TOWN CREEK FLOOD PROTECTION PLAN
City of Cibolo, Texas

Prepared for:

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DRAFT – May 1, 2007

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In Memoriam
Colonel Gary M. Kelly
October 1, 1948 – October 15, 2006

This report is dedicated in the memory of Mayor Pro-Tem Colonel Gary M. Kelly. Gary's commitment to his community was exemplified during his work on this project. His energy and direction during the course of this work, and the work leading up to it, set a path for improving the quality of life and public safety for the citizens of Cibolo.

1.0 EXECUTIVE SUMMARY

1.1 SCOPE OF PROJECT

This document is a Flood Protection Plan for Town Creek, located in the City of Cibolo and Guadalupe County, Texas. In response to local concern over drainage problems and the need to approach the issues on a comprehensive, watershed basis, the City of Cibolo and its supporting partners (Guadalupe County, GBRA, SARA) applied for funding assistance through the Flood Protection Planning Program of the Texas Water Development Board. The project funding was awarded in March 2005 and contracts were executed in June of 2005.

The purpose of the project was to develop a comprehensive model of the Town Creek watershed, to be utilized in developing flood protection alternatives, both structural and non-structural. The study follows the natural course of the watershed, and therefore evaluates the creeks as a system independent of political boundaries.

1.2 QUANTIFYING THE FLOODING PICTURE

This study included the development of a new hydrologic model (HEC-HMS) to estimate the peak discharges at various points of interest throughout the watershed. These peak discharges were determined for several different scenarios representing flood risk for both present and future conditions. In terms of annual chance exceedance, the following frequency events were modeled: 1%, 4%, 10%, and 50% for existing and ultimate development conditions. In addition, this study includes a natural conditions model to assess the impact of development on the watershed. Generally, peak discharges throughout the watershed were higher than previously assumed, and were consistent with recent, comparable studies.

To determine the flooding extents in the community, the results of the hydrologic model are included in a hydraulic model (HEC-RAS), in order to generate a series of flood profiles and floodplain boundaries for the various conditions.

1.3 FLOOD PROBLEM AREAS

The results of the hydrologic and hydraulic analyses indicate that more than 300 buildings are at risk of flooding in a 1% annual chance event. The majority of these structures, mostly residences, are situated in three distinct problem areas, referred to throughout the study as Haeckerville Road, Country Lane and the Railroad, and Town Creek East and Town Creek West.

The major contributing factors to the flooding are as follows:

- The watershed generates a large volume of water that peaks very suddenly.
- The flat terrain and relatively poor natural channel definition allows floodwaters to spread out widely.
- Homes were built in harm's way; before the first floodplain maps, based on outdated flood maps, and according to the preliminary floodplain maps. Some areas would currently be considered at risk in a 10% event.
- Unattenuated runoff from new development exacerbated a problem that was existing before the housing boom of the last ten years.

1.4 FLOOD PROTECTION GOALS

To set some direction and policy guidance in addressing the City's flooding issues, the following goals were established:

Goal 1: "Fix what we can, as soon as we can": Recognizing that many homes were built in harm's way, relieve the flooding experienced by existing development to the greatest extent practical.

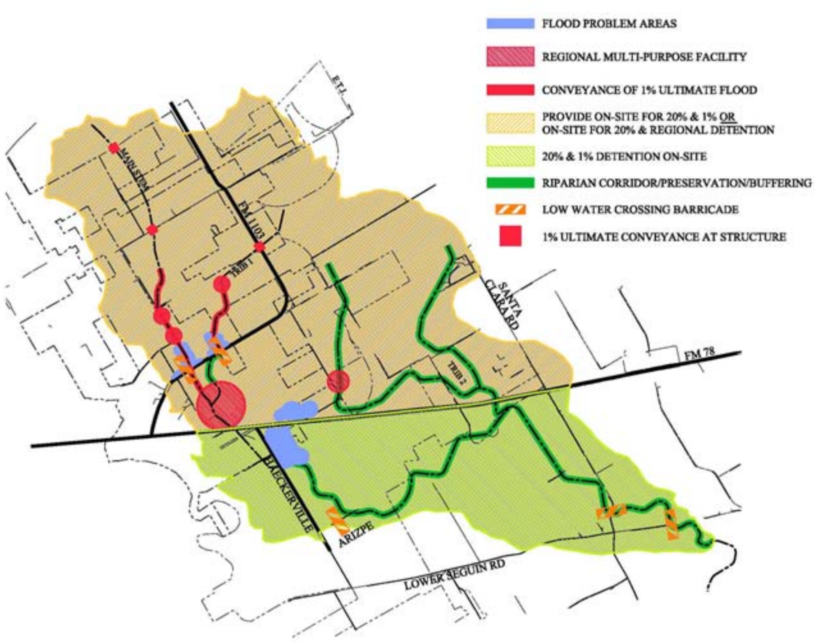
Goal 2: "Be a good neighbor": Ensure that new development in the watershed does not adversely affect property downstream.
Goal 3: "Keep an exit strategy": Critical facilities must be accessible during a 1% annual chance event.
Goal 4: "The small stuff adds up": Provide a means to reduce nuisance flooding events
Goal 5: "Turn around, don't drown": Eliminate the greatest risk of flood-related death – vehicles trying to cross at low-water crossings.
Goal 6: "Knowledge is power": Leverage the efforts of various entities in keeping the citizens of Cibolo informed about the risk of flooding before disaster strikes, so that they also know how to respond in a flooding event.
Goal 7: "Keep more eyes to the sky, and an ear to the ground": Leverage the resources of other regional stakeholders and begin discussions of a flood early warning system.
Goal 8: "Multiple birds, one stone": Seek coordinate opportunities to implement multi-purpose projects, particularly with regard to water quality and erosion mitigation.
Goal 9: "Give the creek the room it needs": Protect the integrity of Town Creek's geomorphology and ecology.
Goal 10: "Plan time with friends": Recognizing that the City is a growing entity, identify current and future partners in floodplain management, and cultivate relationships for regional disaster resistance into the future.

1.5 ALTERNATIVES ANALYSIS AND RANKING

Towards achieving these goals, a series of action items were developed that correspond to discrete projects that are recommended for implementation. This included seven specific alternatives that were evaluated initially in terms of hydraulic impact and cost, and ultimately scored with a multi-factor ranking matrix.

1.6 POLICY, IMPLEMENTATION AND PHASING

Addressing the flood protection needs of the watershed requires a policy approach as well as structural improvements. Implementing a comprehensive watershed policy is guided by the ten goals established in Chapter 5. For the purposes of administration, the watershed can be thought of in terms of different policy areas and objectives. The schematic below shows the relative location of these different policy areas, relative to their application in the watershed and the most significant flood problem areas.

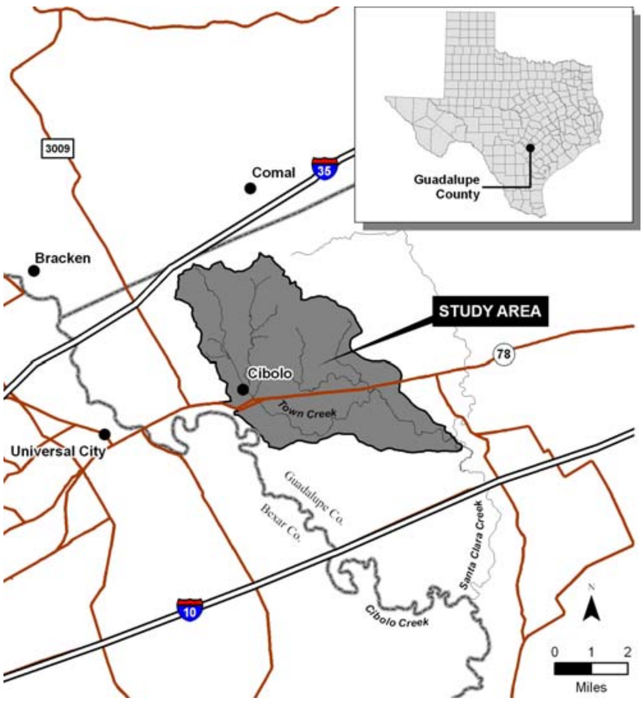


These policy statements, together with the actions developed through the alternatives analysis and ranking process, comprise the blueprint for the Town Creek Flood Protection Plan.

2.0 INTRODUCTION

The Town Creek watershed is a rapidly changing landscape, one that can be described in the framework of two pictures: the natural landscape and its constraints, and the rapid growth picture. As these pictures come into focus, Cibolo has seen the need for a master plan to guide future development with respect toward managing its flooding risk. The City understands that the wave of development that has developed the neighboring Dietz Creek watershed is extending eastward into the Town Creek watershed, and in a pattern that is not sustainable without stepping back and committing the resources to develop and implement a flood protection plan.

Figure 1: Location Map



Cibolo is situated between I-35 and I-10 north and east of Randolph Air Force Base approximately 15 miles from San Antonio. "Old town" Cibolo lies at the base of the Town Creek valley. This area is characterized by flat slope topography (0-2%) and poor channel definition. The upland areas of the watershed are predominantly 5-7% slopes, enabling quick runoff on rocky-clayey soils. The most recent developments have come in the upland areas of the watershed and have exacerbated the pre-existing conveyance deficiencies with increased flowrates, velocities, erosion/sedimentation problems, and water surface elevations. Simply put, much of the Town Creek watershed is prone to flooding, and the hydrology of the watershed has changed significantly to cloud the picture of the watershed's behavior.

In the last 7 years, Cibolo has seen an explosion of new residential growth, as new residents have seen the city as an attractive, convenient alternative to San Antonio. Cibolo's population has grown nearly 288% since 1995, and more than 140% since 2000. The City's drainage ordinance was not structured in a way that required evaluation of hydrologic and hydraulic impacts of development on a comprehensive, watershed basis, as is needed in a growing city. Cibolo simply didn't have the resources at that time to plan comprehensively. However, the City imposed impact fees to help offset the costs associated with new development, which are just now beginning to offer a source of funds to begin comprehensive flood protection planning and the implementation of flood control measures.

The pattern of development in the watershed has been quick and fragmented. Cibolo's development permitting jurisdiction, both its city limits and ETJ, moves in and out of Cibolo's regulatory floodplain and Guadalupe County's. This necessitates a combined, coordinated effort between the city and the county, but also creates confusion in trying to view Town Creek as a comprehensive, yet dynamic entity. The current, effective FIS is now vastly outdated (9 years old) relative to the wave of new growth. This adds to the confusion about what the most accurate picture of the watershed is and the best means to implement flood protection planning.

Before 1995, flooding on Town Creek was limited to agricultural and large–acre estate lands, as well as numerous local, county and state road crossings. The October 1998 floods, which affected most of central Texas, also had an impact on Cibolo. Significant floods came again in 2000, 2002, and in November

2004. These events have flooded slab-on-grade homes, mobile homes, the city cemetery, and damaged roads and culvert crossings. The recent construction of the new Byron Steele High School on FM 1103 and the demand that this places on the road infrastructure places a further, urgent light on the need to keep roadways above floodwaters. When the floodwaters rise, a large portion of the city's jurisdiction remains isolated, delaying emergency access or requiring support from interlocal EMS partners, Schertz and Marion.

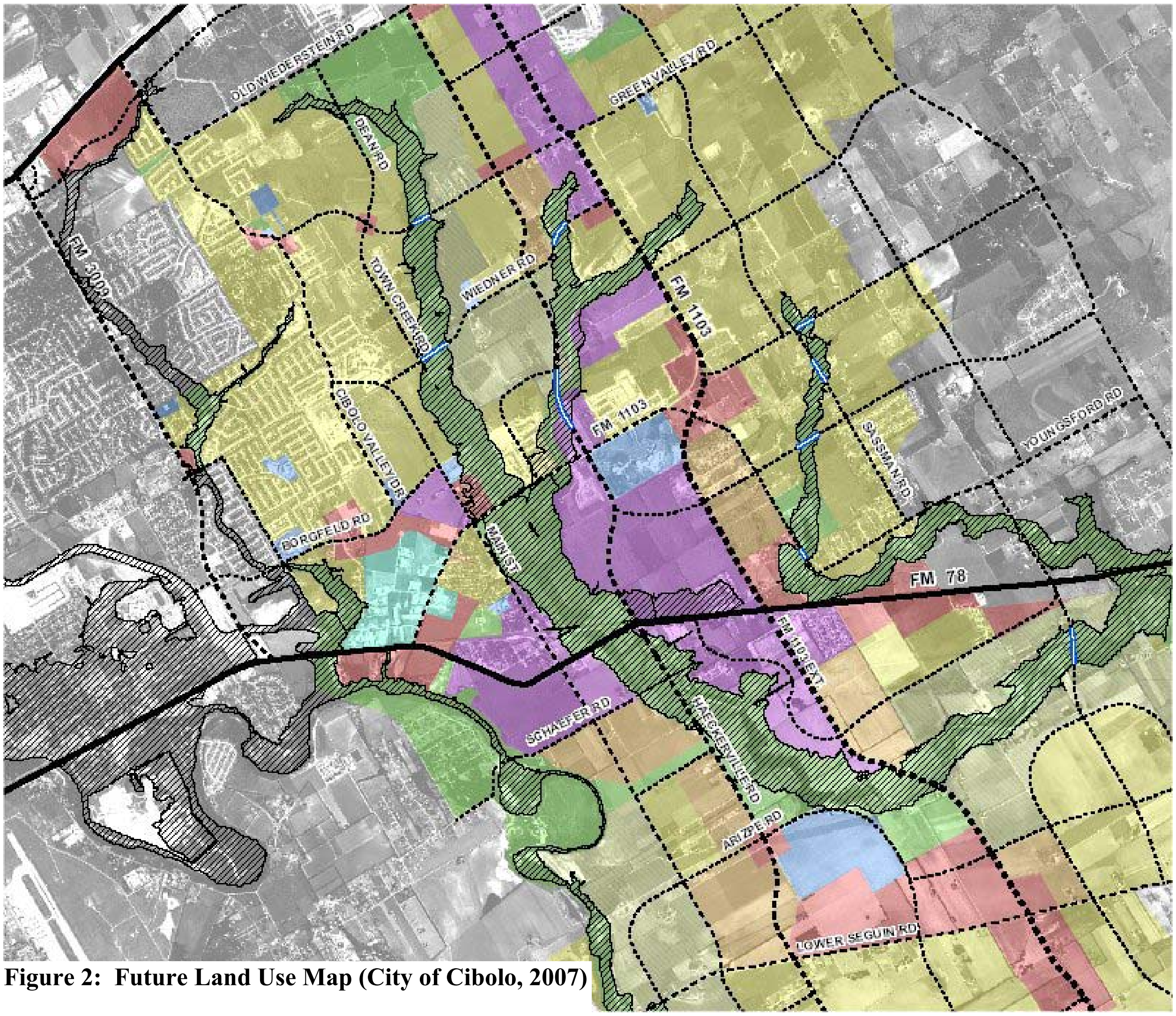


Figure 2: Future Land Use Map (City of Cibolo, 2007)

Furthermore, the City recently has undertaken an update to its city-wide Master Plan. Part of this effort involved a community issues survey, in which respondents were asked questions about their priorities for city initiatives and other topics. The need for drainage improvements was cited most frequently in this survey. Another part of this Master Plan focused on making downtown the center of community activity, reinvigorating the sense of identity that can be unique to Cibolo. The major obstacle preventing this community vision from being carried forward is the need for flood protection planning.

3.0 HYDROLOGY

3.1 HYDROLOGIC ANALYSIS

Version 3.0.0 of the HEC-HMS computer program developed by the Hydrologic Engineering Center of the U. S. Army Corps of Engineers (USACE) is used in this analysis to estimate peak flow rates.

