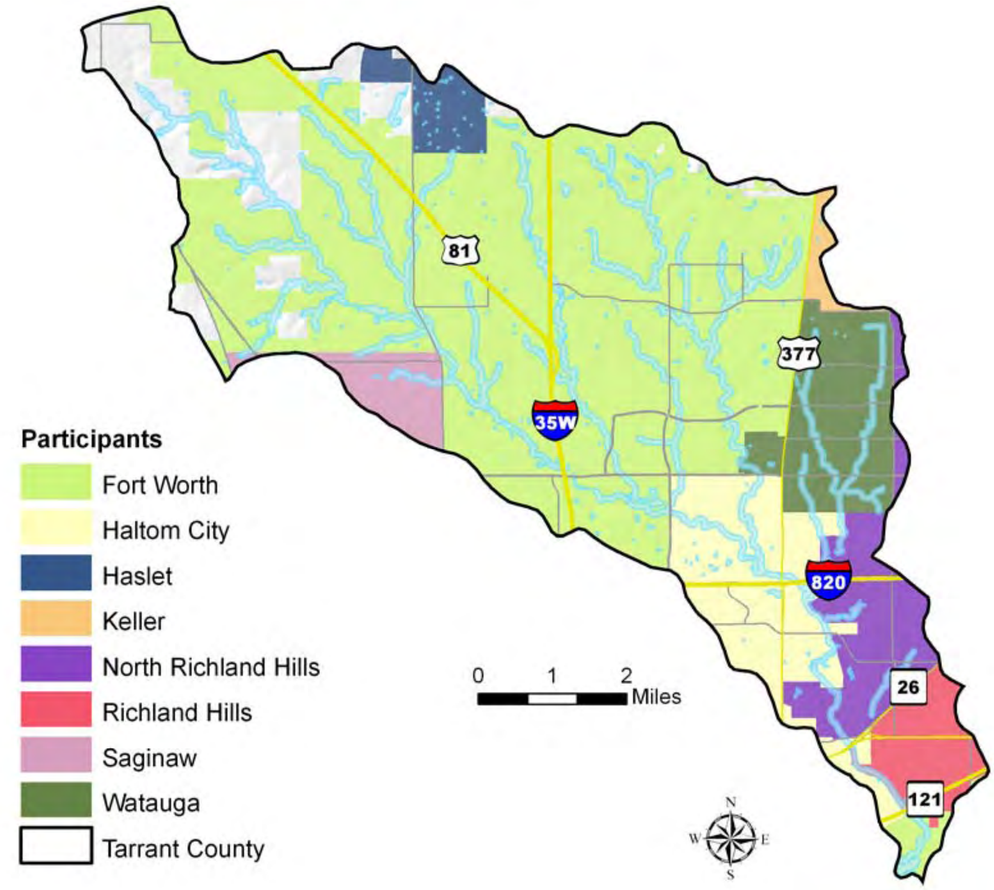
Big Fossil Creek Watershed

Interim Information Paper



North Central Texas Council of Governments

US Army Corps of Engineers
Fort Worth District

Texas Water Development Board

Final March 2009

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Final March 2009

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BIG FOSSIL CREEK WATERSHED INTERIM INFORMATION PAPER

INTRODUCTION

This interim information paper presents the results of investigations of the Big Fossil Creek watershed's existing conditions and problem areas identified to date. These results may be utilized by the sponsors to determine where participation in a more detailed study would be beneficial to their community in terms of identification of measures aimed at reducing flood risks. The next phase of the feasibility study would provide details regarding viable alternatives for reducing flood risks, environmental restoration, and recreation facilities throughout the watershed.

The Big Fossil Creek study is currently in the Feasibility Phase. Portions of the feasibility process have been completed and their results are being conveyed through this paper. This interim information paper provides the communities basic information of the watershed, the problems, and potential alternatives designed to reduce or eliminate the problems.

STUDY AUTHORITY

The Big Fossil Creek study is being conducted under the Upper Trinity River Feasibility Study. The study of Big Fossil Creek Watershed is contained in a resolution by the United States Senate Committee on Environment and Public Works Resolution dated April 22, 1988, as quoted below:

> *Resolved by the Committee on Environment and Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors is hereby requested to review the report of the Chief of Engineers on the Trinity River and Tributaries, Texas, House Document No. 276, Eighty-Ninth Congress, and other pertinent reports, with a view to determining the advisability of modifying the recommendations contained therein, with particular reference to providing improvements in the interest of flood protection, environmental enhancement, water quality, recreation, and other allied purposes in the Upper Trinity River Basin with specific attention on the Dallas-Fort Worth Metroplex.*

The above cited legislation defined the area of investigations as the Upper Trinity River Basin with specific emphasis on the Dallas – Fort Worth Metroplex. Big Fossil Creek is a sub-basin of the Upper Trinity River watershed and is therefore authorized under this legislation. Big Fossil Creek Watershed study fits into the overall concept of the Upper Trinity Vision to conduct an integrated and coordinated approach to locating and implementing opportunities for flood risk reduction, ecosystem restoration, recreation, and other allied purposes along the Trinity River system.

Big Fossil Creek is a major tributary of the West Fork of the Trinity River, which encompasses 57 square miles of contributing drainage area. It is located north of the confluence of Big Fossil Creek with the West Fork of the Trinity River, proceeding northeastward along Big Fossil Creek to its headwaters near US 287, and its tributaries. See ***Figure 1*** which shows the Big Fossil watershed and displays participants' city boundaries within the watershed.

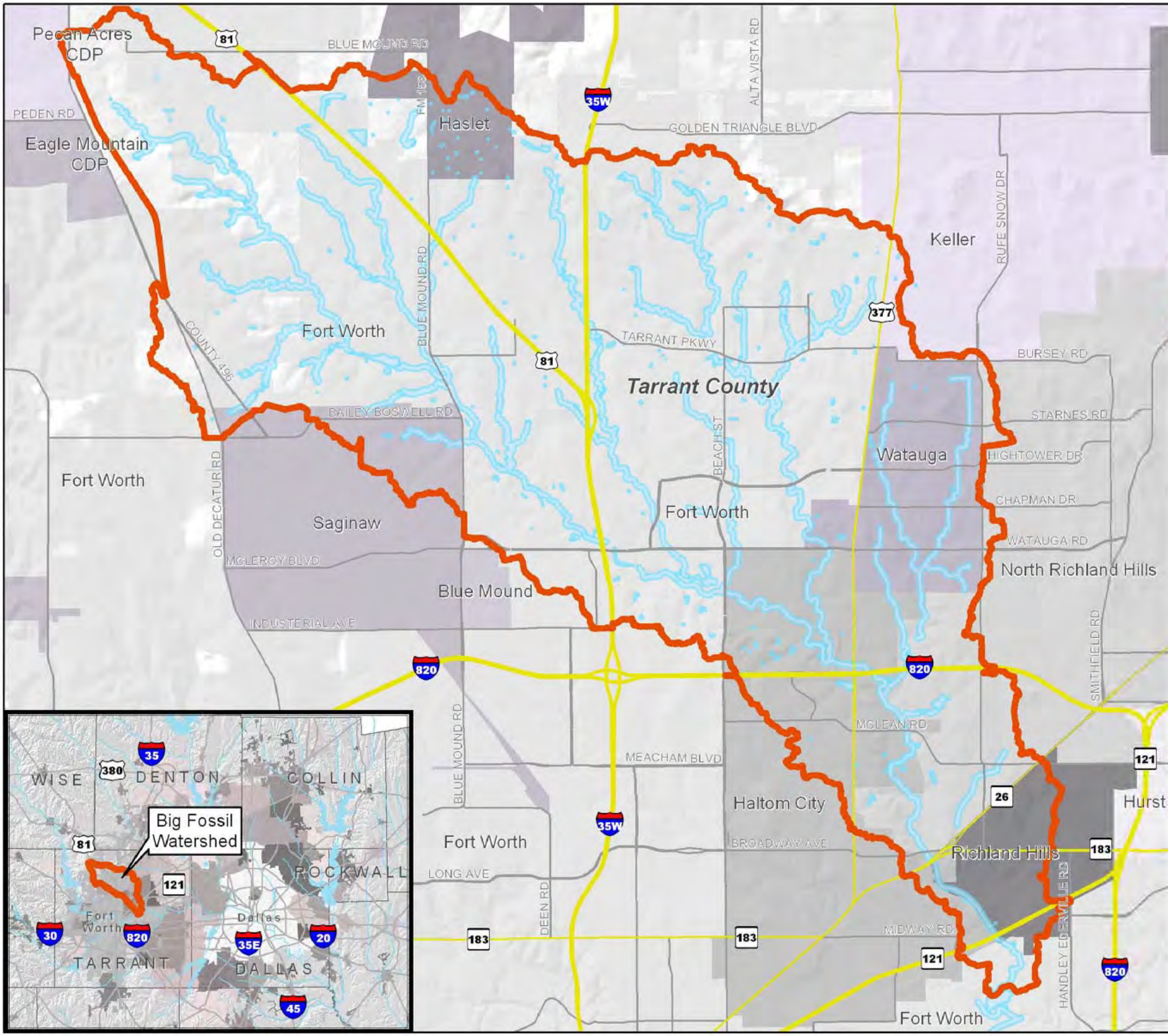
PARTICIPANTS

The study is being sponsored by North Central Texas Council of Governments (NCTCOG), who is primarily representing the municipalities of Haltom City, Saginaw, Watauga, Fort Worth, Richland Hills, North Richland Hills, Keller, and Haslet. Also represented are Tarrant County and the Texas Water Development Board (TWDB). The communities whose city limits and/or boundaries fall within the Big Fossil Creek watershed decided to jointly participate in this study to explore strategic methods of managing the watershed systematically instead of piece-meal efforts by each individual entity.

Big Fossil Creek Watershed

FIGURE 1

LOCATION MAP



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March 2008

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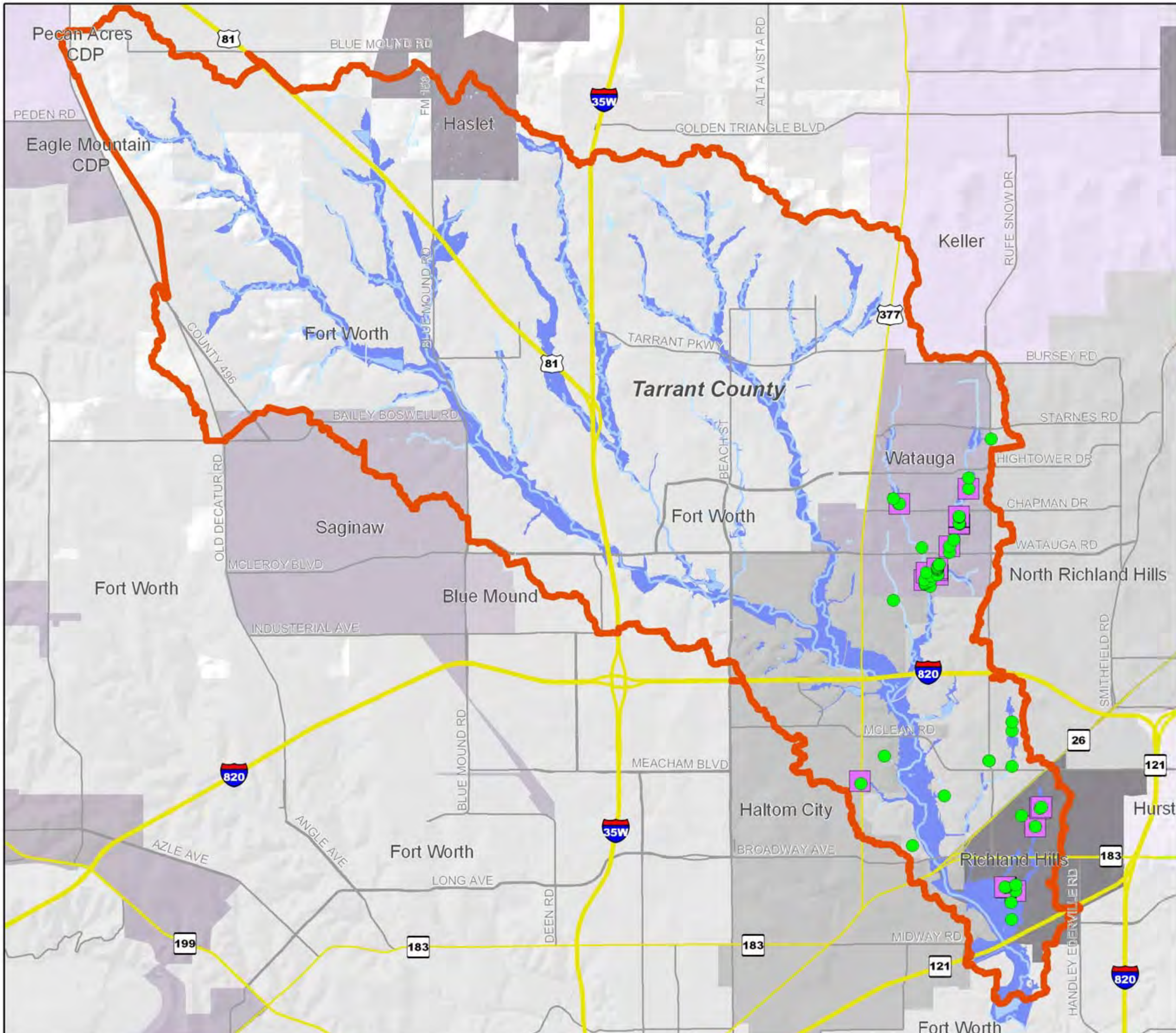
NJH 03-01-08

Big Fossil Creek Watershed

FIGURE 2

FEMA CLAIMS AND REPETITIVE LOSS



Legend

- FEMA Claims
- FEMA Repetitive Loss
- Big Fossil Creek Watershed
- Big Fossil Creek
- 100-year Floodplain

N W E S

0 4,000 8,000 Feet

1 inch equals 7,950 feet

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FLOOD HISTORY

Big Fossil Creek has experienced floods as far back as September of 1900. The creek has reportedly long-suffered from flooding problems. The major flood events that have occurred since that time are numerous and have resulted in substantial losses to property and persons in the watershed.

Flooding along Big Fossil Creek and its tributaries, notably Whites Branch, is a well documented, on-going problem. The September 1962 flood was the largest in the watershed until the flood of June 18, 2007 which devastated the Skyline Mobile Home Park on Whites Branch in Haltom City. This occurred in a brief period of time, following a rainfall event of 4.5-inches during a two hour period. This rainfall fell on heavily-saturated ground increasing the runoff into Whites Branch. This event was estimated as a 100-year flood with an annual exceedance probability of 1-percent. Flood waters claimed a life. This area has been declared a National Disaster Area and may be eligible to receive assistance from the State, County, and FEMA under their respective missions and programs. On 3 July 2007, a very intense storm event occurred over portions of the Big Fossil Creek watershed in and around Richland Hills. This particular storm was centered over the headwaters of Stream BFC-5 and resulted in significant flooding along the relatively narrow watercourses which feed into the Big Fossil Creek Levee Sump. ***Table 1*** and the accompanying ***Figure 2*** shows the locations where FEMA claims have been made from 1978-2001. This does not represent all damages in the Big Fossil Creek watershed. In fact the figure and table only show where claims have been recorded. The dollar amount represented in the table includes the entire city not just the portion of the city limits within Big Fossil Creek Watershed. This area is experiencing repeated problems that may be reduced through a systematic management plan of the watershed experiencing repeated problems that may be reduced through a systematic management plan of the watershed.

Table 1: FEMA Claims by City in Big Fossil Creek Watershed (1978-2001)

Local Government	Percent of Area	*FEMA Claims by City (1978-2001)	FEMA Repetitive Losses by City (1978-2001)
Fort Worth	44%	$ 1,755,220	$ 1,675,865
Tarrant County	24%	$ 1,603,118	$ 860,559
Haltom City	10%	$ 2,461,862	$ 4,207,327
Watauga	7%	$ 445,989	$ 494,022
North Richland Hills	5%	$ 476,883	$ 286,127
Richland Hills	4%	$ 595,892	$ 599,460
Saginaw	3%	$ 10,826	$ 414,853
Haslet	2%		
Keller	1%	$ 91,315	$ 145,612
Totals:	**100.00%**	**$ 7,441,105**	**$ 8,683,825**

Source: FEMA * Note that the columns for FEMA Claims and Repetitive Losses include total amounts for each city. Further analysis and mapping will be conducted once the Geo-Coding for the locations are completed

PROBLEM AREAS AND OPPORTUNITIES

At the initiation of this study the participants identified existing problem areas and they also identified areas of potential opportunities for improvement within the watershed. The problem areas fall into the following categories: flooding, bank sloughing, loss of habitat, and ecosystem degradation. The opportunities for better management fall into the categories of environmental restoration, flood risk reduction, and recreation enhancements. ***Figures 3a*** and ***3b*** depict specific areas of concerns and potential solutions to these problems. These are areas where potential structural and non-structural alternatives may be implemented, provided further analysis determines that a site(s) is viable, a federal interest exists, and interest among the local communities continues. Additional figures correspond to either problem areas or potential projects. ***Figures 3.1*** through ***3.17*** are close up aerials of the specific locations where many of the problems and opportunities or both are located. Specific references will be made to these figures in the discussion of alternatives.

Figures 3a and ***3b*** and the sub-figures show areas of concern and potential alternatives by a shape, color, number and letter coding system. Light blue squares labeled with the letter F indicate areas identified as having increased flood risks. The yellow circles labeled with the letter S indicate areas that have sloughing issues. A red circle labeled with the letter R shows where recreational features could be added. The green circles labeled with the letter P indicate where potential ecosystem restoration projects may be evaluated.

Areas with increased flood risks include the following written descriptions along with their respective mapping indicator code.

- F-1 Recurrent flooding along main stem Big Fossil Creek at the head waters
- F-2 Recurrent flooding along Big Fossil Creek-32 in north Fort Worth; some homes could be impacted
- F-3 Recurrent flooding along Big Fossil Creek-31 in north Fort Worth
- F-4 Recurrent flooding along main stem of Big Fossil Creek in north Fort Worth
- F-5 Recurrent flooding along Bunker Creek adjacent to Harvest Church
- F-6 Recurrent flooding along Whites Branch Creek especially throughout the Skyline Mobile Home Park
- F-7 Recurrent flooding along main stem Big Fossil Creek adjacent to North Park

Areas with sloughing issues include the following written descriptions along with their respective mapping indicator code.

- S-1 Sloughing area along main stem Big Fossil Creek behind residences along Fenway Court in Haltom City
- S-2 Sloughing area along main stem Big Fossil Creek in Buffalo Ridge Park in Haltom City
- S-3 Sloughing area along main stem Big Fossil Creek in North Park in Haltom City
- S-4 Sloughing area along Big Fossil Creek Main stem between Union Pacific Railroad and US HWY 377 in Haltom City

Areas identified that might be potential ecosystem restoration sites include the following written descriptions along with their respective mapping indicator code.

- P-1 The area above County Road 496 and Union Pacific Railroad in Tarrant County to the upper end of the basin channel is small and likely intermittent flows limit restoration opportunities. However creation of a large impoundment where water supply would be used to benefit downstream aquatic and riparian vegetation might be possible
- P-2 The overflow area above Walnut Lake near BNSF Railroad in upper end of lake east of Blue Mound Road and north of East Bailey Boswell Road creates an ephemeral wetland. Limited opportunities may exist for riparian forest improvement
- P-3 East of I-35, south of North Tarrant Parkway and north of Basswood Boulevard in Fort Worth Big Fossil Creek Stream-2 contains large tracts of undeveloped land, old channel scars, natural pools and runs. Could improve by adding riparian woods while emphasizing emergent wetlands development
- P-4 The area from FM156 to I-35 in Fort Worth Big Fossil Creek contains large tracts of undeveloped land with few owners, old channel scars, natural pools and runs and could improve by adding riparian woods while emphasizing emergent wetlands development
- P-5 Between I-35W and Beach Street south of Western Center Boulevard in Big Fossil Creek. Could incorporate wetlands into floodplain downstream of impounded reach near I-35 and improve riparian woodlands
- P-6 The channelized reach upstream and downstream of Haltom Road in Buffalo Ridge Park in Haltom City could benefit from general ecosystem restoration.
- P-7 Reaches between 820, 377 North and Railroad could benefit from stream and riparian woodlands restoration
- P-8 Main stem Big Fossil Creek at North Park could benefit from general ecosystem restoration
- P-9 The area Adjacent to Big Fossil Park and Diamond Oaks County Club in Haltom City along Big Fossil Creek could benefit from general ecosystem restoration
- P-10 The Birdville Independent School District (BISD)land adjacent to Fossil Creek downstream of Onyx Drive and BISD has a Nature Trail area that could be improved by riparian woodlands
- P-11 The sump area providing detention on east side of existing flood control project north of Hwy 121 in Richland Hills could benefit from the improvement of emergent wetlands with riparian stringers
- P-12 The old water park area on west side of existing flood control project and adjacent flooded area south of Hwy 121 in Richland Hills could benefit from general ecosystem restoration

P-13 Whites Branch Creek could benefit from ecosystem restoration including improved pool riffle glide geomorphic structures in the stream, added shading, and improved stream habitat

P-14 800 North Blue Mound Road adjacent to the 80 plus acre Saginaw High School Campus could benefit from ecosystem restoration

P-15 The main stem of Big Fossil Creek at the intersection with Haltom Road in Haltom City near the high school could benefit from ecosystem restoration of riparian re-vegetation and added shading

Areas identified that might be recreational opportunities include the following written descriptions along with their respective mapping indicator code.

R-1 Recreational opportunities exist at the head waters of the main stem of Big Fossil Creek near the recurrent flooding areas

R-2 Recreational opportunities, such as greenways and trails, exist along the main stem Big Fossil Creek above County Road 496 and Union Pacific Railroad in Tarrant County to the upper end of the basin channel

R-3 Recreational opportunities, such as added greenways and trails, exist along the main stem of Big Fossil Creek in Tarrant County in the north eastern section of the watershed

R-4 Recreational opportunities exist along Big Fossil Creek-32 in North Fort Worth

R-5 Recreational opportunities, centered around an improved ephemeral wetland, exist in the overflow area above Walnut Lake near BNSF Railroad in upper end of lake east of Blue Mound Road and north of East Bailey Boswell Road

R-6 Recreational opportunities in large floodplain around Blue Mound Road south of E. Harmon Road and north of East Bailey Boswell Road

R-7 Recreational opportunity exists to improvement Highland Station Park in Saginaw

R-8 Recreational opportunities exist around FM156 to I-35 where a large tract of land with few owners has old channel scars, natural pools and runs that could be improved by adding riparian woods while emphasizing emergent wetlands development

R-9 Recreational opportunities exist around FM156 to I-35 where a large tract of land with few owners has old channel scars, natural pools and runs that could be improved with vision of continued linear park dedications with trails along main stem

R-10 Recreational opportunities exist to create and improve greenway parks and trails within and connecting Buffalo Ridge Park and North Park

R-11 Recreational opportunities to increase park area and create additional recreational features exist around the reaches between North East Loop 820, US HWY, 377 North, and Union Pacific Railroad

R-12 Recreational opportunities exist a sump area providing detention on the east side of the existing flood control project near Hwy 121 and around the old water park area

R-13 Recreational opportunities to create trails and features exists around the channelized Whites Branch along Haltom Road, west of HWY 377

R-14 Recreational opportunities, including greenway park/trail connections to existing Master Trail Plan for Big Bear Creek and Little Bear Creek in Keller, exist along Whites Branch-3

R-15 Recreational opportunities exist to create a greenway park/trail segment in Capp Smith Park in Watauga that would continue northward to a possible connection with City of Keller

R-16 Recreational opportunities, including greenway trail integration and restoration, exist at 800 North Blue Mound Road adjacent to the 80 plus acre Saginaw High School Campus

In addition to Figure 3 with sub-figures showing where the areas are located on maps and aerial photographs a written description for activities that could be analyzed to meet the objectives of reducing flood risks, ecosystem restoration, and recreation enhancements is listed below both by watershed and by cities.

- **Watershed-wide**
  - Flood proofing or relocation of structures in the Floodplain
  - Priority Sub-watershed/catchment management planning
  - Greenway/Recreational Trail System (linking parks/trails to community centers, recreation centers, senior centers, libraries, schools, environmental educations centers, etc. while also utilizing non-environmental corridors such as utility easements and vacated rail lines as other off-road options for trial connections)
  - Floodplain Development permitting system to establish a set of common regional criteria and procedures for development within the Big Fossil Creek watershed; similar to Corridor Development Certificate (CDC) process for the Trinity River Corridor
  - Comprehensive Drainage policies for water quality and quantity - integrated Storm Water Management (iSWM) or other consistent storm water control across watershed
  - Hazard mitigation action planning
  - Flood warning system

- Planning and/or development review for sites over a specified size or for developments of watershed impact

- Mitigation bank

- Transfer or Purchase of Development Rights (TDR/PDR) program

- Controlled development through zoning

- Regional detention facilities located in the upper reaches of the watershed that have not yet been fully developed to reduce watershed wide flooding

- Ecosystem restoration/preservation of native grasslands and/or emergent wetlands in upper watershed west of I-35

- Coordinate with railroads and TxDOT to improve maintenance of existing and future structures and to facilitate proper sizing of future structures

- **Haltom City**
  - Flood damage reduction at Whites Branch Creek - Skyline Mobile Home Park (acquisition/removal of structures, ecosystem restoration, and passive recreation)

  - Greenway park/trail to connect North Park and Buffalo Ridge Park

  - Ecosystem Restoration along Big Fossil Creek main stem between Union Pacific Railroad and US HWY 377 (severe bank sloughing)

  - Greenway park/trail possibilities in conjunction with Little Fossil Creek

  - Relocation and/or reactivation of stream gage just north of SH 183

  - Ecosystem Restoration in Buffalo Ridge Park (severe bank sloughing as identified by Friends of Big Fossil Creek Stakeholders and recommended by the Stream Team)

  - Ecosystem Restoration to eliminate sloughing in main stem of Big Fossil Creek reach through Buffalo Ridge Park, near Fenway Court , and along North Park

  - Greenway park/trail connections under I-820 along Big Fossil Creek main stem and Singing Hills Creek

  - Ecosystem Restoration and Greenway Trail in Diamond Oaks Golf Course (severe bank sloughing and loss of riparian habitat)

- **Richland Hills**
  - Big Fossil Creek levee- existing level of protection verses the authorized/constructed level of protection and future level of protection.

  - Big Fossil Creek levee sump area – opportunities for ecosystem restoration (wetland, open water, revegetation)

  - Big Fossil Creek levee sump area – opportunities for recreation expanding the existing park

  - Greenway park/trail segment along the levee structure near Rosebud Park and possible linkage with Fort Worth and the West Fork of the Trinity River to the south

  - Ecosystem restoration with construction of an in-channel wetland

  - Flood damage reduction with a sump in the area of repetitive loss structures

  - Flood damage reduction with detention ponds in residential areas

  - Flood damage reduction acquisition/removal of repetitive loss structures

  - Flood damage reduction channel improvement to the existing levee

- **Watauga**
  - Flood damage reduction acquisition/removal of repetitive loss structures

  - Greenway park/trail segment in Capp Smith Park to continue northward with possible connection with the City of Keller

- **Saginaw**
  - Flood damage reduction, ecosystem restoration and recreation improvements to Highland Station Park (possible detention and environmental education opportunities because of nearby middle school)

- **North Richland Hills**
  - Greenway park/trail integration with Cottonbelt Trail as Veloweb and possible connections with future parks at Mullendore Elementary, Snow Heights Elementary, and the future off-road trail along the South Electric Trail

  - Greenway park/trail improvement in Fossil Park where the loop bridge is not designed to 100 year floodplain and has been overtopped/damaged in more frequent storm events

  - Flood damage reduction acquisition/removal of repetitive loss structures

- Ecosystem restoration in the reach from Broadway to Onyx additionally on Macky Creek at State Highway 26, and Iron Horse Golf Course.

- Future floodplain limits

- **Keller**
  - Greenway park/trail connections to existing Master Trail Plan for Big Bear Creek and Little Bear Creek

- **Tarrant County**
  - Upper portion of watershed under intense development pressure and needs flood damage reduction, ecosystem restoration, and recreation features

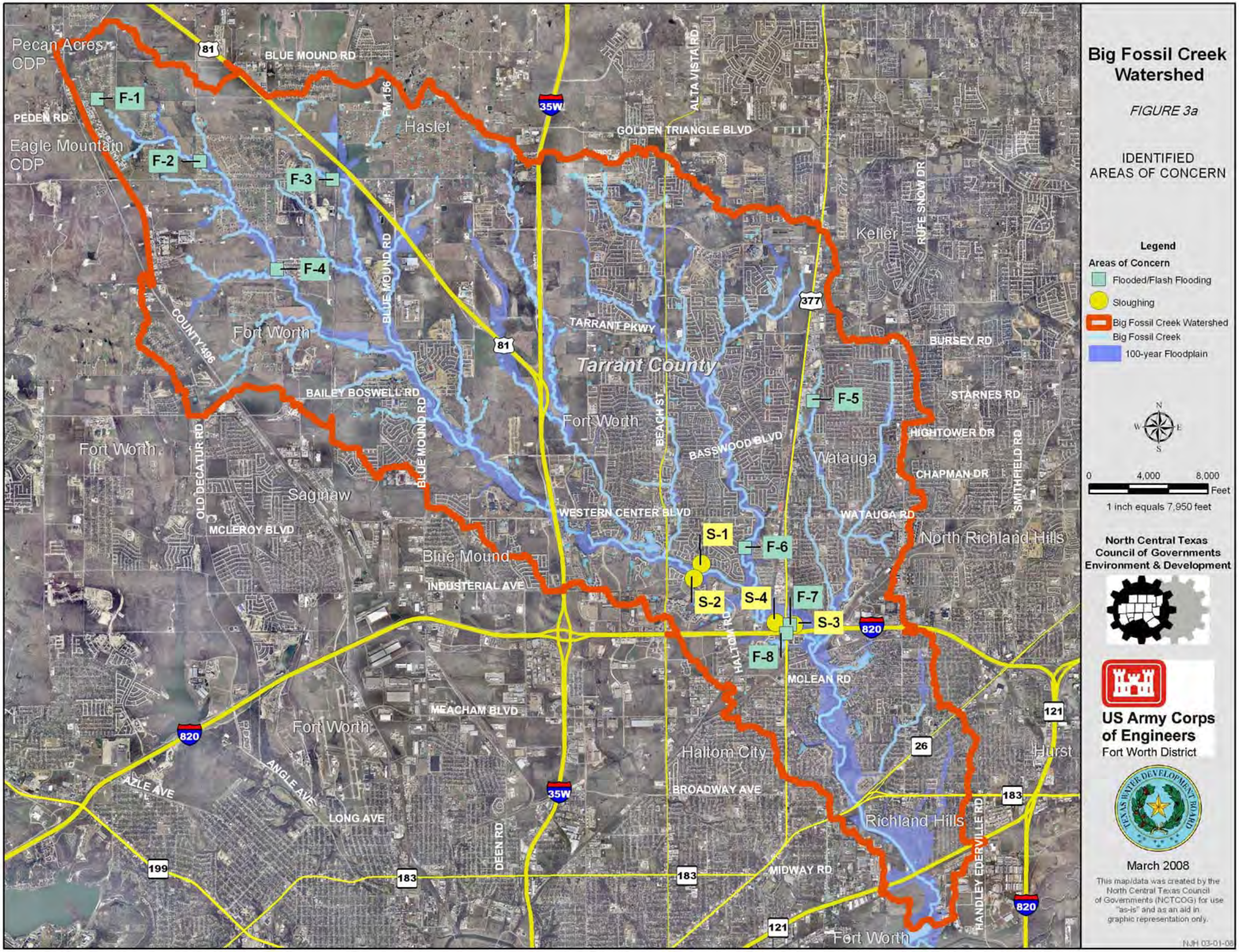
  - Flood damage reduction through detention in various areas

  - Model of hydrology and hydraulics (H&H) for future conditions

- **Fort Worth**
  - Greenway park/trail: continued linear park dedications with trails along main stem, White's Branch and other tributaries

- **Haslet**
  - Greenway park/trail connecting to future Fort Worth trail system

Big Fossil Creek watershed is very complex due to the many different types of land uses, competing interests in the existing water resources, and the high rate of development throughout the watershed. The entire downstream half of the watershed is almost fully developed, and similar growth is anticipated for the upper half of the watershed in the coming years. See ***Figure 4*** showing the land uses of 1995 adjacent to the land uses of 2005 for an illustration of the development trends within the watershed. There is a dramatic change in the amount of undeveloped land in 1995 compared to what is undeveloped in 2005. This loss of undeveloped real estate limits potential alternatives providing solutions to some of the watershed problems and also eliminates areas for public recreation.



Big Fossil Creek Watershed
FIGURE 3a
IDENTIFIED AREAS OF CONCERN
Legend
Areas of Concern
Flooded/Flash Flooding
Sloughing
Big Fossil Creek Watershed
Big Fossil Creek
100-year Floodplain
N
W
E
S
0
4,000
8,000
Feet
1 inch equals 7,950 feet
North Central Texas Council of Governments Environment & Development
US Army Corps of Engineers
Fort Worth District
TEXAS WATER DEVELOPMENT BOARD
March 2008
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NJH 03-01-08
Pecan Acres CDP
Eagle Mountain CDP
PEDEN RD
BLUE MOUND RD
FM 156
Haslet
GOLDEN TRIANGLE BLVD
ALTA VISTA RD
RUFE SNOW DR
Keller
BURSEY RD
STARNES RD
HIGHTOWER DR
CHAPMAN DR
SMITHFIELD RD
North Richland Hills
WATAUGA RD
Watauga
BASSWOOD BLVD
BEACH ST
TARRANT PKWY
Tarrant County
Fort Worth
WESTERN CENTER BLVD
HALTOM RD
MCLEAN RD
Haltom City
BROADWAY AVE
MIDWAY RD
Richland Hills
HANDLEY EDERVILLE RD
Hurst
Blue Mound
INDUSTERIAL AVE
MEACHAM BLVD
DEEN RD
BAILEY BOSWELL RD
Saginaw
MCLEROY BLVD
OLD DECATUR RD
COUNTY 496
LONG AVE
ANGLE AVE
AZLE AVE
F-1
F-2
F-3
F-4
F-5
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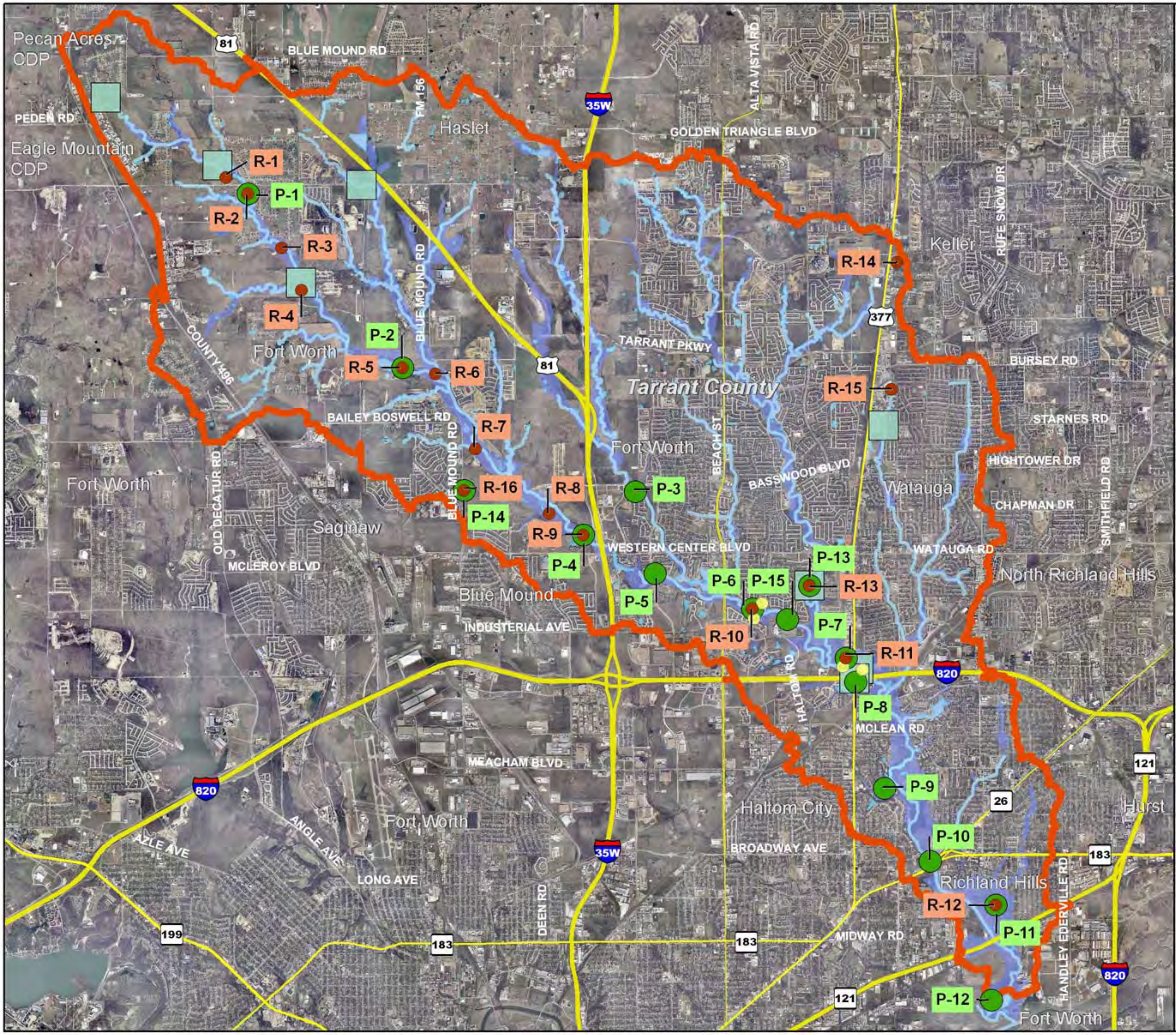
820
121
26
183
199



Big Fossil Creek Watershed

FIGURE 3b

IDENTIFIED POTENTIAL ALTERNATIVES

Legend

- Big Fossil Creek Watershed
- Big Fossil Creek
- 100-year Floodplain

Potential Alternatives

- Ecosystem Restoration Sites
- Recreational Opportunities

Areas of Concern

- Flooded/Flash Flooding
- Sloughing

0 4,000 8,000 Feet

1 inch equals 7,950 feet

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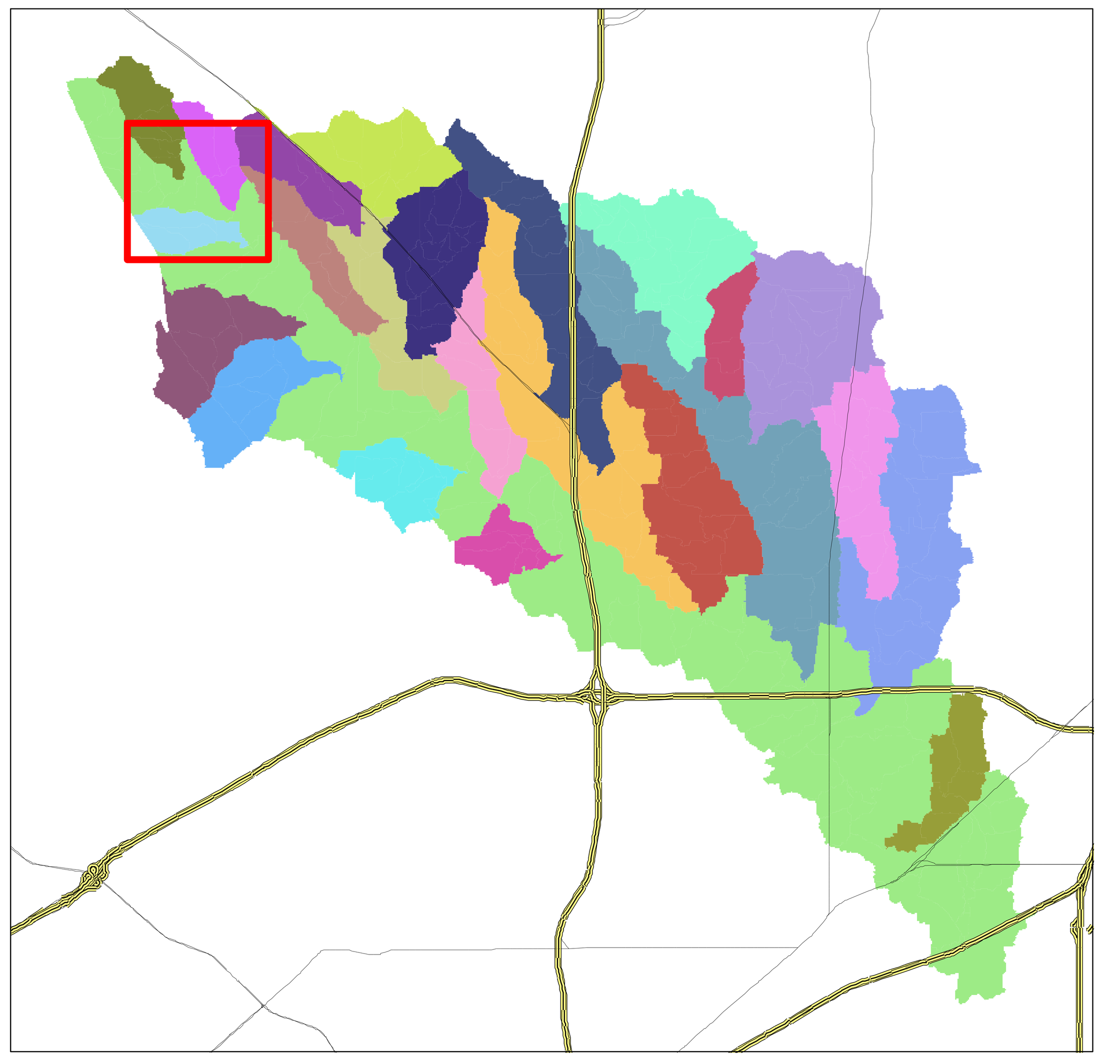
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
RR and Upstream
Fig. 3.1



Legend

Preliminary 100 Yy Flood Plain

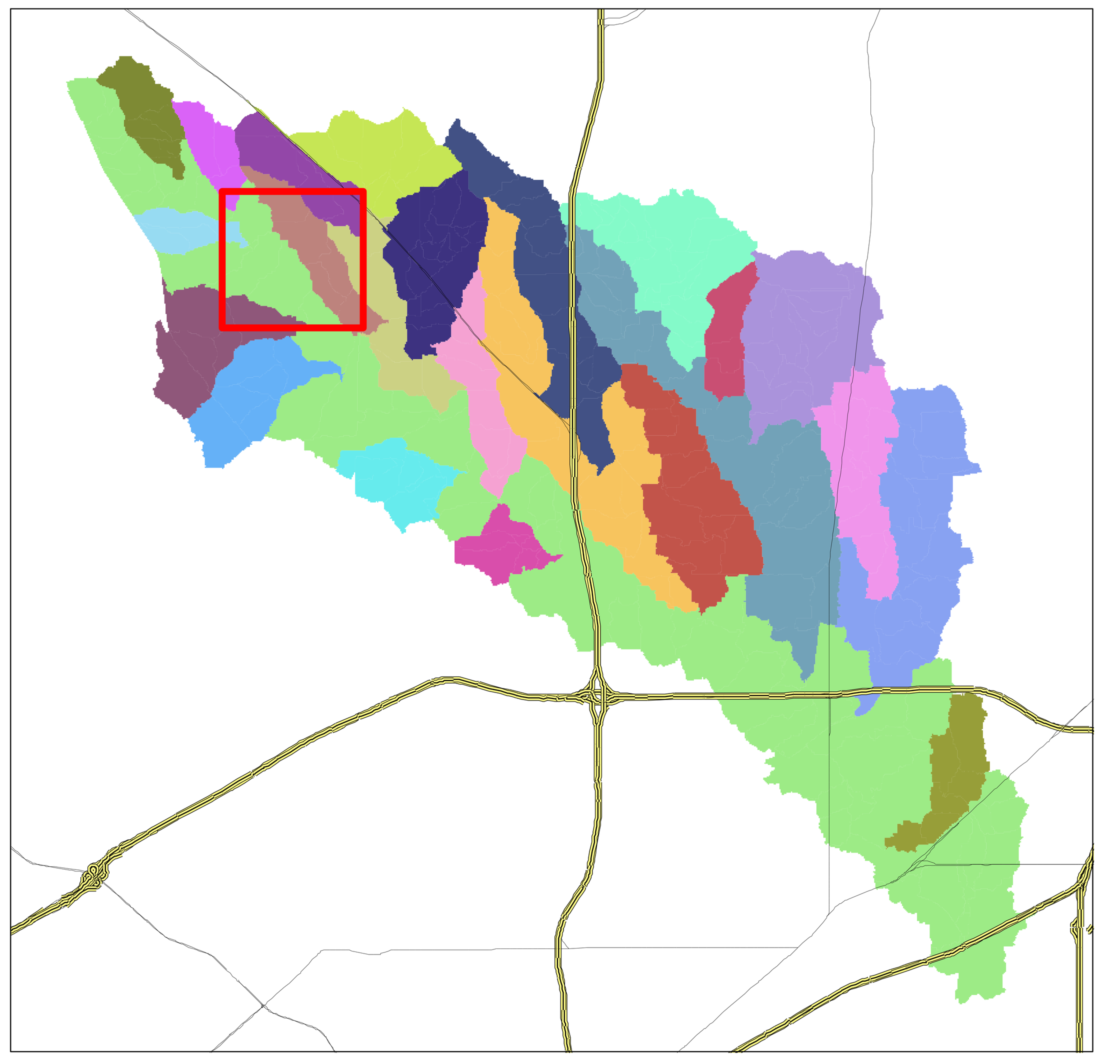
Potential Projects or Areas of Concern:

F-1
F-2

Flooding of Homes

U S Army Corps of Engineers
Fort Worth District

BIG FOSSIL CREEK WATERSHED
Big Fossil Creek
RR and Upstream
Fig. 3.2



Legend

Preliminary 100 Yy Flood Plain

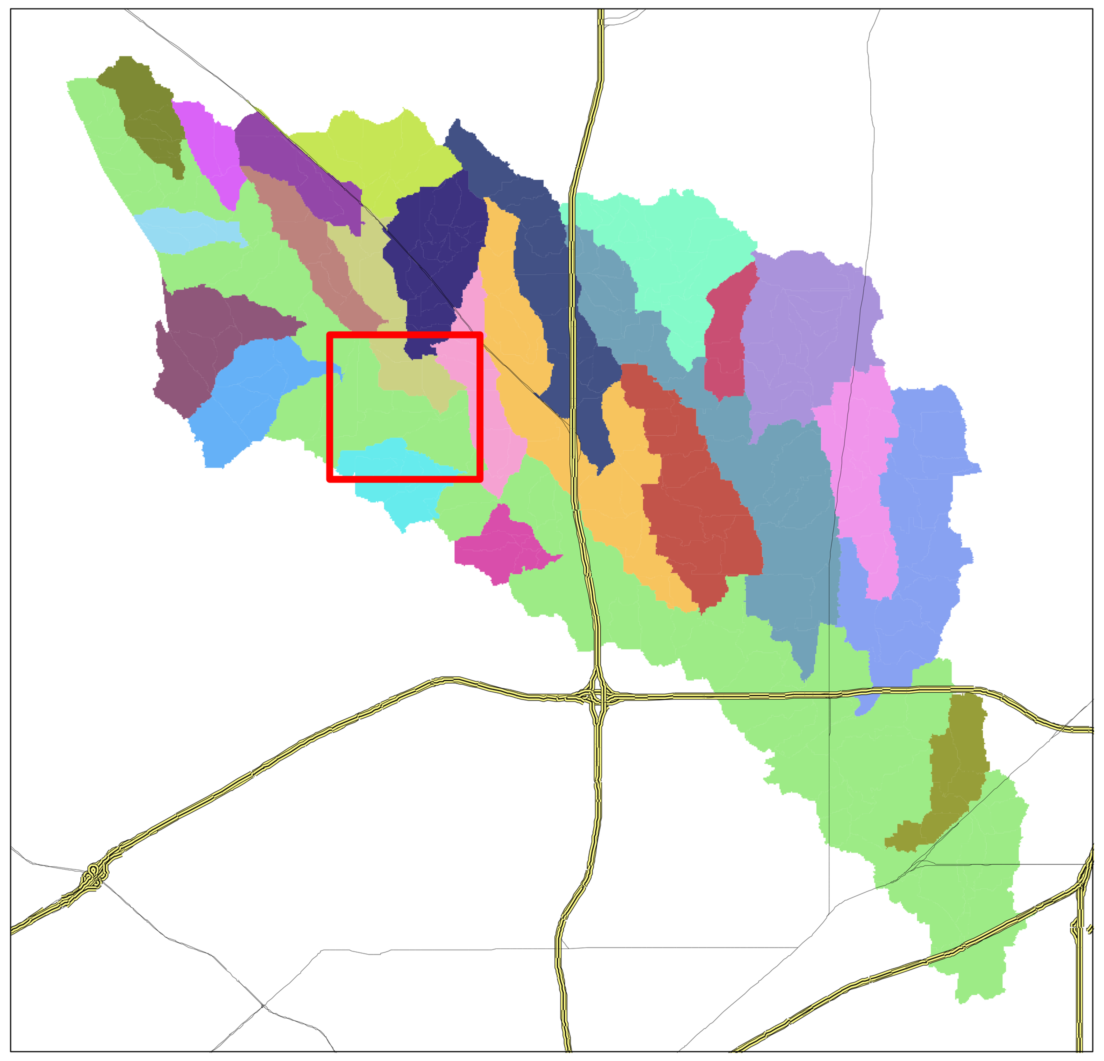
Potential Projects or Areas of Concern:
F-2 R-1 F-4
R-2 P-1 F-3
R-3 R-4

Flooding of Homes
Ecosystem Restoration

U S Army Corps of Engineers
Fort Worth District

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
FM 156 and US to RR
Fig. 3.3



Legend

Preliminary 100 Yy Flood Plain

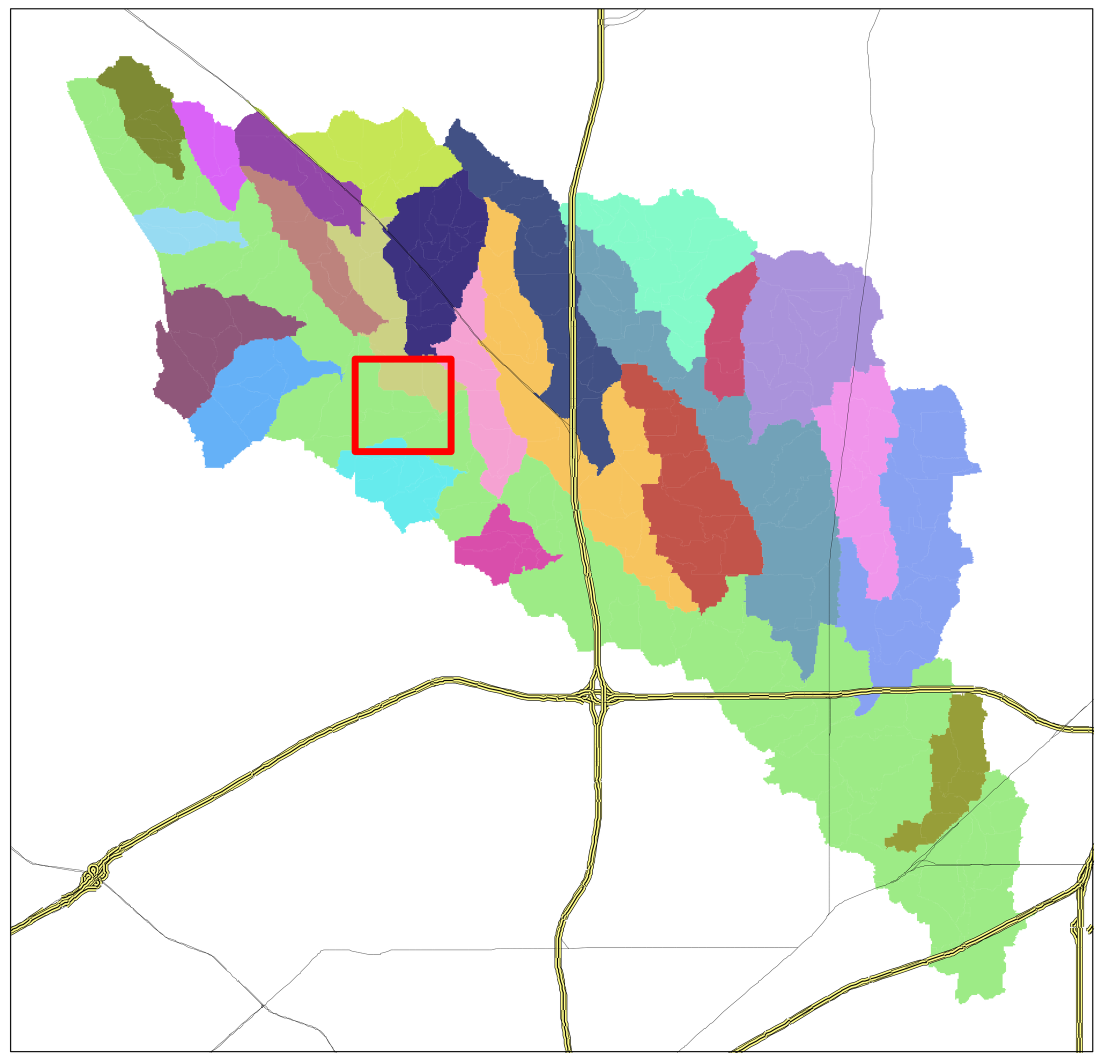
Potential Projects or Areas of Concern:

P-2
R-5
R-6
R-7
Ecosystem Restoration of created wetlands
Riparian Forest Planting

U S Army Corps of Engineers
Fort Worth District

0 250 500 1,000 1,500
Feet

BIG FOSSIL CREEK WATERSHED
Big Fossil Creek
FM 156 and US to RR
Fig. 3.4



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-2
R-5
R-6
Improve Ephemeral Wetland

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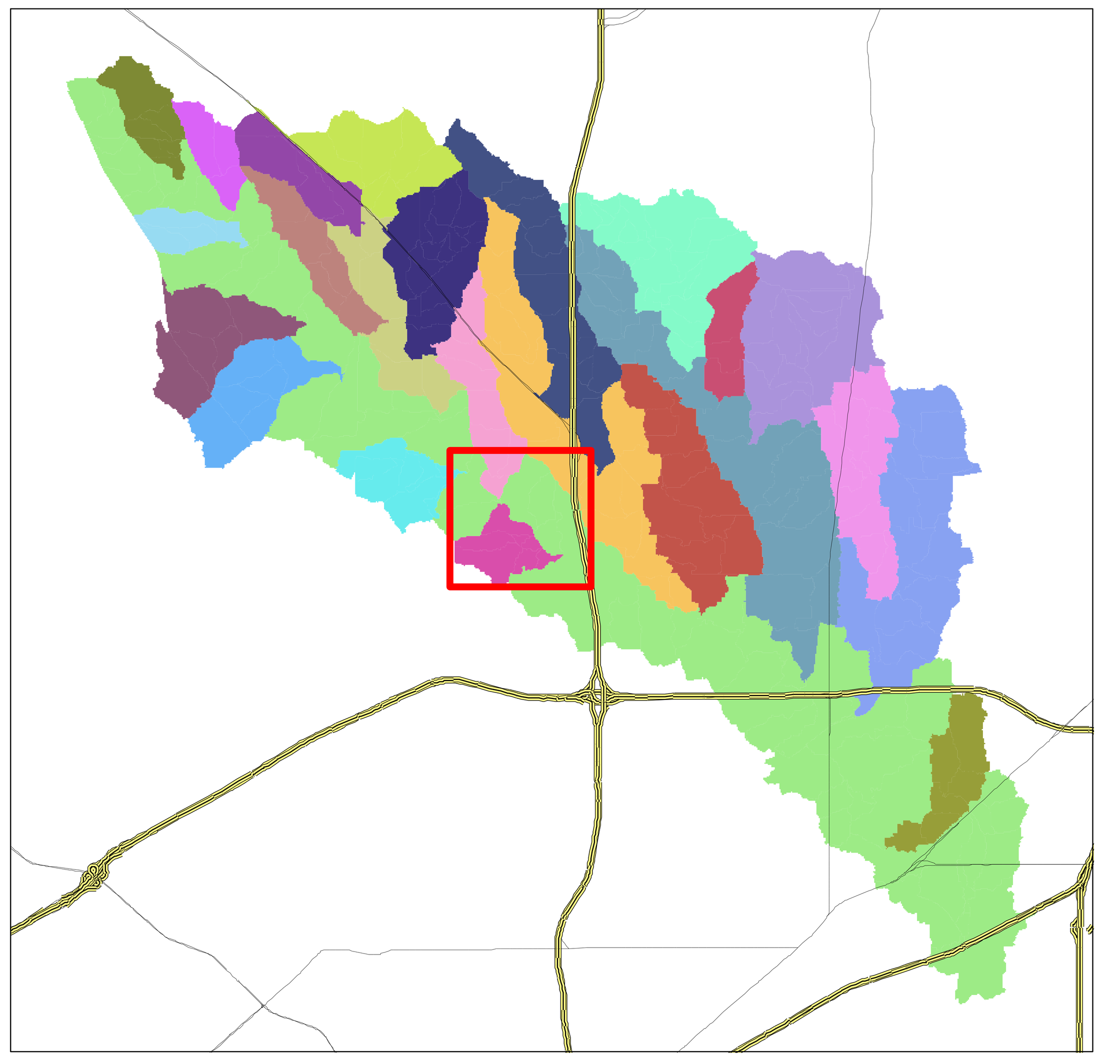
Fort Worth District

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
FM 156 to I-35W
Fig 3.5



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

R-7 R-16
R-8 P-14
R-9
P-4
Riparian Area Restoration
Recreational Trails

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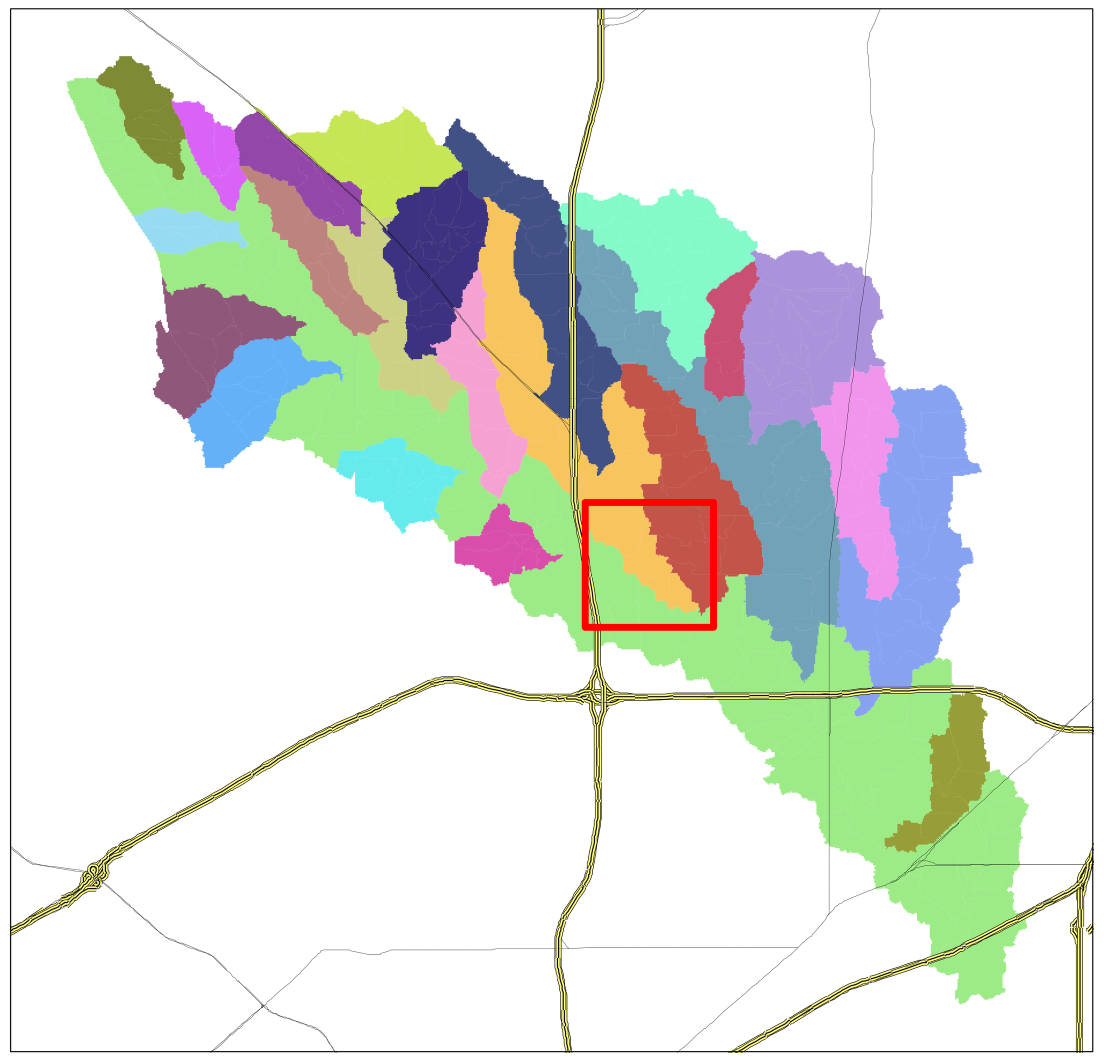
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Beach to I-35W
Fig. 3.6



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

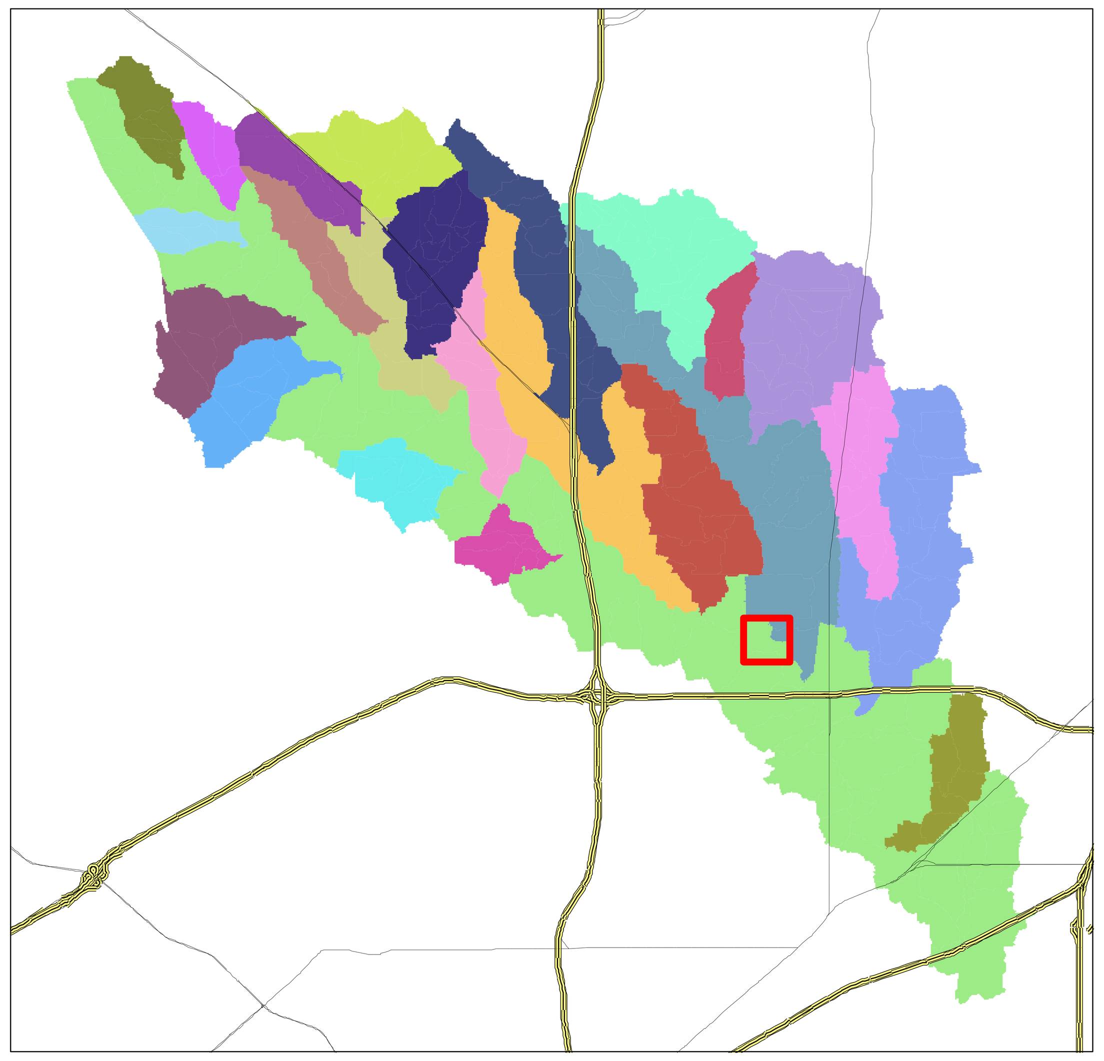
P-5
P-3

Incoorporate wetlands into floodplain downstream of impounded reach

U S Army Corps
of Engineers
Fort Worth District

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Haltom Road Channel
Fig. 3.7



