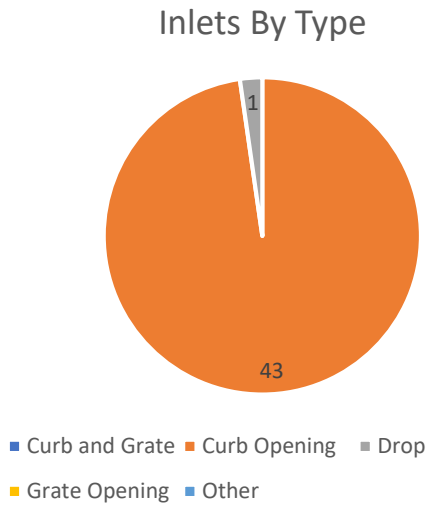
Existing storm drain systems are present mostly in the existing developed areas, such as on Yosemite Lane, Redwood Lane, and Shady Creek Lane. The existing storm drain systems vary in age and condition, though are generally in fair or better condition.

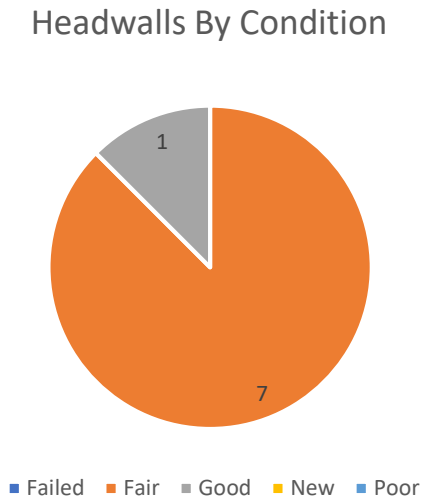
Rain-on-mesh analysis shows lots are generally elevated above the 100-year flood risk and developed areas are containing the flooding to the ROW.

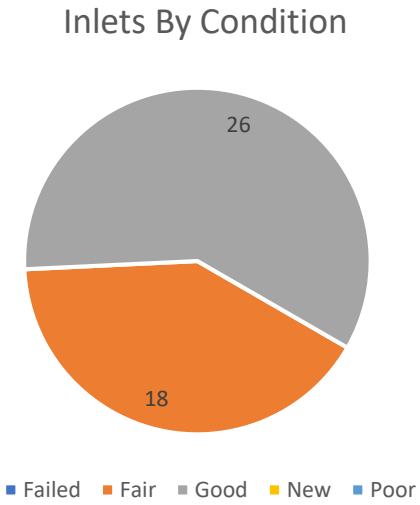
DATA COLLECTED

The 1989 Drainage Master Plan did not identify any projects in the watershed, as it was even less developed at the time.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 44 inlets, 8 headwalls, and 0.7 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 1.







Conduit by Width	
Conduit Width	Total Length (ft)
2'	826
3'	14,769
4'	4,263
6'	1,837
9'	656
10'	1,092
<Null>	398

Figure 1: Summary graphs of watershed infrastructure

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the KC3 HEC-RAS model. A map depicting the area of study is shown in Exhibit KC3-01.

Results of the data collection and modeling show:

- 4 flooded roadway block segments with a maximum depth of 1.6 feet in the 100-year storm
- 34 properties experience flooding during the 100-year storm

- The first structure is flooded in the 2-year storm
- The public noted flooding in 13 areas and there were 10 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

No significant flood prone zones were identified in the study area, however, there appears to be a culvert capacity issue at the Frances Street crossing. This could be addressed quickly if reports of flooding become common, as the results suggest may be possible, but care should be taken to ensure the downstream impacts of upsizing the culvert are assessed.

There were also several public survey responses from the Forrest Creek development. The comments appear to be caused by certain parts of the developer designed drainage network.

PROPOSED IMPROVEMENTS

The major drainage infrastructure is generally not yet built. It will be critical as new development occurs in the watershed to preserve the floodplain corridor and valley storage of the existing floodplain. There are no proposed improvements at this time, but the existing infrastructure is shown in Exhibit KC3-02.

The comments from the Forrest Creek development and Poetry Road could be addressed by increased maintenance to the drainage infrastructure in the area.

In the future, the City might need to revisit the culvert at Frances. Future developers in the area should, at a minimum, **analyze the full length** of the existing channel to the confluence with Kings Creek to make sure no existing structure will be flooded by increased runoff from new impervious areas.

Small Projects

There were no small projects identified within this watershed.

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Inundated Buildings

- 25-YR Inundation (1)
- 100-YR Inundation (0)

Depth

- < 0.5'
- 0.5' - 1.0'
- 1.0' - 2.0'
- 2.0' - 3.0'
- > 3.0'

- 2D Model Extent
- 1D Model Extent
- 100-YR FEMA Floodplain

BC5
KC4
KC2
BC1
KT3

Eastgate
Town North
Poetry
Laurel
Yosemite
Redwood
Creekside
Frances
June
Davidson
State
9th
Griffith
Elm
Damon
Rockwall
Catherine
Virginia
James
McCoulskey
San Jacinto
Blanche
34

0 350 700 1,400 Feet

FIGURE KC3-01

FN JOB NO	TER17602
FILE	KC3-01
DATE	1/13/2020
SCALE	1:8,400
DRAFTED	02730

Existing Conditions - KC3

City of Terrell Drainage Master Plan

FREESE AND NICHOLS
2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

Document Path: H:\STORMWATER\Final Exhibits\01_REPORT\KC3-01.mxd

NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

BC5

KC4

KC2

KT3

BC1

FM 986

Poetry

Eastgate

Town North

Laurel

Yosemite

Redwood

Other
BW: 2' TW: 21' D: 5'

Natural
BW: 17' TW: 53' D: 8'

Natural
BW: 1' TW: 24' D: 5'

Natural
BW: 5' TW: 45' D: 3.5'

Natural
BW: 4' TW: 20' D: 2'

Natural
BW: 10' TW: 60' D: 6'

Natural
BW: 15' TW: 35' D: 7'

Natural
BW: 5' TW: 43' D: 7'

36"

10'x6'

58"

42"

54"

42"

10'x7'

9'x5'

34

Shady Creek

Creekside

Frances

June

Davidson

State

Griffith

9th

Elm

Damon

Rockwall

Catherine

Virginia

McCoulskey

James

San Jacinto

0 350 700 1,400 Feet

Document Path: H:\STORMWATER\Final Exhibits\01_REPORT\KC3-02.mxd

FIGURE KC3-02

FN JOB NO	TER17602
FILE	KC3-02
DATE	1/10/2020
SCALE	1:8,400
DRAFTED	02730

Infrastructure - KC3

City of Terrell Drainage Master Plan

FREESE AND NICHOLS
2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
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KC4

STUDY AREA: KC4

BACKGROUND

KC4 drainage area begins just west of Poetry Road and drains southeast to its confluence with Kings Creek just downstream of SH 34. The watershed is mostly undeveloped but has been developing quickly in recent years with the Creekside development. The City expects developers to address relevant drainage issues as part of ongoing development activities. There is only one primary channel in the watershed, which becomes defined just downstream of Poetry Road.

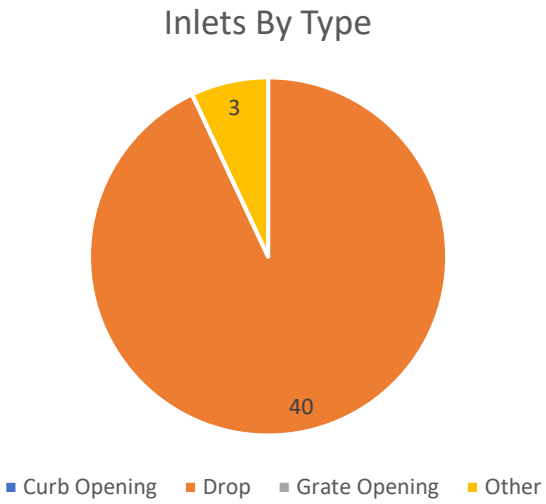
Existing storm drain systems are present mostly in the existing developed areas, with the largest being along Town North Drive just north of Terrell High School, which channelizes the original creek to Eastgate Drive. The existing storm drain systems vary in age and condition, though are generally in fair or better condition.

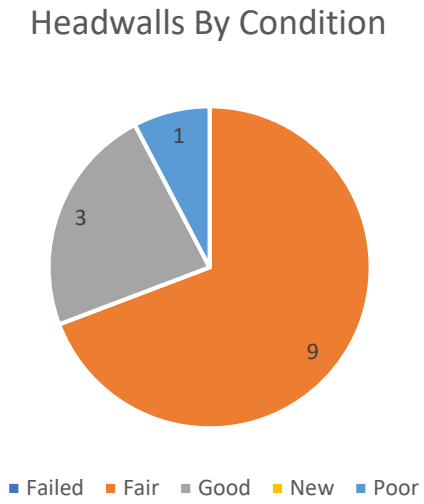
Rain-on-mesh analysis shows lots are generally elevated above the 100-year flood risk and developed areas are containing the flooding to the ROW.

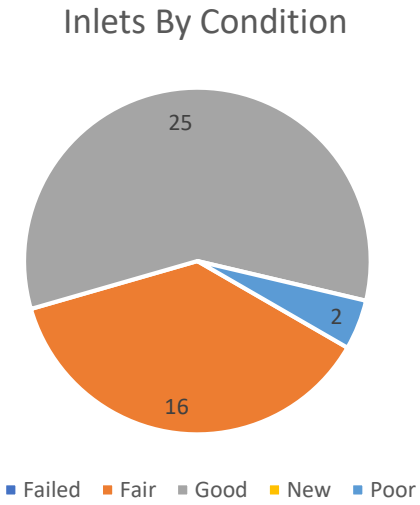
DATA COLLECTED

The 1989 Drainage Master Plan did not identify any projects in the watershed, as it was even less developed at the time.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 43 inlets, 13 headwalls, and 1.1 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 1.







Conduit by Width	
Conduit Width	Total Length (ft)
1'	47
2'	3,196
3'	1,087
4'	1,178
8'	47
10'	93

Figure 1: Summary graphs of watershed infrastructure

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the KC4 HEC-RAS model. A map depicting the area of study for is shown in Exhibit KC4-01.

Results of the data collection and modeling show:

- 3 flooded roadway block segments with a maximum depth of 1.0 feet in the 100-year storm
- 26 properties experience flooding during the 100-year storm

- No structures are flooded during the 100-year storm
- The public noted flooding in 7 areas and there were no maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

No significant flood prone zones were identified in the study area, however, there appears to be a culvert capacity issue at the Frances Street crossing, and a channel capacity issue adjacent to June Street. This could be addressed as a localized drainage fix if reports of flooding become common, as the results suggest may be possible, but care should be taken to ensure the downstream impacts of upsizing the culvert are assessed.

Because the original creek has been replaced with a storm drain on the east end of the High School, any development upstream should demonstrate clearly that they are not exceeding the capacity of the system, using detention mitigation if necessary. This may be a challenge as part of the drainage area extends beyond the City Limits.

PROPOSED IMPROVEMENTS

The major drainage infrastructure is generally not yet built. It will be critical as new development occurs in the watershed to preserve the floodplain corridor and valley storage of the existing floodplain. There are no proposed improvements at this time, but the existing infrastructure is shown in Exhibit KC4-02.

In the future, the City might need to revisit the culvert at Frances and the channel adjacent to June Street. Doing so would address the feedback received from the public survey for this area. A significant portion of this watershed is currently undeveloped. Future developers in the area should, at a minimum, **analyze the full length** of the existing channel to the confluence with Kings Creek to make sure no existing structure will be flooded by increased runoff from new impervious areas.

Small Projects

There were no small projects identified within this watershed.

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Inundated Buildings

- 25-YR Inundation (0)
- 100-YR Inundation (0)

Depth

- < 0.5'
- 0.5' - 1.0'
- 1.0' - 2.0'
- 2.0' - 3.0'
- > 3.0'

- 2D Model Extent
- 1D Model Extent
- 100-YR FEMA Floodplain

Eastgate
Town North
Poetry
Yosemite
Redwood
Creekside
Shady Creek
Frances
June
State
9th
KC3
KC2
34
34

0 300 600 1,200 Feet

Existing Conditions - KC4

City of Terrell Drainage Master Plan

FIGURE	KC4-01
FN JOB NO	TER17602
FILE	KC4-01
DATE	1/13/2020
SCALE	1:7,200
DRAFTED	02730

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2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

BC5

KC3

FM 986

Poetry

Yosemite

Redwood

Shady Creek

Eastgate

Town North

Frances

Creekside

June

34

Natural
BW: 2' TW: 10' D: 4'

48"

36"

Natural
BW: 10' TW: 35' D: 4'

Natural
BW: 10' TW: 40' D: 4'

36"

21"

Natural
BW: 3' TW: 40' D: 3'

Natural
BW: 20' TW: 40' D: 4'

Natural
BW: 5' TW: 12' D: 4'

Natural
BW: 5' TW: 12' D: 4'

Concrete
BW: 5' TW: 15' D: 3'

Natural
BW: 5' TW: 12' D: 4'

Natural
BW: 5' TW: 15' D: 3'

Natural
BW: 5' TW: 12' D: 4'

18"

18"

18"

27"

30"

33"

Natural
BW: 4' TW: 12' D: 4.5'

2-8'x7'

Natural
BW: 12' TW: 18' D: 4'

Legend

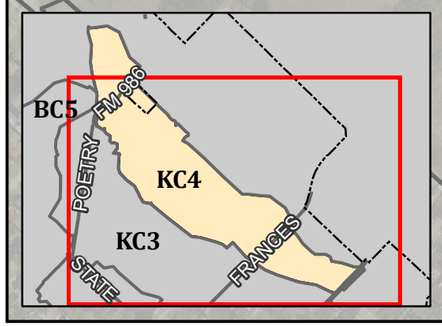
- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth



0 300 600 1,200 Feet

FIGURE KC4-02

FN JOB NO	TER17602
FILE	KC4-02
DATE	1/10/2020
SCALE	1:7,200
DRAFTED	02730

Infrastructure - KC4

City of Terrell Drainage Master Plan

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Dallas, Texas 75204
P: 214-217-2200

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KC5

STUDY AREA: KC5

BACKGROUND

KC5 includes the longest open channel network in the City of Terrell and stretches from just south of the Southwestern Christian College to its confluence with Kings Creek just east of Airport Road and Skyline Drive. The watershed is almost entirely developed and has several detention ponds and improved channel sections, though not as much storm drain.

A portion of the KC5 watershed spills across the watershed boundary to the south, near the intersection of SH34 and Virginia Street.

Existing storm drain systems are present mostly on SH 34, Virginia Street, and S Rockwall Avenue. The existing storm drain systems vary in age and condition, though are generally in good condition.

Rain-on-mesh analysis shows that though storm drain systems exist, there is general widespread shallow flooding throughout the watershed.

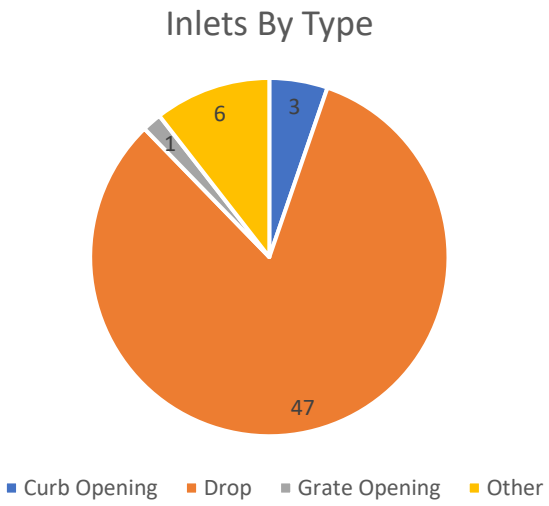
DATA COLLECTED

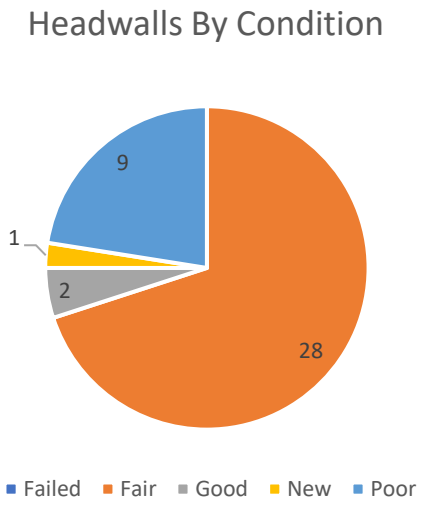
The 1989 Drainage Master Plan identified several projects in the area, but the most relevant are called Line “I” and Line “K” for a total of $320,000 (1989 dollars). The proposed project from that study is shown in Figure 1. New improvements have been made in the vicinity of these projects and are included in the analysis of the system. Line “K” is a bit different than drawn in the 1989 study but was constructed in 2017 as part of the Oldcastle property on Airport Road.