3.2 DRAINAGE AREA DELINEATION

The watershed is divided into subareas at points of critical interest (i.e., confluences of large tributaries, floodwater retarding dams, etc.) using SARA/GBRA/USACE 5-ft contour interval derived from LIDAR data flown in 2002 using the North American Datum of 1983. This is the same source data used for the Draft FIS analysis. In addition, existing aerial photography and field investigations were also used in the delineation. Exhibit 1 shows the Drainage Area Map.

3.3 PRECIPITATION

The precipitation depths for the four design storm events selected for this study are taken from a USGS publication by Asquith and Roussel, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004. The table below shows the precipitation depths for various durations for the each annual chance exceedance event.

Table 1: USGS Storm Depths for the Town Creek Flood Protection Plan Recurrence Intervals

		USGS Cummulative Depth (in) Annual Percent Chance Exceedance			
Time	Time (min)	50%	10%	4%	1%
15 minutes	15	1.06	1.60	2.00	2.60
1 hour	60	1.82	2.75	3.35	4.40
2 hours	120	2.20	3.50	4.20	5.70
3 hours	180	2.45	3.85	4.80	6.50
6 hours	360	2.75	4.50	5.40	7.00
12 hours	720	3.15	5.25	6.25	8.30
24 hours	1,440	3.60	6.00	7.50	10.00
48 hours	2,880	4.00	7.00	9.00	12.00

There are several distributions that may be applied to a hydrologic model. The NRCS Type II, the NRCS Type III, and the balanced and nested distribution are each acceptable and widely used distributions. The figure below illustrates the differences between these three standard distributions.

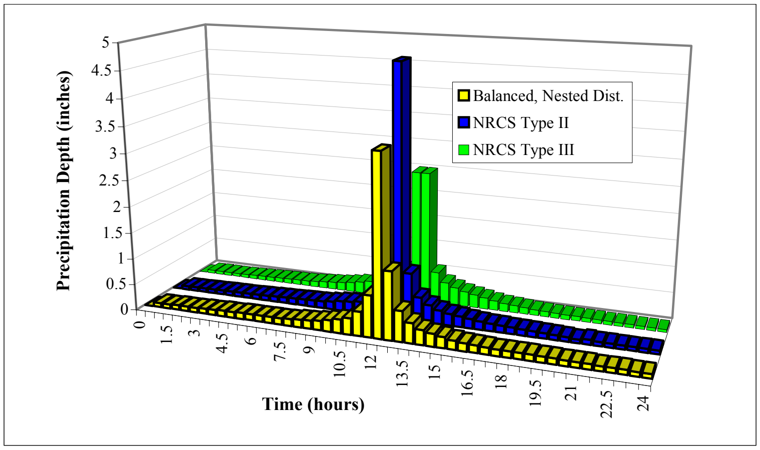


Figure 3: Comparison of Rainfall Hyetographs (1/2-Hour Time Step)

A balanced and nested distribution is assumed for this analysis due to its flexibility with regard to storm duration. The distribution is balanced in that the precipitation is centered about the center of the duration. The distribution is nested in that the precipitation depths from the USGS publication are applied in an alternating block format (i.e., the 15-minute depth is applied as the hyetograph peak, the 30-minute depth is applied such that the peak 15-minute block and the adjacent 15-minute block sum to be the 30-minute depth). A 24-hour storm duration was used for the Town Creek Watershed.

FEMA has recently completed a complete restudy of the Town Creek watershed as part of the Guadalupe County FIS. The effort was undertaken by Halff Associates, Inc. and completed in the September of 2004. It should be noted that the rainfall depths and storm distribution used in this study differ from the assumptions used by Halff. The FEMA update used rainfall depths from the City of New Braunfels FIS update completed in May 2003 and an NRCS Type III 24-hour storm distribution. Figure 2, below, shows the difference between the FEMA Town Creek update assumption (FIS) and the assumptions used in this study (EC). In general, the depths used for this study are slightly less than those used for the FEMA update.

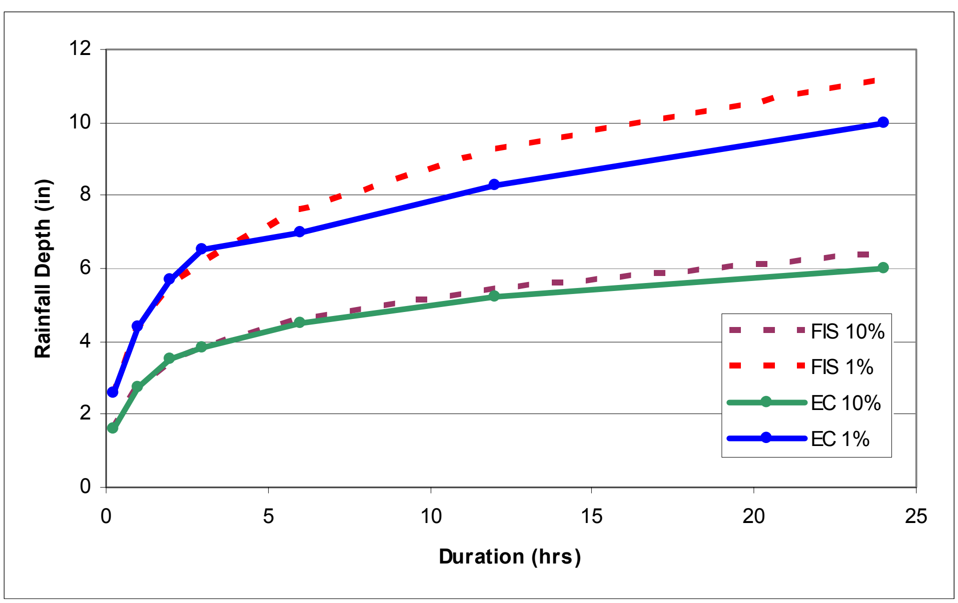


Figure 4: Comparison of Rainfall Depths

3.4 INFILTRATION LOSSES

The U.S. Department of Agriculture Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service, SCS) has developed a rainfall runoff index called the runoff curve number (CN), which takes into account such factors as soil characteristics, land use/land condition, and antecedent soil moisture to derive a generalized rainfall/runoff relationship for a given area. A description of these components and the equations for calculating runoff depth from rainfall are provided below.

The NRCS classifies soils into four hydrologic soil groups: A, B, C, and D. These groups indicate the runoff potential of a soil, ranging from a low runoff potential (group A) to a high runoff potential (group D). Digital soil data is available from the Texas Natural Resource Information System (TNRIS) post-processed from the US Department of Agriculture Soil Survey Geographic (SSURGO) database into the Texas statewide mapping system. The hydrologic soil groups contained within each drainage basin were determined from a GIS analysis of this data and shown on Exhibit 2.

Impervious cover values are entered separately from CN values into the HEC-HMS model. HEC-HMS computes 100 percent runoff from impervious areas, while runoff from pervious areas is computed using the selected CN value and the following equations:

$$Q = (P - 0.2\times S)^2 / (P + 0.8\times S) \qquad \text{Equation 1}$$

And

$$CN = 1000 / (10 + S) \qquad \text{Equation 2}$$

Where:

Q = depth of runoff (in),
P = depth of precipitation (in),
S = potential maximum retention after runoff begins, and
CN = runoff curve number.

Table 2: NRCS Curve Number Summary Table

Group	AMC I	AMC II	AMC III
A	21	39	59
B	41	61	78
C	55	74	88
D	63	80	91

Key Assumption: Undeveloped grassland or range land.
Reference: National Engineering Handbook 4 (NEH-4)

3.4.1 Existing Impervious Cover Determination

Land use data is provided by the Texas Natural Resource Information System (TNRIS) and the City of Cibolo. The City's existing land use map (EC, 2004, 2005 revised) is merged with the national land use map[1] from TNRIS to create a composite—in the areas of overlap, the City's land use map controls. This data reflects land use for the year 1992 for the national map and reflects land use for the year 2005 for the City's map. Impervious cover values are assigned to the various land use types. Land use types are based

[1] The national land use map dataset was obtained from the United States Environmental Protection Agency (EPA) and was projected by TNRIS to the Texas State Mapping System Lambert Projection.

on nationally accepted land use categories for the rural portion of the study area and based on City land use categories for the urban portion of the study area.

The hydrologic models utilize a weighted impervious cover value calculated for each watershed subarea. A table listing the assumed impervious cover values for the various land use categories is shown below.

Table 3: Land Use Impervious Cover Summary

LU Code		Description	I.C. %	LU Code		Description	I.C. %
National	11	Residential	60%	National	61	Forested wetland	0%
	12	Commercial and services	80%		62	Nonforested wetland	0%
	13	Industrial	80%		73	Sandy areas not beaches	0%
	14	Transportation, communication, utilities	80%		74	Bare exposed rock	100%
	16	Mixed urban or built-up land	60%		75	Strip mines, quarries, gravel pits	0%
	17	Other urban or built-up land	60%		76	Transitional areas	0%
	21	Cropland and pasture	0%	City of Cibolo	AG	Agricultural and Open Space	0%
	22	Orchards, groves, vineyards, nurseries	0%		COM	Commercial	80%
	23	Confined feeeding operations	0%		INST	Institutional	60%
	24	Other agricultural land	0%		LDR	Low Density Residential	40%
	31	Herbaceous rangeland	0%		MDR	Medium Density Residential	70%
	32	Shrub and brush rangeland	0%		MF	Multifamily	75%
	33	Mixed rangeland	0%		MH	Manufactured Housing	50%
	41	Deciduous forest land	0%		PARK	Park and Recreation	0%
	42	Evergreen forest land	0%		PUB	Public Use	60%
	43	Mixed forest land	0%		R	Retail	80%
	51	Streams and canals	100%		UNK	Unknown	25%
	52	Lakes	100%		VAC	Vacant	0%
	53	Reservoirs	100%				

A spectral analysis was also conducted for this watershed using 2004 color infrared aerial photographs. When compared to recent aerial photographs, it was determined that the national land-use data set was significantly outdated, and much more development has occurred within this watershed than was reflected by these data. Spectral analysis is a type of remote sensing technology that searches aerial images for specific spectral signatures to identify impervious areas. This method was employed to determine a impervious area for each sub-basin within the Town Creek watershed. The results of this analysis, shown in Table 4, gave slightly higher impervious percentages than the 1992 national land-use data described above. The results of the spectral analysis were used to define the existing condition impervious cover. Exhibit 3A shows the results of the spectral analysis. Exhibit 3B shows the resulting impervious percentage for each drainage basin sub-area using the spectral analysis.

Table 4: Existing Condition Impervious Cover Summary

Sub-Area	National Dataset % Impervious	Spectral Analysis % Impervious	Sub-Area	National Dataset % Impervious	Spectral Analysis % Impervious
A-01	0	20	A-23	0	5
A-02	20	30	A-24	0	5
A-03	5	5	A-25	0	5
A-04	3	5	B-01	0	10
A-05	5	5	B-02	21	20
A-06	18	25	B-03	1	5
A-07	21	30	B-04	0	5
A-08	1	10	B-05	0	20
A-09	0	5	B-06a	2	5
A-10	14	25	B-06b	2	25
A-11	16	15	B-07	22	30
A-12	10	15	B-08	15	25
A-13	5	5	C-01	4	5
A-14	27	30	C-02	9	10
A-15	12	15	C-03	15	15
A-16	1	5	C-04	9	10
A-17	8	10	C-05	8	10
A-18	0	5	C-06	0	10
A-19	3	5	C-07	0	10
A-20	0	5	D-01a	0	5
A-21	0	20	D-01b	0	10
A-22	0	5	D-02	0	10

3.4.2 Ultimate Impervious Cover Determination

Ultimate conditions are derived from the adopted Future Land Use Map of the City of Cibolo (2004). This map was developed during the City's master plan process, and shows varying densities and locations of residential and non-residential development within the city limits and Extraterritorial Jurisdiction (ETJ). Areas that fall outside of the city's jurisdiction, yet inside the Town Creek watershed, are assumed to be a continuation of the adjacent use within the city's statutory jurisdiction. Table 5 shows the existing and ultimate impervious cover percentage for each sub-area used in this analysis. The ultimate condition impervious cover assumptions are shown on Exhibit 3C.

Table 5: Existing and Ultimate Condition Impervious Cover Summary

Sub-area	Existing % Impervious	Ultimate % Impervious	Sub-area	Existing % Impervious	Ultimate % Impervious
A-01	20	60	A-23	5	5
A-02	30	30	A-24	5	5
A-03	5	21	A-25	5	5
A-04	5	15	B-01	10	32
A-05	5	35	B-02	20	47
A-06	25	25	B-03	5	45
A-07	30	30	B-04	5	24
A-08	10	45	B-05	20	25
A-09	5	51	B-06a	5	45
A-10	25	62	B-06b	25	49
A-11	15	24	B-07	30	46
A-12	15	45	B-08	25	35
A-13	5	61	C-01	5	25
A-14	30	51	C-02	10	25
A-15	15	46	C-03	15	47
A-16	5	42	C-04	10	39
A-17	10	40	C-05	10	36
A-18	5	9	C-06	10	29
A-19	5	37	C-07	10	20
A-20	5	5	D-01a	5	18
A-21	20	20	D-01b	10	25
A-22	5	5	D-02	10	15

In addition, a natural conditions model was developed. This hydrologic model uses the same general input parameters as the existing conditions model except all areas are assumed to have zero impervious cover. The intent of this analysis was to determine an idea of how existing development has impacted flooding within this watershed. The natural conditions model removes the effects of existing development to impervious cover and lag time (T_{LAG}) but does not consider any differences in drainage areas or routing.

3.5 UNIT HYDROGRAPH METHOD

A rainfall/runoff transformation is required to convert rainfall excess (total rainfall minus infiltration losses) into runoff from a particular subarea. The NRCS unit hydrograph option in HEC-HMS is used in this analysis to generate runoff hydrographs for each defined subarea.

The dimensionless unit hydrograph developed by the NRCS (figure below) was developed by Victor Mockus and presented in *National Engineering Handbook, Section 4, Hydrology*, published by the U. S. Natural Resource Conservation Service. The dimensionless unit hydrograph has its ordinate values expressed in a dimensionless ratio, q/qp, and its abscissa values as t/Tp. This unit hydrograph has a point of inflection approximately 1.7 times the time to peak (Tp), and the time-to-peak 0.2 of the time-of-base (Tb) (NRCS 1985).

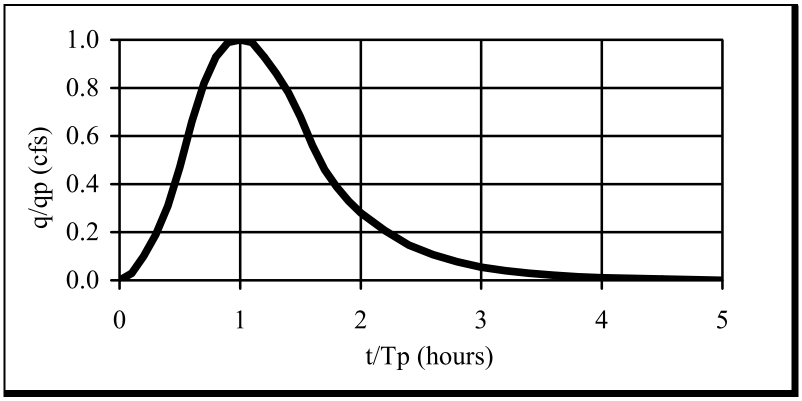


Figure 5: NRCS Unit Graph

In HEC-HMS, input data for this method consists of a single input parameter, T_{LAG}, which is equal to the time (hours) between the center of mass of rainfall excess and the peak of the unit hydrograph (NRCS 1985).