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

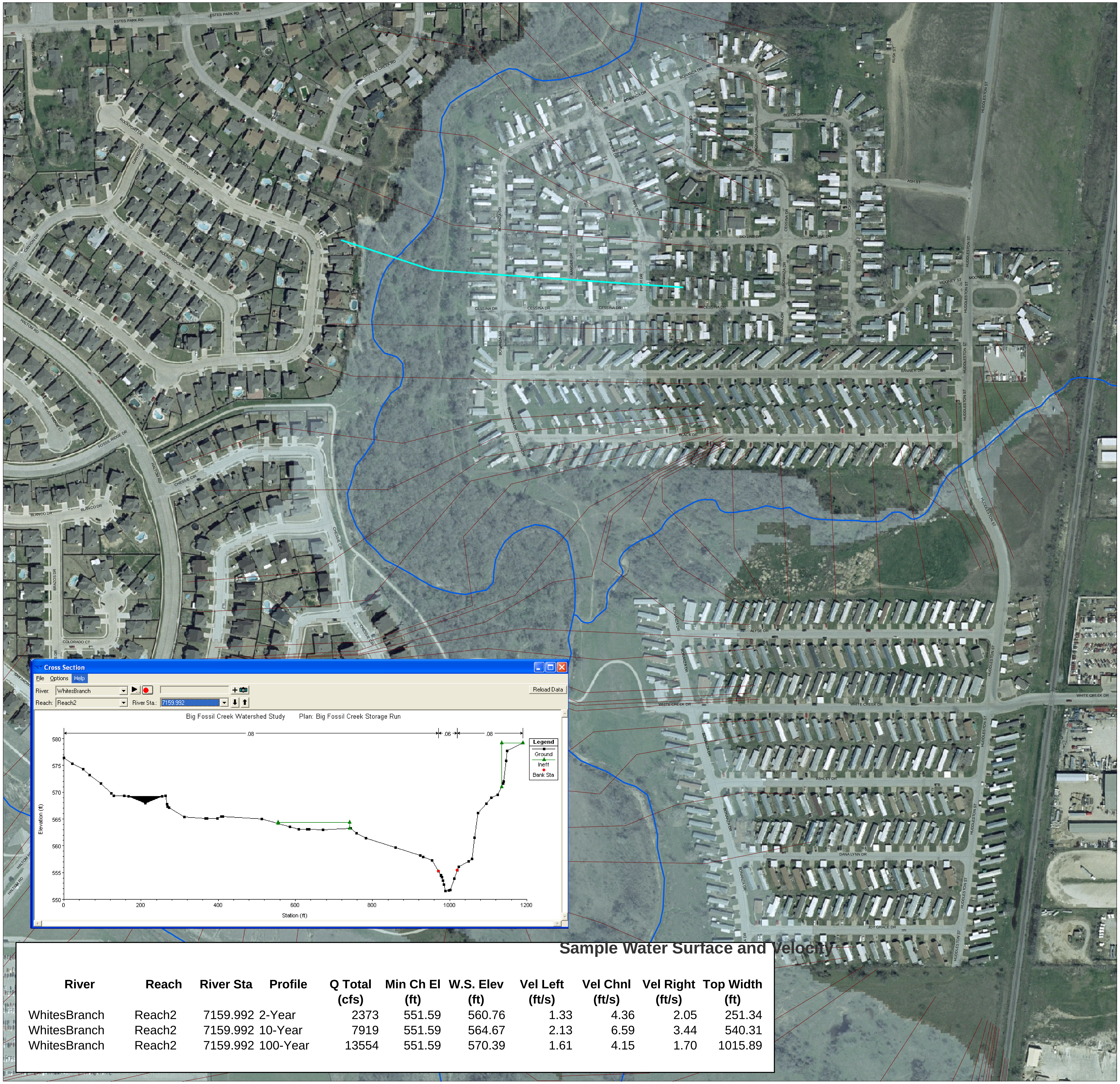
P-15

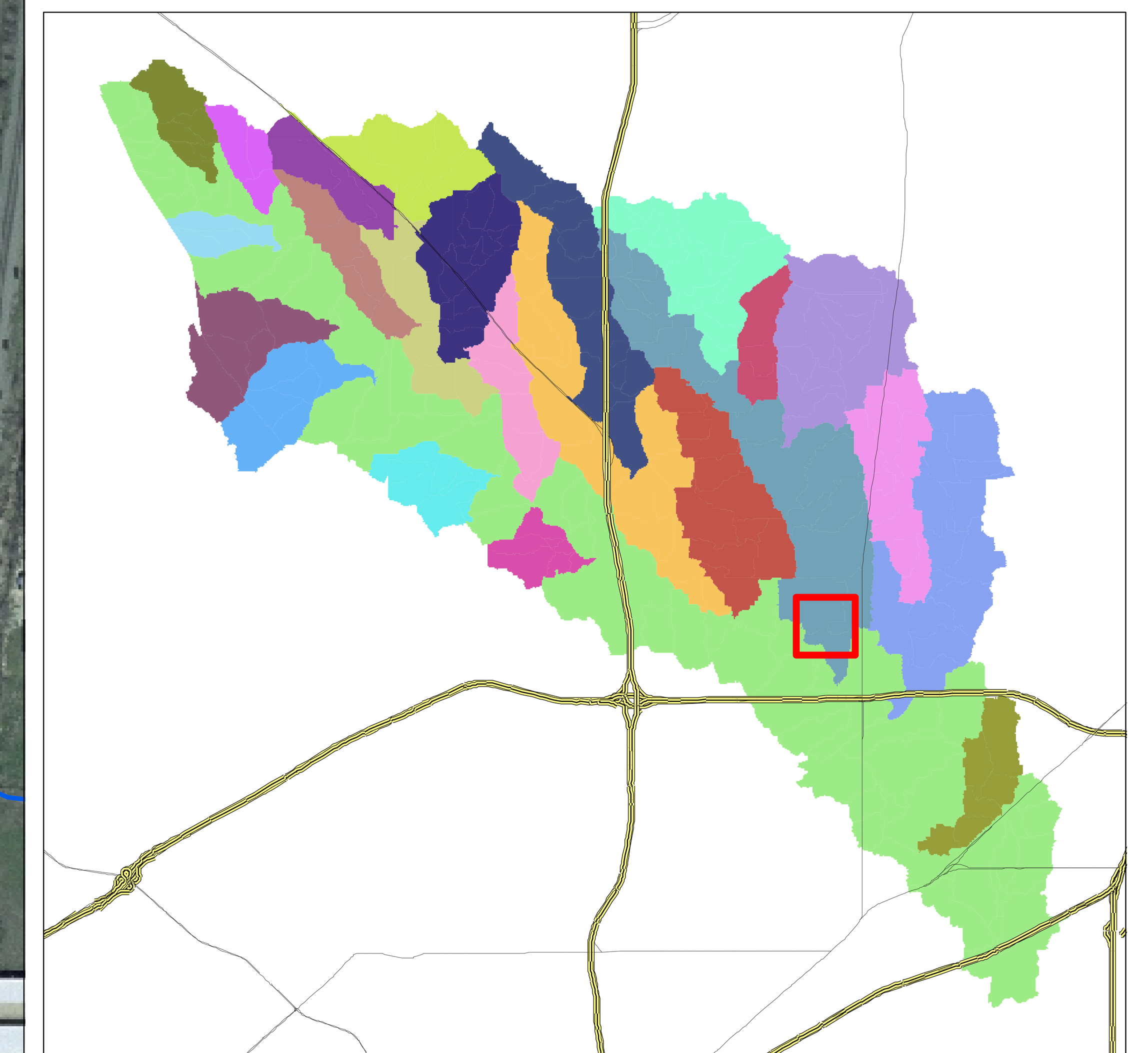
Stream and Riparian Woodland Restoration

U S Army Corps of Engineers
Fort Worth District

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Skyline Mobile Home Park
Fig. 3.8





Legend

Cross Section Layouts

- Cross Sections
- Sample Section
- Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

F-6
P-13
R-13

Flooding of houses
Ecosystem Restoration
Recreation features

Sample Water Surface and Velocity

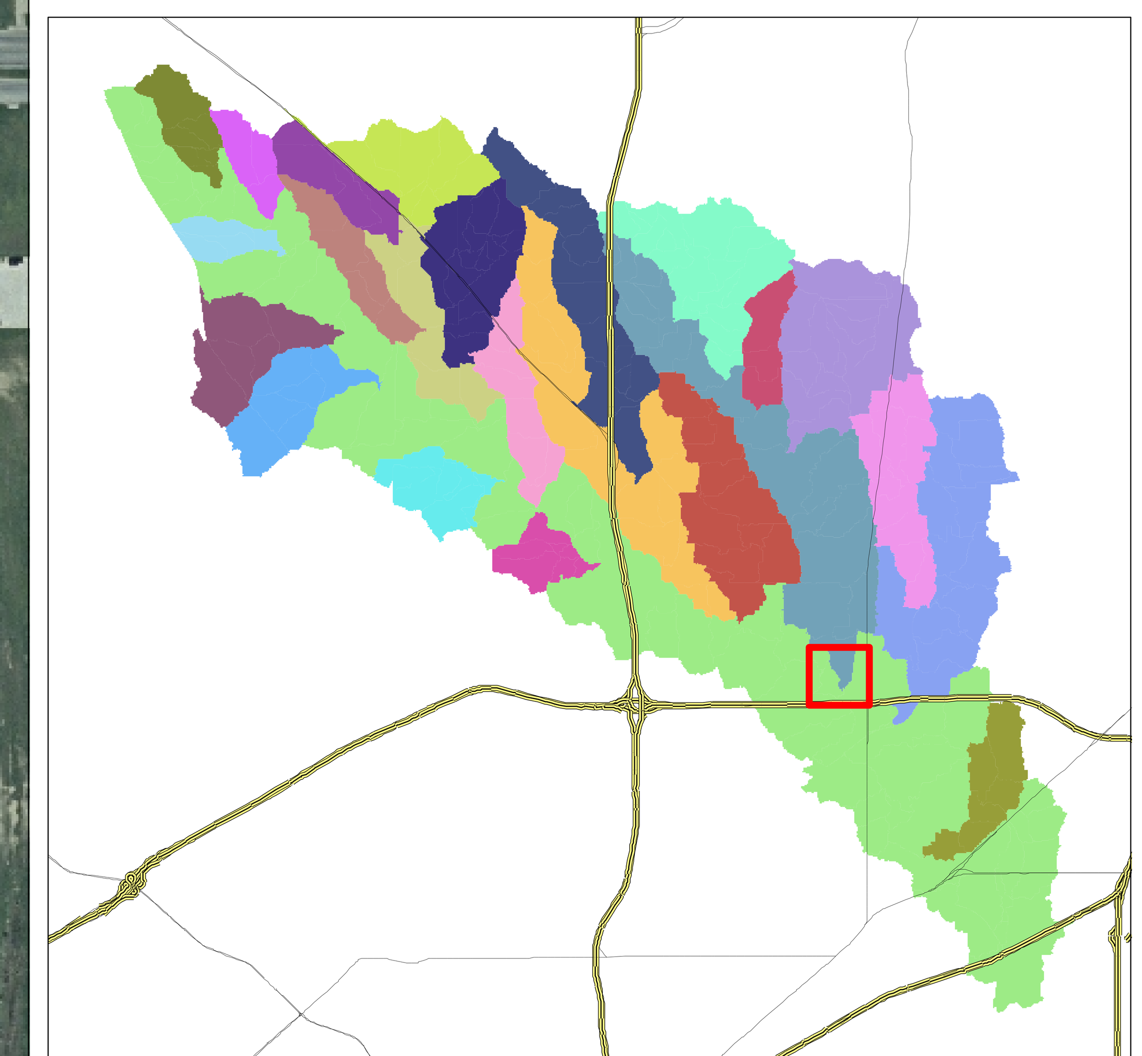
River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Left (ft/s)	Vel Chnl (ft/s)	Vel Right (ft/s)	Top Width (ft)
WhitesBranch	Reach2	7159.992	2-Year	2373	551.59	560.76	1.33	4.36	2.05	251.34
WhitesBranch	Reach2	7159.992	10-Year	7919	551.59	564.67	2.13	6.59	3.44	540.31
WhitesBranch	Reach2	7159.992	100-Year	13554	551.59	570.39	1.61	4.15	1.70	1015.89

0 250 500 1,000 1,500 Feet

U S Army Corps of Engineers
Fort Worth District

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Loop 820 at HW 377 North
Fig. 3.9



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-8
R-11
P-7

Stream and Riparian revegetation

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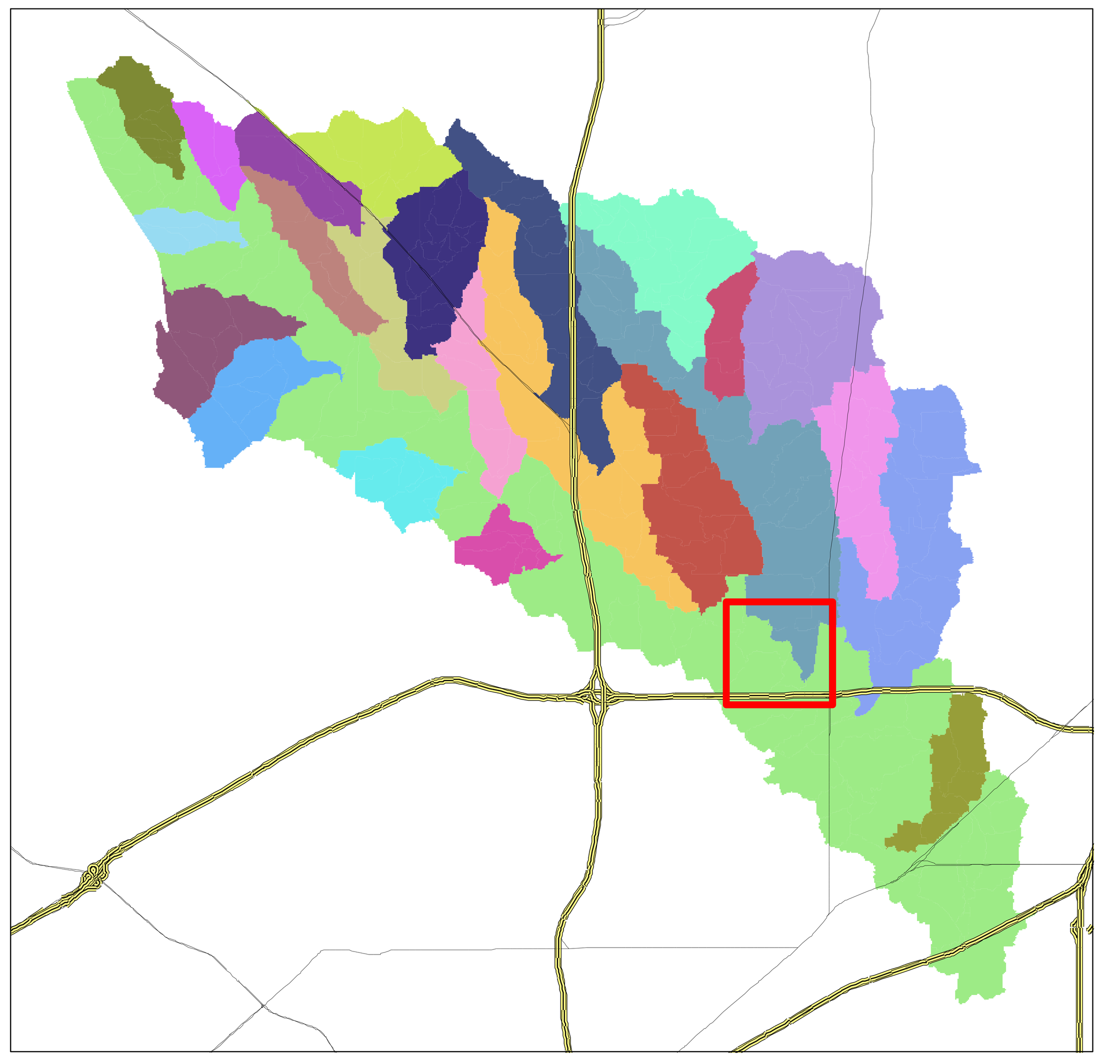
Fort Worth District

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
HW 377 to Beach St.
Fig. 3.9 b



Legend

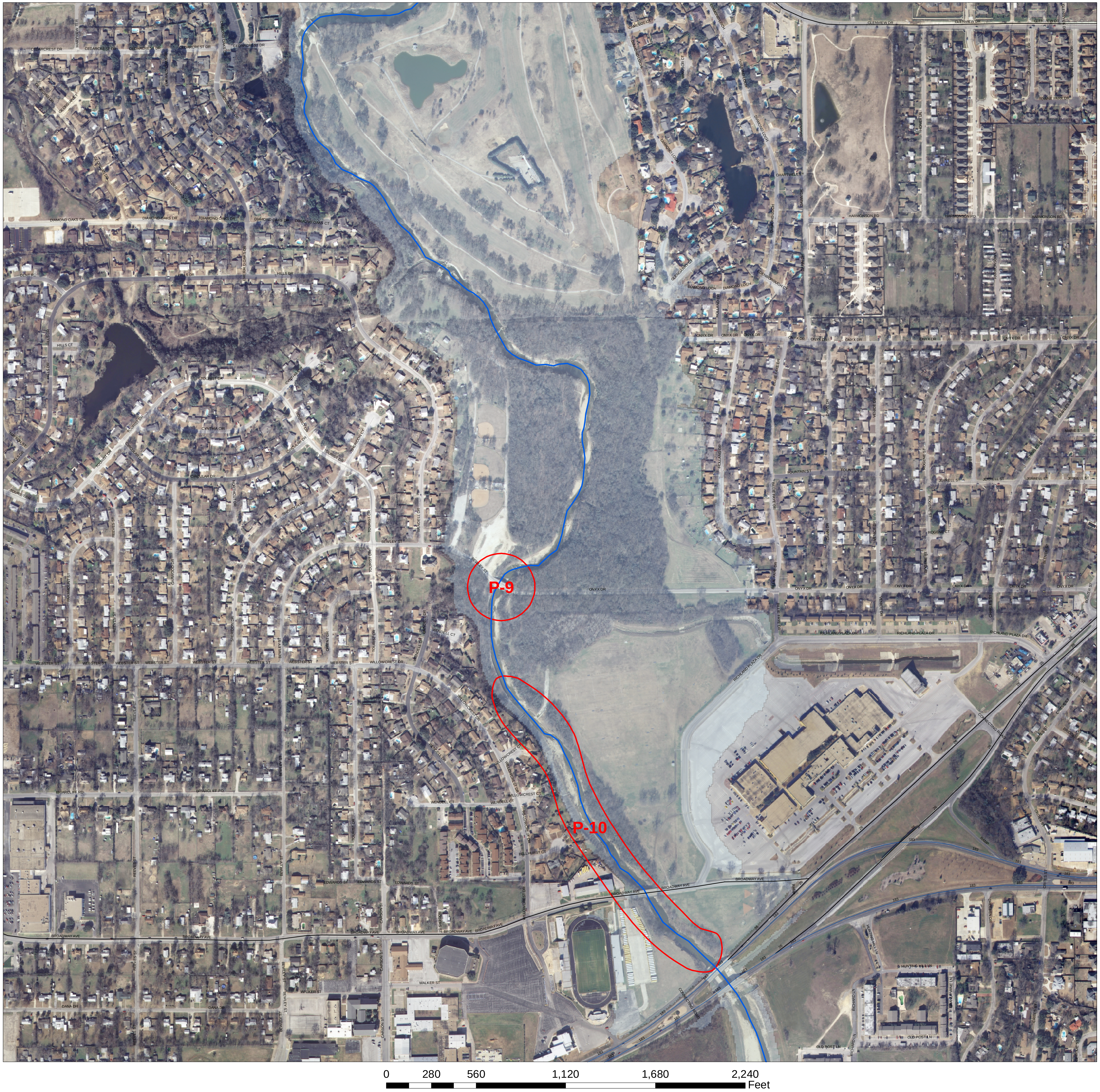
Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-6	**S-3**	**F-6**
P-8	**R-10**	**F-7**
R-11	**P-13**	
P-7	**R-13**	

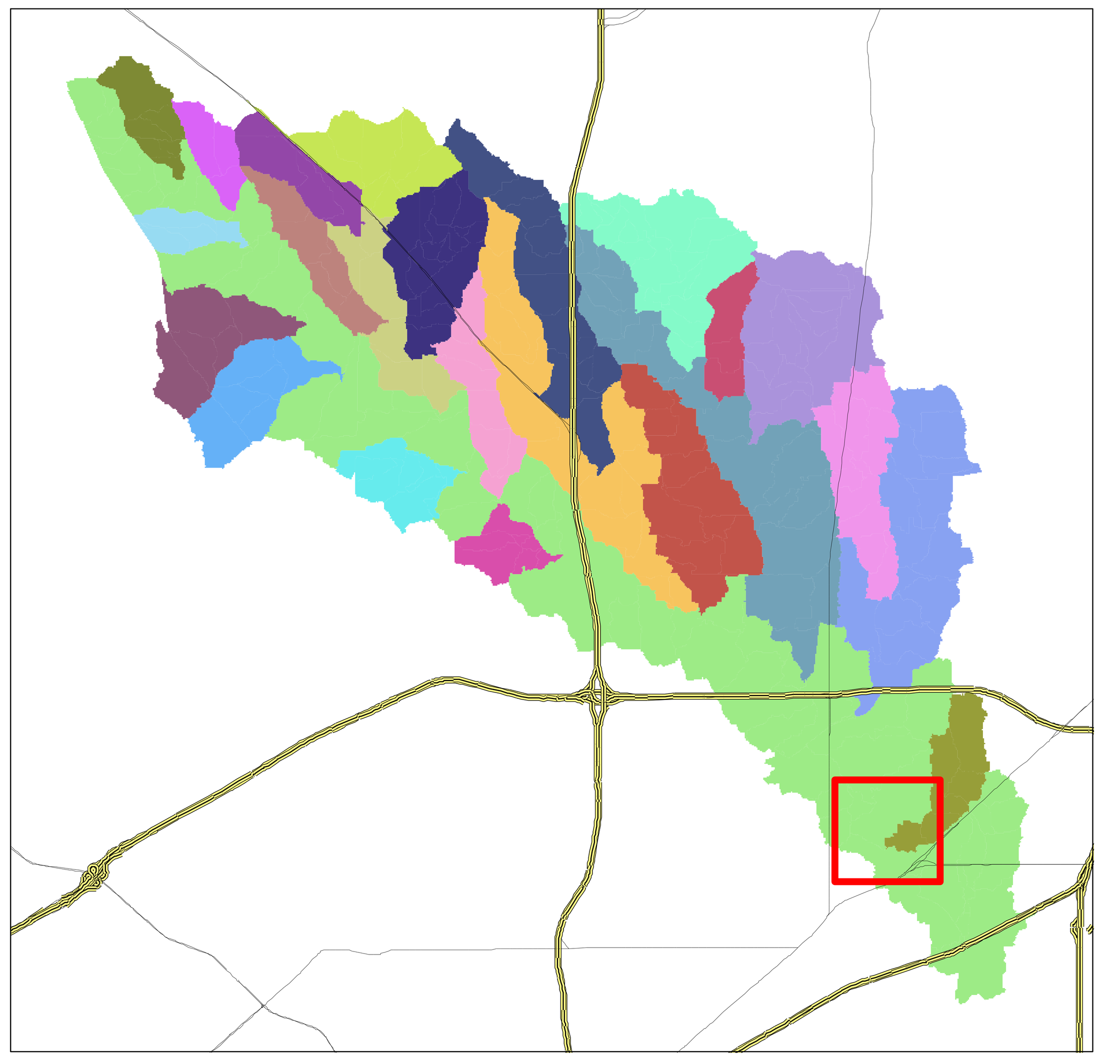
Stream and Riparian revegetation

U S Army Corps of Engineers
Fort Worth District



BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
HW 183 North
Fig. 3.9 c



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

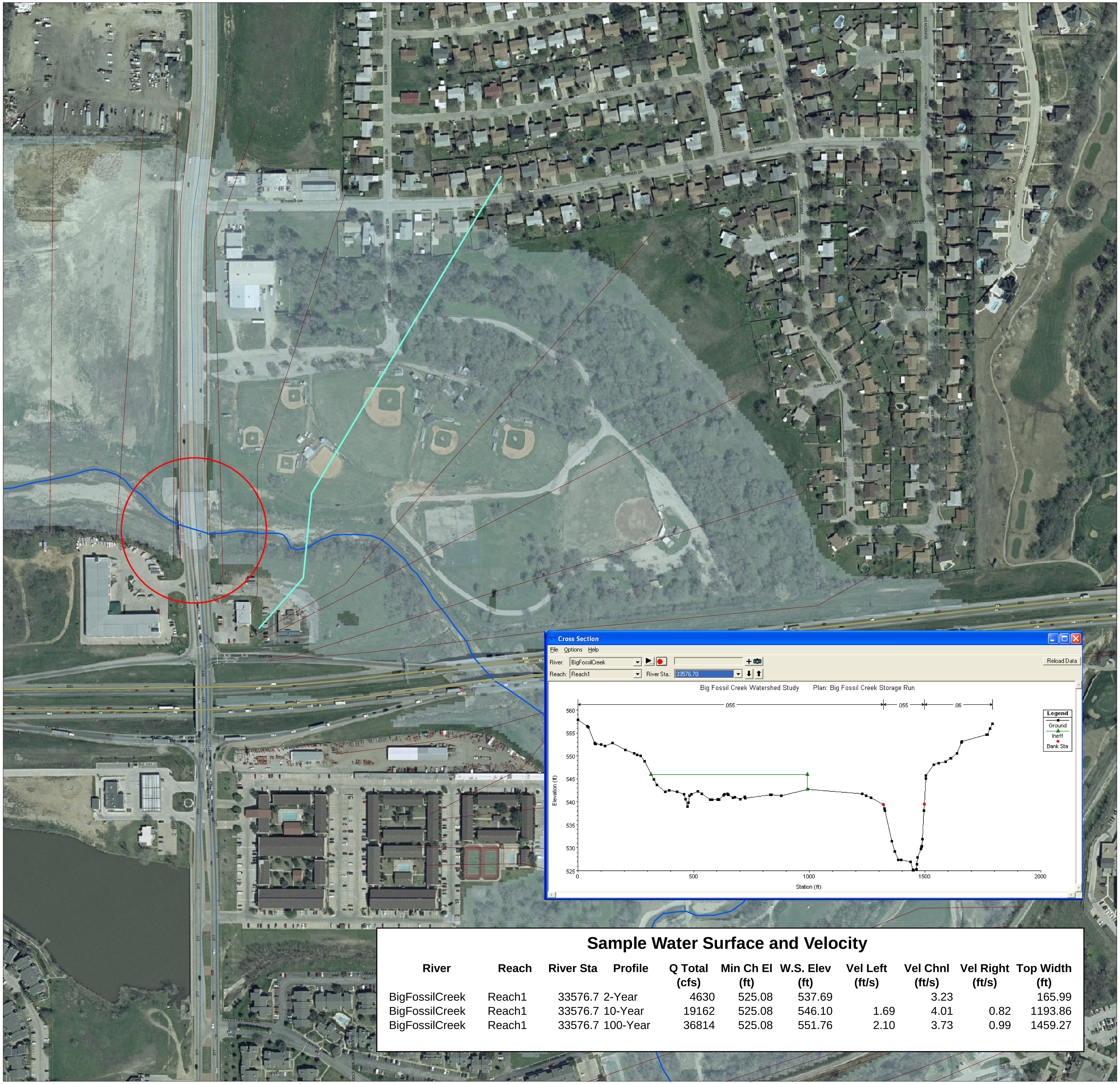
P-9
P10

Stream and Riparian revegetation

U S Army Corps of Engineers
Fort Worth District

BIG FOSSIL CREEK WATERSHED

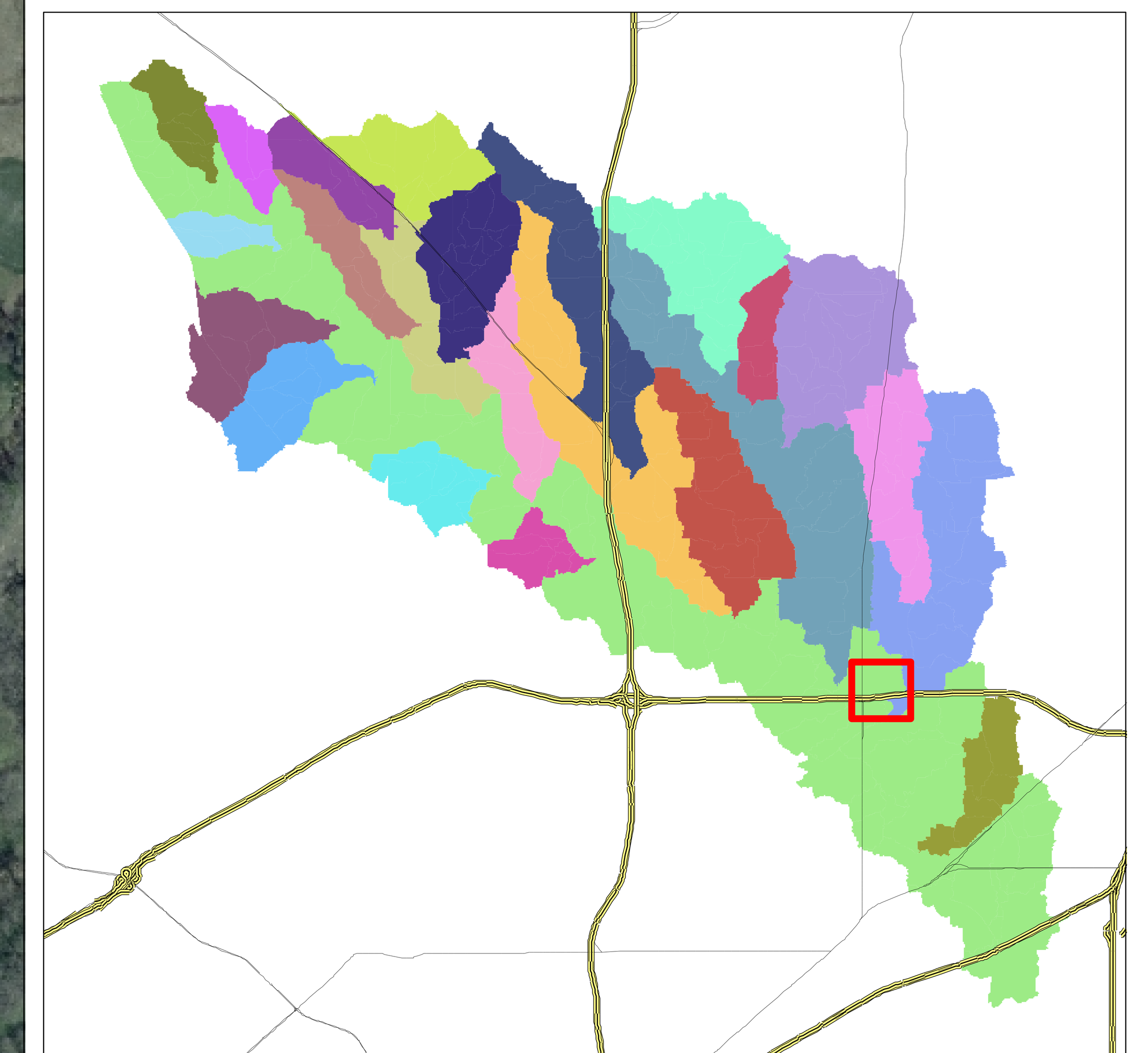
Big Fossil Creek
Loop 820 at HW 377
Fig. 3.10



Sample Water Surface and Velocity

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Left (ft/s)	Vel Chnl (ft/s)	Vel Right (ft/s)	Top Width (ft)
BigFossilCreek	Reach1	33576.7	2-Year	4630	525.08	537.69		3.23		165.99
BigFossilCreek	Reach1	33576.7	10-Year	19162	525.08	546.10	1.69	4.01	0.82	1193.86
BigFossilCreek	Reach1	33576.7	100-Year	36814	525.08	551.76	2.10	3.73	0.99	1459.27

0 150 300 600 900 1,200 Feet



Legend

Cross Section Layouts

- Cross Sections
- Sample Section
- Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-8

Riparian revegetation

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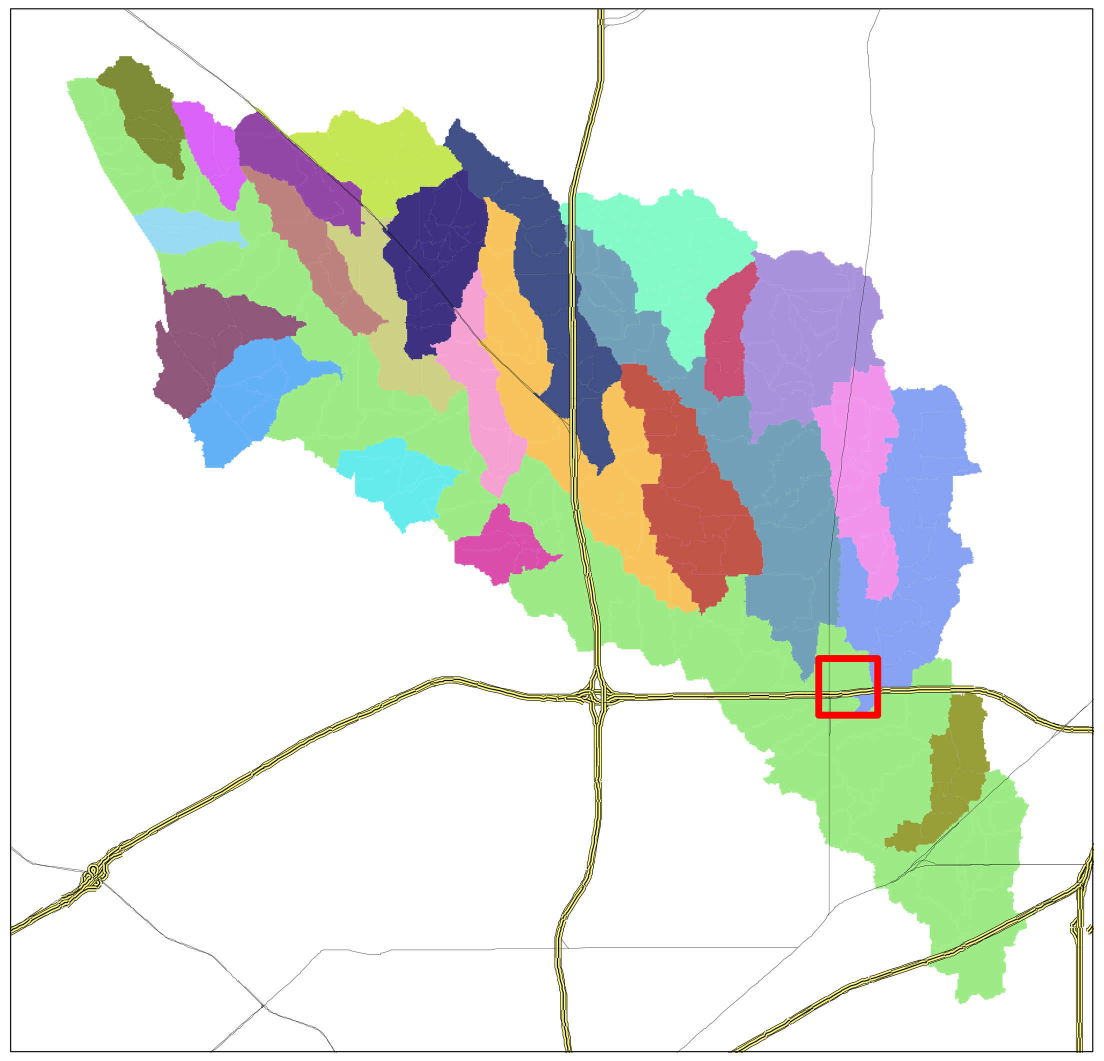
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Loop 820 at HW 377
Fig. 3.10 b

0 150 300 600 900 1,200 Feet



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-8 F-7
S-3 S-4

Riparian revegetation

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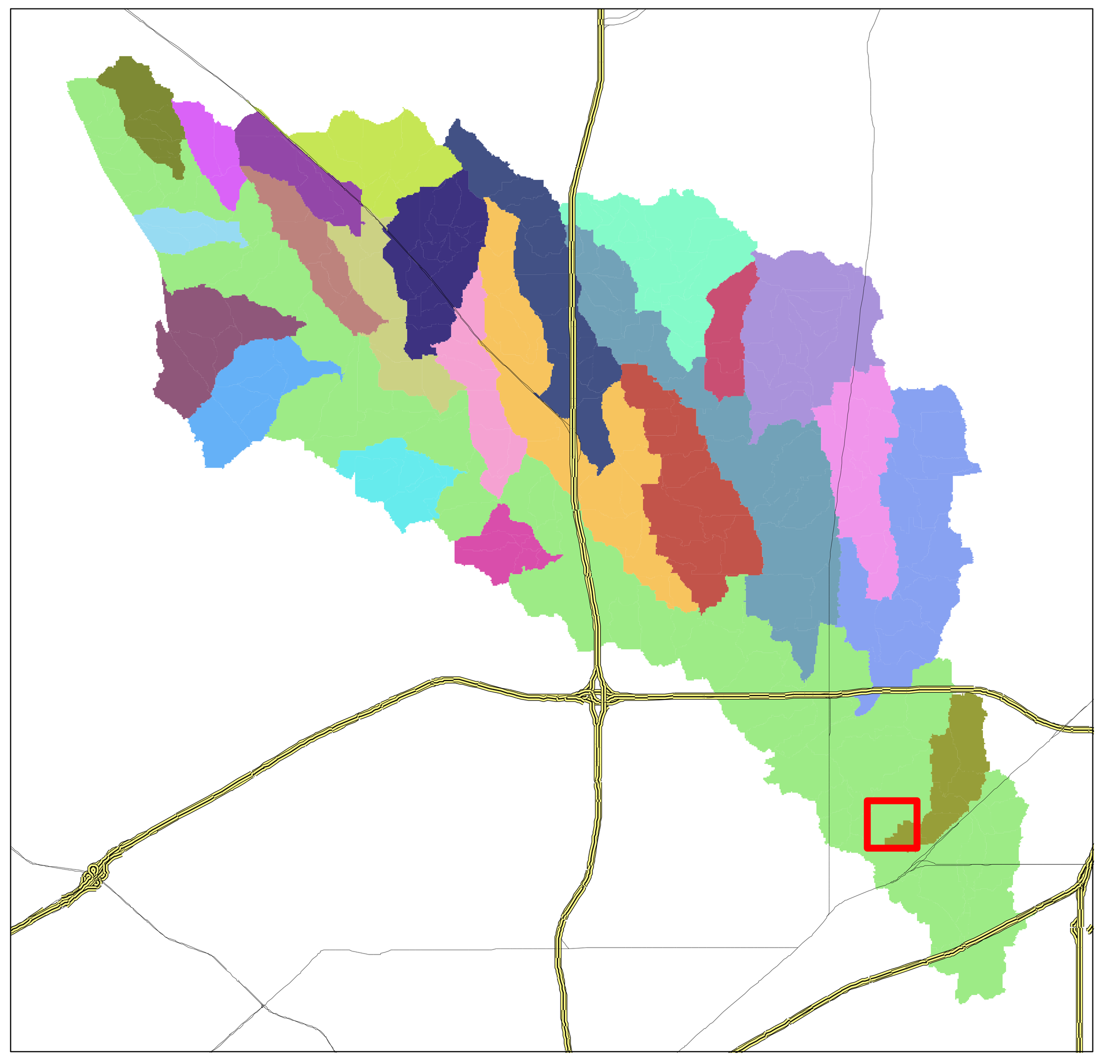
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Onyx Drive
Fig. 3.11



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-10

Improve Riparian Area

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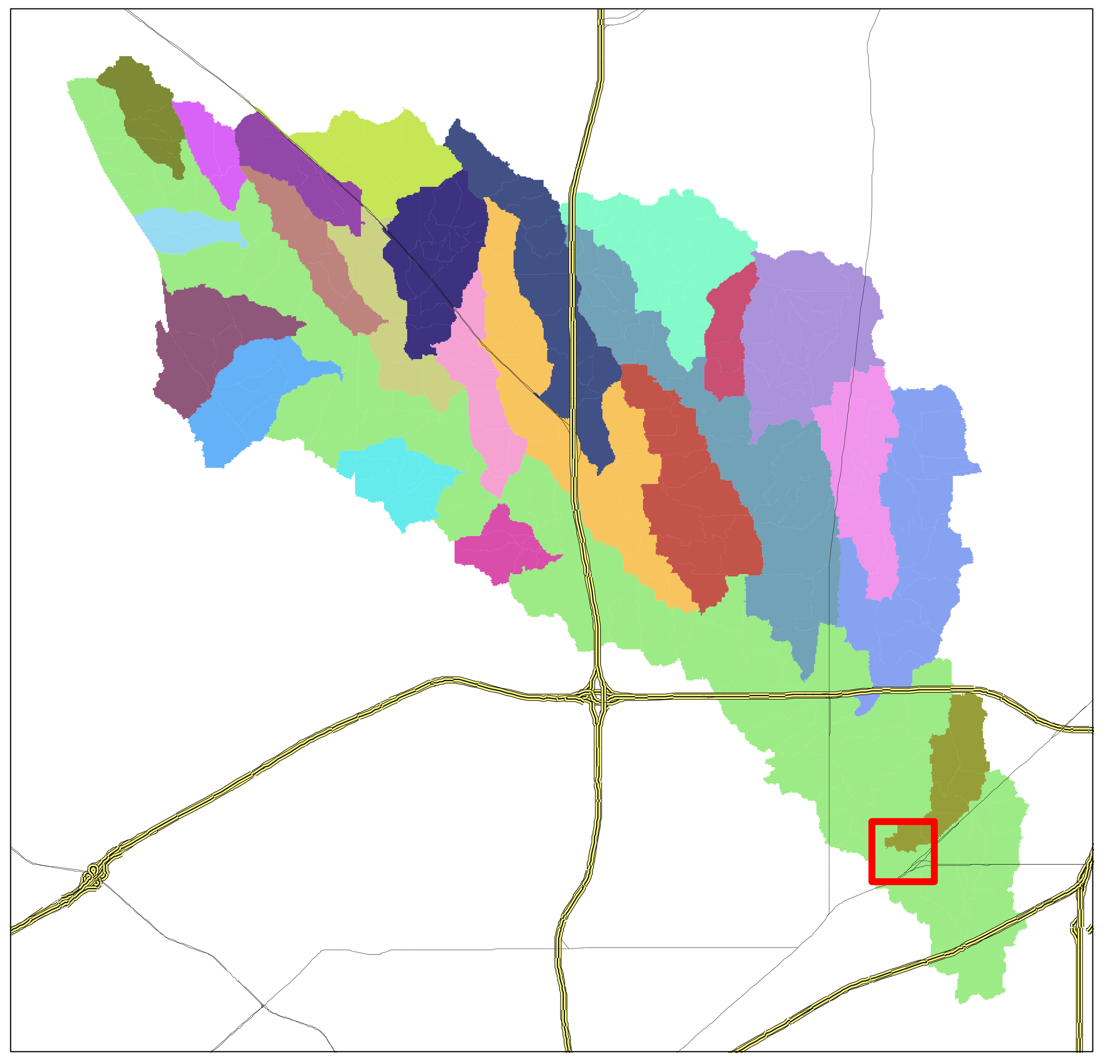
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Birdville ISD
Fig. 3.12



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-10

Improve Riparian Area

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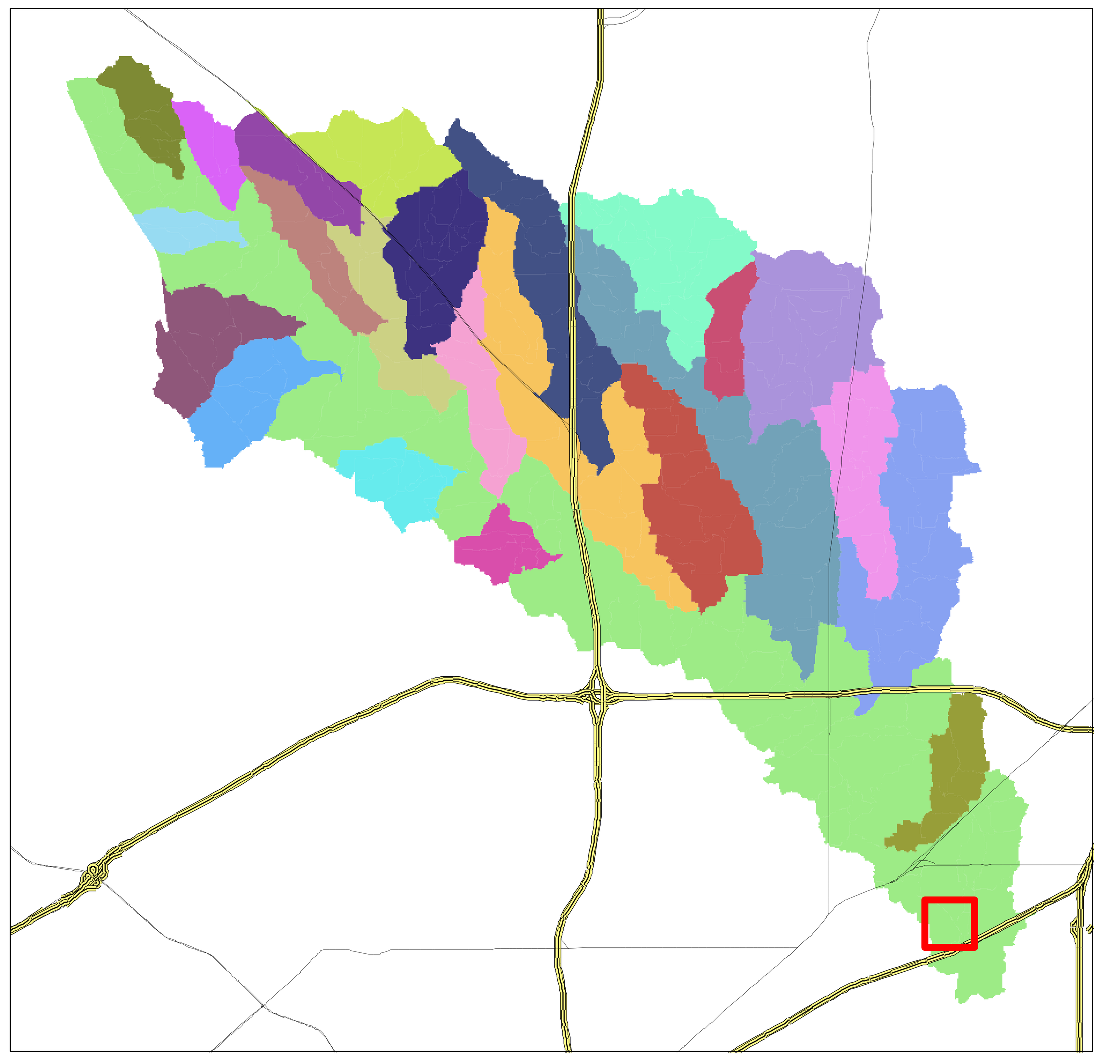
0 130 260 520 780 1,040
Feet

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
East Sump
Fig. 3.13



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-11
R-12

Improve emergent wetlands w/ riparian stringers

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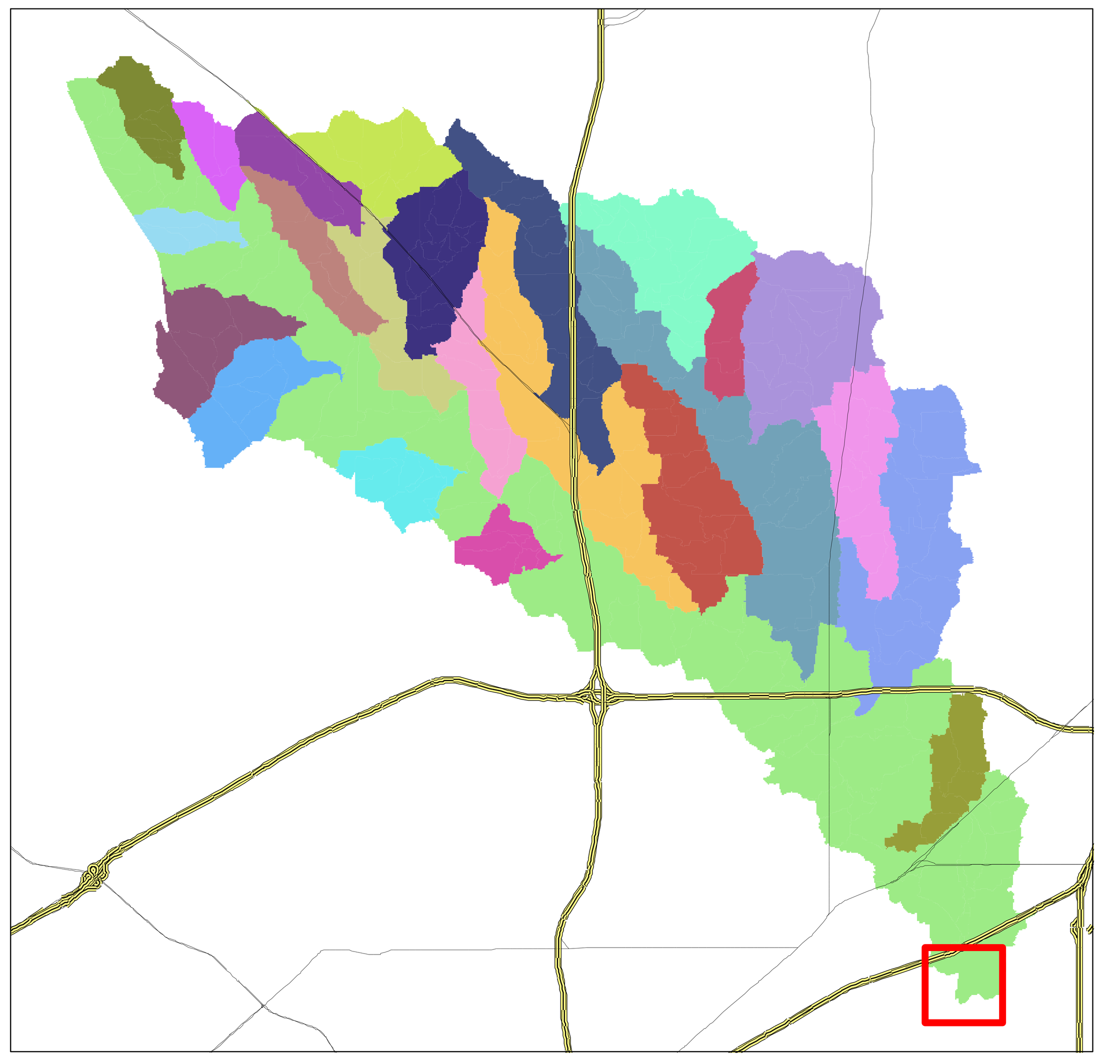
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
West Sump At SH121
Fig. 3.14



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-12

Improve riparian woodlands add recreational features

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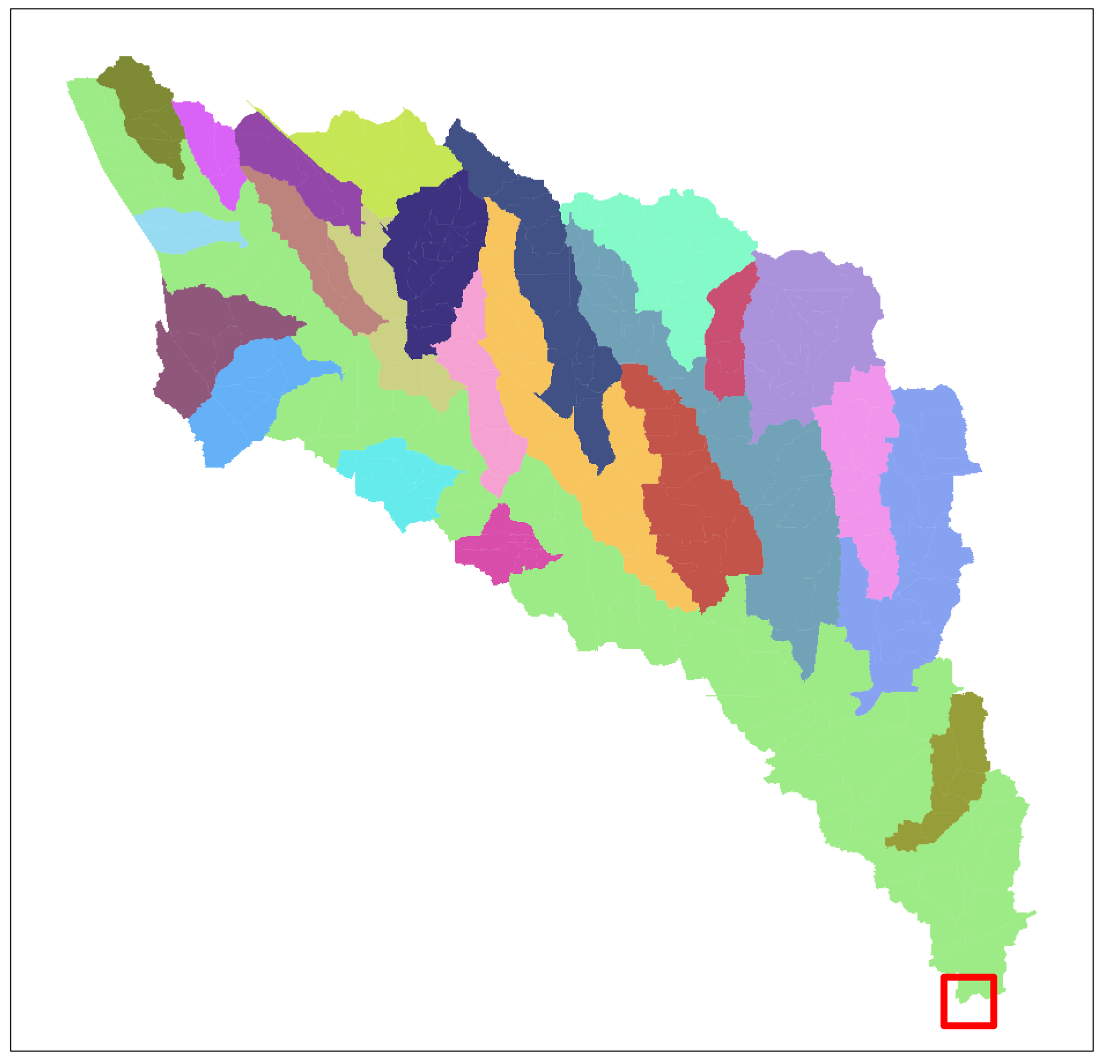
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
East Sump Below SH 121
Fig. 3.15



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

P-12

Improve emergent wetlands

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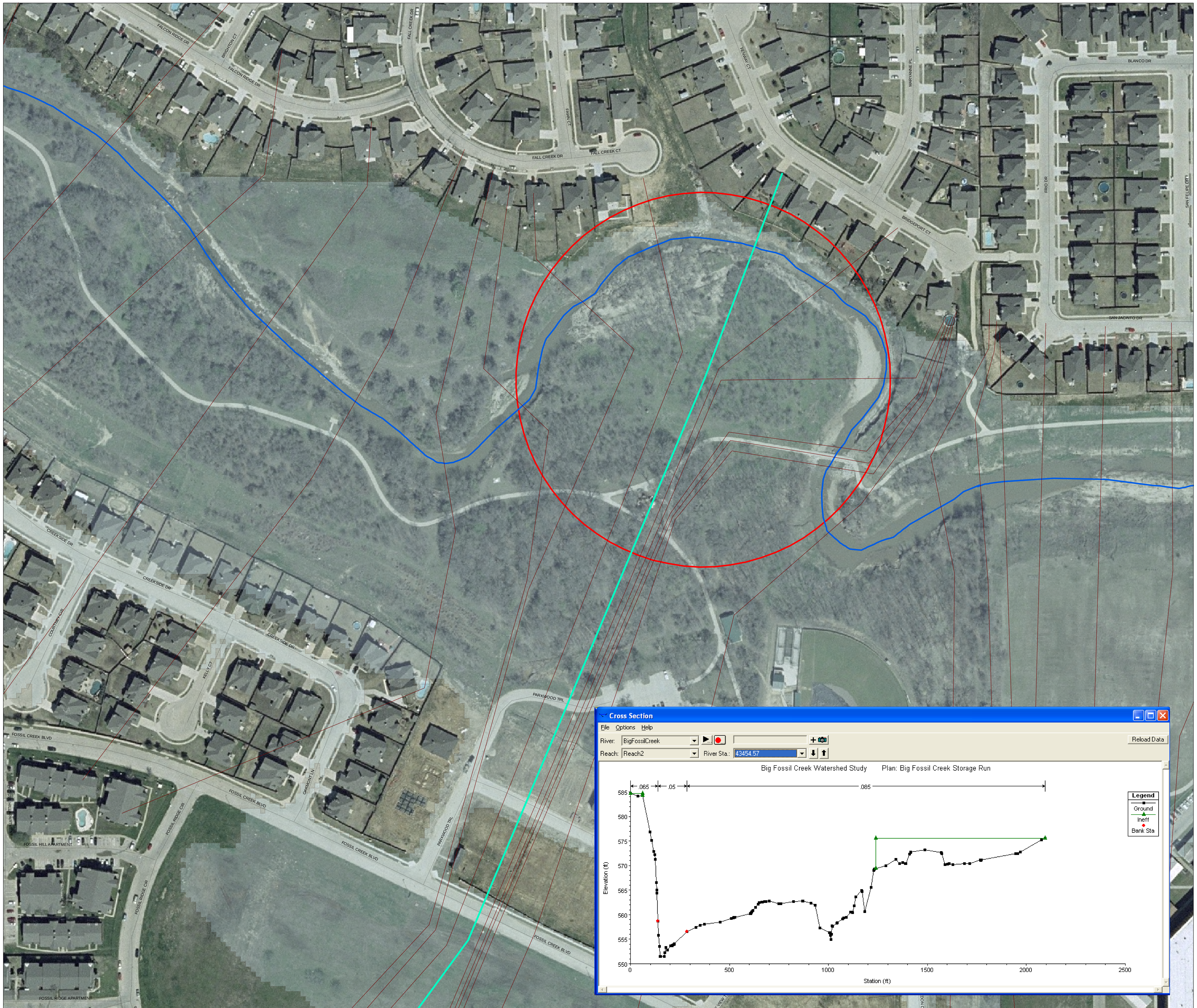
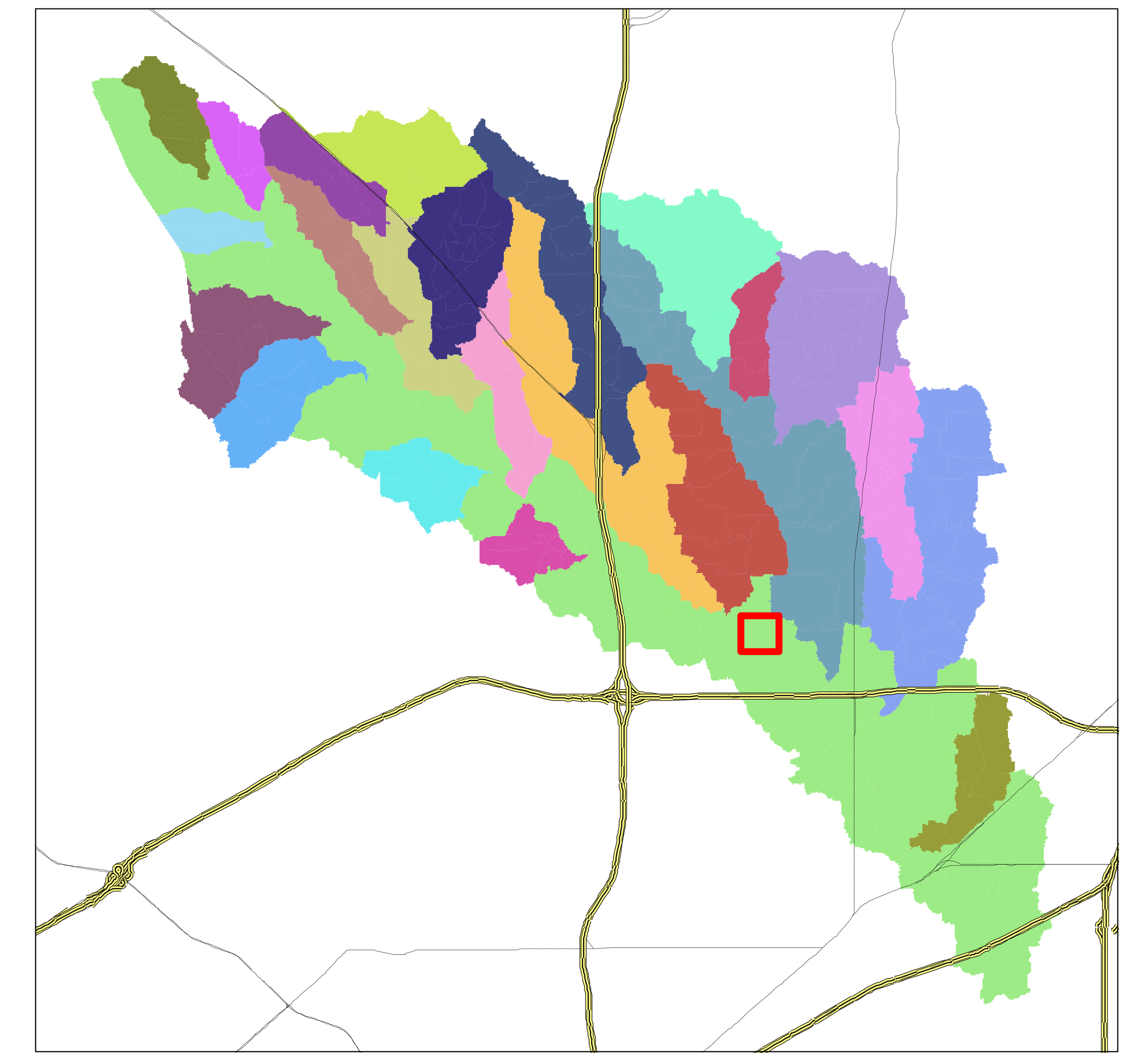
BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Fenway Court
Fig. 3.16





Legend

Cross Section Layouts

- Cross Sections
- Sample Section
- Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

S-1
P-6
R-10

Sloughing Areas Ecosystem Restoration

Sample Water Surface and Velocity

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Left (ft/s)	Vel Chnl (ft/s)	Vel Right (ft/s)	Top Width (ft)
BigFossilCreek	Reach2	43454.57	2-Year	3527	551.46	558.07		5.59	1.22	324.51
BigFossilCreek	Reach2	43454.57	10-Year	13746	551.46	562.61	1.53	6.98	2.23	890.34
BigFossilCreek	Reach2	43454.57	100-Year	27732	551.46	572.58	1.03	3.53	1.57	1684.15

0 87.5 175 350 525 700 Feet

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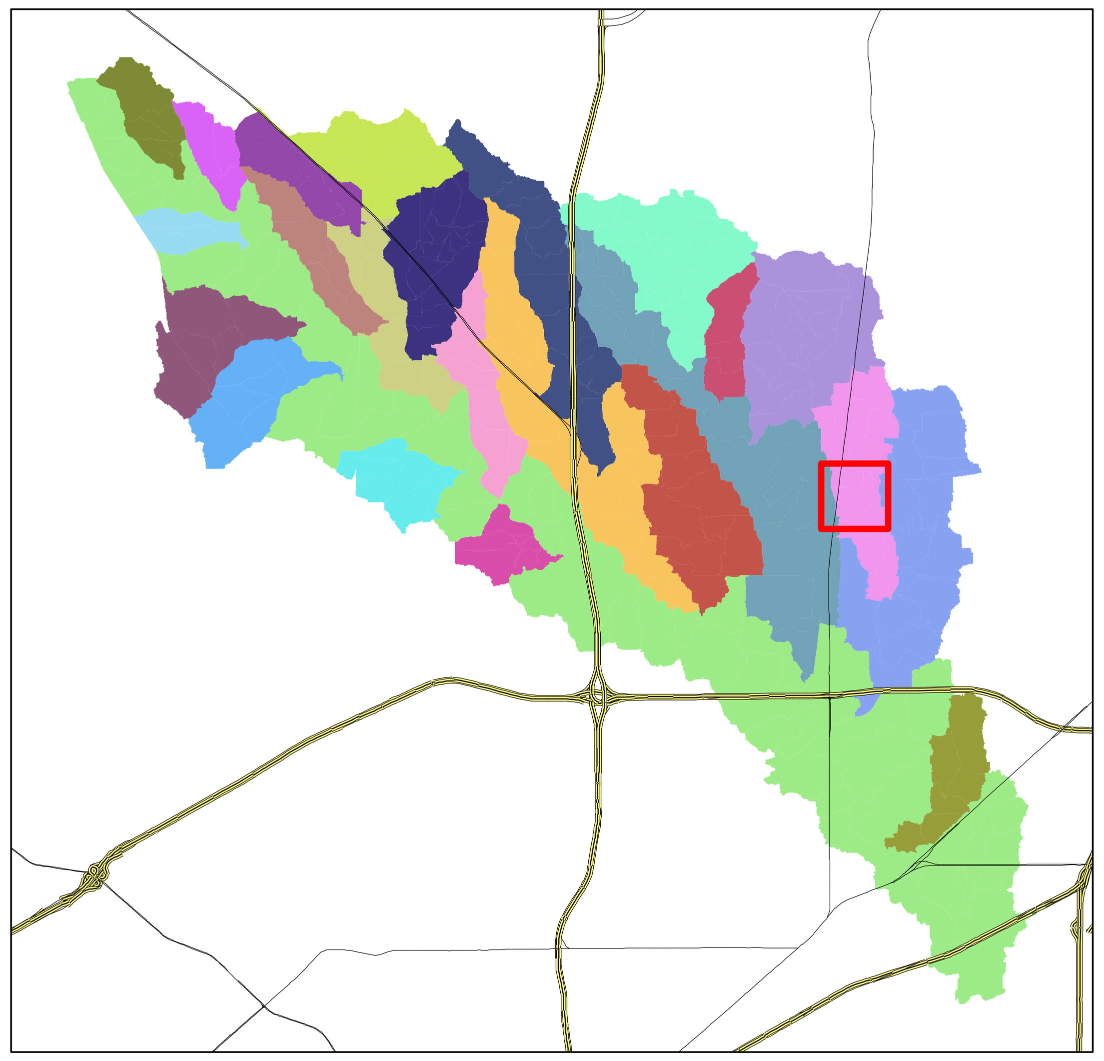
0 0.02 0.04 0.08 0.12 0.16
Miles

BIG FOSSIL CREEK WATERSHED

Big Fossil Creek
Bunker Creek
Fig. 3.17



Legend

Preliminary 100 Yy Flood Plain

Potential Projects or Areas of Concern:

F-5

Flash Flooding Area

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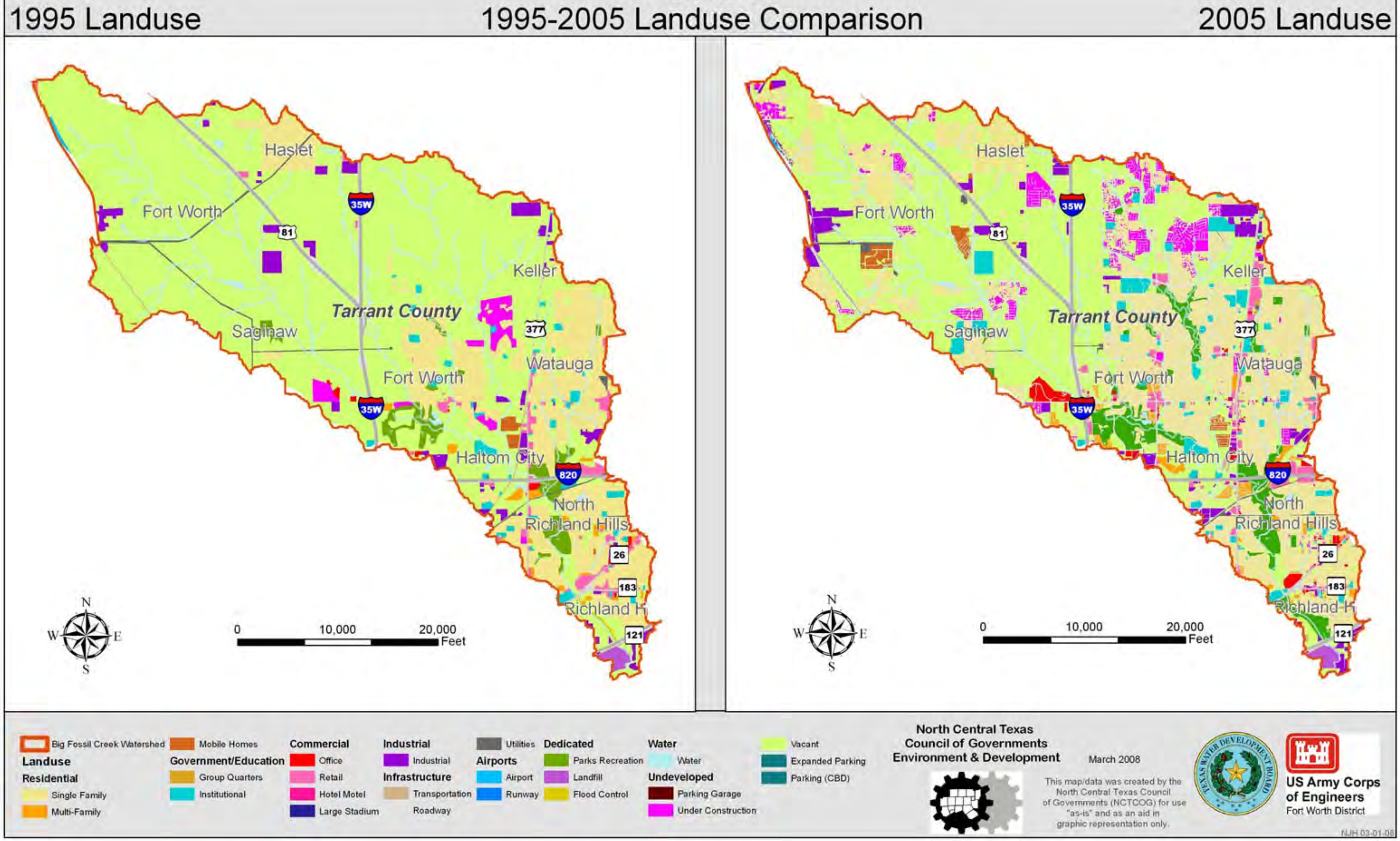
Fort Worth District

Big Fossil Creek Watershed

FIGURE 4

1995-2005 Landuse Comparison



HYDROLOGY AND HYDRAULICS EXISTING CONDITIONS

In order to adequately evaluate how this watershed functions and what occurs during storm events the existing conditions needed to be analyzed. The first step of this evaluation was to complete the hydrology, and hydraulics, followed by an economics analysis, environmental resources investigation and a cultural investigation. In May 2006 a thorough hydrologic and hydraulic analysis of the existing conditions, through 2005, was completed.