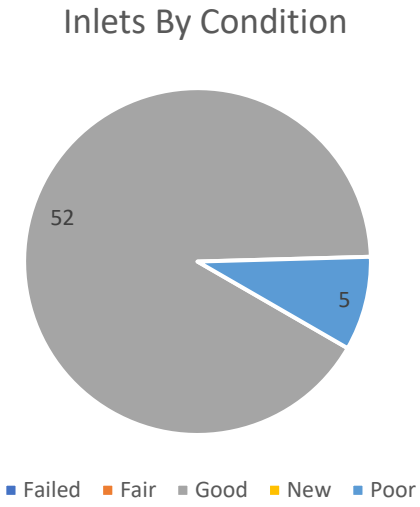


Figure 1: Proposed structures from 1989 Drainage Master Plan.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 57 inlets, 40 headwalls, and 2.3 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 2.







Conduit by Width	
Conduit Width	Total Length (ft)
1'	75
2'	5,446
3'	2,474
4'	1,201
5'	1,317
6'	473
7'	169
10'	49
<Null>	830

Figure 2: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the KC5 HEC-RAS model, and the Airport ICM model for overflow to the south.

Only open channels were modeled using HEC-HMS and HEC-RAS to the confluence with Kings Creek. A map depicting the area of study for each component is shown in Exhibit KC5-01.

Results of the data collection and modeling show:

- 12 flooded roadway block segments with a maximum depth of 2.2 feet in the 100-year storm
- 117 properties experience flooding during the 100-year storm
- The first structure is flooded in the 50-year storm
- The public noted flooding in 3 areas and there were 15 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

There are several different flood prone zones identified within the study area that have separate solutions. In general there are three (3) primary drivers for the causes of flooding within the watershed:

Railroad Spur Capacity — The capacity of the culvert crossing of the railroad spur is a significant issue that causes a good amount of ponding in the watershed and increases the amount of flow spilling south into the KT1 watershed.

Drainage system sized for smaller storm event — Though much of the infrastructure in the watershed is in good condition because it was built in the last 10-20 years, it was sized based on the old criteria at best, and therefore does not contain the flooding of the current design storm within the ROW. Fortunately, there is significant topographic relief in the basin, which helps prevent water from being too deep outside the ROW.

Watershed spill — Because of the lack of capacity for efficient flow in culverts and channels, flows are transferring across the watershed divide and instead of flowing east, they flow south.

PROPOSED IMPROVEMENTS

The major drainage infrastructure in the watershed, though not explicitly designed to the current design standard, is providing adequate drainage of the watershed with few flood hazards evident. The key proposed improvements are to the railroad spur culvert crossing and adjacent channel. The proposed infrastructure improvements are shown in Exhibit KC5-02.

Upsizing the culvert at the railroad spur will increase not only the peak flow rate, but also the total volume of flood flow downstream. Because the Oldcastle improvements were oversized, there is no need for additional mitigation of the removal of the bottleneck beyond the additional valley storage provided by the channel improvements.

The combined effect of the proposed improvements results in the improved 100-year floodplain shown in Exhibit KC5-03. The overtopping across Virginia Street and SH34 is significantly reduced and the flooding is better contained to the ROW downstream of Virginia Street.

The combined improvements in this watershed are expected to increase discharges downstream. Detention to mitigate approximately 16 acre-feet should be considered during the more detailed design phase prior to implementation to mitigate downstream adverse impacts.

Cost Estimates were prepared for the project. In total the cost for the projects within the watershed is approximately $1.8 million to meet current City criteria, with more detail shown in the OPCCs.

IMPLEMENTATION

The costs for all the improvements in the study area exceed what can feasibly be financed from the City's current revenue streams without significant modification. FNI recommends breaking the project into discrete segments based on ability to fund each. Projects should be implemented from downstream to upstream to achieve optimal drainage conditions, as seen in the conceptual phasing outlined in Exhibit KC5-04. The sequencing explained below takes ranking, feasibility, and coordination into consideration. Phased costs are estimated based on the tabulated OPCC for each full CIP.

CIP18: Railroad Spur Culvert Improvements

CIP18 can be implemented in a single phase at a cost of around $1.8 million. This culvert and channel improvement project is critical to improving the drainage upstream, but more so for the area in the path of the spill over Virginia Street and SH 34. Nationwide Permits should be applicable for compliance with Section 404.

The single public survey response for this watershed, located on Medora Street, that stated flooding was limited to the street for a short duration should benefit from the removal of the bottleneck proposed via CIP18.

Small Projects

The following small projects are within this watershed:

- Airport and SH 34 — Repair failing retaining walls and improve conveyance through the area by removing driveway.

A summary of the projects and the suggested implementation order is located in Table 1. Costs have been conservatively rounded up during the estimating process and will need to be refined as part of the future design process.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Airport and SH 34	$ 228,800
		Total Small Project Cost	**$ 228,800**
Large Projects	2	CIP18	$ 1,836,000
		Total Large Project Cost	**$ 1,836,000**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Inundated Buildings

- 25-YR Inundation (0)
- 100-YR Inundation (4)

Depth

- < 0.5'
- 0.5' - 1.0'
- 1.0' - 2.0'
- 2.0' - 3.0'
- > 3.0'

- 2D Model Extent
- 1D Model Extent
- 100-YR FEMA Floodplain

BC1
KC1
KT4
KT1

Nash
Blanche
Bowser
Grove
West End
Cottage
Rochester
Virginia
Delphine
Rockwall
Catherine
Adelaide
Frances
Medora
Myers
Bethlehem
Crenshaw
College Mound
Oldcastle Channel
RR Spur Culvert
Airport
Windsor
80
34

0 450 900 1,800 Feet

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FIGURE KC5-01

Existing Conditions - KC5

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	KC5-01
DATE	1/13/2020
SCALE	1:10,800
DRAFTED	02730

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

Medora

Concrete
BW: 4' TW: 15' D: 4'

Natural
BW: 10' TW: 19' D: 5'

Natural
BW: 8' TW: 26' D: 4'

3-42"

3-36"

Frances

Catherine

Adelaide

48"

2-5'x3'

2-48"

2-5'x4'

2-7'x3'

Natural
BW: 8' TW: 19' D: 4.5'

Natural
BW: 10' TW: 17' D: 4'

Virginia

Concrete
BW: 6' TW: 21' D: 4'

Delphine

34

3-6'x4'

Natural
BW: 3' TW: 19' D: 6'

Natural
BW: 6' TW: 24' D: 10'

Other
BW: 85' TW: 100' D: 4'

7'x5'

3 - 7'x5'

Grass Channel
BW: 13' TW: 60' D: 6.5'

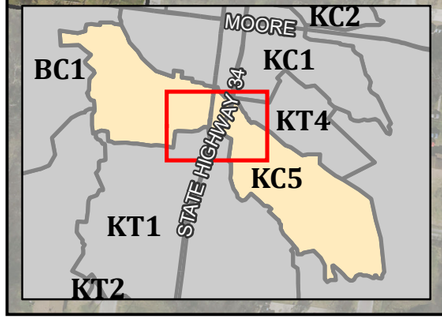
Grass Channel
BW: 84' TW: 125' D: 5'

Myers

KT1

Airport

0 100 200 400 Feet



FN JOB NO	TER17602
FILE	KC5-02
DATE	1/9/2020
SCALE	1:2,400
DRAFTED	02730

FIGURE KC5-02

Infrastructure - KC5

City of Terrell Drainage Master Plan

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NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Buildings Impacted

- Protected - 25YR (0)
- Protected - 100YR (1)
- 25-YR Inundation (0)
- 100-YR Inundation (3)
- Buyout (0)

- Existing 100-YR Floodplain
- Proposed 100-YR Floodplain
- 100-YR FEMA Floodplain

BC1
KC1
KT4
KT1

Nash
Grove
West End
Cottage
Rochester
Rockwall
Virginia
Delphine
Catherine
Adelaide
Frances
Myers
Medora
Crenshaw
Bethlehem
College Mound
RR Spur Culvert
Oldcastle Channel
Airport
Windsor

80
34

0 450 900 1,800 Feet

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FIGURE KC5-03

100-YR Floodplain - KC5

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	KC5-03
DATE	1/10/2020
SCALE	1:10,800
DRAFTED	02730

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

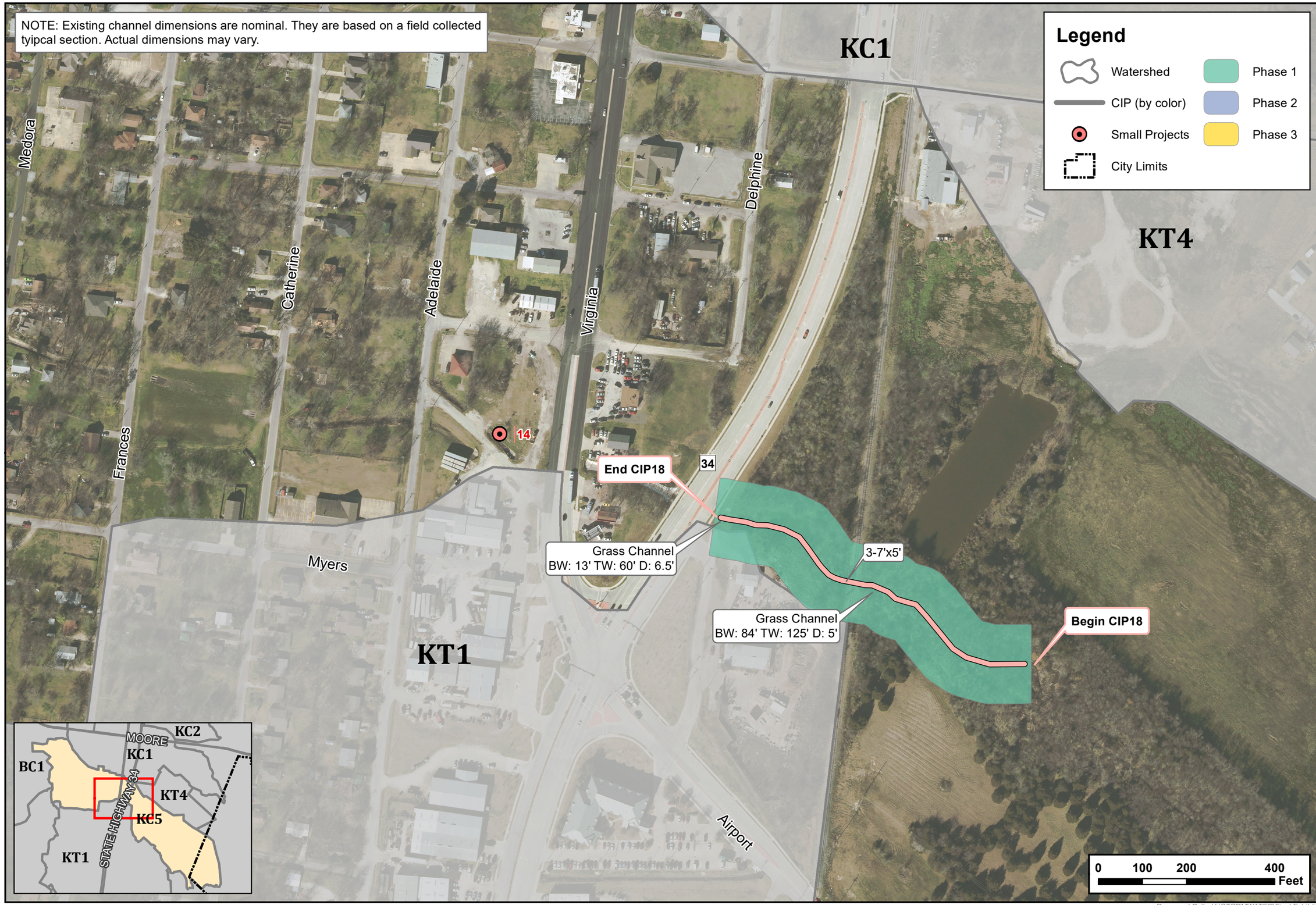

FIGURE KC5-04

FN JOB NO	TER17602
FILE	KC5-04
DATE	6/10/2020
SCALE	1:2,400
DRAFTED	02730

Conceptual Phasing - KC5

City of Terrell Drainage Master Plan

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Drainage Master Plan Update
Project: RR SPUR CULVERT

Project Information

Project ID:	CIP18	**Status:**	Studied
Project Name:	RR SPUR CULVERT	**Council District:**	3
Project Type:	Channel & RR Crossing	**Watershed:**	KC5
Date Identified:	2019	**# Structures Impacted:**	2

Problem Description:

The channel and railroad crossing are significantly undersized and causing a limiting tailwater effect for the system upstream. The channel downstream has recently been improved and has the capacity to handle calculated ultimate flows. The railroad crossing and adjacent channels are the limiting factors.

Proposed Improvements:

Upsize the railroad spur culverts to meet the need for the watershed. Apply channel improvement downstream of railroad until tieing in with the Oldcastle improvements.

Project Photos



Photo 1: Open channel on downstream side of railroad crossing

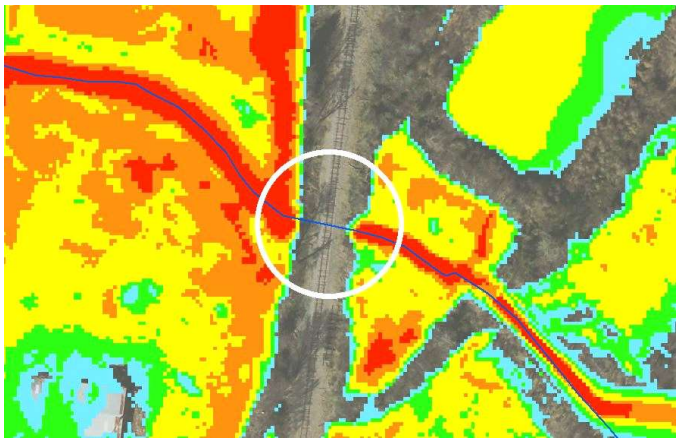


Photo 2: Existing depth results show railroad crossing causes damming effect

CIP Ranking Criteria

Weight		Score
30	Life Safety/Road Flooding:	5
20	Property Damage:	2
22.5	Frequency of Flooding:	2
10	Project Cost:	4
17.5	Public Impact:	0
	Total Weighted Point Score:	275
	CIP Rank:	10

Project Costs

Total OPCC:	$1,836,000.00
Estimated Easement:	$198,540.00

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KC5	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #18: RR SPUR CULVERT					
1	REMOVAL OF EXISTING HEADWALL	22	CY	$ 200	$ 4,400
2	REMOVAL OF EXISTING CULVERT (7'X5')	96	LF	$ 100	$ 9,600
3	EXCAVATION AND HAUL	5,514	CY	$ 20	$ 110,280
4	INSTALL 7'X5' RCB	96	LF	$ 550	$ 52,800
5	HEADWALL (LARGE)	2	EA	$ 20,000	$ 40,000
6	BORE CULVERT (7'X5')	96	LF	$ 3,750	$ 360,000
7	SHORING	736	SF	$ 25	$ 18,400
8	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
9	CLEARING/GRUBBING	3	AC	$ 2,500	$ 7,500
10	GRADING	11,706	SY	$ 15	$ 175,590
11	SEED/SOD	11,706	SY	$ 5	$ 58,530
12	SWPPP	1	EA	$ 5,000	$ 5,000
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 198,540	$ 198,540

SUBTOTAL		$	1,055,640
ASSOC INFRASTRUCTURE	20%	$	211,128
SUBTOTAL		$	1,266,768
OH&P	15%	$	190,015
SUBTOTAL		$	1,456,783
MOBILIZATION	5%	$	72,839
SUBTOTAL		$	1,529,622
CONTINGENCY	20%	$	305,924

PROJECT TOTAL (2019 COSTS)		**$**	**1,836,000**

COST ESCALATION FACTOR	2.9%	$	282,000
PROJECT TOTAL (2024 COSTS)		**$**	**2,118,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.