The time to peak is computed using the following equation:

$$T_{PEAK} = \Delta t/2 + T_{LAG} \qquad \text{Equation 3}$$

Where:

T_{PEAK}	=	time to peak of the unitgraph (hours),
Δt	=	computation interval or duration of unit excess (hours), and
T_{LAG}	=	watershed lag (hours).

The peak flow rate of the unit graph is computed using the following equation:

$$qp = 484A/T_{PEAK} \qquad \text{Equation 4}$$

Where:

qp	=	peak flow rate of the unit graph (cubic feet per second [cfs] / inch) and
A	=	watershed area (square miles).

3.5.1 Time of Concentration

The NRCS method assumes that the lag time (T_{LAG}) of a watershed is 60 percent of the watershed's time of concentration. The time of concentration is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed (NRCS 1985). The time of concentration may be estimated by calculating and summing the travel time for each subreach defined by the flow type: sheet flow, shallow concentrated flow, and channelized flow (including roadways, storm sewers, and natural/manmade channels). The methods prescribed in the NRCS' Technical Release 55 (TR-55) are used to determine the times of concentration for each flow segment in this analysis.

3.5.2 Sheet Flow (≤ 300 feet)

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact, of drag over the plane surface and obstacles such as litter, crop ridges, and rocks, and of erosion and transportation of sediment. These n values are for very shallow flow depths of approximately 0.1

foot. Assuming sheet flow of less than or equal to 300 feet in natural areas and 150 ft in developed areas, travel time is computed as follows:

$$Tt = (0.007 \times (n \times L)^{0.8}) / (P_2^{0.5} \times s^{0.4}) \quad \text{Equation 5}$$

Where:

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

3.5.3 Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from the following figure in which average velocity is a function of watercourse slope and type of channel (TR-55). The flow is still considered shallow in depth and flows in a swale or gutter instead of a channel, which has greater depth.

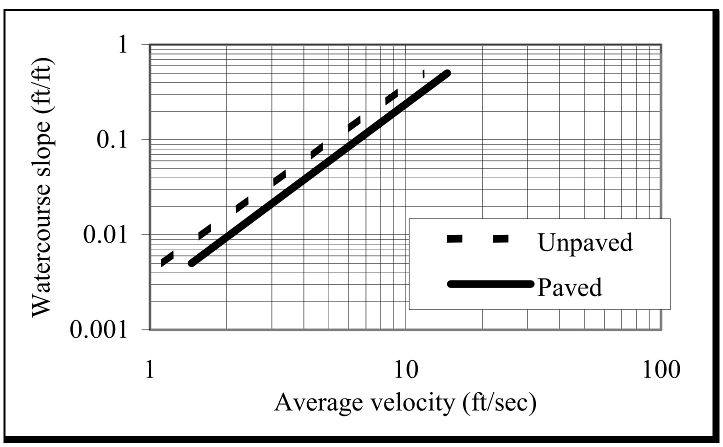


Figure 6: Avg. Velocities for Estimating Travel Time in Shallow Concentrated Flow Segments

After determining the average velocity, the following equation is used to compute travel time:

$$Tt = L / (3600 \times V) \quad \text{Equation 6}$$

Where:

- Tt = travel time (hr),
- L = flow length (ft),
- V = average velocity (ft/sec), and
- 3,600 = conversion factor from seconds to hours.

3.5.4 Channelized Flow

As the depth of concentrated flow increases, the shallow concentrated flow evolves into channelized flow. Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle maps. Manning's equation or water surface profile information (available from HEC-2 or HEC-RAS) can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevations.

Manning's equation is:

$$V = 1.49 \times r^{2/3} \times s^{0.5} / n \qquad \text{Equation 7}$$

Where:

- V = average velocity (ft/sec),
- r = hydraulic radius (ft), equal to flow area divided by wetted perimeter,
- s = slope of the hydraulic grade line (channel slope, ft/ft), and
- n = Manning's roughness coefficient.

3.6 HYDROGRAPH ROUTING

3.6.1 Stream Flow Routing

The Modified Puls standard method of stream flow routing is used in this analysis to modify hydrographs to reflect the effects of translation and attenuation within a channel reach. The Modified Puls routing method, also known as storage routing or level-pool routing, is based upon a finite difference approximation of the continuity equation, coupled with an empirical representation of the momentum equation (Chow, 1964; Henderson, 1966). The HEC-RAS models discussed in Section 4.0 were used to develop Storage-Outflow relationships for the routing reaches within the Town Creek watershed.

Two routing reaches within the modeled area were not evaluated using HEC-RAS. These reaches were the most upstream reach on Tributary 4 and the most downstream reach on Town Creek. These routing reaches are modeled in HEC-HMS using the Muskingum-Cunge method. The required input for this method includes: channel length, channel slope, Manning's roughness coefficients, and an estimate of the hydraulic grade line slope. A trapezoidal channel shape is used to represent a typical channel section through each stream routing reach.

3.6.2 Detention Routing

There are small impoundments throughout the watershed; however, no existing regional detention ponds in the watershed that offer significant detention or attenuation of the hydrograph are modeled.

3.7 HYDROLOGIC RESULTS

3.7.1 Comparison of Results

The tables that follow present the results from the hydrologic analysis. The HEC-HMS models are compared to the following: *Town Creek Hydrology & Hydraulics* by Givler Engineering (GE), TxDOT construction documents for FM 1103 box culverts, the Effective Flood Insurance Study (FIS), and the Draft FIS.

The effective FIS is dated June 2, 1995. As mentioned above, FEMA has recently completed (Fall 2005) a complete restudy of the Town Creek watershed as part of the Guadalupe County Map Modernization Project. This study and the associated Flood Insurance Rate Maps will be considered "draft" until they are adopted and become effective. This will likely occur in the spring of 2007. The following table compares the results to both the effective FIS (1995) and the draft FIS (2005).

Table 6: Comparison Table for Town Creek to Published Studies

Flow Comparison at Town Creek West at FM 1103

Storm Event	Peak Flow Rate (cfs)					Relative Difference to Draft FIS			
	EC	GE Existing	TxDOT	Effective FIS	Draft FIS	EC	GE Existing	TxDOT	Effective FIS
1%	6,959	5,624	3,855	6,000	7,497	-7.2%	-25.0%	-48.6%	-20.0%
10%	3,077	n/a	1,812	3,350	3,632	-15.3%	n/a	-50.1%	-7.8%

Drainage Area Comparison at Town Creek West at FM 1103

Storm Event	Drainage Area (mi²)					Relative Difference to Draft FIS			
	EC	GE Existing	TxDOT	Effective FIS	Draft FIS	EC	GE Existing	TxDOT	Effective FIS
All	3.79	3.62	3.67	3.65	3.65	3.9%	-0.9%	0.6%	0.0%

Hydrograph Volume Comparison at Town Creek West at FM 1103

Storm Event	Volume (ac-ft)		
	EC	GE Existing	Draft FIS
1%	1,546	1,404	1,698

There were considerable differences between the Draft FIS hydrologic study and that performed under this study. Subarea delineations, curve number, impervious cover, rainfall depths and distribution assumptions were developed completely independently. However, it is still useful to compare the results of the two studies. It should be noted that the hydrologic nodes compared are not all in the same location.

Table 7: 1% Peak Discharge Comparison Table

DFIS HEC-HMS Node	Espey HEC-HMS Node	Discharge (cfs)			Location
		Espey	Draft FIS	% Diff	
JTOWN040	J-A03	6,471	6,031	7%	1860 feet US of Wiedner Road
JTOWN45	J-A04	6,876	7,417	-7%	Downstream of Borgfeld Road
JTOWN050	J-A05	6,959	7,497	-7%	Downstream of FM 1103
JTOWN050A	Town Creek West	6,795	7,731	-12%	2500 feet US of SH Spur 539
JTOWN055	J-A06	13,783	15,079	-9%	Confluence of Town Creek and Tributary 1
JTOWN060	J-A08	13,848	14,096	-2%	Downstream of FM 78
JTOWN070	J-A09	13,497	14,147	-5%	Downstream of Schafer Road
JTOWN070A	J-A14a	13,128	15,648	-16%	700 ft downstream of Cattle Creek Lane
JTOWN080	J-A14	16,137	19,767	-18%	Confluence of Town Creek and Tributary 2
JTN04020A	J-B02a	4,162	3,913	6%	Tributary 4 @ Tributary 1
JTN01020A	J-B05a	3,403	3,390	0%	Tributary 1 @ Tributary 4
JTN01030	J-B03	7,535	7,287	3%	Confluence of Tributary 1 and Tributary 4
JTN01040A	Town Creek East	8,148	8,144	0%	Tributary 1 @ Town Creek
JTN02030	J-C02	5,197	5,277	-2%	Tributary 2 @ Country Lane
JTN02040	J-C04	9,327	9,082	3%	Confluence of Tributary 2 and Tributary 2a

Table 8. Drainage Area Comparison Table

DFIS HEC-HMS Node	Espey HEC-HMS Node	Drainage Area (sq mi)			Location
		Espey	Draft FIS	% Diff	
JTOWN040	J-A03	2.79	2.54	10%	1860 feet US of Wiedner Road
JTOWN45	J-A04	3.46	3.45	0%	Downstream of Borgfeld Road
JTOWN050	J-A05	3.79	3.65	4%	Downstream of FM 1103
JTOWN050A	Town Creek West	4.00	4.04	-1%	2500 feet US of SH Spur 539
JTOWN055	J-A06	7.39	7.44	-1%	Confluence of Town Creek and Tributary 1
JTOWN060	J-A08	8.38	8.14	3%	Downstream of FM 78
JTOWN070	J-A09	8.74	8.38	4%	Downstream of Schafer Road
JTOWN070A	J-A14a	12.29	11.81	4%	700 ft downstream of Cattle Creek Lane
JTOWN080	J-A14	18.52	18.22	2%	Confluence of Town Creek and Tributary 2
JTN04020A	J-B02a	1.35	1.33	2%	Tributary 4 @ Tributary 1
JTN01020A	J-B05a	1.17	1.15	1%	Tributary 1 @ Tributary 4
JTN01030	J-B03	2.52	2.48	2%	Confluence of Tributary 1 and Tributary 4
JTN01040A	Town Creek East	3.39	3.39	0%	Tributary 1 @ Town Creek
JTN02030	J-C02	2.31	2.57	-10%	Tributary 2 @ Country Lane
JTN02040	J-C04	5.60	5.95	-6%	Confluence of Tributary 2 and Tributary 2a

The results of this study are very similar to the Draft FIS results. Many of the differences shown in Tables 7 and 8, above, correlate with the slight differences in drainage areas since the hydrologic nodes are not located in the same places. In general, the peak discharges calculated in this study are slightly lower than those calculated in the Draft FIS. Two key differences between this study and the Draft FIS could account for this slight decrease in calculated peak discharges. They are rainfall and curve number assumptions. The specific differences are discussed below:

1. Rainfall. More recent rainfall data was used in this study. The rainfall depths are similar, but those used in this study are slightly lower.
2. Curve Number. A composite (weighted average) curve number was calculated for the entire drainage basin and it can be seen that the Draft FIS would expect less losses than this study. The composite curve number was determined by calculating a composite curve number for each basin, assuming a curve number of 98 for impervious areas. The basin-wide weighted average was then calculated using these composite values. The calculated composite curve number for this study is approximately 81 while that of the Draft FIS is 83.5.

3.7.2 Hydrograph Comparison

The lack of in-line Town Creek gage data necessitates a comparison of hydrographs to available existing studies. Givler Engineering published a drainage report entitled *Town Creek Hydrology & Hydraulics* in June 2005. The study did not examine the entirety of the Town Creek Watershed—only the portion of the western-most branch, and terminates at FM 1103, but it is useful on a comparative basis. In general, the peak flow rates, hydrograph timing and storm volumes appear very similar between these various independent studies.

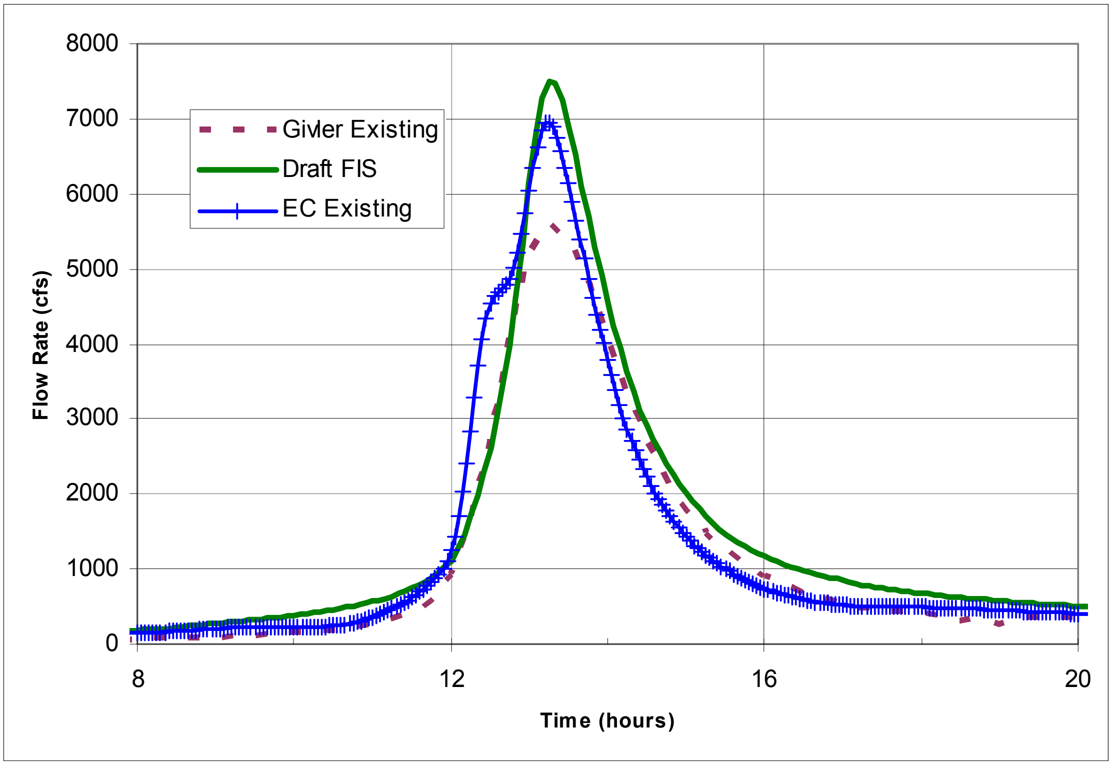


Figure 7: Comparison of 1% Hydrograph (Town Creek West at FM 1103)

3.7.3 USGS and Draft FIS Data Comparison

The USGS published a report entitled *Regional Equations for Estimation of Peak-Streamflow Frequency for Natural Basins in Texas* dated 1997. The report contains analysis of over 100 gages in the Central Texas area (USGS Region 5). The figure compares EC computed peak flow values to USGS historical computed peak flow values for the 1% annual chance exceedance event. In addition, draft FIS results are included in this comparison. While it is difficult to compare flow rates at specific locations (see Tables 7 and 8, above) because hydrologic nodes may not be found in the same location from study to study, a comparison of flow rate versus drainage area will show the relative results. Figure 8 shows that the results are very similar between the various studies.