Engineering Methods

Hydrologic analysis computer models are mathematical representations, configured to reflect the rainfall-to-runoff physical processes within a given watershed. These tools are used to develop temporal relationships for flood-producing rainfall events, for typically a wide range of event probabilities in any given year. They provide the means to translate the amounts of source rainfall into amounts of excess runoff, by extracting the portion of rainfall which is lost to initial abstractions (surface storage, etc.) and infiltration over time. They subsequently provide the means of transforming the temporal pattern of the excess runoff into a temporal pattern of streamflow at selected analysis nodes within the overall watershed. This result is commonly known as the flood hydrograph. The peak of this flood hydrograph represents the peak discharge for the given storm runoff event and this value is typically used as input for the hydraulic analysis.

Typical input for the hydrologic analysis computer models includes depth-duration-frequency precipitation data, subbasin measurements (drainage area size, source flowpath length, source flowpath length-to-centroid, source flowpath slope, soil type characteristics, relative percentage of impervious cover and degree of urbanization, etc.), and flood hydrograph routing characteristics (valley storage versus discharge relationships in each routing reach).

Hydraulic analysis computer models are mathematical representations, configured to reflect the physical processes that control how deep the floodwaters will be for a given discharge, as described above. They are capable of determining a water surface elevation profile reflecting the cumulative resistance of flow passage, considering energy head losses associated with flowing friction and flow area contraction and expansion head losses. They are most often referred to as backwater models, reflecting their step-by-step computational scheme, from one valley cross section to the next, beginning at the downstream limit of the modeled reach.

Typical input for the hydraulic analysis computer models includes the aforementioned hydrologic analysis results (i.e. peak discharges at given nodes), 2-dimensional representations of the valley cross sections (all arranged perpendicular to the flow), flowing reach lengths between the valley sections (including separate figures for each overbank and the main channel), contraction and expansion head loss coefficients, and what are known as Manning's roughness coefficients. The valley cross sections are typically derived through some combination of field surveying and topographic mapping extraction. The headloss and roughness coefficients are typically estimated, based on engineering judgment, considering the physical conditions of the study area.

For purposes of this study, the standard suite of modeling software developed by the USACE Hydrologic Engineering Center (HEC) was applied. This included HEC-geoHMS, HEC-HMS, HEC-geoRAS, and HEC-RAS. HMS stands for Hydrologic Modeling System and RAS stands for River Analysis System. Subsequent to the hydrologic and hydraulic analyses, the USACE HEC-FDA (Flood Damage Analysis) software was used to assess both the single-event and expected annual flood (inundation) damages to be expected for the given flooding depths along each study reach. Input data for this tool is extracted from the results of the backwater modeling. It is comprised primarily of relationships between "discharge and probability" and "stage and discharge". This tool applies a Monte Carlo statistical analysis technique to develop expected annual damages, considering the relative likelihood of potential discharges and stages from year to year, over a vast prediction period.

For all flooding sources studied in detail within the watershed, standard hydrologic and hydraulic study methods were used to determine water surface elevations along the water course and flood extents in those areas where flow exceeds channel capacity. Existing conditions discharges were developed to define current flood plain conditions and support the future analysis of alternatives. Peak discharges for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year events were computed. The recurrence interval designation is meant to reflect those flood events of a magnitude that are expected to be equaled or exceeded once on the average during each stated time period.

Digital mapping was provided that included mass points, contours and a basin-wide digital terrain model with break lines. This data was used as the basis for both the hydrologic and hydraulic model development for existing conditions.

The analysis completed as part of existing conditions reflects flooding potentials based on conditions existing in the community in 2005. As the next phase is implemented, existing conditions will be updated to incorporate any significant changes since 2005 and future conditions through 2050 will be analyzed.

During the subsequent phase of study, additional detail will be provided regarding the performance characteristics of the Big Fossil Creek Floodway, Levee, and Sump system in Richland Hills. For purposes of the initial existing conditions analyses, the focus of the current study was placed on the overall watershed and potential impacts of the rapid development taking place in the upper portions of the watershed. It should be noted that the outflows from the Big Fossil Creek Sump, during either gravity-driven releases (when stages on Big Fossil Creek are low) or during pumping (when stages on Big Fossil Creek are high), are relatively insignificant in relation to the magnitude of flood discharges along Big Fossil Creek itself.

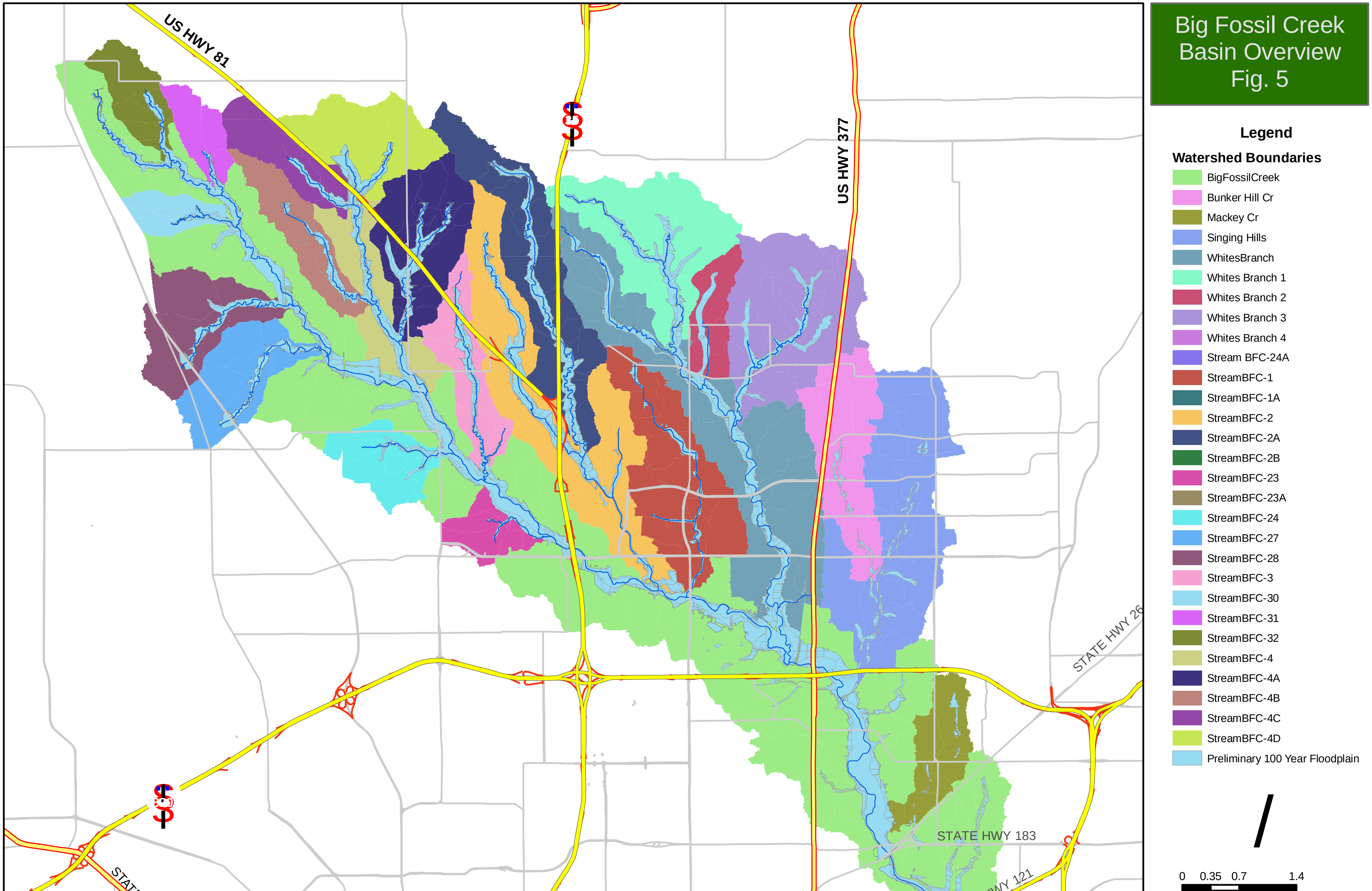
Hydrologic Analysis

Hydrologic analyses were carried out to establish the peak discharge-frequency and peak elevation-frequency relationships for each flooding source studied in detail. The standard USACE software suite, including HEC-geoHMS and HEC-HMS, was used to develop drainage basins and determine the physical hydrologic parameters required for modeling. These parameters include drainage area, stream length, stream length from the outlet to the centroid of the sub-basin, slope, percent impervious, percent of urbanization, time to peak, basin lag time, initial loss, and infiltration rates, which is related to the imperviousness of the surface. These parameters were determined for each sub-basin. Urbanization is the percentage of a subbasin that has been developed and improved with channelization and/or a storm collection network and its value affects the timing of the hydrograph peak. Imperviousness is the percentage of a subbasin that is covered with impervious material and is hydraulically connected to the drainage network. It affects the volume of rainfall lost through interception and infiltration.

Calculations and engineering judgment were used to determine the parameters discussed above for Big Fossil Creek and all significant tributaries except Little Fossil Creek, which is not part of this study effort. The Big Fossil Creek watershed was divided into approximately 208 subareas, and synthetic unit flood hydrographs were developed at appropriate locations to define existing conditions and support future alternatives analysis. See ***Figure 5*** for an overview of the subareas showing how the watershed is divided and color-coded for identification.

Final results were compared to the effective FEMA discharges. The effective FEMA discharges are a mixture of several different studies performed over different time periods, each done with somewhat different methodology, leading to variations in the results. Refer to **Appendix A** for information on (1) Comparison between the Current Study Discharges and the Effective FEMA Discharges, (2) Summary of Discharge Tables, (3) List of Streams Studied, (4) RAS Output Table, (5) Profile Plots and (6) Table of Profile Comparisons.

Big Fossil Creek Basin Overview Fig. 5



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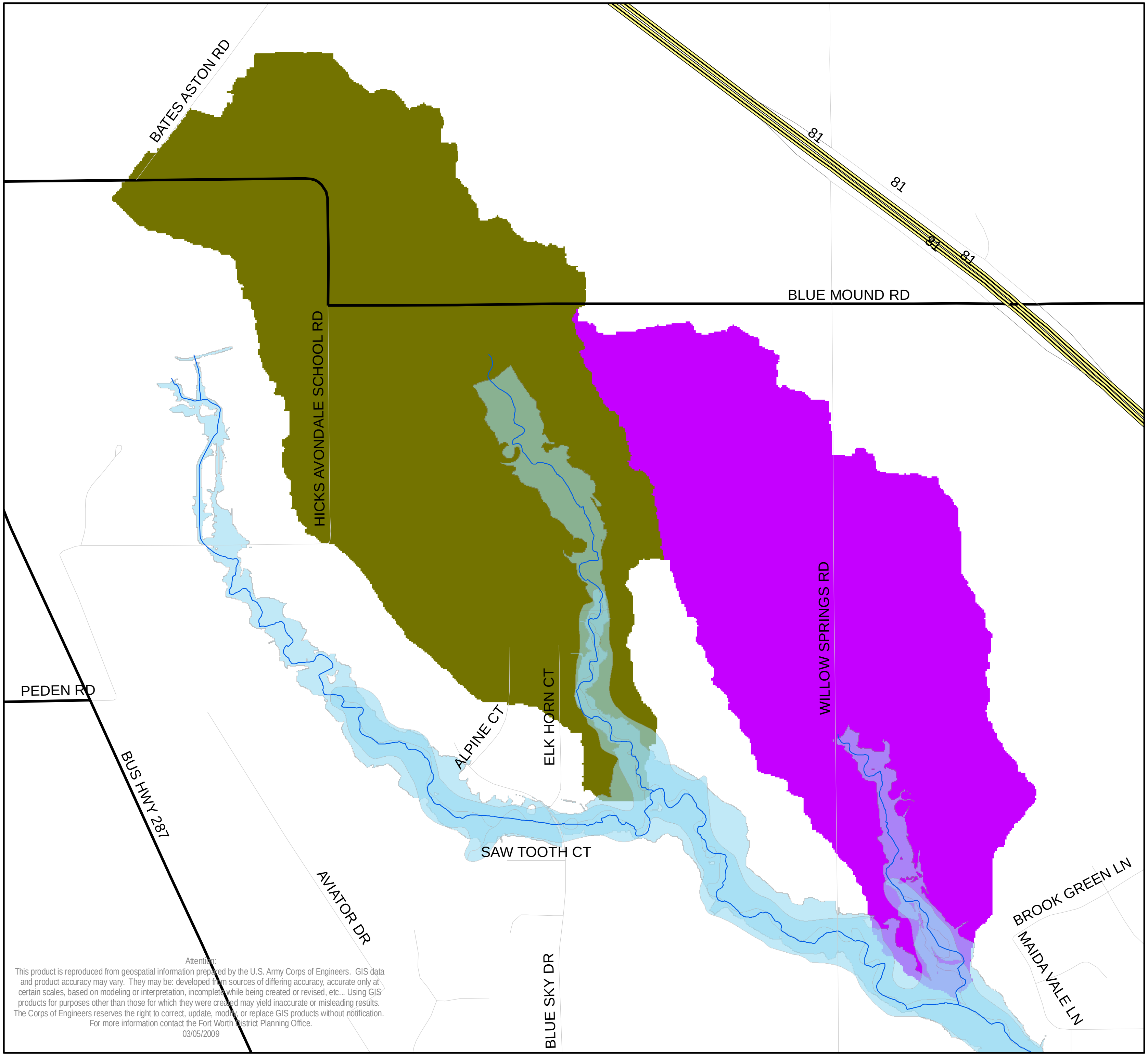
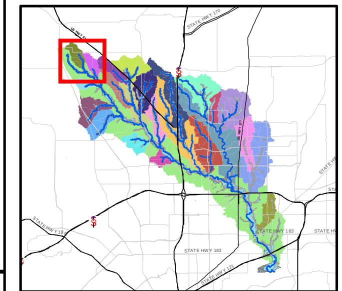
Map Document Location:
\\swf-fs1fbgis\projects\cvljobs\Big_Fossil\20090305_Fig_5_Overview.mxd
Project Manager: Rob Newman
Section: CESWF-PER

Big Fossil Creek Watershed Tributary 31 and 32 Fig. 5-1





Legend

- Big Fossil Creek
- Tributary 31
- Tributary 32
- Preliminary 100 Year Floodplain

0 0.125 0.25
Miles

US Army Corps of Engineers
Fort Worth District

Date: March 5, 2009
Map Document Location:
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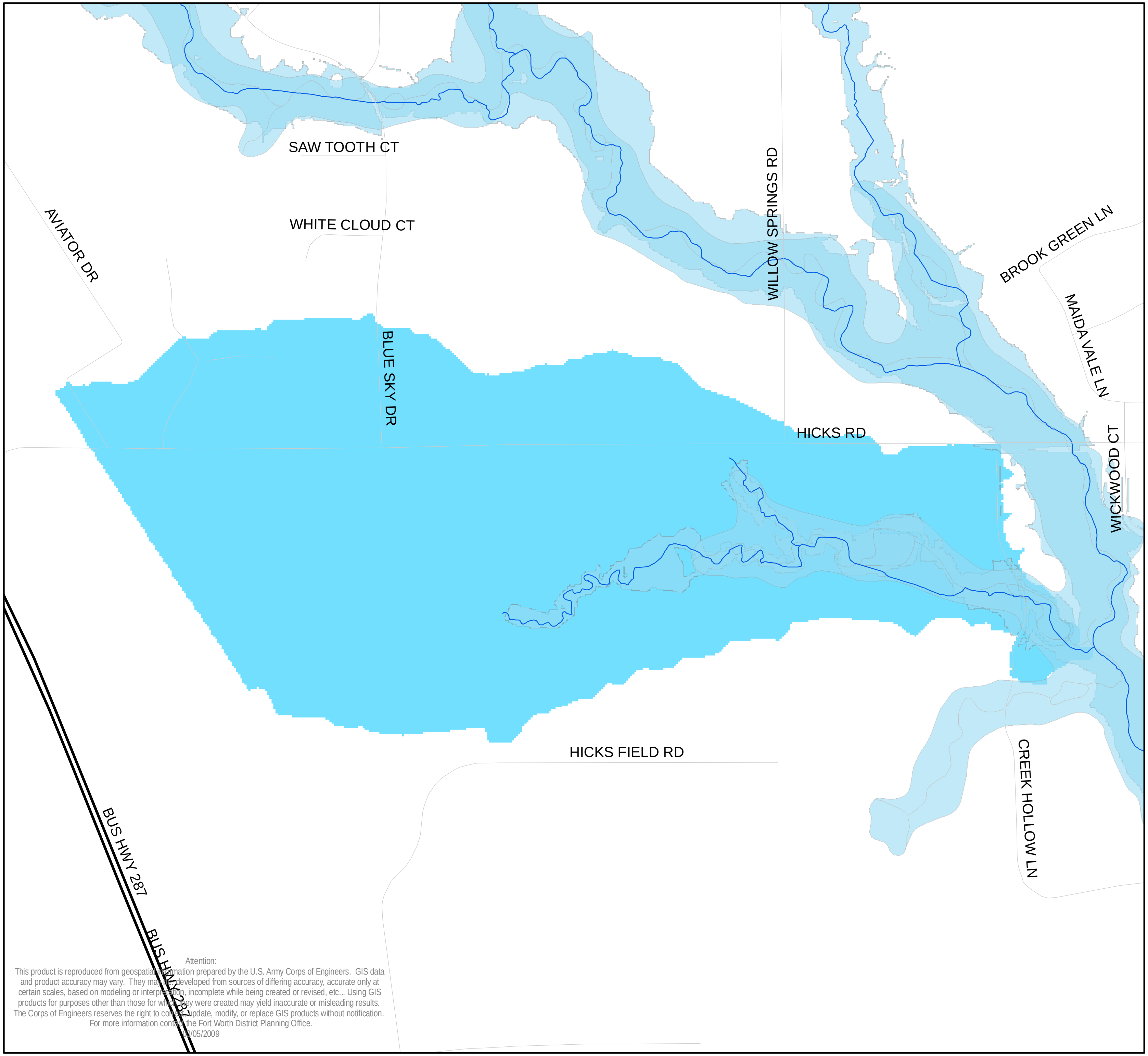
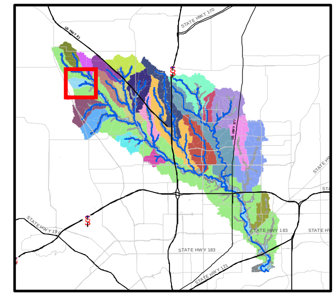
Project Manager: Rob Newman
Section: CESWF-PER

Big Fossil Creek Watershed
Tributary 30 and 30A
Fig. 5-2





Legend

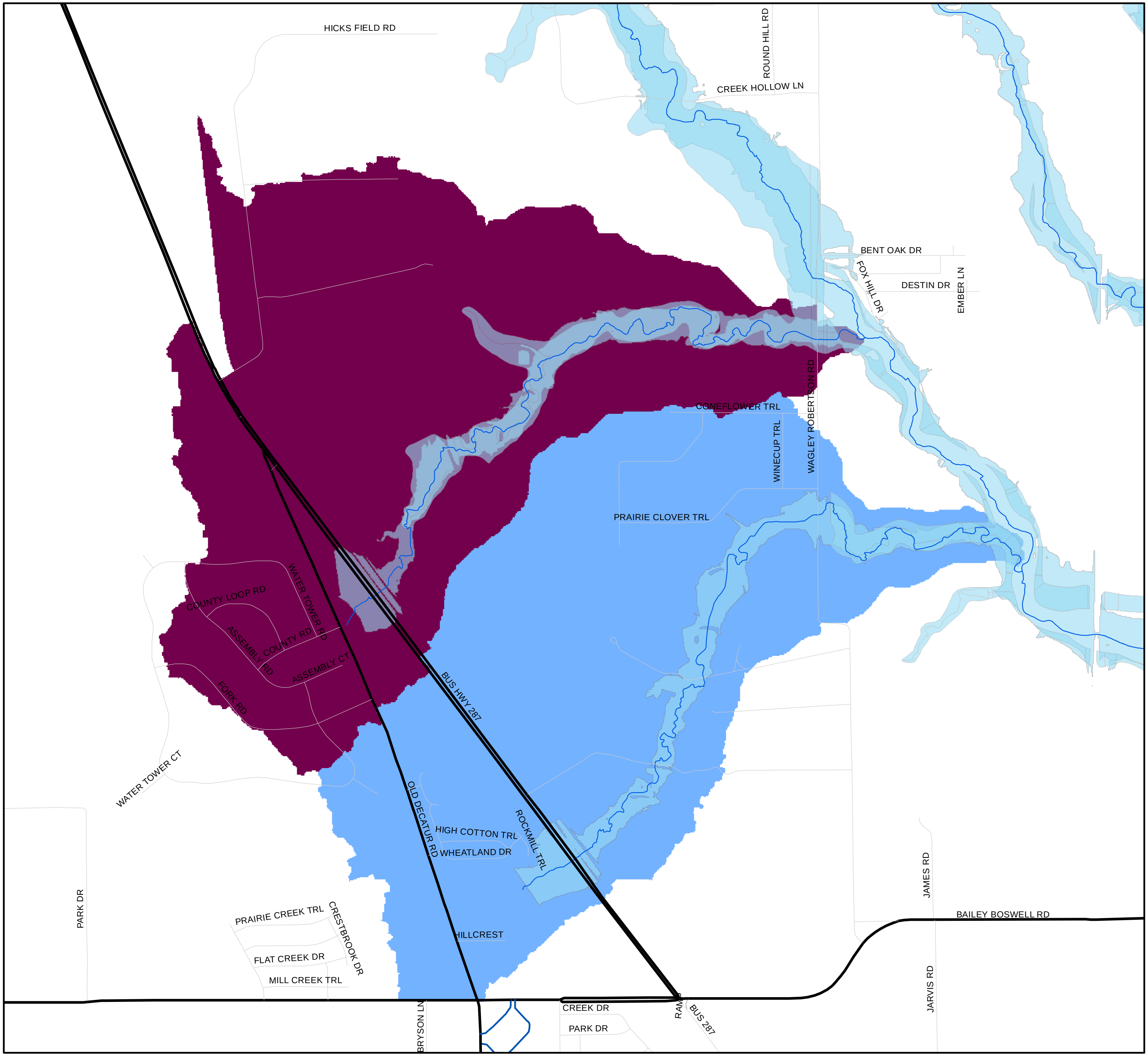
- Big Fossil Creek
- Tributary 30 and 30A
- Preliminary 100 Year Floodplain

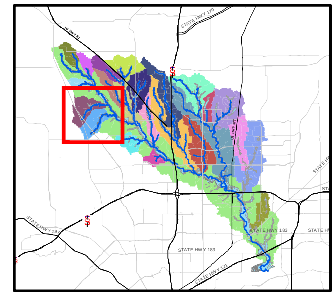
0 0.125 0.25
Miles

US Army Corps
of Engineers
Fort Worth District

Date: March 5, 2009
Map Document Location:
\\swf-fs1fbgis\projects\cvljobs\Big_Fossil\20090305_Fig_5-2.mxd
Project Manager: Rob Newman
Section: CESWF-PER

Big Fossil Creek Watershed Tributary 27 and 28 Fig. 5-3





Legend

- Big Fossil Creek
- Tributary 27
- Tributary 28
- Preliminary 100 Year Floodplain

0 0.125 0.25 0.5
Miles

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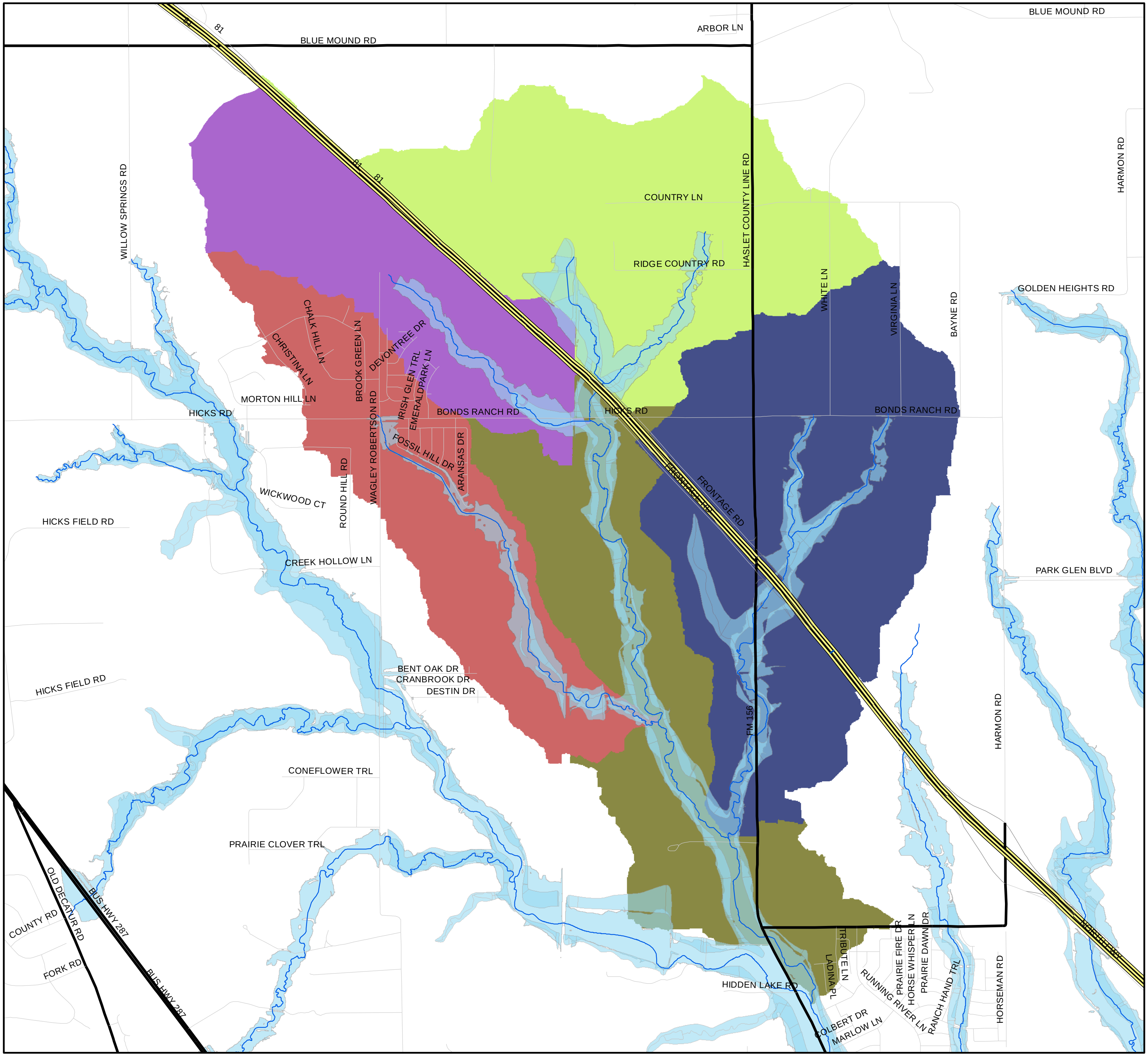
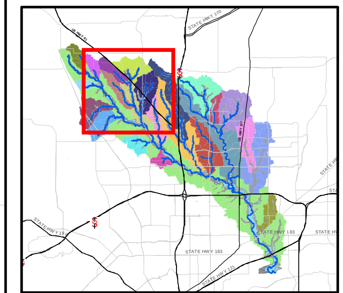
Section: CESWF-PER

Big Fossil Creek Watershed Tributary 4 Fig. 5-4





Legend

- Big Fossil Creek
- Tributary 4
- Tributary 4A
- Tributary 4B
- Tributary 4C
- Tributary 4D
- Preliminary 100 Year Floodplain

0 0.25 0.5
Miles

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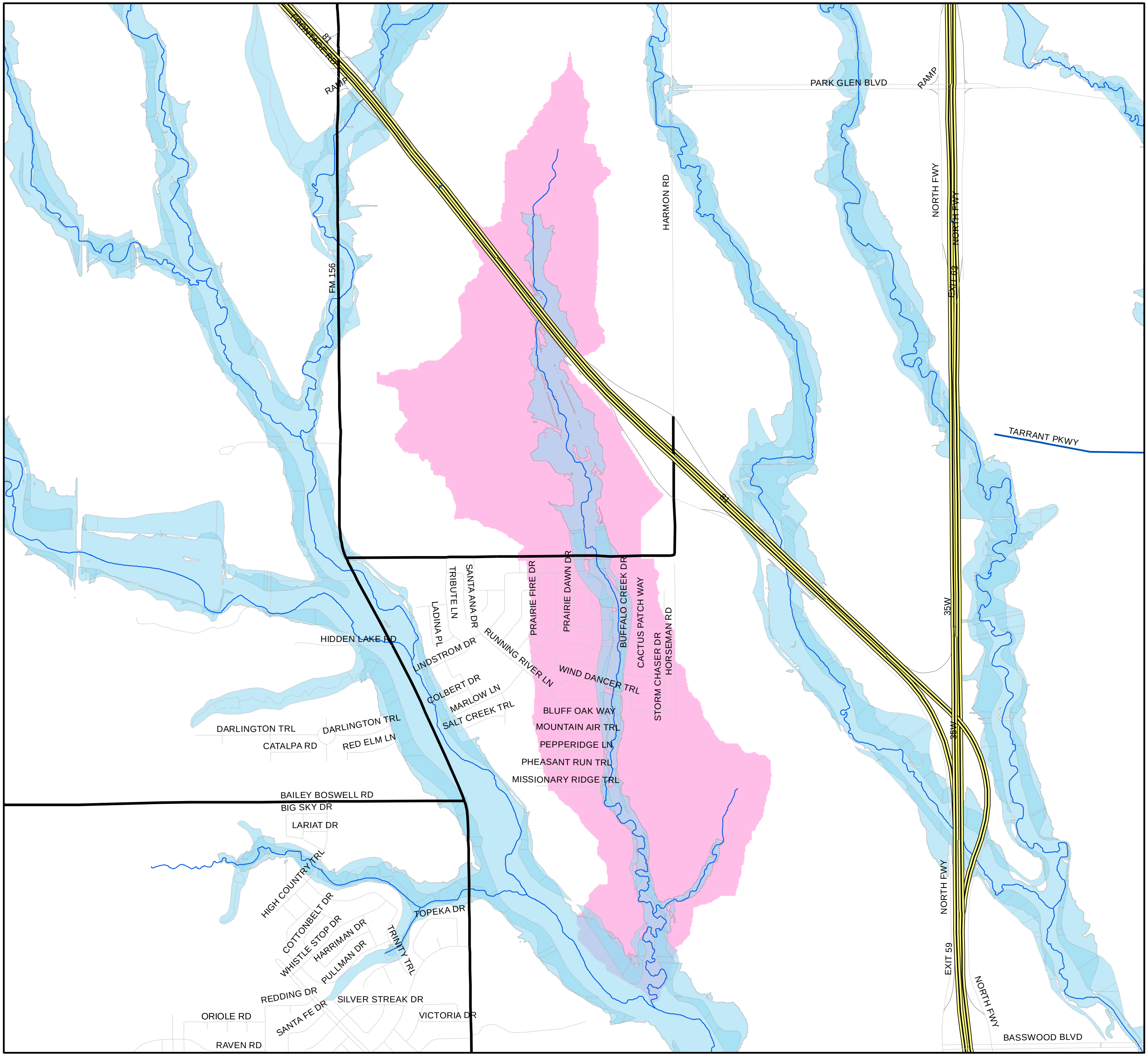
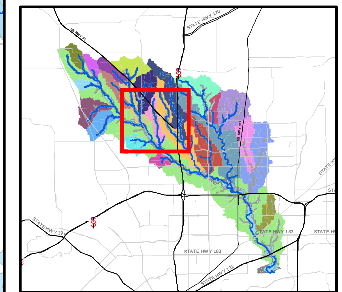
Project Manager: Rob Newman
Section: CESWF-PER

Big Fossil Creek Watershed Tributary 3 Fig. 5-5





Legend

- Big Fossil Creek
- Tributary 3
- Preliminary 100 Year Floodplain

0 0.25 0.5
Miles

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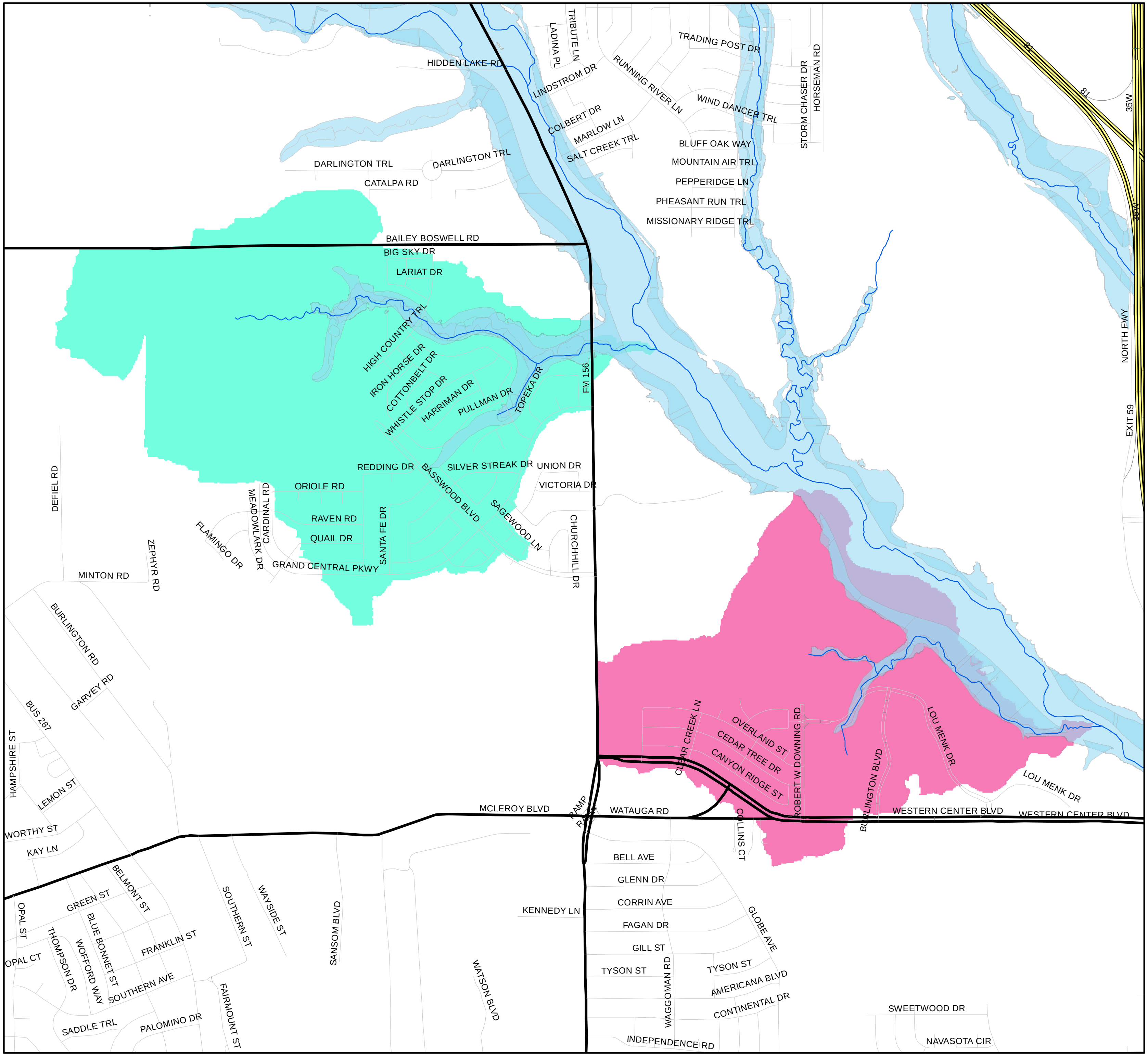
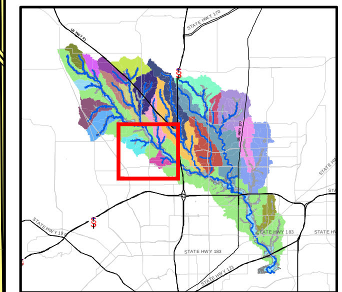
Project Manager: Rob Newman
Section: CESWF-PER



Big Fossil Creek Watershed Tributary 23 and 24 Fig. 5-6



Legend

- Big Fossil Creek
- StreamBFC-23
- StreamBFC-24
- Preliminary 100 Year Floodplain

0 0.25 0.5
Miles

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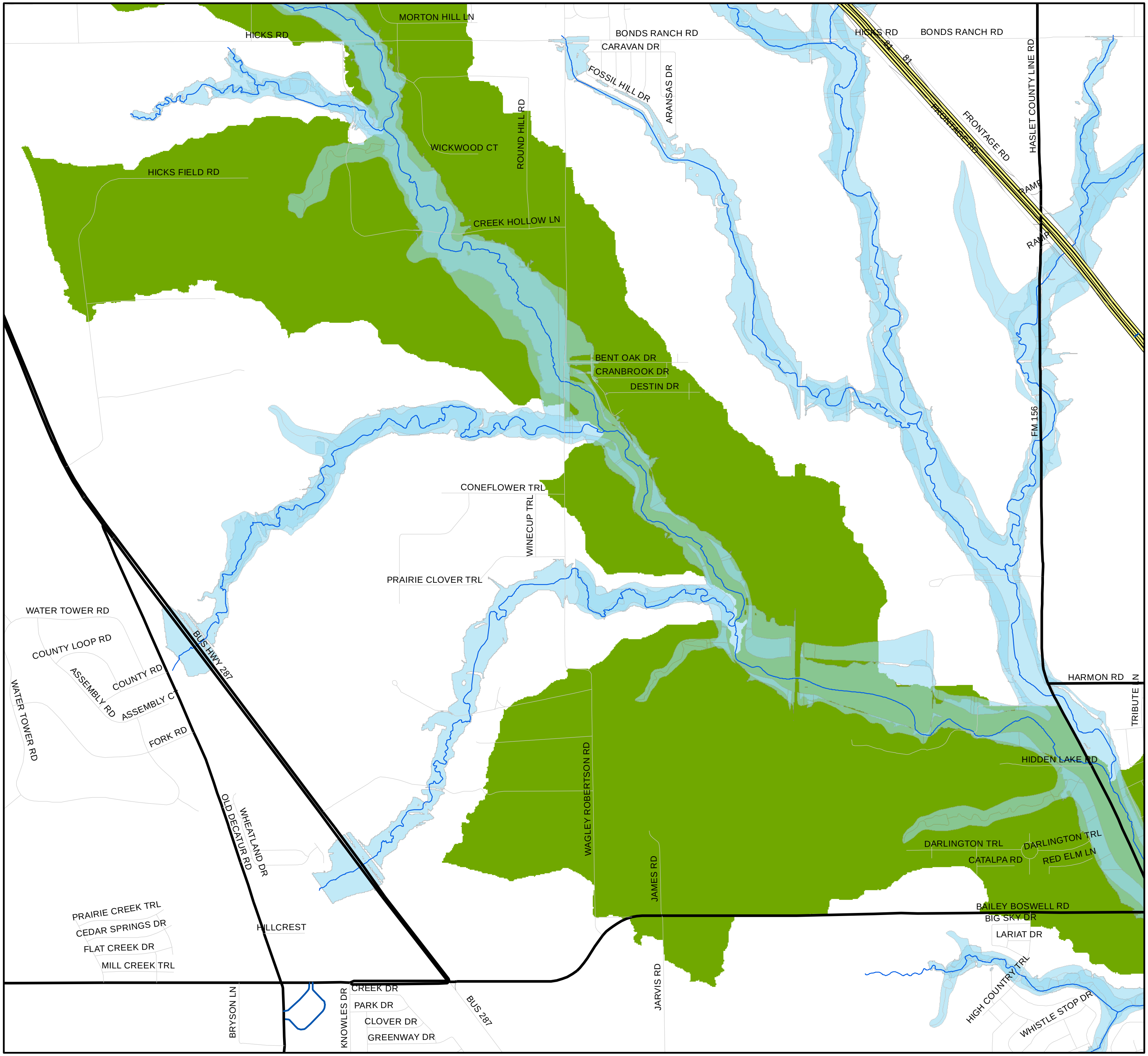
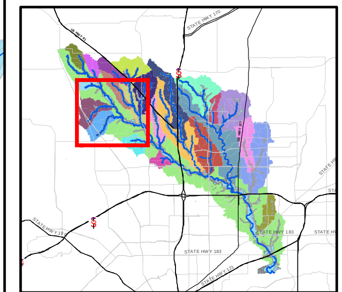
Section: CESWF-PER

Big Fossil Creek Watershed Main Stem Fig. 5-7





Legend

- Big Fossil Creek
- Main Stem
- Preliminary 100 Year Floodplain

0 0.25 0.5
Miles

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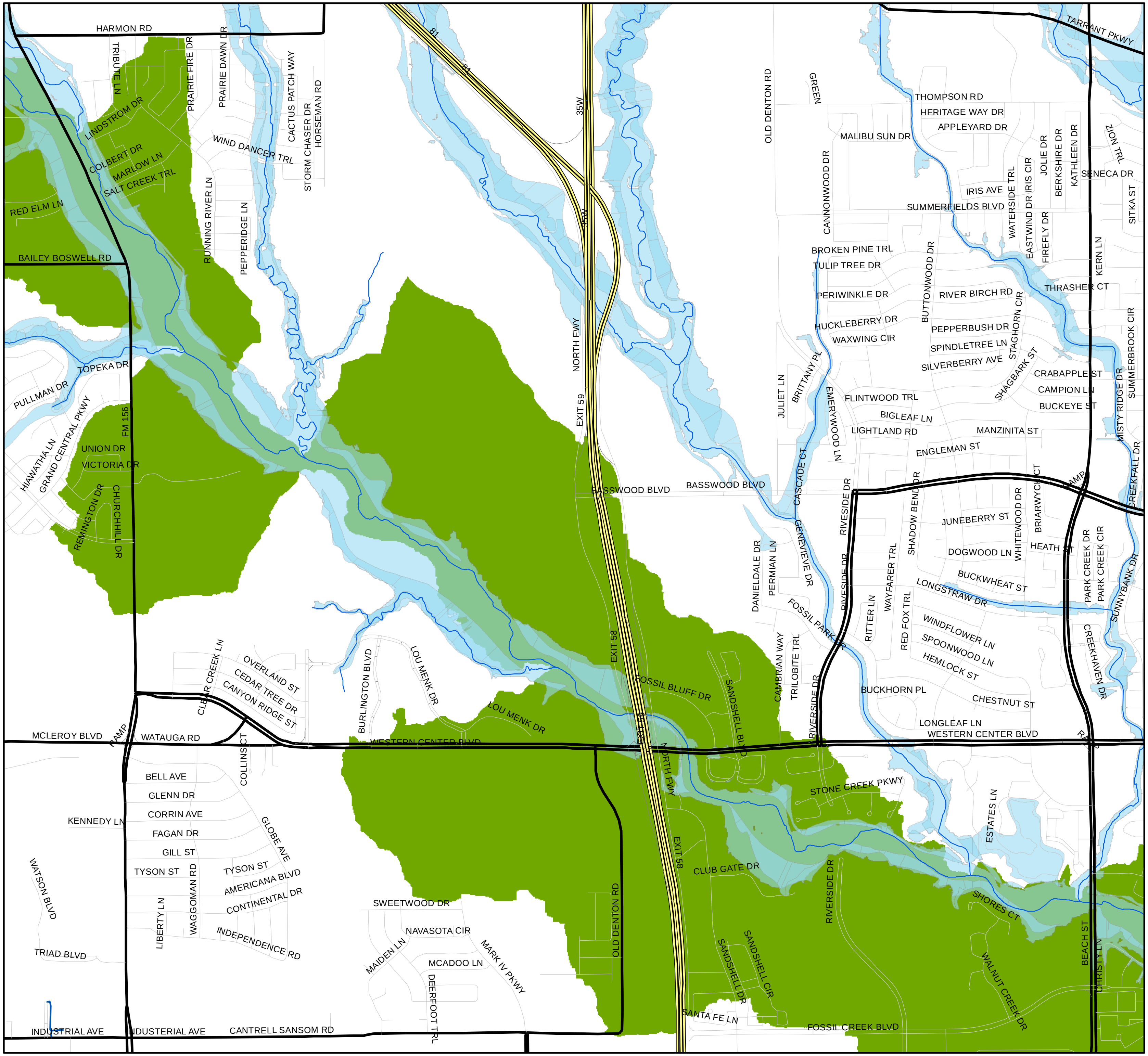

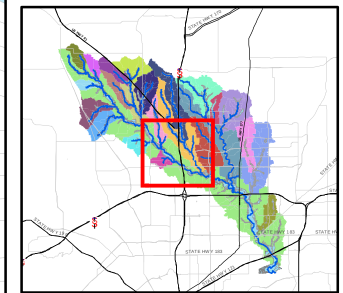

Big Fossil Creek Watershed Main Stem Fig. 5-8

Legend

- Big Fossil Creek
- Main Stem
- Preliminary 100 Year Floodplain

0 0.25 0.5
Miles

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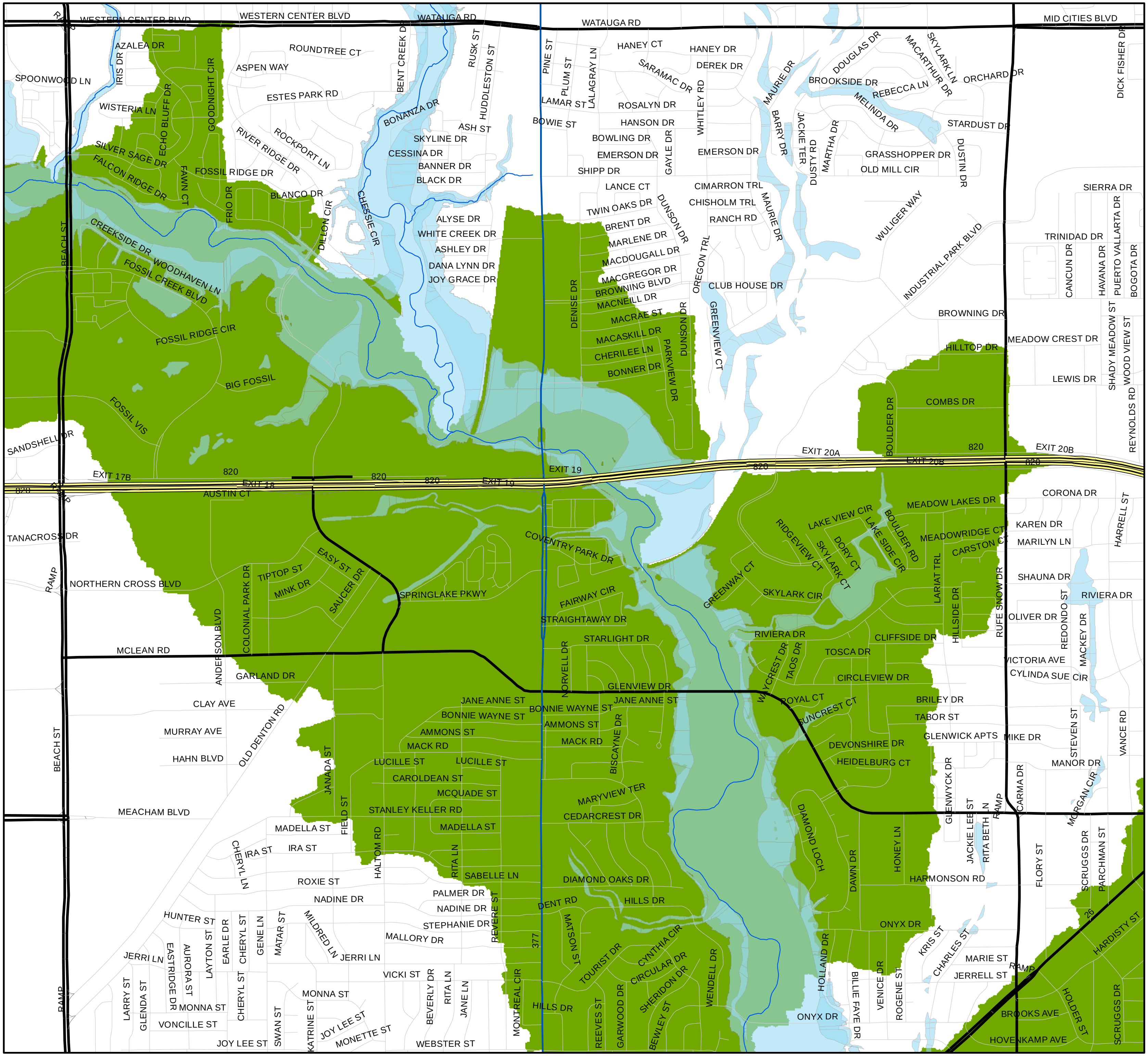
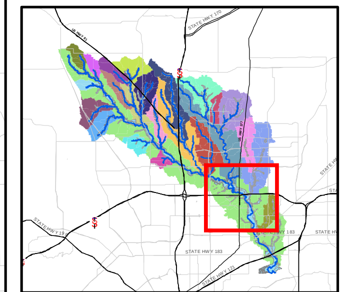
Big Fossil Creek Watershed Main Stem Fig. 5-9





Legend

- Big Fossil Creek
- Main Stem
- Preliminary 100 Year Floodplain

0 0.25 0.5
Miles

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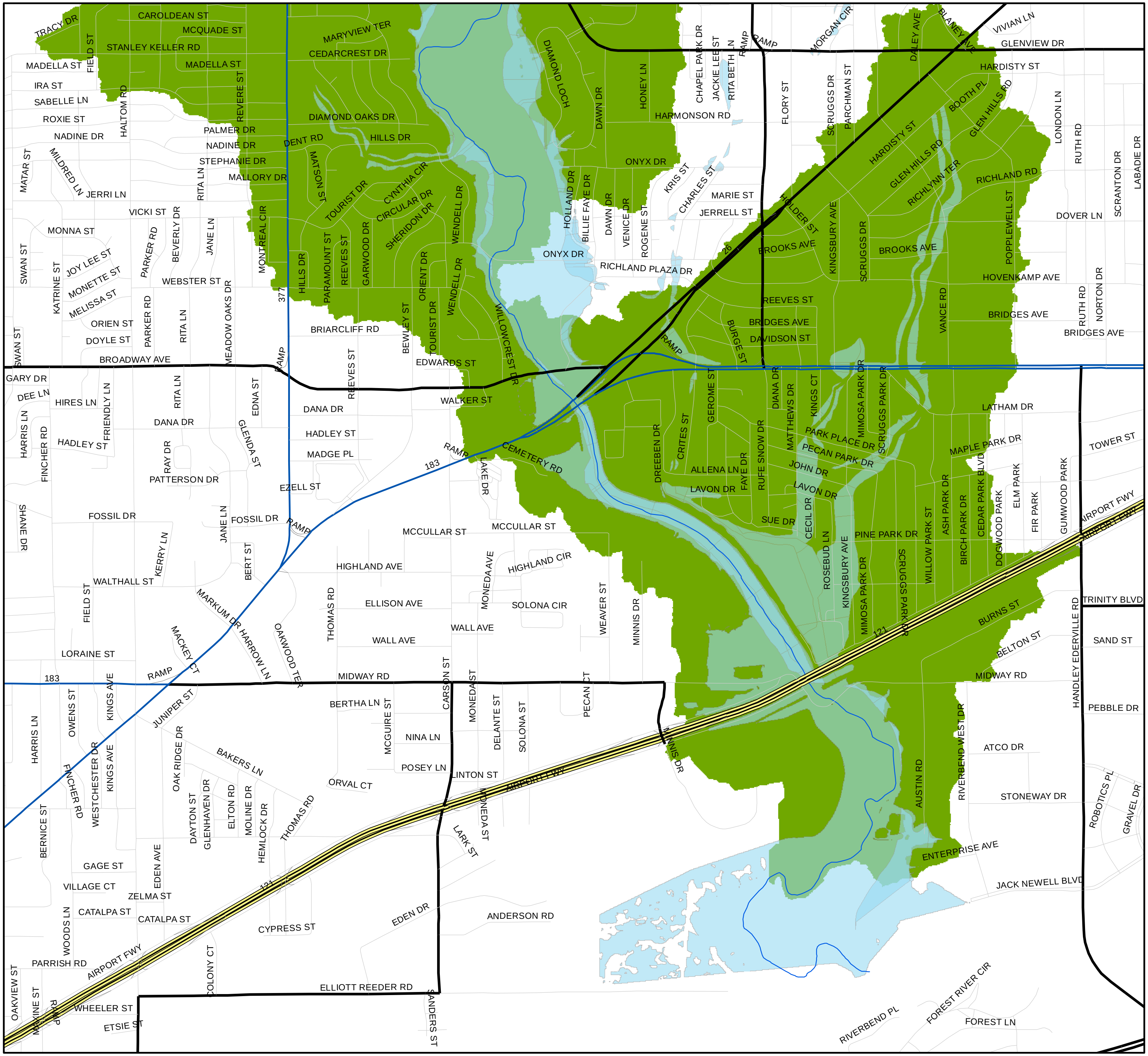
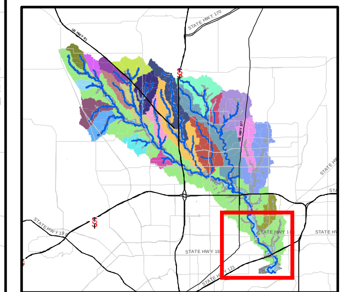
Big Fossil Creek Watershed Main Stem Fig. 5-10





Legend

- Big Fossil Creek
- Main Stem
- Preliminary 100 Year Floodplain

0 0.25 0.5

Miles

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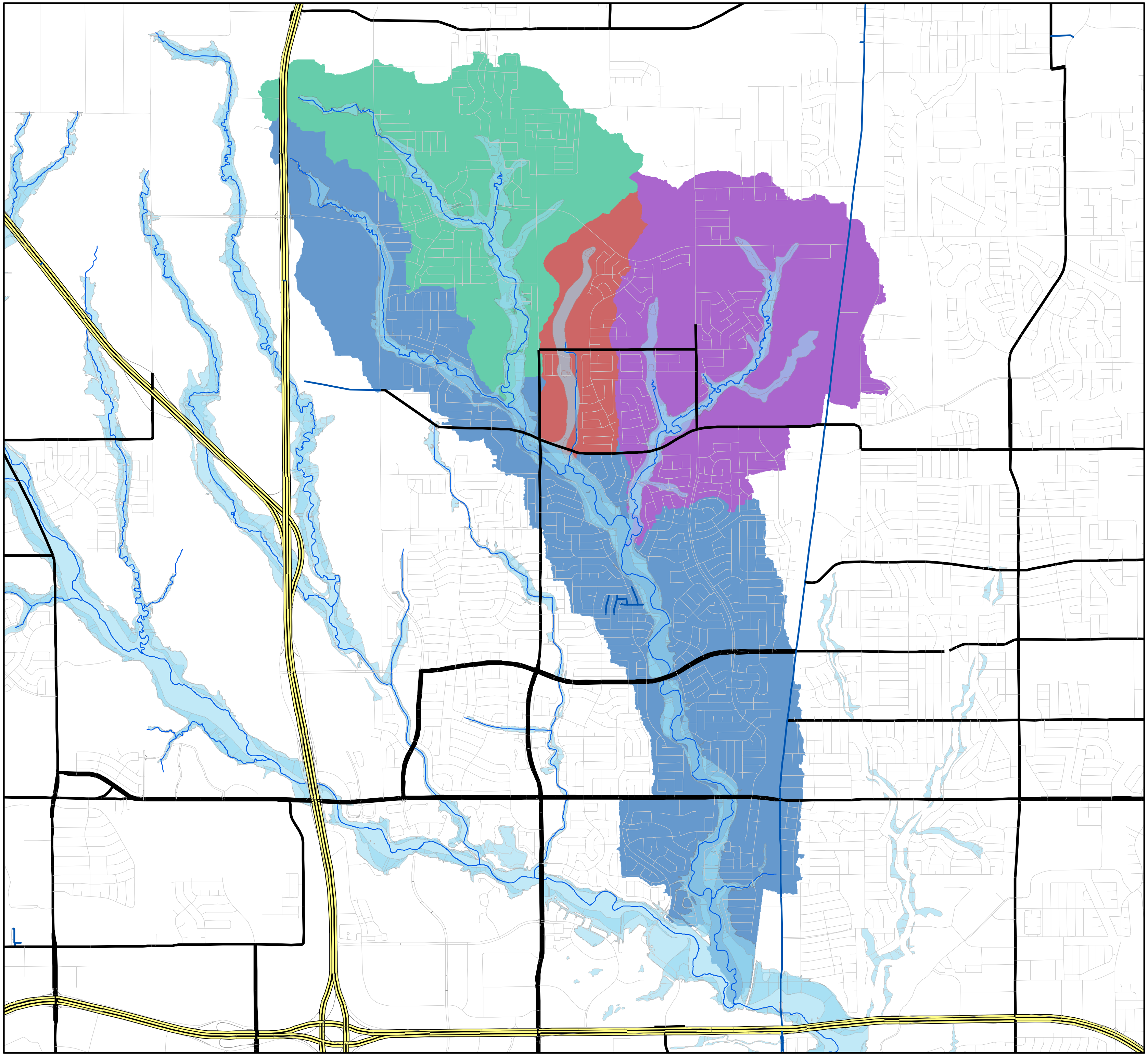
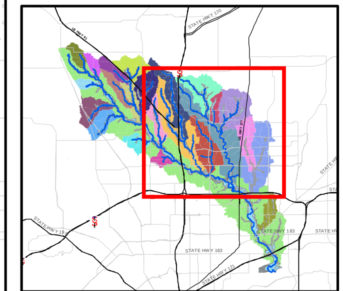
Big Fossil Creek Watershed White's Branch Fig. 5-11





Legend

- Big Fossil Creek
- White's Branch Tributary 1
- White's Branch Tributary 2
- White's Branch Tributary 4
- White's Branch
- Preliminary 100 Year Floodplain

0 0.25 0.5 1
Miles

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Date: March 5, 2009
Map Document Location:
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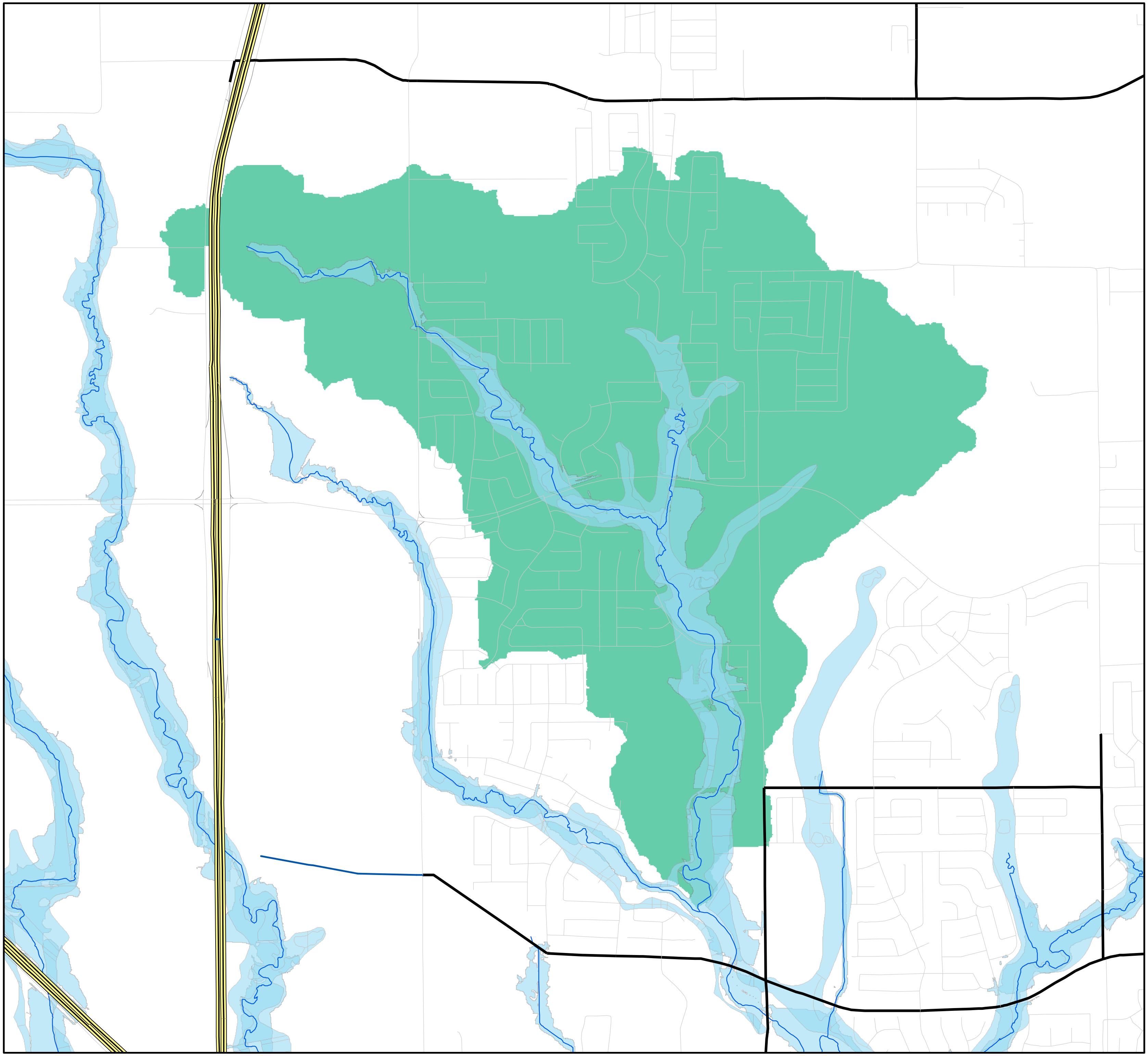
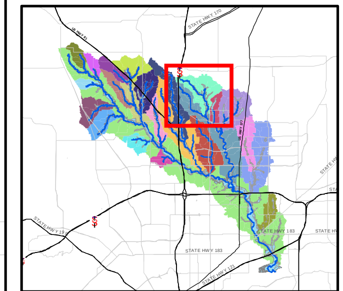


Big Fossil Creek Watershed
White's Branch Tributary 1
Fig. 5-12



Legend

- Big Fossil Creek
- White's Branch Tributary 1
- Preliminary 100 Year Floodplain

0 0.25 0.5

Miles

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Map Document Location:
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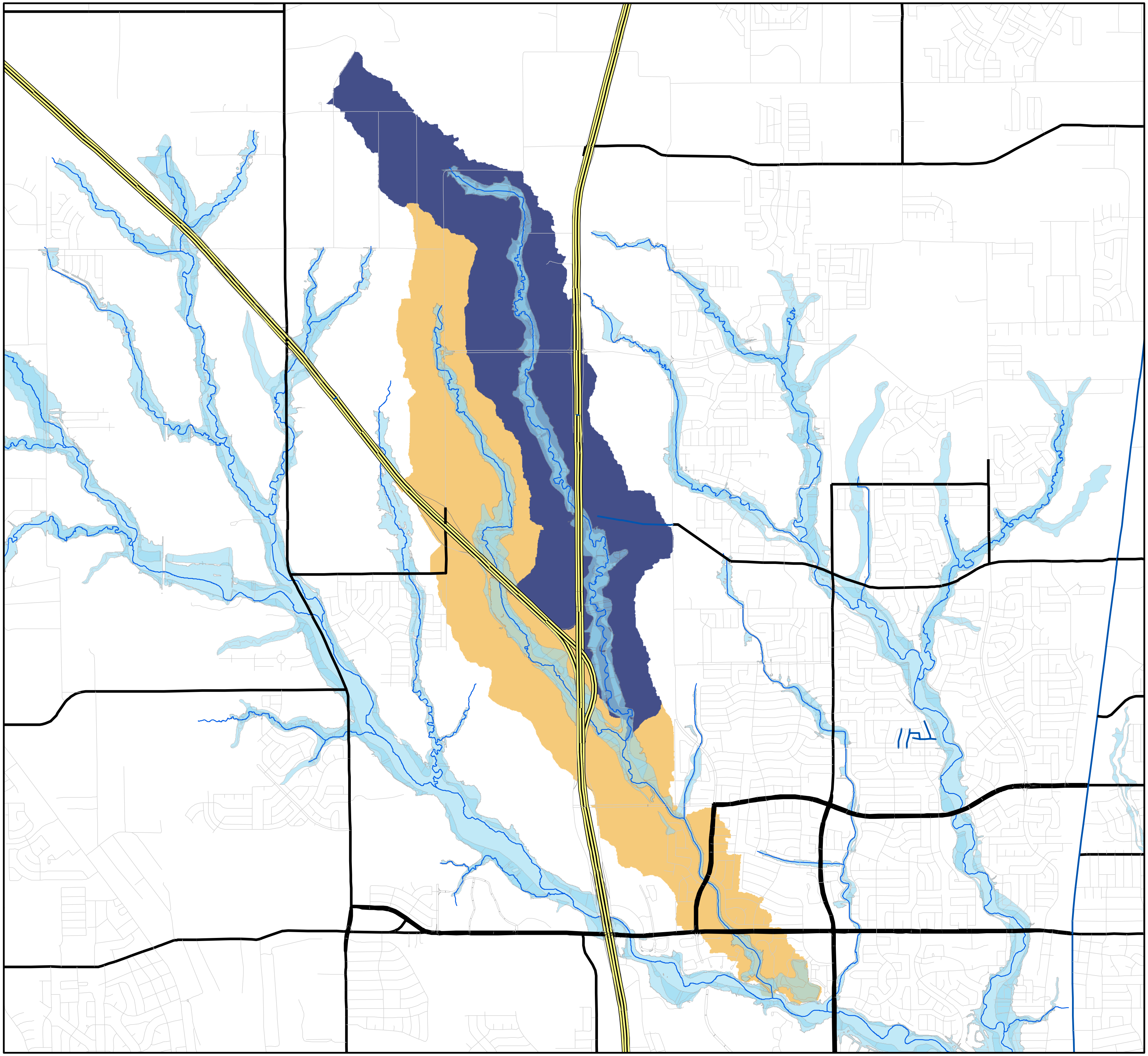
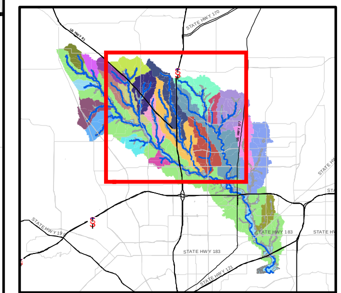
Big Fossil Creek Watershed Tributary 2 and 2A Fig. 5-13