2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.

KC6

STUDY AREA: KC6

BACKGROUND

KC6 drainage area is generally west of SH 34 and south of IH 20 and drains southeast to its confluence with Kings Creek near the City Limits. The watershed is mostly undeveloped but includes part of the Tanger Outlet development and some other Interstate Commercial development. The primary channel begins downstream of a detention pond and crosses CR 301 before spilling into the Kings Creek Floodplain. Upstream of the detention pond are two channels, KC6 and KC6-A. KC6 is generally an engineered channel on the south side of the Tanger development, and KC6-A is generally a natural channel

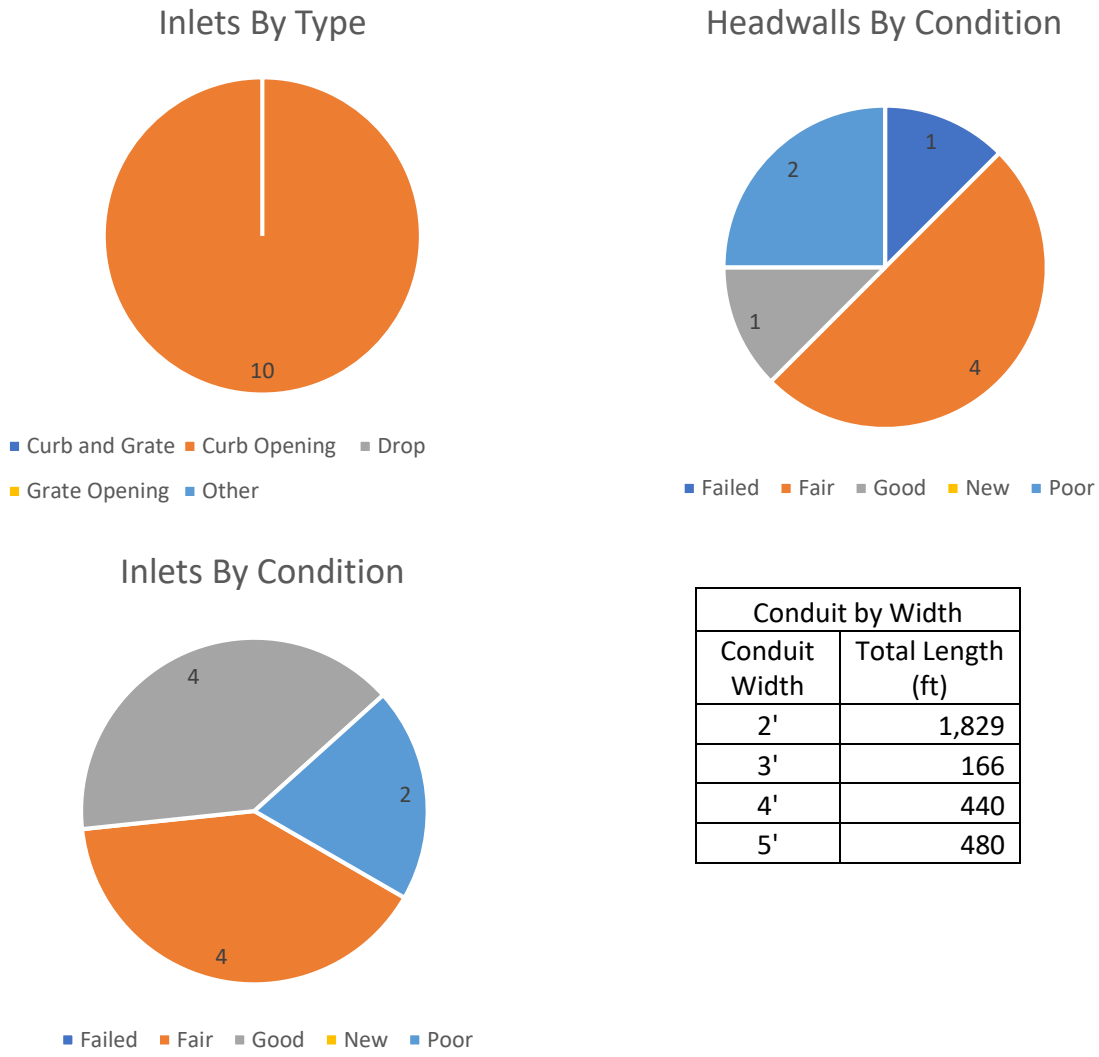
Existing storm drain systems are present only on Tanger Drive. The existing storm drain systems vary in age and condition, though are generally in fair condition.

Rain-on-mesh analysis shows the undeveloped areas are storing a significant amount of water in what appear to be terraces. It also shows that flow spills across Tanger Drive.

DATA COLLECTED

The 1989 Drainage Master Plan did not identify any projects in the watershed, as it was even less developed at the time.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 10 inlets, 8 headwalls, and 0.6 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 1.



Conduit by Width	
Conduit Width	Total Length (ft)
2'	1,829
3'	166
4'	440
5'	480

Figure 1: Summary graphs of watershed infrastructure

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the KC4 HEC-RAS model. A map depicting the area of study for is shown in Exhibit KC6-01.

Results of the data collection and modeling show:

- 3 flooded roadway block segments with a maximum depth of 1.4 feet in the 100-year storm
- 8 properties experience flooding during the 100-year storm

- No structures are flooded during the 100-year storm
- The public noted flooding in no areas and there were no maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

No significant flood prone zones were identified in the study area, however; when some properties are developed in the future, the local drainage issues will need to be addressed, especially those located along Tanger Drive. The City should expect to see additional detention mitigation, which could perhaps be handled by a regional detention facility.

PROPOSED IMPROVEMENTS

The major drainage infrastructure includes a storm drain line, open channels, and a detention pond. There are no proposed improvements at this time, but the existing infrastructure is shown in Exhibit KC6-02.

In the future, the City might consider a regional detention solution to better facilitate development of the area near Tanger Drive.

Small Projects

The following small projects are within this watershed:

- Tanger Drive — Several headwalls were noted to be failing during field inspection and should be repaired.

A summary of the projects and the suggested implementation order is located in Table 1.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Tanger Drive	$ 68,700
		Total Small Project Cost	**$ 68,700**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

KT2

Tanger

34

20

County Road 301

34

Legend

City Limits

Watershed

Inundated Buildings

25-YR Inundation (0)

100-YR Inundation (0)

Depth

< 0.5'

0.5' - 1.0'

1.0' - 2.0'

2.0' - 3.0'

> 3.0'

2D Model Extent

1D Model Extent

100-YR FEMA Floodplain

0 250 500 1,000 Feet

Existing Conditions - KC6

City of Terrell Drainage Master Plan

FIGURE	KC6-01
FN JOB NO	TER17602
FILE	KC6-01
DATE	1/13/2020
SCALE	1:6,000
DRAFTED	02730

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

KT2

Tanger

48"

60"

27"

33"

30"

Natural
BW: 8' TW: 30' D: 0.5'

Natural
BW: 6' TW: 40' D: 6'

TANGLER RD

Natural
BW: 12' TW: 40' D: 6.5'

3-48"

2-48"

Natural
BW: 12' TW: 41' D: 6'

Natural
BW: 12' TW: 40' D: 6.5'

Natural
BW: 5' TW: 60' D: 2'

34

20

34

County Road 301

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size	*Existing Channel Material Bottom Width, Top Width, Depth*
Proposed SD Size	**Proposed Channel Material Bottom Width, Top Width, Depth**

0 250 500 1,000 Feet

FIGURE KC6-02

FN JOB NO	TER17602
FILE	KC6-02
DATE	6/11/2020
SCALE	1:6,000
DRAFTED	02730

Infrastructure - KC6

City of Terrell Drainage Master Plan

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KT1

STUDY AREA: KT1

BACKGROUND

KT1 is bounded to the north by Crenshaw Street and Myers Street. The boundary to the east consists of a portion of the industrial space on the southwest side of Airport Road and the Airport property to the west of the runways. The southern and western boundaries do not follow the street grid, but the watershed lies entirely north of Interstate 20 and includes the majority of the neighborhoods bounded by Winsdor Avenue and Bethlehem Street. The KT1 tributary becomes a significant channel after crossing SH 34 south of University Street. The tributary currently forks just south of the British Flying School crossing. The second fork starts along the northeast backside of the community near Winsdor Avenue.

There is watershed overflow from the KC5 watershed to this watershed just north of the Airport Road and SH34 interchange.

Most of the existing storm drain system in this watershed is concentrated around SH 34. This network is in fair or better condition due to the recent renovations done by TxDOT. The residential areas in the north half of this watershed rely mainly on driveway ditch components. The industrial and airport areas have local systems that outlet into the larger, open channel reach.

Rain-on-mesh analysis shows consistent flood depth outside of the Right-of-Way (ROW) in the areas reliant on driveway ditch infrastructure with some of the depths reaching a level of concern. In the remaining portions of the watershed there is frequent flooding outside of the ROW that is currently occupied by open space.

DATA COLLECTED

The 1989 Drainage Master Plan identified a project called Line “J” for a total of $615,000 (1989 dollars). The proposed project from that study is shown in Figure 1. New improvements have been made in the vicinity of this project and are included in the analysis of the system.

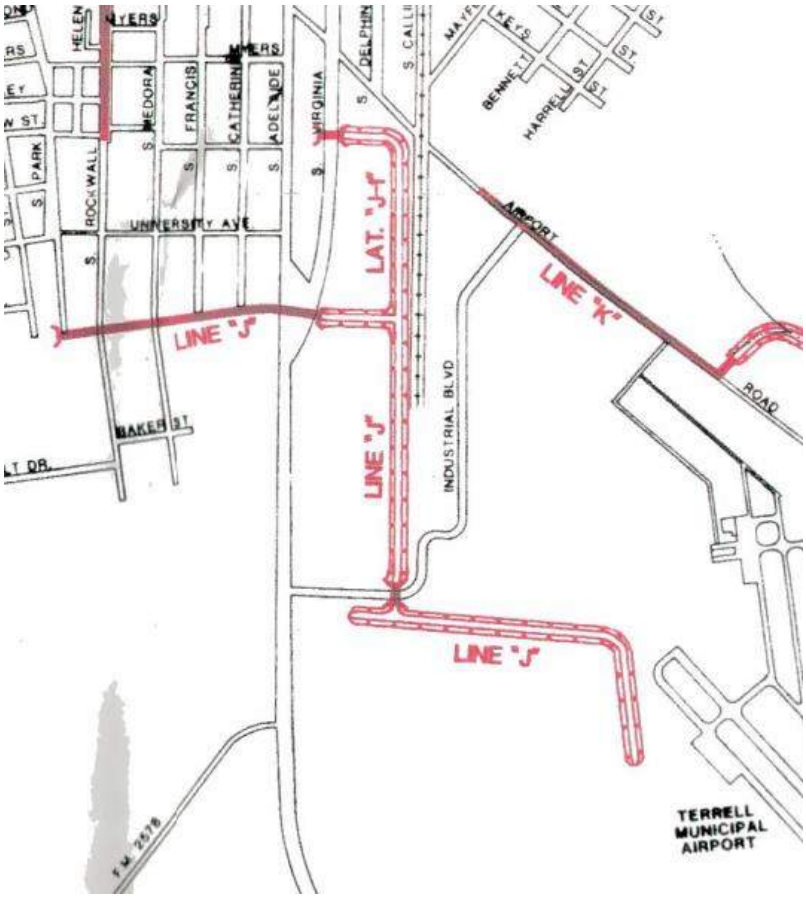
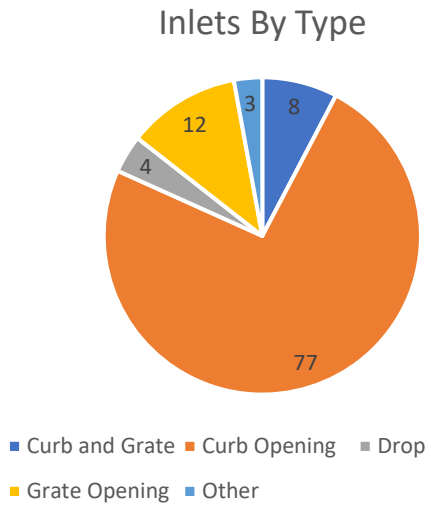


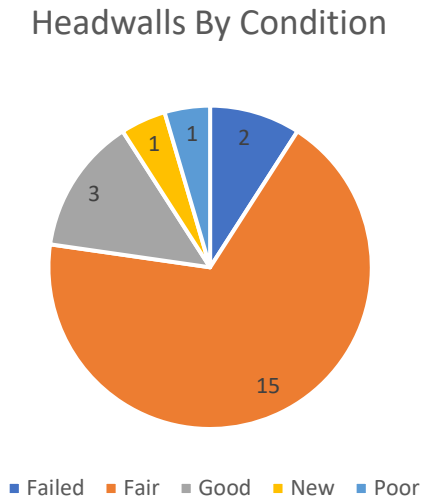
Figure 1: Proposed structures from 1989 Drainage Master Plan.

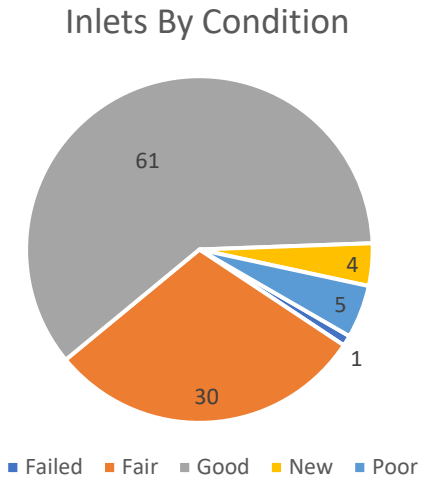
The previously identified project has been completed. The east-west portion of "Trib J-I" has since been upgraded from an open channel to a 7'x3' RCB.

The tributary was previously studied as a part of a LOMR in 2015. The extents of the open channel study include the lower fork past SH 34, and half of the north-south portion of the main reach.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 104 inlets, 22 headwalls, and 2.0 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 2.







Conduit by Width	
Conduit Width	Total Length (ft)
2'	6,744
3'	1,689
4'	612
5'	699
6'	372
7'	29
8'	23
9'	72
<Null>	256

Figure 2: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the Airport ICM model.

The watershed was modeled using InfoWorks ICM due to the strong presence of storm drain and drainage ditch infrastructure. The lower portion of the tributary was previously modelled so the ICM model extents include a portion of the open channel to overlap and tie into the existing HEC-RAS models. A map depicting the area of study for each component is shown in Exhibit KT1-01.

Results of the data collection and modeling show:

- 49 flooded roadway block segments with a maximum depth of 3.4 feet in the 100-year storm
- 121 properties experience flooding during the 100-year storm
- The first structure is flooded in the 2-year storm
- The public noted flooding in no areas and there were 22 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

There are several different flood prone zones identified within the study area that have separate solutions:

Bottlenecks at culvert crossings — The existing results indicate there are multiple undersized culvert crossings that result in a backwater effect on the upstream face of the culvert and typically lead to overtopping.

Undersized driveway ditches — The driveway ditches that act as the main source of drainage infrastructure in the residential areas are undersized and inefficient. They are a significant source of the maintenance requests, and the site visits showed there are multiple areas where sedimentation has reduced the capacity of the features. There were multiple instances where the driveway culvert or road culvert was completely blocked or submerged.

Inefficient and undersized Airport Lead — The channel south of the community center has an inconsistent slope an undersized channel to accommodate the overflows from the KC5 watershed to the north.

PROPOSED IMPROVEMENTS

Improving the residential drainage in this area will significantly reduce the number of watershed deficiencies noted above. Improving the Airport Lead portion of the open channel will improve the efficiency of the open channel and provide relief for the KC5 watershed. The proposed infrastructure improvements are shown in Exhibit KT1-02.