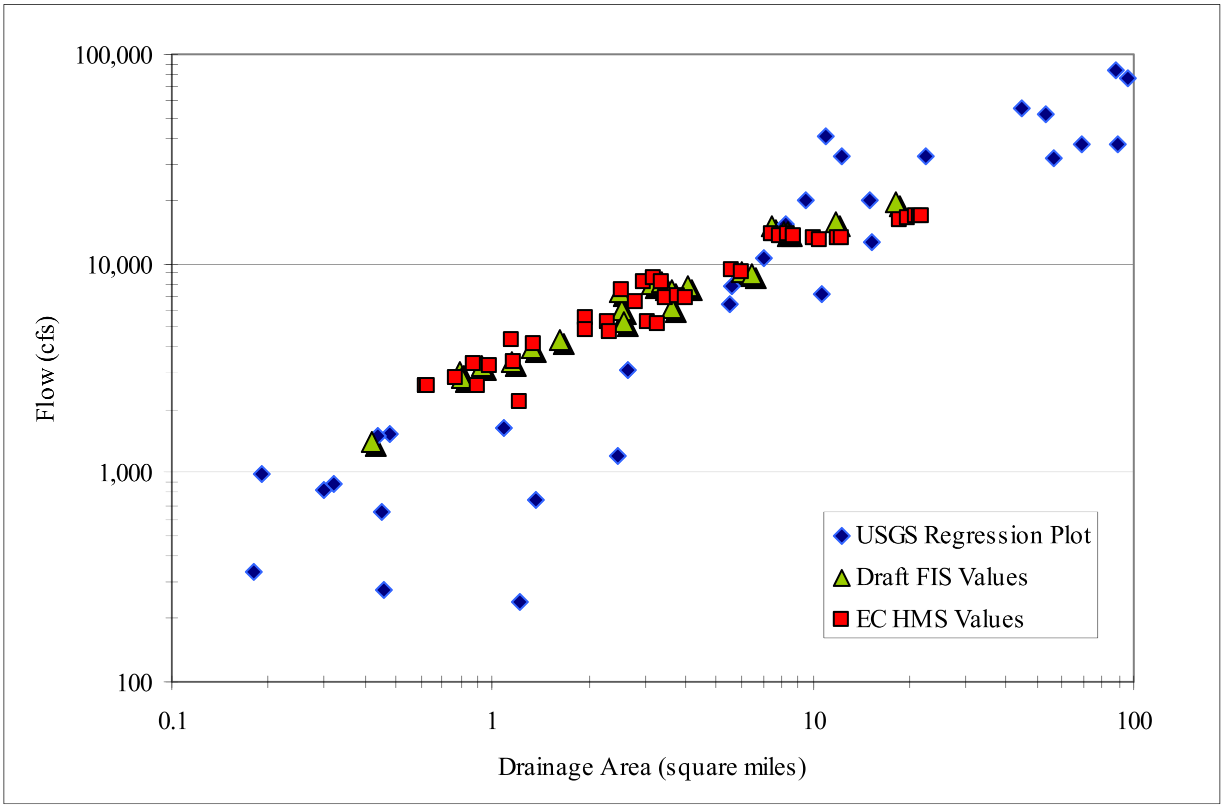


Figure 8: USGS Regression Plot Comparison to EC Hydrologic Model (1% Annual Chance Exceedance Event)

1.7.4 Summary of Results

The tables below show the results of the hydrologic study. These tables show the peak discharges for the existing, ultimate and natural conditions events. In general, the existing conditions peak flow rates are 1% to 6% greater than the natural condition events. The ultimate conditions events are 3% to 14% greater than the existing conditions events. From this analysis it can be seen that existing development within the Town Creek watershed has increased storm discharges, but the impact is relatively minor. This suggests that flooding problem areas currently within Cibolo were not likely caused by recent development. However, the potential exists for significant increases in flooding in the future. It should also be noted that relative discharge increases are generally greatest in the more frequent flood events. This can have a large impact on channel stability, erosion and nuisance flows

Table 9: 25-Year (4%) Peak Discharge Summary

Reach	HEC-HMS Node	PEAK DISCHARGE SUMMARY (cfs)		
Town Creek (Mainstem)		**4% Existing**	**4% Ultimate**	**4% Natural**
FM 1103	J-A05	4,394	4,880	4,256
US of Confluence w/ Tributary 1	Town Creek West	4,304	4,721	4,172
Confluence w/ Tributary 1	J-A07a	8,763	9,725	8,461
FM 78	J-A08	8,997	9,956	8,679
Confluence w/ Tributary 2	J-A14a	8,273	9,096	7,896
Confluence w/ Santa Clara Creek	OUT	10,715	12,046	10,159
Tributary 1				
Confluence w/ Tributary 4	J-B05a	2,263	2,563	2,249
FM 1103	J-B07	4,976	5,527	4,844
Confluence w/ Town Creek	Town Creek East	5,004	5,541	4,839
Tributary 2				
Confluence w/ Tributary 2A	J-C04a	3,454	3,685	3,245
Confluence w/ Town Creek	Trib2	6,096	6,376	5,740
Tributary 2A				
Confluence w/ Tributary 2	J-D02	3,218	3,451	3,140
Tributary 4				
Confluence w/ Tributary 1	J-B02a	2,871	3,277	2,799

Table 10: 100-Year (1%) Peak Discharge Summary

Reach	HEC-HMS Node	PEAK DISCHARGE SUMMARY (cfs)		
Town Creek (Mainstem)		**1% Existing**	**1% Ultimate**	**1% Natural**
FM 1103	J-A05	6,959	7,559	6,867
US of Confluence w/ Tributary 1	Town Creek West	6,795	7,365	6,689
Confluence w/ Tributary 1	J-A07a	13,419	14,684	13,169
FM 78	J-A08	13,848	15,125	13,564
Confluence w/ Tributary 2	J-A14a	13,128	13,863	12,813
Confluence w/ Santa Clara Creek	OUT	16,689	18,103	16,015
Tributary 1				
Confluence w/ Tributary 4	J-B05a	3,403	3,760	3,413
FM 1103	J-B07	8,454	8,945	8,353
Confluence w/ Town Creek	Town Creek East	8,148	8,929	7,995
Tributary 2				
Confluence w/ Tributary 2A	J-C04a	5,124	5,287	4,971
Confluence w/ Town Creek	Trib2	9,019	9,352	8,524
Tributary 2A				
Confluence w/ Tributary 2	J-D02	4,746	5,046	4,662
Tributary 4				
Confluence w/ Tributary 1	J-B02a	4,162	4,540	4,108

4.0 HYDRAULICS

4.1 HYDRAULICS SUMMARY

The hydraulic analysis is conducted on various reaches within the Town Creek Flood Protection Plan watersheds. There are 24.3 miles of stream included with this hydraulic analysis, which computes water surface elevations for the existing and ultimate 50%, 10%, 4%, 1% annual chance storm events. The hydraulic analysis includes the delineation of various existing and ultimate floodplains. The studied streams include the following reaches:

Table 11: Studied Streams

Reach	Reach Limits	Reach Length (ft)	Number of Structures
Town Creek (Detailed)	From E. Schaefer Rd. to 2,000 ft southwest of the intersection of Old Wiederstein Rd. and Dean Rod. The section of this reach upstream of the confluence with Tributary 1 is also known as Town Creek West.	25,160	7
Town Creek (Limited Detail)	From 2,200 ft downstream of Stagecoach Rd. to E. Schaefer Rd.	43,200	4
Town Creek Tributary 1	From the confluence with Town Creek to 2,400 ft upstream of FM 1103. This reach is also known as Town Creek East.	17,360	2
Town Creek Tributary 2	From the confluence with Town Creek to 1,100 ft north of the intersection of Weil Rd. and Short Weyel Rd.	26,260	9
Town Creek Tributary 2A	From the confluence with Tributary 2 to 8,700 ft upstream of Youngsford Rd.	13,100	1
Town Creek Tributary 4	From the confluence with Tributary 1 to 1,200 ft upstream of FM 1103.	3,370	1
	Total:	*128,450 ft*	24
	Total Reach Length:	*24.3 miles*	

The Town Creek watershed hydraulic analysis for the Guadalupe County FEMA restudy was conducted by Halff Associates, Inc. and submitted in November 2005. While this analysis is not yet the effective Flood Insurance Study and is still in "draft" format, it was assumed to represent the best available data. The HEC-RAS models developed for the draft FIS were used as a basis of this Flood Prevention Plan. Many changes were made to these models as a result of our study and these are discussed in more detail below. Two new reaches were added to the study, including Tributary 2A (2.5 miles) and extending Town Creek (LD) downstream to the confluence with Santa Clara Creek (3.5 miles).

4.2 METHODOLOGY

The USACE HEC-RAS software version 3.1.2 is used for the hydraulic analyses. All modeling is one dimensional and steady state. The sections that follow describe the development of the hydraulic models both in general terms and specifics that apply to certain reaches.

4.3 PROCESSING

The new geometry needed for Tributary 2A and the downstream portion of Town Creek was generated using HEC-GeoRAS as a preprocessor to HEC-RAS. HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface. HEC-RAS is then executed to determine the flood elevation at each cross section of the modeled stream. The resulting elevations are then imported back to HEC-GeoRAS for creation of the flood boundaries. The techniques and tools utilized to perform the analyses meet FEMA's adopted standards. No individual community criteria are incorporated within this study.

4.4 CROSS-SECTION

As stated above, the majority of the cross-section data was taken directly from the draft FIS. New cross-section data was obtained only for Tributary 2A and for an additional 3.5 miles of Town Creek downstream of the draft FIS study. In general, model cross sections are placed along the study streams using the available contour data. Where roads or other structures are encountered, supplemental cross sections are required to meet HEC-RAS data input needs. The HEC-RAS model generated from HEC-GeoRAS then receives an extensive quality check / quality assurance to ensure that LIDAR and Field Survey data are merged correctly. The cross-section location map is included as Exhibit 4.

4.5 PARAMETER ESTIMATION

The tables below show the various hydraulic parameters used to analyze the detailed reaches of the Town Creek Restudy. The Manning's "n" value assumptions were not changed from the draft FIS.

Table 12: Manning's Roughness Coefficients

Reach	N-Value Ranges in HEC-RAS	
	Channel "n" Values	Overbank "n" Values
Town Creek (Detailed)	0.06 – 0.07	0.065 – 0.09
Town Creek (Limited Detail)	0.06 – 0.07	0.065 – 0.09
Town Creek Tributary 1	0.055	0.065 – 0.075
Town Creek Tributary 2	0.026 – 0.065	0.065 – 0.075
Town Creek Tributary 2A	0.055	0.065
Town Creek Tributary 4	0.055	0.065 – 0.075

The downstream boundary condition assumptions were modified as compared to the draft FIS. In general, the starting water-surface elevations used in the draft FIS were normal depth. This assumes a free outfall. The confluences within this study were examined to determine if coincident peaks could occur within this area. Coincident peaks would assume that the receiving waters contained the peak discharge at the same time. This is generally a more conservative assumption than normal depth (free outfall). FEMA regulations state that it may be appropriate to assume coincident peaks if all of the following are true; the ratio of the drainage areas lies between 0.6 and 1.4, the times of peak flow are similar for the two combining watersheds, and the likelihood of both watersheds being covered by the storm being modeled is high. With these considerations, it seemed appropriate to consider the following confluences as having coincident peaks; Tributary 1 and 4, Tributary 1 and Town Creek, and Tributaries 2 and 2A.

Table 13: Relative Drainage Areas at Confluences

Reach	HEC-HMS Node	Drainage Area (sq mi)	Ratio
Town Creek Tributary 1	J-B05a	1.17	0.87
Town Creek Tributary 4	J-B02a	1.35	
Town Creek (Detailed)	Town Creek West	3.99	0.85
Town Creek Tributary 1	Town Creek East	3.39	
Town Creek Tributary 2	J-C04a	3.28	0.70
Town Creek Tributary 2A	J-D02	2.32	

In addition, it was shown that the timing of the peaks was within a less than 30 minutes in each case. Coincident peaks were modeled in the cases of Tributaries 1 and 4 and Tributaries 2 and 2a by simple adding the smaller tributary to the larger tributary's HEC-RAS model. For the confluence of Town Creek and Tributary 1, the cross-section on Town Creek just downstream of the confluence was added to the Tributary 1 model. Tributary 1 was then modeled with a known water surface elevation dictated by the Town Creek model at this location. The differences between the FIS assumptions and those of this study are shown below. It should be noted that the normal depth assumption for the lower section of Town Creek (Limited Detail) differs from the FIS because the Espey model terminates at a different location than the draft FIS.

Table 14: Reach Boundary Condition

Reach	Boundary Condition in HEC-RAS	
	Draft FIS	**Espey FPP**
Town Creek (Detailed)	known water surface elevation (WSE) (from Town Creek LD)	same
Town Creek (Limited Detail)	normal depth, s = 0.00152	normal depth, s = 0.002
Town Creek Tributary 1	normal depth, s = 0.00175	known WSE (Town Creek)
Town Creek Tributary 2	normal depth, s = 0.00185	same
Town Creek Tributary 2A	NA	known WSE (Trib 2)
Town Creek Tributary 4	critical depth	known WSE (Trib 1)

4.6 MODELING CONSIDERATIONS

4.6.1 Town Creek (Detailed)

The main stem of Town Creek is also known as Town Creek West upstream of the confluence with Tributary 1. This reach was generally unchanged when compared to the draft FIS with the exception of the FM 1103 bridge. FM 1103 underwent a widening between IH-35 and Main Street in Cibolo. The culvert in the HEC-RAS model was updated to be consistent with the construction plans developed by HDR in the fall of 2004.

4.6.2 Town Creek (Limited Detail)

This is the section of Town Creek downstream of E. Shaefer Road to the confluence with Santa Clara Creek. This reach was extended by 3.5 miles beyond the downstream limit of the draft FIS. The stationing was also revised to accommodate the new downstream sections.

4.6.3 Town Creek Tributary 1

Tributary 1 is also known as Town Creek East. There are several significant changes in this model when compared to the draft FIS. The draft FIS includes this stream in two sections, a detailed study downstream of FM 1103, and a limited detail study upstream of FM 1103. These two reaches were combined into one model. Tributary 1 also crosses under FM 1103 in two places. Both locations were improved in the FM 1103 widening mentioned above. The HEC-RAS model was updated to include the new FM 1103 crossings. In addition, Tributary 4 was added to this model since it was determined that Tributary 4 and Tributary 1 could have coincident peaks.

4.6.4 Town Creek Tributary 2

Tributary 2 was only modified from the draft FIS to add Tributary 2A where these two streams confluence, just upstream of FM 78.

4.6.5 Town Creek Tributary 2A

Town Creek Tributary 2a is a new reach, not modeled in the draft FIS. The drainage area to Tributary 2a, at its confluence with Tributary 2, is approximately 2.32 square miles. This is well in excess of the 1 square mile threshold that FEMA uses to determine which streams merit study. Tributary 2a was included in the Tributary 2 model to show that these streams could have coincident peaks.

4.6.6 Town Creek Tributary 4

Tributary 4 was added into the Tributary 1 modified HEC-RAS model.

4.7 HYDRAULIC FLOODPLAIN DELINEATION AND WORK MAP

The respective floodplain delineations were carried out using HEC-GeoRAS. Work maps were developed using 2-foot contour interval topographic maps at 1” to 500’ scale for the Town Creek watershed. This map includes the delineation of the 100-Year (1%) existing and ultimate floodplains and are included as Exhibit 5, Appendix A. Existing and ultimate floodplains were also delineated for the 10-Year (10%) and 25-Year (4%). These are included in digital format in Appendix I.