Legend

- Big Fossil Creek
- Tributary 2
- Tributary 2A
- Preliminary 100 Year Floodplain

0 0.25 0.5 1
Miles

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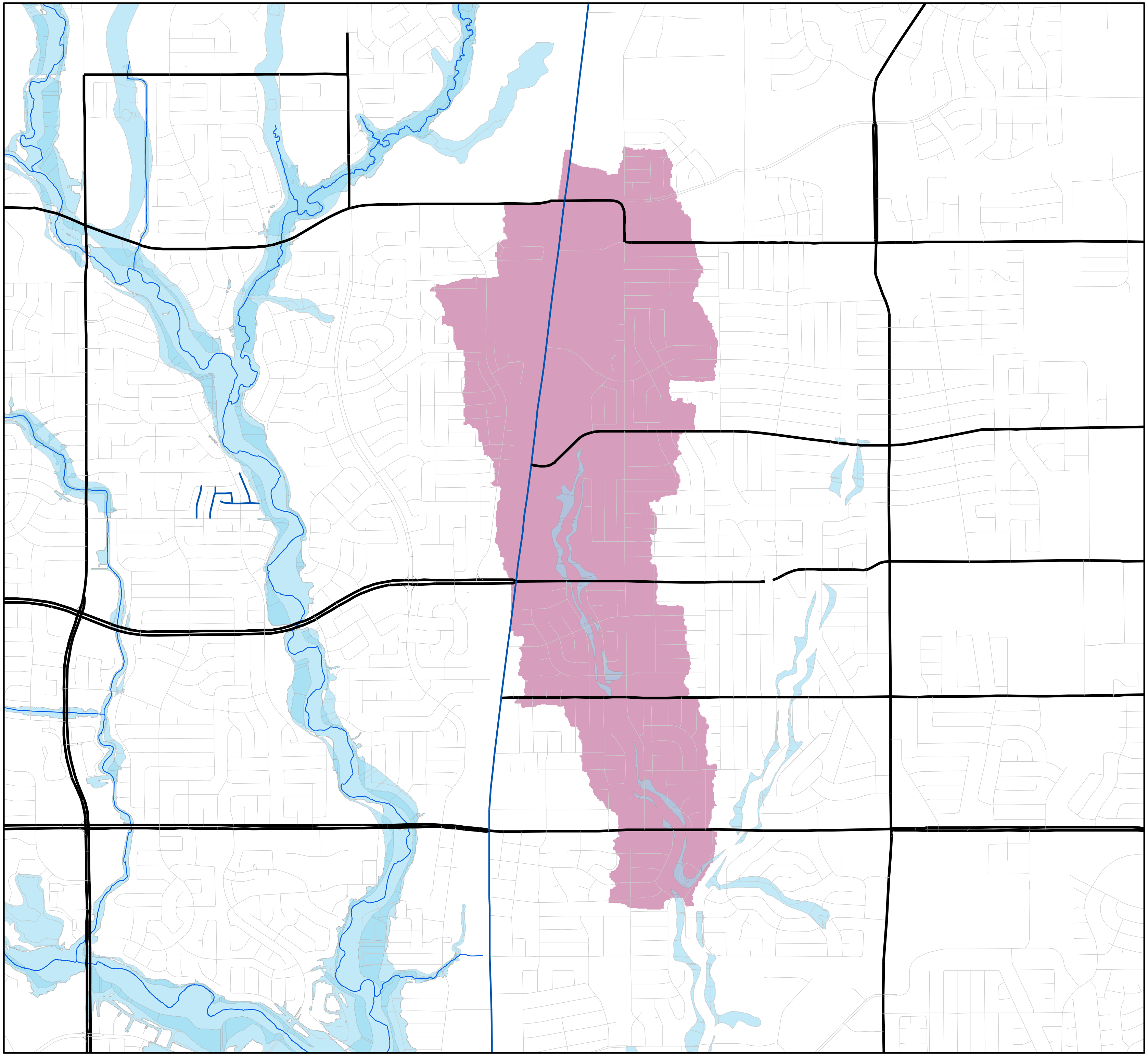
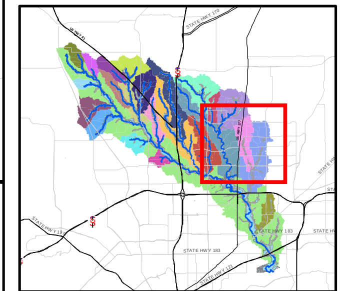


Big Fossil Creek Watershed Bunker Hills Creek Fig. 5-14



Legend

- Big Fossil Creek
- Bunker Hills Creek
- Preliminary 100 Year Floodplain

0 0.25 0.5

Miles

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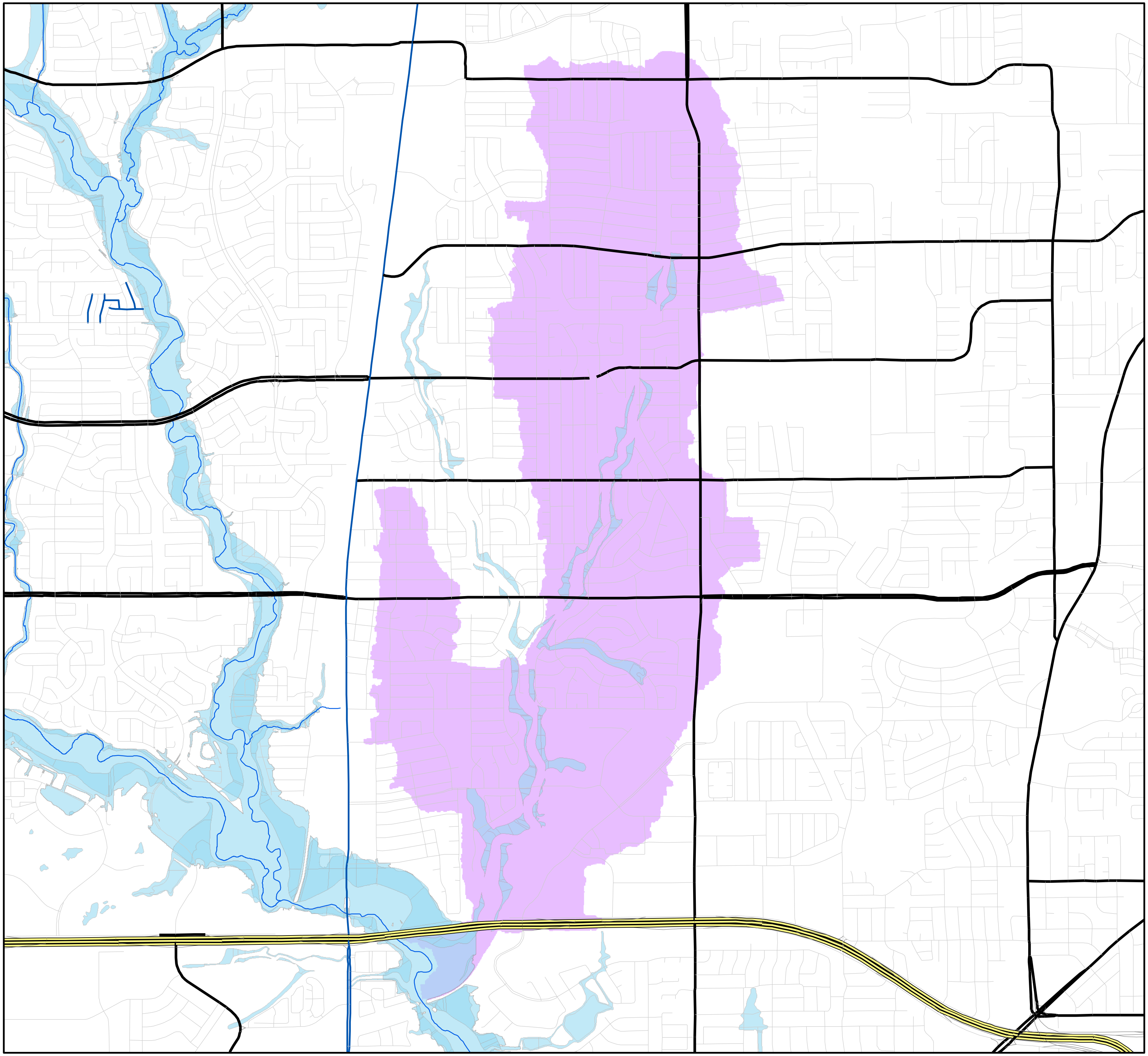
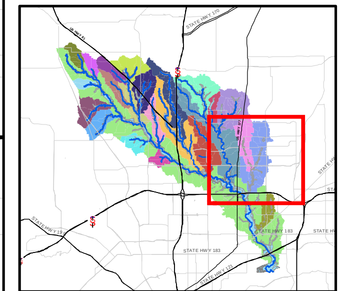
Big Fossil Creek Watershed Singing Hills Creek Fig. 5-15





Legend

- Big Fossil Creek
- Preliminary 100 Year Floodplain
- Singing Hills Creek

0 0.25 0.5
Miles

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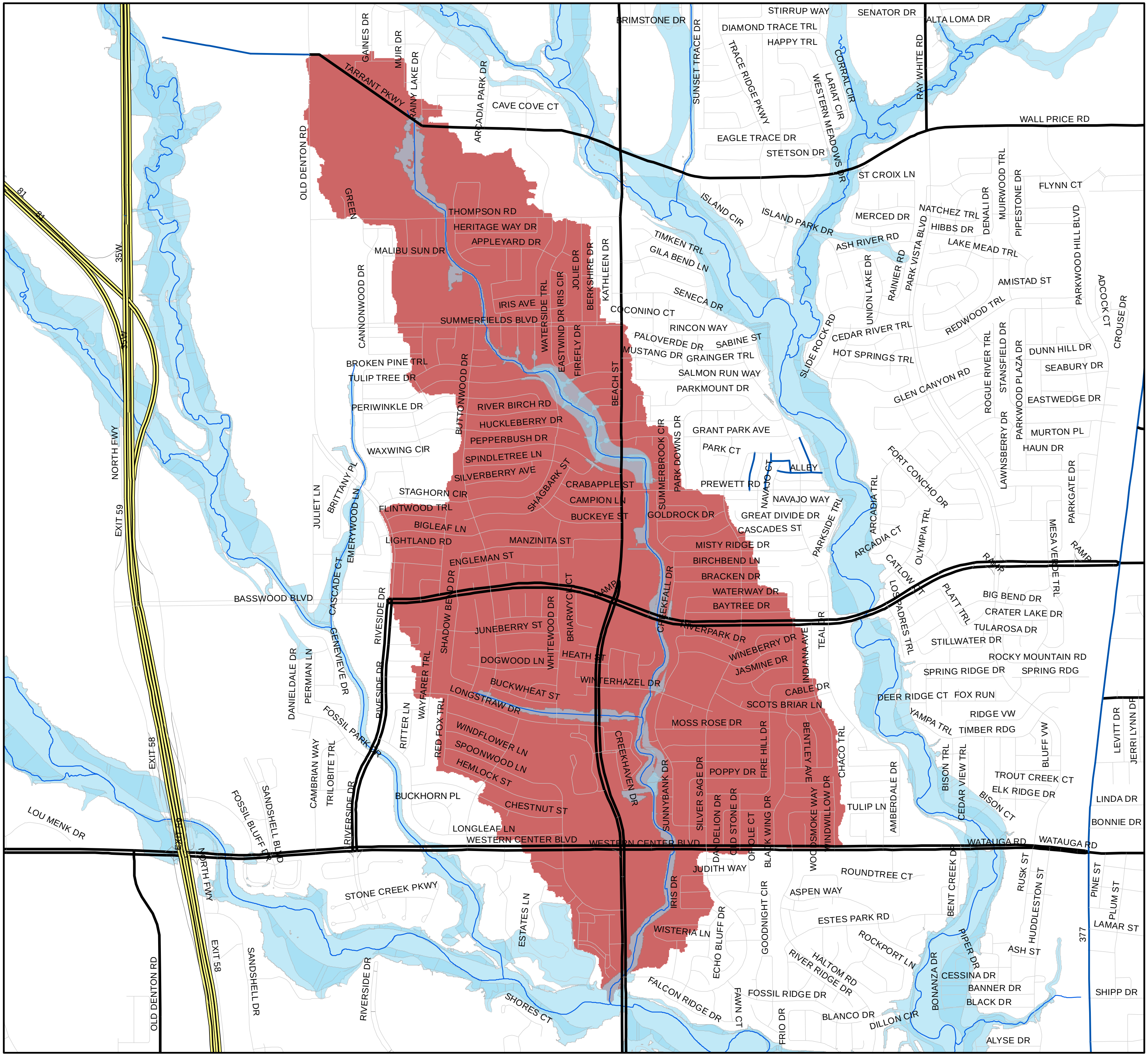
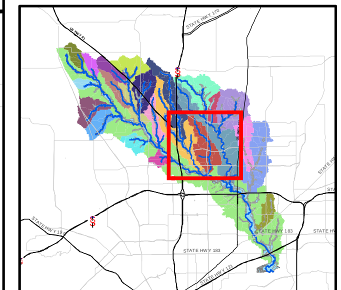
Big Fossil Creek Watershed
Tributary 1
Fig. 5-16





Legend

- Big Fossil Creek
- Tributary 1
- Preliminary 100 Year Floodplain

0 — 0.25 — 0.5

Miles

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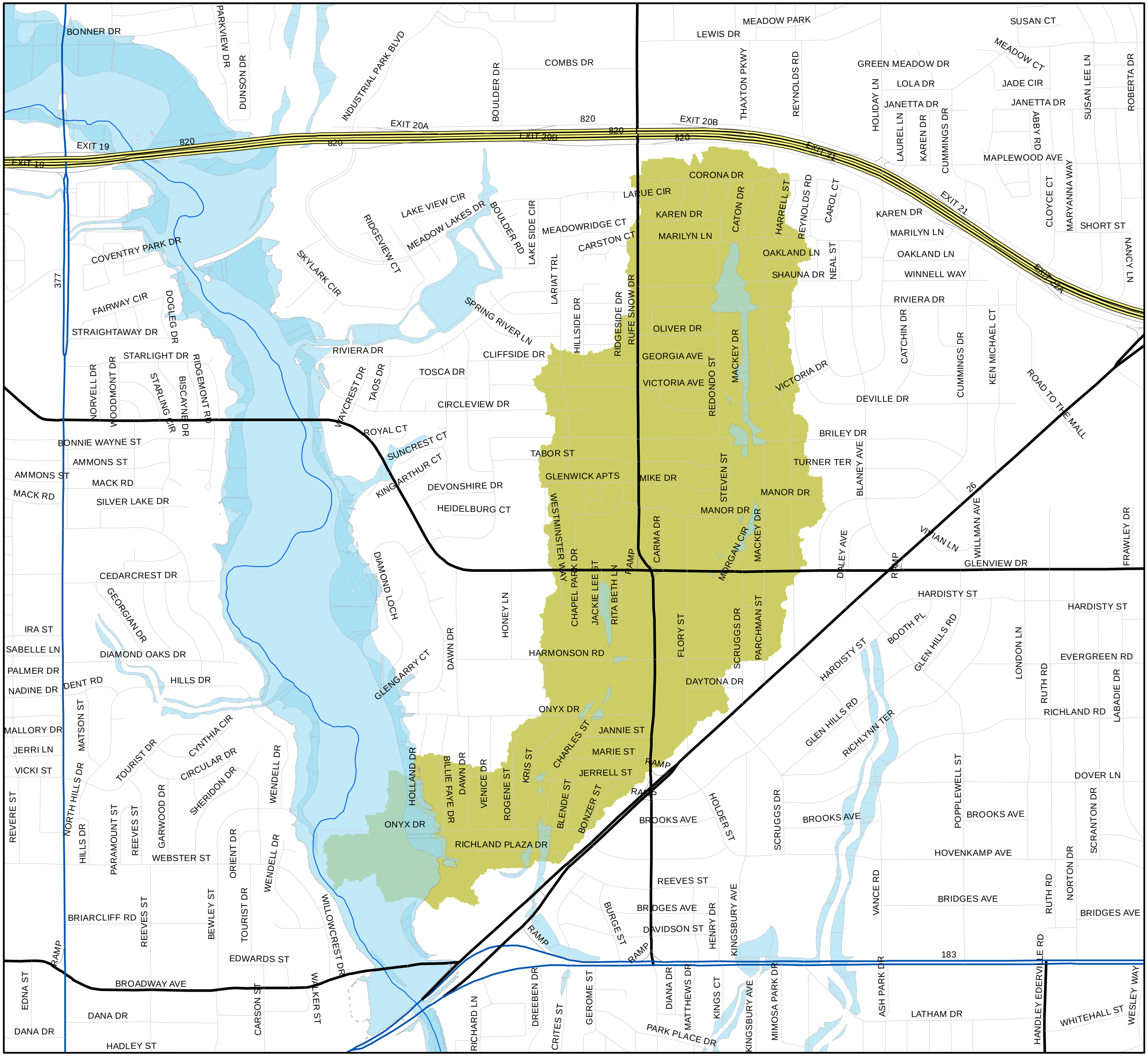
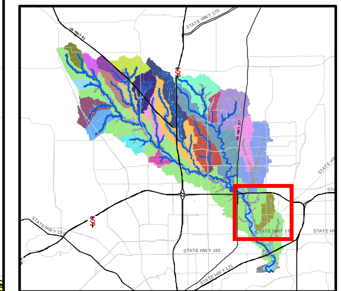
Big Fossil Creek Watershed Mackey Creek Fig. 5-17





Legend

- Watershed Boundaries selection
- Big Fossil Creek
- Preliminary 100 Year Floodplain

0 0.25 0.5

Miles

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Hydraulic Analysis

Analysis of the hydraulic characteristics of Big Fossil Creek, and all identified tributaries that confluence up-stream of US HWY 377, were executed to provide estimates of the water surface elevations for the selected recurrence intervals stated above. Tributaries studied in detail were limited to those with a drainage area greater than 1.0 square mile or which had been studied previously in the Tarrant County, Texas and Incorporated Areas Flood Insurance Study, with an effective date of August 23, 2000. This included 22 Big Fossil Creek tributaries and the main stem of Big Fossil Creek, which totaled approximately 75 stream miles. The hydraulic analysis for the study area was performed using the standard USACE software suite, including HEC-geoRAS and HEC-RAS .

Bridge and culvert models were completed, roughness values were added for the channel and left and right over-banks and other physical parameters were added as required to accurately depict channel and overbank hydraulic conditions. The HEC-RAS model was developed for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency floods and included Big Fossil Creek, Whites Branch and 31 tributaries. All streams studied were modeled in detail and flood plain delineations for the 25-, 100-, and 500-year frequency floods were developed.

Water surface profile elevations for the eight computed discharges were produced for each stream studied in detail. Model results were reviewed to ensure results were reasonable. As a check, final results were compared to the effective FEMA profiles, and previous U.S. Army Corps of Engineers studies.

Big Fossil Creek drains approximately ten-percent of the area within Tarrant County, where it originates. It flows southeast through multiple communities to its confluence with the West Fork Trinity River. Two major tributaries are Little Fossil Creek and Whites Branch. See **Appendix A** Big Fossil Creek Hydrology and Hydraulics.

Tarrant County and the Big Fossil Creek Watershed in particular, have terrain characteristic of the Blackland Prairie with elevations ranging from approximately 535 to 850 feet. The soils are generally deep and clayey with underlying limestone. Native vegetation consists of bunch and short grasses with scattered mesquite trees. The combination of steep headwaters and low infiltration soils has consistently produced high-volume runoff from the Big Fossil watershed.

Under natural conditions, excess rainfall works its way to the channel through a variety of paths, finally aggregating in the main channel and flowing downstream. In an urbanized watershed, excess rainfall is handled in a variety of ways such as routing through detention ponds, collection in storm sewers or allowed to reach the channel by flowing down curb lined streets.

Because the natural, physical characteristics of the watershed contribute to effective runoff, the change from grass lands to urbanization does not radically affect the volume of flow in the Big Fossil channel. However, urbanization does affect both the timing and duration of floods due to the excess rainfall being collected and added to the channel as a point discharge.

Conversely, on the tributaries, the rapid increase in urbanization is affecting both flood volumes, as well as timing. Another issue evident due to the increased urbanization includes increased sediment load in the streams, which has the induced impact of reducing flow capacity of bridges, culverts, designed channels and detention ponds. This is especially evident in the upper part of the Whites Branch watershed, and other smaller tributaries to Big Fossil.

Another serious issue related to urbanization is stream corridor encroachment. Participating study sponsors enforce the FEMA National Flood Insurance Program to limit loss of conveyance within the floodplain. However, the health of the stream and opportunities to retain or re-establish quality habitat within the stream corridors is being lost at an alarming rate. Many opportunities for flood risk reduction and ecosystem restoration have been lost because real estate to support these options has already been developed.

ECONOMICS

The next step in preparing the existing conditions for any watershed study is to complete and economic analysis of the areas to determine what damages the communities experience during a severe storm event. This analysis also provides information of the primary damage centers in the watershed allowing communities to determine the most efficient and effect use of their resources. This analysis is a tool useful for systematic long-term planning important for all communities, municipalities, and organizations.

Methodology

The theoretical computation of flood damages is relatively simple. It is based on the depth of flooding for various flood events (exceedence probabilities), and a relationship between the depth of flooding and the estimated damages based on a percentage of the structure and content, or vehicle value. The nomenclature used in this appendix to describe the relative risk reflects the actual probability, rather than the average recurrence interval, of flood events. For example, the commonly used term "100-year frequency flood", meaning that flood which stands a one percent chance of being equaled or exceeded in any given year period, will hereafter be known as the “1 percent annual chance exceedence (ACE) flood.” Damages to the various structures, accumulated by frequency, produce a frequency-damage function. An integration process using this frequency-damage data calculates estimates of expected annual damages. This involves aggregating the multiplication of the mean damage between each pair of flood events by the difference in exceedence probabilities. This is then repeated for the range of flood events in each damage category.

Hydrologic Engineering Center-Flood Damage Assessment (FDA) Program

Big Fossil Creek watershed economic analysis utilized the Hydrologic Engineering Center-Flood Damage Assessment (FDA) Program. This program is used to compute Flood damages under without- and with-project conditions. This portion of the study the economic analysis explores the flood risk assessment under without project conditions. The next phase of the study would incorporate with-project conditions currently and into the future. The program integrates hydrologic, hydraulic, and flood plain characteristics through application of a Monte Carlo simulation, and computes single event and expected annual damages while accounting for uncertainty in the values of structures and contents. Damage susceptibility factors used by the program to estimate flood damages include the number and type of structures, structures and content values, the elevation where the structure begins to sustain measurable damages, and a flood depth-damage relationship.

An inventory of properties lying within the limits of the 0.2% annual chance exceedence (500-yr) flood plain was conducted to determine the number and type of structures, values of structures and contents, and ground and finished floor elevations (elevation where water enters the structure). Structure values were obtained from the Tarrant County appraisal district and used as a base value. In compliance with ER-1105-2-101, in order to accurately reflect replacement cost less depreciation to the existing structures, values for a sample of nine commercial structures were calculated using Marshall and Swift based on the information collected during a field survey. This sample represents 20 percent of commercial structures in the study area. Residential structures were also adjusted based on a sample of 84 one- and two-story structures, representing just over 10 percent of those structures. A sample of multifamily residences made up sixteen percent of the 37 structures in the study area. Replacement cost is the cost of physically replacing (reconstructing) the structure. Depreciation accounts for deterioration occurring prior to flooding, and variations in remaining useful life of the structure. Structure values for single family residential were adjusted by upward by 31.8 percent; commercial properties were adjusted upward by four percent. Multifamily structures were adjusted by 19 percent. This adjustment was also applied to mobile residences. Values for public structures were based on the square footage of the applicable estimates produced by Marshall and Swift. Uncertainty distributions associated with estimating the depth-damage functions, structure values, content ratios, and first flood stage are used to develop the total aggregated stage-damage uncertainty function by damage categories for each damage reach. An uncertainty factor of 10 percent was used for residential structures and 15 percent for commercial and public structures.

The 0.2% ACE of the defined study area contains 405 structures with a total structures and contents value of $70,684,700. Residential structures make up 84 percent of the structures and 89 percent of the structure and contents value. Commercial structures make up four percent of the structures and 8.3 percent of the structure and contents value. Public structures make up three percent of the structures and 8 percent of the structure and contents value. Damages begin at the 20% ACE (5-yr event) in the BFC-2nd and WB-2nd reaches. At the 0.2% ACE (500-yr event) the study area experiences an estimated $8,577,400 in damages. The BFC-2nd reach contributes 60.3 percent to the damages, the BFC-3rd contributes 2.1 percent, the WB-1st reach contributes 32.8 percent of the single-event damages, and the WB-2nd reach accounts for 4.8 percent of the damages.

The economic analysis clearly demonstrates that the Big Fossil Creek watershed experiences flood risks at frequent storm events. There are particular damage centers more prone to risks than other areas within the watershed. The major damage center is on the Whites Branch Creek adjacent to the Skyline Mobile Home Park. The economic analysis indicates that without modifying the existing conditions either structurally or non-structurally in the watershed the likelihood of continual impacts from frequent storm events is high.

ENVIRONMENTAL

The study area commences at the confluence of Big Fossil Creek and the West Fork of the Trinity River, proceeding northeastward along Big Fossil Creek to its headwaters near US HWY 287. This area lies entirely within Tarrant County, Texas but crosses many city and municipality boundaries. Urban expansion has resulted in large scale alterations to the natural features of practically all tributaries, and a significant amount of Big Fossil Creek. The floodplains vary from broad in the upper reaches, to narrow as the creeks meanders through the many developed areas. The cut banks are steep and at normal low flow the water surface elevation conditions may be 10 to 20 feet below the top of the banks.

Located in the Coastal Plain Province, Tarrant County is predominately underlain with nearly horizontal beds of hard limestone and shale of marine origin from the Fredericksburg and Washita groups of the Cretaceous Age. Geological units present include Quaternary floodplain and terrace deposits near the surface, consisting of clays, sands, and gravels. The soils are generally Frio silty clay, well drained with moderately permeability and slow surface runoff.

Climate

The Big Fossil study area is situated in a region of temperate mean climatological conditions that experiences occasional extremes of temperature and rainfall of relatively short duration. According to the National Oceanic and Atmospheric Administration (NOAA 2000) Station at Dallas-Fort Worth, Texas, the 30-year mean annual rainfall amount is 34.73 inches. The extreme annual rainfall values recorded since 1887 measured a maximum of 53.54 inches 1991 and a minimum of 17.91 inches in 1921. Precipitation is distributed fairly uniformly throughout the year, with the exception of a slight peak in the spring and a low in mid-to-late summer. The mean relative humidity is 65 percent and the average temperature is 65.5^{o}F. Recent temperature extremes range from –1^{o}F as recorded in December 1989 to 113^{o}F recorded in June 1980. The last average freeze occurs on March 23 in the spring and the first average freeze occurs on November 13 in the fall. The temperature falls below freezing an average of 41 days a year, but this drop is usually followed by daily thaws. The length of the growing season is approximately 235 days.

The major storms experienced in the study area are produced by heavy rainfall from frontal-type storms that generally occur in the spring and summer months. Major flooding can also be produced by intense rainfall associated with localized thunderstorms that may occur at any time during the year, but are more prevalent in spring and summer months.

Surface Water and Other Aquatic Resources

The City of Fort Worth Environmental Management Department and the U.S. Corps of Engineers collected macroinvertebrate and physico-chemical data at eight locations along Big Fossil creek and its tributaries. Two preliminary reports with the data were released in 14 October 2002 and 04 March 2003. **Appendix I**.

U.S. Fish and Wildlife Service conducted an assessment of the biological integrity of Big Fossil Creek and released the findings in a report 21 February 2003. **Appendix E**.

Vegetation

Historically Big Fossil Creek and its tributaries were typically bordered by a narrow fringe of bottomland hardwoods composed of oaks, green ash, cottonwood, black willow, and a dense under story of greenbriar, immature hardwoods, and shrubs. Wetland systems have been degraded due to human encroachment. There are some areas in the watershed that still have wetlands within the floodplain. These wetlands are generally characterized by black willow, swamp privet, sedges, and/or cattail vegetation complexes. The majority of the study area may be characterized as severely degraded prairie and fragmented bottomland forest that is primarily residential and commercial areas. Only a very narrow strip of riparian corridor still exists in this region.

Wildlife Resources

Tarrant County lies within the Texan biotic provinces. The proposed project area lies primarily within the Eastern Cross Timbers natural subregion and is in an area where rapid development and urbanization has taken place over the last few years as the City of Fort Worth and other local cities expand. Due to the severely degraded vegetation and fragmented bottomland forest wildlife resources are limited to those species that can adapt to residential and commercial areas. Riparian corridors are important to many types of wildlife species. Suitable habitat is a limiting factor for all types of wildlife within the Big Fossil Creek watershed.

Terrestrial animals that would normally be found in this type of environment are: raccoon (*Procyon lotor*), Eastern cottontail (*Sylvilagus floridanus*), Eastern fox squirrel (*Sciurus niger*), Virginia opossum (*Didelphis virginiana*), Hispid cotton rat (*Sigmodon hispidus*), and striped skunk (*Mephitis mephitis*). There are many species of birds, both migrant and resident, in Tarrant County and the proposed project area. Some of the most common are: northern cardinal (*Cardinalis cardinalis*), northern mockingbird (*Mimus polyglottos*), red-tailed hawk (*Buteo jamaicensis*), and turkey vulture (*Cathartes aura*). A species list of observed birds in 2002 and 2003 in the Big Fossil Creek corridor is listed in **Appendix C.** Common reptiles and amphibians likely to inhabit the proposed project area are: cricket (*Acris crepitans*) and leopard frogs (*Rana sphenocephala*), slider (*Trachemys scripta*), yellow mud turtle (*Kinosternon flavescens*), and diamondback water snake (*Nerodia rhombifer*). Fish species that may occur in the watershed include largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and blue gill (*Lepomis macrochirus*). Exotic species that may occur are common carp (*Cyprinus carpio*), introduced sunfish species (*Lepomis spp.*) and introduced shad species (*Dorosoma spp*.). Other tolerant species such as mosquito fish (*Gambusia spp.*) may also occur.

Endangered and Threatened Species

There are currently two Federally-listed endangered species and one Federally-proposed threatened species in Tarrant County as shown in **Table 2** below. In addition, several species designated by the Texas Parks and Wildlife (TPWD) as threatened, endangered, or rare are located within Tarrant County.

Table 2 – Federally Listed Threatened and Endangered Species for Tarrant County

Common Name	Scientific Name	Listing Status
Bald Eagle	*Haliaeetus leucocephalus*	Threatened
Whooping Crane	*Grus americana*	Endangered
Least Tern	*Sterna antillarum*	Endangered

Based on respective habitat requirements and field observations, no Federally-listed endangered species or Federally-proposed threatened species are expected to be encountered within the proposed project area. In addition, the probability of encountering TPWD-designated threatened, endangered, or rare species would be very low.

Summary of wildlife resources

Wildlife resources including terrestrial species, aquatic species and birds have been negatively impact by the loss of habitat, the degradation of habitat and human encroachment. Much of the watershed has been impacted by urban construction and non-point source pollution. The riparian corridors are very narrow providing little benefits to the watershed. Ecosystem restoration throughout the watershed could be implemented to improve water quality, stabilize eroding banks, filter sediment, nutrients, pesticides and animal waste from run off water. Additional benefits include providing shade, shelter, and food for fish and other aquatic organisms. Ecosystem restoration of wetlands provides non-point source pollution control, which can improve water quality.

CULTURAL RESOURCES

Any proposed undertaking under the responsibility of the US Army Corps of Engineers must follow and account for the responsibilities under Federal and State cultural resources laws and regulations, Executive Orders, and US Army Corps of Engineers regulations. All applicable legislative and regulatory mandates are to be considered in the event that any study provides a basis for a Federal undertaking. Any projects will need to consider the legal responsibilities and obligations of the US Army Corps of Engineers with respect to the National Historic Preservation Act (NHPA) of 1966 (PL 89-665 et seq.), National Environmental Policy Act (NEPA) of 1969 (PL 90-190), Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 (PL 101-601), Executive Order 13007 (Accommodation of Sacred Sites- 24 May 1996), Government-to-Government Relations with Native American Indian Tribal Governments (Presidential Memorandum of 29 April 1994), and Engineer Regulation (ER) 1105-2-100 (Guidance for Conducting Civil Works Planning Studies).

The scale of the relevant study area and the level of effort to collect and prepare detailed information restricted the data collection to that of currently known and recorded cultural resources and a reconnaissance of the drainage area conducted by an archaeologist. Project planning has not progressed to the level of a clear definition of a specific project, therefore impact areas and the nature of those impacts could not be specifically addressed. The proposed study area is extensive and will require definitive project boundaries and descriptions before potential impacts to cultural resources can be assessed and appropriate mandated considerations of impacts described and evaluated.

The potential impacts to cultural resources to be considered include a variety of solutions that could include structural and non-structural flood control and relief systems, easements, borrow and disposal areas, mitigation areas, creation of wetland areas, reforestation, and revegetation, among other possibilities. Any of these undertakings would generate a requirement to consider possible impacts to a potentially broad range of cultural resources in areas selected for project locations. These considerations include the completion of archaeological and architectural surveys of project-specific parcels for properties eligible and potentially eligible to the National Register of Historic Places (NRHP) in consultation with the Texas State Historic Preservation Officer (SHPO). An additional consultation with other interested parties and Native American Indian tribal groups is also necessary regarding properties of traditional cultural significance.

Despite best efforts to locate and evaluate all the cultural resources within any given project area, unanticipated subsurface deposits are possible at any ground-breaking undertaking. If previously unknown cultural materials are exposed by construction activities related to the undertaking, work will stop in the immediate vicinity, the resource will be protected, and the SHPO will be notified within 24 hours of discovery. If, in consultation with the SHPO, it is determined that the resource is significant, and cannot be avoided by construction, then a mitigation plan will be prepared in consultation with the SHPO and implemented before construction is allowed to continue in that vicinity.

ARCHAEOLOGICAL RESOURCES

A check of state archaeological site records kept at the Texas Archeological Sites Atlas (TASA) online database indicated no recorded sites within the immediate Big Fossil Creek drainage study area. The lack of recorded sites may be due to the dearth of cultural resources surveys that have been conducted in the region. Only two surveys show up in the database, one along I-35W, north of the interchange with I-820 and another extending north along Texas SH 156. Both of these surveys were conducted by the Federal Highway Administration.

The Fort Worth District contracted Geo-Marine, Inc. to investigate the potential for cultural resources within the Big Fossil Creek drainage area. The archaeological field reconnaissance carried out between November 21 and December 5 in 2001, revealed that the project area has been subject to severe impact and alteration through modern development and construction. Observed creek cut banks showed intact stratigraphic deposits in areas where the creek bank or course had not been altered by construction or channelization. The results of research, field observation, and geographis information system (GIS) models were analyzed to create a predictive model for site potential within the Big Fossil Creek drainage (Parrish and Burson 2002).

As project alternatives are developed and evaluated, cultural resources surveys may be needed within the specific project area(s) of potential effect. For example, in the southeastern portion of the drainage, near the confluence of Big Fossil Creek and the West Fork of the Trinity River, backhoe trenching in floodplain areas along with intensive cut bank survey is recommended to locate deeply buried deposits, whereas, no archaeological survey is necessary west of I-35W, in the upland prairie region of the drainage. In areas that cannot be surveyed prior to construction (where pavement prevents excavation, for example), archaeological monitoring may be required if planned project excavation is deeper than modern disturbances. The full need for or extent of survey will not be known until plan formulation progresses during the next phase of the study.

ALTERNATIVES

Based on the problem areas and the potential solutions identified at the initiation of the study shown (**Figure 3)**, there are many alternatives which could be evaluated. These include both structural and non-structural measures that could be implemented in order to reduce the flood risks within the watershed. Additionally, there are many areas in the watershed where ecosystem restoration would benefit multiple communities by improving water quality, stabilize eroding banks, decrease turbidity, decrease sediment loading, increase flood water storage, and collect peak flows known to carry most of the non-point source pollution.

Structural alternatives to reduce flood risks could include detention ponds, design channels, earth cuts, and or levees. Reviewing the map of the areas of concerns, structural measures would likely be investigated for the areas labeled F-1, F-2, F-3, F-4, F-5, F-6 and F-7. These are areas where recurrent flooding has occurred in the watershed. The next phase of the study would determine which structures would be feasible to meet the overall objective and also the most efficient in terms of time involved and costs.

Structural measures aimed at improving aquatic habitat by improving the pool/run/riffle ratio in various reaches of the watershed would also be investigated. These improvements are generally accomplished by the use of gabion weirs, earth berms angled strategically in the creek, and substrate changes such as cobble and rubble. Areas that have been identified that would benefit by geomorphic changes in the reach correspond to potential projects and recreation enhancements labeled P-1, P-4, P-5, P-7, P-8, P-13, R-1, R-2, R-8, R-9 and P-13.

The intent of the structural projects would be to reduce or eliminate flood risks, and also to improve the water quality of the entire watershed by restoring a healthy pool/run/riffle ratio important for quality aquatic habitat.

Non-structural alternatives that could be investigated include warning systems, flood proofing, buy-outs, watershed management, and ecosystem restoration. These types of alternatives would be investigated both for specific and non-specific locations throughout the watershed. We expect also to investigate a flood warning system for all areas that are labeled as F-# on the Area of Concerns Map. This investigation would include the Whites Branch Creek labeled as F-6 where a recent flood claimed a life. Additionally, all areas identified as flood prone would be considered for flood proofing. Buy-outs would be evaluated for all flood prone areas in the watershed.

Table 3 – Potential Alternatives and Area of Concern by Cities

City	*Potential Projects*	*Area of Concerns*
Fort Worth	P-1, P-2, P-3, P-4, P-5, P-10, P-12, R-1, R-2, R-3, R-4, R-5, R-6, R-8, R-9,	F-1,F-2, F-3, F-4
Haltom City	P-6, P-7, P-8, P-9, P-13, P-15, R-10, R-11, R-13	S-1, S-2, S-3, S-4, F-6, F-7
Haslet		
Keller	R-14	
North Richland Hills	P-10	
Richland Hills	P-11, R-12	
Saginaw	P-14, R-7, R-16	
Watauga	R-15	F-5

Watershed Management for the entire watershed would include investigating various types of ecosystem restoration. Many areas of the watershed have little to no riparian zone. Riparian buffer zones of at least 30 feet on each side of the creek could be used to enhance and protect aquatic resources from further adverse impacts of urbanization. Riparian zones provide several benefits that extend beyond just aquatic resources. Riparian zones would be beneficial in the Big Fossil reach that contains potential solutions labeled P-6 and recreation enhancement R-10, shown in more detail on figure 3.9b. This non-structural solution would provide benefits to the reach of stream bank stabilization. Additionally the entire watershed would benefit in time by the riparian buffer absorbing the erosive force of flowing water while roots hold soil in place. This would decrease sediment loading for the entire watershed. Sediment loading has been a problem which is identified and shown on the potential project area as P-11, shown in more detail in Figure 3.13 Riparian buffers would improve the overall water quality of the watershed as they filter sediment, nutrients, pesticides, and animal waste from runoff. Riparian zones provide shade, shelter, and food for fish and other aquatic organisms. In this particular reach some recreational trails exist which could be an opportunity to extend those trails and connect them providing the communities with more public recreational areas.

In both of these non-structural management measures, wetlands could be restored off of small permanent or ephemeral streams such as the ones located at P-2, shown in more detail in figure 3.4. Overflow from small ephemeral streams could be preserved and potentially expanded. The majority of the potential wetland restoration sites to be investigated are in the upper reaches of the watershed.

Multi-Objective Management (MOM) is another non-structural tool that allows for watershed wide planning for wetlands, greenways, wildlife, and cultural resources. These features are equally important to the watershed as flood control, transportation and other development. MOM measures compose the integral parts of a Watershed Management Plan. The purpose of a Watershed Management Plan is to address the water and related land resource environment problems and opportunities that exist within a watershed in a holistic manner. It provides recommendations for potential partnerships (government to government, and private to public) to solve identified problems and take advantage of opportunities. Further, it identifies efforts necessary to fully develop a Watershed Management Plan for the basin. This approach offers a unique opportunity for solving water resources related problems in a holistic manner. Studies associated with preparation of a Watershed Management Plan include natural and cultural resources protection and restoration, recreation, environmentally sustainable development, environmental education, measures for protecting and enhancing water quality, and other water related needs such as runoff and erosion control, water supply, and flood damage reduction. Traditionally, plan formulation techniques have used a hierarchical approach, where the primary purpose is formulated first without regard to the other purposes. Other secondary measures to address other purposes are then added with little, if any, changes to the primary design. The multi-objective watershed management approach attempts to formulate plans to address all measures simultaneously. Several flood protection measures may be in direct conflict with important environmental aspects, and thus the flood protection measure would perhaps be modified to minimize the conflicts while still maintaining the objective of reducing or eliminating the flood risk.

Another tool that is being utilized by some municipal jurisdictions in the region is the NCTCOG tool for examining and dealing with such issues, Integrated Storm Water Management (iSWM). This guidance tool provides design and implementation guidelines assuring that development conforms to strict, yet feasible and enforceable guidelines that consider impacts to water quality and water flow. iSWM is a policy and design guidance manual for development within the watershed and should be implemented by parties who are responsible for managing their municipalities natural resources.

All of the potential alternatives discuss for the area of concerns could be utilized in a combined plan to address the issues watershed wide. This would improve the overall health of the system and every participant would retain benefits. These solutions could be analyzed individually to address concerns in an isolated manner. The combination of these strategies will ensure that the residents of the Big Fossil Creek watershed are provided with multiple tiers of investment and improvements, while balancing the burden of responsibility between the current partners of the watershed. The result of holistic Watershed Management Plan will allow for mutual goal setting, and objectives between the stakeholders. A combined plan will strengthen the partnership and focus between all the participants. This will provide for greater benefits within Big Fossil Creek watershed due to dedication and teamwork.

CONCLUSION

The purpose of this analysis was to document existing conditions of the Big Fossil Creek watershed. These existing conditions support the identification of changes necessary in the watershed that assure immediate and long-term benefits impacts to bank stability, maintenance of channel capacity, stream and overbank health, protection of existing environmental assets, and the support of floodplain management practices within the watershed.

This is a decision point for the participants to determine if there is interest in moving forward with further study. The next phase of this analysis will evaluate the problems and opportunities already identified by the communities for the possibility of Federal participation and feasibility of implementation. Additionally the next phase would provide cost estimates of developing alternatives and the costs associated with implementing those alternatives. Moving forward would allow for cooperative stream maintenance and a holistic plan that addresses many of the flood related problems while improving the overall quality of the water system. It is recommended that the study in its entirety, continue in order to identify problems and opportunities so that systematically, issues are planned and implemented. However it not a requirement that the entire study area be included for this effort to continue.

Historically the Big Fossil Creek Watershed has faced flooding events, and will continue to experience them. This is not an uncommon occurrence in any watershed, and should be expected as a normal event. There is no way of predicting the severity of an event, but there are methods by which individuals and entities can work for a common cause to minimize both the flood extent and the human causes which increase the magnitude of flooding. There are solutions and strategies for dealing with flood-associated events that can be introduced and implemented on various scales, many of which depend upon the ability of the jurisdictions within the watershed to identify solutions on a watershed-wide basis and to implement those solutions in a concerted effort such that the goals and objectives of each city overlap and provide catalysts for each to work together in not only minimizing the impacts of urbanization and development on the watershed, but also in understanding why the flooding occurs and the strategies that can be utilized to reduce flooding.

Unpredictable and extreme weather events, the geology and geography of the watershed, and the manipulation of the naturally existing flora and fauna and fluvial processes within the watershed are natural elements play an intricate roll in the mechanics of the watershed. Resulting pollution, erosion, ecological degradation, decrease in biodiversity and decreases in natural resources in general are inevitable consequences of human interaction with or manipulation of, the environment.

The stakeholders are at an important juncture in the overall study and projects related to the Big Fossil Creek watershed. It is at this point at which the stakeholders in Big Fossil Creek will determine, based on their interest and desire, to pursue further analyses of possible solutions and cost estimates. The existing conditions have been completed during this phase of the study. Participants should review the existing conditions, along the problems and area of concerns identified with an eye towards determining whether they intend to move forward with the NCTCOG and the USACE to develop specific detailed plans and strategies for watershed management, improved safety for residents and ecosystem restoration projects. Cost estimates for implementation of the potential solutions will be examined and provided to enable the participants the ability to adequately assemble their respective resources for future phases. The benefit of this approach is that not only will there be improvements on a watershed-wide basis, but that these improvements will provide reliable and potentially life-saving improvements that will be funded in-part by the federal government.

APPENDIX A

Hydrology and Hydraulics Summary

13 July 2006

Big Fossil Creek Watershed
Feasibility Study
Existing Conditions
Hydrology and Hydraulics

Purpose: The purpose of the hydrology and hydraulics analysis was to develop hydrologic and hydraulic models of Big Fossil Creek and Tributaries within the Big Fossil Creek watershed to represent existing conditions.

Flood History: The historical stage data for Big Fossil Creek at the Haltom City Gage began about 1900. Known major flood events occurred on Big Fossil Creek in September 1900, May 1908, April 1922, September 1933, 20 April 1942, May 1949, 25 May 1957, 25 June 1961, 7 September 1962, March 1977, 13 October 1981, and 17 May 1989. The September 1962 flood is the largest known event since 1900 on Big Fossil Creek. The flood discharges can only be roughly estimated from the Big Fossil Creek gage data. The construction of the Big Fossil Creek levees and channel and enlargement of bridge openings in the vicinity of the gage has altered the stages of floods since 1962.

Hydrology

A hydrologic analysis for the study area was performed using the Hydrologic Engineering Center (HEC) Geo-HMS and HEC-HMS programs. A hydrologic model was developed for Big Fossil Creek and all significant tributaries except for Little Fossil Creek. All subbasin parameters including drainage area, stream length, stream length from the outlet to the centroid of the subbasin, slope, percent impervious, percent of urbanization, time to peak, basin lag time, initial loss, and infiltration rates were defined for each subbasin. Discharges were computed for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency flood events for existing conditions (2005).

Existing conditions (year 2005) and future (fully developed) conditions were analyzed for this study. Based on the analysis, it is expected that increases in future urbanization and imperviousness will have relatively minimal impacts on the peak discharges for the less frequent events. This is especially true for the streams for the main stem area of Big Fossil Creek and Whites Branch.

Though it is not generally considered in USACE planning studies, future channelization could have a significant impact on the undeveloped smaller tributaries such as Streams BFC-2 and BFC-2A. A number of farm ponds and small lakes still exist in some of the less developed subbasins. If these structures were removed and/or the streams channelized, a significant increase in downstream discharge could occur.

Computer Models Developed: For the hydrology portion of this study, a Geo-HMS (version 1.0 running on an ArcView 3.3 platform) was used to develop digital drainage basins and determine the measurements required for the hydrology parameters for the study area. The data for 277 subbasins and associated streams was imported to the HEC-HMS version 2.2 computer model. The final stream schematic was corrected, and modified puls routing data and hydrologic parameters were added. The HMS version 2.2 model was set up to run only the 100-year frequency flood event. The HMS version 2.2 model was imported to the HEC-HMS version 3.0 to facilitate the automated depth area rainfall adjustment using Figure 15 from the National Weather Service (NWS) Technical Paper 40 (TP 40), Depth-Area-Duration curves. HEC-HMS version 3.0 models were developed for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency floods. Due to the size of the HMS model, the version 3.0 depth area rainfall analyses had to be split up into seven separate models. Table 1 is an existing conditions Summary of Discharges Table for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency floods, as computed.

Model results were reviewed to ensure that results were reasonable. Final results were compared to the effective FEMA discharges. Table 2 presents the comparison between the discharges developed for this study and the current effective FEMA discharges.

Digital Mapping Data: The base map data (DEM) used for the Geo-HMS model was provided by the North Central Texas Council of Government. The data provided was LIDAR DEM data with a 5-meter spacing, flown in 2001. Heavy vegetative growth near, and adjacent to, some stream channels severely affected the accuracy of the LIDAR DEM data in these areas. Also, DEM data does not include any break lines, which are usually necessary to accurately reflect stream channels. The DEM was extensively edited to properly reflect stream and drainage paths.

There were numerous changes in the watershed after the 2001 flight that required editing of and modification to the LIDAR DEM data to accurately reflect current conditions. These changes included several new sub-divisions, channel modifications, new street and roads, and small lakes. From this revised data, an ArcView Grid file was developed with a 15-foot spacing in a NAD 83 Texas State Plain North Central region in U.S. feet map projection.

It was not feasible to splice the more accurate 2003 DTM data (see Hydraulics, Digital Mapping data section below) with the LIDAR DEM data to create the 15-foot ArcView Grid file. This was because of the limited and irregular coverage of the 2003 DTM data. The digital 2 foot contour maps produced from this 2003 DTM data were used as a aid in the determination of where editing of the LIDAR data was required.

Initial Abstractions and Infiltration Rates: The rainfall loss values were assumed to vary with both soil type and the frequency of each storm event. These values are similar to those used in other models developed for the Dallas-Fort Worth area and are appropriate for this analysis. Soil type for each subbasin was assessed by digitally overlaying the watershed map and SURGO soil maps for Tarrant County. Soils were evaluated to determine the permeability for each subbasin. Soil type and permeability were used to set the initial and uniform loss rates.

Urbanization and Imperviousness: Values of percent urbanization and percent imperviousness were developed for each subbasin. Urbanization is the percentage of a subbasin that has been developed and improved with channelization and/or a storm collection network. It affects the Snyder's unit hydrograph lag time (t_p). Imperviousness is the percentage of a subbasin that is covered with impervious material and is hydraulically connected to the drainage network. It affects the volume of rainfall lost through interception and infiltration. The percent urbanization and imperviousness for each sub-basin was determined using January 2003 digital aerial photographs and observed data from field reconnaissance.

Development of Unit Hydrographs: Snyder's unit hydrograph method was used for consistency with previous studies in the region. Snyder's unit hydrographs were developed for each subbasin based on the specific physical measurements generated by Geo-HMS. These measurements are used in the standard equations for determining Snyder's lag time (t_p) which include the length of the major stream (L), the distance from the subbasin outflow point to the location of the subbasin centroid (L_{ca}), the weighted slope (S_{st})of the major stream that shows the best representation of the valley slope, and the percent urbanization. The Snyder's unit hydrograph lag time (t_p) was calculated for each subbasin using methodology described in the following reports:

> "Synthetic Hydrograph Relationships, Trinity River Tributaries, Fort Worth-Dallas Urban Area" by T.L. Nelson, 1970.
>
> "Effects of Urbanization on Various Frequency Peak Discharges" by Paul K. Rodman, October 1977.

Frequency Rainfall Data: Rainfall data for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events were developed from the NWS Technical Paper No. 40 and NOAA Technical Memorandum NWS Hydro-35. Rainfall for the 250- and 500-year storm events were extrapolated from the above rainfall data. The rainfall data was adjusted based on drainage area for each required computation point using the HEC-HMS version 3.0 depth area rainfall adjustment based on Figure 15 of Technical Paper No. 40.

Comparison with FIS Discharges: Final results were compared to the effective FEMA discharges. The effective FEMA discharges are a mixture of several different studies performed over different time periods, each done with somewhat different methodology, leading to variations in the results (Table 2).

Hydraulics

A detailed hydraulic analysis was completed for Big Fossil Creek and all identified tributaries that confluence upstream of Highway 377. Tributaries studied in detail were limited to those with a drainage area greater than 1.0 square mile or were studied previously for a Flood Insurance Study. This included 22 Big Fossil Creek tributaries and the main stem of Big Fossil Creek, which totaled approximately 75 stream miles. Table 3 is a listing of all streams modeled and the number of culvert crossings, bridges, dams, and digital cross-sections for each stream.

The hydraulic analysis for the study area was performed using the Hydrologic Engineering Center (HEC) Geo-RAS version 4.0 and HEC-RAS version 3.3 programs.

Computer Models Developed: For the hydraulics portion of this study a Geo-RAS (version 4.0 running on an ArcMap 9.0 platform) was used to develop digital stream lines, cross sections, top of road profiles, set up ineffective flow area boundaries, establish stream stations at the cross-sections in feet, and to measure channel and overbank reach lengths. This data was imported into the HEC-RAS version 3.3. Bridge and culvert models were completed, roughness values (Mannings "n" values) were added for the channel and left and right overbanks. Water surface profiles were computed for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency floods. The HEC-RAS models developed included Big Fossil Creek, Whites Branch and 31 tributaries. All streams in the original scope of work were modeled in detail and 10 additional small tributaries, with a discharge point in the HMS model, were modeled to aid in the digital floodplain delineations. Digital floodplain delineations for the 25-, 100-, and 500-year frequency floods were developed.

Digital Mapping Data: The base map data (DTM) used for the Geo-RAS model was prepared by Dallas Aerial Surveying under contract. The data provided was the DTM digital data which included 3-dimensional (3-D) mass points and break lines. Break lines were used to reflect all major changes in grade including streams, streets and roads, ditches and drainage paths. Also, digital 3-D 2-foot contour interval topographic maps and digital aerial photographs were provided. This data was based on January 2003 aerial photography. The vertical accuracy of the data was stated as at least 90 percent of the values were within + or – 1-foot. Vertical elevations were provided in the North American Vertical Datum (NAVD) of 1988. The horizontal position was provided in a map projection of NAD 83 Texas State Plain North Central region in U.S. feet. It was stated that the horizontal accuracy exceeded the industry standards for 2-foot topo. There were several areas that had been changed since January 2003 and were not reflected in the above data. These changes included additional improved channel reaches, ponds and several new and/or modified street and road crossings. From the field reconnaissance and field surveying (see below), the map data was edited as accurately as possible to reflect these changes. From the DTM data including revisions, an ArcView TIN was created and used in the Geo-RAS model.

Field Reconnaissance and Surveying: Field reconnaissance and surveying was done in August and September 2005. About 130 bridge and culvert crossings were measured and/or field surveyed. At a few locations, an attempt was made to survey channel modifications and at least 10 additional new street and road crossings which were not reflected on the 2003 DTM. The field survey work was done using survey grade Trimble 5700 GPS units (Base station and roving unit) and a Trimble optical total station.

Roughness Value (n-value) Determination: Mannings "n" values were determined for the channel and left and right over-banks by over-laying the digital cross sections on the January 2003 aerial photographs. The "n" values were adjusted using photographs and observations made during the field reconnaissance done in August/September 2005. A number of changes had occurred to the streams, including additional improved channels and new street and road crossings. Some of the improved channel reaches were not being mowed or maintained; therefore, higher “n” values were used.

Range of Manning’s n Values

Stream	Min. Channel	Max. Channel	Min. Overbk.	Max. Overbk.
Big Fossil Cr.	0.020	0.075	0.040	0.085
Whites Branch	0.020	0.075	0.050	0.080
Tributaries	0.018	0.070	0.055	0.085

Final Products: HEC-RAS models were completed for Big Fossil Creek, Whites Branch and 31 tributaries. Bridge and culvert models were done for approximately 120 street and road crossings. There were a large number of farm ponds, detention ponds, etc. which had to be accounted for in the hydraulic models. There were a total of 3,499 digital cross sections used in the HEC-RAS models.

Existing conditions water surface profiles were developed for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency floods for all streams studied. Table 4 is a sample of HEC-RAS output for Big Fossil Creek Reach 2 which extends from the Whites Branch confluence to Stream BFC-1 and Whites Branch Reaches 1 and 2 which cover a major damage center in the study area. Water surface profile plots for Big Fossil Creek and Whites Branch are included in Table 5.

Digital floodplain delineations were done using Geo-RAS for the existing conditions 25-, 100- and 500-year frequency flood events. Because of the size of the study area, a plot was not included in this write-up.

Comparison with FIS Profiles: Final results were compared to the effective FEMA profiles. The effective FEMA profiles are a mixture of several different studies performed over different time periods, each done with somewhat different methodology, leading to variations in the results (Table 6).

Summary and Conclusions

The Big Fossil Creek Watershed is rapidly changing and developing, especially in the upper part of the Whites Branch watershed, Streams BFC-1, BFC-2, BFC-2A, BFC-3, BFC-3A and Stream BFC-4 and Tributaries. Potential problems observed in the watershed, due largely to development were: increased sediment load in the streams and lack of maintenance in and near culvert crossings that has resulted in blockage of the openings from sediment and heavy growth in and near the crossings. Also, many of the improved grass lined channel reaches were not being mowed and adequately maintained.

Mapping for use in this study has been an issue from the beginning. One lesson learned is that LIDAR DEM data alone cannot produce digital products with a sufficient accuracy to perform digital hydrology and hydraulic analyses. LIDAR data in combination with conventional aerial mapping can produce satisfactory results. The only way to efficiently develop break lines is with aerial mapping techniques. Break lines are required to produce a digital product with sufficient accuracy to develop digital hydrology and hydraulic models.

Results from the hydraulic analysis indicate that the main damage center is the mobile home park on Whites Branch. The ongoing economic analyses will further define these areas.

The effects of future development on the main stem Big Fossil Creek discharges is expected to be minimal compared to the smaller undeveloped tributaries. Future development could have a significant impact on the undeveloped smaller tributaries such as Streams BFC-2 and BFC-2A.