Recall the future land use conditions were used to model ultimate flows. A significant portion of the watershed is currently open space. Proper detention to match the time of concentration between future development and existing conditions will be paramount.

The combined effect of the proposed improvements results in the improved 100-year floodplain shown in Exhibit KT1-03. The overland flooding in the northern half of the watershed is significantly reduced. All of the structures are protected in the 25- and 100-year storm events.

The combined improvements in this watershed are expected to increase discharges downstream. Detention to mitigate approximately 6 acre-feet should be considered during the more detailed design phase prior to implementation to mitigate downstream adverse impacts.

Cost Estimates were prepared for each project. In total the cost for the projects within the watershed is approximately $6.2 million to meet current City criteria, with more detail shown in the OPCCs.

IMPLEMENTATION

The costs for all the improvements in the study area exceed what can feasibly be financed from the City's current revenue streams without significant modification. FNI recommends breaking the projects into discrete segments based on ability to fund each. Projects should be implemented from downstream to upstream to achieve optimal drainage conditions, as seen in the conceptual phasing outlined in Exhibit KT1-04. The sequencing explained below takes ranking, feasibility, and coordination into consideration. Phased costs are estimated based on the tabulated OPCC for each full CIP.

CIP19: Fuji Drainage

CIP19 is the priority for this watershed and can be implemented through three phases. Phase 1 consists of upsizing the SH34 crossing south of University Street for approximately $800,000. Phase 2 will consist of extending the storm drain network into the residential area north on Adelaide Street and then west on University Street until it intersects with Rockwall Avenue for around $2.0 million. Phase 3 will replace the shallow open channel with storm drain due west of the SH34 crossing for a final $1.4 million. This project will require coordination with TxDOT to upsize the SH34 crossing.

CIP20: Airport Lead

CIP20 should follow after CIP19 and can be implemented in a single phase at a cost of $2.0 million. A consistent grade will key to achieving the desired results from this project. It would be optimal if this

project was completed before additional development occurs in the adjacent open spaces to reduce constructability obstacles.

Small Projects

The Small Project originally called S Airport Road was ultimately relocated to the Large Projects List and renamed Airport Lead. However, the original Small Project is under design at the time of this report to improve conditions in the interim.

A summary of the projects and the suggested implementation order is located in Table 1. Costs have been conservatively rounded up during the estimating process and will need to be refined as part of the future design process.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Large Projects	2	CIP19 Phase 1	$ 800,000
	3	CIP19 Phase 2	$ 2,000,000
	4	CIP19 Phase 3	$ 1,400,000
	5	CIP20 Phase 1	$ 2,018,000
		Total Large Project Cost	**$ 6,218,000**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Inundated Buildings

- 25-YR Inundation (4)
- 100-YR Inundation (6)

Depth

- < 0.5'
- 0.5' - 1.0'
- 1.0' - 2.0'
- 2.0' - 3.0'
- > 3.0'

- 2D Model Extent
- 1D Model Extent
- 100-YR FEMA Floodplain

Rockwall
Myers
Virginia
Crenshaw
Bethlehe
Catherine
Adelaide
University
Medora
Frances
34
Fuji Drainage
Airport Lead
KC5
KC5
Airport
34
Windsor
FM 2578
British Flying School
KT2
20

0 350 700 1,400 Feet

FIGURE KT1-01

FN JOB NO	TER17602
FILE	KT1-01
DATE	1/13/2020
SCALE	1:8,400
DRAFTED	02730

Existing Conditions - KT1

City of Terrell Drainage Master Plan

FREESE AND NICHOLS
2711 North Haskell Ave.
Suite 3300
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Document Path: H:\STORMWATER\Final Exhibits\01_REPORT\KT1-01.mxd

NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

KC5

Myers

Rockwall

Crenshaw

Medora

Frances

Catherine

Adelaide

Virginia

University

Airport

34

27"

1 - 5'x3'

21"

1 - 6'x3'

21"

21"

24"

1 - 8'x4'

Natural
BW: 6' TW: 20' D: 4'

Natural
BW: 4' TW: 20' D: 1'

42"

1 - 42"

36"

1 - 5'x3'

42"

4'x2'

6'x3'

2 - 7'x4'

2-6'x3'

Natural
BW: 6' TW: 23' D: 4.5'

Natural
BW: 10' TW: 55' D: 5'

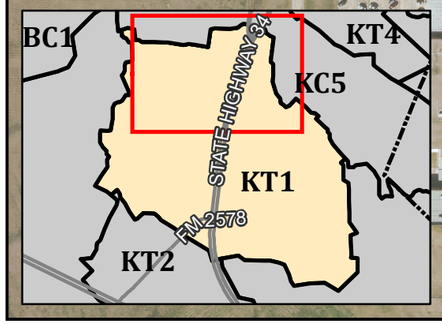
7'x3'

2-48"

30"

Grass Channel
BW: 3' TW: 15' D: 3'

Natural
BW: 3' TW: 15' D: 3'



0 150 300 600 Feet

FN JOB NO	TER17602
FILE	KT1-02
DATE	6/10/2020
SCALE	1:3,600
DRAFTED	02730

FIGURE KT1-02

Infrastructure - KT1

City of Terrell Drainage Master Plan

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NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Buildings Impacted

- Protected - 25YR (4)
- Protected - 100YR (6)
- 25-YR Inundation (0)
- 100-YR Inundation (0)
- Buyout (0)

- Existing 100-YR Floodplain
- Proposed 100-YR Floodplain
- 100-YR FEMA Floodplain

Rockwall
Frances
Virginia
Bethlehem
Crenshaw
Medora
Catherine
Adelaide
34
University
Fuji Drainage
Airport Lead
KC5
Airport
KT2
Windsor
FM 2578
British Flying School
20
0 350 700 1,400 Feet

FIGURE KT1-03

FN JOB NO	TER17602
FILE	KT1-03
DATE	1/10/2020
SCALE	1:8,400
DRAFTED	02730

100-YR Floodplain - KT1

City of Terrell Drainage Master Plan

FREESE NICHOLS AND
2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Watershed
- CIP (by color)
- Small Projects
- City Limits
- Phase 1
- Phase 2
- Phase 3

KC5

14

Myers

Rockwall

Crenshaw

Virginia

Medora

Catherine

Adelaide

34

Airport

University

Frances

1 - 5'x3'

1 - 6'x3'

1 - 8'x4'

End CIP19

1 - 42"

1 - 5'x3'

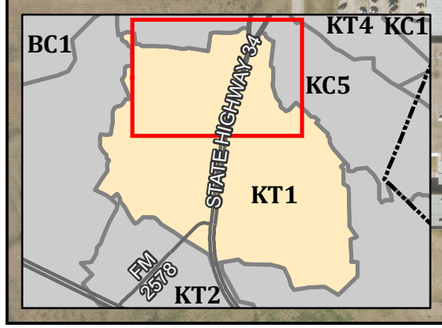
2 - 7'x4'

Begin CIP19

End CIP20

Grass Channel
BW: 3' TW: 15' D: 3'

Begin CIP20



0 150 300 600 Feet

Conceptual Phasing - KT1

City of Terrell Drainage Master Plan

FIGURE KT1-04

FN JOB NO	TER17602
FILE	KT1-04
DATE	6/10/2020
SCALE	1:3,600
DRAFTED	02730

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Drainage Master Plan Update
Project: FUJI DRAINAGE IMPROVEMENTS

Project Information

Project ID:	CIP19	**Status:**	Studied
Project Name:	FUJI DRAINAGE IMPROVEMENTS	**Council District:**	3
Project Type:	Pipe System	**Watershed:**	KT1
Date Identified:	2019	**# Structures Impacted:**	9

Problem Description:

The existing drainage ditch infrastructure does not meet the needs of this area. A significant part of the residential area experiences sheet flow through private property. The culverts crossing SH 34 are undersized and causing a limiting tailwater effect.

Proposed Improvements:

Replace drainage ditches with storm drain along Univeristy Street. Replace open channel south of University Street with storm drain as well. Upsize SH 34 crossing.

Project Photos



Photo 1: Driveway culverts along S Delphine Street



Photo 2: Downstream side of S Medora Street crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	3
20	**Property Damage:**	4
22.5	**Frequency of Flooding:**	5
10	**Project Cost:**	3
17.5	**Public Impact:**	5
	Total Weighted Point Score:	400
	CIP Rank:	5

Project Costs

Total OPCC:	$4,182,000.00
Estimated Easement:	$24,990.00

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KT1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #19: FUJI DRAINAGE IMPROVEMENTS					
1	REMOVAL OF EXISTING CULVERT (6'X3')	458	LF	$ 100	$ 45,800
2	REMOVAL OF EXISTING HEADWALL	6	CY	$ 200	$ 1,200
3	INSTALL 42" RCP	225	LF	$ 201	$ 45,225
4	INSTALL 5'x3' RCB	1,899	LF	$ 320	$ 607,680
5	INSTALL 6'x3' RCB	620	LF	$ 440	$ 272,800
6	INSTALL 7'x4' RCB	480	LF	$ 530	$ 254,400
7	INSTALL 8'x4' RCB	868	LF	$ 610	$ 529,480
8	TRENCH SAFETY	3,852	LF	$ 5	$ 19,260
9	EXCAVATION AND HAUL	3,075	CY	$ 20	$ 61,500
10	ROAD EXCAVATION	1,800	CY	$ 27	$ 48,600
11	ASPHALT PAVEMENT REPLACEMENT	3,557	SY	$ 80	$ 284,560
12	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
13	UTILITY RELOCATION	1	LS	$ 85,479	$ 85,479
14	SWPPP	1	EA	$ 12,700	$ 12,700
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 24,990	$ 24,990

SUBTOTAL		$	2,308,674
ASSOC INFRASTRUCTURE	20%	$	461,735
SUBTOTAL		$	2,770,409
OH&P	15%	$	415,561
SUBTOTAL		$	3,185,970
MOBILIZATION	5%	$	159,299
SUBTOTAL		$	3,345,269
CONTINGENCY	25%	$	836,317
PROJECT TOTAL (2019 COSTS)		**$**	**4,182,000**
COST ESCALATION FACTOR	2.9%	$	643,000
PROJECT TOTAL (2024 COSTS)		**$**	**4,825,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.
2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.

Drainage Master Plan Update
Project: AIRPORT LEAD

Project Information

Project ID:	CIP20	**Status:**	Studied
Project Name:	AIRPORT LEAD	**Council District:**	3
Project Type:	Channel & Road Crossing	**Watershed:**	KT1
Date Identified:	2019	**# Structures Impacted:**	1

Problem Description:

Inconsistent flowline in channel near high traffic and industrial areas is causing ponding and reducing the efficiency of the upstream storm drain.

Proposed Improvements:

Regrade channel from Airport Road until it ties into the main reach. Apply new typical section to increase channel conveyance. Improved channel will allow KC5 overflows to enter KT2 water without overtopping Aiport Road.

Project Photos



Photo 1: Downstream side of Airport Road crossing near railroad crossing



Photo 2: Open channel downstream of Airport Road crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	0
20	**Property Damage:**	0
22.5	**Frequency of Flooding:**	0
10	**Project Cost:**	3
17.5	**Public Impact:**	0
	Total Weighted Point Score:	30
	CIP Rank:	20

Project Costs

Total OPCC:	$2,018,000.00
Estimated Easement:	$3,680.00

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	KT1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #20: AIRPORT LEAD					
1	EXCAVATION AND HAUL	7,305	CY	$ 20	$ 146,100
2	SEED/SOD	46,129	SY	$ 5	$ 230,645
3	GRADING	46,129	SY	$ 15	$ 691,935
4	CLEARING/GRUBBING	10	AC	$ 2,500	$ 25,000
5	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
6	SWPPP	1	EA	$ 48,200	$ 48,200
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 3,680	$ 3,680

SUBTOTAL		$	1,160,560
ASSOC INFRASTRUCTURE	20%	$	232,112
SUBTOTAL		$	1,392,672
OH&P	15%	$	208,901
SUBTOTAL		$	1,601,573
MOBILIZATION	5%	$	80,079
SUBTOTAL		$	1,681,651
CONTINGENCY	20%	$	336,330
PROJECT TOTAL (2019 COSTS)		**$**	**2,018,000**
COST ESCALATION FACTOR	2.9%	$	310,000
PROJECT TOTAL (2024 COSTS)		**$**	**2,328,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.

2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.

KT2

STUDY AREA: KT2

BACKGROUND

KT2 drainage area is generally west of SH 34 and north of IH 20 and drains east to its confluence with Kings Creek near the City Limits. The watershed is partially undeveloped but includes part of the Tanger Outlet development, other Interstate Commercial development, Home Depot, and several multifamily residential developments. The primary channel begins at FM2578 just southwest of Windsor Avenue, and enters a storm drain system at the Home Depot on Windsor Avenue. The storm drain outfalls on the east side of the Home Depot parking lot north of IH 20, where it joins with storm drain outfalls from the Tanger Development that crosses IH 20. Open channel flow resumes, flowing southeast and then northeast to the crossing of SH 34, where it enters another storm drain installed as part of the QT gas station prior to 2017.

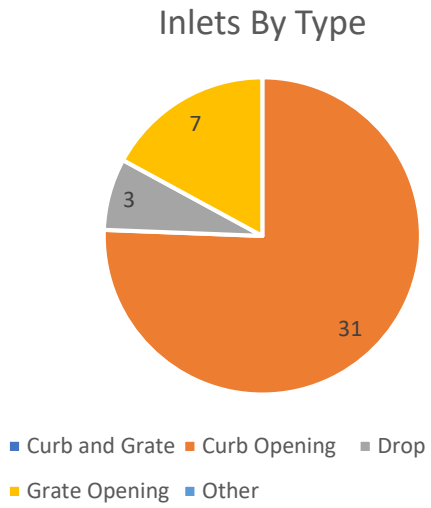
Existing storm drain systems are present throughout the watershed and are generally in fair condition.

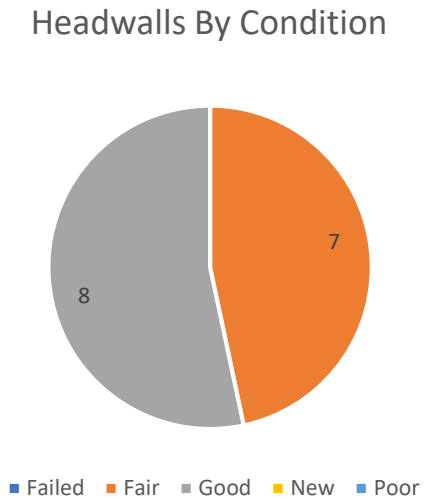
Rain-on-mesh analysis shows the undeveloped areas are storing a significant amount of water, but the results are not necessarily applicable because of the extensive storm drain use in the watershed.

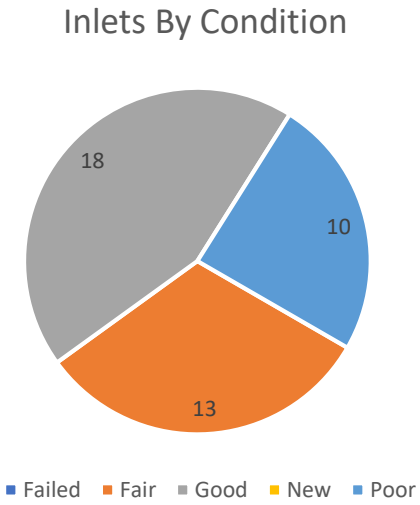
DATA COLLECTED

The 1989 Drainage Master Plan did not identify any projects in the watershed, as it was even less developed at the time.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 41 inlets, 15 headwalls, and 2.3 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 1.







Conduit by Width	
Conduit Width	Total Length (ft)
2'	4,218
3'	2,120
4'	1,207
6'	462
8'	88
<Null>	3,976

Figure 1: Summary graphs of watershed infrastructure

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the Far South ICM model. A map depicting the area of study for is shown in Exhibit KC6-01.

Results of the data collection and modeling show:

- 7 flooded roadway block segments with a maximum depth of 2.2 feet in the 100-year storm
- 14 properties experience flooding during the 100-year storm

- No structures are flooded until the 100-year storm
- The public noted flooding in no areas and there was only 1 maintenance work order performed between 2013-2017

SYSTEM DEFICIENCIES

No significant flood prone zones were identified in the study area, however, some properties, when developed, will need to address local drainage issues, especially those located along Windsor Drive just west of SH 34. The City should expect to see additional detention mitigation, which could perhaps be handled by a regional detention facility, with the primary goal to prevent the overloading of the storm drain system that has replaced the original channel alignment.