4.8 RESULTS AND CONCLUSIONS

The 100-Year (1%) existing condition floodplain were very similar to that presented in the Draft FIS. This study, however, not only adds floodplain delineations for ultimate conditions but also for more frequent events. Most noteworthy was the determination of the relative extents of flooding problems that exist even at the 10-Year (10%) level.

The results of these hydrologic and hydraulic analyses indicate that there are several areas at risk within the city that will need to be addressed. There are more than 300 structures in the Town Creek watershed (which includes areas of the County) that are at risk for flooding in a 1% annual chance event. The majority of these structures are within the mobile home community near the railroad and Country Lane, and in the community along Haeckerville Road. A number of structures and/or lots are at risk in the Buffalo Crossing / Cibolo Valley Ranch area along Town Creek East, and multiple commercial structures along N. Main St. are at risk.

The major contributing factors to the flooding are as follows:

1. The watershed generates a large volume of water that peaks very suddenly.
2. The flat terrain and relatively poor natural channel definition allows floodwaters to spread out widely.
3. Homes were built in harm’s way; before the first floodplain maps, based on outdated flood maps, and according to the preliminary floodplain maps. Some areas would currently be considered at risk in a 10% event.
4. Unattenuated runoff from new development exacerbated a problem that was pre-existing.

5.0 FLOOD PROTECTION PLAN

The response to these flooding issues is directed by a series of policy goals, analyses and actions, as formulated below. A goal is a desired end or outcome. The analysis discusses the technical basis behind the goal, and supplies the impetus to the individual actions. The actions are specific projects, programs or activities which are recommended for implementation in order to achieve the goal. Taken all together, these goals represent the long term approach that the City and its partners in floodplain management must undertake in order to address the flood hazard risk posed by Town Creek. In short, these goals are as follows:

> ***Goal 1****: "Fix what we can, as soon as we can": Recognizing that many homes were built in harm's way, relieve the flooding experienced by existing development to the greatest extent practical.*
> ***Goal 2****: "Be a good neighbor": Ensure that new development in the watershed does not adversely affect property downstream.*
> ***Goal 3****: "Keep an exit strategy": Critical facilities must be accessible during a 1% annual chance event.*
> ***Goal 4****: "The small stuff adds up": Provide a means to reduce nuisance flooding events*
> ***Goal 5****: "Turn around, don't drown": Eliminate the greatest risk of flood-related death – vehicles trying to cross at low-water crossings.*
> ***Goal 6****: "Knowledge is power": Leverage the efforts of various entities in keeping the citizens of Cibolo informed about the risk of flooding before disaster strikes, so that they also know how to respond in a flooding event.*
> ***Goal 7****: "Keep more eyes to the sky, and an ear to the ground": Leverage the resources of other regional stakeholders and begin discussions of a flood early warning system.*
> ***Goal 8****: "Multiple birds, one stone": Seek coordinate opportunities to implement multi-purpose projects, particularly with regard to water quality and erosion mitigation.*
> ***Goal 9****: "Give the creek the room it needs": Protect the integrity of Town Creek's geomorphology and ecology.*
> ***Goal 10****: "Plan time with friends": Recognizing that the City is a growing entity, identify current and future partners in floodplain management, and cultivate relationships for regional disaster resistance into the future.*

5.1 "FIX WHAT WE CAN, AS SOON AS WE CAN": RECOGNIZING THAT MANY HOMES WERE BUILT IN HARM'S WAY, RELIEVE THE FLOODING EXPERIENCED BY EXISTING DEVELOPMENT TO THE GREATEST EXTENT PRACTICAL (GOAL 1).

The following analysis first discusses the main problem areas and potential protection measures individually, and then as a whole strategy relative to the watershed. Through this analysis of alternatives, the maximum potential for reduction can be determined.

5.1.1 Haeckerville Road Area Analysis

The most severe problem area is located along the eastern side of Haeckerville Road, south of Schaefer Road. These buildings were constructed, in many cases, prior to the adoption of floodplain management regulations, and according to this study there are 59 homes at risk during a 1% chance event. The severity of flood problem here is evidenced by the fact that during a 4% chance event, there are still 54 homes at risk. The problem is that to achieve even a 4% level of service through structural measures requires the mitigation of more than 12% of the peak discharge flowing through this area.

EC considered four structural approaches that would provide specific relief to this area: channel improvements, a flood diversion channel, and upstream regional detention – inline and offline. First, channel improvements from Schaefer Road through the problem area to Arizpe Road were considered. However, the topographic constraints through this reach, the presence of a cemetery and the likely presence of wetland areas downstream of Haeckerville Road were determined to be prohibitive to constructing a channel of sufficient size.

The second alternative considered the construction of a storm sewer relief tunnel or channel, conveying excess storm water in a diversion structure approximately 3,300 feet to the west and discharging to Cibolo Creek. Again, the size required of such a facility was so large (10-12' x 10' RCB) that it was determined to not be feasible. In addition, any such diversion would need to consider impacts to Cibolo Creek.

The third alternative considered was an inline detention pond located at the confluence of Town Creek Mainstem and Town Creek Tributary No. 1. In order to reduce a 1% annual chance event down to a 4% chance level of service at this problem area, a regional detention pond would need to provide at least 1,025 acre-feet of detention storage, amounting to a pond of approximately 87 acres in surface area and 16 feet deep. To provide a 1% annual chance level of protection (reducing the 1% chance event to a 10% chance event), such a facility would need to be able to detain more than 1,400 acre-feet of water – enough to cover an 100 acre site more than 16 feet in depth and more water than is generated by the entire Town Creek Tributary No. 1 watershed in this same 1% event.

The general area upstream of FM 78 and just below the confluence of the mainstem and Tributary No. 1 is a logical site for construction of a regional detention facility. In order to minimize the potential environmental impact, an offline facility was evaluated further instead of the inline concept. Maximizing the available land area and depth at this site with an inline concept yields approximately 650 acre-feet of volume. However, the downstream benefit of this facility is partly limited due to the poor conveyance between FM 78 and Haeckerville Road, and more significantly due to the level of encroachment into the floodplain by existing buildings. Figure 9 depicts the potential floodplain reduction of such a facility which has an outlet configured to detain for the 1%. Appendix F includes a schematic of this facility as well.

While the reduction in floodplain width appears nominal for the 1% event, a pond of this volume offers considerable potential to mitigate for more frequent events. For instance, a 600 acre-foot pond can reduce the 4% ultimate event (which is almost as wide as a 1% floodplain) to a 10% level. Figure 10 depicts this reduction of floodplain. The result is that of approximately 54 structures which are flooded in a 4% ultimate event (without a facility in place), only 21 are flooded with such a facility in place. Over time, this facility will provide more damage reduction if configured to reduce floods from a 4% level down to a 10% level, while allowing the 1% event to pass, as opposed to if it is configured to reduce the 1% ultimate down to a 1% existing level of risk.

Figure 9: Floodplain comparison (1% ultimate) pre- and post-improvements

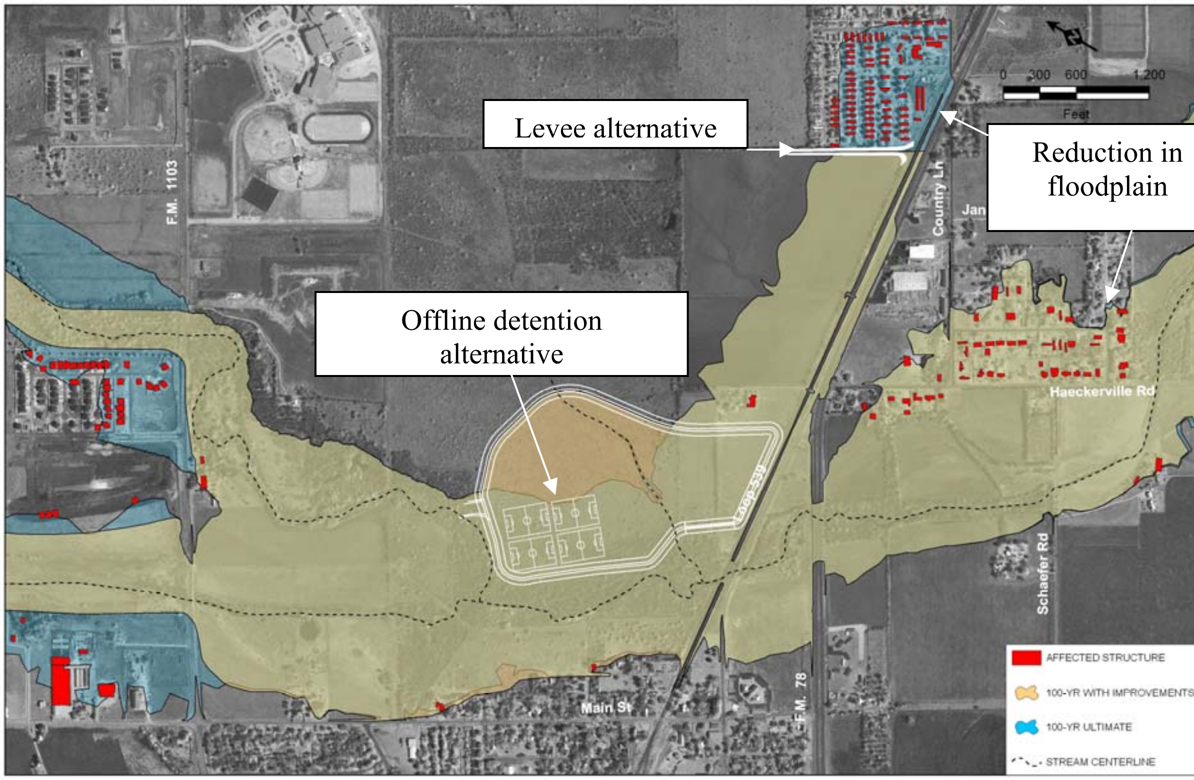
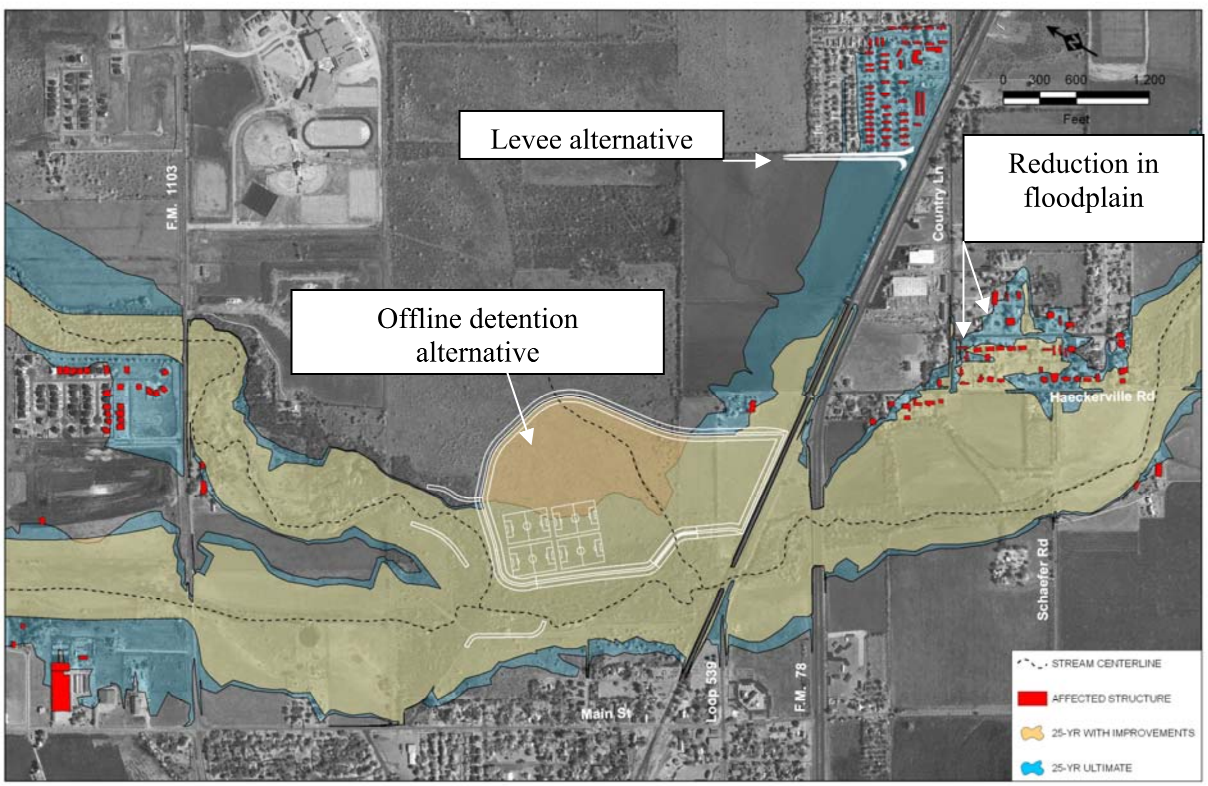


Figure 10: Floodplain comparison (4% ultimate) pre- and post-improvements



5.1.2 Country Lane/Union Pacific Railroad Area Analysis

The railroad bridge at Town Creek creates significant backwater affecting the mobile home community at the railroad and Country Lane. While this section of the floodplain does not provide active conveyance of flood flows, the results of this study indicate that as many as 80 buildings are inundated by up to 2 feet of water in a 1% event. This depth of ponding also covers the only routes of ingress and egress. For the 4% event, the number of affected buildings drops to 24, and no structures are affected in the 10% event.

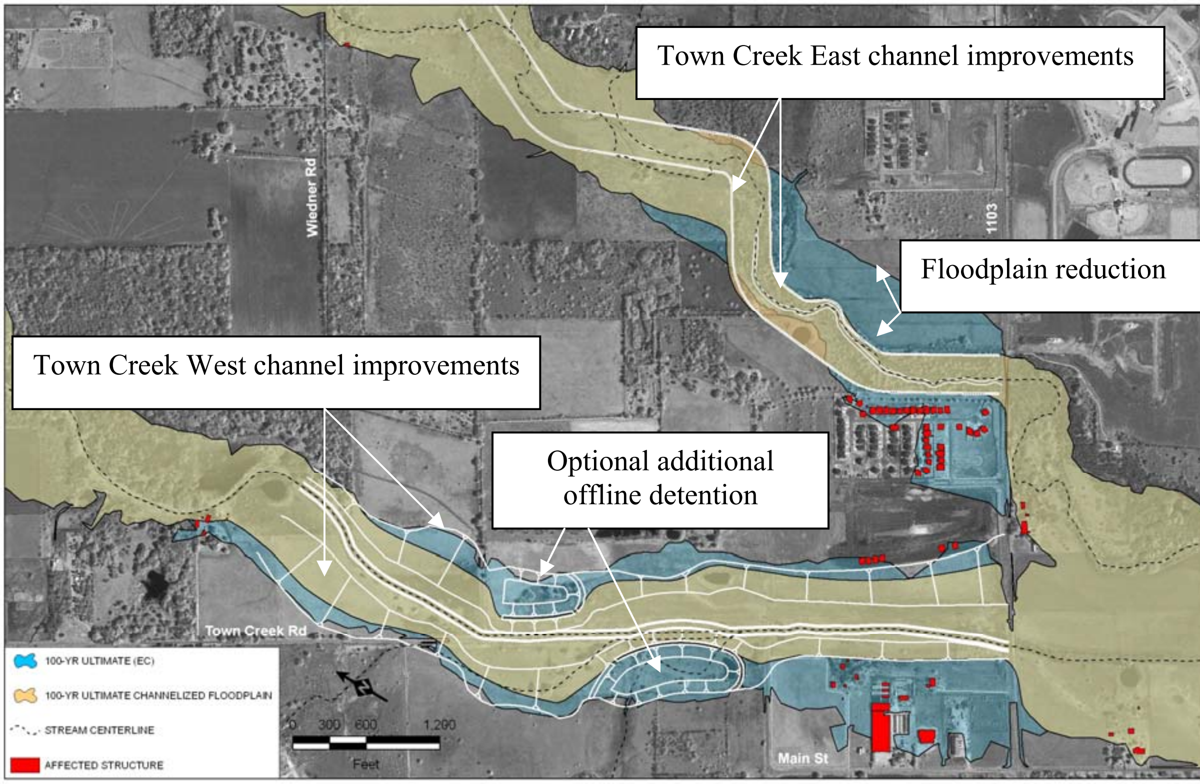
To address this problem area, a small levee could be constructed to protect the residents of the mobile home park. This levee would extend from the railroad to the north approximately 1,000 linear feet at a maximum height of six feet, transitioning back to natural grade along this course (see Figure 9 above and Appendix F). A one-directional pipe with a flapgate would be utilized to still enable the area to drain. No additional solutions were studied for this problem area.