TABLE 1 - SUMMARY DISCHARGE TABLE

Big Fossil Creek										
Description	**Analysis Point**	**Drainage Area (Sq. Miles)**	**2-Year (CFS)**	**5-Year (CFS)**	**10-Year (CFS)**	**25-Year (CFS)**	**50-Year (CFS)**	**100-Year (CFS)**	**250-Year (CFS)**	**500-Year (CFS)**
Head Water	BFC-01	0.20	172	349	414	497	555	615	692	749
Below Stream BFC-33.	JRBFC-01	0.24	208	425	506	607	678	752	846	916
@ Hicks Avondale School Rd.	JRBFC-02	0.36	284	635	767	932	1047	1162	1309	1420
@ Cross Section 1089+78.	JRBFC-03	0.43	264	644	808	995	1127	1259	1425	1549
@ Cross Section 1061+78.	JRBFC-04	0.58	292	776	991	1227	1391	1563	1779	1939
@Stream BFC Tr-01.	JRBFC-05	0.76	303	803	1089	1396	1585	1792	2065	2288
BelowStream BFC Tr-01.	JRBFC-05b	0.87	348	899	1216	1583	1797	2017	2331	2562
@Stream BFC-32.	JRBFC-06	0.96	346	887	1214	1593	1834	2079	2384	2625
Below Stream BFC-32.	JRBFC-06b	1.74	653	1752	2321	2992	3428	3870	4419	4846
@ Cross Section 997+59.	JRBFC-07	1.93	651	1745	2329	3016	3487	3977	4571	5016
@ Stream BFC-31.	JRBFC-08	2.08	637	1758	2341	3027	3512	4014	4630	5098
Below Stream BFC-31.	JRBFC-08b	2.66	744	2152	2866	3724	4337	4972	5748	6335
@ Stream BFC-30.	JRBFC-09	2.90	745	2163	2878	3763	4375	5021	5807	6422
Below Stream BFC-30.	JRBFC-09b	3.40	839	2504	3333	4391	5111	5863	6763	7479
Below Stream BFC Tr-02.	JRBFC-10b	3.84	937	2853	3821	5012	5790	6604	7631	8441
@ Cross Section 903+15.	JRBFC-11	4.16	897	2860	3865	5085	5897	6732	7796	8622
@ Stream BFC-28.	JRBFC-12	4.56	807	2676	3727	5019	5875	6752	7820	8659
Below Stream BFC-28.	JRBFC-12b	6.06	1176	3920	5449	7296	8494	9691	11162	12318
@ Stream BFC-27.	JRBFC-13	6.48	1149	3882	5440	7354	8609	9591	10845	11802
Below Stream BFC-27.	JRBFC-13b	7.85	1337	4785	6743	9182	10749	12208	13595	14730
Below Stream BFC Tr-03.	JRBFC-14b	8.27	1361	4970	7030	9598	11175	12663	13655	14658
@Rail Road above Walnut Lake.	JRBFC-15	8.62	1365	5042	7068	9520	10964	12277	12927	13616
@ Walnut Lake.	JRBFC-16	8.87	1116	4713	6890	9457	10986	12335	13033	13708
@ Stream BFC-4.	JRBFC-17	8.97	1101	4653	6826	9423	10988	12352	13084	13748
Below Stream BFC-4.	JRBFC-17b	15.51	2251	8189	11539	15415	17831	20045	22035	23410
Below Stream BFC Tr-04.	JRBFC-18b	16.01	2256	8305	11742	15732	18239	20525	22692	24172
@ Stream BFC-24.	JRBFC-19	16.41	2185	8211	11671	15713	18245	20593	22828	24358
Below Stream BFC-24.	JRBFC-19b	17.36	2193	8317	11908	16116	18758	21170	23661	25419
@ Stream BFC-3.	JRBFC-20	17.61	2170	8124	11756	16019	18706	21179	23682	25471
Below Stream BFC-3.	JRBFC-20b	18.78	2236	8429	12238	16770	19630	22275	25081	27107

Below Stream BFC Tr-05.	JRBFC-21b	19.01	2233	8433	12258	16819	19701	22371	25225	27281
@ Stream BFC Tr-06.	JRBFC-22	19.27	2212	8299	12190	16784	19719	22432	25318	27410
Below Stream BFC Tr-06.	JRBFC-22b	19.42	2210	8297	12196	16806	19752	22479	25388	27499
@ Stream BFC-23.	JRBFC-23	19.53	2202	8185	12064	16718	19703	22445	25343	27446
Below Stream BFC-23.	JRBFC-23b	20.17	2201	8205	12128	16858	19890	22694	25701	27885
@ I.H.-35.	JRBFC-24	21.14	2188	8156	12001	16749	19844	22751	25751	27920
@ Stream BFC Tr-07.	JRBFC-25	21.61	2177	8126	11834	16638	19769	22734	25793	27971
Below Stream BFC Tr-07.	JRBFC-25b	21.81	2175	8124	11837	16654	19793	22771	25847	28036
@ Stream BFC-2.	JRBFC-26	22.15	2165	8080	11797	16638	19769	22777	25866	28066
Below Stream BFC-2.	JRBFC-26b	28.21	2467	9299	13637	19526	23418	27359	31419	34393
@ Stream BFC-1.	JRBFC-27	28.32	2462	9280	13616	19512	23399	27362	31402	34390
Below Stream BFC-1.	JRBFC-27b	30.76	3445	9367	13778	19846	23786	27937	32138	35336
@ Stream BFC Tr-08.	JRBFC-28	30.99	3427	9329	13728	19767	23515	27660	31924	35097
Below Stream BFC Tr-08.	JRBFC-28b	31.46	3527	9337	13746	19811	23563	27732	32024	35219
@ Stream BFC Tr-09.	JRBFC-29	31.67	3425	9307	13653	19605	23243	27194	31294	34278
Below Stream BFC Tr-09.	JRBFC-29b	31.94	3441	9306	13653	19619	23262	27219	31330	34324
@Whites Branch.	JRBFC-30	32.02	3348	9247	13548	19421	23101	26965	31194	34160
Below Whites Branch.	JRBFC-30b	42.61	4630	13384	19162	26981	31947	36814	42693	46671
@ Tributary B.	JRBFC-31	43.22	4601	13114	18800	26328	31304	35865	41288	46005
Below Tributary B.	JRBFC-31b	44.00	4640	13184	18869	26419	31423	36006	41454	46211
Below Singing Hills Creek.	JRBFC-32b	49.35	5848	14031	19092	26822	32002	36768	42297	47165
@ Stream BFC-7.	JRBFC-33	49.72	5812	14017	19035	26768	31954	36763	42247	47017
Below Stream BFC-7.	JRBFC-33b	50.22	5834	14092	19042	26786	31980	36807	42294	47063
@ Stream BFC-6.	JRBFC-34	50.77	5691	13511	18882	26527	31787	36732	42084	46592
Below Stream BFC-6.	JRBFC-34b	51.50	5712	13567	18887	26546	31819	36793	42143	46652
@ Mackey Creek Diversion.	JRBFC-35	52.11	5684	13158	18481	25949	31506	36588	41572	45644
Below Mackey Creek Diversion.	JRBFC-35b	53.15	5742	13269	18498	25970	31559	36677	41670	45749
@ Belnap Street.	JRBFC-36	53.69	5752	13286	18445	25849	31486	36650	41505	45496
@ Big Fossil Project Sump Inlet.	JRBFC-37	54.02	5588	13203	18286	25766	31383	36568	41435	45391
Below Big Fossil Sump Inlet.	JRBFC-37b	55.17	5648	13373	18306	25785	31455	36680	41557	45516
@ U.S. Highway 121.	JRBFC-38	55.54	5654	13387	18286	25765	31452	36688	41570	45527
@ Little Fossil Creek.	JRBFC-39	56.10	5223	13343	18058	25387	31133	36358	41463	45369

Whites Branch

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	WB-01	0.07	50	137	164	197	219	243	273	295
@ Cross Section 442+14.	JRWB-02	0.18	142	282	331	394	438	485	543	587
@ Herritage Trace Parkway.	JRWB-03	0.28	240	479	570	684	762	844	948	1024
@ Stream WB Tr-01.	JRWB-04	0.41	295	623	762	930	1047	1168	1321	1436
Below Stream WB Tr-01.	JRWB-04b	0.54	437	903	1090	1321	1481	1649	1860	2019
@ Stream WB Tr-02.	JRWB-05	0.59	420	914	1111	1352	1519	1693	1918	2084
Below Stream WB Tr-02.	JRWB-05b	0.77	577	1243	1501	1818	2040	2271	2564	2783
@ Cross Section 353+72.	JRWB-06	1.00	588	1328	1657	2049	2325	2603	2960	3225
@ Stream WB-1.	JRWB-07	1.23	610	1398	1789	2247	2566	2891	3310	3623
Below Stream WB-1.	JRWB-07b	3.65	1564	3580	4537	5676	6421	7132	7994	8688
@ Stream WB-2.	JRWB-08	3.87	1542	3543	4535	5667	6441	7163	8050	8709
Below Stream WB-2.	JRWB-08b	4.57	1695	3934	5051	6316	7200	8024	9033	9745
@ Stream WB-3.	JRWB-09	4.85	1611	3858	5026	6333	7233	8109	9161	9923
Below Stream WB-3.	JRWB-09b	7.67	2601	6289	8227	10460	12039	13589	15474	16904
@ Stream WB Tr-03.	JRWB-10	8.31	2491	6230	8253	10554	12177	13833	15775	17258
Below Stream WB Tr-03.	JRWB-10b	8.68	2506	6287	8348	10689	12364	14050	16027	17577
@ Stream WB Tr-04.	JRWB-11	8.81	2445	6122	8198	10567	12236	13930	15932	17454
Below Stream WB Tr-04.	JRWB-11b	9.07	2454	6152	8252	10642	12328	14050	16072	17608
Below Watauga Road.	JRWB-12	9.64	2416	5940	8060	10498	12226	13984	16043	17629
@ Stream WB-4.	JRWB-13	10.10	2373	5803	7919	10377	12072	13554	15468	16963
Below Stream WB-4.	JRWB-13b	10.39	2377	5818	7949	10430	12145	13633	15561	17070
@ Big Fossil Creek.	JRWB-14	10.59	2325	5216	6914	8904	10275	11553	13041	14097

Stream WB-1

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream WB-1-01	0.06	78	159	185	218	241	265	296	319
@ Cross Section 168+85.	JRSWB-1-02	0.15	117	304	365	439	491	546	614	666
@ Stream WB-1 Tr-01.	JRSWB-1-03	0.18	50	232	337	440	503	565	645	705
Below Stream WB-1 Tr-01.	JRSWB-1-03b	0.23	99	281	417	573	660	746	850	930
@ Old Denton Road.	JRSWB-1-04	0.34	197	487	591	823	971	1105	1261	1377
@ Stream WB-1 Tr-02.	JRSWB-1-05	0.39	182	544	664	884	1039	1189	1364	1487
Below Stream WB-1 Tr-02.	JRSWB-1-05b	0.50	272	740	902	1192	1380	1560	1773	1929
@ Cross Section 113+20.	JRSWB-1-06	0.61	205	632	874	1240	1477	1723	1999	2205
@ Stream WB-1B.	JRSWB-1-07	0.85	405	826	1097	1476	1740	2010	2337	2562
Below Stream WB-1B.	JRSWB-1-07b	1.49	964	1951	2383	2996	3419	3835	4312	4662
@ Stream WB-1A.	JRSWB-1-08	1.61	931	1964	2421	3032	3448	3858	4359	4732
Below Stream WB-1A.	JRSWB-1-08b	1.96	1121	2445	3021	3769	4277	4779	5398	5861
@ Cross Section 46+81.	JRSWB-1-09	2.10	1064	2543	3112	3843	4346	4839	5502	6033
@ Shiver Road.	JRSWB-1-10	2.30	1105	2582	3253	4014	4530	5035	5674	6206
@ Whites Branch.	JRSWB-1-11	2.42	1098	2534	3216	4023	4549	5049	5687	6201

Stream WB-1B

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream WB-1B-01	0.39	452	824	966	1147	1276	1409	1580	1708
Below Stream WB-1B Tr-01.	JRSWB-1B-01b	0.55	638	1187	1392	1652	1836	2028	2273	2456
@ Stream WB-1.	JRSWB-1B-02	0.64	653	1169	1334	1559	1720	1874	2065	2215

Stream WB-2

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Shiver Road.	Stream WB-2-01	0.38	252	596	722	872	977	1086	1223	1326
@ Cross Section 21+17.	JRSWB-2-02	0.52	306	672	832	1020	1152	1287	1454	1580
@ Whites Branch.	JRSWB-2-03	0.70	518	1003	1272	1547	1736	1931	2173	2358

Stream WB-3

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream WB-3-01	0.43	563	1039	1212	1429	1583	1743	1949	2103
Below Stream WB-3 Tr-01.	JRSWB-3-01b	0.48	600	1122	1312	1550	1718	1893	2118	2286
@ Cross Section 149+40.	JRSWB-3-02	0.61	577	1126	1358	1631	1822	2017	2267	2454
@ Cross Section 127+51.	JRSWB-3-03	0.75	583	1195	1469	1806	2039	2277	2575	2797
@ Stream WB-3 Tr-02.	JRSWB-3-04	0.89	605	1282	1599	1984	2260	2535	2883	3143
@ Stream WB-3B.	JRSWB-3-05	1.66	1127	2361	2918	3583	4051	4527	5125	5573
Below Stream WB-3B.	JRSWB-3-05b	1.85	1242	2607	3213	3940	4454	4977	5648	6153
@ Stream WB-3A.	JRSWB-3-06	1.94	1220	2611	3222	3965	4486	5016	5685	6184
@ Island Park.	JRSWB-3-07	2.60	1394	3135	3920	4833	5473	6112	6918	7466
@ Whites Branch.	JRSWB-3-08	2.82	1305	3072	3927	4904	5588	6272	7109	7706

Stream WB-3A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Shiver Road.	Stream WB-3A-01	0.26	198	470	562	674	754	836	940	1018
@ Stream WB-3.	JRSWB-3A-02	0.41	319	696	829	991	1107	1229	1386	1503

Stream WB-4

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Whites Branch.	Stream WB-4-01	0.30	288	544	644	769	858	950	1068	1156

Stream BFC-1

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water and @ Thompson Rd.	Stream BFC-1-01	0.25	291	540	632	751	836	924	1037	1120
@ Summerfields Boulevard.	JRSBFC-1-02	0.37	383	741	873	1045	1166	1292	1443	1554
@ Cross Section 128+20.	JRSBFC-1-03	0.64	641	1256	1486	1777	1982	2197	2468	2674
@ Beach Street.	JRSBFC-1-04	0.84	797	1580	1900	2289	2558	2836	3180	3437
Below North Tarrant Parkway.	JRSBFC-1-05	1.19	1058	2081	2530	3011	3350	3684	4099	4451
@ Stream BFC-1A.	JRSBFC-1-06	1.28	1113	2176	2636	3147	3491	3845	4333	4709
Below Stream BFC-1A.	JRSBFC-1-06b	1.65	1478	2820	3396	4053	4503	4965	5591	6071
@ Stream BFC-1 Tr-01.	JRSBFC-1-07	1.92	1709	3209	3863	4621	5144	5680	6375	6903
Below Stream BFC-1 Tr-01.	JRSBFC-1-07b	2.22	2072	3777	4549	5450	6080	6705	7518	8115
@ Big Fossil Creek.	JRSBFC-1-08	2.44	1969	3779	4597	5566	6248	6931	7683	8298

Stream BFC-1A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-1.	Stream BFC-1A-01	0.37	414	683	803	956	1065	1178	1323	1431

Stream BFC-2

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream BFC-2-01	0.20	207	426	500	595	662	732	821	887
@ Cross Section 289+70.	JRSBFC-2-02	0.40	289	632	789	988	1118	1244	1401	1519
@ Stream BFC-2 Tr-01.	JRSBFC-2-03	0.61	260	655	847	1086	1248	1414	1619	1781
Below Stream BFC-2 Tr-01.	JRSBFC-2-03b	0.86	448	1030	1305	1640	1873	2111	2407	2634
@ U.S. Highway 287.	JRSBFC-2-04	1.12	278	891	1216	1628	1958	2262	2629	2899
@ Cross Section 154+77.	JRSBFC-2-05	1.52	426	880	1145	1571	1898	2265	2694	3032
@ Stream BFC-2A.	JRSBFC-2-06	1.93	528	1166	1460	1906	2201	2510	2825	3014
Below Stream BFC-2A.	JRSBFC-2-06b	4.52	776	1799	2566	3713	4479	5289	6381	7199
@ Stream BFC-2B.	JRSBFC-2-07	4.78	723	1838	2591	3742	4516	5336	6413	7250
Below Stream BFC-2B.	JRSBFC-2-07b	5.39	1047	2434	3129	4238	5053	5874	6784	7689
Below Riverside Drive.	JRSBFC-2-08b	5.65	1199	2784	3558	4695	5567	6476	7490	8239
Below Western Center Boulevard.	JRSBFC-2-09	5.88	1204	2892	3731	4918	5823	6765	7854	8643
@ Stream BFC-2 Tr-02.	JRSBFC-2-10	5.96	1212	2913	3738	4937	5869	6830	7962	8761
@ Big Fossil Creek.	JRSBFC-2-11	6.06	1230	2958	3797	4997	5940	6922	8086	8888

Stream BFC-2A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream BFC-2A-01	0.39	296	641	767	923	1033	1148	1292	1401
Below Lakes and Section 286+93.	JRSBFC-2A-02	0.55	182	442	670	983	1210	1383	1568	1717
@ Cross Section 263+30.	JRSBFC-2A-03	0.72	241	596	755	1089	1350	1589	1850	2039
@ Cross Section 224+12.	JRSBFC-2A-04	0.89	276	728	955	1320	1609	1911	2247	2490
@ Herritage Trace Parkway.	JRSBFC-2A-05	1.12	480	1109	1406	1772	2056	2380	2711	3022
@ Cross Section 175+48.	JRSBFC-2A-06	1.38	355	981	1336	1855	2202	2566	2992	3337
@I.H.-35.	JRSBFC-2A-07	1.71	425	1146	1513	2005	2373	2779	3229	3582
@ North Tarrant Parkway.	JRSBFC-2A-07b	1.77	443	1187	1562	2061	2427	2843	3313	3672
@ Stream BFC-2A Tr-02.	JRSBFC-2A-08	1.83	356	1006	1429	2030	2422	2840	3328	3613
Below Stream BFC-2A Tr-02.	JRSBFC-2A-08b	1.99	358	1025	1471	2114	2521	2958	3485	3751
@ Stream BFC-2A Tr-04.	JRSBFC-2A-09	2.04	350	1023	1467	2083	2526	2965	3497	3790
Below Stream BFC-2A Tr-03.	JRSBFC-2A-09b	2.29	379	1051	1528	2203	2678	3159	3752	4100
@ Big Fossil Creek.	JRSBFC-2A-10	2.58	319	1042	1495	2163	2679	3219	3860	4302

Stream BFC-2B

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream BFC-2B-01	0.31	355	655	768	913	1017	1124	1261	1363
@ North Riverside Drive.	JRSBFC-2B-02	0.50	485	938	1114	1331	1485	1646	1852	2006
@ Big Fossil Creek.	JRSBFC-2B-03	0.61	591	1122	1342	1613	1804	1999	2245	2430

Stream BFC-3

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ U.S. Highway 287.	Stream BFC-3-01	0.19	166	350	415	498	557	618	695	753
@ Cross Section 148+50.	JRSBFC-3-02	0.26	125	314	406	503	572	646	747	828
@ Cross Section 127+15.	JRSBFC-3-03	0.42	202	416	528	665	763	870	1005	1110
@ Harmon Road.	JRSBFC-3-04	0.60	297	652	819	1025	1156	1289	1458	1588
@ Cross Section 84+46.	JRSBFC-3-05	0.79	306	680	868	1113	1277	1443	1648	1806
@Stream BFC-3A.	JRSBFC-3-06	1.00	317	795	1045	1358	1568	1783	2047	2252
Below Stream BFC-3A.	JRSBFC-3-06b	1.10	369	907	1185	1532	1770	2009	2305	2527
@ Big Fossil Creek.	JRSBFC-3-07	1.17	341	909	1206	1573	1817	2064	2362	2589

Stream BFC-3A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-3.	Stream BFC-3A-01	0.10	103	208	245	293	327	362	406	439

Stream BFC-4

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water and @ Lake.	Stream BFC-4-01	0.21	244	431	506	602	671	743	834	902
@ Stream BFC-4 Tr-01.	JRSBFC-4-02	0.50	407	778	928	1115	1250	1389	1565	1697
Below Stream BFC-4 Tr-01.	JRSBFC-4-02b	0.80	477	909	1067	1250	1372	1495	1656	1794
@Stream BFC-4D.	JRSBFC-4-03	0.87	440	828	983	1134	1248	1348	1478	1588
Below Stream BFC-4D.	JRSBFC-4-03b	1.49	862	1645	1948	2272	2494	2714	2953	3125
Below Stream BFC-4C.	JRSBFC-4-04b	2.44	1170	2515	3005	3494	3802	4120	4482	4725
@ Stream BFC-4 Tr-02.	JRSBFC-4-05	2.57	1079	2344	2980	3502	3842	4183	4555	4837
Below Stream BFC-4 Tr-02.	JRSBFC-4-05b	2.75	1097	2410	3083	3657	4022	4387	4819	5144
@Stream BFC-4B.	JRSBFC-4-06	3.07	1049	2463	3136	3825	4274	4710	5223	5641
Below Stream BFC-4B.	JRSBFC-4-06b	4.08	1348	2865	3583	4330	4814	5301	5867	6328
@Stream BFC-4A.	JRSBFC-4-07	4.26	1248	2796	3536	4327	4845	5351	5946	6426
Below Stream BFC-4A.	JRSBFC-4-07b	6.10	1646	3998	5158	6443	7345	8301	9489	10434
@ F.M. 156 Blue Mound Road.	JRSBFC-4-08	6.32	1578	3950	5165	6510	7454	8453	9657	10616
@ Big Fossil Creek.	JRSBFC-4-09	6.54	1567	3949	5196	6587	7569	8595	9843	10825

Stream BFC-4A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Below Bonds Ranch Road.	Stream BFC-4A-01	0.15	200	364	424	501	556	613	686	740
@ Stream BFC-4A Tr-01.	JRSBFC-4A-02	0.21	223	432	508	606	675	747	838	905
Below Stream BFC-4A Tr-01.	JRSBFC-4A-02b	0.30	306	606	714	852	950	1051	1180	1276
@ Stream BFC-4A-1.	JRSBFC-4A-03	0.35	279	600	718	867	976	1089	1231	1338
Below Stream BFC-4A-1.	JRSBFC-4A-03b	0.67	454	1112	1361	1654	1863	2078	2350	2555
@ Stream BFC-4A Tr-02.	JRSBFC-4A-04	0.83	383	846	991	1158	1353	1586	1903	2172
Below Stream BFC-4A Tr-02.	JRSBFC-4A-04b	1.20	589	1320	1587	1892	2106	2327	2745	3129
@ Stream BFC-4A Tr-03.	JRSBFC-4A-05	1.23	579	1298	1581	1899	2121	2347	2758	3128
Below Stream BFC-4A Tr-03.	JRSBFC-4A-05b	1.56	787	1762	2166	2612	2925	3245	3656	4017
@ Blue Mound Road(South Cross)	JRSBFC-4A-06	1.67	787	1787	2218	2701	3044	3391	3828	4171
@ Stream BFC-4.	JRSBFC-4A-07	1.84	737	1810	2286	2835	3208	3597	4096	4490

Stream BFC-4A-1

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Below Bonds Ranch Road.	Stream BFC-4A-1-01	0.17	196	375	439	521	580	640	718	776
@ Stream BFC-4A-1 Tr-1.	JRSBFC-4A-1-02	0.19	185	378	444	530	590	657	740	801
Below Stream BFC-4A-1 Tr-1.	JRSBFC-4A-1-02b	0.24	233	499	587	698	777	859	968	1050
@ Cross Section 14+50.	JRSBFC-4A-1-03	0.28	206	534	639	765	854	947	1067	1156
@ Stream BFC-4A.	JRSBFC-4A-1-04	0.33	189	515	646	791	891	995	1125	1223

Stream BFC-4B

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Bonds Ranch Road.	Stream BFC-4B-01	0.28	327	573	671	797	887	980	1099	1188
@ East side of a Subdivision.	JRSBFC-4B-02	0.54	467	975	1176	1405	1571	1738	1954	2122
@ Stream BFC-4B-1 Tr-1.	JRSBFC-4B-03	0.69	455	752	839	921	974	1030	1102	1166
Below Stream BFC-4B-1 Tr-1.	JRSBFC-4B-03b	0.83	519	971	1122	1288	1384	1485	1612	1711
@ Stream BFC-4.	JRSBFC-4B-04	1.01	322	445	574	720	796	874	972	1044

Stream BFC-4C

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream BFC-4C-01	0.34	317	599	709	851	952	1056	1189	1288
@ Cross Section 19+67.	JRSBFC-4C-02	0.57	331	717	881	1084	1230	1379	1572	1716
@ Stream BFC-4.	JRSBFC-4C-03	0.92	513	1074	1274	1496	1633	1777	1961	2102

Stream BFC-4D

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-4D-1 Tr-1.	Stream BFC-4D-01	0.26	250	474	559	670	748	829	932	1010
Below Stream BFC-4D-1 Tr-1.	JRSBFC-4D-01b	0.51	514	961	1133	1354	1512	1675	1883	2038
@ Stream BFC-4.	JRSBFC-4D-02	0.62	442	837	975	1149	1262	1376	1485	1546

Stream BFC-23

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-23A.	Stream BFC-23-01	0.24	268	483	566	674	750	830	931	1006
Below Stream BFC-23A.	JRSBFC-23-01b	0.36	369	699	824	984	1097	1214	1363	1475
Below Stream BFC-23 Tr-01.	JRSBFC-23-02b	0.50	410	883	1059	1282	1434	1597	1797	1950
@ Stream BFC-23 Tr-02.	JRSBFC-23-03	0.53	398	865	1035	1267	1421	1588	1802	1970
Below Stream BFC-23 Tr-02.	JRSBFC-23-03b	0.60	419	909	1089	1335	1516	1700	1930	2111
@ Big Fossil Creek.	JRSBFC-23-04	0.64	397	900	1082	1336	1514	1697	1925	2099

Stream BFC-23A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-23.	Stream BFC-23A-01	0.12	104	224	265	318	355	394	443	480

Stream BFC-24

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-24 Tr-01.	Stream BFC-24-01	0.16	136	295	350	420	469	520	585	634
Below Stream BFC-24 Tr-01.	JRSBFC-24-01b	0.26	227	497	590	707	789	875	984	1065
Below Stream BFC-24 Tr-02.	JRSBFC-24-02b	0.45	329	770	951	1154	1292	1430	1607	1741
@ Cross Section 32+79.	JRSBFC-24-03	0.54	332	803	995	1219	1361	1509	1742	1905
@ Stream BFC-24A.	JRSBFC-24-04	0.62	318	796	995	1233	1390	1551	1774	1952
Below Stream BFC-24A.	JRSBFC-24-04b	0.87	574	1207	1525	1864	2103	2359	2678	2913
@ Big Fossil Creek.	JRSBFC-24-05	0.95	537	1222	1557	1950	2222	2488	2825	3107

Stream BFC-24A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Stream BFC-24.	Stream BFC-24A-01	0.26	363	594	693	819	909	1003	1123	1213

Stream BFC-27

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Highway 287 Business.	Stream BFC-27-01	0.38	424	757	889	1061	1184	1311	1473	1593
@ Stream BFC-27 Tr-01.	JRSBFC-27-02	0.54	295	759	962	1190	1344	1501	1695	1843
Below Stream BFC-27 Tr-01.	JRSBFC-27-02b	0.72	404	1054	1319	1622	1828	2039	2302	2501
@ Stream BFC-27 Tr-02.	JRSBFC-27-03	0.86	183	971	1343	1728	1965	2205	2508	2737
Below Stream BFC-27 Tr-02.	JRSBFC-27-03b	1.12	273	1271	1773	2305	2624	2942	3338	3637
@ Big Fossil Creek.	JRSBFC-27-04	1.37	279	1273	1853	2528	2915	3265	3704	4063

Stream BFC-28

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@ Highway 287 Business.	Stream BFC-28-01	0.42	483	913	1069	1271	1413	1562	1751	1892
@ Cross Section 102+42.	JRSBFC-28-02	0.64	473	1014	1216	1462	1638	1818	2051	2227
@ Stream BFC-28 Tr-01.	JRSBFC-28-03	0.76	410	1024	1280	1569	1770	1981	2248	2453
Below Stream BFC-28 Tr-01.	JRSBFC-28-03b	1.18	605	1565	1953	2395	2699	3017	3417	3721
@ Big Fossil Creek.	JRSBFC-28-04	1.51	500	1547	2045	2593	2976	3370	3858	4222

Stream BFC-30

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream BFC-30-01	0.13	100	244	291	349	390	433	487	527
@ Stream BFC-30A.	JRSBFC-30-02	0.24	90	291	386	501	575	649	745	815
Below Stream BFC-30A.	JRSBFC-30-02b	0.42	170	519	668	844	960	1078	1227	1338
@ Big Fossil Creek.	JRSBFC-30-03	0.50	148	528	691	863	978	1112	1279	1403

Stream BFC-30A

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@Stream BFC-30.	Stream BFC-30A-01	0.18	82	229	286	352	396	442	499	542

Stream BFC-31

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water.	Stream BFC-31-01	0.30	188	424	512	622	699	780	880	955
Below Stream BFC-31 Tr-01.	JRSBFC-31-01b	0.44	298	658	795	962	1081	1204	1358	1474
@ Big Fossil Creek.	JRSBFC-31-02	0.58	153	551	779	1039	1193	1343	1536	1682

Stream BFC-32

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
Head Water	Stream BFC-32-01	0.40	339	689	820	985	1103	1224	1377	1492
"@ Stream BFC-32 Tr-01.	JRSBFC-32-02	0.52	260	691	859	1060	1197	1335	1512	1659
"Below Stream BFC-32 Tr-01.	JRSBFC-32-02b	0.62	304	818	1039	1279	1443	1609	1822	1995
"@ Stream BFC-32 Tr-02.	JRSBFC-32-03	0.66	299	814	1042	1291	1464	1641	1861	2030
"Below Stream BFC-32 Tr-02.	JRSBFC-32-03b	0.73	316	873	1116	1398	1590	1781	2020	2204
@Big Fossil Creek.	JRSBFC-32-04	0.79	314	875	1135	1414	1612	1810	2059	2250

Stream BFC-33

Description	Analysis Point	Drainage Area (Sq. Miles)	2-Year (CFS)	5-Year (CFS)	10-Year (CFS)	25-Year (CFS)	50-Year (CFS)	100-Year (CFS)	250-Year (CFS)	500-Year (CFS)
@Big Fossil Creek	Stream BFC-33-01	0.04	54	109	127	150	166	183	205	221

TABLE 2 – BIG FOSSIL CREEK DISCHARGES COMPARED TO THE FIS DISCHARGES

TABLE 2 - Big Fossil Creek Discharges Compared to the FIS Discharges

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
@ Stream BFC-28.	JRBFC-12	4.56	3727	4550	**-18.1**	5875	6150	**-4.5**	6752	6900	**-2.1**	8659	8600	**0.7**
Below Stream BFC-28.	JRBFC-12b	6.06	5449	6100	**-10.7**	8494	8300	**2.3**	9691	9250	**4.8**	12318	11550	**6.7**
@Rail Road above Walnut Lake.	JRBFC-15	8.62	7068	5350	**32.1**	10964	8700	**26.0**	12277	9950	**23.4**	13616	12800	**6.4**
@ Stream BFC-4.	JRBFC-17	8.97	6826	5300	**28.8**	10988	8700	**26.3**	12352	10050	**22.9**	13748	13100	**4.9**
Below Stream BFC Tr-04.	JRBFC-18b	16.01	11742	10400	**12.9**	18239	16200	**12.6**	20525	18600	**10.4**	24172	24450	**-1.1**
@ Stream BFC-3.	JRBFC-20	17.61	11756	10510	**11.9**	18706	16900	**10.7**	21179	19950	**6.2**	25471	25960	**-1.9**
Below Stream BFC-3.	JRBFC-20b	18.78	12238	11180	**9.5**	19630	17900	**9.7**	22275	21090	**5.6**	27107	27510	**-1.5**
@ I.H.-35.	JRBFC-24	21.14	12001	10570	**13.5**	19844	16990	**16.8**	22751	20310	**12.0**	27920	26750	**4.4**
@ Stream BFC-2.	JRBFC-26	22.15	11797	10520	**12.1**	19769	16780	**17.8**	22777	20040	**13.7**	28066	26580	**5.6**
Below Stream BFC-2.	JRBFC-26b	28.21	13637	14600	**-6.6**	23418	22390	**4.6**	27359	26570	**3.0**	34393	34950	**-1.6**
@ Stream BFC-1.	JRBFC-27	28.32	13616	14590	**-6.7**	23399	22420	**4.4**	27362	26620	**2.8**	34390	34950	**-1.6**
Below Stream BFC-1.	JRBFC-27b	30.76	13778	15140	**-9.0**	23786	23180	**2.6**	27937	27450	**1.8**	35336	36180	**-2.3**
@Whites Branch.	JRBFC-30	32.02	13548	13700	**-1.1**	23101	20040	**15.3**	26965	23070	**16.9**	34160	29360	**16.3**
Below Whites Branch.	JRBFC-30b	42.61	19162	20020	**-4.3**	31947	28590	**11.7**	36814	32840	**12.1**	46671	41080	**13.6**
Below Tributary B.	JRBFC-31b	44.00	18869	19640	**-3.9**	31423	28020	**12.1**	36006	31770	**13.3**	46211	39400	**17.3**
Below Singing Hills Creek.	JRBFC-32b	49.35	19092	20670	**-7.6**	32002	29320	**9.1**	36768	33570	**9.5**	47165	41300	**14.2**
@ Mackey Creek Diversion.	JRBFC-35	52.11	18481	20520	**-9.9**	31506	29250	**7.7**	36588	33600	**8.9**	45644	41440	**10.1**
Below Mackey Creek Diversion.	JRBFC-35b	53.15	18498	20570	**-10.1**	31559	29340	**7.6**	36677	33730	**8.7**	45749	41670	**9.8**
@ Belnap Street.	JRBFC-36	53.69	18445	20300	**-9.1**	31486	29230	**7.7**	36650	33820	**8.4**	45496	42080	**8.1**
@ U.S. Highway 121.	JRBFC-38	55.54	18286	20269	**-9.8**	31452	29205	**7.7**	36688	33813	**8.5**	45527	42083	**8.2**
@ Little Fossil Creek.	JRBFC-39	56.10	18058	19469	**-7.2**	31133	28623	**8.8**	36358	33444	**8.7**	45369	42000	**8.0**

Whites Branch

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
@ Stream WB-1.	JRWB-07	1.23	1789	1850	**-3.3**	2566	2500	**2.6**	2891	2750	**5.1**	3623	3450	**5.0**
Below Stream WB-1.	JRWB-07b	3.65	4537	5150	**-11.9**	6421	6900	**-6.9**	7132	7600	**-6.2**	8688	9550	**-9.0**
@ Stream WB-2.	JRWB-08	3.87	4535	4900	**-7.4**	6441	6800	**-5.3**	7163	7550	**-5.1**	8709	9650	**-9.8**
Below Stream WB-2.	JRWB-08b	4.57	5051	5950	**-15.1**	7200	8200	**-12.2**	8024	9100	**-11.8**	9745	11550	**-15.6**
@ Stream WB-3.	JRWB-09	4.85	5026	5950	**-15.5**	7233	8200	**-11.8**	8109	9100	**-10.9**	9923	11700	**-15.2**
Below Stream WB-3.	JRWB-09b	7.67	8227	9100	**-9.6**	12039	12450	**-3.3**	13589	13850	**-1.9**	16904	17700	**-4.5**
Below Watauga Road.	JRWB-12	9.64	8060	8340	**-3.4**	12226	12040	**1.5**	13984	13860	**0.9**	17629	17580	**0.3**
@ Big Fossil Creek.	JRWB-14	10.59	6914	7980	**-13.4**	10275	11560	**-11.1**	11553	13320	**-13.3**	14097	17140	**-17.8**

Stream WB-1

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change

Below Stream WB-1A.	JRSWB-1-08b	1.96	3021	2900	4.2	4277	3850	11.1	4779	4250	12.5	5861	5400	8.5
@ Whites Branch.	JRSWB-1-11	2.42	3216	3400	-5.4	4549	4550	0.0	5049	5050	0.0	6201	6550	-5.3

Stream BFC-1

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
Below North Tarrant Parkway.	JRSBFC-1-05	1.19	2530	2390	5.9	3350	3150	6.3	3684	3480	5.9	4451	4240	5.0
@ Stream BFC-1A.	JRSBFC-1-06	1.28	2636	2660	-0.9	3491	3520	-0.8	3845	3890	-1.2	4709	4740	-0.7
Below Stream BFC-1A.	JRSBFC-1-06b	1.65	3396	3340	1.7	4503	4410	2.1	4965	4880	1.7	6071	5940	2.2
@ Stream BFC-1 Tr-01.	JRSBFC-1-07	1.92	3863	3830	0.9	5144	5080	1.3	5680	5630	0.9	6903	6860	0.6
Below Stream BFC-1 Tr-01.	JRSBFC-1-07b	2.22	4549	4070	11.8	6080	5410	12.4	6705	6000	11.7	8115	7310	11.0
@ Big Fossil Creek.	JRSBFC-1-08	2.44	4597	4070	12.9	6248	5420	15.3	6931	6010	15.3	8298	7320	13.4

Stream BFC-2

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
@ Stream BFC-2A.	JRSBFC-2-06	1.93	1460	2000	-27.0	2201	2850	-22.8	2510	3150	-20.3	3014	3950	-23.7
Below Stream BFC-2A.	JRSBFC-2-06b	4.52	2566	4450	-42.3	4479	6050	-26.0	5289	6750	-21.6	7199	8450	-14.8
@ Big Fossil Creek.	JRSBFC-2-11	6.06	3797	5350	-29.0	5940	7500	-20.8	6922	8400	-17.6	8888	10600	-16.2

Stream BFC-2A

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
@ Big Fossil Creek.	JRSBFC-2A-10	2.58	1495	2500	-40.2	2679	3400	-21.2	3219	3800	-15.3	4302	4750	-9.4

Stream BFC-3

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
@ Big Fossil Creek.	JRSBFC-3-07	1.17	1206	1600	-24.6	1817	2150	-15.5	2064	2350	-12.2	2589	3000	-13.7

Stream BFC-4

Description	Analysis Point	Drainage Area (Sq. Miles)	10-Year (CFS)	FEMA 10-Year (CFS)	% Change	50-Year (CFS)	FEMA 50-Year (CFS)	% Change	100-Year (CFS)	FEMA 100-Year (CFS)	% Change	500-Year (CFS)	FEMA 500-Year (CFS)	% Change
@Stream BFC-4D.	JRSBFC-4-03	0.87	983	1350	-27.2	1248	1800	-30.7	1348	2000	-32.6	1588	2500	-36.5
Below Stream BFC-4C.	JRSBFC-4-04b	2.44	3005	4050	-25.8	3802	5400	-29.6	4120	5950	-30.8	4725	7500	-37.0
@Stream BFC-4B.	JRSBFC-4-06	3.07	3136	3550	-11.7	4274	4900	-12.8	4710	5500	-14.4	5641	7050	-20.0
Below Stream BFC-4B.	JRSBFC-4-06b	4.08	3583	4950	-27.6	4814	6750	-28.7	5301	7600	-30.2	6328	9700	-34.8
@Stream BFC-4A.	JRSBFC-4-07	4.26	3536	4900	-27.8	4845	6800	-28.8	5351	7600	-29.6	6426	9650	-33.4
Below Stream BFC-4A.	JRSBFC-4-07b	6.10	5158	7150	-27.9	7345	9800	-25.1	8301	11000	-24.5	10434	13850	-24.7

@ Big Fossil Creek.	JRSBFC-4-09	6.54	5196	7100	**-26.8**	7569	9900	**-23.5**	8595	11200	**-23.3**	10825	14200	**-23.8**
Stream BFC-4A														
				FEMA			**FEMA**			**FEMA**			**FEMA**	
Description	**Analysis Point**	**Drainage Area**	**10-Year**	**10-Year**	%	**50-Year**	**50-Year**	%	**100-Year**	**100-Year**	%	**500-Year**	**500-Year**	%
		(Sq. Miles)	**(CFS)**	**(CFS)**	**Change**	**(CFS)**	**(CFS)**	**Change**	**(CFS)**	**(CFS)**	**Change**	**(CFS)**	**(CFS)**	**Change**
@ Stream BFC-4.	JRSBFC-4A-07	1.84	2286	2600	**-12.1**	3208	3500	**-8.3**	3597	3900	**-7.8**	4490	4900	**-8.4**

TABLE 3 – LIST OF STREAMS STUDIED

Streams modeled in Detail with Geo-RAS and HEC-RAS

Stream Name	Number of Reaches	End Stream Station (Ft.)	Stream Miles	Number of Culverts	Number of Bridges	Number of Dams	Number of Cross Sections
Big Fossil Creek	14	112595.90	21.32	10	24	23	741
Stream BFC-1	2	18997.94	3.60	7	1	1	192
Stream BFC-1A	1	2879.88	0.55	4		1	48
Stream BFC-2	3	32775.16	6.21	8	5	8	262
Stream BFC-2A	1	31558.63	5.98	5		9	242
Stream BFC-2B	1	4542.81	0.86	2			43
Stream BFC-3	2	17485.98	3.31	2		4	110
Stream BFC-3A	1	2060.06	0.39				17
Stream BFC-4	5	21600.77	4.09	3	2	3	146
Stream BFC-4A	2	12191.36	2.31	6		3	128
Stream BFC-4A-1	1	3834.15	0.73	1		3	41
Stream BFC-4B	1	11483.20	2.17	2		3	98
Stream BFC-4C	1	6088.76	1.15	2		1	61
Stream BFC-4D	1	4730.34	0.90	1		2	42
Stream BFC-23	2	4817.78	0.91				41
Stream BFC-23A	1	1212.27	0.23				17
Stream BFC-24	2	5963.95	1.13	2		2	62
Stream BFC-24A	1	933.94	0.18	1			26
Stream BFC-27	1	14590.35	2.76	4		3	117
Stream BFC-28	1	13651.07	2.59	4		5	112
Stream BFC-30	2	6325.68	1.20	1		3	71
Stream BFC-30A	1	981.90	0.19				12
Stream BFC-31	1	4013.46	0.76			2	40
Stream BFC-32	1	6331.22	1.20			3	50
Stream BFC-33	1	469.52	0.09	1			10
Whites Branch	5	47067.06	8.91	5	3	2	345
Stream WB-1	2	18644.34	3.53	5		5	200
Stream WB-1B	1	2723.83	0.52	1			26
Stream WB-2	1	4445.19	0.84	2			37
Stream WB-3	3	15511.62	2.94	3			122
Stream WB-3A	1	1134.18	0.21				11
Stream WB-3B	1	756.94	0.14	1			11
Stream WB-4	1	2131.16	0.40	1			18
Total			**82.30**	**84**	**35**	**86**	**3499**

Streams modeled with Geo-RAS and HEC-RAS to produce storage and rating data for the Hydrology(HMS).

Stream Name	Number of Reaches	End Stream Station (Ft.)	Stream Miles	Number of Culverts	Number of Bridges	Number of Dams	Number of Cross Sections
Mackey Creek Diversion	1	3498.77	0.66	2			44
Mackey Creek	1	5549.02	0.39	3			33
Singing Hills Creek	2	24132.70	4.57	9	2	3	263
Bunker Hill Creek	1	14960.35	2.83	10		1	194
Total			8.45	24	2	4	534

TABLE 4 – RAS OUTPUT TABLE

HEC-RAS Plan: BFC_Watershd

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	35784.58	2-Year	3348.00	532.89	542.49	6.21	177.77	342.68	164.91
BigFossilCreek	Reach2	35784.58	5-Year	9247.00	532.89	550.18	4.72	0.00	365.23	365.23
BigFossilCreek	Reach2	35784.58	10-Year	13548.00	532.89	554.46	4.55	0.00	380.36	380.36
BigFossilCreek	Reach2	35784.58	25-Year	19421.00	532.89	560.22	4.39	0.00	399.24	399.24
BigFossilCreek	Reach2	35784.58	50-Year	23101.00	532.89	564.04	4.26	0.00	401.99	401.99
BigFossilCreek	Reach2	35784.58	100-Year	26965.00	532.89	569.72	3.90	0.00	407.82	407.82
BigFossilCreek	Reach2	35784.58	250-Year	31194.00	532.89	570.39	4.41	0.00	408.50	408.50
BigFossilCreek	Reach2	35784.58	500-Year	34160.00	532.89	570.81	4.75	0.00	408.93	408.93
BigFossilCreek	Reach2	35898.64	2-Year	3348.00	533.06	543.14	4.23	242.87	427.97	185.11
BigFossilCreek	Reach2	35898.64	5-Year	9247.00	533.06	550.32	3.88	0.00	452.70	452.70
BigFossilCreek	Reach2	35898.64	10-Year	13548.00	533.06	554.57	3.74	0.00	460.75	460.75
BigFossilCreek	Reach2	35898.64	25-Year	19421.00	533.06	560.31	3.61	0.00	471.64	471.64
BigFossilCreek	Reach2	35898.64	50-Year	23101.00	533.06	564.11	3.52	0.00	478.45	478.45
BigFossilCreek	Reach2	35898.64	100-Year	26965.00	533.06	569.78	3.23	0.00	488.69	488.69
BigFossilCreek	Reach2	35898.64	250-Year	31194.00	533.06	570.46	3.64	0.00	489.91	489.91
BigFossilCreek	Reach2	35898.64	500-Year	34160.00	533.06	570.89	3.92	0.00	490.70	490.70
BigFossilCreek	Reach2	36023.67	2-Year	3348.00	533.06	543.18	7.02	310.24	381.37	71.12
BigFossilCreek	Reach2	36023.67	5-Year	9247.00	533.06	550.35	4.98	0.00	405.32	405.32
BigFossilCreek	Reach2	36023.67	10-Year	13548.00	533.06	554.58	4.49	0.00	425.43	425.43
BigFossilCreek	Reach2	36023.67	25-Year	19421.00	533.06	560.32	4.12	0.00	448.24	448.24
BigFossilCreek	Reach2	36023.67	50-Year	23101.00	533.06	564.12	3.93	0.00	455.53	455.53
BigFossilCreek	Reach2	36023.67	100-Year	26965.00	533.06	569.79	3.52	0.00	466.40	466.40
BigFossilCreek	Reach2	36023.67	250-Year	31194.00	533.06	570.47	3.96	0.00	467.70	467.70
BigFossilCreek	Reach2	36023.67	500-Year	34160.00	533.06	570.90	4.26	0.00	468.53	468.53
BigFossilCreek	Reach2	36273.23	2-Year	3348.00	533.31	544.59	4.74	27.28	359.54	332.26
BigFossilCreek	Reach2	36273.23	5-Year	9247.00	533.31	550.61	4.61	0.00	382.28	382.28
BigFossilCreek	Reach2	36273.23	10-Year	13548.00	533.31	554.72	4.40	0.00	387.66	387.66
BigFossilCreek	Reach2	36273.23	25-Year	19421.00	533.31	560.39	4.22	0.00	399.09	399.09
BigFossilCreek	Reach2	36273.23	50-Year	23101.00	533.31	564.17	4.10	0.00	408.28	408.28
BigFossilCreek	Reach2	36273.23	100-Year	26965.00	533.31	569.81	3.81	0.00	480.59	480.59
BigFossilCreek	Reach2	36273.23	250-Year	31194.00	533.31	570.50	4.28	0.00	482.45	482.45
BigFossilCreek	Reach2	36273.23	500-Year	34160.00	533.31	570.93	4.60	0.00	483.65	483.65
BigFossilCreek	Reach2	36513.31	2-Year	3348.00	533.56	545.12	3.79	8.88	273.78	264.90
BigFossilCreek	Reach2	36513.31	5-Year	9247.00	533.56	550.81	4.92	0.00	302.47	302.47
BigFossilCreek	Reach2	36513.31	10-Year	13548.00	533.56	554.83	4.98	0.00	325.79	325.79
BigFossilCreek	Reach2	36513.31	25-Year	19421.00	533.56	560.45	4.86	0.00	364.16	364.16
BigFossilCreek	Reach2	36513.31	50-Year	23101.00	533.56	564.21	4.68	0.00	372.05	372.05
BigFossilCreek	Reach2	36513.31	100-Year	26965.00	533.56	569.83	4.25	0.00	395.46	395.46
BigFossilCreek	Reach2	36513.31	250-Year	31194.00	533.56	570.52	4.81	0.00	405.37	405.37
BigFossilCreek	Reach2	36513.31	500-Year	34160.00	533.56	570.96	5.18	0.00	410.40	410.40
BigFossilCreek	Reach2	36721.00	2-Year	3348.00	534.06	545.42	3.62	0.00	295.65	289.97
BigFossilCreek	Reach2	36721.00	5-Year	9247.00	534.06	551.13	4.16	0.00	406.39	406.39
BigFossilCreek	Reach2	36721.00	10-Year	13548.00	534.06	555.09	4.06	0.00	431.82	431.82
BigFossilCreek	Reach2	36721.00	25-Year	19421.00	534.06	560.65	3.86	0.00	464.92	464.92
BigFossilCreek	Reach2	36721.00	50-Year	23101.00	534.06	564.38	3.70	0.00	474.96	474.96
BigFossilCreek	Reach2	36721.00	100-Year	26965.00	534.06	569.96	3.32	0.00	490.12	490.12
BigFossilCreek	Reach2	36721.00	250-Year	31194.00	534.06	570.68	3.73	0.00	492.10	492.10
BigFossilCreek	Reach2	36721.00	500-Year	34160.00	534.06	571.15	4.01	0.00	493.37	493.37
BigFossilCreek	Reach2	37057.29	2-Year	3348.00	534.06	545.89	5.92	90.60	312.23	221.64
BigFossilCreek	Reach2	37057.29	5-Year	9247.00	534.06	551.39	5.74	0.00	435.26	435.26
BigFossilCreek	Reach2	37057.29	10-Year	13548.00	534.06	555.27	4.97	0.00	473.39	473.39
BigFossilCreek	Reach2	37057.29	25-Year	19421.00	534.06	560.76	4.29	0.00	521.13	521.13
BigFossilCreek	Reach2	37057.29	50-Year	23101.00	534.06	564.47	3.91	0.00	534.12	534.12
BigFossilCreek	Reach2	37057.29	100-Year	26965.00	534.06	570.02	3.35	0.00	557.35	557.35
BigFossilCreek	Reach2	37057.29	250-Year	31194.00	534.06	570.76	3.74	0.00	560.14	560.14
BigFossilCreek	Reach2	37057.29	500-Year	34160.00	534.06	571.24	4.01	0.00	561.94	561.94
BigFossilCreek	Reach2	37354.69	2-Year	3348.00	534.06	546.81	3.90	131.48	428.42	296.94
BigFossilCreek	Reach2	37354.69	5-Year	9247.00	534.06	551.88	4.41	0.00	555.71	555.71
BigFossilCreek	Reach2	37354.69	10-Year	13548.00	534.06	555.55	3.90	0.00	590.34	590.34
BigFossilCreek	Reach2	37354.69	25-Year	19421.00	534.06	560.92	3.37	0.00	639.68	639.68
BigFossilCreek	Reach2	37354.69	50-Year	23101.00	534.06	564.58	3.10	0.00	671.61	671.61
BigFossilCreek	Reach2	37354.69	100-Year	26965.00	534.06	570.10	2.63	0.00	693.78	693.78

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	37354.69	250-Year	31194.00	534.06	570.85	2.93	0.00	696.91	696.91
BigFossilCreek	Reach2	37354.69	500-Year	34160.00	534.06	571.34	3.14	0.00	698.95	698.95
BigFossilCreek	Reach2	37721.35	2-Year	3348.00	535.81	547.38	3.46	186.07	582.68	212.89
BigFossilCreek	Reach2	37721.35	5-Year	9247.00	535.81	552.24	3.56	0.00	624.38	624.38
BigFossilCreek	Reach2	37721.35	10-Year	13548.00	535.81	555.75	3.17	0.00	663.67	663.67
BigFossilCreek	Reach2	37721.35	25-Year	19421.00	535.81	561.03	2.75	0.00	718.67	718.67
BigFossilCreek	Reach2	37721.35	50-Year	23101.00	535.81	564.66	2.54	0.00	756.50	756.50
BigFossilCreek	Reach2	37721.35	100-Year	26965.00	535.81	570.14	2.18	0.00	790.89	790.89
BigFossilCreek	Reach2	37721.35	250-Year	31194.00	535.81	570.90	2.43	0.00	795.30	795.30
BigFossilCreek	Reach2	37721.35	500-Year	34160.00	535.81	571.40	2.60	0.00	798.17	798.17
BigFossilCreek	Reach2	38077.48	2-Year	3441.00	537.82	548.05	4.73	632.21	937.15	304.94
BigFossilCreek	Reach2	38077.48	5-Year	9306.00	537.82	552.53	3.52	0.00	958.38	958.38
BigFossilCreek	Reach2	38077.48	10-Year	13653.00	537.82	555.91	2.78	0.00	972.03	972.03
BigFossilCreek	Reach2	38077.48	25-Year	19619.00	537.82	561.12	2.25	0.00	993.06	993.06
BigFossilCreek	Reach2	38077.48	50-Year	23262.00	537.82	564.73	2.03	0.00	1010.91	1010.91
BigFossilCreek	Reach2	38077.48	100-Year	27219.00	537.82	570.18	1.73	0.00	1056.69	1056.69
BigFossilCreek	Reach2	38077.48	250-Year	31330.00	537.82	570.96	1.91	0.00	1060.94	1060.94
BigFossilCreek	Reach2	38077.48	500-Year	34324.00	537.82	571.46	2.04	0.00	1063.36	1063.36
BigFossilCreek	Reach2	38515.55	2-Year	3441.00	539.31	548.87	3.13	220.65	1067.44	587.10
BigFossilCreek	Reach2	38515.55	5-Year	9306.00	539.31	552.73	2.91	0.00	1129.90	1129.90
BigFossilCreek	Reach2	38515.55	10-Year	13653.00	539.31	555.99	2.37	0.00	1197.24	1197.24
BigFossilCreek	Reach2	38515.55	25-Year	19619.00	539.31	561.16	1.87	0.00	1315.65	1315.65
BigFossilCreek	Reach2	38515.55	50-Year	23262.00	539.31	564.75	1.65	0.00	1363.96	1363.96
BigFossilCreek	Reach2	38515.55	100-Year	27219.00	539.31	570.20	1.38	0.00	1455.75	1455.75
BigFossilCreek	Reach2	38515.55	250-Year	31330.00	539.31	570.98	1.53	0.00	1502.80	1502.80
BigFossilCreek	Reach2	38515.55	500-Year	34324.00	539.31	571.49	1.65	0.00	1536.07	1536.07
BigFossilCreek	Reach2	38960.83	2-Year	3441.00	539.32	549.30	3.67	212.78	481.49	268.71
BigFossilCreek	Reach2	38960.83	5-Year	9306.00	539.32	552.88	4.91	0.00	681.53	681.53
BigFossilCreek	Reach2	38960.83	10-Year	13653.00	539.32	556.04	4.25	0.00	690.91	690.91
BigFossilCreek	Reach2	38960.83	25-Year	19619.00	539.32	561.15	3.51	0.00	709.09	709.09
BigFossilCreek	Reach2	38960.83	50-Year	23262.00	539.32	564.73	3.37	0.00	1128.86	1094.88
BigFossilCreek	Reach2	38960.83	100-Year	27219.00	539.32	570.19	2.65	0.00	2022.29	2022.29
BigFossilCreek	Reach2	38960.83	250-Year	31330.00	539.32	570.97	2.86	0.00	2062.59	2062.59
BigFossilCreek	Reach2	38960.83	500-Year	34324.00	539.32	571.48	3.00	0.00	2085.38	2085.38
BigFossilCreek	Reach2	39144.58	2-Year	3425.00	539.32	549.57	2.10	249.30	542.74	293.43
BigFossilCreek	Reach2	39144.58	5-Year	9307.00	539.32	553.15	3.40	0.00	688.77	688.77
BigFossilCreek	Reach2	39144.58	10-Year	13653.00	539.32	556.16	3.40	0.00	697.76	697.76
BigFossilCreek	Reach2	39144.58	25-Year	19605.00	539.32	561.20	3.08	0.00	712.84	712.84
BigFossilCreek	Reach2	39144.58	50-Year	23243.00	539.32	564.77	2.90	0.00	755.49	755.49
BigFossilCreek	Reach2	39144.58	100-Year	27194.00	539.32	570.20	2.58	0.00	2041.21	2036.30
BigFossilCreek	Reach2	39144.58	250-Year	31294.00	539.32	570.97	2.82	0.00	2072.15	2072.15
BigFossilCreek	Reach2	39144.58	500-Year	34278.00	539.32	571.48	2.98	0.00	2092.84	2092.84
BigFossilCreek	Reach2	39428.62	2-Year	3425.00	539.31	549.69	1.94	129.89	623.15	482.56
BigFossilCreek	Reach2	39428.62	5-Year	9307.00	539.31	553.36	3.07	0.00	749.16	749.16
BigFossilCreek	Reach2	39428.62	10-Year	13653.00	539.31	556.31	3.15	0.00	759.63	759.63
BigFossilCreek	Reach2	39428.62	25-Year	19605.00	539.31	561.28	2.98	0.00	777.20	777.20
BigFossilCreek	Reach2	39428.62	50-Year	23243.00	539.31	564.84	2.83	0.00	789.74	789.74
BigFossilCreek	Reach2	39428.62	100-Year	27194.00	539.31	570.24	2.55	0.00	2137.55	2137.55
BigFossilCreek	Reach2	39428.62	250-Year	31294.00	539.31	571.02	2.78	0.00	2162.07	2162.07
BigFossilCreek	Reach2	39428.62	500-Year	34278.00	539.31	571.53	2.95	0.00	2179.54	2179.54
BigFossilCreek	Reach2	39519.57	2-Year	3425.00	539.31	549.74	1.74	1136.92	1633.71	482.06
BigFossilCreek	Reach2	39519.57	5-Year	9307.00	539.31	553.44	2.88	994.17	1729.21	735.04
BigFossilCreek	Reach2	39519.57	10-Year	13653.00	539.31	556.37	3.20	736.45	1740.99	1004.54
BigFossilCreek	Reach2	39519.57	25-Year	19605.00	539.31	561.33	2.76	652.19	1761.19	1109.00
BigFossilCreek	Reach2	39519.57	50-Year	23243.00	539.31	564.88	2.52	618.11	1820.58	1202.47
BigFossilCreek	Reach2	39519.57	100-Year	27194.00	539.31	570.27	2.32	0.00	3123.46	3123.46
BigFossilCreek	Reach2	39519.57	250-Year	31294.00	539.31	571.06	2.47	0.00	3149.35	3149.35
BigFossilCreek	Reach2	39519.57	500-Year	34278.00	539.31	571.57	2.58	0.00	3167.03	3167.03
BigFossilCreek	Reach2	39614.37	2-Year	3425.00	539.31	549.76	2.25	786.78	1140.59	353.81
BigFossilCreek	Reach2	39614.37	5-Year	9307.00	539.31	553.46	3.51	778.01	1204.22	426.20
BigFossilCreek	Reach2	39614.37	10-Year	13653.00	539.31	556.36	3.80	771.02	1216.30	445.28

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	39614.37	25-Year	19605.00	539.31	561.28	3.90	661.66	1239.22	577.56
BigFossilCreek	Reach2	39614.37	50-Year	23243.00	539.31	564.83	3.65	642.00	1316.83	674.83
BigFossilCreek	Reach2	39614.37	100-Year	27194.00	539.31	570.23	3.26	0.00	2579.50	2511.00
BigFossilCreek	Reach2	39614.37	250-Year	31294.00	539.31	571.02	3.47	0.00	2605.59	2605.59
BigFossilCreek	Reach2	39614.37	500-Year	34278.00	539.31	571.53	3.59	0.00	2622.05	2622.05
BigFossilCreek	Reach2	39973.03	2-Year	3425.00	539.50	549.83	3.38	474.35	631.35	157.00
BigFossilCreek	Reach2	39973.03	5-Year	9307.00	539.50	553.46	5.68	458.03	646.08	188.05
BigFossilCreek	Reach2	39973.03	10-Year	13653.00	539.50	556.29	6.18	446.20	661.20	215.00
BigFossilCreek	Reach2	39973.03	25-Year	19605.00	539.50	561.18	5.83	425.59	681.57	255.98
BigFossilCreek	Reach2	39973.03	50-Year	23243.00	539.50	564.72	5.35	385.40	727.35	341.95
BigFossilCreek	Reach2	39973.03	100-Year	27194.00	539.50	570.20	3.99	0.00	1895.75	1813.82
BigFossilCreek	Reach2	39973.03	250-Year	31294.00	539.50	570.98	4.26	0.00	1921.25	1921.25
BigFossilCreek	Reach2	39973.03	500-Year	34278.00	539.50	571.49	4.42	0.00	1940.75	1940.75
BigFossilCreek	Reach2	40159.99	2-Year	3425.00	540.12	549.92	3.69	398.37	554.84	156.46
BigFossilCreek	Reach2	40159.99	5-Year	9307.00	540.12	553.63	5.94	383.10	570.25	187.16
BigFossilCreek	Reach2	40159.99	10-Year	13653.00	540.12	556.44	6.43	371.86	582.00	210.14
BigFossilCreek	Reach2	40159.99	25-Year	19605.00	540.12	561.27	6.04	352.55	607.68	255.13
BigFossilCreek	Reach2	40159.99	50-Year	23243.00	540.12	564.80	5.50	320.40	803.30	374.84
BigFossilCreek	Reach2	40159.99	100-Year	27194.00	540.12	570.21	4.19	0.00	1646.42	1569.27
BigFossilCreek	Reach2	40159.99	250-Year	31294.00	540.12	570.99	4.49	0.00	1673.11	1673.11
BigFossilCreek	Reach2	40159.99	500-Year	34278.00	540.12	571.50	4.68	0.00	1692.24	1692.24
BigFossilCreek	Reach2	40320.39	2-Year	3425.00	540.90	550.03	3.83	551.39	696.29	144.90
BigFossilCreek	Reach2	40320.39	5-Year	9307.00	540.90	553.79	6.19	534.73	713.23	178.50
BigFossilCreek	Reach2	40320.39	10-Year	13653.00	540.90	556.58	6.71	523.73	726.19	202.46
BigFossilCreek	Reach2	40320.39	25-Year	19605.00	540.90	561.35	6.33	504.77	749.51	244.73
BigFossilCreek	Reach2	40320.39	50-Year	23243.00	540.90	564.85	5.79	481.09	857.51	346.69
BigFossilCreek	Reach2	40320.39	100-Year	27194.00	540.90	570.21	4.57	142.11	1648.11	1461.73
BigFossilCreek	Reach2	40320.39	250-Year	31294.00	540.90	570.99	4.89	0.00	1676.35	1607.56
BigFossilCreek	Reach2	40320.39	500-Year	34278.00	540.90	571.50	5.11	0.00	1694.59	1694.59
BigFossilCreek	Reach2	40540.54	2-Year	3425.00	541.33	550.18	4.16	474.60	614.21	139.61
BigFossilCreek	Reach2	40540.54	5-Year	9307.00	541.33	554.04	6.54	459.39	630.44	171.05
BigFossilCreek	Reach2	40540.54	10-Year	13653.00	541.33	556.80	7.09	448.65	642.02	193.37
BigFossilCreek	Reach2	40540.54	25-Year	19605.00	541.33	561.48	6.71	430.42	663.68	233.26
BigFossilCreek	Reach2	40540.54	50-Year	23243.00	541.33	564.93	6.13	416.07	781.68	355.83
BigFossilCreek	Reach2	40540.54	100-Year	27194.00	541.33	570.23	4.85	156.82	1457.81	1228.12
BigFossilCreek	Reach2	40540.54	250-Year	31294.00	541.33	571.01	5.22	100.63	1487.33	1386.70
BigFossilCreek	Reach2	40540.54	500-Year	34278.00	541.33	571.52	5.44	0.00	1502.76	1502.76
BigFossilCreek	Reach2	40679.40	2-Year	3425.00	541.33	550.33	3.94	465.05	610.45	145.39
BigFossilCreek	Reach2	40679.40	5-Year	9307.00	541.33	554.30	6.20	450.16	624.49	174.33
BigFossilCreek	Reach2	40679.40	10-Year	13653.00	541.33	557.04	6.79	438.19	634.18	195.99
BigFossilCreek	Reach2	40679.40	25-Year	19605.00	541.33	561.63	6.54	418.15	653.81	235.67
BigFossilCreek	Reach2	40679.40	50-Year	23243.00	541.33	565.04	6.03	403.31	781.89	378.58
BigFossilCreek	Reach2	40679.40	100-Year	27194.00	541.33	570.26	4.94	167.43	1393.19	1129.20
BigFossilCreek	Reach2	40679.40	250-Year	31294.00	541.33	571.04	5.34	157.77	1442.00	1280.37
BigFossilCreek	Reach2	40679.40	500-Year	34278.00	541.33	571.55	5.60	0.00	1453.61	1398.69
BigFossilCreek	Reach2	40795.45	2-Year	3425.00	541.33	550.42	3.99	616.09	760.11	144.02
BigFossilCreek	Reach2	40795.45	5-Year	9307.00	541.33	554.45	6.21	601.00	776.11	175.12
BigFossilCreek	Reach2	40795.45	10-Year	13653.00	541.33	557.18	6.79	588.59	786.87	198.28
BigFossilCreek	Reach2	40795.45	25-Year	19605.00	541.33	561.73	6.53	567.77	806.98	239.21
BigFossilCreek	Reach2	40795.45	50-Year	23243.00	541.33	565.11	6.02	551.26	844.56	293.30
BigFossilCreek	Reach2	40795.45	100-Year	27194.00	541.33	570.29	4.91	320.42	1519.38	1085.05
BigFossilCreek	Reach2	40795.45	250-Year	31294.00	541.33	571.07	5.31	309.87	1572.29	1164.52
BigFossilCreek	Reach2	40795.45	500-Year	34278.00	541.33	571.58	5.59	66.42	1594.24	1320.06
BigFossilCreek	Reach2	40902.65	2-Year	3425.00	541.73	550.44	5.27	594.70	687.00	92.31
BigFossilCreek	Reach2	40902.65	5-Year	9307.00	541.73	554.28	9.15	591.48	690.30	98.82
BigFossilCreek	Reach2	40902.65	10-Year	13653.00	541.73	556.84	10.70	589.34	692.50	103.16
BigFossilCreek	Reach2	40902.65	25-Year	19605.00	541.73	561.22	11.24	585.66	696.27	110.60
BigFossilCreek	Reach2	40902.65	50-Year	23243.00	541.73	564.56	10.95	580.99	701.27	120.28
BigFossilCreek	Reach2	40902.65	100-Year	27194.00	541.73	569.98	8.77	277.19	1347.63	968.57
BigFossilCreek	Reach2	40902.65	250-Year	31294.00	541.73	570.74	9.36	267.46	1388.89	1092.33
BigFossilCreek	Reach2	40902.65	500-Year	34278.00	541.73	571.23	9.80	260.22	1451.62	1191.40

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	40961.98		Bridge						
BigFossilCreek	Reach2	41011.24	2-Year	3425.00	541.73	550.71	4.89	568.88	661.19	92.31
BigFossilCreek	Reach2	41011.24	5-Year	9307.00	541.73	554.96	8.40	565.19	664.86	99.67
BigFossilCreek	Reach2	41011.24	10-Year	13653.00	541.73	557.69	9.85	562.82	667.21	104.39
BigFossilCreek	Reach2	41011.24	25-Year	19605.00	541.73	561.98	10.60	559.10	670.91	111.81
BigFossilCreek	Reach2	41011.24	50-Year	23243.00	541.73	565.44	10.34	534.21	690.17	155.95
BigFossilCreek	Reach2	41011.24	100-Year	27194.00	541.73	570.91	8.07	244.34	1304.10	983.15
BigFossilCreek	Reach2	41011.24	250-Year	31294.00	541.73	571.50	8.74	239.92	1308.95	1009.96
BigFossilCreek	Reach2	41011.24	500-Year	34278.00	541.73	572.12	8.99	35.68	1308.95	1256.84
BigFossilCreek	Reach2	41089.96	2-Year	3425.00	541.73	551.01	3.47	540.30	687.67	147.37
BigFossilCreek	Reach2	41089.96	5-Year	9307.00	541.73	555.95	5.10	519.18	710.28	191.10
BigFossilCreek	Reach2	41089.96	10-Year	13653.00	541.73	559.12	5.52	505.51	724.81	219.30
BigFossilCreek	Reach2	41089.96	25-Year	19605.00	541.73	563.71	5.48	485.06	748.44	263.38
BigFossilCreek	Reach2	41089.96	50-Year	23243.00	541.73	567.12	5.10	451.68	803.56	351.88
BigFossilCreek	Reach2	41089.96	100-Year	27194.00	541.73	571.69	4.38	240.55	1113.44	872.89
BigFossilCreek	Reach2	41089.96	250-Year	31294.00	541.73	572.37	4.82	219.36	1113.44	894.08
BigFossilCreek	Reach2	41089.96	500-Year	34278.00	541.73	572.98	5.07	152.96	1113.44	960.48
BigFossilCreek	Reach2	41222.01	2-Year	3527.00	542.14	551.07	3.53	446.96	599.87	152.91
BigFossilCreek	Reach2	41222.01	5-Year	9337.00	542.14	556.06	5.02	429.01	620.94	191.93
BigFossilCreek	Reach2	41222.01	10-Year	13746.00	542.14	559.22	5.48	414.74	633.55	218.81
BigFossilCreek	Reach2	41222.01	25-Year	19811.00	542.14	563.77	5.51	393.53	651.71	258.18
BigFossilCreek	Reach2	41222.01	50-Year	23563.00	542.14	567.16	5.18	369.12	926.18	382.51
BigFossilCreek	Reach2	41222.01	100-Year	27732.00	542.14	571.71	4.48	158.92	998.85	815.77
BigFossilCreek	Reach2	41222.01	250-Year	32024.00	542.14	572.39	4.94	153.13	1008.03	854.90
BigFossilCreek	Reach2	41222.01	500-Year	35219.00	542.14	572.99	5.22	116.53	1008.03	891.50
BigFossilCreek	Reach2	41421.11	2-Year	3527.00	542.55	551.19	3.58	385.20	537.74	152.55
BigFossilCreek	Reach2	41421.11	5-Year	9337.00	542.55	556.19	5.06	364.81	555.66	190.85
BigFossilCreek	Reach2	41421.11	10-Year	13746.00	542.55	559.34	5.53	350.12	566.75	216.63
BigFossilCreek	Reach2	41421.11	25-Year	19811.00	542.55	563.87	5.58	328.49	583.15	254.66
BigFossilCreek	Reach2	41421.11	50-Year	23563.00	542.55	567.23	5.29	303.63	846.20	390.31
BigFossilCreek	Reach2	41421.11	100-Year	27732.00	542.55	571.74	4.60	113.19	1013.42	788.75
BigFossilCreek	Reach2	41421.11	250-Year	32024.00	542.55	572.43	5.07	107.16	1028.57	837.50
BigFossilCreek	Reach2	41421.11	500-Year	35219.00	542.55	573.04	5.37	101.83	1054.96	909.30
BigFossilCreek	Reach2	41585.53	2-Year	3527.00	543.10	551.29	3.53	266.62	413.27	146.65
BigFossilCreek	Reach2	41585.53	5-Year	9337.00	543.10	556.32	5.00	238.80	433.54	194.74
BigFossilCreek	Reach2	41585.53	10-Year	13746.00	543.10	559.47	5.46	227.70	445.24	217.54
BigFossilCreek	Reach2	41585.53	25-Year	19811.00	543.10	563.97	5.53	202.07	460.69	258.62
BigFossilCreek	Reach2	41585.53	50-Year	23563.00	543.10	567.30	5.23	176.39	711.82	367.07
BigFossilCreek	Reach2	41585.53	100-Year	27732.00	543.10	571.79	4.52	145.59	1012.53	866.93
BigFossilCreek	Reach2	41585.53	250-Year	32024.00	543.10	572.49	4.97	0.00	1013.19	899.27
BigFossilCreek	Reach2	41585.53	500-Year	35219.00	543.10	573.11	5.22	0.00	1013.19	934.95
BigFossilCreek	Reach2	41723.96	2-Year	3527.00	543.34	551.37	3.50	262.63	408.62	145.99
BigFossilCreek	Reach2	41723.96	5-Year	9337.00	543.34	556.41	5.01	235.11	427.36	192.25
BigFossilCreek	Reach2	41723.96	10-Year	13746.00	543.34	559.56	5.49	222.44	439.28	216.84
BigFossilCreek	Reach2	41723.96	25-Year	19811.00	543.34	564.04	5.56	201.05	456.75	255.70
BigFossilCreek	Reach2	41723.96	50-Year	23563.00	543.34	567.35	5.26	175.64	725.91	461.19
BigFossilCreek	Reach2	41723.96	100-Year	27732.00	543.34	571.83	4.49	145.38	1065.20	919.82
BigFossilCreek	Reach2	41723.96	250-Year	32024.00	543.34	572.53	4.91	136.37	1065.20	928.83
BigFossilCreek	Reach2	41723.96	500-Year	35219.00	543.34	573.16	5.15	0.00	1065.20	962.25
BigFossilCreek	Reach2	41949.52	2-Year	3527.00	543.34	551.47	4.15	260.69	409.77	149.08
BigFossilCreek	Reach2	41949.52	5-Year	9337.00	543.34	556.54	5.47	240.44	430.22	189.77
BigFossilCreek	Reach2	41949.52	10-Year	13746.00	543.34	559.67	5.87	228.13	443.38	215.25
BigFossilCreek	Reach2	41949.52	25-Year	19811.00	543.34	564.13	5.85	209.22	463.74	254.53
BigFossilCreek	Reach2	41949.52	50-Year	23563.00	543.34	567.42	5.52	185.41	623.72	438.31
BigFossilCreek	Reach2	41949.52	100-Year	27732.00	543.34	571.85	4.80	167.53	1182.68	1015.15
BigFossilCreek	Reach2	41949.52	250-Year	32024.00	543.34	572.55	5.25	164.47	1238.33	1073.86
BigFossilCreek	Reach2	41949.52	500-Year	35219.00	543.34	573.18	5.51	0.00	1272.39	1138.34
BigFossilCreek	Reach2	42093.87	2-Year	3527.00	543.75	551.62	4.07	256.15	408.21	152.06
BigFossilCreek	Reach2	42093.87	5-Year	9337.00	543.75	556.69	5.36	237.10	430.45	193.35
BigFossilCreek	Reach2	42093.87	10-Year	13746.00	543.75	559.81	5.76	225.38	443.80	218.43
BigFossilCreek	Reach2	42093.87	25-Year	19811.00	543.75	564.23	5.78	206.42	467.86	261.44