PROPOSED IMPROVEMENTS

The major drainage infrastructure includes storm drain lines, open channels, and a detention pond. There are no proposed improvements at this time, but the existing infrastructure is shown in Exhibit KT2-02.

In the future, the City might consider a regional detention solution to better facilitate development of the area near Windsor Avenue.

Small Projects

There were no small projects identified within this watershed.

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

KT1

KC6

FM 2578

Tanger

Windsor

34

20

Legend

Watershed

City Limits

Inundated Buildings

25-YR Inundation (0)

100-YR Inundation (1)

Depth

< 0.5'

0.5' - 1.0'

1.0' - 2.0'

2.0' - 3.0'

> 3.0'

2D Model Extent

1D Model Extent

100-YR FEMA Floodplain

0 200 400 800 Feet

FIGURE KT2-01

FN JOB NO	TER17602
FILE	KT2-01
DATE	1/13/2020
SCALE	1:4,800
DRAFTED	02730

Existing Conditions - KT2

City of Terrell Drainage Master Plan

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

KT1

39"
42"
42"
3-36"
Natural
BW: 30' TW: 165' D: 4.5'
Natural
BW: 9' TW: 65' D: 3.5'
34
FM 2578
33"
9'x4'
Windsor
Natural
BW: 2' TW: 14' D: 4'
Natural
BW: 7' TW: 32' D: 4'
Natural
BW: 3' TW: 16' D: 4'
Natural
BW: 30' TW: 64' D: 7'
33"
42"
4-6'x3'
34
20
36"
2-36"
36"
2-36"
Tanger
36"
KC6

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

0 200 400 800 Feet

FIGURE KT2-02

FN JOB NO	TER17602
FILE	KT2-02
DATE	1/9/2020
SCALE	1:4,800
DRAFTED	02730

Infrastructure - KT2

City of Terrell Drainage Master Plan

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Dallas, Texas 75204
P: 214-217-2200

KT3

STUDY AREA: KT3

BACKGROUND

KT3 drainage area is generally bounded by Catherine and Frances Street to the west, and does not follow the grid structure on the north and south boundaries. The watershed is slightly more than halfway undeveloped and includes the north side of the city hospital. A natural drainage pattern can be seen starting just north of the Virginia and James Streets intersection. The primary channel truly starts downstream of the Blanche Street crossing. Shortly after it begins to spill into the Kings Creek Floodplain. The upper half of the KT3 watershed is a mix of general ponding and driveway ditch drainage.

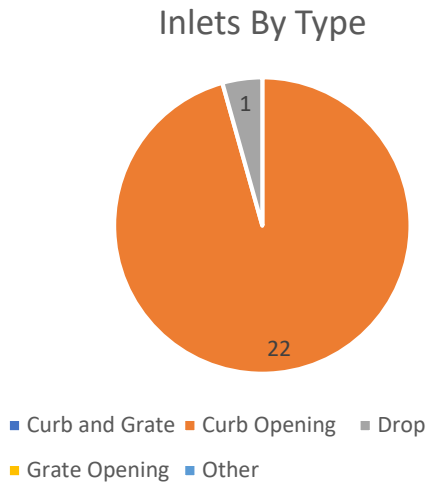
Existing storm drain systems are present only on SH 34. The existing storm drain system is in good condition due to the recent road projects by TxDOT.

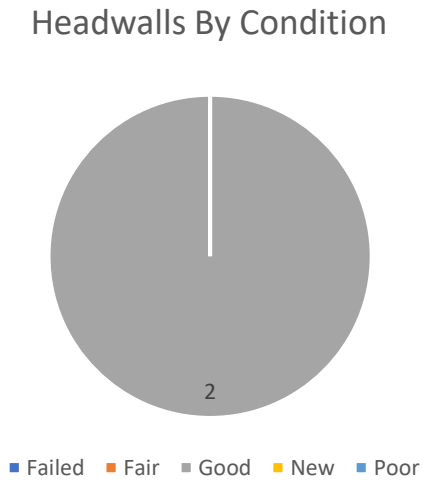
Rain-on-mesh analysis shows that most of the rainfall is conveyed or stored by the driveway ditches prevalent in the upper half of the watershed. There is a significant amount of ponding on personal property due to the current terrain.

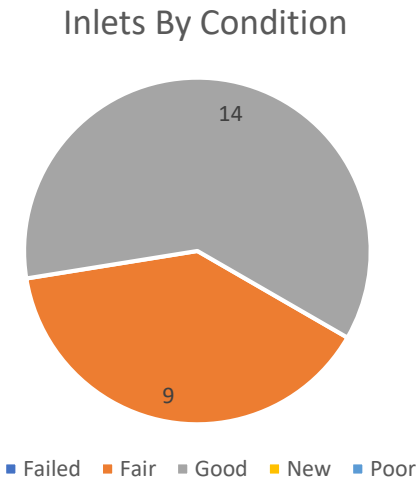
DATA COLLECTED

The 1989 Drainage Master Plan did not identify any projects in the watershed, as it was even less developed at the time.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 23 inlets, 2 headwalls, and 0.6 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 1.







Conduit by Width	
Conduit Width	Total Length (ft)
2'	2,051
3'	1,030
7'	98

Figure 1: Summary graphs of watershed infrastructure

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzed existing hydraulic conditions using the ROM results. A map depicting the area of study is shown in Exhibit KT3-01.

Results of the data collection and modeling show:

- 3 flooded roadway block segments with a maximum depth of 1.4 feet in the 100-year storm
- 8 properties experience flooding during the 100-year storm
- No structures are flooded during the 100-year storm

- The public noted flooding in 4 areas and there were 22 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

No significant flood prone zones were identified in the study area, however, some properties, when developed, will need to address local drainage issues, especially those located north of the hospital. The City should expect to see additional detention mitigation, which could perhaps be handled by a regional detention facility.

PROPOSED IMPROVEMENTS

The major drainage infrastructure includes a storm drain line, natural channels, and a detention pond. There are no proposed improvements at this time, but the existing infrastructure is shown in Exhibit KT3-02.

The public survey responses yielded comments from James Street, Cherokee Street, and N San Jacinto. The street and yard flooding mentioned could be addressed through City maintenance to the local driveway ditches.

In the future, the City might consider a regional detention solution to better facilitate development of the area near north of the hospital. Drainage easements in the areas of significant ponding may also be considered in between the backyards to reduce impact on personal property.

Small Projects

The following small projects are within this watershed:

- Rose St at N. Blanche Washout — Remove accumulated silt and transition from the outfall into the natural channel

A summary of the projects and the suggested implementation order is located in Table 1.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Rose St. at Blanche Washout	$ 75,400
		Total Small Project Cost	**$ 75,400**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Inundated Buildings

- 25-YR Inundation (0)
- 100-YR Inundation (0)

Depth

- < 0.5'
- 0.5' - 1.0'
- 1.0' - 2.0'
- 2.0' - 3.0'
- > 3.0'

- 2D Model Extent
- 1D Model Extent
- 100-YR FEMA Floodplain

KC3

KC2

Frances
McCoulskey
San Jacinto
James
Virginia
Catherine
Cherokee
Rose
34
Blanche
Alamo
Adelaide

0 150 300 600 Feet

FIGURE KT3-01

FN JOB NO	TER17602
FILE	KT3-01
DATE	1/9/2020
SCALE	1:3,600
DRAFTED	02730

Existing Conditions - KT3

City of Terrell Drainage Master Plan

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

KC3

KC2

Frances
McCoulskey
San Jacinto
Rose
James
Virginia
Catherine
Cherokee
Alamo
Adelaide
Blanche
34

7'x3'
36"
24"
24"

0 150 300 600 Feet

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FIGURE KT3-02

FN JOB NO	TER17602
FILE	KT3-02
DATE	1/9/2020
SCALE	1:3,600
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Infrastructure - KT3

City of Terrell Drainage Master Plan

FREESE NICHOLS
2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

KT4

STUDY AREA: KT4

BACKGROUND

KT4 drainage area generally includes the Stallings Addition residential community and the open area to the southeast. It drains southeast to its confluence with Kings Creek near the City Limits. The primary channel starts to form at the community's outfall on the southeast side. Shortly after the channel starts, there is a combination of detention ponds. The watershed is about halfway developed.

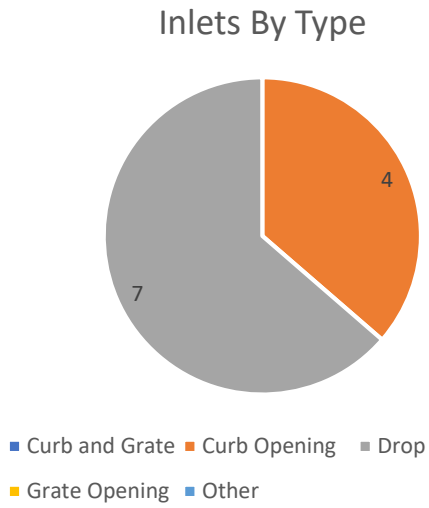
A minimal amount of existing storm drain is present in the residential community. The existing storm drain system is in fair or better condition.

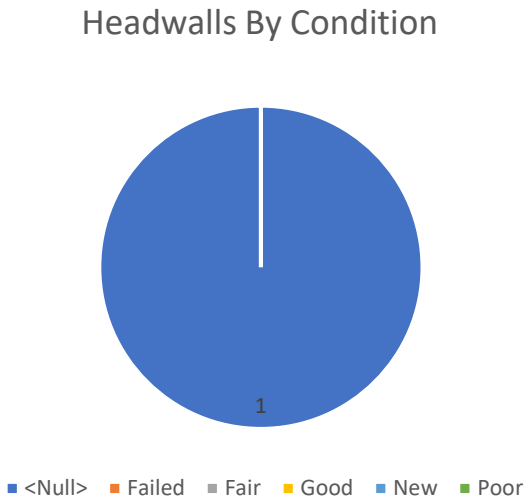
Rain-on-mesh analysis shows the driveway ditches that make up most of the watershed are partially effective. There are still multiple road overtopping instances and significant ponding on personal property.

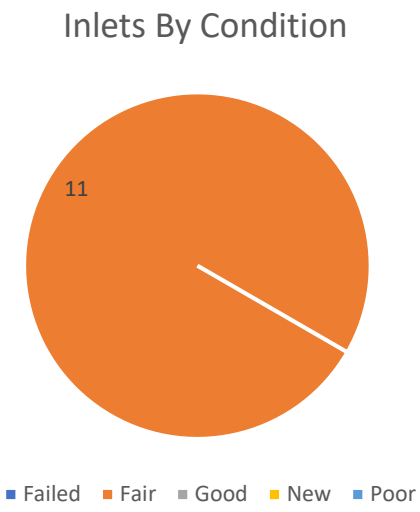
DATA COLLECTED

The 1989 Drainage Master Plan did not identify any projects in the watershed.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 11 inlets, one headwall, and 0.3 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 1.







Conduit by Width	
Conduit Width	Total Length (ft)
2'	252
3'	412
4'	817

Figure 1: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzed existing hydraulic conditions using the ROM results. A map depicting the area of study is shown in Exhibit KT4-01.

Results of the data collection and modeling show:

- 3 flooded roadway block segments with a maximum depth of 1.4 feet in the 100-year storm

- 8 properties experience flooding during the 100-year storm
- No structures are flooded during the 100-year storm
- The public noted flooding in no areas and there were 11 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

No significant flood prone zones were identified in the study area, however, if additional properties are developed, the City will need to expect to see additional detention mitigation, which could perhaps be handled by a regional detention facility.

PROPOSED IMPROVEMENTS

The major drainage infrastructure includes a storm drain line, natural channels, and detention ponds. There are no proposed improvements at this time, but the existing infrastructure is shown in Exhibit KT4-02.

In the future, the City might consider a regional detention solution to better facilitate development of the area on the southeast half of the hospital.

Small Projects

There were no small projects identified within this watershed.

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

KC1

KC5

College Mound

Legend

Watershed

City Limits

Inundated Buildings

25-YR Inundation (0)

100-YR Inundation (0)

Depth

< 0.5'

0.5' - 1.0'

1.0' - 2.0'

2.0' - 3.0'

> 3.0'

2D Model Extent

1D Model Extent

100-YR FEMA Floodplain

0 150 300 600 Feet

Existing Conditions - KT4

City of Terrell Drainage Master Plan

FIGURE	KT4-01
FN JOB NO	TER17602
FILE	KT4-01
DATE	1/9/2020
SCALE	1:3,600
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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

KC1

34

College Mound

KC5

KT1

Airport

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

0 150 300 600 Feet

FIGURE KT4-02

FN JOB NO	TER17602
FILE	KT4-02
DATE	1/9/2020
SCALE	1:3,600
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Infrastructure - KT4

City of Terrell Drainage Master Plan

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BC1

STUDY AREA: BC1

BACKGROUND

BC1 drainage area boundaries do not follow the street grid, but the watershed lies entirely southwest of Griffith Avenue, entirely west of Bowser Circle and drains to the west and south to Bachelor Creek. Reach BC1 becomes a significant channel between the parks and the Terrell ISD stadium, which follows a course nearly due south. BC1 upstream of US 80 is called the Stadium Channel. BC1 between US 80 and the UPRR Railroad is called the Cemetery Channel.

A portion of the BC1 watershed drains to a dam in Ben Gill Park, which outfalls to a natural creek before ultimately draining into Bachelor Creek. There is a watershed overflow from the BC1 watershed to this watershed between Colquitt Road and the Stadium Channel.

Existing storm drain systems are present mostly in the upper watershed on 9th Street, Colquitt Road, and US 80. The existing storm drain systems vary in age and condition, though are generally in fair or better condition.

Rain-on-mesh analysis shows that storm drain systems exist and there are few areas where flood depths are significant outside the Right-of-Way (ROW) though, in some instances, the depths in the ROW are significant.

DATA COLLECTED

The 1989 Drainage Master Plan identified a project called Line “E” with multiple branches for a total of $320,000 (1989 dollars). The proposed project from that study is shown in Figure 1. New improvements have been made in the vicinity of this project and are included in the analysis of the system.