5.1.3 Town Creek East

Immediately upstream of FM 1103 along Town Creek Tributary No. 1, large sections of the Buffalo Crossing Subdivision are at risk in the events analyzed. TxDoT recently constructed new box culverts at FM 1103 which offer significant reduction in water surface elevation. However, there are currently approximately 63 homes at risk in the 1% annual chance event, of which 42 are still at risk in a 10% event.

A channel improvement alternative was evaluated to provide enhanced conveyance through this reach and lower water surface elevations. With some additional bermed earth placement along the western bank, an approximate 3,500 linear foot trapezoidal earthen channel section at a 300’ bottom width should remove these homes from the floodplain. See Figure 11 below, and Appendix F. However, if an offline detention structure is constructed that runs adjacent to the railroad, this alternative may not be necessary.

Figure 11: Town Creek East and Town Creek West channel improvements effect on 1% ultimate event.



Constructing a bridge at FM 1103 was also evaluated as an alternative, in which the section from the High School to Main Street would be elevated to allow better conveyance. Ultimately, this alternative drops the floodplain by 1.3', removing some homes from the floodplain, but would be very expensive (~$17M) replacing culverts which have only recently been installed at FM 1103.

Upstream detention was not specifically modeled because there does not appear to be an appropriate location, considering topography, contributing area and the surface area requirement for such a facility.

5.1.4 Town Creek West

The structures affected in this problem area were mostly constructed before the effective flood insurance study. There is significant backwater at FM 1103 and poor positive drainage, which has precluded further development near the intersection of FM 1103 and Main Street. However, the development pressure to the floodplain fringe is expected to intensify over the next several years. The predominant issue in this problem area is conveyance, as Town Creek is very poorly defined and exhibits a very broad floodplain.

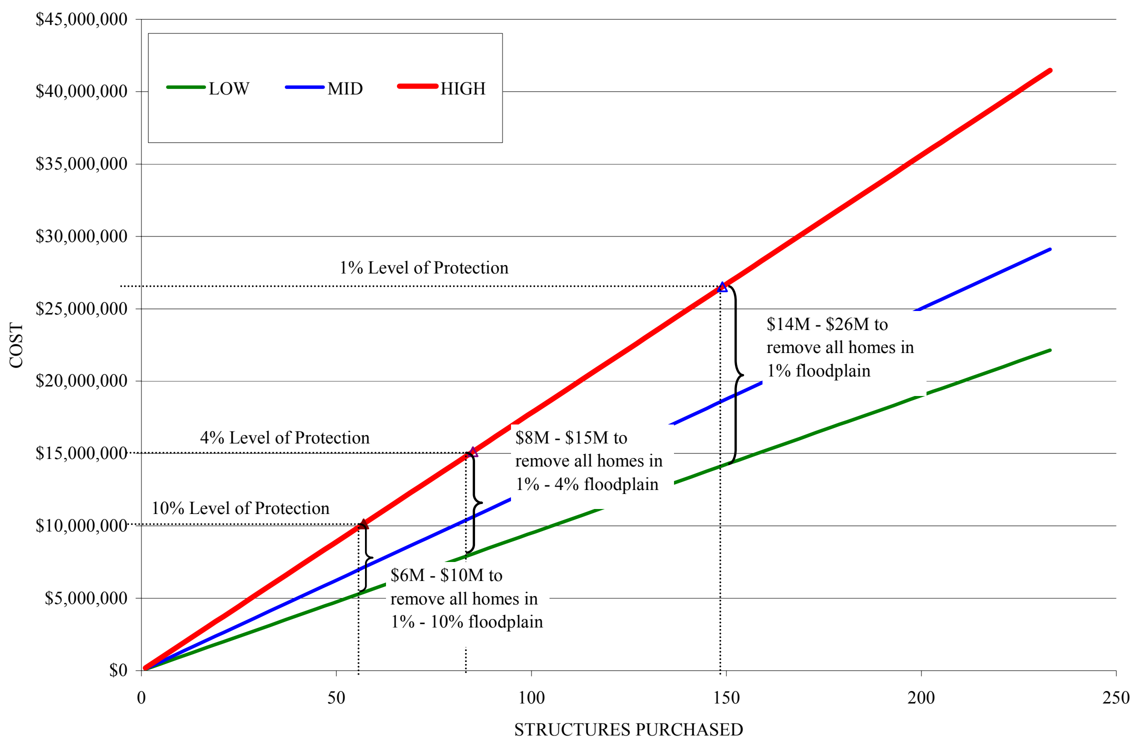
A channel improvement alternative was evaluated here, as well. This improvement is mostly needed for conveyance of ultimate conditions flows generated by recent and future development upstream. The area designated for this improvement has been largely dedicated to the city as drainage right-of-way and parkland. Multiple uses can be well accommodated in this area, and is identified as such on the City's Future Land Use Map and Master Plan. A meandering, 350 foot bottom width, earthen, multi-stage trapezoidal section channel is capable of containing the 1% annual chance ultimate conditions floodplain (Figure 10 above).

5.1.5 Non-structural Approaches

In addition to the structural alternatives investigated above, three non-structural alternatives were considered as a means of mitigating risk: a voluntary acquisition program, a relocation program, and elevation of floodprone structures. An acquisition program utilizes funds (typically leveraged public funds) to acquire repetitive loss properties which are then dedicated as open space into perpetuity. Such a program is also known as a "buyout program" and is always voluntary. If developed and identified on the community's Multi-Hazard Mitigation Action Plan, these projects may be eligible for Federal funding assistance.

In order to facilitate the comparisons of structural alternatives with the acquisition alternative, the following chart was developed (Figure 12).

Figure 12: Acquisition Alternative



Each line in the graph represents the cost to purchase a given number of structures. The middle line assumes a median property value, whereas the upper and lower lines indicate likely bounds based upon 2006 Guadalupe County appraisal data. Developing and funding a program depends on the level to-which protection is desired. For instance, to achieve a 4% annual chance level of protection in the Town Creek watershed (i.e., community-wide), the City would have to spend between $8 million and $15 million in acquisitions.

Another option with this program is to utilize it as a "last measure" in providing mitigation where all other measures cannot provide relief.

A relocation program is another strategy that is eligible for funding under FEMA's Flood Mitigation Assistance (FMA) Program. With this strategy, structures from acquired or restricted real property are relocated to non hazard-prone sites. Relocation is obviously most suitable for pier and beam foundation structures, and must be considered in connection with zoning restrictions and other building code issues.

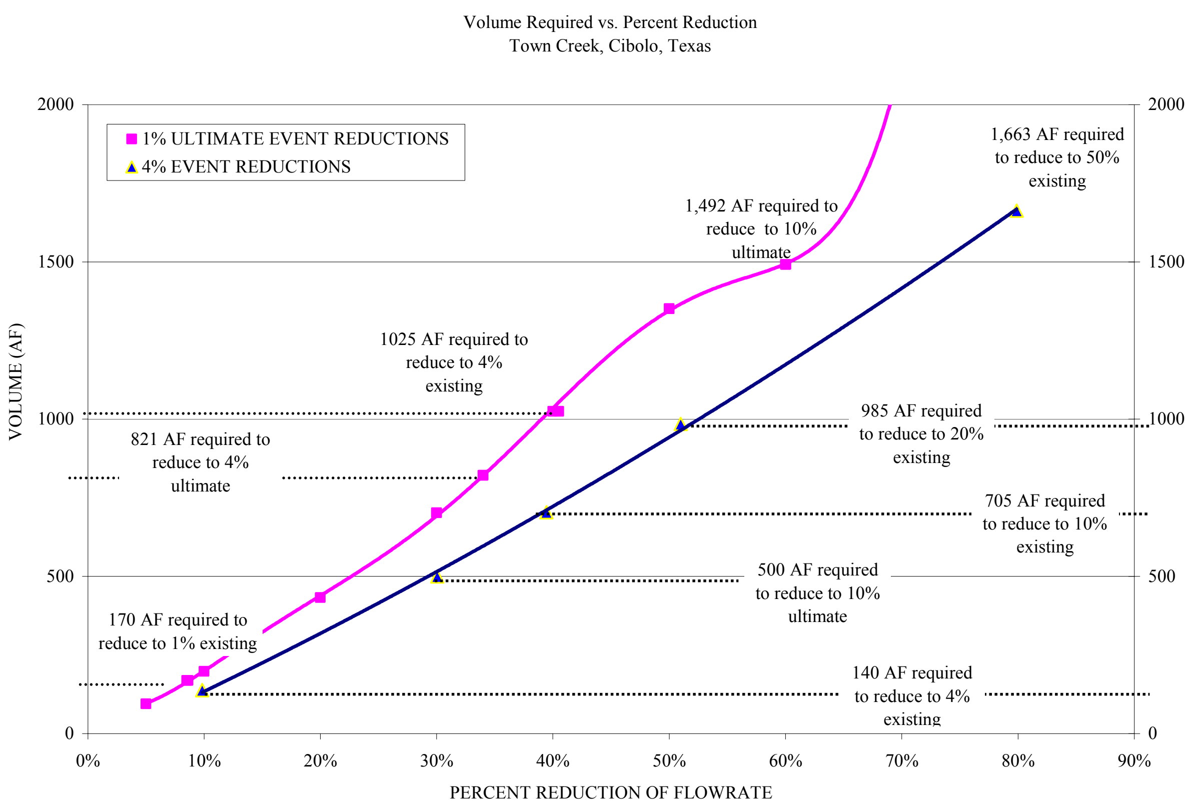
Elevation is a third non-structural option which is available to pier and beam structures. However, it should be weighed carefully versus acquisition or relocation, since elevation does not remove lives from the harm's way – only property. It should not be used in areas which do not have at least a 4% annual chance level of service for ingress or egress.

5.1.6 Evaluating a System of Alternatives

The analyses above indicate that targeted structural improvements have some direct effectiveness in the flood problem areas, and with considerably varied cost/benefit terms. However, since no single alternative can solve all of the problems, but each alternative has some level of effectiveness in a localized context, clearly a system of alternatives must be developed that balances the relative degrees of effectiveness with their relative costs in order to meet this primary goal.

The levee solution for the Country Lane area is clearly a cost-effective measure that can provide protection independent of any other solutions. The channel improvement projects for Town Creek East and Town Creek West provide immediate relief to adjacent floodprone areas, as well as provide needed conveyance capacity for ultimate conditions flows. However, these improvements do not solve the problems at Haeckerville Road or Country Lane/Union Pacific Railroad. At the same time, the channel improvements in and of themselves do not exacerbate conditions at these areas. Some level of detention is necessary in connection with the channel improvements, in order to remediate some of the flood risk posed to Haeckerville Rd. The following figure shows two sets of options for sizing the detention facility.

Figure 13: Detention volume



The upper line (square data points) represents the volume-reduction relationship if the intent is to manage the 1% ultimate event. The lower line (triangular data points) represents the volume-reduction relationship if the intent is to manage for the 4% event. What is very evident through this graph is the tradeoff between heightened level of protection and efficiency of the pond. The 1% event delivers such a volume of water to the detention site that the available storage is easily and quickly filled. Thus, utilizing detention to mitigate for the 1% ultimate event is not easily effective within the limits of feasible storage construction.

If the intent then is shifted to bringing the 4% ultimate event down to lower levels, the storage is more efficiently used. For instance, the 600 AF that is available at this site will reduce the effects of a 4% ultimate event down to a point between a 10% ultimate and 10% existing flooding level. On the ground, this is a much more significant difference in flooding limits and number of affected buildings. On the other hand, it must be understood that if configured for a 4% ultimate event, the 1% event is not significantly mitigated – essentially passing through.

5.1.7 Recommended Actions

The following table and action items summarize efforts that should be undertaken in order to relieve flooding experienced by existing development to the greatest extent practical.

Action 1.1: Construct a channel improvement project along Town Creek Tributary No. 1 upstream of FM 1103.
Action 1.2: Construct a channel improvement project along Town Creek (Mainstem) upstream of FM 1103.
Action 1.3: Construct a levee at Country Lane with the participation of the affected landowner.
Action 1.4: Construct a regional detention facility downstream of FM 1103 and upstream of FM 78 to mitigate the increase of the 4% ultimate event.
Action 1.5: Develop a voluntary acquisition and relocation fund and program that can be used to purchase properties at risk in a 4% chance or higher event, and convert them to open space.

5.2 "BE A GOOD NEIGHBOR": ENSURE THAT NEW DEVELOPMENT IN THE WATERSHED DOES NOT ADVERSELY AFFECT PROPERTY DOWNSTREAM (GOAL 2).

In a hydrologic and hydraulic context, there are two components to employing a "good neighbor" approach. First, new development must not increase the peak discharges relative to key points downstream. Second, conveyance of ultimate development flows must be maintained from the point of release to a point of control. As a community, the objective is to permit no net increase in peak discharge as stormwater leaves the community. Primarily, this is accomplished through heightened drainage standards for new developments, requiring on-site detention, participation in regional detention facilities, off-site conveyance improvements, and dedication of easements and rights-of-way. The extent to which these "good neighbor" standards are exacted becomes a question of measurable need and the proportionality of the individual measure required to the impact being generated.

5.2.1 Analysis

Currently, the conveyance system of the Town Creek watershed is underdeveloped relative to both existing and ultimate anticipated need. This is partially the result of the following factors: development that did not provide stormwater detention on-site, poorly defined natural channels, and encroachment into flood hazard areas. Another issue surrounds unmitigated increases to flow velocities, which has historically resulted in erosion, scour and unwanted sedimentation. Future development must not exacerbate these issues.

5.2.2 Recommended Action

To this end, the following actions are recommended:

Action 2.1: Require detention for the 1% annual chance event; either on-site or regional.

Action 2.2: Require conveyance for the ultimate 1% annual chance event.

Action 2.3: Require dedication of drainage right-of-way for the ultimate 1% annual chance event allowing Town Creek the room that it needs to move.

Action 2.4: Develop specific maximum permissible velocities as a criterion for design within the city.

5.3 "KEEP AN EXIT STRATEGY": CRITICAL FACILITIES MUST BE ACCESSIBLE DURING A 1% ANNUAL EVENT (GOAL 3)

The city's ability to respond during a flood disaster is critical to minimizing loss of life during such an event. It is also expected that, among other things, emergency and law enforcement responders have the capability to reach the incidences they are called to. At the same time, citizens who are evacuating need to be able to reach critical facilities: major evacuation routes, hospitals, etc.. This need provides the impetus for a standard level of service that should be maintained as the city grows and develops.