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	42093.87	50-Year	23563.00	543.75	567.49	5.47	181.59	641.25	459.66
BigFossilCreek	Reach2	42093.87	100-Year	27732.00	543.75	571.89	4.75	161.54	1041.85	880.30
BigFossilCreek	Reach2	42093.87	250-Year	32024.00	543.75	572.59	5.23	153.80	1136.16	982.35
BigFossilCreek	Reach2	42093.87	500-Year	35219.00	543.75	573.22	5.52	147.12	1228.05	1080.94
BigFossilCreek	Reach2	42213.51	2-Year	3527.00	544.03	551.73	4.07	263.25	417.29	154.04
BigFossilCreek	Reach2	42213.51	5-Year	9337.00	544.03	556.80	5.35	245.12	438.54	193.42
BigFossilCreek	Reach2	42213.51	10-Year	13746.00	544.03	559.90	5.77	234.00	450.28	216.29
BigFossilCreek	Reach2	42213.51	25-Year	19811.00	544.03	564.30	5.82	215.67	476.30	260.63
BigFossilCreek	Reach2	42213.51	50-Year	23563.00	544.03	567.53	5.53	192.88	627.28	434.40
BigFossilCreek	Reach2	42213.51	100-Year	27732.00	544.03	571.90	4.88	163.86	1068.90	905.05
BigFossilCreek	Reach2	42213.51	250-Year	32024.00	544.03	572.61	5.37	156.65	1152.89	996.25
BigFossilCreek	Reach2	42213.51	500-Year	35219.00	544.03	573.23	5.66	153.33	1219.34	1066.01
BigFossilCreek	Reach2	42288.98	2-Year	3527.00	544.15	551.59	6.33	261.74	375.61	113.87
BigFossilCreek	Reach2	42288.98	5-Year	9337.00	544.15	556.59	7.49	240.77	403.66	162.88
BigFossilCreek	Reach2	42288.98	10-Year	13746.00	544.15	559.71	7.63	226.76	419.94	193.18
BigFossilCreek	Reach2	42288.98	25-Year	19811.00	544.15	564.17	7.13	189.32	476.23	286.91
BigFossilCreek	Reach2	42288.98	50-Year	23563.00	544.15	567.44	6.56	174.59	929.87	462.65
BigFossilCreek	Reach2	42288.98	100-Year	27732.00	544.15	571.85	5.59	125.64	1065.55	939.91
BigFossilCreek	Reach2	42288.98	250-Year	32024.00	544.15	572.55	6.14	124.54	1145.43	1020.89
BigFossilCreek	Reach2	42288.98	500-Year	35219.00	544.15	573.17	6.45	123.56	1196.52	1072.96
BigFossilCreek	Reach2	42337.66	2-Year	3527.00	544.15	551.70	6.58	307.30	405.65	98.35
BigFossilCreek	Reach2	42337.66	5-Year	9337.00	544.15	556.55	8.46	295.45	429.86	134.40
BigFossilCreek	Reach2	42337.66	10-Year	13746.00	544.15	559.58	8.92	270.69	445.92	175.23
BigFossilCreek	Reach2	42337.66	25-Year	19811.00	544.15	564.00	8.67	190.94	847.62	656.68
BigFossilCreek	Reach2	42337.66	50-Year	23563.00	544.15	567.30	7.98	129.01	974.93	838.96
BigFossilCreek	Reach2	42337.66	100-Year	27732.00	544.15	571.73	6.96	117.34	1165.30	1047.97
BigFossilCreek	Reach2	42337.66	250-Year	32024.00	544.15	572.40	7.73	115.35	1201.49	1086.13
BigFossilCreek	Reach2	42337.66	500-Year	35219.00	544.15	572.98	8.22	113.24	1234.37	1121.13
BigFossilCreek	Reach2	42436.95	2-Year	3527.00	545.35	552.07	6.86	382.77	485.83	103.06
BigFossilCreek	Reach2	42436.95	5-Year	9337.00	545.35	556.93	8.41	339.44	749.63	366.65
BigFossilCreek	Reach2	42436.95	10-Year	13746.00	545.35	560.20	8.04	229.00	903.25	674.26
BigFossilCreek	Reach2	42436.95	25-Year	19811.00	545.35	564.69	7.14	194.72	1151.18	956.47
BigFossilCreek	Reach2	42436.95	50-Year	23563.00	545.35	567.84	6.59	154.62	1170.13	1015.51
BigFossilCreek	Reach2	42436.95	100-Year	27732.00	545.35	572.09	5.80	98.31	1451.52	1353.21
BigFossilCreek	Reach2	42436.95	250-Year	32024.00	545.35	572.84	6.39	96.00	1501.72	1405.72
BigFossilCreek	Reach2	42436.95	500-Year	35219.00	545.35	573.49	6.76	92.25	1603.39	1511.14
BigFossilCreek	Reach2	42697.67	2-Year	3527.00	546.16	553.59	4.17	412.30	743.83	304.82
BigFossilCreek	Reach2	42697.67	5-Year	9337.00	546.16	558.36	4.31	269.58	752.12	482.54
BigFossilCreek	Reach2	42697.67	10-Year	13746.00	546.16	561.25	4.43	173.49	811.15	637.66
BigFossilCreek	Reach2	42697.67	25-Year	19811.00	546.16	565.33	4.15	103.11	1113.45	1010.35
BigFossilCreek	Reach2	42697.67	50-Year	23563.00	546.16	568.34	3.60	76.08	1158.14	1082.06
BigFossilCreek	Reach2	42697.67	100-Year	27732.00	546.16	572.46	3.00	60.58	1754.78	1500.74
BigFossilCreek	Reach2	42697.67	250-Year	32024.00	546.16	573.28	3.26	57.48	1802.42	1667.73
BigFossilCreek	Reach2	42697.67	500-Year	35219.00	546.16	573.97	3.42	55.36	1833.29	1777.93
BigFossilCreek	Reach2	42835.83	2-Year	3527.00	546.96	553.95	5.18	372.61	540.32	167.70
BigFossilCreek	Reach2	42835.83	5-Year	9337.00	546.96	558.44	5.45	286.40	1083.71	590.04
BigFossilCreek	Reach2	42835.83	10-Year	13746.00	546.96	561.32	5.12	172.94	1135.49	807.06
BigFossilCreek	Reach2	42835.83	25-Year	19811.00	546.96	565.39	4.34	98.69	1326.32	1227.63
BigFossilCreek	Reach2	42835.83	50-Year	23563.00	546.96	568.40	3.65	75.10	1337.55	1262.45
BigFossilCreek	Reach2	42835.83	100-Year	27732.00	546.96	572.49	2.99	53.54	2119.19	1899.88
BigFossilCreek	Reach2	42835.83	250-Year	32024.00	546.96	573.31	3.25	50.39	2159.70	2109.31
BigFossilCreek	Reach2	42835.83	500-Year	35219.00	546.96	574.01	3.40	48.19	2193.76	2145.57
BigFossilCreek	Reach2	42858.12	2-Year	3527.00	550.28	554.05	8.68	348.46	528.67	180.21
BigFossilCreek	Reach2	42858.12	5-Year	9337.00	550.28	558.27	7.30	294.60	1103.36	487.54
BigFossilCreek	Reach2	42858.12	10-Year	13746.00	550.28	561.25	6.28	180.32	1144.40	751.28
BigFossilCreek	Reach2	42858.12	25-Year	19811.00	550.28	565.38	4.92	97.43	1318.43	1221.00
BigFossilCreek	Reach2	42858.12	50-Year	23563.00	550.28	568.39	3.99	74.45	1331.60	1257.15
BigFossilCreek	Reach2	42858.12	100-Year	27732.00	550.28	572.49	3.19	52.05	2078.58	1865.33
BigFossilCreek	Reach2	42858.12	250-Year	32024.00	550.28	573.31	3.46	48.93	2119.65	2070.72
BigFossilCreek	Reach2	42858.12	500-Year	35219.00	550.28	574.01	3.61	46.68	2154.17	2107.49
BigFossilCreek	Reach2	42881.13	2-Year	3527.00	547.66	554.97	5.73	326.47	1080.52	179.49

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	42881.13	5-Year	9337.00	547.66	558.28	7.83	297.30	1096.26	420.28
BigFossilCreek	Reach2	42881.13	10-Year	13746.00	547.66	561.18	7.22	183.23	1260.73	718.97
BigFossilCreek	Reach2	42881.13	25-Year	19811.00	547.66	565.35	5.57	89.01	1301.76	1212.75
BigFossilCreek	Reach2	42881.13	50-Year	23563.00	547.66	568.39	4.43	70.22	1316.52	1246.30
BigFossilCreek	Reach2	42881.13	100-Year	27732.00	547.66	572.49	3.49	48.55	2060.50	1850.99
BigFossilCreek	Reach2	42881.13	250-Year	32024.00	547.66	573.31	3.77	44.03	2101.39	2057.36
BigFossilCreek	Reach2	42881.13	500-Year	35219.00	547.66	574.01	3.92	41.75	2135.77	2094.03
BigFossilCreek	Reach2	43049.03	2-Year	3527.00	548.30	555.75	7.06	171.14	1111.15	168.21
BigFossilCreek	Reach2	43049.03	5-Year	9337.00	548.30	558.90	8.73	166.59	1127.04	560.91
BigFossilCreek	Reach2	43049.03	10-Year	13746.00	548.30	561.58	7.33	163.16	1283.69	764.37
BigFossilCreek	Reach2	43049.03	25-Year	19811.00	548.30	565.51	5.57	86.96	1318.62	1231.66
BigFossilCreek	Reach2	43049.03	50-Year	23563.00	548.30	568.46	4.41	72.00	1333.00	1261.00
BigFossilCreek	Reach2	43049.03	100-Year	27732.00	548.30	572.52	3.45	53.91	2077.76	1863.71
BigFossilCreek	Reach2	43049.03	250-Year	32024.00	548.30	573.35	3.72	49.48	2118.84	2069.36
BigFossilCreek	Reach2	43049.03	500-Year	35219.00	548.30	574.05	3.87	47.14	2153.29	2106.16
BigFossilCreek	Reach2	43290.31	2-Year	3527.00	548.77	557.44	4.93	163.23	1071.00	319.56
BigFossilCreek	Reach2	43290.31	5-Year	9337.00	548.77	560.39	6.56	160.59	1228.17	669.93
BigFossilCreek	Reach2	43290.31	10-Year	13746.00	548.77	562.24	6.59	159.26	1241.23	775.59
BigFossilCreek	Reach2	43290.31	25-Year	19811.00	548.77	565.72	5.35	156.90	1265.72	1108.82
BigFossilCreek	Reach2	43290.31	50-Year	23563.00	548.77	568.54	4.33	154.80	1279.27	1124.47
BigFossilCreek	Reach2	43290.31	100-Year	27732.00	548.77	572.55	3.43	151.78	2025.57	1714.68
BigFossilCreek	Reach2	43290.31	250-Year	32024.00	548.77	573.39	3.70	151.16	2066.80	1915.64
BigFossilCreek	Reach2	43290.31	500-Year	35219.00	548.77	574.08	3.86	145.71	2101.31	1955.60
BigFossilCreek	Reach2	43454.57	2-Year	3527.00	551.46	558.07	5.59	139.83	1034.29	324.45
BigFossilCreek	Reach2	43454.57	5-Year	9337.00	551.46	560.92	6.78	137.27	1185.44	671.49
BigFossilCreek	Reach2	43454.57	10-Year	13746.00	551.46	562.61	6.98	135.75	1196.27	890.26
BigFossilCreek	Reach2	43454.57	25-Year	19811.00	551.46	565.86	5.55	132.51	1216.59	1084.08
BigFossilCreek	Reach2	43454.57	50-Year	23563.00	551.46	568.61	4.48	128.51	1227.99	1099.48
BigFossilCreek	Reach2	43454.57	100-Year	27732.00	551.46	572.58	3.53	120.08	1961.96	1684.15
BigFossilCreek	Reach2	43454.57	250-Year	32024.00	551.46	573.42	3.80	115.53	1999.36	1883.82
BigFossilCreek	Reach2	43454.57	500-Year	35219.00	551.46	574.12	3.96	111.85	2029.87	1918.02
BigFossilCreek	Reach2	43652.80	2-Year	3527.00	552.27	559.24	6.11	114.39	1048.28	409.27
BigFossilCreek	Reach2	43652.80	5-Year	9337.00	552.27	561.71	7.56	111.93	1083.14	633.98
BigFossilCreek	Reach2	43652.80	10-Year	13746.00	552.27	563.18	8.15	110.45	1143.12	976.51
BigFossilCreek	Reach2	43652.80	25-Year	19811.00	552.27	566.08	6.27	107.46	1158.26	1050.80
BigFossilCreek	Reach2	43652.80	50-Year	23563.00	552.27	568.71	4.97	104.50	1169.40	1064.90
BigFossilCreek	Reach2	43652.80	100-Year	27732.00	552.27	572.63	3.83	100.36	1910.85	1652.67
BigFossilCreek	Reach2	43652.80	250-Year	32024.00	552.27	573.47	4.11	99.89	1954.72	1854.83
BigFossilCreek	Reach2	43652.80	500-Year	35219.00	552.27	574.16	4.27	99.50	1983.65	1884.15
BigFossilCreek	Reach2	43848.16	2-Year	3527.00	553.25	560.39	6.13	228.46	1108.25	331.24
BigFossilCreek	Reach2	43848.16	5-Year	9337.00	553.25	562.62	9.11	213.45	1116.88	577.55
BigFossilCreek	Reach2	43848.16	10-Year	13746.00	553.25	563.94	10.22	200.92	1126.09	925.17
BigFossilCreek	Reach2	43848.16	25-Year	19811.00	553.25	566.34	8.13	171.32	1143.80	968.92
BigFossilCreek	Reach2	43848.16	50-Year	23563.00	553.25	568.83	6.37	161.60	1177.97	1016.37
BigFossilCreek	Reach2	43848.16	100-Year	27732.00	553.25	572.67	4.69	139.31	1919.27	1677.58
BigFossilCreek	Reach2	43848.16	250-Year	32024.00	553.25	573.51	5.00	129.72	1974.86	1845.14
BigFossilCreek	Reach2	43848.16	500-Year	35219.00	553.25	574.21	5.15	124.65	1998.64	1873.98
BigFossilCreek	Reach2	44100.92	2-Year	3527.00	554.13	561.58	5.73	401.83	1059.44	268.11
BigFossilCreek	Reach2	44100.92	5-Year	9337.00	554.13	564.15	8.71	234.06	1076.33	705.19
BigFossilCreek	Reach2	44100.92	10-Year	13746.00	554.13	565.57	8.73	194.52	1085.69	868.23
BigFossilCreek	Reach2	44100.92	25-Year	19811.00	554.13	567.05	8.90	176.99	1103.75	926.76
BigFossilCreek	Reach2	44100.92	50-Year	23563.00	554.13	569.15	7.17	151.67	1120.60	968.93
BigFossilCreek	Reach2	44100.92	100-Year	27732.00	554.13	572.79	5.12	116.12	1868.54	1752.42
BigFossilCreek	Reach2	44100.92	250-Year	32024.00	554.13	573.64	5.39	112.36	1923.49	1811.13
BigFossilCreek	Reach2	44100.92	500-Year	35219.00	554.13	574.35	5.69	109.19	1935.52	1826.33
BigFossilCreek	Reach2	44301.57	2-Year	3527.00	554.13	562.41	4.65	571.78	941.62	195.75
BigFossilCreek	Reach2	44301.57	5-Year	9337.00	554.13	565.50	7.36	224.97	985.83	479.47
BigFossilCreek	Reach2	44301.57	10-Year	13746.00	554.13	566.56	8.65	211.48	988.93	765.37
BigFossilCreek	Reach2	44301.57	25-Year	19811.00	554.13	567.83	9.40	208.75	992.66	783.91
BigFossilCreek	Reach2	44301.57	50-Year	23563.00	554.13	569.48	8.19	204.34	997.20	792.85
BigFossilCreek	Reach2	44301.57	100-Year	27732.00	554.13	572.88	6.02	120.92	1281.45	996.81
BigFossilCreek	Reach2	44301.57	250-Year	32024.00	554.13	573.73	6.26	118.81	1617.94	1166.80

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
BigFossilCreek	Reach2	44301.57	500-Year	35219.00	554.13	574.44	6.36	117.05	1636.67	1310.45
BigFossilCreek	Reach2	44521.68	2-Year	3427.00	554.21	562.94	6.20	507.33	898.30	226.86
BigFossilCreek	Reach2	44521.68	5-Year	9329.00	554.21	566.60	6.87	267.53	914.86	459.83
BigFossilCreek	Reach2	44521.68	10-Year	13728.00	554.21	567.86	8.01	262.57	917.79	649.38
BigFossilCreek	Reach2	44521.68	25-Year	19767.00	554.21	569.06	9.30	257.82	920.60	662.78
BigFossilCreek	Reach2	44521.68	50-Year	23515.00	554.21	570.18	9.31	210.73	923.21	712.48
BigFossilCreek	Reach2	44521.68	100-Year	27660.00	554.21	573.11	7.41	129.08	1100.71	928.39
BigFossilCreek	Reach2	44521.68	250-Year	31924.00	554.21	573.96	7.69	126.10	1106.58	980.47
BigFossilCreek	Reach2	44521.68	500-Year	35097.00	554.21	574.66	7.80	123.65	1451.93	1072.60
BigFossilCreek	Reach2	44755.49	2-Year	3427.00	555.75	564.03	4.87	409.93	866.71	261.04
BigFossilCreek	Reach2	44755.49	5-Year	9329.00	555.75	567.32	6.77	318.31	895.73	566.98
BigFossilCreek	Reach2	44755.49	10-Year	13728.00	555.75	568.68	7.60	313.94	899.70	585.76
BigFossilCreek	Reach2	44755.49	25-Year	19767.00	555.75	570.01	8.65	309.64	903.63	593.99
BigFossilCreek	Reach2	44755.49	50-Year	23515.00	555.75	570.99	9.04	230.54	906.49	675.96
BigFossilCreek	Reach2	44755.49	100-Year	27660.00	555.75	573.48	7.62	121.06	1381.45	1260.39
BigFossilCreek	Reach2	44755.49	250-Year	31924.00	555.75	574.33	7.89	118.13	1392.80	1274.67
BigFossilCreek	Reach2	44755.49	500-Year	35097.00	555.75	575.01	7.98	115.76	1401.63	1285.88
BigFossilCreek	Reach2	44985.92	2-Year	3427.00	557.72	564.73	4.41	408.45	919.54	301.83
BigFossilCreek	Reach2	44985.92	5-Year	9329.00	557.72	568.06	6.32	407.09	931.02	523.93
BigFossilCreek	Reach2	44985.92	10-Year	13728.00	557.72	569.43	7.26	405.03	953.28	548.25
BigFossilCreek	Reach2	44985.92	25-Year	19767.00	557.72	570.82	8.37	362.94	959.28	596.35
BigFossilCreek	Reach2	44985.92	50-Year	23515.00	557.72	571.80	8.68	330.15	963.38	633.24
BigFossilCreek	Reach2	44985.92	100-Year	27660.00	557.72	573.89	8.01	265.36	1147.95	792.92
BigFossilCreek	Reach2	44985.92	250-Year	31924.00	557.72	574.72	8.36	261.05	1156.63	886.87
BigFossilCreek	Reach2	44985.92	500-Year	35097.00	557.72	575.39	8.52	257.62	1163.52	905.91
BigFossilCreek	Reach2	45248.08	2-Year	3427.00	558.32	565.40	6.67	339.84	898.86	190.07
BigFossilCreek	Reach2	45248.08	5-Year	9329.00	558.32	568.85	7.75	333.03	906.13	573.10
BigFossilCreek	Reach2	45248.08	10-Year	13728.00	558.32	570.28	8.24	330.29	923.99	593.70
BigFossilCreek	Reach2	45248.08	25-Year	19767.00	558.32	571.77	9.03	327.43	935.59	608.16
BigFossilCreek	Reach2	45248.08	50-Year	23515.00	558.32	572.70	9.31	325.63	1112.55	615.70
BigFossilCreek	Reach2	45248.08	100-Year	27660.00	558.32	574.50	8.67	322.18	1128.82	799.95
BigFossilCreek	Reach2	45248.08	250-Year	31924.00	558.32	575.33	9.12	320.59	1136.36	815.77
BigFossilCreek	Reach2	45248.08	500-Year	35097.00	558.32	575.97	9.37	319.36	1151.54	832.18
BigFossilCreek	Reach2	45514.73	2-Year	3427.00	558.32	566.73	5.61	276.95	824.76	209.12
BigFossilCreek	Reach2	45514.73	5-Year	9329.00	558.32	570.00	7.80	260.17	844.07	559.49
BigFossilCreek	Reach2	45514.73	10-Year	13728.00	558.32	571.31	9.08	256.23	851.34	595.11
BigFossilCreek	Reach2	45514.73	25-Year	19767.00	558.32	572.77	10.03	251.85	1033.01	617.36
BigFossilCreek	Reach2	45514.73	50-Year	23515.00	558.32	573.64	10.41	249.22	1041.08	660.90
BigFossilCreek	Reach2	45514.73	100-Year	27660.00	558.32	575.15	9.98	244.67	1055.02	740.29
BigFossilCreek	Reach2	45514.73	250-Year	31924.00	558.32	575.99	10.42	242.16	1067.75	825.59
BigFossilCreek	Reach2	45514.73	500-Year	35097.00	558.32	576.62	10.68	240.25	1129.44	889.19
BigFossilCreek	Reach2	45787.15	2-Year	3427.00	558.32	567.56	4.20	311.90	804.37	156.40
BigFossilCreek	Reach2	45787.15	5-Year	9329.00	558.32	570.95	7.06	247.08	828.50	581.42
BigFossilCreek	Reach2	45787.15	10-Year	13728.00	558.32	572.37	8.29	216.12	833.92	617.80
BigFossilCreek	Reach2	45787.15	25-Year	19767.00	558.32	573.82	9.61	204.77	1016.71	667.16
BigFossilCreek	Reach2	45787.15	50-Year	23515.00	558.32	574.66	10.20	202.98	1024.84	709.67
BigFossilCreek	Reach2	45787.15	100-Year	27660.00	558.32	575.92	10.27	200.28	1037.63	837.36
BigFossilCreek	Reach2	45787.15	250-Year	31924.00	558.32	576.75	10.79	198.50	1138.23	939.73
BigFossilCreek	Reach2	45787.15	500-Year	35097.00	558.32	577.37	11.11	197.17	1218.29	1021.12
BigFossilCreek	Reach2	45995.01	2-Year	3427.00	558.32	567.94	2.68	262.99	486.02	223.03
BigFossilCreek	Reach2	45995.01	5-Year	9329.00	558.32	571.76	4.25	229.40	876.30	646.16
BigFossilCreek	Reach2	45995.01	10-Year	13728.00	558.32	573.31	5.28	207.03	884.58	677.55
BigFossilCreek	Reach2	45995.01	25-Year	19767.00	558.32	574.86	6.53	194.54	1147.73	863.22
BigFossilCreek	Reach2	45995.01	50-Year	23515.00	558.32	575.70	7.21	191.68	1274.09	1038.15
BigFossilCreek	Reach2	45995.01	100-Year	27660.00	558.32	576.78	7.74	187.75	1389.61	1201.87
BigFossilCreek	Reach2	45995.01	250-Year	31924.00	558.32	577.58	8.39	184.57	1477.18	1292.62
BigFossilCreek	Reach2	45995.01	500-Year	35097.00	558.32	578.16	8.83	182.45	1515.70	1333.25
BigFossilCreek	Reach2	46185.53	2-Year	3445.00	558.32	568.07	2.46	254.99	475.09	220.11
BigFossilCreek	Reach2	46185.53	5-Year	9367.00	558.32	571.94	4.09	243.32	796.23	438.23
BigFossilCreek	Reach2	46185.53	10-Year	13778.00	558.32	573.52	5.16	234.00	896.60	617.82
BigFossilCreek	Reach2	46185.53	25-Year	19846.00	558.32	575.11	6.49	225.75	908.83	683.08

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Sta W.S. Lft (ft)	Sta W.S. Rgt (ft)	Top Width (ft)
BigFossilCreek	Reach2	46185.53	50-Year	23786.00	558.32	575.96	7.27	192.02	960.68	749.16
BigFossilCreek	Reach2	46185.53	100-Year	27937.00	558.32	577.03	7.90	183.03	1294.85	1111.83
BigFossilCreek	Reach2	46185.53	250-Year	32138.00	558.32	577.85	8.59	174.61	1494.42	1319.81
BigFossilCreek	Reach2	46185.53	500-Year	35336.00	558.32	579.00	6.98	162.35	1606.40	1444.05
BigFossilCreek	Reach2	46209.58	2-Year	3445.00	558.30	568.09	2.34	267.81	474.83	207.02
BigFossilCreek	Reach2	46209.58	5-Year	9367.00	558.30	571.96	4.07	260.51	482.38	221.87
BigFossilCreek	Reach2	46209.58	10-Year	13778.00	558.30	573.54	5.18	257.53	485.47	227.94
BigFossilCreek	Reach2	46209.58	25-Year	19846.00	558.30	575.13	6.56	254.52	488.57	234.05
BigFossilCreek	Reach2	46209.58	50-Year	23786.00	558.30	575.98	7.38	252.92	1210.70	575.48
BigFossilCreek	Reach2	46209.58	100-Year	27937.00	558.30	577.05	8.02	242.91	1254.16	958.79
BigFossilCreek	Reach2	46209.58	250-Year	32138.00	558.30	577.86	8.74	240.33	1292.04	1051.71
BigFossilCreek	Reach2	46209.58	500-Year	35336.00	558.30	578.69	9.11	49.80	1326.48	1142.31
BigFossilCreek	Reach2	46305.16		Bridge						
BigFossilCreek	Reach2	46338.11	2-Year	3445.00	558.30	568.18	2.31	238.65	446.01	207.36
BigFossilCreek	Reach2	46338.11	5-Year	9367.00	558.30	572.16	3.99	231.13	453.77	222.64
BigFossilCreek	Reach2	46338.11	10-Year	13778.00	558.30	573.84	5.05	227.96	457.06	229.10
BigFossilCreek	Reach2	46338.11	25-Year	19846.00	558.30	575.60	6.33	224.65	460.48	235.83
BigFossilCreek	Reach2	46338.11	50-Year	23786.00	558.30	576.56	7.07	47.15	462.36	368.03
BigFossilCreek	Reach2	46338.11	100-Year	27937.00	558.30	577.72	7.67	2.98	467.36	438.09
BigFossilCreek	Reach2	46338.11	250-Year	32138.00	558.30	578.75	8.07	0.00	760.15	592.14
BigFossilCreek	Reach2	46338.11	500-Year	35336.00	558.30	579.91	8.13	0.00	920.42	860.44
BigFossilCreek	Reach2	46351.48	2-Year	3445.00	558.32	568.20	2.14	203.72	431.56	227.84
BigFossilCreek	Reach2	46351.48	5-Year	9367.00	558.32	572.22	3.65	194.62	447.29	252.66
BigFossilCreek	Reach2	46351.48	10-Year	13778.00	558.32	573.94	4.61	188.63	453.65	265.02
BigFossilCreek	Reach2	46351.48	25-Year	19846.00	558.32	575.75	5.78	8.14	463.44	446.22
BigFossilCreek	Reach2	46351.48	50-Year	23786.00	558.32	576.80	6.29	0.00	486.78	486.78
BigFossilCreek	Reach2	46351.48	100-Year	27937.00	558.32	578.04	6.70	0.00	528.15	514.68
BigFossilCreek	Reach2	46351.48	250-Year	32138.00	558.32	579.07	7.13	0.00	540.30	540.30
BigFossilCreek	Reach2	46351.48	500-Year	35336.00	558.32	580.22	7.22	0.00	878.53	777.38
BigFossilCreek	Reach2	46448.70	2-Year	3445.00	558.32	568.11	7.56	248.21	314.39	66.18
BigFossilCreek	Reach2	46448.70	5-Year	9367.00	558.32	572.05	10.89	218.36	454.04	235.68
BigFossilCreek	Reach2	46448.70	10-Year	13778.00	558.32	573.78	11.89	102.44	461.55	359.11
BigFossilCreek	Reach2	46448.70	25-Year	19846.00	558.32	575.67	12.37	0.00	469.71	469.71
BigFossilCreek	Reach2	46448.70	50-Year	23786.00	558.32	576.77	12.36	0.00	474.47	474.47
BigFossilCreek	Reach2	46448.70	100-Year	27937.00	558.32	578.06	11.99	0.00	483.43	483.43
BigFossilCreek	Reach2	46448.70	250-Year	32138.00	558.32	579.10	12.01	0.00	507.80	507.80
BigFossilCreek	Reach2	46448.70	500-Year	35336.00	558.32	580.27	11.50	0.00	580.46	580.46
WhitesBranch	Reach1	238.9885	2-Year	2325.00	531.88	542.15	2.93	2152.30	2300.00	147.71
WhitesBranch	Reach1	238.9885	5-Year	5216.00	531.88	550.20	1.46	757.19	2358.51	1601.32
WhitesBranch	Reach1	238.9885	10-Year	6914.00	531.88	554.50	1.26	650.15	2358.51	1708.36
WhitesBranch	Reach1	238.9885	25-Year	8904.00	531.88	560.29	1.10	503.31	2358.51	1855.20
WhitesBranch	Reach1	238.9885	50-Year	10275.00	531.88	564.11	1.05	166.21	2358.51	2094.49
WhitesBranch	Reach1	238.9885	100-Year	11553.00	531.88	569.78	0.34	134.28	2358.51	2224.23
WhitesBranch	Reach1	238.9885	250-Year	13041.00	531.88	570.46	0.37	131.64	2358.51	2226.87
WhitesBranch	Reach1	238.9885	500-Year	14097.00	531.88	570.90	0.39	129.94	2358.51	2228.57
WhitesBranch	Reach1	363.9402	2-Year	2325.00	532.17	542.45	2.85	2028.14	2179.09	150.95
WhitesBranch	Reach1	363.9402	5-Year	5216.00	532.17	550.22	1.50	753.00	2280.21	1527.21
WhitesBranch	Reach1	363.9402	10-Year	6914.00	532.17	554.51	1.26	643.78	2280.21	1636.43
WhitesBranch	Reach1	363.9402	25-Year	8904.00	532.17	560.30	1.07	294.89	2280.21	1888.27
WhitesBranch	Reach1	363.9402	50-Year	10275.00	532.17	564.12	1.01	155.32	2280.21	2084.25
WhitesBranch	Reach1	363.9402	100-Year	11553.00	532.17	569.78	0.35	133.84	2280.21	2146.37
WhitesBranch	Reach1	363.9402	250-Year	13041.00	532.17	570.46	0.38	131.35	2280.21	2148.86
WhitesBranch	Reach1	363.9402	500-Year	14097.00	532.17	570.90	0.40	128.54	2280.21	2151.67
WhitesBranch	Reach1	495.9509	2-Year	2325.00	532.17	542.81	2.96	1898.47	2090.64	192.17
WhitesBranch	Reach1	495.9509	5-Year	5216.00	532.17	550.25	1.40	749.62	2203.93	1454.31
WhitesBranch	Reach1	495.9509	10-Year	6914.00	532.17	554.53	1.15	361.07	2203.93	1574.47
WhitesBranch	Reach1	495.9509	25-Year	8904.00	532.17	560.31	0.97	308.22	2203.93	1859.82
WhitesBranch	Reach1	495.9509	50-Year	10275.00	532.17	564.12	0.92	155.61	2203.93	2016.38
WhitesBranch	Reach1	495.9509	100-Year	11553.00	532.17	569.78	0.35	126.99	2203.93	2076.94
WhitesBranch	Reach1	495.9509	250-Year	13041.00	532.17	570.46	0.38	122.38	2203.93	2081.55
WhitesBranch	Reach1	495.9509	500-Year	14097.00	532.17	570.90	0.40	119.44	2203.93	2084.49

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach1	748.9072	2-Year	2325.00	532.32	543.46	2.77	1667.50	2013.96	346.46
WhitesBranch	Reach1	748.9072	5-Year	5216.00	532.32	550.30	1.24	708.72	2046.31	1337.59
WhitesBranch	Reach1	748.9072	10-Year	6914.00	532.32	554.55	1.00	437.50	2046.31	1484.13
WhitesBranch	Reach1	748.9072	25-Year	8904.00	532.32	560.32	0.83	399.76	2046.31	1646.55
WhitesBranch	Reach1	748.9072	50-Year	10275.00	532.32	564.13	0.77	153.71	2046.31	1751.55
WhitesBranch	Reach1	748.9072	100-Year	11553.00	532.32	569.78	0.39	111.81	2046.31	1934.51
WhitesBranch	Reach1	748.9072	250-Year	13041.00	532.32	570.46	0.43	108.11	2046.31	1938.21
WhitesBranch	Reach1	748.9072	500-Year	14097.00	532.32	570.90	0.45	105.74	2046.31	1940.57
WhitesBranch	Reach1	1222.601	2-Year	2325.00	534.67	544.10	2.26	1152.18	1712.25	508.88
WhitesBranch	Reach1	1222.601	5-Year	5216.00	534.67	550.36	1.35	680.90	1858.55	1177.65
WhitesBranch	Reach1	1222.601	10-Year	6914.00	534.67	554.58	1.10	502.41	1858.55	1331.19
WhitesBranch	Reach1	1222.601	25-Year	8904.00	534.67	560.33	0.92	281.27	1858.55	1577.28
WhitesBranch	Reach1	1222.601	50-Year	10275.00	534.67	564.14	0.86	167.13	1858.55	1629.27
WhitesBranch	Reach1	1222.601	100-Year	11553.00	534.67	569.78	0.45	153.52	1858.55	1705.03
WhitesBranch	Reach1	1222.601	250-Year	13041.00	534.67	570.46	0.49	120.07	1858.55	1708.36
WhitesBranch	Reach1	1222.601	500-Year	14097.00	534.67	570.90	0.51	117.40	1858.55	1715.58
WhitesBranch	Reach1	1989.823	2-Year	2325.00	537.42	545.47	5.56	1009.30	1431.26	139.26
WhitesBranch	Reach1	1989.823	5-Year	5216.00	537.42	550.52	2.30	692.78	1809.26	1116.48
WhitesBranch	Reach1	1989.823	10-Year	6914.00	537.42	554.63	1.21	460.53	1809.26	1170.54
WhitesBranch	Reach1	1989.823	25-Year	8904.00	537.42	560.35	0.80	235.61	1809.26	1559.30
WhitesBranch	Reach1	1989.823	50-Year	10275.00	537.42	564.16	0.68	156.54	1809.26	1652.72
WhitesBranch	Reach1	1989.823	100-Year	11553.00	537.42	569.79	0.51	119.73	1809.26	1689.53
WhitesBranch	Reach1	1989.823	250-Year	13041.00	537.42	570.47	0.55	116.52	1809.26	1692.74
WhitesBranch	Reach1	1989.823	500-Year	14097.00	537.42	570.90	0.58	114.48	1809.26	1694.79
WhitesBranch	Reach1	2293.212	2-Year	2325.00	538.17	547.26	4.59	972.51	1103.49	130.97
WhitesBranch	Reach1	2293.212	5-Year	5216.00	538.17	550.69	4.13	622.87	1540.25	917.38
WhitesBranch	Reach1	2293.212	10-Year	6914.00	538.17	554.66	1.82	540.65	1540.25	999.60
WhitesBranch	Reach1	2293.212	25-Year	8904.00	538.17	560.36	1.07	450.02	1540.25	1090.24
WhitesBranch	Reach1	2293.212	50-Year	10275.00	538.17	564.16	0.90	141.23	1540.25	1399.03
WhitesBranch	Reach1	2293.212	100-Year	11553.00	538.17	569.79	0.66	102.60	1540.25	1437.66
WhitesBranch	Reach1	2293.212	250-Year	13041.00	538.17	570.47	0.71	97.62	1540.25	1442.63
WhitesBranch	Reach1	2293.212	500-Year	14097.00	538.17	570.90	0.75	94.06	1540.25	1446.19
WhitesBranch	Reach1	2746.557	2-Year	2325.00	538.92	548.84	4.46	951.62	1055.82	104.19
WhitesBranch	Reach1	2746.557	5-Year	5216.00	538.92	551.55	5.74	503.69	1360.28	856.59
WhitesBranch	Reach1	2746.557	10-Year	6914.00	538.92	554.77	2.78	429.88	1360.28	930.40
WhitesBranch	Reach1	2746.557	25-Year	8904.00	538.92	560.38	1.41	303.54	1360.28	1056.74
WhitesBranch	Reach1	2746.557	50-Year	10275.00	538.92	564.17	1.11	220.57	1360.28	1139.71
WhitesBranch	Reach1	2746.557	100-Year	11553.00	538.92	569.79	0.82	128.82	1360.28	1231.46
WhitesBranch	Reach1	2746.557	250-Year	13041.00	538.92	570.47	0.88	108.36	1360.28	1251.92
WhitesBranch	Reach1	2746.557	500-Year	14097.00	538.92	570.91	0.92	103.61	1360.28	1256.67
WhitesBranch	Reach1	2955.221	2-Year	2325.00	540.43	549.46	3.62	872.82	1023.77	150.94
WhitesBranch	Reach1	2955.221	5-Year	5216.00	540.43	552.24	4.58	422.66	1129.29	706.63
WhitesBranch	Reach1	2955.221	10-Year	6914.00	540.43	554.87	3.10	362.80	1129.29	766.49
WhitesBranch	Reach1	2955.221	25-Year	8904.00	540.43	560.40	1.71	284.10	1129.29	845.19
WhitesBranch	Reach1	2955.221	50-Year	10275.00	540.43	564.18	1.38	212.69	1129.29	916.60
WhitesBranch	Reach1	2955.221	100-Year	11553.00	540.43	569.79	1.02	124.58	1129.29	1004.71
WhitesBranch	Reach1	2955.221	250-Year	13041.00	540.43	570.48	1.10	109.74	1129.29	1019.55
WhitesBranch	Reach1	2955.221	500-Year	14097.00	540.43	570.91	1.16	100.24	1129.29	1029.05
WhitesBranch	Reach1	3283.866	2-Year	2325.00	541.67	550.09	3.04	709.41	882.44	173.03
WhitesBranch	Reach1	3283.866	5-Year	5216.00	541.67	552.86	4.18	457.47	1048.29	469.95
WhitesBranch	Reach1	3283.866	10-Year	6914.00	541.67	555.09	3.38	361.12	1048.29	687.17
WhitesBranch	Reach1	3283.866	25-Year	8904.00	541.67	560.43	1.88	318.94	1048.29	729.35
WhitesBranch	Reach1	3283.866	50-Year	10275.00	541.67	564.20	1.50	278.53	1048.29	769.76
WhitesBranch	Reach1	3283.866	100-Year	11553.00	541.67	569.80	1.14	166.51	1048.29	881.78
WhitesBranch	Reach1	3283.866	250-Year	13041.00	541.67	570.48	1.24	152.74	1048.29	895.55
WhitesBranch	Reach1	3283.866	500-Year	14097.00	541.67	570.92	1.30	134.58	1048.29	913.71
WhitesBranch	Reach1	3532.305	2-Year	2377.00	543.42	550.69	5.15	587.81	747.18	159.38
WhitesBranch	Reach1	3532.305	5-Year	5818.00	543.42	553.45	6.21	524.25	926.47	402.22
WhitesBranch	Reach1	3532.305	10-Year	7949.00	543.42	555.33	5.58	517.54	1178.10	660.56
WhitesBranch	Reach1	3532.305	25-Year	10430.00	543.42	560.48	2.60	502.45	1365.91	863.45
WhitesBranch	Reach1	3532.305	50-Year	12145.00	543.42	564.21	1.89	472.60	1395.41	922.81

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach1	3532.305	100-Year	13633.00	543.42	569.81	1.30	176.58	1930.02	1753.44
WhitesBranch	Reach1	3532.305	250-Year	15561.00	543.42	570.49	1.62	146.37	2007.11	1860.74
WhitesBranch	Reach1	3532.305	500-Year	17070.00	543.42	570.93	1.69	126.03	2007.11	1881.08
WhitesBranch	Reach1	3821.940	2-Year	2377.00	543.42	552.39	5.28	436.19	554.30	118.11
WhitesBranch	Reach1	3821.940	5-Year	5818.00	543.42	554.98	8.04	422.40	806.33	300.93
WhitesBranch	Reach1	3821.940	10-Year	7949.00	543.42	556.26	8.15	417.55	1056.35	638.80
WhitesBranch	Reach1	3821.940	25-Year	10430.00	543.42	560.59	3.87	402.93	1176.85	773.91
WhitesBranch	Reach1	3821.940	50-Year	12145.00	543.42	564.26	2.59	390.53	1202.37	811.84
WhitesBranch	Reach1	3821.940	100-Year	13633.00	543.42	569.82	1.66	162.96	1733.96	1571.00
WhitesBranch	Reach1	3821.940	250-Year	15561.00	543.42	570.51	2.05	137.32	1779.87	1642.55
WhitesBranch	Reach1	3821.940	500-Year	17070.00	543.42	570.95	2.14	120.37	1779.87	1659.50
WhitesBranch	Reach1	3991.239	2-Year	2377.00	544.00	553.19	5.16	464.84	565.70	100.85
WhitesBranch	Reach1	3991.239	5-Year	5818.00	544.00	556.19	7.51	428.10	983.52	555.42
WhitesBranch	Reach1	3991.239	10-Year	7949.00	544.00	557.34	7.46	424.70	1043.76	619.06
WhitesBranch	Reach1	3991.239	25-Year	10430.00	544.00	560.72	4.46	414.75	1126.59	711.85
WhitesBranch	Reach1	3991.239	50-Year	12145.00	544.00	564.30	2.97	363.45	1159.46	796.01
WhitesBranch	Reach1	3991.239	100-Year	13633.00	544.00	569.83	1.85	145.08	1693.87	1548.79
WhitesBranch	Reach1	3991.239	250-Year	15561.00	544.00	570.53	2.25	121.82	1722.90	1601.08
WhitesBranch	Reach1	3991.239	500-Year	17070.00	544.00	570.97	2.34	107.87	1722.90	1615.03
WhitesBranch	Reach1	4186.706	2-Year	2377.00	544.17	554.06	4.27	446.94	603.96	157.02
WhitesBranch	Reach1	4186.706	5-Year	5818.00	544.17	557.38	5.22	398.02	990.60	592.58
WhitesBranch	Reach1	4186.706	10-Year	7949.00	544.17	558.32	5.65	394.37	1045.78	651.41
WhitesBranch	Reach1	4186.706	25-Year	10430.00	544.17	560.93	4.20	384.25	1118.48	734.23
WhitesBranch	Reach1	4186.706	50-Year	12145.00	544.17	564.36	2.87	330.07	1141.41	811.33
WhitesBranch	Reach1	4186.706	100-Year	13633.00	544.17	569.85	1.79	150.41	1539.95	1389.54
WhitesBranch	Reach1	4186.706	250-Year	15561.00	544.17	570.55	1.93	121.74	1772.46	1566.32
WhitesBranch	Reach1	4186.706	500-Year	17070.00	544.17	570.99	2.05	86.75	1827.72	1740.97
WhitesBranch	Reach1	4371.306	2-Year	2377.00	544.17	554.59	3.92	443.13	720.48	277.35
WhitesBranch	Reach1	4371.306	5-Year	5818.00	544.17	557.91	4.47	391.15	959.77	568.63
WhitesBranch	Reach1	4371.306	10-Year	7949.00	544.17	558.86	4.95	386.86	1034.94	648.08
WhitesBranch	Reach1	4371.306	25-Year	10430.00	544.17	561.15	4.15	376.61	1069.21	692.60
WhitesBranch	Reach1	4371.306	50-Year	12145.00	544.17	564.44	2.98	361.78	1098.36	736.58
WhitesBranch	Reach1	4371.306	100-Year	13633.00	544.17	569.87	1.91	152.78	2016.58	1266.40
WhitesBranch	Reach1	4371.306	250-Year	15561.00	544.17	570.57	2.06	128.32	2023.76	1358.53
WhitesBranch	Reach1	4371.306	500-Year	17070.00	544.17	571.01	2.18	108.11	2028.25	1407.72
WhitesBranch	Reach1	4571.844	2-Year	2377.00	545.65	554.94	3.26	485.42	786.27	300.85
WhitesBranch	Reach1	4571.844	5-Year	5818.00	545.65	558.18	3.86	399.34	939.31	539.97
WhitesBranch	Reach1	4571.844	10-Year	7949.00	545.65	559.17	4.33	398.62	991.69	593.07
WhitesBranch	Reach1	4571.844	25-Year	10430.00	545.65	561.32	3.85	397.03	1091.35	694.32
WhitesBranch	Reach1	4571.844	50-Year	12145.00	545.65	564.50	2.90	364.49	1120.10	755.61
WhitesBranch	Reach1	4571.844	100-Year	13633.00	545.65	569.89	1.87	107.39	1933.51	1300.38
WhitesBranch	Reach1	4571.844	250-Year	15561.00	545.65	570.60	2.01	84.97	1939.96	1368.65
WhitesBranch	Reach1	4571.844	500-Year	17070.00	545.65	571.04	2.12	73.87	1944.23	1400.22
WhitesBranch	Reach1	4591.664	2-Year	2377.00	545.92	554.96	3.23	457.20	783.00	325.81
WhitesBranch	Reach1	4591.664	5-Year	5818.00	545.92	558.20	3.85	388.39	904.08	515.68
WhitesBranch	Reach1	4591.664	10-Year	7949.00	545.92	559.18	4.43	382.94	965.86	582.92
WhitesBranch	Reach1	4591.664	25-Year	10430.00	545.92	561.32	4.06	375.09	1066.54	691.46
WhitesBranch	Reach1	4591.664	50-Year	12145.00	545.92	564.50	3.10	336.50	1093.62	757.12
WhitesBranch	Reach1	4591.664	100-Year	13633.00	545.92	569.89	2.04	77.98	1894.20	1244.51
WhitesBranch	Reach1	4591.664	250-Year	15561.00	545.92	570.60	2.20	58.01	1899.94	1343.20
WhitesBranch	Reach1	4591.664	500-Year	17070.00	545.92	571.04	2.32	46.70	1903.55	1371.36
WhitesBranch	Reach1	4605.425	2-Year	2377.00	549.75	554.96	3.77	464.14	801.84	337.69
WhitesBranch	Reach1	4605.425	5-Year	5818.00	549.75	558.21	3.99	395.54	912.23	516.69
WhitesBranch	Reach1	4605.425	10-Year	7949.00	549.75	559.19	4.55	389.80	975.55	585.75
WhitesBranch	Reach1	4605.425	25-Year	10430.00	549.75	561.33	4.11	382.15	1078.49	696.34
WhitesBranch	Reach1	4605.425	50-Year	12145.00	549.75	564.51	3.10	346.25	1104.52	758.27
WhitesBranch	Reach1	4605.425	100-Year	13633.00	549.75	569.89	2.04	83.64	1628.68	1237.08
WhitesBranch	Reach1	4605.425	250-Year	15561.00	549.75	570.60	2.19	64.05	1900.63	1346.75
WhitesBranch	Reach1	4605.425	500-Year	17070.00	549.75	571.04	2.32	52.68	1904.57	1379.49
WhitesBranch	Reach1	4642.575	2-Year	2377.00	546.67	554.97	4.56	483.51	714.72	231.22
WhitesBranch	Reach1	4642.575	5-Year	5818.00	546.67	558.16	5.47	413.75	919.97	506.22

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach1	4642.575	10-Year	7949.00	546.67	559.14	5.98	409.03	977.27	568.24
WhitesBranch	Reach1	4642.575	25-Year	10430.00	546.67	561.31	5.11	398.25	1094.02	695.78
WhitesBranch	Reach1	4642.575	50-Year	12145.00	546.67	564.51	3.61	369.90	1118.33	748.43
WhitesBranch	Reach1	4642.575	100-Year	13633.00	546.67	569.89	2.27	100.16	1634.85	1240.04
WhitesBranch	Reach1	4642.575	250-Year	15561.00	546.67	570.60	2.43	79.74	1905.64	1362.77
WhitesBranch	Reach1	4642.575	500-Year	17070.00	546.67	571.04	2.57	68.37	1909.70	1399.66
WhitesBranch	Reach1	4741.197	2-Year	2377.00	546.67	555.32	3.97	519.79	691.80	172.01
WhitesBranch	Reach1	4741.197	5-Year	5818.00	546.67	558.39	5.42	417.51	927.46	490.61
WhitesBranch	Reach1	4741.197	10-Year	7949.00	546.67	559.38	5.98	412.84	957.63	544.78
WhitesBranch	Reach1	4741.197	25-Year	10430.00	546.67	561.44	5.18	403.09	1078.48	675.40
WhitesBranch	Reach1	4741.197	50-Year	12145.00	546.67	564.56	3.53	386.35	1110.85	724.49
WhitesBranch	Reach1	4741.197	100-Year	13633.00	546.67	569.90	2.15	93.18	1617.69	1220.32
WhitesBranch	Reach1	4741.197	250-Year	15561.00	546.67	570.61	2.29	68.91	1887.09	1368.39
WhitesBranch	Reach1	4741.197	500-Year	17070.00	546.67	571.06	2.42	53.59	1891.52	1420.27
WhitesBranch	Reach1	4832.364	2-Year	2377.00	546.67	555.66	3.51	464.43	699.51	235.08
WhitesBranch	Reach1	4832.364	5-Year	5818.00	546.67	558.83	3.91	415.51	923.75	508.23
WhitesBranch	Reach1	4832.364	10-Year	7949.00	546.67	559.86	4.27	411.59	948.98	537.38
WhitesBranch	Reach1	4832.364	25-Year	10430.00	546.67	561.71	4.01	404.52	996.39	591.87
WhitesBranch	Reach1	4832.364	50-Year	12145.00	546.67	564.64	3.05	393.30	1115.18	721.88
WhitesBranch	Reach1	4832.364	100-Year	13633.00	546.67	569.92	1.92	42.63	1607.56	1259.33
WhitesBranch	Reach1	4832.364	250-Year	15561.00	546.67	570.63	2.05	14.30	1877.74	1371.22
WhitesBranch	Reach1	4832.364	500-Year	17070.00	546.67	571.09	2.13	0.00	1882.31	1474.49
WhitesBranch	Reach2	5011.910	2-Year	2373.00	546.92	556.12	2.39	725.83	1077.77	351.95
WhitesBranch	Reach2	5011.910	5-Year	5803.00	546.92	559.20	3.06	652.10	1132.39	480.29
WhitesBranch	Reach2	5011.910	10-Year	7919.00	546.92	560.25	3.54	628.28	1160.10	531.82
WhitesBranch	Reach2	5011.910	25-Year	10377.00	546.92	561.99	3.63	453.87	1206.52	719.21
WhitesBranch	Reach2	5011.910	50-Year	12072.00	546.92	564.77	2.76	248.15	1326.19	1078.04
WhitesBranch	Reach2	5011.910	100-Year	13554.00	546.92	569.96	1.55	154.43	1809.49	1368.02
WhitesBranch	Reach2	5011.910	250-Year	15468.00	546.92	570.68	1.64	136.90	2080.02	1478.69
WhitesBranch	Reach2	5011.910	500-Year	16963.00	546.92	571.13	1.72	122.72	2084.68	1588.28
WhitesBranch	Reach2	5161.123	2-Year	2373.00	546.92	556.28	1.93	623.80	1056.74	432.94
WhitesBranch	Reach2	5161.123	5-Year	5803.00	546.92	559.36	2.51	602.60	1112.88	510.28
WhitesBranch	Reach2	5161.123	10-Year	7919.00	546.92	560.44	2.91	573.17	1125.66	552.48
WhitesBranch	Reach2	5161.123	25-Year	10377.00	546.92	562.16	3.09	407.89	1168.53	760.64
WhitesBranch	Reach2	5161.123	50-Year	12072.00	546.92	564.84	2.52	251.91	1265.39	1013.47
WhitesBranch	Reach2	5161.123	100-Year	13554.00	546.92	569.98	1.55	151.49	1736.54	1289.58
WhitesBranch	Reach2	5161.123	250-Year	15468.00	546.92	570.69	1.65	133.52	2008.57	1395.37
WhitesBranch	Reach2	5161.123	500-Year	16963.00	546.92	571.15	1.76	118.81	2013.25	1500.70
WhitesBranch	Reach2	5630.007	2-Year	2373.00	548.92	556.79	4.76	836.80	1251.36	304.32
WhitesBranch	Reach2	5630.007	5-Year	5803.00	548.92	559.83	4.40	649.35	1293.55	599.67
WhitesBranch	Reach2	5630.007	10-Year	7919.00	548.92	560.96	4.61	610.71	1305.61	694.90
WhitesBranch	Reach2	5630.007	25-Year	10377.00	548.92	562.61	4.23	549.96	1381.99	832.03
WhitesBranch	Reach2	5630.007	50-Year	12072.00	548.92	565.06	3.17	370.68	1425.25	1054.57
WhitesBranch	Reach2	5630.007	100-Year	13554.00	548.92	570.03	1.74	142.12	2110.90	1467.11
WhitesBranch	Reach2	5630.007	250-Year	15468.00	548.92	570.75	1.83	120.64	2126.52	1568.63
WhitesBranch	Reach2	5630.007	500-Year	16963.00	548.92	571.21	1.94	107.50	2126.52	1656.22
WhitesBranch	Reach2	5904.419	2-Year	2373.00	549.82	558.03	4.21	1037.29	1294.74	257.45
WhitesBranch	Reach2	5904.419	5-Year	5803.00	549.82	560.54	5.37	639.47	1306.05	584.52
WhitesBranch	Reach2	5904.419	10-Year	7919.00	549.82	561.60	5.59	608.12	1318.11	709.99
WhitesBranch	Reach2	5904.419	25-Year	10377.00	549.82	563.04	5.26	531.52	1325.75	794.22
WhitesBranch	Reach2	5904.419	50-Year	12072.00	549.82	565.25	3.81	360.22	1337.57	977.36
WhitesBranch	Reach2	5904.419	100-Year	13554.00	549.82	570.07	2.07	129.21	1937.15	1469.39
WhitesBranch	Reach2	5904.419	250-Year	15468.00	549.82	570.79	2.15	113.32	1943.01	1564.49
WhitesBranch	Reach2	5904.419	500-Year	16963.00	549.82	571.25	2.22	103.17	1946.75	1587.32
WhitesBranch	Reach2	6054.181	2-Year	2373.00	549.82	558.46	3.45	960.29	1317.38	357.08
WhitesBranch	Reach2	6054.181	5-Year	5803.00	549.82	561.01	4.60	597.91	1324.97	630.04
WhitesBranch	Reach2	6054.181	10-Year	7919.00	549.82	562.05	4.94	512.51	1343.97	831.46
WhitesBranch	Reach2	6054.181	25-Year	10377.00	549.82	563.37	4.94	425.18	1351.10	925.93
WhitesBranch	Reach2	6054.181	50-Year	12072.00	549.82	565.39	3.73	317.59	1362.29	1044.70
WhitesBranch	Reach2	6054.181	100-Year	13554.00	549.82	570.09	2.10	135.50	1830.46	1349.59
WhitesBranch	Reach2	6054.181	250-Year	15468.00	549.82	570.82	2.20	116.15	1837.20	1415.49
WhitesBranch	Reach2	6054.181	500-Year	16963.00	549.82	571.28	2.30	103.77	1841.51	1464.86

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	6236.385	2-Year	2373.00	550.27	558.74	3.56	945.89	1292.73	346.84
WhitesBranch	Reach2	6236.385	5-Year	5803.00	550.27	561.32	4.85	561.71	1297.35	735.63
WhitesBranch	Reach2	6236.385	10-Year	7919.00	550.27	562.35	5.23	482.73	1298.98	816.25
WhitesBranch	Reach2	6236.385	25-Year	10377.00	550.27	563.62	5.38	406.51	1331.12	911.55
WhitesBranch	Reach2	6236.385	50-Year	12072.00	550.27	565.50	4.04	343.74	1348.53	1004.79
WhitesBranch	Reach2	6236.385	100-Year	13554.00	550.27	570.12	2.37	169.49	1468.37	1298.88
WhitesBranch	Reach2	6236.385	250-Year	15468.00	550.27	570.84	2.48	147.65	1521.41	1373.76
WhitesBranch	Reach2	6236.385	500-Year	16963.00	550.27	571.30	2.59	134.02	1550.49	1416.47
WhitesBranch	Reach2	6432.119	2-Year	2373.00	550.29	559.07	3.76	967.53	1251.60	284.08
WhitesBranch	Reach2	6432.119	5-Year	5803.00	550.29	561.69	5.10	602.20	1257.93	617.88
WhitesBranch	Reach2	6432.119	10-Year	7919.00	550.29	562.71	5.54	478.75	1260.39	781.65
WhitesBranch	Reach2	6432.119	25-Year	10377.00	550.29	563.94	5.76	399.43	1263.37	863.94
WhitesBranch	Reach2	6432.119	50-Year	12072.00	550.29	565.65	4.42	338.02	1267.49	929.47
WhitesBranch	Reach2	6432.119	100-Year	13554.00	550.29	570.15	2.61	187.73	1479.93	1292.20
WhitesBranch	Reach2	6432.119	250-Year	15468.00	550.29	570.87	2.72	160.80	1644.45	1401.55
WhitesBranch	Reach2	6432.119	500-Year	16963.00	550.29	571.34	2.83	149.30	1669.18	1519.88
WhitesBranch	Reach2	6678.184	2-Year	2373.00	550.22	559.54	3.99	919.46	1204.71	285.25
WhitesBranch	Reach2	6678.184	5-Year	5803.00	550.22	562.24	5.36	556.66	1223.86	639.43
WhitesBranch	Reach2	6678.184	10-Year	7919.00	550.22	563.27	5.97	431.90	1230.08	798.18
WhitesBranch	Reach2	6678.184	25-Year	10377.00	550.22	564.50	5.57	401.04	1233.65	832.60
WhitesBranch	Reach2	6678.184	50-Year	12072.00	550.22	565.91	4.83	358.94	1237.76	878.81
WhitesBranch	Reach2	6678.184	100-Year	13554.00	550.22	570.21	2.84	208.96	1250.26	1041.30
WhitesBranch	Reach2	6678.184	250-Year	15468.00	550.22	570.94	2.97	185.89	1253.20	1067.31
WhitesBranch	Reach2	6678.184	500-Year	16963.00	550.22	571.40	3.09	171.51	1255.69	1084.18
WhitesBranch	Reach2	6911.609	2-Year	2373.00	550.67	560.04	5.53	841.72	1085.76	244.04
WhitesBranch	Reach2	6911.609	5-Year	5803.00	550.67	562.80	7.06	571.89	1090.31	518.42
WhitesBranch	Reach2	6911.609	10-Year	7919.00	550.67	563.87	7.49	519.64	1091.94	572.30
WhitesBranch	Reach2	6911.609	25-Year	10377.00	550.67	564.95	7.77	447.50	1093.58	646.08
WhitesBranch	Reach2	6911.609	50-Year	12072.00	550.67	566.19	7.42	254.68	1105.48	850.80
WhitesBranch	Reach2	6911.609	100-Year	13554.00	550.67	570.28	3.72	101.69	1115.21	1013.52
WhitesBranch	Reach2	6911.609	250-Year	15468.00	550.67	571.00	3.80	88.54	1117.06	1028.52
WhitesBranch	Reach2	6911.609	500-Year	16963.00	550.67	571.47	3.90	80.09	1118.20	1038.11
WhitesBranch	Reach2	7159.992	2-Year	2373.00	551.59	560.76	4.36	811.49	1062.83	251.34
WhitesBranch	Reach2	7159.992	5-Year	5803.00	551.59	563.59	5.75	584.18	1068.31	484.13
WhitesBranch	Reach2	7159.992	10-Year	7919.00	551.59	564.67	6.59	530.21	1070.52	540.31
WhitesBranch	Reach2	7159.992	25-Year	10377.00	551.59	565.69	7.43	305.00	1072.61	767.61
WhitesBranch	Reach2	7159.992	50-Year	12072.00	551.59	566.78	6.73	281.04	1082.20	801.15
WhitesBranch	Reach2	7159.992	100-Year	13554.00	551.59	570.39	4.15	114.51	1130.41	1015.89
WhitesBranch	Reach2	7159.992	250-Year	15468.00	551.59	571.11	4.21	103.52	1135.08	1031.55
WhitesBranch	Reach2	7159.992	500-Year	16963.00	551.59	571.59	4.30	96.39	1138.11	1041.71
WhitesBranch	Reach2	7351.512	2-Year	2373.00	554.32	561.21	5.69	873.77	1064.29	190.52
WhitesBranch	Reach2	7351.512	5-Year	5803.00	554.32	564.01	7.34	841.67	1072.24	230.57
WhitesBranch	Reach2	7351.512	10-Year	7919.00	554.32	565.12	8.28	673.16	1074.75	401.59
WhitesBranch	Reach2	7351.512	25-Year	10377.00	554.32	566.21	8.91	438.88	1077.20	522.52
WhitesBranch	Reach2	7351.512	50-Year	12072.00	554.32	567.08	8.98	376.87	1079.19	702.32
WhitesBranch	Reach2	7351.512	100-Year	13554.00	554.32	570.48	5.19	167.61	1090.38	922.77
WhitesBranch	Reach2	7351.512	250-Year	15468.00	554.32	571.21	5.22	148.67	1092.86	944.18
WhitesBranch	Reach2	7351.512	500-Year	16963.00	554.32	571.68	5.30	136.34	1094.47	958.13
WhitesBranch	Reach2	7647.993	2-Year	2373.00	555.23	562.75	6.18	927.57	1047.28	119.71
WhitesBranch	Reach2	7647.993	5-Year	5803.00	555.23	565.60	8.43	645.38	1059.35	413.97
WhitesBranch	Reach2	7647.993	10-Year	7919.00	555.23	566.85	8.35	423.48	1064.51	585.31
WhitesBranch	Reach2	7647.993	25-Year	10377.00	555.23	567.98	8.94	245.07	1066.51	821.44
WhitesBranch	Reach2	7647.993	50-Year	12072.00	555.23	568.74	8.27	232.80	1067.74	834.94
WhitesBranch	Reach2	7647.993	100-Year	13554.00	555.23	570.89	5.68	174.39	1071.18	896.79
WhitesBranch	Reach2	7647.993	250-Year	15468.00	555.23	571.59	5.68	155.56	1072.31	916.75
WhitesBranch	Reach2	7647.993	500-Year	16963.00	555.23	572.06	5.74	142.83	1073.48	930.65
WhitesBranch	Reach2	7946.355	2-Year	2373.00	555.98	564.06	5.05	614.93	982.55	262.44
WhitesBranch	Reach2	7946.355	5-Year	5803.00	555.98	567.06	5.65	301.91	990.18	606.31
WhitesBranch	Reach2	7946.355	10-Year	7919.00	555.98	568.12	6.26	258.16	992.87	734.71
WhitesBranch	Reach2	7946.355	25-Year	10377.00	555.98	569.22	6.26	213.37	995.69	782.32
WhitesBranch	Reach2	7946.355	50-Year	12072.00	555.98	569.74	6.51	193.59	997.01	803.42

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	7946.355	100-Year	13554.00	555.98	571.27	5.37	180.34	1276.35	824.83
WhitesBranch	Reach2	7946.355	250-Year	15468.00	555.98	571.95	5.45	176.83	1280.26	865.48
WhitesBranch	Reach2	7946.355	500-Year	16963.00	555.98	572.41	5.55	174.45	1282.92	874.91
WhitesBranch	Reach2	8209.452	2-Year	2373.00	556.73	564.80	4.39	608.30	962.26	319.25
WhitesBranch	Reach2	8209.452	5-Year	5803.00	556.73	567.63	5.13	460.52	971.05	510.53
WhitesBranch	Reach2	8209.452	10-Year	7919.00	556.73	568.71	5.54	438.00	975.23	537.23
WhitesBranch	Reach2	8209.452	25-Year	10377.00	556.73	569.73	5.99	429.01	979.13	550.12
WhitesBranch	Reach2	8209.452	50-Year	12072.00	556.73	570.25	6.38	423.61	981.11	557.50
WhitesBranch	Reach2	8209.452	100-Year	13554.00	556.73	571.56	6.23	247.98	986.13	738.15
WhitesBranch	Reach2	8209.452	250-Year	15468.00	556.73	572.22	6.43	209.90	993.20	770.22
WhitesBranch	Reach2	8209.452	500-Year	16963.00	556.73	572.68	6.64	184.28	996.99	812.71
WhitesBranch	Reach2	8386.322	2-Year	2373.00	557.05	565.17	5.71	588.37	875.13	286.76
WhitesBranch	Reach2	8386.322	5-Year	5803.00	557.05	567.92	6.52	436.37	883.71	447.34
WhitesBranch	Reach2	8386.322	10-Year	7919.00	557.05	569.01	6.92	421.40	886.91	465.51
WhitesBranch	Reach2	8386.322	25-Year	10377.00	557.05	570.03	7.45	334.23	889.75	555.52
WhitesBranch	Reach2	8386.322	50-Year	12072.00	557.05	570.56	7.86	283.28	891.25	607.97
WhitesBranch	Reach2	8386.322	100-Year	13554.00	557.05	571.84	6.99	254.89	894.80	639.90
WhitesBranch	Reach2	8386.322	250-Year	15468.00	557.05	572.50	7.61	240.96	954.12	713.16
WhitesBranch	Reach2	8386.322	500-Year	16963.00	557.05	572.97	7.69	232.44	955.84	723.41
WhitesBranch	Reach2	8490.864	2-Year	2416.00	557.23	565.61	5.36	455.84	719.15	263.31
WhitesBranch	Reach2	8490.864	5-Year	5940.00	557.23	568.24	6.35	432.33	794.72	362.39
WhitesBranch	Reach2	8490.864	10-Year	8060.00	557.23	569.30	6.86	414.01	797.32	383.31
WhitesBranch	Reach2	8490.864	25-Year	10498.00	557.23	570.32	7.33	339.49	799.82	418.75
WhitesBranch	Reach2	8490.864	50-Year	12226.00	557.23	570.86	7.77	258.90	801.19	542.29
WhitesBranch	Reach2	8490.864	100-Year	13984.00	557.23	572.01	7.54	232.67	804.44	571.78
WhitesBranch	Reach2	8490.864	250-Year	16043.00	557.23	572.71	7.70	216.91	806.42	589.51
WhitesBranch	Reach2	8490.864	500-Year	17629.00	557.23	573.16	7.88	206.67	807.71	601.04
WhitesBranch	Reach2	8615.602	2-Year	2416.00	558.56	566.11	5.96	378.40	602.90	224.49
WhitesBranch	Reach2	8615.602	5-Year	5940.00	558.56	568.62	7.49	257.82	635.47	377.65
WhitesBranch	Reach2	8615.602	10-Year	8060.00	558.56	569.68	7.90	232.46	639.47	407.02
WhitesBranch	Reach2	8615.602	25-Year	10498.00	558.56	570.70	8.36	206.79	643.43	436.64
WhitesBranch	Reach2	8615.602	50-Year	12226.00	558.56	571.27	8.76	194.53	645.72	451.20
WhitesBranch	Reach2	8615.602	100-Year	13984.00	558.56	572.34	8.35	173.03	650.15	477.12
WhitesBranch	Reach2	8615.602	250-Year	16043.00	558.56	573.02	8.68	159.91	658.67	498.75
WhitesBranch	Reach2	8615.602	500-Year	17629.00	558.56	573.47	8.96	151.23	663.84	512.61
WhitesBranch	Reach2	8755.626	2-Year	2416.00	559.29	566.91	4.94	363.59	548.43	184.84
WhitesBranch	Reach2	8755.626	5-Year	5940.00	559.29	569.34	7.06	262.31	634.69	372.38
WhitesBranch	Reach2	8755.626	10-Year	8060.00	559.29	570.36	7.68	230.27	660.37	430.10
WhitesBranch	Reach2	8755.626	25-Year	10498.00	559.29	571.36	8.13	198.63	664.74	466.12
WhitesBranch	Reach2	8755.626	50-Year	12226.00	559.29	571.95	8.48	180.21	667.29	487.08
WhitesBranch	Reach2	8755.626	100-Year	13984.00	559.29	572.89	8.21	157.32	671.38	514.06
WhitesBranch	Reach2	8755.626	250-Year	16043.00	559.29	573.57	8.42	141.48	673.92	532.43
WhitesBranch	Reach2	8755.626	500-Year	17629.00	559.29	574.03	8.61	131.58	675.41	543.83
WhitesBranch	Reach2	8898.284	2-Year	2416.00	559.80	567.52	5.33	367.09	568.55	201.47
WhitesBranch	Reach2	8898.284	5-Year	5940.00	559.80	570.14	7.06	282.81	620.41	337.61
WhitesBranch	Reach2	8898.284	10-Year	8060.00	559.80	571.15	7.75	251.38	623.39	372.01
WhitesBranch	Reach2	8898.284	25-Year	10498.00	559.80	572.11	8.46	219.68	626.18	406.50
WhitesBranch	Reach2	8898.284	50-Year	12226.00	559.80	572.69	8.88	203.86	627.89	424.03
WhitesBranch	Reach2	8898.284	100-Year	13984.00	559.80	573.49	8.90	183.74	629.96	446.22
WhitesBranch	Reach2	8898.284	250-Year	16043.00	559.80	574.15	9.22	168.37	631.65	463.28
WhitesBranch	Reach2	8898.284	500-Year	17629.00	559.80	574.60	9.48	157.92	632.80	474.89
WhitesBranch	Reach2	9090.119	2-Year	2416.00	560.31	568.34	4.13	373.14	587.28	214.14
WhitesBranch	Reach2	9090.119	5-Year	5940.00	560.31	571.07	5.91	316.00	667.15	351.15
WhitesBranch	Reach2	9090.119	10-Year	8060.00	560.31	572.13	6.62	292.38	691.68	399.30
WhitesBranch	Reach2	9090.119	25-Year	10498.00	560.31	573.14	7.22	269.26	699.40	430.14
WhitesBranch	Reach2	9090.119	50-Year	12226.00	560.31	573.76	7.60	254.25	702.85	448.59
WhitesBranch	Reach2	9090.119	100-Year	13984.00	560.31	574.48	7.83	229.11	706.84	477.73
WhitesBranch	Reach2	9090.119	250-Year	16043.00	560.31	575.14	8.18	205.77	710.54	504.77
WhitesBranch	Reach2	9090.119	500-Year	17629.00	560.31	575.61	8.44	189.39	713.10	523.72
WhitesBranch	Reach2	9205.375	2-Year	2416.00	560.73	568.66	3.69	365.52	632.12	235.55
WhitesBranch	Reach2	9205.375	5-Year	5940.00	560.73	571.50	5.15	319.30	692.01	372.71