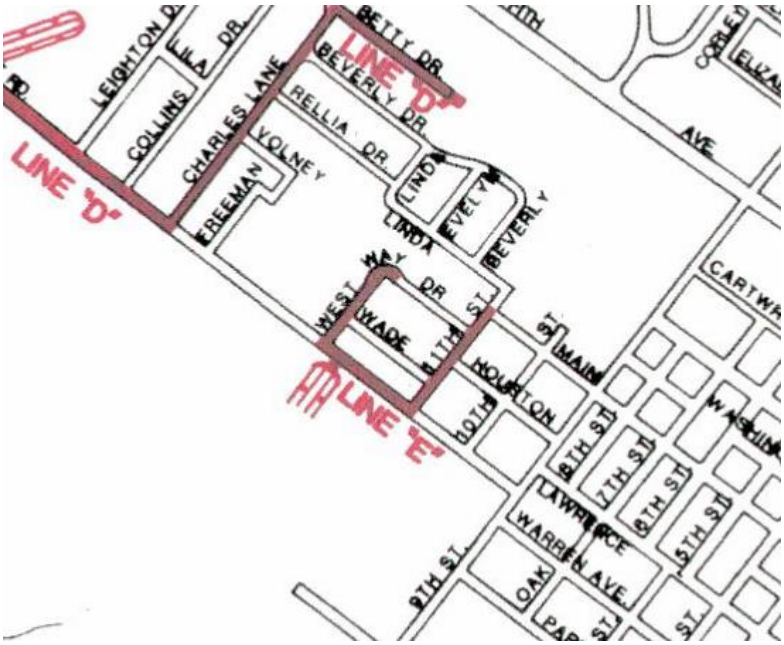
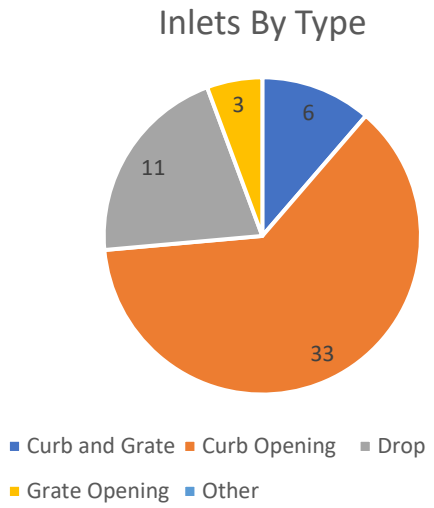
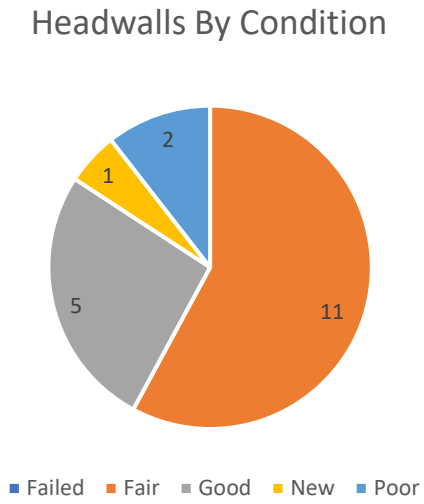


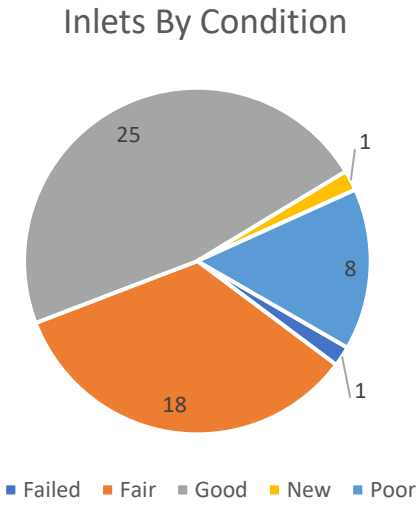
Figure 1: Proposed structures from 1989 Drainage Master Plan.

Part of the previously identified project has been completed although the final design differs from what is shown in Figure 1. There is less storm drain on 11th Street, more on 10th. Also, Line D drains to the southeast and outfalls at the same location as Line E is shown in Figure 1.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 53 inlets, 19 headwalls, and 2.0 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 2.







Conduit by Width	
Conduit Width	Total Length (ft)
1'	89
2'	5,511
3'	1,620
4'	1,582
5'	1,229
6'	83
9'	54
10'	585

Figure 2: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the BC1 HEC-RAS model and the West ICM model.

Upper watershed storm drains were modeled using InfoWorks ICM. Lower watershed open channels were modeled using HEC-HMS and HEC-RAS to the confluence with Bachelor Creek. A map depicting the area of study for each component is shown in Exhibit BC1-01.

Results of the data collection and modeling show:

- 39 flooded roadway block segments with a maximum depth of 2.6 feet in the 100-year storm
- 3 properties experience flooding during the 100-year storm
- The first structure is flooded in the 10-year storm
- The public noted flooding in 2 areas and there were 19 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

There are several different flood prone zones identified within the study area that have separate solutions. In general, there are three (3) primary drivers for the causes of flooding within the watershed:

Bottlenecks at culvert crossings — Existing culvert crossings are sized in such a way that the culverts do not increase in size when going from upstream to downstream. For example, the US 80 culvert, currently a 10'x8' RCB, is larger than either the UPRR culvert, currently 6'x4' RCB, and the West End Drive culvert, currently 5'x2' RCB. These undersized culverts serve to create a backwater effect that increases the flooding at the upstream face of each culvert. The culverts are seen as the principal issue in the watershed.

Inefficient and undersized channels — Many open channels in the watershed are sufficiently sized, but do not have a consistent slope or section, leading to inefficient conveyance properties. Other open channels are undersized and need to be expanded to convey the full design flow.

Watershed spill — Because of the lack of capacity for efficient flow in culverts and channels, flows are transferring across the watershed divide and instead of flowing south, they flow west and cause flow to spill from the side of the dam in Ben Gill Park.

PROPOSED IMPROVEMENTS

The major drainage infrastructure in the watershed generally needs to be overhauled, with most of the work being represented by upsized open channels. The proposed infrastructure improvements are shown in Exhibit BC1-02.

New culverts at West End Drive, UPRR crossing, US 80, throughout the park, and adjacent to the Cemetery remove the bottlenecking of flows, but without any additional channel improvement, will only move flooding to new locations by passing the increased flows downstream.

Channel improvements will be required to provide adequate conveyance of the design flow, but also to establish a confined floodplain extent by providing new valley storage volume.

Implementing the channel and culvert improvements identified will reduce the volume of flood water that spills across the watershed boundary.

Flooding was noted at the intersection of 9th Street and US 80 via modelling as well as through the public survey. This issue will need to be addressed my TxDOT. It is proposed that the City make sure the data from this study is made available to TxDOT to utilize when they assess drainage in this area.

The combined effect of the proposed improvements results in the improved 100-year floodplain shown in Exhibit BC1-03. The high depths detained in the watershed are significantly reduced and the flooding is better contained to the park and proposed drainage easements.

The combined improvements in this watershed are expected to increase discharges downstream. Detention to mitigate approximately 26 acre-feet should be considered during the more detailed design phase prior to implementation to mitigate downstream adverse impacts.

Cost estimates were prepared for each project. In total the cost for the projects within the watershed is approximately $6.6 million to meet current City criteria, with more detail shown in the OPCCs.

IMPLEMENTATION

The costs for all the improvements in the study area exceed what can feasibly be financed from the City's current revenue streams without significant modification. FNI recommends breaking the projects into discrete segments based on ability to fund each. Projects should be implemented from downstream to upstream to achieve optimal drainage conditions, as seen in the conceptual phasing outlined in Exhibit BC1-04. The sequencing explained below takes ranking, feasibility, and coordination into consideration. Phased costs are estimated based on the tabulated OPCC for each full CIP.

CIP02: West End Street Culvert Improvements

CIP02 can be implemented in a single phase at a cost of around $698,000. This culvert and channel improvement project is critical to improving the drainage upstream and must be done first so there is no

adverse impact downstream. Channel improvements may need to extend upstream of West End Street to maximize the use of Nationwide Permits for compliance with Section 404 (this would increase the cost based on the extent).

CIP03: BC1 Railroad Crossing (UPRR183.74) & Channel Improvements

CIP03 should follow next after CIP02 and can also be completed in one Phase. It will extend the typical section up to the railroad and upsize the railroad crossing for a cost of approximately $1.3 million. Upsizing the Railroad Crossing will require coordination with UPRR. FNI performed an analysis of the railroad crossing and included a draft version of the application forms that UPRR requires for submittal. UPRR is a potential funding source for the proposed improvements. Channel improvements may need to extend upstream of the railroad to maximize the use of Nationwide Permits for compliance with Section 404, and would increase the cost based on the extent, however any work done as part of CIP02 north of West End Street could be deducted from the total cost.

CIP04: Cemetery Channel Improvements

There are three logical phases for CIP04 improvements: CIP04 Phase 1 would extend the typical section from the railroad to the US 80 culvert outfall, for an estimated $500,000. CIP05 Phases 1 and 2 would be most likely to proceed next, to address the more pressing flooding concerns.

If drainage infrastructure located along the CIP04 alignment is observed to fail before CIP05, FNI recommends addressing CIP04 Phase 2 and 3 next, at an estimated cost of $2.3 million combined. These two phases include a significant amount of existing storm drain/culvert, and engineered channels, so Nationwide Permit applicability may not be as stringent.

CIP05: Stadium Channel Improvements

The Stadium Channel Improvements could be implemented in three phases. CIP05 Phase 1 would include the channel improvements at the downstream end of the park for an approximate cost of $850,000.

CIP05 Phase 2 would be the extension of the typical section through the park adjacent to the Stadium, up to 9th Street for an approximate cost of $500,000.

CIP05 Phase 3 would complete the typical section through the park including the culvert crossing of Lions Club Lane at an approximate cost of $450,000.

CIP06: SWCC Railroad Crossing (UPRR183.15) Improvements

CIP06 should be done last and only if a failure occurs with the existing culvert, at an approximate cost of $126,000. The culvert should be replaced in kind and will require coordination with UPRR. FNI performed an analysis of the railroad crossing and included a draft version of the application forms that UPRR requires for submittal. UPRR is a potential funding source for the proposed improvements.

Small Projects

The following small projects are within this watershed:

- Gill Park/Lions Club Lane — Provide drainage relief for the Chamber of Commerce building. FNI developed two options, one is a channel and culvert flowing south across US 80, and the other is a channel and culvert flowing east through the park to the existing channel.
- Park/Moore — Address erosion that is undermining headwalls. This small project may be omitted if the channel improvements of CIP04 are implemented soon.
- Cemetery — Channel improvements to improve drainage of daily flows. This small project may be omitted if the channel improvements of CIP04 are implemented soon.

A summary of the projects and the suggested implementation order is located in Table 1. Costs have been conservatively rounded up during the estimating process and will need to be refined as part of the future design process.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Gill Park/Lions Club Lane	$ 167,400
	2	Cemetery	$ 138,300
	3	Park/Moore	$ 30,800
		Total Small Project Cost	**$ 336,500**
Large Projects	4	CIP02	$ 698,000
	5	CIP03	$ 1,258,000
	6	CIP04 Phase 1	$ 500,000
	7	CIP05 Phase 1	$ 850,000
	8	CIP05 Phase 2	$ 500,000
	9	CIP05 Phase 3	$ 450,000
	10	CIP04 Phase 2	$ 1,200,000
	11	CIP04 Phase 3	$ 1,100,000
	12	CIP06 Phase 1	$ 126,000
		Total Large Project Cost	**$ 6,682,000**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

Watershed

City Limits

Inundated Buildings

25-YR Inundation (3)

100-YR Inundation (3)

Depth

< 0.5'

0.5' - 1.0'

1.0' - 2.0'

2.0' - 3.0'

> 3.0'

2D Model Extent

1D Model Extent

100-YR FEMA Floodplain

205

Colquitt

Griffith

Damon

Elm

9th

Lions Club

Stadium Channel

Pacific

College

80

Nash

Bowser

Railroad Crossing

Cemetery Channel

West End

Grove

Cottage

Rockwall

West End Street Culvert

Rochester

Myers

Bethlehem

Crenshaw

Medora

Frances

0 450 900 1,800 Feet

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Existing Conditions - BC1

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC1-01
DATE	1/13/2020
SCALE	1:10,800
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FIGURE
BC1-01

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

BC5

KC5

West End

Colquitt

9th

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

Grass Channel
BW: 12' TW: 60' D: 4'

3 - 36"

Natural
BW: 4' TW: 50' D: 2'

Natural
BW: 5' TW: 28' D: 2'

3 - 36"

Grass Channel
BW: 6' TW: 60' D: 3'

Grass Channel
BW: 12' TW: 60' D: 6'

Natural
BW: 6' TW: 18' D: 3'

Grass Channel
BW: 12' TW: 60' D: 2.5'

Grass Channel
BW: 12' TW: 60' D: 4'

Natural
BW: 12' TW: 23' D: 3.4'

Natural
BW: 6' TW: 20' D: 6'

5 - 48"

Natural
BW: 6' TW: 20' D: 3'

Concrete
BW: 7.5' TW: ' D: 0.5'

Grass Channel
BW: 12' TW: 60' D: 4'

Natural
BW: 17' TW: 40' D: 4'

54"

48"

2 - 10'x8'

Grass Channel
BW: 56' TW: 80' D: 4'

1 - 54"

1 - 54"

Natural
BW: 7' TW: 21' D: 2'

80

Natural
BW: 10' TW: 62' D: 6'

1 - 54"

Grass Channel
BW: 6' TW: 50' D: 7'

1 - 54"

80

Natural
BW: 2' TW: 80' D: 4'

Concrete
BW: 6.5' TW: 6.5' D: 1.5'

Natural
BW: 8' TW: 131' D: 4'

Grass Channel
BW: 6' TW: 50' D: 7'

1 - 54"

2 - 10'x4'

6'x4'

Natural
BW: 5' TW: 73' D: 5'

Concrete Channel
BW: 13' TW: 13' D: 4.5'

1 - 48"

Grass Channel
BW: 80' TW: 130' D: 5'

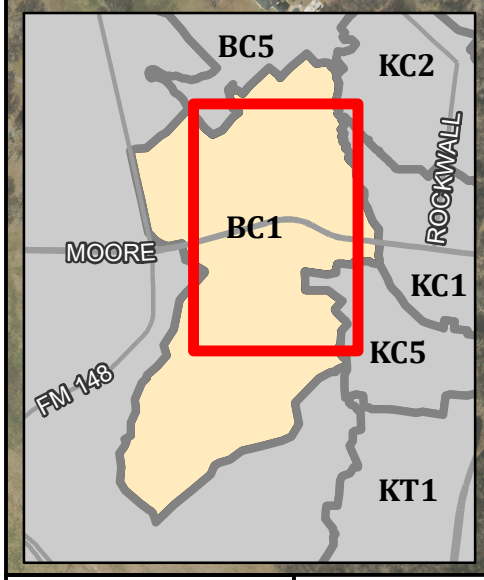
Natural
BW: 5' TW: 35' D: 2.5'

Natural
BW: 18' TW: 40' D: 3'

3 - 10'x4'

5'x2'

Grass Channel
BW: 20' TW: 98' D: 4'



0 200 400 800 Feet

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Infrastructure - BC1

City of Terrell Drainage Master Plan

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FIGURE
BC1-02

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NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

- Watershed
- City Limits

Buildings Impacted

- Protected - 25YR (3)
- Protected - 100YR (3)
- 25-YR Inundation (0)
- 100-YR Inundation (0)
- Buyout (0)

- Existing 100-YR Floodplain
- Proposed 100-YR Floodplain
- 100-YR FEMA Floodplain

BC5
KC1
KC2
KC5
KT1
Colquitt
Griffith
Damon
Elm
9th
Lions Club
Stadium Channel
Cemetery Channel
Railroad Crossing
West End Street Culvert
West End
College
Nash
Bowser
Grove
Cottage
Rochester
Rockwall
Myers
Bethlehem
Crenshaw
Medora
Frances
205
80
0 450 900 1,800 Feet

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100-YR Floodplain - BC1

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC1-03
DATE	1/9/2020
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FIGURE
BC1-03

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Conceptual Phasing - BC1

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC1-04
DATE	6/10/2020
SCALE	1:4,800
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FIGURE
BC1-04

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Drainage Master Plan Update
Project: WEST END ST. CULVERT

Project Information

Project ID:	CIP02	**Status:**	Studied
Project Name:	WEST END ST. CULVERT	**Council District:**	2
Project Type:	Channel & Road Crossing	**Watershed:**	BC1
Date Identified:	2019	**# Structures Impacted:**	3

Problem Description:

Culvert crossing is significantly smaller than that of the railroad upstream. Detention occurs until the flows spill over West End Street.

Proposed Improvements:

Raise the road profile at the West End Street sag and upsize culvert crossing conveyance. Take care to protect private residential immediately downstream and apply channel improvements to transition from road crossing to the natural channel downstream.