5.3.1 Analysis

The following arterial level roadways are under more than one foot of water in a 1% and 4% annual event.

Table 15: Depth of flooding over arterial roadways.

Stream	Crossing	Depth over Roadway (4% Chance Event) (ft)	Depth over Roadway (1% Chance Event) (ft)	Future Thoroughfare Plan Classification
Mainstem	Dean Road	1.39	1.61	Secondary Arterial
	Green Valley Road	4.00	4.67	Secondary Arterial
	Weidner Road	3.09	3.66	Secondary Arterial
	FM 1103	1.98	2.72	Primary Arterial
	Loop 539	3.58	4.29	-
	FM 78	1.41	3.68	Primary Arterial
	Schaefer Road	5.14	5.97	-
	Haeckerville Road	6.06	7.44	-
Trib 1	FM 1103 (Upstream)	1.87	2.42	Primary Arterial
	FM 1103 (Downstream)	1.79	2.31	Primary Arterial

Green Valley Road is listed as a secondary arterial roadway in the City's Master Thoroughfare Plan. In order for this road to provide critical east-west connectivity during a flood event, the crossing must be upgraded to provide full conveyance for the 1% annual chance event.

5.3.2 Recommended Actions

Thus, the following actions are recommended:

Action 3.1: Include an upgrade of the Green Valley Road crossing of Town Creek in the City's CIP, to provide clear conveyance of the 1% annual event.

Action 3.2: Actively seek funding partners for this project, such as developer and County participation, and grant program assistance.

Action 3.3: The location of future Fire/EMS stations or emergency medical facilities should be located along a major collector/secondary arterial road that has uninterruptible access across Town Creek.

5.4 "THE SMALL STUFF ADDS UP": PROVIDE A MEANS TO REDUCE NUISANCE FLOODING EVENTS (GOAL 4).

Given the flashy nature of the Town Creek watershed, and the similarities in hydraulic response of the stream network to different storm events, a 50% or 20% annual chance event will create nuisance issues such as minor yard flooding, displacement of debris and mud, and channel forming scour and deposition. While this may not cause the same level of damage to homes and businesses as a 4% or 1% event, the more frequent nature of these events can be at best termed a nuisance, if not a community problem. Apart from the expense of clean-up activities, nuisance flooding will cause many community health vectors such as snakes and rodents to make unwanted contact with humans returning to flood-damaged areas. In addition, at this level of discharge there is enough stream power to destabilize existing infrastructure. For these reasons, it is important to consider a means of reducing the impact of these nuisance events in the flood planning effort.

5.4.1 Analysis

The introduction of an on-site requirement for detention of the 20% event to pre-development conditions strikes a balance among some important considerations for the overall function of the Town Creek watershed, if 1% level detention can be provided regionally and conveyance to the regional facility is available. Detaining for the 20% on-site can greatly reduce the effects of nuisance events beyond simply the 20% event, including minor flooding, scour and sedimentation problems seen at the 50% level. This level of detention is also beneficial during lower frequency (higher flow) events, simply through the provision of additional storage.

5.4.2 Recommended Actions

Multiple benefits may be obtained from the following course of action:

Action 4.1: Provide a regional detention facility for the 1% event (see Action 1.4)

Action 4.2: Require conveyance to this facility at the 1% ultimate level (see Actions 1.1 and 1.2)

Action 4.3: Require on-site detention for the 20% event in all new development.

Apart from the structural mitigation alternatives that can be implemented to reduce risk, as a first line of defense, there are a number of programs that can be implemented to educate the community about the nature of risk posed and remove those areas subject to the most frequent risk. As a second line of defense, a coordinated, but leveraged and cost-effective approach will be required to provide early warning of an impending flood event. These measures are important in building a disaster resistant community, and can be viewed as a series of goals and implementation actions described through Goals 5 and 6.

5.5 "TURN AROUND, DON'T DROWN": ELIMINATE THE GREATEST RISK OF FLOOD-RELATED DEATH – VEHICLES TRYING TO CROSS AT LOW-WATER CROSSINGS (GOAL 5).

The leading cause of flood related deaths in Texas results from people trying to pass low water crossings in vehicles during flood events. Simple structural controls such as railroad style safety gates with flashing lights provide a physical barrier to prevent crossing a dangerous stream. Automated controls are activated by streamflow gages that trigger gate closing based on specified flow rates or stages. These controls may qualify for Pre-Disaster Mitigation (PDM) Grants though the State of Texas or FEMA. Coordination with Guadalupe County Emergency Management, Sheriff's Office, area Fire/EMS units and Cibolo police departments should be undertaken to recommend specific locations.

Figure 14: Low-water crossing at Haeckerville Road

Action 5.1: Install Low Water Crossing safety features (cross-arm or retractable fence) at low water crossings.

Action 5.2: Utilize "Turn Around Don't Drown" material available to the City, and involve the Schertz Cibolo Universal City ISD and Marion ISD in an outreach program.

5.6 "KNOWLEDGE IS POWER": LEVERAGE THE EFFORTS OF VARIOUS ENTITIES IN KEEPING THE CITIZENS OF CIBOLO INFORMED ABOUT THE RISK OF FLOODING BEFORE DISASTER STRIKES, SO THAT THEY ALSO KNOW HOW TO RESPOND IN A FLOODING EVENT (GOAL 6).

Action 6.1: Provide free access to the floodplain maps, both in paper and digital form. Create an atlas of maps, which can be viewed at City Hall, downloaded in .pdf format from the City's website, and eventually viewed on the City's website.

Action 6.2: Utilize educational material available through FEMA, TFMA, GBRA and others (such as the "Turn Around Don't Drown" sticker campaign, and GBRA's "Staying Safe" Flood Guide) in dissemination efforts.

Action 6.3: Identify neighborhood leaders in Haeckerville and develop a specific outreach campaign for this neighborhood with their guidance.

Action 6.4: Make an initial presentation to the Chamber of Commerce, and follow up with subsequent "annual update presentations" or contributing articles to the Chamber's newsletter with updates on various projects and action items.

Action 6.5: In connection with the development of a Town Center Park, place a large sculpture at a prominent location that helps to identify flood levels. For example, a large bronze buffalo could be erected in the park, with the tips of his horns deliberately crafted at the 1% annual flood elevation. It could be then described in literature to all new residents, making an easy cognitive connection between the risk as we know it on paper and real space perception.

Action 6.6: Work with private industry and other stakeholders to further an existing program, or develop and implement a program to distribute NOAA All Hazards Weather Radios to the public.

Action 6.7: In any public outreach program, heighten awareness of GBRA's KWED 1580 AM radio broadcasts as a means of reaching the public even during power outages.

5.7 "KEEP MORE EYES TO THE SKY, AND AN EAR TO THE GROUND": LEVERAGE THE RESOURCES OF OTHER REGIONAL STAKEHOLDERS AND BEGIN DISCUSSIONS OF A FLOOD EARLY WARNING SYSTEM (GOAL 7).

Action 7.1: Coordinate with Guadalupe County Office of Emergency Management, GBRA and SARA about the introduction of streamflow gages on Town Creek.

Action 7.2: Officially request USGS assistance in the placement of a streamflow gage at Loop 539 or the railroad.

Action 7.3: Continue dialogue with GBRA about the placement of additional automated rainfall gauges in the Town Creek watershed to enhance their network. This network data is collected and placed on a non-public internet page to allow emergency management personnel and the National Weather Service access to the data.

5.8 "MULTIPLE BIRDS, ONE STONE": SEEK COORDINATED OPPORTUNITIES TO IMPLEMENT MULTI-PURPOSE PROJECTS, PARTICULARLY WITH REGARD TO WATER QUALITY AND EROSION MITIGATION (GOAL 8)

Action 8.1: As each structural flood control measure is evaluated in a preliminary engineering stage, the viability of water quality benefit should be assessed and implemented where feasible. It is often easier to integrate water quality Best Management Practices (BMPs) into flood control projects during the initial design phase, than to retrofit at a later date at additional cost. A project which offers multiple benefits is also more likely to receive grant funding.

Action 8.2: Channel improvement projects offer the opportunity for hike-and-bike or wilderness trail implementation, and should be coordinated with the Parks and Recreation Department in its planning efforts.

5.9 "GIVE THE CREEK THE ROOM IT NEEDS": PROTECT THE INTEGRITY OF TOWN CREEK'S GEOMORPHOLOGY AND ECOLOGY (GOAL 9).

The frequent impact of development is a disruption of natural stream function. This stream function is important because streams in their natural condition provide a number of benefits, including: water quality constituent removal, habitat, valley storage and flood peak attenuation. The National Wetland Inventory Maps were analyzed, and field investigations by a certified wetlands biologist indicated US Army Corps of Engineers jurisdictional areas along Tributary 1, upstream of FM 1103. It is also anticipated that jurisdictional areas exist adjacent to the centerlines of much of Town Creek and its tributaries. Therefore, in channel improvement projects, it will be important to bring wetland biologists in for determination and delineation.

Action 9.1: Allow Town Creek room to move with normal geomorphologic processes. Dedicate stream buffers that contain the 1% chance ultimate conditions floodplain.

Action 9.2: Protect riparian woodland areas and riparian stream bank edges as a continuous corridor.

Action 9.3: Identify high quality wetland areas and protect these against changes in supporting conditions.

Action 9.4: Reintroduce riparian habitat areas into stream corridors that have been impacted.

5.10 "PLAN TIME WITH FRIENDS": RECOGNIZING THAT THE CITY IS A GROWING ENTITY, IDENTIFY CURRENT AND FUTURE PARTNERS IN FLOODPLAIN MANAGEMENT, AND CULTIVATE RELATIONSHIPS FOR REGIONAL DISASTER RESISTANCE INTO THE FUTURE (GOAL 10).

Action 10.1: Continue to share technical information with Guadalupe County, GBRA and SARA, the City's key partners in floodplain management.

Action 10.2: Build upon the existing cooperative relationships at the law enforcement level with neighboring communities, to develop specific emergency management and forecasting communications measures that can be mutually beneficial.

Action 10.3: Review and update this plan at the same time updates are made to the Master Plan, the Multi-Hazard Mitigation Action Plan, Emergency Action Plans, and Capital Improvements Plans.

6.0 IMPLEMENTATION

6.1 COST BENEFIT ANALYSIS

The viability of alternatives is primarily measured through a comparison of the relative costs and benefits. Each alternative is evaluated for the benefit associated with removing at-risk properties from the floodplain (i.e. benefit = damage avoided), and also for the initial cost of implementation. It was not within the scope of this study to perform more detailed net present value analysis or other time-weighted analysis. Benefits are determined from Guadalupe County Appraisal District 2006 tax roll values. Construction costs are based on recent bid tabulations and unit prices for similar regional construction projects. The detail of the cost estimates are included in Appendix G. The following table summarizes the benefit-cost ratio.

Table 16: Benefit-Cost Summary

	ALTERNATIVE	EST. COST OF IMPLEMENTATION	VALUE REMOVED	BCR
1A	Town Creek East Channel Improvements	$1,863,000	$8,505,000	4.57
1B	Town Creek West Channel Improvements	$3,360,000	$1,053,000	0.31
2	Offline Regional Detention	$3,270,000	$3,800,000	1.16
3	Online Regional Detention	$29,000,000	$1,200,000	0.04
4	FM 1103 Bridge	$11,550,000	$3,375,000	0.29
5	Levee	$338,000	$5,400,000	15.98
6	Voluntary Acquisition	$19,365,000	$19,365,000	1
0	Do Nothing	$19,365,000	$0	<0.01

Included in this analysis is the "Do Nothing" option, which implies simply that the community accepts the risk level it is currently experiencing. The voluntary acquisition alternative always has a BCR of 1.0.

6.2 ALTERNATIVES RANKING

Each alternative that was studied offers distinct benefit and cost comparisons in regards to independent hydraulic performance and the specific goal that it is considered to further. Yet the viability or importance of a proposed alternative may not be fully recognized in simple flood damage reduction – cost of construction terms. Therefore, it is important to evaluate all alternatives in a weighted context as well as a simple benefit-cost context.

The San Antonio River Authority (SARA), through the Bexar Regional Watershed Management Program, has developed a scoring matrix for capital projects that can be used to prioritize alternatives based upon a number of factors. This matrix was utilized to assist in ranking the seven most feasible projects. The factors included in this matrix are as follows:

Figure 15: SARA Prioritization factors.

Prioritization Ranking Factors
Hydraulic/ Hydrologic Significance or Impact
Public Safety
Benefit/ Cost Ratio
Benefit to existing development
Element of Impact Fee program
Dependency on other Projects
Mobility or effects on Transportation System
Sustainability or Low Operations & Maintenance Cost
Level of Protection Provided (i.e. 10%, 4%, 1%)
Funding Sources (leverage of participants available funds)
Benefit to future development
Promote Orderly Development or Improve Economic dev./redev. Potential
Beneficial neighborhood impacts
Water quality enhancement
Time to implement or construct
Permitting resistance or difficulty
Environmental or habitat enhancement
Potential for Recreation/Open Space/Connectivity for linear parks

From this exercise, the following order of priority for projects was established:

Table 17: Alternatives ranking summary

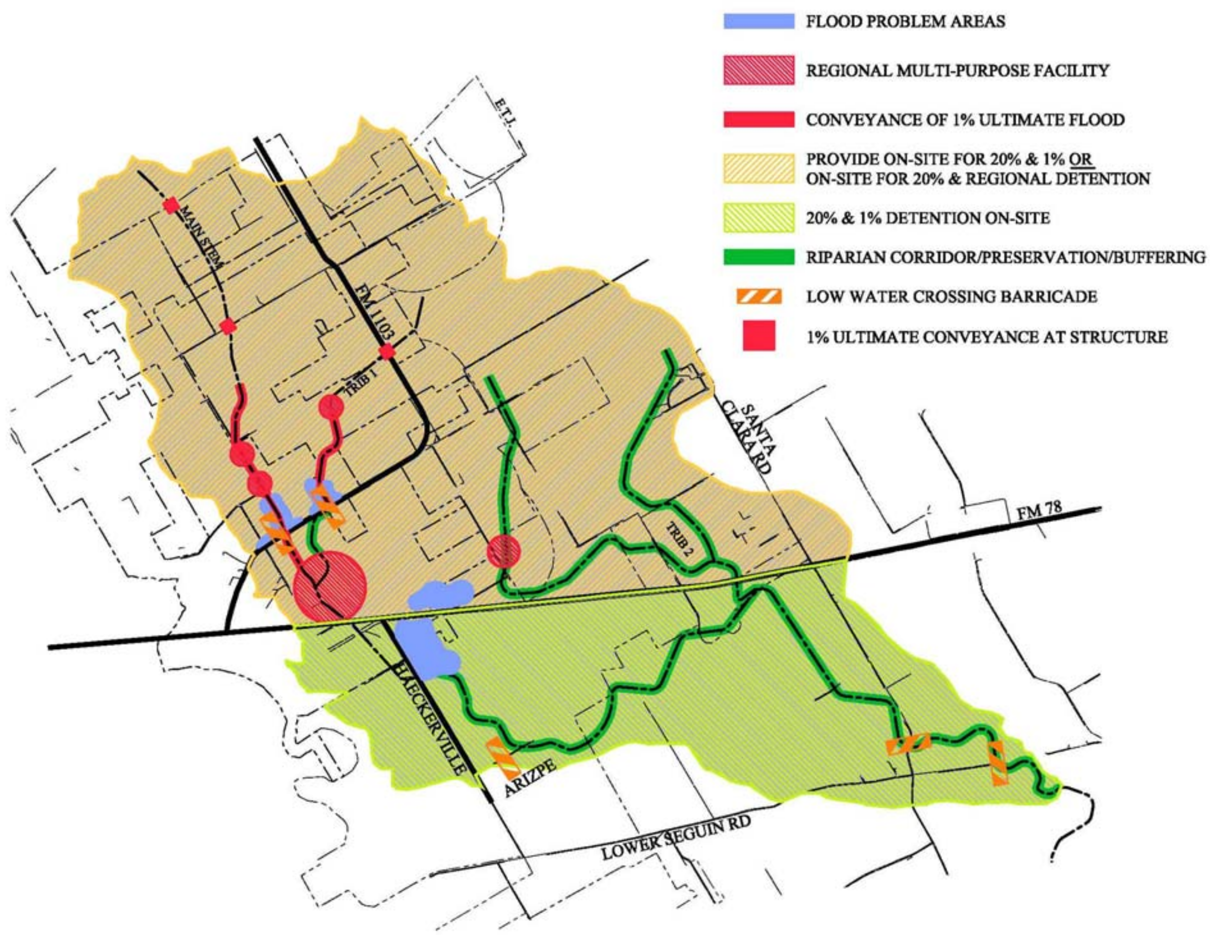
RANKING	PROJECT	SCORE
1	Levee at Country Ln/Railroad	98
2	Town Creek East Channel Improvements	93
3	Town Creek West Channel Improvements	86
4	Offline Regional Detention	86
5	Voluntary Acquisition Program	85
6	FM 1103 Bridge	60

The scoring utilized to develop this ranking is included as Appendix H.