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	9205.375	10-Year	8060.00	560.73	572.61	5.78	294.06	723.95	429.90
WhitesBranch	Reach2	9205.375	25-Year	10498.00	560.73	573.65	6.28	266.38	736.18	469.80
WhitesBranch	Reach2	9205.375	50-Year	12226.00	560.73	574.30	6.58	248.33	738.23	489.90
WhitesBranch	Reach2	9205.375	100-Year	13984.00	560.73	575.01	6.73	228.31	740.51	512.20
WhitesBranch	Reach2	9205.375	250-Year	16043.00	560.73	575.69	6.99	209.19	742.69	533.50
WhitesBranch	Reach2	9205.375	500-Year	17629.00	560.73	576.17	7.19	194.93	744.22	549.28
WhitesBranch	Reach2	9359.926	2-Year	2416.00	560.73	568.98	4.59	254.74	599.18	300.29
WhitesBranch	Reach2	9359.926	5-Year	5940.00	560.73	571.91	5.18	190.15	628.37	438.21
WhitesBranch	Reach2	9359.926	10-Year	8060.00	560.73	573.06	5.54	182.44	652.21	469.78
WhitesBranch	Reach2	9359.926	25-Year	10498.00	560.73	574.13	5.97	174.71	674.92	500.21
WhitesBranch	Reach2	9359.926	50-Year	12226.00	560.73	574.79	6.32	169.88	701.99	532.11
WhitesBranch	Reach2	9359.926	100-Year	13984.00	560.73	575.49	6.53	164.69	727.99	563.30
WhitesBranch	Reach2	9359.926	250-Year	16043.00	560.73	576.18	6.81	159.60	753.49	593.89
WhitesBranch	Reach2	9359.926	500-Year	17629.00	560.73	576.66	6.96	154.50	759.20	604.70
WhitesBranch	Reach2	9534.423	2-Year	2416.00	560.73	569.50	4.40	151.46	474.54	219.32
WhitesBranch	Reach2	9534.423	5-Year	5940.00	560.73	572.31	5.84	132.43	541.62	409.19
WhitesBranch	Reach2	9534.423	10-Year	8060.00	560.73	573.45	6.39	124.56	634.77	510.21
WhitesBranch	Reach2	9534.423	25-Year	10498.00	560.73	574.54	6.60	115.12	648.51	533.38
WhitesBranch	Reach2	9534.423	50-Year	12226.00	560.73	575.21	6.75	109.25	653.28	544.03
WhitesBranch	Reach2	9534.423	100-Year	13984.00	560.73	575.91	6.82	103.16	658.32	555.16
WhitesBranch	Reach2	9534.423	250-Year	16043.00	560.73	576.61	6.99	97.10	663.32	566.22
WhitesBranch	Reach2	9534.423	500-Year	17629.00	560.73	577.10	7.13	93.15	666.82	573.67
WhitesBranch	Reach2	9765.110	2-Year	2416.00	561.01	570.05	2.79	166.84	430.42	263.59
WhitesBranch	Reach2	9765.110	5-Year	5940.00	561.01	572.95	4.15	140.85	535.51	394.66
WhitesBranch	Reach2	9765.110	10-Year	8060.00	561.01	574.11	4.72	129.57	599.50	469.93
WhitesBranch	Reach2	9765.110	25-Year	10498.00	561.01	575.14	5.17	119.22	605.91	486.69
WhitesBranch	Reach2	9765.110	50-Year	12226.00	561.01	575.79	5.45	112.70	609.94	497.25
WhitesBranch	Reach2	9765.110	100-Year	13984.00	561.01	576.45	5.67	106.21	614.07	507.86
WhitesBranch	Reach2	9765.110	250-Year	16043.00	561.01	577.12	5.95	99.64	618.29	518.65
WhitesBranch	Reach2	9765.110	500-Year	17629.00	561.01	577.60	6.15	95.00	621.26	526.26
WhitesBranch	Reach2	9908.647	2-Year	2416.00	562.05	570.18	4.12	177.07	413.76	184.39
WhitesBranch	Reach2	9908.647	5-Year	5940.00	562.05	573.06	5.92	140.54	442.19	301.65
WhitesBranch	Reach2	9908.647	10-Year	8060.00	562.05	574.21	6.71	126.01	608.96	365.51
WhitesBranch	Reach2	9908.647	25-Year	10498.00	562.05	575.22	7.50	113.26	613.60	496.41
WhitesBranch	Reach2	9908.647	50-Year	12226.00	562.05	575.86	7.86	105.05	616.56	511.50
WhitesBranch	Reach2	9908.647	100-Year	13984.00	562.05	576.52	8.12	96.69	619.56	522.87
WhitesBranch	Reach2	9908.647	250-Year	16043.00	562.05	577.20	8.45	88.13	622.64	534.51
WhitesBranch	Reach2	9908.647	500-Year	17629.00	562.05	577.67	8.70	82.09	624.81	542.72
WhitesBranch	Reach2	9992.958	2-Year	2416.00	562.05	570.40	3.03	178.62	332.20	153.58
WhitesBranch	Reach2	9992.958	5-Year	5940.00	562.05	573.31	5.00	156.89	350.87	193.98
WhitesBranch	Reach2	9992.958	10-Year	8060.00	562.05	574.42	6.00	147.71	371.00	223.29
WhitesBranch	Reach2	9992.958	25-Year	10498.00	562.05	575.38	7.08	137.93	608.62	407.27
WhitesBranch	Reach2	9992.958	50-Year	12226.00	562.05	575.99	7.66	131.74	612.31	480.57
WhitesBranch	Reach2	9992.958	100-Year	13984.00	562.05	576.61	8.15	125.66	616.42	490.76
WhitesBranch	Reach2	9992.958	250-Year	16043.00	562.05	577.24	8.70	119.45	620.65	501.20
WhitesBranch	Reach2	9992.958	500-Year	17629.00	562.05	577.69	9.08	115.03	623.65	508.62
WhitesBranch	Reach2	10047.02	2-Year	2416.00	562.04	570.47	2.75	151.36	318.53	167.17
WhitesBranch	Reach2	10047.02	5-Year	5940.00	562.04	573.45	4.42	133.28	337.45	204.17
WhitesBranch	Reach2	10047.02	10-Year	8060.00	562.04	574.62	5.25	125.76	344.92	219.16
WhitesBranch	Reach2	10047.02	25-Year	10498.00	562.04	575.66	6.14	117.26	352.17	234.91
WhitesBranch	Reach2	10047.02	50-Year	12226.00	562.04	576.26	6.78	112.32	594.50	469.22
WhitesBranch	Reach2	10047.02	100-Year	13984.00	562.04	576.88	7.28	107.01	601.67	494.66
WhitesBranch	Reach2	10047.02	250-Year	16043.00	562.04	577.51	7.85	100.70	609.81	509.11
WhitesBranch	Reach2	10047.02	500-Year	17629.00	562.04	577.95	8.28	96.33	626.15	529.82
WhitesBranch	Reach2	10068.37	2-Year	2416.00	562.20	570.47	2.96	137.33	293.28	155.95
WhitesBranch	Reach2	10068.37	5-Year	5940.00	562.20	573.45	4.57	126.00	311.51	185.51
WhitesBranch	Reach2	10068.37	10-Year	8060.00	562.20	574.63	5.39	120.75	319.47	198.72
WhitesBranch	Reach2	10068.37	25-Year	10498.00	562.20	575.66	6.28	115.45	563.99	213.11
WhitesBranch	Reach2	10068.37	50-Year	12226.00	562.20	576.27	6.87	112.01	586.89	336.91
WhitesBranch	Reach2	10068.37	100-Year	13984.00	562.20	576.88	7.40	109.24	597.35	465.52
WhitesBranch	Reach2	10068.37	250-Year	16043.00	562.20	577.50	8.00	106.16	612.06	505.90
WhitesBranch	Reach2	10068.37	500-Year	17629.00	562.20	577.93	8.46	104.04	648.37	544.33

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Sta W.S. Lft (ft)	Sta W.S. Rgt (ft)	Top Width (ft)
WhitesBranch	Reach2	10091.32	2-Year	2416.00	560.30	570.55	2.27	136.65	268.18	131.53
WhitesBranch	Reach2	10091.32	5-Year	5940.00	560.30	573.58	3.98	123.79	276.79	153.00
WhitesBranch	Reach2	10091.32	10-Year	8060.00	560.30	574.77	4.80	118.71	278.00	159.29
WhitesBranch	Reach2	10091.32	25-Year	10498.00	560.30	575.83	5.67	114.20	559.25	190.82
WhitesBranch	Reach2	10091.32	50-Year	12226.00	560.30	576.45	6.26	111.54	598.19	282.54
WhitesBranch	Reach2	10091.32	100-Year	13984.00	560.30	577.07	6.80	108.92	614.05	366.36
WhitesBranch	Reach2	10091.32	250-Year	16043.00	560.30	577.70	7.42	106.25	643.02	447.49
WhitesBranch	Reach2	10091.32	500-Year	17629.00	560.30	578.13	7.88	104.41	664.30	506.18
WhitesBranch	Reach2	10136.76		Bridge						
WhitesBranch	Reach2	10201.39	2-Year	2416.00	560.30	570.61	2.26	149.40	281.36	131.96
WhitesBranch	Reach2	10201.39	5-Year	5940.00	560.30	573.73	3.92	136.13	290.23	154.10
WhitesBranch	Reach2	10201.39	10-Year	8060.00	560.30	574.98	4.71	130.81	292.72	161.90
WhitesBranch	Reach2	10201.39	25-Year	10498.00	560.30	576.11	5.53	125.99	294.70	168.71
WhitesBranch	Reach2	10201.39	50-Year	12226.00	560.30	576.83	6.06	122.96	591.47	338.42
WhitesBranch	Reach2	10201.39	100-Year	13984.00	560.30	577.56	6.53	119.83	692.14	526.15
WhitesBranch	Reach2	10201.39	250-Year	16043.00	560.30	578.36	7.03	116.41	727.44	611.02
WhitesBranch	Reach2	10201.39	500-Year	17629.00	560.30	578.96	7.38	113.86	752.26	638.40
WhitesBranch	Reach2	10247.90	2-Year	2416.00	562.55	570.08	9.78	745.38	828.51	83.12
WhitesBranch	Reach2	10247.90	5-Year	5940.00	562.55	573.32	9.09	650.51	835.67	185.16
WhitesBranch	Reach2	10247.90	10-Year	8060.00	562.55	574.60	9.54	601.74	838.95	237.21
WhitesBranch	Reach2	10247.90	25-Year	10498.00	562.55	575.80	9.92	551.46	871.43	319.98
WhitesBranch	Reach2	10247.90	50-Year	12226.00	562.55	576.59	9.97	535.42	1110.60	497.95
WhitesBranch	Reach2	10247.90	100-Year	13984.00	562.55	577.43	9.82	531.28	1239.27	693.70
WhitesBranch	Reach2	10247.90	250-Year	16043.00	562.55	578.33	9.66	527.02	1278.59	751.57
WhitesBranch	Reach2	10247.90	500-Year	17629.00	562.55	579.00	9.56	491.08	1291.84	784.48
WhitesBranch	Reach2	10288.56	2-Year	2416.00	562.55	571.56	6.60	654.80	790.58	135.78
WhitesBranch	Reach2	10288.56	5-Year	5940.00	562.55	573.81	10.21	601.83	793.70	191.87
WhitesBranch	Reach2	10288.56	10-Year	8060.00	562.55	575.01	11.07	575.71	802.72	227.00
WhitesBranch	Reach2	10288.56	25-Year	10498.00	562.55	576.15	11.79	554.72	924.10	310.35
WhitesBranch	Reach2	10288.56	50-Year	12226.00	562.55	576.85	12.16	544.55	1055.02	510.46
WhitesBranch	Reach2	10288.56	100-Year	13984.00	562.55	577.60	12.25	533.71	1208.06	674.35
WhitesBranch	Reach2	10288.56	250-Year	16043.00	562.55	578.43	12.32	521.74	1220.31	698.56
WhitesBranch	Reach2	10288.56	500-Year	17629.00	562.55	579.68	9.29	505.86	1238.68	732.82
WhitesBranch	Reach2	10371.61	2-Year	2416.00	562.58	572.26	5.26	605.99	788.04	182.05
WhitesBranch	Reach2	10371.61	5-Year	5940.00	562.58	575.17	7.28	539.28	801.79	262.50
WhitesBranch	Reach2	10371.61	10-Year	8060.00	562.58	576.47	7.70	527.27	957.82	430.55
WhitesBranch	Reach2	10371.61	25-Year	10498.00	562.58	577.65	8.16	517.35	1145.46	628.11
WhitesBranch	Reach2	10371.61	50-Year	12226.00	562.58	578.36	8.50	511.41	1155.85	644.44
WhitesBranch	Reach2	10371.61	100-Year	13984.00	562.58	579.19	7.68	504.61	1168.01	663.41
WhitesBranch	Reach2	10371.61	250-Year	16043.00	562.58	579.98	7.57	499.69	1179.61	679.93
WhitesBranch	Reach2	10371.61	500-Year	17629.00	562.58	580.20	7.99	498.31	1182.87	684.56
WhitesBranch	Reach2	10447.79	2-Year	2416.00	562.62	572.62	4.67	528.01	720.77	192.75
WhitesBranch	Reach2	10447.79	5-Year	5940.00	562.62	575.65	6.36	484.63	752.91	268.28
WhitesBranch	Reach2	10447.79	10-Year	8060.00	562.62	576.91	6.94	472.81	859.76	386.95
WhitesBranch	Reach2	10447.79	25-Year	10498.00	562.62	578.08	7.46	461.76	1034.69	572.93
WhitesBranch	Reach2	10447.79	50-Year	12226.00	562.62	578.80	7.79	454.52	1044.70	590.18
WhitesBranch	Reach2	10447.79	100-Year	13984.00	562.62	579.43	7.69	448.13	1053.29	605.15
WhitesBranch	Reach2	10447.79	250-Year	16043.00	562.62	580.19	7.75	440.49	1063.57	623.09
WhitesBranch	Reach2	10447.79	500-Year	17629.00	562.62	580.43	8.18	438.05	1066.85	628.79
WhitesBranch	Reach2	10569.43	2-Year	2416.00	563.55	573.06	2.98	629.72	806.40	176.67
WhitesBranch	Reach2	10569.43	5-Year	5940.00	563.55	576.17	4.53	534.49	831.18	296.68
WhitesBranch	Reach2	10569.43	10-Year	8060.00	563.55	577.44	5.11	521.83	918.55	396.72
WhitesBranch	Reach2	10569.43	25-Year	10498.00	563.55	578.62	5.61	513.27	1006.80	493.53
WhitesBranch	Reach2	10569.43	50-Year	12226.00	563.55	579.34	5.94	507.99	1012.44	504.45
WhitesBranch	Reach2	10569.43	100-Year	13984.00	563.55	579.85	6.37	504.31	1016.16	511.85
WhitesBranch	Reach2	10569.43	250-Year	16043.00	563.55	580.54	6.72	499.25	1021.23	521.97
WhitesBranch	Reach2	10569.43	500-Year	17629.00	563.55	580.81	7.16	344.19	1023.17	559.18
WhitesBranch	Reach2	10750.56	2-Year	2416.00	564.62	573.36	4.36	611.16	736.67	125.51
WhitesBranch	Reach2	10750.56	5-Year	5940.00	564.62	576.51	6.28	467.75	770.59	302.84
WhitesBranch	Reach2	10750.56	10-Year	8060.00	564.62	577.81	6.76	453.30	796.39	343.09

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	10750.56	25-Year	10498.00	564.62	579.01	7.19	447.04	808.18	361.14
WhitesBranch	Reach2	10750.56	50-Year	12226.00	564.62	579.75	7.48	443.26	814.06	370.80
WhitesBranch	Reach2	10750.56	100-Year	13984.00	564.62	580.29	7.91	440.47	818.40	377.93
WhitesBranch	Reach2	10750.56	250-Year	16043.00	564.62	581.00	8.24	436.82	824.07	387.25
WhitesBranch	Reach2	10750.56	500-Year	17629.00	564.62	581.32	8.71	435.20	830.51	395.31
WhitesBranch	Reach2	10939.62	2-Year	2416.00	565.85	574.06	4.39	738.73	874.51	135.78
WhitesBranch	Reach2	10939.62	5-Year	5940.00	565.85	577.31	6.29	644.77	880.79	236.01
WhitesBranch	Reach2	10939.62	10-Year	8060.00	565.85	578.57	6.97	635.35	883.21	247.86
WhitesBranch	Reach2	10939.62	25-Year	10498.00	565.85	579.73	7.70	629.86	885.44	255.57
WhitesBranch	Reach2	10939.62	50-Year	12226.00	565.85	580.44	8.17	626.63	886.81	260.18
WhitesBranch	Reach2	10939.62	100-Year	13984.00	565.85	581.01	8.71	624.06	887.90	263.84
WhitesBranch	Reach2	10939.62	250-Year	16043.00	565.85	581.70	9.23	620.92	889.23	268.31
WhitesBranch	Reach2	10939.62	500-Year	17629.00	565.85	582.07	9.73	477.39	889.94	280.41
WhitesBranch	Reach2	11112.65	2-Year	2416.00	566.62	574.79	5.16	656.74	819.82	163.08
WhitesBranch	Reach2	11112.65	5-Year	5940.00	566.62	578.11	6.29	597.67	825.67	228.00
WhitesBranch	Reach2	11112.65	10-Year	8060.00	566.62	579.40	6.88	592.37	827.95	235.58
WhitesBranch	Reach2	11112.65	25-Year	10498.00	566.62	580.60	7.53	587.13	830.09	242.96
WhitesBranch	Reach2	11112.65	50-Year	12226.00	566.62	581.35	7.97	583.87	831.42	247.55
WhitesBranch	Reach2	11112.65	100-Year	13984.00	566.62	581.98	8.45	581.10	832.54	251.45
WhitesBranch	Reach2	11112.65	250-Year	16043.00	566.62	582.72	8.93	577.88	835.01	257.13
WhitesBranch	Reach2	11112.65	500-Year	17629.00	566.62	583.16	9.37	419.51	838.59	299.62
WhitesBranch	Reach2	11294.36	2-Year	2416.00	568.37	575.84	5.96	749.47	856.75	107.28
WhitesBranch	Reach2	11294.36	5-Year	5940.00	568.37	578.87	8.27	647.18	863.41	216.23
WhitesBranch	Reach2	11294.36	10-Year	8060.00	568.37	580.13	8.86	638.74	866.19	227.45
WhitesBranch	Reach2	11294.36	25-Year	10498.00	568.37	581.34	9.49	630.73	869.23	238.49
WhitesBranch	Reach2	11294.36	50-Year	12226.00	568.37	582.10	9.90	625.72	871.42	245.70
WhitesBranch	Reach2	11294.36	100-Year	13984.00	568.37	582.77	10.35	621.13	873.35	252.21
WhitesBranch	Reach2	11294.36	250-Year	16043.00	568.37	583.51	11.13	592.43	875.54	283.12
WhitesBranch	Reach2	11294.36	500-Year	17629.00	568.37	583.99	11.69	573.14	877.03	303.89
WhitesBranch	Reach2	11531.32	2-Year	2416.00	569.41	577.27	4.83	825.73	964.43	138.70
WhitesBranch	Reach2	11531.32	5-Year	5940.00	569.41	580.60	6.56	546.99	969.33	422.34
WhitesBranch	Reach2	11531.32	10-Year	8060.00	569.41	581.85	6.62	501.57	971.16	469.59
WhitesBranch	Reach2	11531.32	25-Year	10498.00	569.41	583.08	6.60	480.07	972.41	492.34
WhitesBranch	Reach2	11531.32	50-Year	12226.00	569.41	583.87	6.61	471.69	973.20	501.51
WhitesBranch	Reach2	11531.32	100-Year	13984.00	569.41	584.60	6.66	463.96	973.92	509.96
WhitesBranch	Reach2	11531.32	250-Year	16043.00	569.41	585.50	6.72	261.36	974.90	546.44
WhitesBranch	Reach2	11531.32	500-Year	17629.00	569.41	586.09	6.73	214.52	975.90	660.61
WhitesBranch	Reach2	11732.89	2-Year	2416.00	570.37	578.02	6.37	959.45	1077.32	117.87
WhitesBranch	Reach2	11732.89	5-Year	5940.00	570.37	581.34	7.85	591.28	1084.66	493.38
WhitesBranch	Reach2	11732.89	10-Year	8060.00	570.37	582.49	7.66	506.48	1087.21	559.54
WhitesBranch	Reach2	11732.89	25-Year	10498.00	570.37	583.64	7.39	494.50	1089.46	594.95
WhitesBranch	Reach2	11732.89	50-Year	12226.00	570.37	584.39	7.22	486.72	1090.60	603.88
WhitesBranch	Reach2	11732.89	100-Year	13984.00	570.37	585.09	7.13	479.81	1091.67	611.85
WhitesBranch	Reach2	11732.89	250-Year	16043.00	570.37	585.96	6.99	462.44	1092.99	630.55
WhitesBranch	Reach2	11732.89	500-Year	17629.00	570.37	586.53	6.94	267.63	1093.87	702.21
WhitesBranch	Reach2	11854.27	2-Year	2416.00	570.37	578.78	5.03	973.27	1085.26	111.99
WhitesBranch	Reach2	11854.27	5-Year	5940.00	570.37	582.07	5.83	537.50	1096.40	558.90
WhitesBranch	Reach2	11854.27	10-Year	8060.00	570.37	583.04	6.12	481.07	1099.19	618.12
WhitesBranch	Reach2	11854.27	25-Year	10498.00	570.37	584.05	6.20	470.91	1102.12	631.20
WhitesBranch	Reach2	11854.27	50-Year	12226.00	570.37	584.74	6.22	464.44	1104.09	639.65
WhitesBranch	Reach2	11854.27	100-Year	13984.00	570.37	585.40	6.24	458.19	1105.97	647.78
WhitesBranch	Reach2	11854.27	250-Year	16043.00	570.37	586.22	6.22	437.85	1108.29	670.43
WhitesBranch	Reach2	11854.27	500-Year	17629.00	570.37	586.78	6.20	249.59	1109.85	779.52
WhitesBranch	Reach2	12192.40	2-Year	2416.00	570.37	580.07	4.81	609.18	807.74	198.56
WhitesBranch	Reach2	12192.40	5-Year	5940.00	570.37	583.10	5.51	463.92	1028.45	564.53
WhitesBranch	Reach2	12192.40	10-Year	8060.00	570.37	584.03	5.80	448.08	1037.08	589.00
WhitesBranch	Reach2	12192.40	25-Year	10498.00	570.37	584.96	6.09	438.67	1053.37	614.70
WhitesBranch	Reach2	12192.40	50-Year	12226.00	570.37	585.58	6.24	431.50	1066.84	635.34
WhitesBranch	Reach2	12192.40	100-Year	13984.00	570.37	586.19	6.38	422.30	1082.16	659.86
WhitesBranch	Reach2	12192.40	250-Year	16043.00	570.37	586.96	6.47	224.34	1143.62	829.69
WhitesBranch	Reach2	12192.40	500-Year	17629.00	570.37	587.47	6.45	202.24	1144.63	900.07

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	12391.35	2-Year	2416.00	570.60	580.65	2.65	450.98	661.10	210.12
WhitesBranch	Reach2	12391.35	5-Year	5940.00	570.60	583.62	3.92	431.38	946.37	514.99
WhitesBranch	Reach2	12391.35	10-Year	8060.00	570.60	584.54	4.49	425.33	983.04	557.71
WhitesBranch	Reach2	12391.35	25-Year	10498.00	570.60	585.46	5.11	391.66	1000.21	608.55
WhitesBranch	Reach2	12391.35	50-Year	12226.00	570.60	586.08	5.38	371.21	1006.02	634.81
WhitesBranch	Reach2	12391.35	100-Year	13984.00	570.60	586.68	5.54	364.36	1007.54	643.18
WhitesBranch	Reach2	12391.35	250-Year	16043.00	570.60	587.43	5.63	180.10	1009.42	664.80
WhitesBranch	Reach2	12391.35	500-Year	17629.00	570.60	587.92	5.76	163.11	1010.66	743.84
WhitesBranch	Reach2	12620.10	2-Year	2416.00	571.61	580.88	4.23	595.65	697.04	101.39
WhitesBranch	Reach2	12620.10	5-Year	5940.00	571.61	583.78	7.31	587.95	783.41	195.46
WhitesBranch	Reach2	12620.10	10-Year	8060.00	571.61	584.65	8.85	585.58	997.72	412.15
WhitesBranch	Reach2	12620.10	25-Year	10498.00	571.61	585.67	9.39	582.68	1031.69	449.01
WhitesBranch	Reach2	12620.10	50-Year	12226.00	571.61	586.33	9.56	580.80	1034.55	453.74
WhitesBranch	Reach2	12620.10	100-Year	13984.00	571.61	586.94	9.71	579.05	1037.21	458.16
WhitesBranch	Reach2	12620.10	250-Year	16043.00	571.61	587.68	9.84	565.64	1040.39	474.75
WhitesBranch	Reach2	12620.10	500-Year	17629.00	571.61	588.17	9.98	552.38	1042.53	490.15
WhitesBranch	Reach2	12816.11	2-Year	2416.00	571.61	581.34	3.72	445.23	555.55	110.32
WhitesBranch	Reach2	12816.11	5-Year	5940.00	571.61	584.78	6.08	435.98	789.25	353.28
WhitesBranch	Reach2	12816.11	10-Year	8060.00	571.61	586.06	6.61	432.62	809.88	377.26
WhitesBranch	Reach2	12816.11	25-Year	10498.00	571.61	587.06	7.26	429.99	816.58	386.60
WhitesBranch	Reach2	12816.11	50-Year	12226.00	571.61	587.64	7.86	405.25	820.44	415.19
WhitesBranch	Reach2	12816.11	100-Year	13984.00	571.61	588.18	8.33	305.94	824.06	473.17
WhitesBranch	Reach2	12816.11	250-Year	16043.00	571.61	588.84	8.74	282.73	828.41	545.67
WhitesBranch	Reach2	12816.11	500-Year	17629.00	571.61	589.32	8.86	260.01	831.62	568.73
WhitesBranch	Reach2	13020.60	2-Year	2454.00	573.86	581.80	5.85	250.14	362.39	112.25
WhitesBranch	Reach2	13020.60	5-Year	6152.00	573.86	585.53	7.48	244.23	573.38	329.15
WhitesBranch	Reach2	13020.60	10-Year	8252.00	573.86	586.82	7.49	242.51	578.16	335.65
WhitesBranch	Reach2	13020.60	25-Year	10642.00	573.86	587.88	7.87	241.09	581.98	340.89
WhitesBranch	Reach2	13020.60	50-Year	12328.00	573.86	588.55	8.11	240.20	584.41	344.21
WhitesBranch	Reach2	13020.60	100-Year	14050.00	573.86	589.16	8.38	239.39	586.60	347.20
WhitesBranch	Reach2	13020.60	250-Year	16072.00	573.86	589.84	8.66	238.48	589.06	350.58
WhitesBranch	Reach2	13020.60	500-Year	17608.00	573.86	590.27	8.93	237.90	590.64	352.74
WhitesBranch	Reach2	13271.20	2-Year	2454.00	574.21	583.20	5.16	235.61	398.28	162.66
WhitesBranch	Reach2	13271.20	5-Year	6152.00	574.21	586.82	5.73	227.07	536.57	309.50
WhitesBranch	Reach2	13271.20	10-Year	8252.00	574.21	587.92	6.25	223.72	542.09	318.37
WhitesBranch	Reach2	13271.20	25-Year	10642.00	574.21	588.95	6.82	220.60	547.23	326.63
WhitesBranch	Reach2	13271.20	50-Year	12328.00	574.21	589.60	7.17	218.61	550.53	331.92
WhitesBranch	Reach2	13271.20	100-Year	14050.00	574.21	590.21	7.49	216.38	553.57	337.19
WhitesBranch	Reach2	13271.20	250-Year	16072.00	574.21	590.89	7.82	212.17	557.04	344.87
WhitesBranch	Reach2	13271.20	500-Year	17608.00	574.21	591.34	8.09	209.35	560.75	351.39
WhitesBranch	Reach2	13430.54	2-Year	2454.00	575.88	583.92	4.56	279.09	426.95	147.87
WhitesBranch	Reach2	13430.54	5-Year	6152.00	575.88	587.29	5.95	262.20	527.95	265.75
WhitesBranch	Reach2	13430.54	10-Year	8252.00	575.88	588.40	6.58	258.32	535.07	276.75
WhitesBranch	Reach2	13430.54	25-Year	10642.00	575.88	589.45	7.23	254.65	541.77	287.12
WhitesBranch	Reach2	13430.54	50-Year	12328.00	575.88	590.11	7.60	252.32	546.04	293.72
WhitesBranch	Reach2	13430.54	100-Year	14050.00	575.88	590.73	7.96	250.17	553.36	303.19
WhitesBranch	Reach2	13430.54	250-Year	16072.00	575.88	591.41	8.36	247.53	562.23	314.70
WhitesBranch	Reach2	13430.54	500-Year	17608.00	575.88	591.87	8.68	243.86	568.14	324.28
WhitesBranch	Reach2	13724.71	2-Year	2454.00	576.52	585.09	5.12	436.90	600.47	163.57
WhitesBranch	Reach2	13724.71	5-Year	6152.00	576.52	588.48	6.22	172.52	606.34	433.82
WhitesBranch	Reach2	13724.71	10-Year	8252.00	576.52	589.65	6.30	168.15	612.74	444.59
WhitesBranch	Reach2	13724.71	25-Year	10642.00	576.52	590.79	6.58	163.90	637.38	473.48
WhitesBranch	Reach2	13724.71	50-Year	12328.00	576.52	591.50	6.72	161.26	652.41	491.15
WhitesBranch	Reach2	13724.71	100-Year	14050.00	576.52	592.16	6.83	158.85	660.06	501.21
WhitesBranch	Reach2	13724.71	250-Year	16072.00	576.52	592.89	6.96	149.85	665.82	515.97
WhitesBranch	Reach2	13724.71	500-Year	17608.00	576.52	593.41	7.07	142.95	669.87	526.92
WhitesBranch	Reach2	13874.34	2-Year	2454.00	576.93	585.57	5.09	541.99	675.99	134.00
WhitesBranch	Reach2	13874.34	5-Year	6152.00	576.93	588.89	6.61	221.15	683.24	462.09
WhitesBranch	Reach2	13874.34	10-Year	8252.00	576.93	590.01	6.68	217.00	685.46	468.46
WhitesBranch	Reach2	13874.34	25-Year	10642.00	576.93	591.14	6.79	213.09	687.83	474.74
WhitesBranch	Reach2	13874.34	50-Year	12328.00	576.93	591.84	6.91	208.55	689.45	480.90
WhitesBranch	Reach2	13874.34	100-Year	14050.00	576.93	592.49	7.05	204.09	690.96	486.87

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	13874.34	250-Year	16072.00	576.93	593.21	7.20	199.10	692.64	493.54
WhitesBranch	Reach2	13874.34	500-Year	17608.00	576.93	593.73	7.32	195.59	693.83	498.24
WhitesBranch	Reach2	14077.06	2-Year	2454.00	577.35	586.36	5.34	543.32	700.28	156.97
WhitesBranch	Reach2	14077.06	5-Year	6152.00	577.35	589.73	6.30	270.40	830.40	560.00
WhitesBranch	Reach2	14077.06	10-Year	8252.00	577.35	590.76	6.34	265.02	838.83	573.81
WhitesBranch	Reach2	14077.06	25-Year	10642.00	577.35	591.82	6.38	259.52	848.79	589.27
WhitesBranch	Reach2	14077.06	50-Year	12328.00	577.35	592.50	6.43	255.99	856.35	600.37
WhitesBranch	Reach2	14077.06	100-Year	14050.00	577.35	593.14	6.49	252.14	861.88	609.74
WhitesBranch	Reach2	14077.06	250-Year	16072.00	577.35	593.85	6.55	247.68	865.86	618.18
WhitesBranch	Reach2	14077.06	500-Year	17608.00	577.35	594.36	6.60	244.51	868.69	624.18
WhitesBranch	Reach2	14309.31	2-Year	2454.00	579.27	587.14	2.99	489.04	677.12	188.09
WhitesBranch	Reach2	14309.31	5-Year	6152.00	579.27	590.44	4.69	311.85	777.75	465.90
WhitesBranch	Reach2	14309.31	10-Year	8252.00	579.27	591.38	5.19	305.28	782.63	477.36
WhitesBranch	Reach2	14309.31	25-Year	10642.00	579.27	592.39	5.59	296.28	788.24	491.96
WhitesBranch	Reach2	14309.31	50-Year	12328.00	579.27	593.04	5.81	290.43	792.54	502.10
WhitesBranch	Reach2	14309.31	100-Year	14050.00	579.27	593.65	6.29	281.19	992.79	711.60
WhitesBranch	Reach2	14309.31	250-Year	16072.00	579.27	594.35	6.40	263.00	999.97	736.97
WhitesBranch	Reach2	14309.31	500-Year	17608.00	579.27	594.85	6.44	257.58	1004.62	747.04
WhitesBranch	Reach2	14498.11	2-Year	2454.00	580.08	587.41	4.52	489.65	636.01	146.36
WhitesBranch	Reach2	14498.11	5-Year	6152.00	580.08	590.75	6.46	446.93	915.86	468.93
WhitesBranch	Reach2	14498.11	10-Year	8252.00	580.08	591.72	7.26	406.93	962.37	555.44
WhitesBranch	Reach2	14498.11	25-Year	10642.00	580.08	592.75	7.57	361.62	995.13	633.51
WhitesBranch	Reach2	14498.11	50-Year	12328.00	580.08	593.42	7.64	339.56	1016.46	676.91
WhitesBranch	Reach2	14498.11	100-Year	14050.00	580.08	594.11	7.59	318.85	1036.93	718.08
WhitesBranch	Reach2	14498.11	250-Year	16072.00	580.08	594.79	7.54	313.60	1042.94	729.33
WhitesBranch	Reach2	14498.11	500-Year	17608.00	580.08	595.28	7.53	310.16	1047.17	737.01
WhitesBranch	Reach2	14720.43	2-Year	2454.00	582.78	588.32	5.27	362.87	510.15	147.28
WhitesBranch	Reach2	14720.43	5-Year	6152.00	582.78	591.68	6.17	355.59	868.90	513.31
WhitesBranch	Reach2	14720.43	10-Year	8252.00	582.78	592.77	6.21	353.31	916.13	562.82
WhitesBranch	Reach2	14720.43	25-Year	10642.00	582.78	593.75	6.38	351.33	950.52	599.19
WhitesBranch	Reach2	14720.43	50-Year	12328.00	582.78	594.35	6.50	350.11	967.83	617.72
WhitesBranch	Reach2	14720.43	100-Year	14050.00	582.78	594.95	6.62	328.06	971.20	643.14
WhitesBranch	Reach2	14720.43	250-Year	16072.00	582.78	595.55	6.78	299.73	974.60	674.87
WhitesBranch	Reach2	14720.43	500-Year	17608.00	582.78	595.98	6.90	237.64	977.05	739.41
WhitesBranch	Reach2	14976.69	2-Year	2454.00	583.02	589.78	5.42	287.26	516.25	228.99
WhitesBranch	Reach2	14976.69	5-Year	6152.00	583.02	592.75	6.31	248.09	821.34	573.25
WhitesBranch	Reach2	14976.69	10-Year	8252.00	583.02	593.68	6.44	243.07	874.36	631.29
WhitesBranch	Reach2	14976.69	25-Year	10642.00	583.02	594.58	6.54	238.23	897.95	659.73
WhitesBranch	Reach2	14976.69	50-Year	12328.00	583.02	595.14	6.61	235.18	906.33	671.15
WhitesBranch	Reach2	14976.69	100-Year	14050.00	583.02	595.71	6.64	231.96	909.08	677.12
WhitesBranch	Reach2	14976.69	250-Year	16072.00	583.02	596.29	6.75	226.45	911.90	685.46
WhitesBranch	Reach2	14976.69	500-Year	17608.00	583.02	596.71	6.83	222.66	913.96	691.31
WhitesBranch	Reach2	15179.97	2-Year	2454.00	583.17	590.71	5.93	277.64	491.14	213.50
WhitesBranch	Reach2	15179.97	5-Year	6152.00	583.17	593.44	6.88	267.20	834.73	567.53
WhitesBranch	Reach2	15179.97	10-Year	8252.00	583.17	594.30	7.07	263.74	862.99	599.25
WhitesBranch	Reach2	15179.97	25-Year	10642.00	583.17	595.14	7.23	260.33	874.69	614.36
WhitesBranch	Reach2	15179.97	50-Year	12328.00	583.17	595.67	7.35	258.06	882.14	624.08
WhitesBranch	Reach2	15179.97	100-Year	14050.00	583.17	596.20	7.42	255.80	885.87	630.07
WhitesBranch	Reach2	15179.97	250-Year	16072.00	583.17	596.76	7.56	249.47	888.20	638.73
WhitesBranch	Reach2	15179.97	500-Year	17608.00	583.17	597.17	7.65	242.90	890.09	647.19
WhitesBranch	Reach2	15321.14	2-Year	2445.00	583.37	591.41	5.89	279.55	370.06	90.52
WhitesBranch	Reach2	15321.14	5-Year	6122.00	583.37	593.97	7.79	271.36	793.26	521.90
WhitesBranch	Reach2	15321.14	10-Year	8198.00	583.37	594.79	8.14	268.92	832.06	563.14
WhitesBranch	Reach2	15321.14	25-Year	10567.00	583.37	595.60	8.33	266.66	845.49	578.84
WhitesBranch	Reach2	15321.14	50-Year	12236.00	583.37	596.12	8.45	265.21	853.20	588.00
WhitesBranch	Reach2	15321.14	100-Year	13930.00	583.37	596.63	8.53	263.78	860.78	596.99
WhitesBranch	Reach2	15321.14	250-Year	15932.00	583.37	597.18	8.63	262.25	865.61	603.36
WhitesBranch	Reach2	15321.14	500-Year	17454.00	583.37	597.58	8.70	261.12	867.70	606.58
WhitesBranch	Reach2	15516.25	2-Year	2445.00	584.72	592.36	5.17	162.67	334.90	172.23
WhitesBranch	Reach2	15516.25	5-Year	6122.00	584.72	595.03	7.19	156.12	656.10	499.97
WhitesBranch	Reach2	15516.25	10-Year	8198.00	584.72	595.79	7.84	154.19	697.99	543.80

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	15516.25	25-Year	10567.00	584.72	596.54	8.34	152.31	723.97	571.66
WhitesBranch	Reach2	15516.25	50-Year	12236.00	584.72	597.02	8.54	151.07	726.73	575.66
WhitesBranch	Reach2	15516.25	100-Year	13930.00	584.72	597.50	8.70	149.94	730.36	580.42
WhitesBranch	Reach2	15516.25	250-Year	15932.00	584.72	598.02	8.94	148.75	743.09	594.34
WhitesBranch	Reach2	15516.25	500-Year	17454.00	584.72	598.40	9.11	147.87	753.83	605.95
WhitesBranch	Reach2	15724.28	2-Year	2445.00	586.27	593.27	4.68	153.47	404.32	250.85
WhitesBranch	Reach2	15724.28	5-Year	6122.00	586.27	596.12	5.52	143.20	731.57	588.37
WhitesBranch	Reach2	15724.28	10-Year	8198.00	586.27	596.93	5.93	136.47	765.76	629.28
WhitesBranch	Reach2	15724.28	25-Year	10567.00	586.27	597.68	6.27	129.77	770.51	640.74
WhitesBranch	Reach2	15724.28	50-Year	12236.00	586.27	598.14	6.50	125.22	771.43	646.21
WhitesBranch	Reach2	15724.28	100-Year	13930.00	586.27	598.59	6.70	120.81	772.33	651.52
WhitesBranch	Reach2	15724.28	250-Year	15932.00	586.27	599.10	6.91	115.81	773.34	657.53
WhitesBranch	Reach2	15724.28	500-Year	17454.00	586.27	599.48	7.06	111.22	774.06	662.84
WhitesBranch	Reach2	15920.89	2-Year	2445.00	587.06	593.84	5.17	332.38	506.12	173.74
WhitesBranch	Reach2	15920.89	5-Year	6122.00	587.06	596.56	5.93	115.32	815.53	700.21
WhitesBranch	Reach2	15920.89	10-Year	8198.00	587.06	597.38	6.12	112.24	844.94	732.70
WhitesBranch	Reach2	15920.89	25-Year	10567.00	587.06	598.14	6.34	109.39	850.34	740.95
WhitesBranch	Reach2	15920.89	50-Year	12236.00	587.06	598.61	6.49	107.62	851.24	743.62
WhitesBranch	Reach2	15920.89	100-Year	13930.00	587.06	599.07	6.63	105.91	852.09	746.18
WhitesBranch	Reach2	15920.89	250-Year	15932.00	587.06	599.58	6.77	103.99	853.04	749.05
WhitesBranch	Reach2	15920.89	500-Year	17454.00	587.06	599.95	6.87	102.58	853.73	751.15
WhitesBranch	Reach2	16124.88	2-Year	2445.00	587.06	594.58	6.10	245.02	623.10	378.09
WhitesBranch	Reach2	16124.88	5-Year	6122.00	587.06	597.22	5.92	86.11	742.97	656.86
WhitesBranch	Reach2	16124.88	10-Year	8198.00	587.06	598.00	6.23	83.43	765.43	682.00
WhitesBranch	Reach2	16124.88	25-Year	10567.00	587.06	598.73	6.54	80.90	768.40	687.50
WhitesBranch	Reach2	16124.88	50-Year	12236.00	587.06	599.20	6.75	79.31	769.29	689.97
WhitesBranch	Reach2	16124.88	100-Year	13930.00	587.06	599.64	6.93	77.78	770.14	692.35
WhitesBranch	Reach2	16124.88	250-Year	15932.00	587.06	600.15	7.12	76.06	771.13	695.07
WhitesBranch	Reach2	16124.88	500-Year	17454.00	587.06	600.51	7.25	74.80	771.86	697.06
WhitesBranch	Reach2	16361.92	2-Year	2445.00	587.45	595.73	5.26	114.22	640.39	526.17
WhitesBranch	Reach2	16361.92	5-Year	6122.00	587.45	597.83	5.69	84.62	644.53	559.91
WhitesBranch	Reach2	16361.92	10-Year	8198.00	587.45	598.58	6.14	82.20	646.02	563.82
WhitesBranch	Reach2	16361.92	25-Year	10567.00	587.45	599.30	6.62	79.90	647.43	567.54
WhitesBranch	Reach2	16361.92	50-Year	12236.00	587.45	599.75	6.94	78.43	650.47	572.04
WhitesBranch	Reach2	16361.92	100-Year	13930.00	587.45	600.19	7.23	77.02	653.87	576.85
WhitesBranch	Reach2	16361.92	250-Year	15932.00	587.45	600.68	7.52	75.43	657.72	582.29
WhitesBranch	Reach2	16361.92	500-Year	17454.00	587.45	601.04	7.73	74.27	660.59	586.32
WhitesBranch	Reach2	16504.78	2-Year	2445.00	588.32	596.16	3.52	97.49	627.52	519.78
WhitesBranch	Reach2	16504.78	5-Year	6122.00	588.32	598.12	4.83	84.65	633.14	548.49
WhitesBranch	Reach2	16504.78	10-Year	8198.00	588.32	598.87	5.38	82.14	635.30	553.16
WhitesBranch	Reach2	16504.78	25-Year	10567.00	588.32	599.60	5.92	79.71	637.39	557.68
WhitesBranch	Reach2	16504.78	50-Year	12236.00	588.32	600.07	6.26	78.17	638.72	560.55
WhitesBranch	Reach2	16504.78	100-Year	13930.00	588.32	600.51	6.57	76.69	639.99	563.30
WhitesBranch	Reach2	16504.78	250-Year	15932.00	588.32	601.01	6.89	75.02	641.42	566.40
WhitesBranch	Reach2	16504.78	500-Year	17454.00	588.32	601.38	7.12	73.82	642.46	568.65
WhitesBranch	Reach2	16601.95	2-Year	2445.00	589.00	596.31	3.03	140.47	610.19	469.72
WhitesBranch	Reach2	16601.95	5-Year	6122.00	589.00	598.29	4.53	97.09	616.18	519.09
WhitesBranch	Reach2	16601.95	10-Year	8198.00	589.00	599.05	5.17	94.27	618.49	524.22
WhitesBranch	Reach2	16601.95	25-Year	10567.00	589.00	599.79	5.80	91.52	620.70	529.17
WhitesBranch	Reach2	16601.95	50-Year	12236.00	589.00	600.26	6.19	89.78	622.09	532.31
WhitesBranch	Reach2	16601.95	100-Year	13930.00	589.00	600.71	6.56	88.12	623.43	535.30
WhitesBranch	Reach2	16601.95	250-Year	15932.00	589.00	601.21	6.95	86.26	625.86	539.60
WhitesBranch	Reach2	16601.95	500-Year	17454.00	589.00	601.57	7.25	84.91	629.41	544.50
WhitesBranch	Reach2	16703.91	2-Year	2445.00	589.00	596.43	1.82	169.81	601.79	431.98
WhitesBranch	Reach2	16703.91	5-Year	6122.00	589.00	598.46	3.12	121.09	606.80	485.71
WhitesBranch	Reach2	16703.91	10-Year	8198.00	589.00	599.24	3.69	117.17	608.73	491.56
WhitesBranch	Reach2	16703.91	25-Year	10567.00	589.00	599.99	4.26	113.36	610.60	497.24
WhitesBranch	Reach2	16703.91	50-Year	12236.00	589.00	600.47	4.63	110.96	611.78	500.82
WhitesBranch	Reach2	16703.91	100-Year	13930.00	589.00	600.93	4.97	108.67	612.90	504.24
WhitesBranch	Reach2	16703.91	250-Year	15932.00	589.00	601.44	5.34	106.11	614.16	508.06
WhitesBranch	Reach2	16703.91	500-Year	17454.00	589.00	601.80	5.61	104.25	615.63	511.38

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	16745.93	2-Year	2445.00	589.00	596.45	1.78	287.56	535.03	247.48
WhitesBranch	Reach2	16745.93	5-Year	6122.00	589.00	598.48	3.21	205.46	540.61	335.15
WhitesBranch	Reach2	16745.93	10-Year	8198.00	589.00	599.26	3.85	195.32	542.59	347.27
WhitesBranch	Reach2	16745.93	25-Year	10567.00	589.00	600.01	4.49	184.70	544.51	359.81
WhitesBranch	Reach2	16745.93	50-Year	12236.00	589.00	600.48	4.90	176.35	545.71	369.37
WhitesBranch	Reach2	16745.93	100-Year	13930.00	589.00	600.94	5.28	51.17	546.86	430.92
WhitesBranch	Reach2	16745.93	250-Year	15932.00	589.00	601.44	5.70	47.43	548.15	495.42
WhitesBranch	Reach2	16745.93	500-Year	17454.00	589.00	601.80	6.00	43.88	549.08	505.20
WhitesBranch	Reach2	16788.10	2-Year	2445.00	589.00	596.46	1.79	228.38	469.97	241.59
WhitesBranch	Reach2	16788.10	5-Year	6122.00	589.00	598.51	3.28	222.22	472.02	249.80
WhitesBranch	Reach2	16788.10	10-Year	8198.00	589.00	599.29	3.98	219.86	472.81	252.95
WhitesBranch	Reach2	16788.10	25-Year	10567.00	589.00	600.05	4.69	217.59	473.57	255.98
WhitesBranch	Reach2	16788.10	50-Year	12236.00	589.00	600.52	5.15	215.97	474.04	258.07
WhitesBranch	Reach2	16788.10	100-Year	13930.00	589.00	600.97	5.59	210.11	474.49	264.38
WhitesBranch	Reach2	16788.10	250-Year	15932.00	589.00	601.47	6.08	203.60	475.00	271.40
WhitesBranch	Reach2	16788.10	500-Year	17454.00	589.00	601.83	6.43	198.90	475.36	276.46
WhitesBranch	Reach2	16804.42	2-Year	2445.00	589.66	596.46	2.17	269.48	475.28	205.80
WhitesBranch	Reach2	16804.42	5-Year	6122.00	589.66	598.49	3.94	268.51	482.93	214.41
WhitesBranch	Reach2	16804.42	10-Year	8198.00	589.66	599.26	4.77	265.61	483.96	218.36
WhitesBranch	Reach2	16804.42	25-Year	10567.00	589.66	600.00	5.61	262.82	484.96	222.14
WhitesBranch	Reach2	16804.42	50-Year	12236.00	589.66	600.46	6.16	261.35	485.58	224.23
WhitesBranch	Reach2	16804.42	100-Year	13930.00	589.66	600.90	6.68	260.20	486.33	226.12
WhitesBranch	Reach2	16804.42	250-Year	15932.00	589.66	601.39	7.26	258.92	487.56	228.64
WhitesBranch	Reach2	16804.42	500-Year	17454.00	589.66	601.74	7.67	258.00	488.45	230.44
WhitesBranch	Reach2	16839.77		Bridge						
WhitesBranch	Reach2	16900.32	2-Year	2445.00	589.66	596.53	2.14	231.46	437.66	206.19
WhitesBranch	Reach2	16900.32	5-Year	6122.00	589.66	598.68	3.84	229.80	445.18	215.38
WhitesBranch	Reach2	16900.32	10-Year	8198.00	589.66	599.52	4.61	226.62	446.32	219.69
WhitesBranch	Reach2	16900.32	25-Year	10567.00	589.66	600.34	5.39	223.67	447.42	223.76
WhitesBranch	Reach2	16900.32	50-Year	12236.00	589.66	600.87	5.89	222.29	448.24	225.95
WhitesBranch	Reach2	16900.32	100-Year	13930.00	589.66	601.37	6.36	220.97	449.51	228.54
WhitesBranch	Reach2	16900.32	250-Year	15932.00	589.66	601.93	6.87	219.50	450.94	231.44
WhitesBranch	Reach2	16900.32	500-Year	17454.00	589.66	602.33	7.23	218.43	451.97	233.54
WhitesBranch	Reach2	16945.40	2-Year	2445.00	589.94	596.55	2.64	195.68	369.41	173.73
WhitesBranch	Reach2	16945.40	5-Year	6122.00	589.94	598.69	4.70	195.21	372.77	177.56
WhitesBranch	Reach2	16945.40	10-Year	8198.00	589.94	599.52	5.64	195.03	374.08	179.05
WhitesBranch	Reach2	16945.40	25-Year	10567.00	589.94	600.34	6.61	192.94	375.36	182.42
WhitesBranch	Reach2	16945.40	50-Year	12236.00	589.94	600.85	7.22	191.37	376.16	184.79
WhitesBranch	Reach2	16945.40	100-Year	13930.00	589.94	601.34	7.81	189.88	376.93	187.05
WhitesBranch	Reach2	16945.40	250-Year	15932.00	589.94	601.88	8.44	188.21	377.78	189.57
WhitesBranch	Reach2	16945.40	500-Year	17454.00	589.94	602.28	8.89	187.01	378.40	191.40
WhitesBranch	Reach2	17008.91		Bridge						
WhitesBranch	Reach2	17058.99	2-Year	2445.00	589.94	596.69	2.57	156.65	330.64	173.99
WhitesBranch	Reach2	17058.99	5-Year	6122.00	589.94	599.04	4.48	156.14	334.32	178.18
WhitesBranch	Reach2	17058.99	10-Year	8198.00	589.94	600.00	5.33	154.97	335.82	180.85
WhitesBranch	Reach2	17058.99	25-Year	10567.00	589.94	600.96	6.17	152.04	337.33	185.29
WhitesBranch	Reach2	17058.99	50-Year	12236.00	589.94	601.58	6.69	150.15	338.30	188.15
WhitesBranch	Reach2	17058.99	100-Year	13930.00	589.94	602.17	7.17	148.33	339.24	190.91
WhitesBranch	Reach2	17058.99	250-Year	15932.00	589.94	602.84	7.69	146.28	340.29	194.01
WhitesBranch	Reach2	17058.99	500-Year	17454.00	589.94	603.33	8.05	144.78	341.11	196.33
WhitesBranch	Reach2	17094.63	2-Year	2445.00	590.36	596.76	2.22	79.66	372.08	292.42
WhitesBranch	Reach2	17094.63	5-Year	6122.00	590.36	599.28	3.40	74.95	509.94	434.99
WhitesBranch	Reach2	17094.63	10-Year	8198.00	590.36	600.36	3.84	72.85	527.72	454.87
WhitesBranch	Reach2	17094.63	25-Year	10567.00	590.36	601.47	4.25	70.72	535.98	465.26
WhitesBranch	Reach2	17094.63	50-Year	12236.00	590.36	602.19	4.49	69.32	541.37	472.05
WhitesBranch	Reach2	17094.63	100-Year	13930.00	590.36	602.89	4.72	67.96	546.59	478.63
WhitesBranch	Reach2	17094.63	250-Year	15932.00	590.36	603.68	4.96	66.36	552.49	486.13
WhitesBranch	Reach2	17094.63	500-Year	17454.00	590.36	604.26	5.13	65.01	556.66	491.65
WhitesBranch	Reach2	17153.39	2-Year	2506.00	590.55	596.79	4.24	102.55	393.76	291.21
WhitesBranch	Reach2	17153.39	5-Year	6287.00	590.55	599.39	4.89	95.72	697.73	602.01

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	17153.39	10-Year	8348.00	590.55	600.51	4.88	93.54	765.36	671.82
WhitesBranch	Reach2	17153.39	25-Year	10689.00	590.55	601.64	4.93	91.33	786.95	695.62
WhitesBranch	Reach2	17153.39	50-Year	12364.00	590.55	602.40	4.99	89.82	800.39	710.57
WhitesBranch	Reach2	17153.39	100-Year	14050.00	590.55	603.12	5.04	88.29	813.38	725.09
WhitesBranch	Reach2	17153.39	250-Year	16027.00	590.55	603.94	5.10	86.56	828.01	741.45
WhitesBranch	Reach2	17153.39	500-Year	17577.00	590.55	604.54	5.17	85.31	832.68	747.37
WhitesBranch	Reach2	17264.95	2-Year	2506.00	590.55	597.20	3.80	104.89	494.10	389.21
WhitesBranch	Reach2	17264.95	5-Year	6287.00	590.55	599.74	4.25	97.53	790.97	693.44
WhitesBranch	Reach2	17264.95	10-Year	8348.00	590.55	600.81	4.19	93.25	835.74	742.49
WhitesBranch	Reach2	17264.95	25-Year	10689.00	590.55	601.92	4.18	81.02	858.52	777.49
WhitesBranch	Reach2	17264.95	50-Year	12364.00	590.55	602.66	4.19	77.44	876.31	798.88
WhitesBranch	Reach2	17264.95	100-Year	14050.00	590.55	603.38	4.20	75.13	899.48	824.35
WhitesBranch	Reach2	17264.95	250-Year	16027.00	590.55	604.19	4.22	72.52	906.41	833.89
WhitesBranch	Reach2	17264.95	500-Year	17577.00	590.55	604.79	4.26	70.61	908.27	837.67
WhitesBranch	Reach2	17410.61	2-Year	2506.00	590.55	597.63	3.56	258.54	714.04	455.50
WhitesBranch	Reach2	17410.61	5-Year	6287.00	590.55	600.03	3.60	242.84	982.35	739.52
WhitesBranch	Reach2	17410.61	10-Year	8348.00	590.55	601.04	3.50	237.59	1014.75	777.16
WhitesBranch	Reach2	17410.61	25-Year	10689.00	590.55	602.11	3.45	230.87	1045.72	814.85
WhitesBranch	Reach2	17410.61	50-Year	12364.00	590.55	602.83	3.44	224.33	1066.61	842.29
WhitesBranch	Reach2	17410.61	100-Year	14050.00	590.55	603.54	3.44	216.23	1072.29	856.06
WhitesBranch	Reach2	17410.61	250-Year	16027.00	590.55	604.34	3.47	184.62	1074.67	890.06
WhitesBranch	Reach2	17410.61	500-Year	17577.00	590.55	604.92	3.48	102.05	1076.43	974.38
WhitesBranch	Reach2	17531.58	2-Year	2506.00	590.59	598.11	4.76	344.32	899.81	531.92
WhitesBranch	Reach2	17531.58	5-Year	6287.00	590.59	600.32	4.34	329.69	1066.01	736.32
WhitesBranch	Reach2	17531.58	10-Year	8348.00	590.59	601.26	4.17	317.09	1100.12	783.03
WhitesBranch	Reach2	17531.58	25-Year	10689.00	590.59	602.29	4.07	274.72	1136.92	862.20
WhitesBranch	Reach2	17531.58	50-Year	12364.00	590.59	603.00	3.99	253.04	1142.52	889.47
WhitesBranch	Reach2	17531.58	100-Year	14050.00	590.59	603.69	3.94	225.27	1144.63	919.36
WhitesBranch	Reach2	17531.58	250-Year	16027.00	590.59	604.48	3.87	126.14	1146.99	1020.85
WhitesBranch	Reach2	17531.58	500-Year	17577.00	590.59	605.06	3.81	117.95	1148.73	1030.78
WhitesBranch	Reach2	17700.03	2-Year	2491.00	591.33	599.05	3.79	429.95	937.49	507.53
WhitesBranch	Reach2	17700.03	5-Year	6230.00	591.33	600.85	4.54	168.06	1074.75	906.69
WhitesBranch	Reach2	17700.03	10-Year	8253.00	591.33	601.68	4.36	152.12	1100.71	948.59
WhitesBranch	Reach2	17700.03	25-Year	10554.00	591.33	602.63	4.09	149.08	1130.34	981.26
WhitesBranch	Reach2	17700.03	50-Year	12177.00	591.33	603.30	3.91	146.97	1135.82	988.85
WhitesBranch	Reach2	17700.03	100-Year	13833.00	591.33	603.96	3.77	144.87	1138.11	993.25
WhitesBranch	Reach2	17700.03	250-Year	15775.00	591.33	604.71	3.65	142.45	1140.74	998.29
WhitesBranch	Reach2	17700.03	500-Year	17258.00	591.33	605.28	3.58	140.66	1142.69	1002.03
WhitesBranch	Reach2	17847.39	2-Year	2491.00	592.02	599.66	4.03	524.32	958.14	433.82
WhitesBranch	Reach2	17847.39	5-Year	6230.00	592.02	601.41	4.50	119.02	1010.56	891.54
WhitesBranch	Reach2	17847.39	10-Year	8253.00	592.02	602.14	4.46	109.14	1031.46	922.32
WhitesBranch	Reach2	17847.39	25-Year	10554.00	592.02	602.99	4.28	105.26	1049.42	944.16
WhitesBranch	Reach2	17847.39	50-Year	12177.00	592.02	603.59	4.13	103.48	1051.52	948.04
WhitesBranch	Reach2	17847.39	100-Year	13833.00	592.02	604.20	3.99	101.66	1053.66	952.00
WhitesBranch	Reach2	17847.39	250-Year	15775.00	592.02	604.92	3.86	99.53	1056.17	956.64
WhitesBranch	Reach2	17847.39	500-Year	17258.00	592.02	605.46	3.79	97.93	1058.05	960.12
WhitesBranch	Reach2	17958.86	2-Year	2491.00	592.10	600.25	6.08	529.24	803.42	274.18
WhitesBranch	Reach2	17958.86	5-Year	6230.00	592.10	601.94	6.97	71.11	878.07	806.96
WhitesBranch	Reach2	17958.86	10-Year	8253.00	592.10	602.60	6.75	65.28	902.53	837.25
WhitesBranch	Reach2	17958.86	25-Year	10554.00	592.10	603.35	6.37	57.69	927.02	869.33
WhitesBranch	Reach2	17958.86	50-Year	12177.00	592.10	603.89	6.03	55.91	928.70	872.79
WhitesBranch	Reach2	17958.86	100-Year	13833.00	592.10	604.46	5.72	54.05	930.44	876.39
WhitesBranch	Reach2	17958.86	250-Year	15775.00	592.10	605.13	5.41	51.84	932.51	880.68
WhitesBranch	Reach2	17958.86	500-Year	17258.00	592.10	605.65	5.22	50.13	934.09	883.96
WhitesBranch	Reach2	18056.49	2-Year	2491.00	593.27	601.25	5.81	201.41	877.31	675.90
WhitesBranch	Reach2	18056.49	5-Year	6230.00	593.27	602.86	5.81	159.43	938.90	779.48
WhitesBranch	Reach2	18056.49	10-Year	8253.00	593.27	603.37	6.16	155.51	956.87	801.36
WhitesBranch	Reach2	18056.49	25-Year	10554.00	593.27	603.96	6.28	151.95	973.31	821.36
WhitesBranch	Reach2	18056.49	50-Year	12177.00	593.27	604.39	6.25	149.31	982.52	833.20
WhitesBranch	Reach2	18056.49	100-Year	13833.00	593.27	604.87	6.13	146.42	988.57	842.15
WhitesBranch	Reach2	18056.49	250-Year	15775.00	593.27	605.47	5.93	142.79	997.13	854.33
WhitesBranch	Reach2	18056.49	500-Year	17258.00	593.27	605.94	5.77	139.90	1002.32	862.42

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	18204.20	2-Year	2491.00	594.28	602.27	5.68	185.68	818.60	632.92
WhitesBranch	Reach2	18204.20	5-Year	6230.00	594.28	603.61	6.48	177.97	846.02	668.05
WhitesBranch	Reach2	18204.20	10-Year	8253.00	594.28	604.13	6.82	174.90	856.68	681.78
WhitesBranch	Reach2	18204.20	25-Year	10554.00	594.28	604.68	7.09	171.14	867.90	696.76
WhitesBranch	Reach2	18204.20	50-Year	12177.00	594.28	605.06	7.19	168.50	875.77	707.27
WhitesBranch	Reach2	18204.20	100-Year	13833.00	594.28	605.47	7.21	165.62	886.81	721.19
WhitesBranch	Reach2	18204.20	250-Year	15775.00	594.28	605.98	7.13	161.93	900.09	738.16
WhitesBranch	Reach2	18204.20	500-Year	17258.00	594.28	606.39	7.03	158.42	910.71	752.29
WhitesBranch	Reach2	18325.43	2-Year	2491.00	595.92	603.10	4.98	180.09	817.29	637.20
WhitesBranch	Reach2	18325.43	5-Year	6230.00	595.92	604.43	6.06	103.35	841.87	738.52
WhitesBranch	Reach2	18325.43	10-Year	8253.00	595.92	604.96	6.35	77.42	851.74	774.32
WhitesBranch	Reach2	18325.43	25-Year	10554.00	595.92	605.50	6.54	63.83	861.73	797.89
WhitesBranch	Reach2	18325.43	50-Year	12177.00	595.92	605.87	6.62	59.34	868.41	809.07
WhitesBranch	Reach2	18325.43	100-Year	13833.00	595.92	606.24	6.65	53.59	875.24	821.65
WhitesBranch	Reach2	18325.43	250-Year	15775.00	595.92	606.69	6.63	46.75	883.55	836.79
WhitesBranch	Reach2	18325.43	500-Year	17258.00	595.92	607.05	6.58	41.49	890.14	848.65
WhitesBranch	Reach2	18489.39	2-Year	2491.00	596.73	604.08	4.52	163.71	801.11	637.41
WhitesBranch	Reach2	18489.39	5-Year	6230.00	596.73	605.48	5.48	66.80	804.42	737.62
WhitesBranch	Reach2	18489.39	10-Year	8253.00	596.73	606.01	5.81	54.64	805.68	751.04
WhitesBranch	Reach2	18489.39	25-Year	10554.00	596.73	606.53	6.15	42.78	806.90	764.12
WhitesBranch	Reach2	18489.39	50-Year	12177.00	596.73	606.87	6.35	34.19	807.70	773.51
WhitesBranch	Reach2	18489.39	100-Year	13833.00	596.73	607.20	6.50	32.46	808.49	776.03
WhitesBranch	Reach2	18489.39	250-Year	15775.00	596.73	607.59	6.63	30.44	810.44	780.00
WhitesBranch	Reach2	18489.39	500-Year	17258.00	596.73	607.90	6.68	28.86	811.95	783.10
WhitesBranch	Reach2	18620.33	2-Year	2491.00	597.14	604.56	3.20	142.09	789.89	647.80
WhitesBranch	Reach2	18620.33	5-Year	6230.00	597.14	605.98	4.38	57.54	793.44	735.90
WhitesBranch	Reach2	18620.33	10-Year	8253.00	597.14	606.53	4.79	48.22	794.79	746.56
WhitesBranch	Reach2	18620.33	25-Year	10554.00	597.14	607.06	5.19	40.10	796.12	756.02
WhitesBranch	Reach2	18620.33	50-Year	12177.00	597.14	607.40	5.42	38.26	796.98	758.72
WhitesBranch	Reach2	18620.33	100-Year	13833.00	597.14	607.74	5.63	36.49	798.02	761.53
WhitesBranch	Reach2	18620.33	250-Year	15775.00	597.14	608.12	5.84	34.46	799.92	765.47
WhitesBranch	Reach2	18620.33	500-Year	17258.00	597.14	608.41	5.97	32.90	801.97	769.07
WhitesBranch	Reach2	18794.21	2-Year	2491.00	597.18	604.92	3.31	155.77	724.85	569.08
WhitesBranch	Reach2	18794.21	5-Year	6230.00	597.18	606.48	4.52	69.43	734.18	664.76
WhitesBranch	Reach2	18794.21	10-Year	8253.00	597.18	607.06	4.95	59.03	737.68	678.65
WhitesBranch	Reach2	18794.21	25-Year	10554.00	597.18	607.63	5.35	55.41	741.10	685.69
WhitesBranch	Reach2	18794.21	50-Year	12177.00	597.18	607.99	5.60	53.43	743.29	689.86
WhitesBranch	Reach2	18794.21	100-Year	13833.00	597.18	608.34	5.84	51.53	745.38	693.85
WhitesBranch	Reach2	18794.21	250-Year	15775.00	597.18	608.74	6.07	49.38	747.75	698.37
WhitesBranch	Reach2	18794.21	500-Year	17258.00	597.18	609.03	6.23	47.77	749.52	701.75
WhitesBranch	Reach2	18926.98	2-Year	2491.00	597.53	605.22	4.22	116.78	616.74	499.95
WhitesBranch	Reach2	18926.98	5-Year	6230.00	597.53	606.90	5.68	65.21	632.83	567.62
WhitesBranch	Reach2	18926.98	10-Year	8253.00	597.53	607.52	6.17	62.14	637.55	575.41
WhitesBranch	Reach2	18926.98	25-Year	10554.00	597.53	608.13	6.72	59.15	658.97	599.81
WhitesBranch	Reach2	18926.98	50-Year	12177.00	597.53	608.51	7.02	57.26	664.87	607.60
WhitesBranch	Reach2	18926.98	100-Year	13833.00	597.53	608.88	7.29	55.46	670.30	614.84
WhitesBranch	Reach2	18926.98	250-Year	15775.00	597.53	609.28	7.57	53.45	675.86	622.40
WhitesBranch	Reach2	18926.98	500-Year	17258.00	597.53	609.58	7.75	51.97	679.70	627.74
WhitesBranch	Reach2	19061.97	2-Year	2491.00	597.53	605.68	4.13	86.95	518.32	431.37
WhitesBranch	Reach2	19061.97	5-Year	6230.00	597.53	607.49	5.59	52.67	562.07	509.40
WhitesBranch	Reach2	19061.97	10-Year	8253.00	597.53	608.15	6.16	50.10	573.00	522.91
WhitesBranch	Reach2	19061.97	25-Year	10554.00	597.53	608.80	6.71	47.54	583.88	536.34
WhitesBranch	Reach2	19061.97	50-Year	12177.00	597.53	609.20	7.09	45.97	596.52	550.56
WhitesBranch	Reach2	19061.97	100-Year	13833.00	597.53	609.59	7.46	44.48	612.02	567.54
WhitesBranch	Reach2	19061.97	250-Year	15775.00	597.53	610.01	7.83	42.82	627.08	584.26
WhitesBranch	Reach2	19061.97	500-Year	17258.00	597.53	610.32	8.08	41.61	638.10	596.49
WhitesBranch	Reach2	19157.01	2-Year	2491.00	597.53	605.93	4.17	103.05	489.68	386.63
WhitesBranch	Reach2	19157.01	5-Year	6230.00	597.53	607.81	5.77	72.87	539.30	466.43
WhitesBranch	Reach2	19157.01	10-Year	8253.00	597.53	608.49	6.39	70.06	553.90	483.84
WhitesBranch	Reach2	19157.01	25-Year	10554.00	597.53	609.17	6.97	67.29	567.30	500.01
WhitesBranch	Reach2	19157.01	50-Year	12177.00	597.53	609.59	7.37	65.57	583.85	518.29