Project Photos



Photo 1: Upstream side of West End Street crossing



Photo 2: Open channel downstream of West End Street crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	1
20	**Property Damage:**	3
22.5	**Frequency of Flooding:**	3
10	**Project Cost:**	5
17.5	**Public Impact:**	0
	Total Weighted Point Score:	207.5
	CIP Rank:	14

Project Costs

Total OPCC:	$698,000.00
Estimated Easement:	$56,360.00

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	BC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #02: WEST END ST. CULVERT					
1	REMOVAL OF EXISTING CULVERT (5'X2')	60	LF	$ 100	$ 6,000
2	REMOVAL OF EXISTING HEADWALL	12	CY	$ 200	$ 2,400
3	RAISE WESTEND ST.	1	LS	$ 50,000	$ 50,000
4	INSTALL 10'X4' RCB	75	LF	$ 1,750	$ 131,250
5	HEADWALL (MEDIUM)	2	EA	$ 15,000	$ 30,000
6	GRADING	2,629	SY	$ 15	$ 39,435
7	TRENCH SAFETY	226	LF	$ 5	$ 1,130
8	SEED/SOD	2,629	SY	$ 5	$ 13,145
9	EXCAVATION AND HAUL	1,436	CY	$ 20	$ 28,720
10	TRAFFIC CONTROL PLAN	1	LS	$ 20,000	$ 20,000
11	CLEARING/GRUBBING	1	AC	$ 2,500	$ 2,500
12	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
13	SWPPP	1	EA	$ 5,000	$ 5,000
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 56,360	$ 56,360

SUBTOTAL		$ 400,940
ASSOC INFRASTRUCTURE	20%	$ 80,188
SUBTOTAL		$ 481,128
OH&P	15%	$ 72,169
SUBTOTAL		$ 553,297
MOBILIZATION	5%	$ 27,665
SUBTOTAL		$ 580,962
CONTINGENCY	20%	$ 116,192
PROJECT TOTAL (2019 COSTS)		**$ 698,000**
COST ESCALATION FACTOR	2.9%	$ 107,000
PROJECT TOTAL (2024 COSTS)		**$ 805,000**

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Drainage Master Plan Update
Project: BC1 RAILROAD CROSSING & CHANNEL IMPROVEMENTS

Project Information

Project ID:	CIP03	**Status:**	Studied
Project Name:	BC1 RAILROAD CROSSING & CHANNEL IMPROVEMENTS	**Council District:**	2
Project Type:	Channel & RR Crossing	**Watershed:**	BC1
Date Identified:	2019	**# Structures Impacted:**	4

Problem Description:

Railroad crossing (UPRR 183.74) is significantly undersized and damming up water halfway through the watershed. Railroad does not overtop, but high depths of water collect immediately upstream and the resulting tailwater effect can be seen throughout the system via significant depths in and outside the ROW. Tailwater effect also causes flows to exceed channel capacities and result in overland flow to adjacent watershed.

Proposed Improvements:

Upsize railroad crossing in cooperation with UPRR. Widen channel downstream to contain increased flows. Extend channel improvements upstream as necessary to provide stable transition to new culvert crossing.

Project Photos



Photo 1: Upstream side of railroad crossing



Photo 2: Channel on downstream side of railroad crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	4
20	**Property Damage:**	3
22.5	**Frequency of Flooding:**	3
10	**Project Cost:**	4
17.5	**Public Impact:**	0
	Total Weighted Point Score:	287.5
	CIP Rank:	9

Project Costs

Total OPCC:	$1,258,000.00
Estimated Easement:	$49,420.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	BC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #03: BC1 RAILROAD CROSSING (UPRR 183.74) & CHANNEL IMPROVEMENTS					
1	REMOVAL OF EXISTING CULVERT (6'X4')	35	LF	$ 100	$ 3,500
2	REMOVAL OF EXISTING HEADWALL	24	CY	$ 200	$ 4,800
3	EXCAVATION AND HAUL	5,304	CY	$ 20	$ 106,080
4	INSTALL 10'X4' RCB	76	LF	$ 1,750	$ 133,000
5	HEADWALL (LARGE)	2	EA	$ 20,000	$ 40,000
6	BORE CULVERT (10'X4')	76	LF	$ 4,500	$ 342,000
7	SHORING	810	SF	$ 25	$ 20,250
8	GRADING	93	SY	$ 15	$ 1,395
9	SEED/SOD	93	SY	$ 5	$ 465
10	CLEARING/GRUBBING	1	AC	$ 2,500	$ 2,500
11	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
12	SWPPP	1	EA	$ 5,000	$ 5,000
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 49,420	$ 49,420

SUBTOTAL		$	723,410
ASSOC INFRASTRUCTURE	20%	$	144,682
SUBTOTAL		$	868,092
OH&P	15%	$	130,214
SUBTOTAL		$	998,306
MOBILIZATION	5%	$	49,915
SUBTOTAL		$	1,048,221
CONTINGENCY	20%	$	209,644
PROJECT TOTAL (2019 COSTS)		**$**	**1,258,000**
COST ESCALATION FACTOR	2.9%	$	193,000
PROJECT TOTAL (2024 COSTS)		**$**	**1,451,000**

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NOTES:

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Drainage Master Plan Update
Project: CEMETERY CHANNEL

Project Information

Project ID:	CIP04	**Status:**	Studied
Project Name:	CEMETERY CHANNEL	**Council District:**	2
Project Type:	Pipe System / Channel	**Watershed:**	BC1
Date Identified:	2019	**# Structures Impacted:**	4

Problem Description:

There are inconsistent flowlines, an outfall that is partially behind another headwall, and intermittent channel and storm drain sections. These factors are causing ponding within the system. The headwall arrangement contributes to scour and puts the structural component at risk.

Proposed Improvements:

Replace channel currently located between two storm drains with storm drain. Implement consistent flowline with proposed infrastructure to reduce long term ponding and increase drainage efficiency. Renovate wingwalls of adjacent headwalls to connect.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	4
20	**Property Damage:**	3
22.5	**Frequency of Flooding:**	2
10	**Project Cost:**	3
17.5	**Public Impact:**	4
	Total Weighted Point Score:	325
	CIP Rank:	8

Project Costs

Total OPCC:	$2,730,000.00
Estimated Easement:	$242,440.00

Project Photos



Photo 1: Undefined channel geometry at downstream section of cemetery channel system



Photo 2: Example of inconsistent flowline in cemetery channel system

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	BC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #04: CEMETERY CHANNEL					
1	REMOVAL OF EXISTING CULVERT (36")	75	LF	$ 45	$ 3,375
2	REMOVAL OF EXISTING CULVERT (48")	199	LF	$ 50	$ 9,950
3	REMOVAL OF EXISTING CULVERT (54")	569	LF	$ 60	$ 34,140
4	REMOVAL OF EXISTING CULVERT (4'X3')	432	LF	$ 60	$ 25,920
5	INSTALL 54" RCP	1,059	LF	$ 278	$ 294,402
6	EXCAVATION AND HAUL	9,888	CY	$ 20	$ 197,760
7	REMOVE CONCRETE CHANNEL	344	SY	$ 20	$ 6,880
8	REMOVAL OF EXISTING HEADWALL	15	CY	$ 200	$ 3,000
9	HEADWALL (SMALL)	6	EA	$ 10,000	$ 60,000
10	UTILITY RELOCATION	1	LS	$ 14,720	$ 14,720
11	TRENCH SAFETY	3,760	LF	$ 5	$ 18,800
12	ROAD EXCAVATION	353	CY	$ 27	$ 9,531
13	ASPHALT PAVEMENT REPLACEMENT	765	SY	$ 80	$ 61,200
14	GRADING	23,237	SY	$ 15	$ 348,555
15	SEED/SOD	23,237	SY	$ 5	$ 116,185
16	CONCRETE LINING	1,513	SY	$ 100	$ 151,300
17	CLEARING/GRUBBING	5	AC	$ 2,500	$ 12,500
18	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
19	SWPPP	1	EA	$ 12,400	$ 12,400
20	EASEMENTS	1	LS	$ 242,440	$ 242,440
	SUBTOTAL				$ 1,638,058
	ASSOC INFRASTRUCTURE		20%		$ 327,612
	SUBTOTAL				$ 1,965,670
	OH&P		15%		$ 294,850
	SUBTOTAL				$ 2,260,520
	MOBILIZATION		5%		$ 113,026
	SUBTOTAL				$ 2,373,546
	CONTINGENCY		15%		$ 356,032

PROJECT TOTAL (2019 COSTS)			**$ 2,730,000**
COST ESCALATION FACTOR	2.9%	$	419,000
PROJECT TOTAL (2024 COSTS)		**$**	**3,149,000**

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NOTES:

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2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.

Drainage Master Plan Update
Project: STADIUM CHANNEL

Project Information

Project ID:	CIP05	**Status:**	Studied
Project Name:	STADIUM CHANNEL	**Council District:**	2
Project Type:	Channel & Road Crossing	**Watershed:**	BC1
Date Identified:	2019	**# Structures Impacted:**	3

Problem Description:

Channels are undersized for developed condition flows. A significant amount of overflow occurs resulting in inundation of nearby structures and significant depths in the park.

Proposed Improvements:

Implement proposed typical sections that will increase channel capacity and maintain consistent flowlines. Upsize culvert crossings to increase conveyance, reduce debris accumulation, and improve drainage of the local facilities.

Project Photos



Photo 1: Open channel on upstream side of Highway 80 crossing



Photo 2: Upstream side of culvert crossing at Lion Clubs Lane

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	2
20	**Property Damage:**	2
22.5	**Frequency of Flooding:**	2
10	**Project Cost:**	4
17.5	**Public Impact:**	4
	Total Weighted Point Score:	255
	CIP Rank:	13

Project Costs

Total OPCC:	$1,791,000.00
Estimated Easement:	$151,920.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	BC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #05: STADIUM CHANNEL					
1	REMOVAL OF EXISTING CULVERT (18")	64	LF	$ 45	$ 2,880
2	REMOVAL OF EXISTING CULVERT (36")	120	LF	$ 45	$ 5,400
3	REMOVAL OF EXISTING CULVERT (6'X1')	224	LF	$ 95	$ 21,280
4	INSTALL 36" RCP	432	LF	$ 170	$ 73,440
5	INSTALL 48" RCP	120	LF	$ 232	$ 27,840
6	EXCAVATION AND HAUL	5,522	CY	$ 20	$ 110,440
7	REMOVAL OF EXISTING HEADWALL	21	CY	$ 200	$ 4,200
8	HEADWALL (SMALL)	4	EA	$ 10,000	$ 40,000
9	HEADWALL (MEDIUM)	2	EA	$ 15,000	$ 30,000
10	UTILITY RELOCATION	1	LS	$ 5,064	$ 5,064
11	TRENCH SAFETY	1,540	LF	$ 5	$ 7,700
12	ROAD EXCAVATION	132	CY	$ 27	$ 3,564
13	ASPHALT PAVEMENT REPLACEMENT	235	SY	$ 80	$ 18,800
14	GRADING	24,546	SY	$ 15	$ 368,190
15	SEED/SOD	24,546	SY	$ 5	$ 122,730
16	CLEARING/GRUBBING	6	AC	$ 2,500	$ 15,000
17	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
18	SWPPP	1	EA	$ 6,100	$ 6,100
19					
20	EASEMENTS	1	LS	$ 151,920	$ 151,920

SUBTOTAL		$	1,029,548
ASSOC INFRASTRUCTURE	20%	$	205,910
SUBTOTAL		$	1,235,458
OH&P	15%	$	185,319
SUBTOTAL		$	1,420,776
MOBILIZATION	5%	$	71,039
SUBTOTAL		$	1,491,815
CONTINGENCY	20%	$	298,363

PROJECT TOTAL (2019 COSTS)		**$**	**1,791,000**

COST ESCALATION FACTOR	2.9%	$	275,000
PROJECT TOTAL (2024 COSTS)		**$**	**2,066,000**

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Drainage Master Plan Update
Project: SWCC RR CROSSING IMPROVEMENTS

Project Information

Project ID:	CIP06	**Status:**	Studied
Project Name:	SWCC RR CROSSING IMPROVEMENTS	**Council District:**	2
Project Type:	RR Crossing	**Watershed:**	BC1
Date Identified:	2019	**# Structures Impacted:**	0

Problem Description:

This railroad crossing (UPRR 183.15) is used as an equalizer between the cemetery system and an open area near the Southwestern Christian College. It is currently in good condition.

Proposed Improvements:

Replace in kind in cooperation with UPRR as needed or when an efficient opportunity is available.

Project Photos



Photo 1: Downstream side of railroad crossing



Photo 2: Undefined open channel downstream of railroad crossing

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	0
20	**Property Damage:**	2
22.5	**Frequency of Flooding:**	0
10	**Project Cost:**	5
17.5	**Public Impact:**	0
	Total Weighted Point Score:	90
	CIP Rank:	19

Project Costs

Total OPCC:	$126,000.00
Estimated Easement:	$0.00

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OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	BC1	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #06: SWCC RAILROAD CROSSING (UPRR 183.15) IMPROVEMENTS					
1	REMOVAL OF EXISTING CULVERT (48")	30	LF	$ 50	$ 1,500
2	REMOVAL OF EXISTING HEADWALL	3	CY	$ 200	$ 600
3	INSTALL 48" RCP	30	LF	$ 232	$ 6,960
4	HEADWALL (SMALL)	2	EA	$ 10,000	$ 20,000
5	BORE CULVERT (48")	30	LF	$ 900	$ 27,000
6	SHORING	150	SF	$ 25	$ 3,750
7	CLEARING/GRUBBING	1	AC	$ 2,500	$ 2,500
8	CARE OF WATER (SMALL)	1	EA	$ 5,000	$ 5,000
9	SWPPP	1	EA	$ 5,000	$ 5,000
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ -	$ -

SUBTOTAL		$	72,310
ASSOC INFRASTRUCTURE	20%	$	14,462
SUBTOTAL		$	86,772
OH&P	15%	$	13,016
SUBTOTAL		$	99,788
MOBILIZATION	5%	$	4,989
SUBTOTAL		$	104,777
CONTINGENCY	20%	$	20,955
PROJECT TOTAL (2019 COSTS)		**$**	**126,000**
COST ESCALATION FACTOR	2.9%	$	19,000
PROJECT TOTAL (2024 COSTS)		**$**	**145,000**

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BC5

STUDY AREA: BC5

BACKGROUND

The BC5 watershed is bounded to the southwest side by a combination of Colquitt Road, Griffith Road, and the Hurmon Furlough Jr. Middle school. The south east border varies by block but is completely to the west of 9th Street and Poetry Road. The north border of the watershed is mostly undeveloped with no identifiable roads to be used as a boundary. For the purposes of this study, the modelled BC5 watershed also includes the identified BC3 and BC4 basins. The latter two basins were significantly smaller than originally expected and had high potential for watershed interaction with BC5. Until further development in this area, it makes technical sense to look at these watersheds together. The main reach for BC5 starts upstream of where the lateral from the Laurel Trail North community outfalls. It is mostly a natural channel, with engineered laterals connecting from the local residential communities.

There are small storm drain systems within a few of the residential communities in this watershed. The main drainage infrastructure relies on the open channel ditches that run along Griffith Avenue. The remaining communities typically rely on Right-of-Way (ROW) capacity and a single engineered channel to convey drainage to the natural streams. The existing storm condition varies, most is fair or better.

Rain-on-mesh analysis shows the ROW generally has a significant amount of capacity but there are multiple cases where the flood depth exceeds the maximum allowed. Yard flooding is prevalent in this watershed.