6.3 COMPREHENSIVE WATERSHED POLICY

A comprehensive watershed policy requires differentiating between pre-existing, existing and future issues, and linking and initiating improvements at the right time in the development process. For Town Creek implementing a comprehensive watershed policy is guided by the ten goals established in Section 4. For the purposes of administration, the watershed can be thought of in terms of different policy areas and objectives. Figure 15 is a schematic that shows the relative location of these different policy areas, relative to their application in the watershed and the most significant flood problem areas.

Figure 16: Policy area map.



6.4 FUNDING SOURCES

The mechanisms for funding of these recommended actions are varied and in many instances very specific to the type of activity. It is the intent of this section to begin to identify funding sources for each action as well as strategies for leverage of funding mechanisms.

Table 18: Funding and Priority Plan

Action Item	Funding Source / Regulation / Effort Type	Priority
Action 1.1 : Construct a channel improvement project along Town Creek Tributary No. 1 upstream of FM 1103.	Impact Fees; CIP Funds	Immediate
Action 1.2 : Construct a channel improvement project along Town Creek (Mainstem) upstream of FM 1103.	Impact Fees; CIP Funds	Immediate
Action 1.3 : Construct a levee at Country Lane with the participation of the affected landowner.	Private Funds; CIP Funds; HMGP Funds	Short-Term
Action 1.4 : Construct a regional detention facility downstream of FM 1103 and upstream of FM 78 to mitigate for the 4% ultimate event.	Impact Fees; CIP Funds; Private Funds; Park Development Funds; Economic Development Funds	Short-Term
Action 1.5 : Develop a voluntary acquisition and relocation fund and program that can be used to purchase properties at risk in a 4% chance or higher event, and convert them to open space.	CIP Funds; HMGP Funds	Short-Term; Ongoing
Action 2.1 : Require detention for the 1% annual chance event, either through on-site or regional.	Regulation	Immediate; Ongoing
Action 2.2 : Require conveyance for the ultimate 1% annual chance event with no freeboard requirement.	Regulation	Immediate; Ongoing
Action 2.3 : Require dedication of drainage right-of-way for the ultimate 1% annual chance event. Town Creek needs room to move.	Regulation	Immediate; Ongoing
Action 2.4 : Develop specific maximum permissible velocities as a criterion for design within the city.	Regulation	Immediate
Action 3.1 : Include an upgrade of the Green Valley Road crossing of Town Creek in the City's CIP, to provide clear conveyance of the 1% annual event.	Impact Fees; CIP Funds; DHS grant funds; Private Funds; County	Short-Term
Action 3.2 : Actively seek funding partners for this project, such as developer and County participation, and grant program assistance.	-	Short-Term
Action 3.3 : The location of future Fire/EMS stations or emergency medical facilities should be located along a major collector/secondary arterial road that has uninterruptible access across Town Creek.	-	Long-Term
Action 4.1 : Provide a regional detention facility for the 4% event (see Action 1.4)	Impact Fees; CIP Funds; Private Funds; Park Development Funds; Economic Development Funds	Short-Term
Action 4.2 : Require conveyance to this facility at the 1% ultimate level. (See Actions 1.1 and 1.2)	Impact Fees; CIP Funds	Immediate; Ongoing
Action 4.3 : Require on-site detention for the 20% event in all new development.	Private Funds	Immediate
Action 5.1 : Install Low Water Crossing safety features (cross-arm or retractable fence) at low water crossings.	CIP Funds; DHS grant funds; HMGP grant funds; County	Long-Term
Action 5.2 : Utilize "Turn Around Don't Drown" material available to the City, and involve the Schertz Cibolo Universal City ISD and Marion ISD in an outreach program.	General Fund; County; GBRA; School Districts	Long-Term; Ongoing
Action 6.1 : Provide free access to the floodplain maps, both in paper and digital form. Create an atlas of maps, which can be viewed at City Hall, downloaded in .pdf format from the City's website, and eventually viewed on the City's website.	-	Long-Term
Action 6.2 : Utilize educational material available through FEMA, TFMA, GBRA and others (such as the "Turn Around Don't Drown" sticker campaign, and GBRA's "Staying Safe" Flood Guide) in dissemination efforts.	General Fund; GBRA/FEMA/TFMA; County	Long-Term
Action 6.3 : Identify neighborhood leaders in Haeckerville and develop a specific outreach campaign for these neighborhoods with their guidance.	-	Short-Term
Action 6.4 : Make an initial presentation to the Chamber of Commerce, and follow up with subsequent "annual update presentations" or contributing articles to the Chamber's newsletter with updates on various projects and action items.	-	Long-Term
Action 6.5 : In connection with the development of a Town Center Park, place a large sculpture at a prominent location that helps to identify flood levels.	Impact Fees; CIP Funds; Private Funds; Park Development Funds; Economic Development Funds	Long-Term
Action 6.6 : Work with private industry and other stakeholders to further an existing program, or develop and implement a program to distribute NOAA All Hazards Weather Radios to the public.	Private; GBRA; General Fund	Long-Term

Action 6.7 : In any public outreach program, heighten awareness of GBRA's KWED 1580 AM radio broadcasts as a means of reaching the public even during power outages.	GBRA	Ongoing
Action 7.1 : Coordinate with Guadalupe County Office of Emergency Management, GBRA and SARA about the introduction of streamflow gages on Town Creek.	-	Long-Term
Action 7.2 : Officially request USGS assistance in the placement of a streamflow gage at Loop 539 or the railroad.	USGS; County; GBRA; SARA; Santa Clara; Cibolo	Long-Term
Action 7.3 : Continue dialogue with GBRA about the placement of additional automated rainfall gauges in the Town Creek watershed to enhance this network. This network data is collected and placed on a non-public internet page to allow emergency management personnel and the National Weather Service access to the data.	Cibolo; County; GBRA; SARA; Santa Clara	Long-Term
Action 8.1 : As each structural flood control measure is evaluated in a preliminary engineering stage, the viability of water quality benefit should be assessed and implemented where feasible.	Impact Fees; CIP; Private	Immediate; Ongoing
Action 8.2 : Channel improvement projects offer the opportunity for hike-and-bike or wilderness trail implementation, and should be coordinated with the Parks and Recreation Department and its planning efforts.	CIP; Parks; Private	Immediate; Ongoing
Action 9.1 : Allow Town Creek room to move with normal geomorphologic processes. Dedicate stream buffers that are at least as wide as the 1% chance ultimate conditions floodplain.	Regulation	Ongoing
Action 9.2 : Protect riparian woodland areas and riparian stream bank edges as a continuous corridor.	Regulation	Ongoing
Action 9.3 : Identify high quality wetland areas and protect these against changes in supporting conditions.	Regulation	Ongoing
Action 9.4 : Reintroduce riparian habitat areas into stream corridors that have been impacted.	CIP; Parks	Immediate; Ongoing
Action 10.1 : Continue to share technical information with Guadalupe County, GBRA and SARA, the City's key partners in floodplain management.	Cooperative	Ongoing
Action 10.2 : Build upon the existing cooperative relationships at the law enforcement level with neighboring communities, to develop specific emergency management and forecasting communications measures that can be mutually beneficial.	Cooperative	Ongoing
Action 10.3: Review and update this plan at the same time updates are made to the Master Plan, the Multi-Hazard Mitigation Action Plan, Emergency Action Plans, and Capital Improvements Plans.	-	Ongoing

6.5 REGULATORY COMPLIANCE

Prior to commencement of construction, it will be necessary to submit the project and appropriate permit applications to regulatory agencies. A detailed review and acquisition of the necessary permits for the construction of these project(s) exceeds the scope of this contract. However, a partial list and brief discussion of permits is included in the following subsections. This following list of agencies and corresponding permit activities is intended to be general in nature and is not intended to represent a definitive list of required permit acquisitions and agency coordination.

6.5.1 Federal Emergency Management Agency (FEMA)

The National Flood Insurance Act of 1968 was enacted by Title XIII of the Housing and Urban Development Act of 1968 (Public Law 90-448, August 1, 1968) to provide previously unavailable flood insurance protection to property owners in flood prone areas. FEMA administers the National Flood Insurance Program (NFIP); however, if a local community elects to participate in the NFIP, the local government is primarily responsible for enforcement. Participating communities are typically covered by FIS which define water surface profiles and floodplain boundaries through their communities.

Most streams included in this hydraulic analysis are studied streams in the current Hays County FIS dated February 18, 1998, revised September 2, 2005. The effective Flood Insurance Rate Maps (FIRM) is dated September 2, 2005. The revision to the FIS consisted of a redelineation of the 1998 FIS data.

The recommended drainage improvement projects summarized in this report are intended to reduce floodplain limits. However, if changes to the current effective FEMA floodplain elevations are desirable based on the results of this study, or from the proposed improvements, a request for a Letter of Map Revision (LOMR) from FEMA will be required.

6.5.2 U. S. Army Corps of Engineers (USACE)

Pursuant to Section 404 of the Clean Water Act and the Rules and Regulations promulgated there under by the United States Environmental Protection Agency (USEPA) and the United States Army Corps of Engineers (USACE), the filling or excavation of waters of the United States, including wetlands, with dredged or fill material, requires the issuance of a permit from the USACE (33 CFR Parts 320-330). For purposes of administering the Section 404 permit program, the USACE defines wetlands as follows:

> *Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. (33 CFR 328.3)*

The *Corps of Engineers Wetlands Delineation Manual (Technical Report Y-87-1)*, issued by the USACE in 1987 states that wetlands must possess three essential characteristics. These characteristics include, under normal circumstances: 1) the presence of hydrophytic vegetation, 2) hydric soils, and 3) wetland hydrology. If all three of these criteria are present on a particular property in areas larger than one-third acre in size, then a permit (general permit or nationwide permit) must be issued by the USACE in order to fill all or a portion of those areas.

Section 404 (b)(1) guidelines (40 CFR Part 230), established by the USEPA, constitute the substantive environmental criteria used in the evaluating activities regulated under Section 404 of the Clear Water Act. The purpose of these guidelines is to restore and maintain the chemical physical and biological integrity of waters of the United States through the control of discharge of dredged or fill material.

All property owners within the United States and its territories must adhere to the provisions of the Clean Water Act. If any contemplated activity might impact waters of the United States, including adjacent or isolated wetlands a permit application must be made. If jurisdictional waters and/or wetlands are found to exist, then any activity which would involve filling, excavating, or dredging these wetlands would require the issuance of a permit. The final authority to determine whether or not jurisdictional waters exist lies with USACE.

There is a strong likelihood that Waters of the U.S. jurisdictional areas exist along the riparian corridor of Town Creek. It is recommended that the City engage the USACE early in its design process.

6.5.3 U.S. Fish and Wildlife Service (USFWS)

The U.S. Fish and Wildlife Service (USFWS), in the Department of the Interior, and the National Marine Fisheries Service (NMFS), in the Department of Commerce, share responsibility for administration of the Endangered Species Act (ESA). Generally, the USFWS is responsible for terrestrial and freshwater species and migratory birds, while the NMFS deals with those species occurring in marine environments and anadromous fish.

Section 9 of the ESA prohibits take of federally listed endangered or threatened species without appropriate authorization. Take is defined in the ESA, in part as "killing, harming, or harassment" of a federally listed species, while incidental take is take that is "incidental to, and not the purpose of, otherwise lawful activities".

Section 10 of the ESA provides a means for non-Federal projects resulting in take of listed species to be permitted subject to carefully prescribed conditions. Application for an incidental take permit is subject to a number of requirements, including preparation of a Habitat Conservation Plan by the applicant. In processing an incidental take permit application, the USFWS must comply with appropriate environmental laws, including the National Environmental Policy Act. Review of the application under Section 7 of the ESA is also required to ensure that permit issuance is not likely to jeopardize listed species. Section 10 issuance criteria require the USFWS to issue and incidental take permit if, after opportunity for public comment, it finds that:

1. the taking will be incidental;
2. the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of the taking;
3. the applicant will ensure that adequate funding and means to deal with unforeseen circumstances will be provided;
4. the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; and
5. the applicant will ensure that other measures that the USFWS may require as being necessary or appropriate will be provided.

The U.S. Fish and Wildlife Service should be contacted to determine the potential occurrence of and consequent impacts to any federal threatened and endangered species. In addition, the Corps of Engineers will require USFWS review of the project to ensure the project is in compliance with the Endangered Species Act prior to the issuance of a Section 404 permit.

6.5.4 Texas Commission on Environmental Quality (TCEQ)

The Texas Commission on Environmental Quality (TCEQ) has regulatory authority over: dam safety, the Edwards Aquifer, water rights, Texas Pollutant Discharge Elimination System and Section 404(b)(1) guidelines for specification of disposal sites for dredged or fill material. The following sections briefly describe these regulations.

- Texas Pollutant Discharge Elimination System (TPDES)

On September 14, 1998, the USEPA authorized Texas to implement its Texas Pollutant Discharge Elimination System (TPDES) program. TPDES is the state program to carry out the National Pollutant Discharge Elimination System (NPDES), a federal regulatory program to control discharges of pollutants to surface waters of the United States. The TCEQ administers the program, and a permit is required for any construction activity that disturbs one acre or more.

- Section 401 Water Quality Certification

Any activity requiring authorization under Section 404 of the Clean Water Act will also require a Section 401 water quality certification from the TCEQ. In Texas, these regulations are administered by the TCEQ.

6.5.5 Texas Historical Commission

The Division of Antiquities Protection of the Texas Historical Commission coordinates the program by identifying and protecting important archeological and historic sites that may be threatened by public construction projects. This department coordinates the nomination of numerous sites as State Archeological Landmarks or for listing in the *National Register of Historic Places*. Designation is often sought by interested parties as the most effective way to protect archeological sites threatened by new development or vandalism. Applicable rules are found in the Texas Administrative Code, Title 13-Cultural Resources, Part II-Texas Historical Commission, Chapters 24-28.

The Corps of Engineers will require that the State Historical Preservation Officer (SHPO) review the project to ensure the project is in compliance with the National Historic Act prior to issuance of a Section 404 permit.

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