DATA COLLECTED

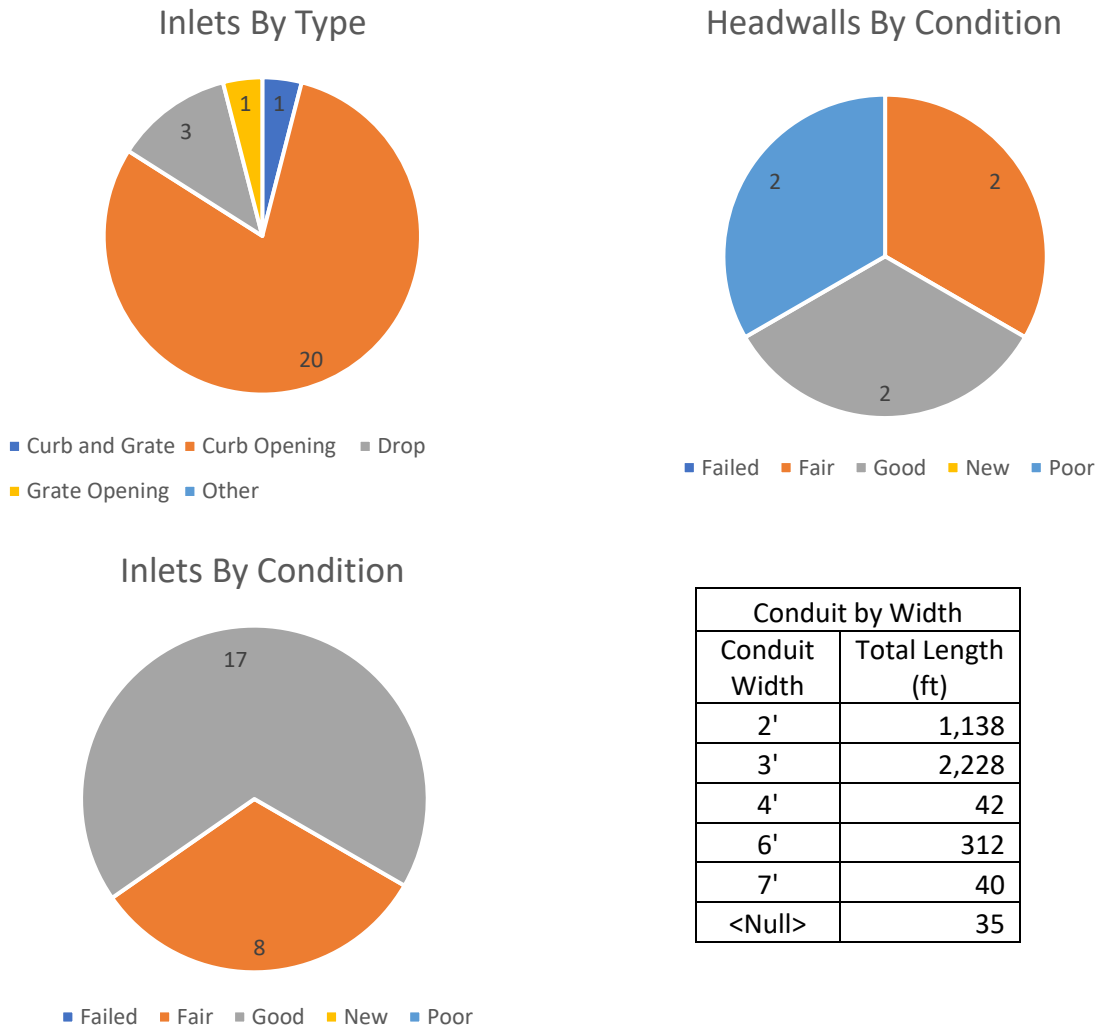
The 1989 Drainage Master Plan identified multiple projects in this area. The proposed infrastructure was called Lines “A,” “B,” “C,” “D,” and “E” for a total of $1.7 million (1989 dollars). The proposed projects from that study are shown in Figure 1. New improvements have been made in the vicinity of this project and are included in the analysis of the system.



Figure 1: Proposed structures from 1989 Drainage Master Plan.

Lines A-C and E from the previously identified projects have been completed. Line D appears to be constructed through the intersection of Colquitt and Charles Lane.

The existing infrastructure, as reported in the ArcGIS Online database, for the watershed was determined from field data collection and survey. There are 25 inlets, 6 headwalls, and 0.7 miles of conduit within this watershed. A summary of inlets, headwall and pipe length within the watershed is provided in the graphics in Figure 2.



Conduit by Width	
Conduit Width	Total Length (ft)
2'	1,138
3'	2,228
4'	42
6'	312
7'	40
<Null>	35

Figure 2: Summary graphs of watershed infrastructure.

EXISTING CONDITIONS

FNI analyzed existing hydrologic conditions by developing the Terrell HEC-HMS model, and analyzing existing hydraulic conditions by developing the Colquitt ICM model.

The watershed was modeled using InfoWorks ICM due to the strong presence of storm drain and driveways ditch infrastructure. There was also a significant amount of overland flow which is best modeled in the 2D format to accurately determine where the flow goes. The model extents were set to include the areas where overland flow direction was uncertain. A map depicting the area of study for each component is shown in Exhibit BC5-01.

Results of the data collection and modeling show:

- 24 flooded roadway block segments with a maximum depth of 2.6 feet in the 100-year storm
- 161 properties experience flooding during the 100-year storm
- The first structure is flooded in the 25-year storm
- The public noted flooding in 21 areas and there were 13 maintenance work orders performed between 2013-2017

SYSTEM DEFICIENCIES

There are several different flood prone zones identified within the study area that have separate solutions. In general there are three (3) primary drivers for the causes of flooding within the watershed:

Development encroachment — The existing channel near Lexington Drive is being encroached upon by development. There is still some open space near the channel. Future development should be controlled to prevent further encroachment. Drainage easements are one solution to ensure private property does not end up within the floodplain.

Lack of storm drain infrastructure — Most of this watershed utilizes the ROW for its main conveyance until it reaches a natural stream or major roadway with clear drainage infrastructure. Many of these communities already have curbs but no storm drain inlets. Increasing the presence of storm drain inlets will reduce the amount of flow that leaves the ROW and turns into overland flow over personal property.

Undersized culvert crossing and channels — Main culvert crossings and channels that make up the trunk line of the storm drain system are undersized. The overtopping that occurs can be prevented with increased conveyance capacity. Channels can be added on the other side of the road, and additional culverts can be installed to be prevent road inundation.

PROPOSED IMPROVEMENTS

Improving the residential drainage in the Brookhollow Drive area will significantly reduce the overland flow that leaves the ROW as noted above. It will also provide relief for the infrastructure along Griffith Avenue. The proposed infrastructure improvements are shown in Exhibit BC5-02.

Recall the future land use conditions were used to model ultimate flows. A significant portion of the watershed is currently open space. Proper detention to match the time of concentration between future development and existing conditions will be paramount.

The combined effect of the proposed improvements results in the improved 100-year floodplain shown in Exhibit BC5-03. The overland flooding in the central part of the watershed is significantly reduced. All of the structures are protected in the 25- and 100-year storm events.

The combined improvements in this watershed are expected to increase discharges downstream. The downstream area is generally undeveloped in existing conditions. Detention to mitigate up to approximately 5 acre-feet should be considered during the more detailed design phase prior to implementation to mitigate downstream adverse impacts.

Cost Estimates were prepared for each project. In total the cost for the projects within the watershed is approximately $2.5 million to meet current City criteria, with more detail shown in the OPCCs.

IMPLEMENTATION

The costs for all the improvements in the study area exceed what can feasibly be financed from the City's current revenue streams without significant modification. FNI recommends breaking the project into discrete segments based on ability to fund each. Projects should be implemented from downstream to upstream to achieve optimal drainage conditions, as seen in the conceptual phasing outlined in Exhibit BC5-04. The sequencing explained below takes ranking, feasibility, and coordination into consideration. Phased costs are estimated based on the tabulated OPCC for each full CIP.

CIP01: Brookhollow Channel and SD

CIP01 can be divided in two phases. Phase 1 will provide increased drainage capacity by installing storm drain from the existing channel northwest of Brookhollow Drive through the upstream side of the intersection of Davidson and Laurel Lane. Phase 2 will install storm drain starting at the intersection of Griffith Avenue and Brookhollow Drive to the downstream face of the existing channel that outfalls onto Brookhollow Drive. The connecting channel will also be enhanced with natural grass and a consistent grade. Phases 1 and 2 will cost about $1.8 million and $700,000, respectively. The order of the two phases for CIP01 can easily be reversed since both will benefit the overflow drainage in this area and tie into different parts of the BC5 system.

This project should address the several public survey responses that reported structural, property, and street flooding between Griffith Avenue and Brookhollow Drive. The remaining comments further upstream on Griffith Avenue should be monitored as maintenance to the drainage ditches might alleviate the flooding in those areas if it continues.

Small Projects

The following small projects are within this watershed:

- Lexington Drive – Repair the existing concrete channel to create consistent channel slope and reduce the level of yard flooding. This will address at least one of the public survey responses received in this area. The remaining comments from the Birdsong Lane and Lexington Drive community were limited to property flooding and should be monitored.

- Colquitt & Lovers – This is currently a driver safety and flooding hazard. Repair the broken guard rail on the south side of the road. Replace the failing headwalls on both faces of the culvert and apply channel improvements to the transitional areas for consistent and stable slope. This small project will address the public survey response that called out this area for significant flooding.

A summary of the projects and the suggested implementation order is located in Table 1. Costs have been conservatively rounded up during the estimating process and will need to be refined as part of the future design process.

Table 1: Suggested Implementation Order for Watershed

	Order	Project	Cost
Small Projects	1	Colquitt & Lovers	$ 38,600
	2	Lexington Drive	$ 182,100
		Total Small Project Cost	**$ 220,700**
Large Projects	4	CIP01 Phase 1	$ 1,800,000
	5	CIP01 Phase 2	$ 730,000
		Total Large Project Cost	**$ 2,530,000**

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

Watershed

City Limits

Inundated Buildings

25-YR Inundation (0)

100-YR Inundation (0)

Depth

< 0.5'

0.5' - 1.0'

1.0' - 2.0'

2.0' - 3.0'

> 3.0'

2D Model Extent

1D Model Extent

100-YR FEMA Floodplain

FM 986

KC4

Griffith

Lexington

Brookhollow

Laurel

Poetry

Yosemite

KC3

Redwood

Brookhollow Channel

Lovers

Davidson

State

KC2

Colquitt

Elm

9th

BC1

0 350 700 1,400 Feet

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Existing Conditions - BC5

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC5-01
DATE	1/13/2020
SCALE	1:8,400
DRAFTED	02730

FIGURE
BC5-01

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NOTE: Existing channel dimensions are nominal. They are based on a field collected tyipcal section. Actual dimensions may vary.

Legend

- Existing Storm Drain
- Proposed Storm Drain
- Existing Channel
- Proposed Channel
- Watershed
- City Limits

Existing SD Size

Existing Channel Material
Bottom Width, Top Width, Depth

Proposed SD Size

Proposed Channel Material
Bottom Width, Top Width, Depth

Lexington

Concrete
BW: 20' TW: 53' D: 5'

Natural
BW: 6' TW: 65' D: 5'

Laurel

48"

Brookhollow

Lovers

2 - 36"

39"

1 - 8'x4'

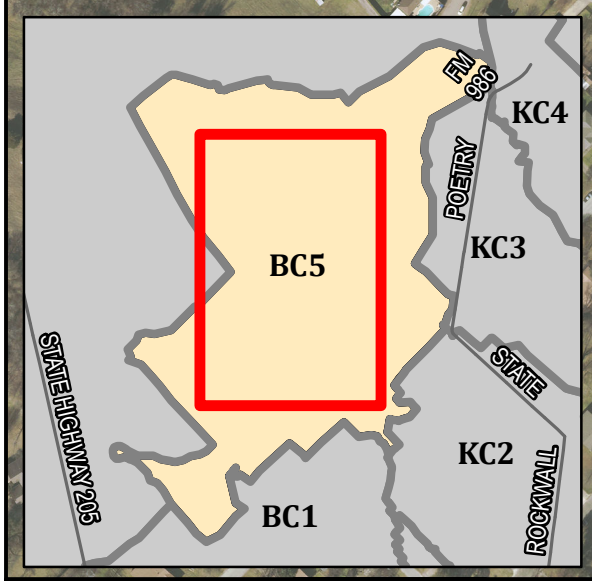
36"

1 - 7'x4'

Davidson

Grass Channel
BW: 4' TW: 16' D: 2'

Griffith



0 150 300 600 Feet

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2711 North Haskell Ave.
Suite 3300
Dallas, Texas 75204
P: 214-217-2200

Infrastructure - BC5

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC5-02
DATE	6/10/2020
SCALE	1:3,600
DRAFTED	02730

FIGURE
BC5-02

H:\STORMWATER\Final Exhibits\01_REPORT\BC5-02.mxd

NOTE:
Building Finish Floor Elevation (FFE) was assumed to be 1 foot above the LIDAR elevation for each structure. Buildings are symbolized for the most frequent storm event where depth is greater than FFE and the building is probably flooded

Legend

Watershed

City Limits

Buildings Impacted

Protected - 25YR (0)

Protected - 100YR (0)

25-YR Inundation (0)

100-YR Inundation (0)

Buyout (0)

Existing 100-YR Floodplain

Proposed 100-YR Floodplain

100-YR FEMA Floodplain

KC4

KC3

KC2

BC1

Lexington

Brookhollow

Laurel

Brookhollow Channel

Poetry

Lovers

Davidson

Colquitt

Griffith

State

Elm

9th

0 350 700 1,400 Feet

FREESE AND NICHOLS
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Dallas, TX 75204
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100-YR Floodplain - BC5

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC5-03
DATE	1/9/2020
SCALE	1:8,400
DRAFTED	02730

FIGURE
BC5-03

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FREESE AND NICHOLS
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Conceptual Phasing - BC5

City of Terrell Drainage Master Plan

FN JOB NO	TER17602
FILE	BC5-04
DATE	6/10/2020
SCALE	1:3,600
DRAFTED	02730

FIGURE
BC5-04

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Drainage Master Plan Update
Project: BROOKHOLLOW CHANNEL & SD

Project Information

Project ID:	CIP01	**Status:**	Studied
Project Name:	BROOKHOLLOW CHANNEL & SD	**Council District:**	5
Project Type:	Pipe System / Channel	**Watershed:**	BC5
Date Identified:	2019	**# Structures Impacted:**	0

Problem Description:

Undersized infrastructure and minimal ROW capacity is causing a wide area to experience uncontained sheet flow through private property.

Proposed Improvements:

Add storm drain onto Brookhollow Drive that ties into Colquitt system. Increase capacity of upstream channel located between backyard property lines. Upsize storm drain on Davidson Street and tie into existing channel downstream.

CIP Ranking Criteria

Weight		Score
30	**Life Safety/Road Flooding:**	2
20	**Property Damage:**	0
22.5	**Frequency of Flooding:**	0
10	**Project Cost:**	3
17.5	**Public Impact:**	4
	Total Weighted Point Score:	160
	CIP Rank:	17

Project Costs

Total OPCC:	$2,527,000.00
Estimated Easement:	$105,850.00

Project Photos



Photo 1: Open channel that runs along backyard property lines out outfalls onto Brookhollow Drive



Photo 2: Existing inlets at intersection of Brookhollow Drive and Davidson Street

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COST

PROJECT NAME	Drainage Master Plan	DATE	8/6/2019
CLIENT	City of Terrell	GROUP	1156
PROJECT AREA	BC5	PM	Jeremy Dixon

ESTIMATED BY	QC CHECKED BY	FNI PROJECT NUMBER
KLM	JEM	TER17602

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PROJECT #01: BROOKHOLLOW CHANNEL & SD					
1	INSTALL 36" RCP	1,272	LF	$ 170	$ 216,240
2	INSTALL 7'x4' RCB	220	LF	$ 530	$ 116,600
3	INSTALL 8'x4' RCB	903	LF	$ 610	$ 550,830
4	HEADWALL (SMALL)	1	EA	$ 10,000	$ 10,000
5	HEADWALL (MEDIUM)	1	EA	$ 15,000	$ 15,000
6	GRADING	3,279	SY	$ 15	$ 49,185
7	SEED/SOD	3,279	SY	$ 5	$ 16,395
8	TRENCH SAFETY	1,757	LF	$ 5	$ 8,785
9	EXCAVATION AND HAUL	1,856	CY	$ 20	$ 37,120
10	ROAD EXCAVATION	947	CY	$ 27	$ 25,569
11	ASPHALT PAVEMENT REPLACEMENT	1,798	SY	$ 80	$ 143,840
12	CLEARING/GRUBBING	1	AC	$ 2,500	$ 2,500
13	CARE OF WATER (MEDIUM)	1	EA	$ 15,000	$ 15,000
14	UTILITY RELOCATION	1	LS	$ 44,184	$ 44,184
15	SWPPP	1	EA	$ 38,000	$ 38,000
16					
17					
18					
19					
20	EASEMENTS	1	LS	$ 105,850	$ 105,850

SUBTOTAL		$	1,395,098
ASSOC INFRASTRUCTU	25%	$	279,020
SUBTOTAL		$	1,674,118
OH&P	15%	$	251,118
SUBTOTAL		$	1,925,235
MOBILIZATION	5%	$	96,262
SUBTOTAL		$	2,021,497
CONTINGENCY	25%	$	505,374

PROJECT TOTAL (2019 COSTS)		**$**	**2,527,000**
COST ESCALATION FACTOR	2.9%	$	388,000
PROJECT TOTAL (2024 COSTS)		**$**	**2,915,000**

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

NOTES:

1 FNI OPCC classified as an AACE Class 4 Estimate with accuracy range or -20 to + 30.
2 FNI OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3 Traffic control plan assumed to be accounted for with an associated city utility project.