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	19157.01	100-Year	13833.00	597.53	609.99	7.73	63.93	595.40	531.46
WhitesBranch	Reach2	19157.01	250-Year	15775.00	597.53	610.43	8.10	62.10	609.04	546.94
WhitesBranch	Reach2	19157.01	500-Year	17258.00	597.53	610.75	8.36	60.76	618.95	558.19
WhitesBranch	Reach2	19302.31	2-Year	2491.00	597.91	606.36	3.73	93.91	437.01	343.10
WhitesBranch	Reach2	19302.31	5-Year	6230.00	597.91	608.39	5.25	58.75	492.99	434.24
WhitesBranch	Reach2	19302.31	10-Year	8253.00	597.91	609.13	5.81	55.28	503.58	448.31
WhitesBranch	Reach2	19302.31	25-Year	10554.00	597.91	609.86	6.37	51.91	516.08	464.17
WhitesBranch	Reach2	19302.31	50-Year	12177.00	597.91	610.32	6.78	49.77	535.98	486.21
WhitesBranch	Reach2	19302.31	100-Year	13833.00	597.91	610.75	7.13	47.78	551.45	503.67
WhitesBranch	Reach2	19302.31	250-Year	15775.00	597.91	611.23	7.49	45.59	565.45	519.86
WhitesBranch	Reach2	19302.31	500-Year	17258.00	597.91	611.57	7.76	44.01	578.05	534.04
WhitesBranch	Reach2	19478.01	2-Year	2491.00	598.13	606.85	3.46	191.51	581.09	389.58
WhitesBranch	Reach2	19478.01	5-Year	6230.00	598.13	609.03	4.45	165.67	592.76	427.09
WhitesBranch	Reach2	19478.01	10-Year	8253.00	598.13	609.83	4.93	153.36	599.61	446.24
WhitesBranch	Reach2	19478.01	25-Year	10554.00	598.13	610.62	5.43	118.80	611.20	492.39
WhitesBranch	Reach2	19478.01	50-Year	12177.00	598.13	611.13	5.71	114.00	618.32	504.33
WhitesBranch	Reach2	19478.01	100-Year	13833.00	598.13	611.60	5.98	109.54	625.90	516.36
WhitesBranch	Reach2	19478.01	250-Year	15775.00	598.13	612.13	6.46	104.59	664.89	560.30
WhitesBranch	Reach2	19478.01	500-Year	17258.00	598.13	612.51	6.79	101.02	695.00	593.98
WhitesBranch	Reach2	19663.40	2-Year	2491.00	598.30	607.21	2.44	136.47	597.96	461.50
WhitesBranch	Reach2	19663.40	5-Year	6230.00	598.30	609.43	3.28	131.26	608.93	477.67
WhitesBranch	Reach2	19663.40	10-Year	8253.00	598.30	610.27	3.67	129.28	615.26	485.98
WhitesBranch	Reach2	19663.40	25-Year	10554.00	598.30	611.10	4.08	127.32	628.82	501.51
WhitesBranch	Reach2	19663.40	50-Year	12177.00	598.30	611.63	4.35	126.07	639.55	513.48
WhitesBranch	Reach2	19663.40	100-Year	13833.00	598.30	612.14	4.71	124.88	675.86	550.98
WhitesBranch	Reach2	19663.40	250-Year	15775.00	598.30	612.71	5.14	123.52	737.18	613.66
WhitesBranch	Reach2	19663.40	500-Year	17258.00	598.30	613.12	5.27	122.57	753.41	630.84
WhitesBranch	Reach2	19838.42	2-Year	2491.00	599.07	607.42	3.35	96.76	512.74	415.98
WhitesBranch	Reach2	19838.42	5-Year	6230.00	599.07	609.66	4.26	89.80	524.93	435.14
WhitesBranch	Reach2	19838.42	10-Year	8253.00	599.07	610.52	4.74	87.13	543.09	455.96
WhitesBranch	Reach2	19838.42	25-Year	10554.00	599.07	611.38	5.20	84.48	561.43	476.95
WhitesBranch	Reach2	19838.42	50-Year	12177.00	599.07	611.92	5.49	82.91	572.09	489.18
WhitesBranch	Reach2	19838.42	100-Year	13833.00	599.07	612.45	6.11	81.53	655.67	574.14
WhitesBranch	Reach2	19838.42	250-Year	15775.00	599.07	613.06	6.25	80.27	678.19	597.92
WhitesBranch	Reach2	19838.42	500-Year	17258.00	599.07	613.46	6.36	79.43	693.16	613.73
WhitesBranch	Reach2	19971.21	2-Year	2491.00	599.07	607.70	3.57	56.03	439.21	383.18
WhitesBranch	Reach2	19971.21	5-Year	6230.00	599.07	609.95	4.62	48.09	473.86	425.76
WhitesBranch	Reach2	19971.21	10-Year	8253.00	599.07	610.83	5.19	46.18	528.19	482.01
WhitesBranch	Reach2	19971.21	25-Year	10554.00	599.07	611.70	5.71	44.28	593.30	549.02
WhitesBranch	Reach2	19971.21	50-Year	12177.00	599.07	612.26	5.86	43.07	601.51	558.43
WhitesBranch	Reach2	19971.21	100-Year	13833.00	599.07	612.84	5.92	41.81	608.11	566.30
WhitesBranch	Reach2	19971.21	250-Year	15775.00	599.07	613.44	6.05	40.51	613.32	572.81
WhitesBranch	Reach2	19971.21	500-Year	17258.00	599.07	613.83	6.19	39.65	782.84	598.30
WhitesBranch	Reach2	20129.47	2-Year	2491.00	599.46	608.11	3.93	95.20	456.68	361.49
WhitesBranch	Reach2	20129.47	5-Year	6230.00	599.46	610.35	4.89	86.45	573.30	486.85
WhitesBranch	Reach2	20129.47	10-Year	8253.00	599.46	611.26	5.13	82.68	596.63	513.94
WhitesBranch	Reach2	20129.47	25-Year	10554.00	599.46	612.16	5.36	78.99	623.11	544.12
WhitesBranch	Reach2	20129.47	50-Year	12177.00	599.46	612.70	5.55	76.77	639.95	563.18
WhitesBranch	Reach2	20129.47	100-Year	13833.00	599.46	613.25	5.70	74.50	660.25	585.75
WhitesBranch	Reach2	20129.47	250-Year	15775.00	599.46	613.83	5.90	72.12	679.96	607.84
WhitesBranch	Reach2	20129.47	500-Year	17258.00	599.46	614.22	6.07	70.50	703.53	633.03
WhitesBranch	Reach2	20289.98	2-Year	2491.00	599.46	608.52	3.61	121.92	520.65	398.73
WhitesBranch	Reach2	20289.98	5-Year	6230.00	599.46	610.79	4.83	106.32	583.50	477.18
WhitesBranch	Reach2	20289.98	10-Year	8253.00	599.46	611.69	5.24	101.13	599.87	498.74
WhitesBranch	Reach2	20289.98	25-Year	10554.00	599.46	612.57	5.63	96.02	616.64	520.62
WhitesBranch	Reach2	20289.98	50-Year	12177.00	599.46	613.12	5.89	92.89	625.22	532.33
WhitesBranch	Reach2	20289.98	100-Year	13833.00	599.46	613.66	6.09	89.79	636.54	546.75
WhitesBranch	Reach2	20289.98	250-Year	15775.00	599.46	614.25	6.29	86.55	639.24	552.68
WhitesBranch	Reach2	20289.98	500-Year	17258.00	599.46	614.65	6.46	84.32	641.10	556.78
WhitesBranch	Reach2	20473.09	2-Year	2491.00	599.46	608.89	4.29	153.33	465.57	312.24
WhitesBranch	Reach2	20473.09	5-Year	6230.00	599.46	611.24	5.68	69.67	550.68	481.02

HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	20473.09	10-Year	8253.00	599.46	612.15	6.00	63.94	575.92	511.98
WhitesBranch	Reach2	20473.09	25-Year	10554.00	599.46	613.06	6.30	58.29	599.46	541.17
WhitesBranch	Reach2	20473.09	50-Year	12177.00	599.46	613.61	6.48	54.80	601.41	546.61
WhitesBranch	Reach2	20473.09	100-Year	13833.00	599.46	614.17	6.62	51.34	603.36	552.02
WhitesBranch	Reach2	20473.09	250-Year	15775.00	599.46	614.75	6.81	47.98	605.56	557.58
WhitesBranch	Reach2	20473.09	500-Year	17258.00	599.46	615.16	6.97	45.83	607.27	561.44
WhitesBranch	Reach2	20613.88	2-Year	2491.00	600.57	609.22	4.87	110.34	504.03	393.69
WhitesBranch	Reach2	20613.88	5-Year	6230.00	600.57	611.63	5.33	69.19	565.24	496.05
WhitesBranch	Reach2	20613.88	10-Year	8253.00	600.57	612.54	5.59	63.04	584.69	521.64
WhitesBranch	Reach2	20613.88	25-Year	10554.00	600.57	613.44	5.85	59.60	603.80	544.19
WhitesBranch	Reach2	20613.88	50-Year	12177.00	600.57	613.99	6.01	57.49	605.65	548.17
WhitesBranch	Reach2	20613.88	100-Year	13833.00	600.57	614.54	6.15	55.39	607.45	552.06
WhitesBranch	Reach2	20613.88	250-Year	15775.00	600.57	615.12	6.32	53.16	609.35	556.19
WhitesBranch	Reach2	20613.88	500-Year	17258.00	600.57	615.53	6.47	51.59	610.68	559.09
WhitesBranch	Reach2	20738.87	2-Year	2491.00	601.91	609.67	4.79	57.70	524.73	467.03
WhitesBranch	Reach2	20738.87	5-Year	6230.00	601.91	611.99	5.05	44.92	539.39	494.47
WhitesBranch	Reach2	20738.87	10-Year	8253.00	601.91	612.89	5.35	39.96	551.76	511.80
WhitesBranch	Reach2	20738.87	25-Year	10554.00	601.91	613.79	5.75	35.04	586.26	551.23
WhitesBranch	Reach2	20738.87	50-Year	12177.00	601.91	614.34	5.99	32.00	603.73	571.73
WhitesBranch	Reach2	20738.87	100-Year	13833.00	601.91	614.88	6.19	29.01	620.96	591.95
WhitesBranch	Reach2	20738.87	250-Year	15775.00	601.91	615.46	6.35	25.79	626.39	600.60
WhitesBranch	Reach2	20738.87	500-Year	17258.00	601.91	615.87	6.47	23.52	628.68	605.16
WhitesBranch	Reach2	20852.14	2-Year	2491.00	602.54	610.08	3.57	68.87	605.32	536.44
WhitesBranch	Reach2	20852.14	5-Year	6230.00	602.54	612.29	3.95	56.11	610.10	553.99
WhitesBranch	Reach2	20852.14	10-Year	8253.00	602.54	613.19	4.23	50.92	637.52	586.60
WhitesBranch	Reach2	20852.14	25-Year	10554.00	602.54	614.09	4.48	45.72	661.74	616.03
WhitesBranch	Reach2	20852.14	50-Year	12177.00	602.54	614.65	4.69	42.50	687.24	644.74
WhitesBranch	Reach2	20852.14	100-Year	13833.00	602.54	615.19	4.82	39.30	698.82	659.52
WhitesBranch	Reach2	20852.14	250-Year	15775.00	602.54	615.78	4.95	35.87	702.38	666.51
WhitesBranch	Reach2	20852.14	500-Year	17258.00	602.54	616.19	5.05	33.43	704.91	671.48
WhitesBranch	Reach2	20983.94	2-Year	2491.00	602.54	610.40	4.63	89.48	507.30	417.82
WhitesBranch	Reach2	20983.94	5-Year	6230.00	602.54	612.57	5.14	57.35	764.79	707.44
WhitesBranch	Reach2	20983.94	10-Year	8253.00	602.54	613.47	5.07	51.48	782.37	730.90
WhitesBranch	Reach2	20983.94	25-Year	10554.00	602.54	614.37	5.05	45.62	787.95	742.33
WhitesBranch	Reach2	20983.94	50-Year	12177.00	602.54	614.93	5.09	41.95	791.36	749.40
WhitesBranch	Reach2	20983.94	100-Year	13833.00	602.54	615.48	5.13	38.40	794.58	756.18
WhitesBranch	Reach2	20983.94	250-Year	15775.00	602.54	616.06	5.22	34.60	800.47	765.87
WhitesBranch	Reach2	20983.94	500-Year	17258.00	602.54	616.48	5.29	31.90	804.79	772.89
WhitesBranch	Reach2	21123.01	2-Year	2491.00	602.93	610.93	4.25	114.27	480.58	306.40
WhitesBranch	Reach2	21123.01	5-Year	6230.00	602.93	613.00	6.12	104.89	744.03	639.14
WhitesBranch	Reach2	21123.01	10-Year	8253.00	602.93	613.83	6.14	96.13	766.28	670.15
WhitesBranch	Reach2	21123.01	25-Year	10554.00	602.93	614.69	6.13	85.21	778.81	693.59
WhitesBranch	Reach2	21123.01	50-Year	12177.00	602.93	615.23	6.14	80.61	781.78	701.18
WhitesBranch	Reach2	21123.01	100-Year	13833.00	602.93	615.76	6.15	77.72	784.55	706.83
WhitesBranch	Reach2	21123.01	250-Year	15775.00	602.93	616.33	6.19	74.61	787.39	712.78
WhitesBranch	Reach2	21123.01	500-Year	17258.00	602.93	616.74	6.26	72.38	791.80	719.41
WhitesBranch	Reach2	21308.41	2-Year	2491.00	603.70	611.47	5.46	112.60	462.53	349.93
WhitesBranch	Reach2	21308.41	5-Year	6230.00	603.70	613.68	6.11	104.06	666.27	562.22
WhitesBranch	Reach2	21308.41	10-Year	8253.00	603.70	614.43	6.38	99.44	685.95	586.51
WhitesBranch	Reach2	21308.41	25-Year	10554.00	603.70	615.21	6.55	93.68	695.27	601.59
WhitesBranch	Reach2	21308.41	50-Year	12177.00	603.70	615.72	6.65	90.33	699.20	608.87
WhitesBranch	Reach2	21308.41	100-Year	13833.00	603.70	616.22	6.74	87.03	703.06	616.03
WhitesBranch	Reach2	21308.41	250-Year	15775.00	603.70	616.76	6.86	83.41	707.29	623.88
WhitesBranch	Reach2	21308.41	500-Year	17258.00	603.70	617.15	6.94	81.40	710.35	628.95
WhitesBranch	Reach2	21547.43	2-Year	2491.00	604.47	612.49	4.76	102.15	532.10	429.95
WhitesBranch	Reach2	21547.43	5-Year	6230.00	604.47	614.61	5.79	70.10	588.90	518.80
WhitesBranch	Reach2	21547.43	10-Year	8253.00	604.47	615.36	6.22	63.20	597.98	534.78
WhitesBranch	Reach2	21547.43	25-Year	10554.00	604.47	616.11	6.59	59.47	603.97	544.50
WhitesBranch	Reach2	21547.43	50-Year	12177.00	604.47	616.60	6.82	57.08	607.91	550.83
WhitesBranch	Reach2	21547.43	100-Year	13833.00	604.47	617.08	7.03	54.76	611.76	557.00
WhitesBranch	Reach2	21547.43	250-Year	15775.00	604.47	617.61	7.25	52.18	616.01	563.82
WhitesBranch	Reach2	21547.43	500-Year	17258.00	604.47	617.99	7.41	50.32	619.08	568.76

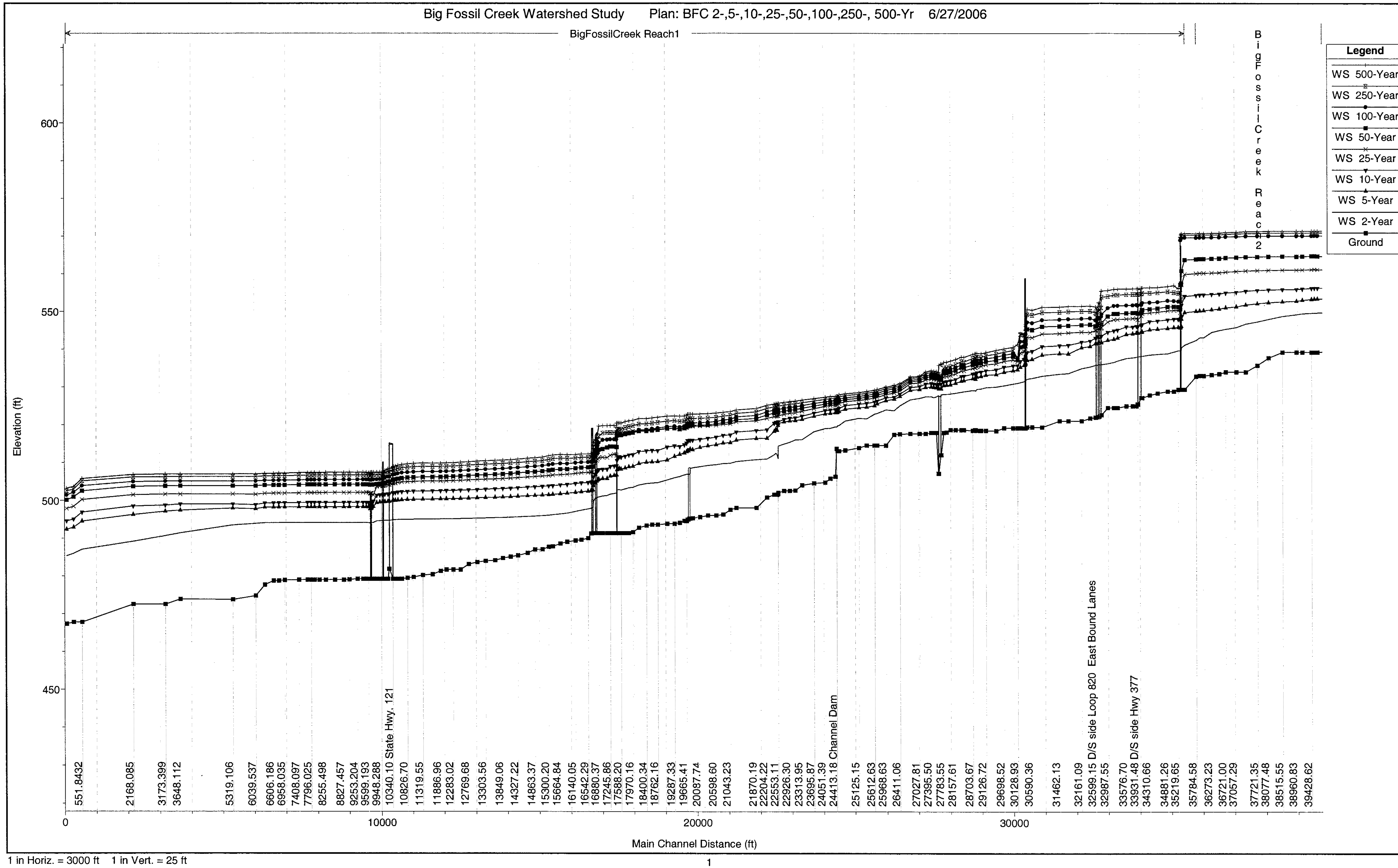
HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	21760.53	2-Year	2491.00	605.24	613.18	3.73	142.20	600.85	458.65
WhitesBranch	Reach2	21760.53	5-Year	6230.00	605.24	615.29	4.69	104.70	648.39	543.69
WhitesBranch	Reach2	21760.53	10-Year	8253.00	605.24	616.07	5.09	97.54	653.96	556.42
WhitesBranch	Reach2	21760.53	25-Year	10554.00	605.24	616.84	5.47	91.50	659.50	568.00
WhitesBranch	Reach2	21760.53	50-Year	12177.00	605.24	617.33	5.70	87.59	663.08	575.50
WhitesBranch	Reach2	21760.53	100-Year	13833.00	605.24	617.82	5.92	83.80	667.30	583.50
WhitesBranch	Reach2	21760.53	250-Year	15775.00	605.24	618.35	6.19	79.60	679.66	600.06
WhitesBranch	Reach2	21760.53	500-Year	17258.00	605.24	618.74	6.39	76.54	691.27	614.72
WhitesBranch	Reach2	21909.75	2-Year	2491.00	605.62	613.51	2.86	133.98	645.59	511.61
WhitesBranch	Reach2	21909.75	5-Year	6230.00	605.62	615.65	3.70	110.57	692.51	581.94
WhitesBranch	Reach2	21909.75	10-Year	8253.00	605.62	616.45	4.09	102.97	717.39	614.42
WhitesBranch	Reach2	21909.75	25-Year	10554.00	605.62	617.24	4.47	95.41	745.36	649.95
WhitesBranch	Reach2	21909.75	50-Year	12177.00	605.62	617.75	4.69	90.53	762.19	671.67
WhitesBranch	Reach2	21909.75	100-Year	13833.00	605.62	618.24	4.89	85.63	778.73	693.10
WhitesBranch	Reach2	21909.75	250-Year	15775.00	605.62	618.80	5.06	80.01	786.94	706.93
WhitesBranch	Reach2	21909.75	500-Year	17258.00	605.62	619.20	5.18	75.93	788.89	712.96
WhitesBranch	Reach2	21921.79	2-Year	2491.00	605.62	613.53	2.71	136.64	652.00	515.36
WhitesBranch	Reach2	21921.79	5-Year	6230.00	605.62	615.68	3.45	114.22	709.92	595.71
WhitesBranch	Reach2	21921.79	10-Year	8253.00	605.62	616.48	3.81	106.57	734.80	628.23
WhitesBranch	Reach2	21921.79	25-Year	10554.00	605.62	617.27	4.16	99.34	762.18	662.84
WhitesBranch	Reach2	21921.79	50-Year	12177.00	605.62	617.78	4.36	94.67	779.69	685.01
WhitesBranch	Reach2	21921.79	100-Year	13833.00	605.62	618.28	4.55	90.16	797.19	707.03
WhitesBranch	Reach2	21921.79	250-Year	15775.00	605.62	618.83	4.73	85.15	816.67	731.52
WhitesBranch	Reach2	21921.79	500-Year	17258.00	605.62	619.23	4.84	81.49	820.89	739.40
WhitesBranch	Reach2	21937.73	2-Year	2491.00	605.62	613.55	2.71	133.40	651.83	518.44
WhitesBranch	Reach2	21937.73	5-Year	6230.00	605.62	615.70	3.52	113.76	716.69	602.93
WhitesBranch	Reach2	21937.73	10-Year	8253.00	605.62	616.50	3.88	106.98	741.87	634.89
WhitesBranch	Reach2	21937.73	25-Year	10554.00	605.62	617.29	4.23	99.79	768.95	669.16
WhitesBranch	Reach2	21937.73	50-Year	12177.00	605.62	617.81	4.44	95.12	786.88	691.76
WhitesBranch	Reach2	21937.73	100-Year	13833.00	605.62	618.30	4.62	90.60	804.19	713.59
WhitesBranch	Reach2	21937.73	250-Year	15775.00	605.62	618.85	4.82	85.59	823.62	738.04
WhitesBranch	Reach2	21937.73	500-Year	17258.00	605.62	619.25	4.94	81.93	841.18	759.25
WhitesBranch	Reach2	22017.42	2-Year	2491.00	605.62	613.67	2.29	123.58	661.17	537.59
WhitesBranch	Reach2	22017.42	5-Year	6230.00	605.62	615.83	2.97	107.20	746.79	639.59
WhitesBranch	Reach2	22017.42	10-Year	8253.00	605.62	616.64	3.27	100.37	772.65	672.27
WhitesBranch	Reach2	22017.42	25-Year	10554.00	605.62	617.44	3.56	93.91	814.45	720.54
WhitesBranch	Reach2	22017.42	50-Year	12177.00	605.62	617.96	3.74	90.34	841.50	751.16
WhitesBranch	Reach2	22017.42	100-Year	13833.00	605.62	618.46	3.89	86.90	862.45	775.56
WhitesBranch	Reach2	22017.42	250-Year	15775.00	605.62	619.02	4.05	83.07	882.55	799.48
WhitesBranch	Reach2	22017.42	500-Year	17258.00	605.62	619.42	4.16	80.31	897.10	816.79
WhitesBranch	Reach2	22201.01	2-Year	2601.00	607.16	613.61	7.06	743.81	855.65	111.84
WhitesBranch	Reach2	22201.01	5-Year	6289.00	607.16	616.03	5.75	140.32	861.51	721.18
WhitesBranch	Reach2	22201.01	10-Year	8227.00	607.16	616.87	5.48	127.13	894.37	767.24
WhitesBranch	Reach2	22201.01	25-Year	10460.00	607.16	617.69	5.39	106.81	928.52	821.71
WhitesBranch	Reach2	22201.01	50-Year	12039.00	607.16	618.21	5.37	94.25	955.78	861.53
WhitesBranch	Reach2	22201.01	100-Year	13589.00	607.16	618.71	5.32	87.22	976.83	889.61
WhitesBranch	Reach2	22201.01	250-Year	15474.00	607.16	619.27	5.30	78.39	987.43	909.05
WhitesBranch	Reach2	22201.01	500-Year	16904.00	607.16	619.67	5.30	71.32	994.29	922.97
WhitesBranch	Reach2	22343.39	2-Year	2601.00	608.50	614.57	1.69	218.79	955.92	737.13
WhitesBranch	Reach2	22343.39	5-Year	6289.00	608.50	616.45	2.29	148.29	961.33	813.05
WhitesBranch	Reach2	22343.39	10-Year	8227.00	608.50	617.22	2.49	136.91	963.55	826.65
WhitesBranch	Reach2	22343.39	25-Year	10460.00	608.50	618.01	2.75	97.11	965.89	868.78
WhitesBranch	Reach2	22343.39	50-Year	12039.00	608.50	618.52	2.91	67.32	967.42	900.11
WhitesBranch	Reach2	22343.39	100-Year	13589.00	608.50	619.01	3.00	63.31	968.88	905.58
WhitesBranch	Reach2	22343.39	250-Year	15474.00	608.50	619.55	3.12	58.83	970.52	911.69
WhitesBranch	Reach2	22343.39	500-Year	16904.00	608.50	619.94	3.20	55.57	971.70	916.13
WhitesBranch	Reach2	22475.63	2-Year	2601.00	608.60	614.63	1.83	246.19	978.23	732.04
WhitesBranch	Reach2	22475.63	5-Year	6289.00	608.60	616.52	2.45	200.72	983.05	782.32
WhitesBranch	Reach2	22475.63	10-Year	8227.00	608.60	617.30	2.67	184.76	984.83	800.07
WhitesBranch	Reach2	22475.63	25-Year	10460.00	608.60	618.09	2.96	124.51	986.46	861.95
WhitesBranch	Reach2	22475.63	50-Year	12039.00	608.60	618.61	3.12	88.39	987.51	899.12

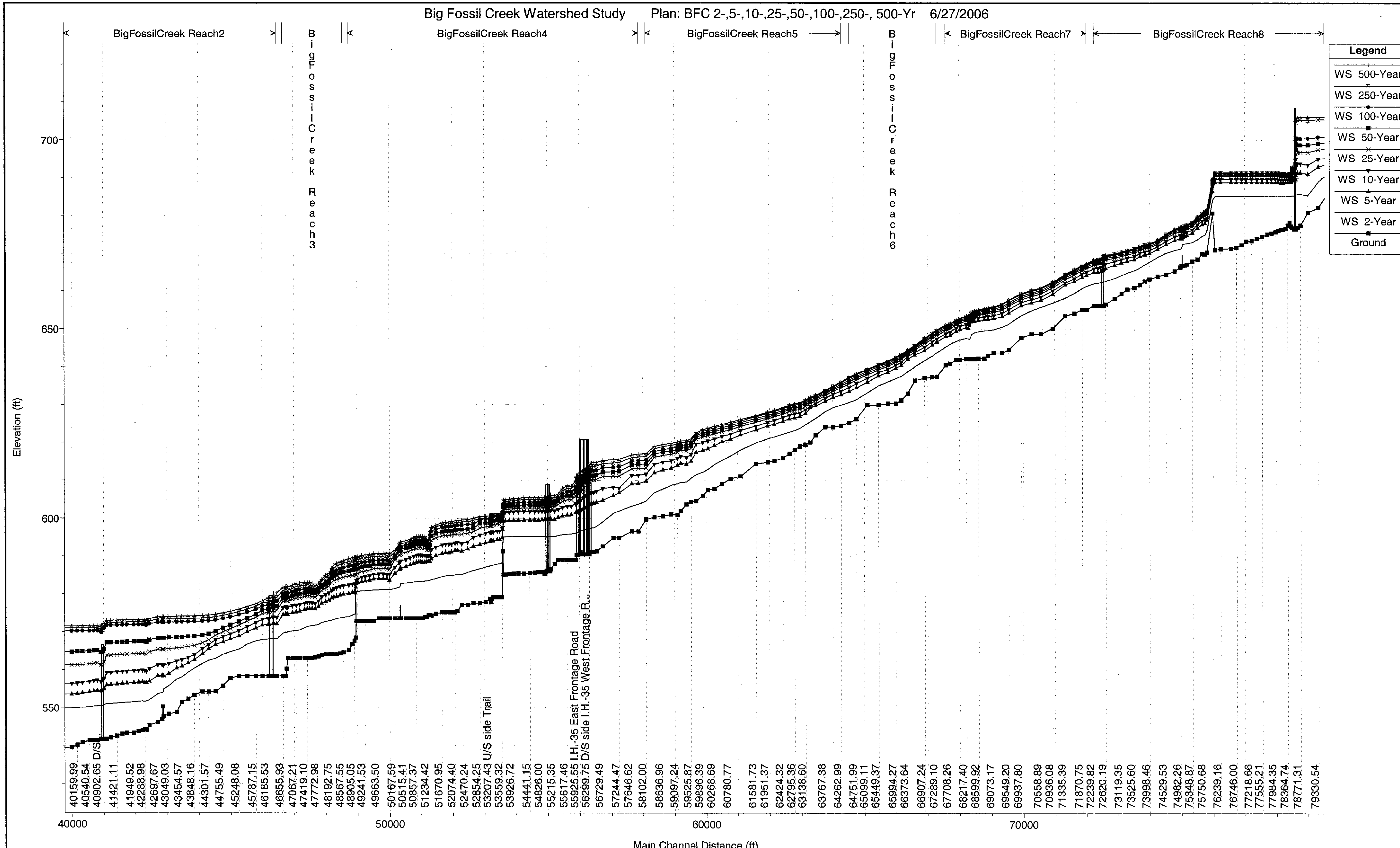
HEC-RAS Plan: BFC_Watershd (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Sta W.S. Lft	Sta W.S. Rgt	Top Width
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft)	(ft)
WhitesBranch	Reach2	22475.63	100-Year	13589.00	608.60	619.09	3.21	84.58	988.51	903.93
WhitesBranch	Reach2	22475.63	250-Year	15474.00	608.60	619.63	3.32	80.79	989.62	908.84
WhitesBranch	Reach2	22475.63	500-Year	16904.00	608.60	620.03	3.40	78.17	990.43	912.27
WhitesBranch	Reach2	22628.15	2-Year	2601.00	608.63	614.72	2.02	312.71	936.00	623.29
WhitesBranch	Reach2	22628.15	5-Year	6289.00	608.63	616.63	2.75	280.44	942.08	661.64
WhitesBranch	Reach2	22628.15	10-Year	8227.00	608.63	617.40	3.04	258.23	944.94	686.71
WhitesBranch	Reach2	22628.15	25-Year	10460.00	608.63	618.21	3.52	113.45	948.00	834.55
WhitesBranch	Reach2	22628.15	50-Year	12039.00	608.63	618.73	3.64	95.78	949.96	854.18
WhitesBranch	Reach2	22628.15	100-Year	13589.00	608.63	619.21	3.72	91.60	1043.15	869.45
WhitesBranch	Reach2	22628.15	250-Year	15474.00	608.63	619.75	3.82	86.91	1048.63	912.59
WhitesBranch	Reach2	22628.15	500-Year	16904.00	608.63	620.14	3.89	83.51	1051.91	926.19
WhitesBranch	Reach2	22815.33	2-Year	2601.00	608.63	614.86	4.29	226.39	801.24	574.85
WhitesBranch	Reach2	22815.33	5-Year	6289.00	608.63	616.82	4.82	196.23	826.18	629.96
WhitesBranch	Reach2	22815.33	10-Year	8227.00	608.63	617.61	5.06	174.15	843.46	669.31
WhitesBranch	Reach2	22815.33	25-Year	10460.00	608.63	618.45	5.43	53.99	858.70	804.71
WhitesBranch	Reach2	22815.33	50-Year	12039.00	608.63	618.96	5.44	51.76	861.67	809.91
WhitesBranch	Reach2	22815.33	100-Year	13589.00	608.63	619.44	5.48	49.69	864.42	814.73
WhitesBranch	Reach2	22815.33	250-Year	15474.00	608.63	619.97	5.54	47.36	1075.15	863.75
WhitesBranch	Reach2	22815.33	500-Year	16904.00	608.63	620.36	5.59	45.67	1080.16	881.61
WhitesBranch	Reach2	23001.79	2-Year	2601.00	608.63	615.51	3.59	203.93	690.11	486.18
WhitesBranch	Reach2	23001.79	5-Year	6289.00	608.63	617.39	4.69	189.89	714.42	524.53
WhitesBranch	Reach2	23001.79	10-Year	8227.00	608.63	618.17	5.24	114.41	724.13	609.72
WhitesBranch	Reach2	23001.79	25-Year	10460.00	608.63	619.01	5.53	43.83	731.64	687.81
WhitesBranch	Reach2	23001.79	50-Year	12039.00	608.63	619.49	5.66	42.49	734.42	691.93
WhitesBranch	Reach2	23001.79	100-Year	13589.00	608.63	619.94	5.77	41.24	737.17	695.93
WhitesBranch	Reach2	23001.79	250-Year	15474.00	608.63	620.45	5.90	39.82	740.31	700.49
WhitesBranch	Reach2	23001.79	500-Year	16904.00	608.63	620.83	5.99	38.78	742.60	703.82
WhitesBranch	Reach2	23193.95	2-Year	2601.00	608.63	616.02	3.47	157.92	697.57	539.65
WhitesBranch	Reach2	23193.95	5-Year	6289.00	608.63	617.98	4.28	62.02	704.20	642.17
WhitesBranch	Reach2	23193.95	10-Year	8227.00	608.63	618.81	4.42	59.11	706.97	647.86
WhitesBranch	Reach2	23193.95	25-Year	10460.00	608.63	619.64	4.60	55.91	709.92	654.01
WhitesBranch	Reach2	23193.95	50-Year	12039.00	608.63	620.11	4.79	54.02	711.30	657.28
WhitesBranch	Reach2	23193.95	100-Year	13589.00	608.63	620.55	4.96	52.25	714.08	661.83
WhitesBranch	Reach2	23193.95	250-Year	15474.00	608.63	621.06	5.15	50.23	717.34	667.12
WhitesBranch	Reach2	23193.95	500-Year	16904.00	608.63	621.42	5.29	48.75	760.90	678.61
WhitesBranch	Reach2	23343.63	2-Year	2601.00	608.63	616.34	3.40	127.48	667.11	539.63
WhitesBranch	Reach2	23343.63	5-Year	6289.00	608.63	618.33	3.99	69.23	739.96	670.73
WhitesBranch	Reach2	23343.63	10-Year	8227.00	608.63	619.14	4.14	66.56	758.10	691.54
WhitesBranch	Reach2	23343.63	25-Year	10460.00	608.63	619.96	4.29	63.85	773.85	710.00
WhitesBranch	Reach2	23343.63	50-Year	12039.00	608.63	620.44	4.44	62.27	782.22	719.95
WhitesBranch	Reach2	23343.63	100-Year	13589.00	608.63	620.88	4.57	60.79	790.03	729.24
WhitesBranch	Reach2	23343.63	250-Year	15474.00	608.63	621.39	4.72	59.10	799.68	740.58
WhitesBranch	Reach2	23343.63	500-Year	16904.00	608.63	621.77	4.84	57.86	813.71	755.84
WhitesBranch	Reach2	23369.12	2-Year	2601.00	608.63	616.39	3.55	156.11	690.84	534.73
WhitesBranch	Reach2	23369.12	5-Year	6289.00	608.63	618.38	4.07	91.88	746.22	654.34
WhitesBranch	Reach2	23369.12	10-Year	8227.00	608.63	619.18	4.22	89.26	767.68	678.42
WhitesBranch	Reach2	23369.12	25-Year	10460.00	608.63	620.00	4.39	86.61	794.93	708.33
WhitesBranch	Reach2	23369.12	50-Year	12039.00	608.63	620.48	4.53	85.05	803.22	718.17
WhitesBranch	Reach2	23369.12	100-Year	13589.00	608.63	620.93	4.65	83.60	810.95	727.35
WhitesBranch	Reach2	23369.12	250-Year	15474.00	608.63	621.44	4.79	81.92	819.82	737.90
WhitesBranch	Reach2	23369.12	500-Year	16904.00	608.63	621.81	4.89	80.70	828.18	747.48

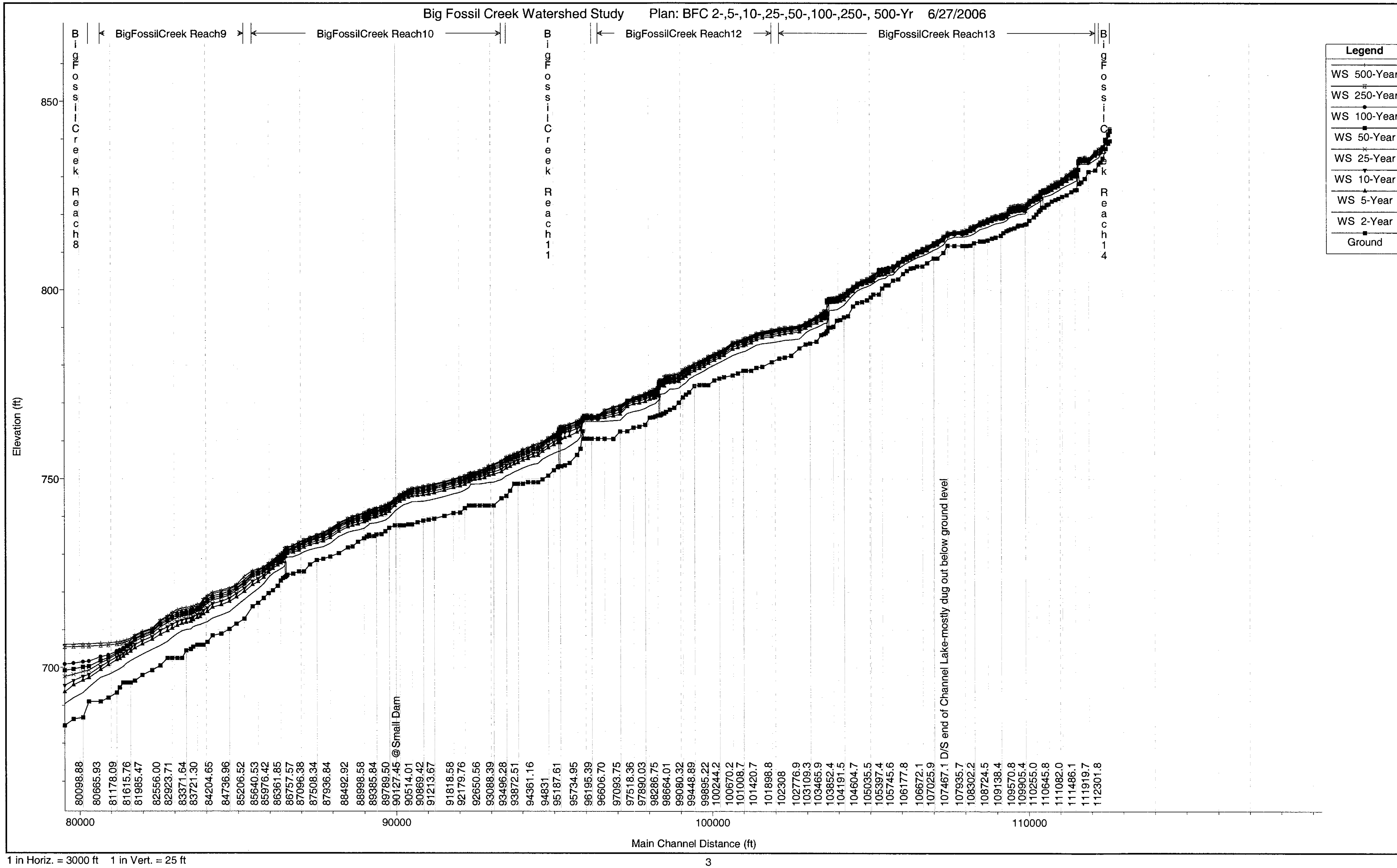
TABLE 5 – PROFILE PLOTS

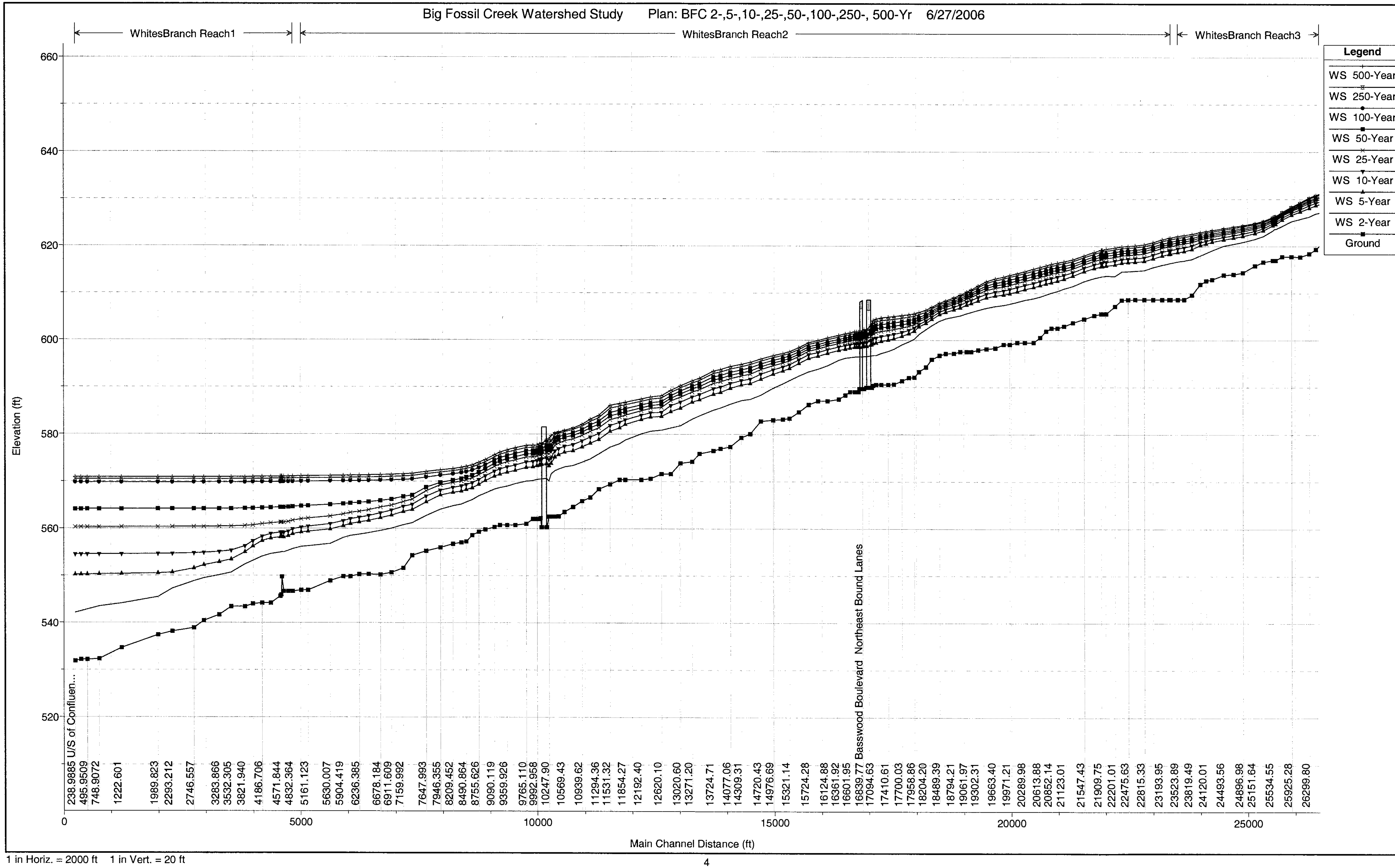


Big Fossil Creek Watershed Study Plan: BFC 2-,5-,10-,25-,50-,100-,250-, 500-Yr 6/27/2006
BigFossilCreek Reach1
BigFossilCreek Reach2
Legend
WS 500-Year
WS 250-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 5-Year
WS 2-Year
Ground
Elevation (ft)
600
550
500
450
Main Channel Distance (ft)
0
10000
20000
30000
551.8432
2168.085
3173.399
3648.112
5319.106
6039.537
6606.186
6958.035
7408.097
7796.025
8255.498
8827.457
9253.204
9599.193
9948.288
10340.10 State Hwy. 121
10826.70
11319.55
11886.96
12283.02
12769.68
13303.56
13849.06
14327.22
14863.37
15300.20
15664.84
16140.05
16542.29
16880.37
17245.86
17588.20
17970.16
18400.34
18762.16
19287.33
19665.41
20087.74
20598.60
21043.23
21870.19
22204.22
22553.11
22926.30
23313.95
23695.87
24051.39
24413.18 Channel Dam
25125.15
25612.63
25968.63
26411.06
27027.81
27395.50
27783.55
28157.61
28703.67
29126.72
29698.52
30128.93
30590.36
31462.13
32161.09
32599.15 D/S side Loop 820 East Bound Lanes
32987.55
33576.70
33931.48 D/S side Hwy 377
34310.66
34881.26
35219.65
35784.58
36273.23
36721.00
37057.29
37721.35
38077.48
38515.55
38960.83
39428.62
1 in Horiz. = 3000 ft 1 in Vert. = 25 ft
1



1 in Horiz. = 3000 ft 1 in Vert. = 25 ft


Big Fossil Creek Watershed Study Plan: BFC 2-,5-,10-,25-,50-,100-,250-, 500-Yr 6/27/2006
BigFossilCreek Reach8
BigFossilCreek Reach9
BigFossilCreek Reach10
BigFossilCreek Reach11
BigFossilCreek Reach12
BigFossilCreek Reach13
BigFossilCreek Reach14
Legend
WS 500-Year
WS 250-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 5-Year
WS 2-Year
Ground
Elevation (ft)
850
800
750
700
80098.88
80665.93
81178.09
81615.76
81985.47
82556.00
82923.71
83371.64
83721.30
84204.65
84736.96
85206.52
85640.53
85976.42
86361.85
86757.57
87096.38
87508.34
87936.84
88492.92
88998.58
89385.84
89789.50
90127.45 @Small Dam
90514.01
90869.42
91213.67
91818.58
92179.76
92650.56
93088.39
93496.28
93872.51
94361.16
94831
95187.61
95734.95
96195.39
96606.70
97093.75
97518.36
97890.03
98286.75
98664.01
99080.32
99448.89
99895.22
100244.2
100670.2
101008.7
101420.7
101898.8
102308
102776.9
103109.3
103465.9
103852.4
104191.5
104604.7
105035.5
105397.4
105745.6
106177.8
106672.1
107025.9
107467.1 D/S end of Channel Lake-mostly dug out below ground level
107935.7
108302.2
108724.5
109138.4
109570.8
109905.4
110255.0
110645.8
111082.0
111486.1
111919.7
112301.8
80000
90000
100000
110000
Main Channel Distance (ft)
1 in Horiz. = 3000 ft 1 in Vert. = 25 ft


Big Fossil Creek Watershed Study Plan: BFC 2-,5-,10-,25-,50-,100-,250-, 500-Yr 6/27/2006
WhitesBranch Reach1
WhitesBranch Reach2
WhitesBranch Reach3
Legend
WS 500-Year
WS 250-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 5-Year
WS 2-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
Basswood Boulevard Northeast Bound Lanes
238.9885 U/S of Confluen...
1 in Horiz. = 2000 ft 1 in Vert. = 20 ft

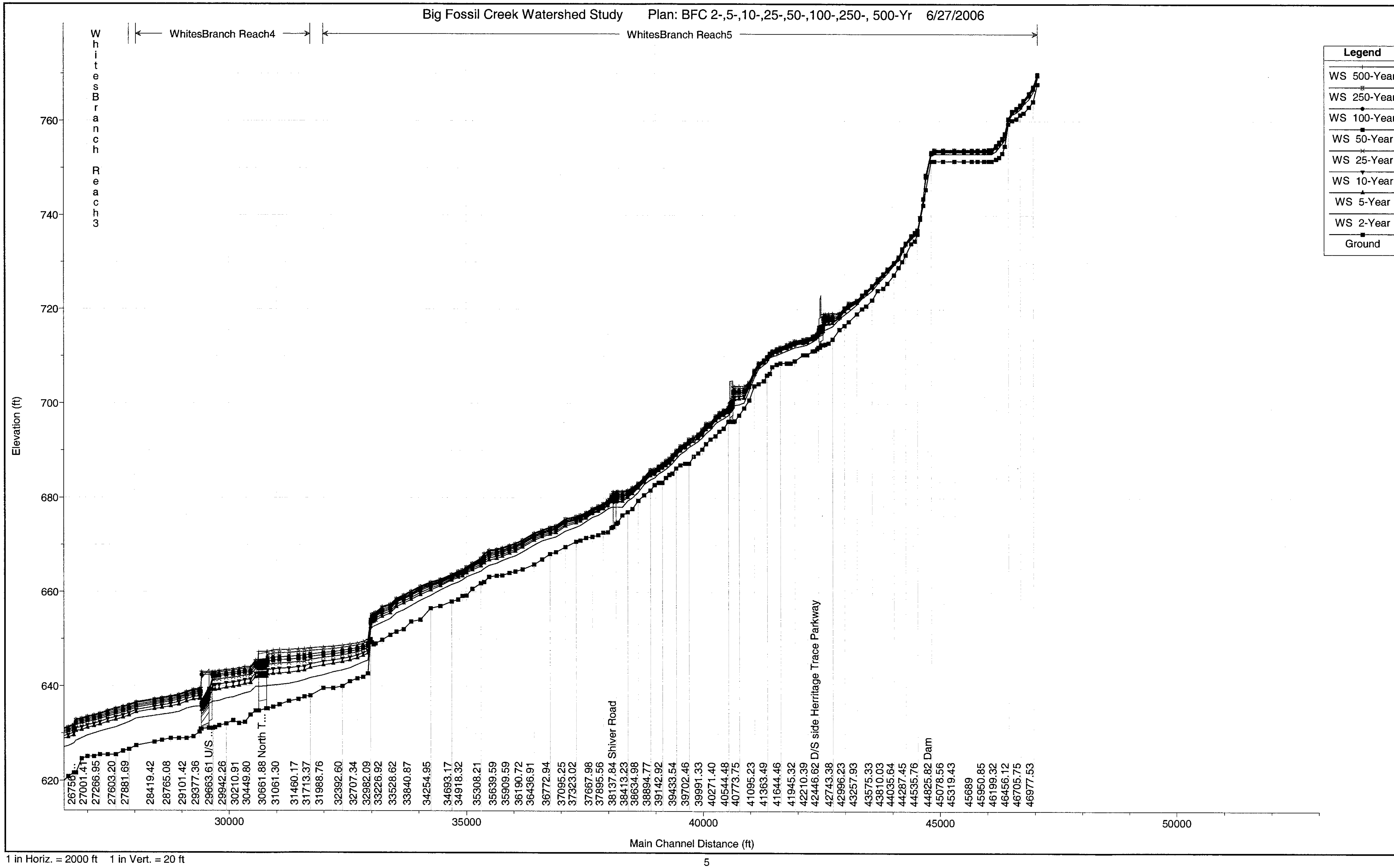

Big Fossil Creek Watershed Study Plan: BFC 2-,5-,10-,25-,50-,100-,250-, 500-Yr 6/27/2006
WhitesBranch Reach3
WhitesBranch Reach4
WhitesBranch Reach5
Legend
WS 500-Year
WS 250-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 5-Year
WS 2-Year
Ground
Elevation (ft)
760
740
720
700
680
660
640
620
29663.61 U/S...
30661.88 North T...
38137.84 Shiver Road
42446.62 D/S side Herritage Trace Parkway
44825.82 Dam
30000
35000
40000
45000
50000
Main Channel Distance (ft)
1 in Horiz. = 2000 ft 1 in Vert. = 20 ft

TABLE 6 – BIG FOSSIL CREEK PROFILES COMPARISON WITH FIS PROFILES

Table 6 - Big Fossil Creek Study

Profile Comparisons with FIS

Big Fossil Creek

Location Description	Study	10-Year Elevation	50-Year Elevation	100-Year Elevation	500-Year Elevation
At Highway 121					
Down-Stream	FEMA FIS	502.8	505.0	506.1	508.1
Down-Stream 10206	Planning Study	501.8	505.0	506.4	508.4
Difference		**-1.0**	**0.0**	**0.3**	**0.3**
Up-Stream	FEMA FIS	502.9	505.2	506.3	508.3
Up-Stream 10442	Planning Study	502.1	505.6	507.0	509.1
Difference		**-0.8**	**0.4**	**0.7**	**0.8**
At Belnap Street/Highway 26					
Down-Stream	FEMA FIS	506.2	509.2	510.3	512.3
Down-Stream 16542	Planning Study	504.8	508.8	510.2	512.4
Difference		**-1.4**	**-0.4**	**-0.1**	**0.1**
Up-Stream	FEMA FIS	506.9	510.7	511.4	517.2
Up-Stream 16880	Planning Study	508.2	513.5	515.3	519.7
Difference		**1.3**	**2.8**	**3.9**	**2.5**
Onyx Drive South					
Up-Stream	FEMA FIS	517.6	519.7	520.4	522.1
Up-Stream 19854	Planning Study	516.0	519.9	520.6	522.9
Difference		**-1.6**	**0.2**	**0.2**	**0.8**
Glenview Drive					
Down-Stream	FEMA FIS	530.9	532.3	532.9	533.9
Down-Stream 27553	Planning Study	530.8	532.7	533.2	534.2
Difference		**-0.1**	**0.4**	**0.3**	**0.3**
Up-Stream	FEMA FIS	532.2	533.3	534.0	535.0
Up-Stream 27784	Planning Study	531.4	533.7	534.4	536.6
Difference		**-0.8**	**0.4**	**0.4**	**1.6**
At Rail Road (approx. 04. miles D/S of N. Loop 820)					
Down-Stream	FEMA FIS	536.6	538.4	539.1	540.3
Down-Stream 30333	Planning Study	537.4	540.8	542.2	544.0
Difference		**0.8**	**2.4**	**3.1**	**3.7**
Up-Stream	FEMA FIS	541.6	545.9	547.8	551.4
Up-Stream 30433	Planning Study	539.3	545.4	547.3	550.7
Difference		**-2.3**	**-0.5**	**-0.5**	**-0.7**
At North Loop 820					
Down-Stream	FEMA FIS	543.0	546.8	548.6	551.9
Down-Stream 32430	Planning Study	542.3	546.6	548.3	551.6
Difference		**-0.7**	**-0.2**	**-0.3**	**-0.3**
Up-Stream	FEMA FIS	544.9	548.9	550.7	554.1
Up-Stream 32988	Planning Study	544.6	548.9	551.1	555.7
Difference		**-0.3**	**0.0**	**0.4**	**1.6**
Big Fossil Creek (continued)					
Location Description	**Study**	**10-Year Elevation**	**50-Year Elevation**	**100-Year Elevation**	**500-Year Elevation**

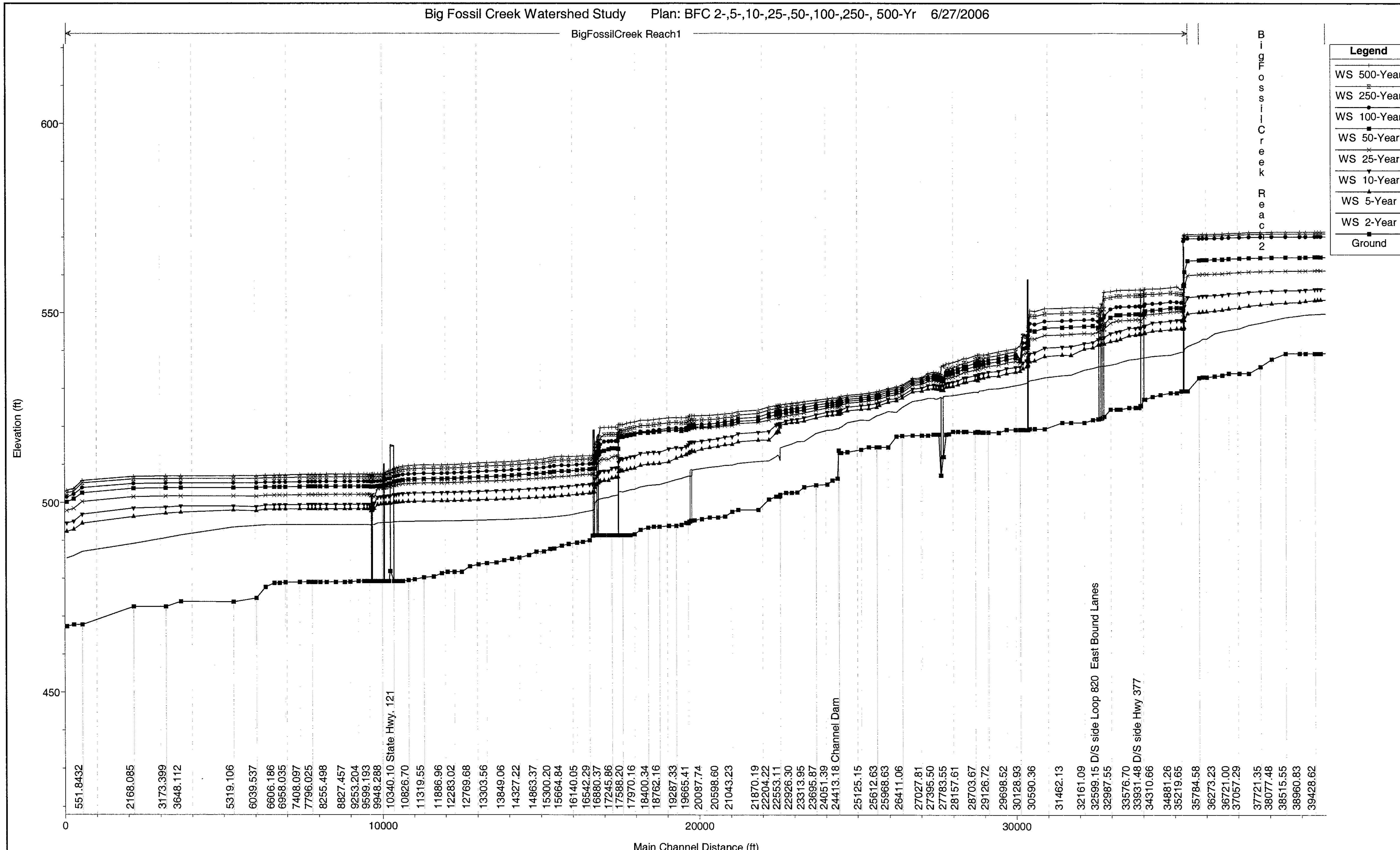
At Rail Road (approx. 1250' U/S of Highway 377)					
Down-Stream	**FEMA FIS**	548.1	551.6	552.7	555.1
Down-Stream 35220	**Planning Study**	548.1	551.4	552.8	556.2
Difference		**0.0**	**-0.2**	**0.1**	**1.1**
Up-Stream	**FEMA FIS**	555.5	562.4	565.1	570.4
Up-Stream 35327	**Planning Study**	551.9	561.0	569.7	570.8
Difference		**-3.6**	**-1.4**	**4.6**	**0.4**
At Haltom Road					
Down-Stream	**FEMA FIS**	559.2	564.1	566.6	571.2
Down-Stream 40795	**Planning Study**	557.2	565.1	570.3	571.6
Difference		**-2.0**	**1.0**	**3.7**	**0.4**
Up-Stream	**FEMA FIS**	560.5	566.4	569.1	572.1
Up-Stream 41090	**Planning Study**	559.1	567.1	571.7	573.0
Difference		**-1.4**	**0.7**	**2.6**	**0.9**
At North Beach Street					
Down-Stream	**FEMA FIS**	574.8	576.4	577.1	578.2
Down-Stream 46186	**Planning Study**	573.5	576.0	577.0	579.0
Difference		**-1.3**	**-0.4**	**-0.1**	**0.8**
Up-Stream	**FEMA FIS**	575.1	576.9	578.0	580.2
Up-Stream 46351	**Planning Study**	573.9	576.8	578.0	580.2
Difference		**-1.2**	**-0.1**	**0.0**	**0.0**
At Western Center Boulevard					
Down-Stream	**FEMA FIS**	601.1	603.0	603.8	605.3
Down-Stream 54910	**Planning Study**	602.0	603.8	604.5	605.7
Difference		**0.9**	**0.8**	**0.7**	**0.4**
Up-Stream	**FEMA FIS**	601.2	603.1	603.9	605.4
Up-Stream 55094	**Planning Study**	602.1	604.1	604.9	606.3
Difference		**0.9**	**1.0**	**1.0**	**0.9**
At Interstate Highway - 35W					
Down-Stream	**FEMA FIS**	601.3	603.2	604.1	605.5
Down-Stream 54910	**Planning Study**	603.9	607.2	608.2	609.9
Difference		**2.6**	**4.0**	**4.1**	**4.4**
Up-Stream	**FEMA FIS**	604.8	607.7	609.0	612.7
Up-Stream 55094	**Planning Study**	606.9	611.3	612.6	614.7
Difference		**2.1**	**3.6**	**3.6**	**2.0**
At approx. FIS Sec. AC	**FEMA FIS**	632.1	633.5	634.0	634.9
64004	**Planning Study**	632.8	634.0	634.4	635.0
Difference		**0.7**	**0.5**	**0.4**	**0.1**
At Blue Mound Road					
Down-Stream	**FEMA FIS**	667.1	668.3	669.0	670.0
Down-Stream 72466	**Planning Study**	666.3	667.7	668.1	668.7
Difference		**-0.8**	**-0.6**	**-0.9**	**-1.3**
Up-Stream	**FEMA FIS**	669.3	670.1	670.4	671.1
Up-Stream 72620	**Planning Study**	667.4	668.8	669.2	669.6
Difference		**-1.9**	**-1.3**	**-1.2**	**-1.5**
Whites Branch					
Location Description	**Study**	**10-Year Elevation**	**50-Year Elevation**	**100-Year Elevation**	**500-Year Elevation**

At Watauga Road					
Down-Stream	**FEMA FIS**	575.0	576.4	577.0	578.1
Down-Stream 10068	**Planning Study**	574.6	576.3	576.9	577.9
Difference		**-0.4**	**-0.1**	**-0.1**	**-0.2**
Up-Stream	**FEMA FIS**	576.6	577.0	577.7	578.7
Up-Stream 10248	**Planning Study**	574.6	576.6	577.4	579.0
Difference		**-2.0**	**-0.4**	**-0.3**	**0.3**
At Basswood Boulevard					
Down-Stream	**FEMA FIS**	598.7	600.0	600.4	601.2
Down-Stream 16788	**Planning Study**	599.3	600.5	601.0	601.8
Difference		**0.6**	**0.5**	**0.6**	**0.6**
Up-Stream	**FEMA FIS**	599.1	600.9	601.4	602.7
Up-Stream 17095	**Planning Study**	600.4	602.2	602.9	604.3
Difference		**1.3**	**1.3**	**1.5**	**1.6**
At North Beach Street					
Down-Stream	**FEMA FIS**	639.3	640.3	640.6	641.2
Down-Stream 29377	**Planning Study**	637.9	638.7	638.9	639.4
Difference		**-1.4**	**-1.6**	**-1.7**	**-1.8**
Up-Stream	**FEMA FIS**	640.0	640.8	641.2	641.8
Up-Stream 29707	**Planning Study**	640.3	642.1	642.5	643.0
Difference		**0.3**	**1.3**	**1.3**	**1.2**
Approx at FIS Sec. P	**FEMA FIS**	664.5	665.1	665.3	665.7
35481	**Planning Study**	667.3	668.1	668.4	668.9
Difference		**2.8**	**3.0**	**3.1**	**3.2**

APPENDIX B

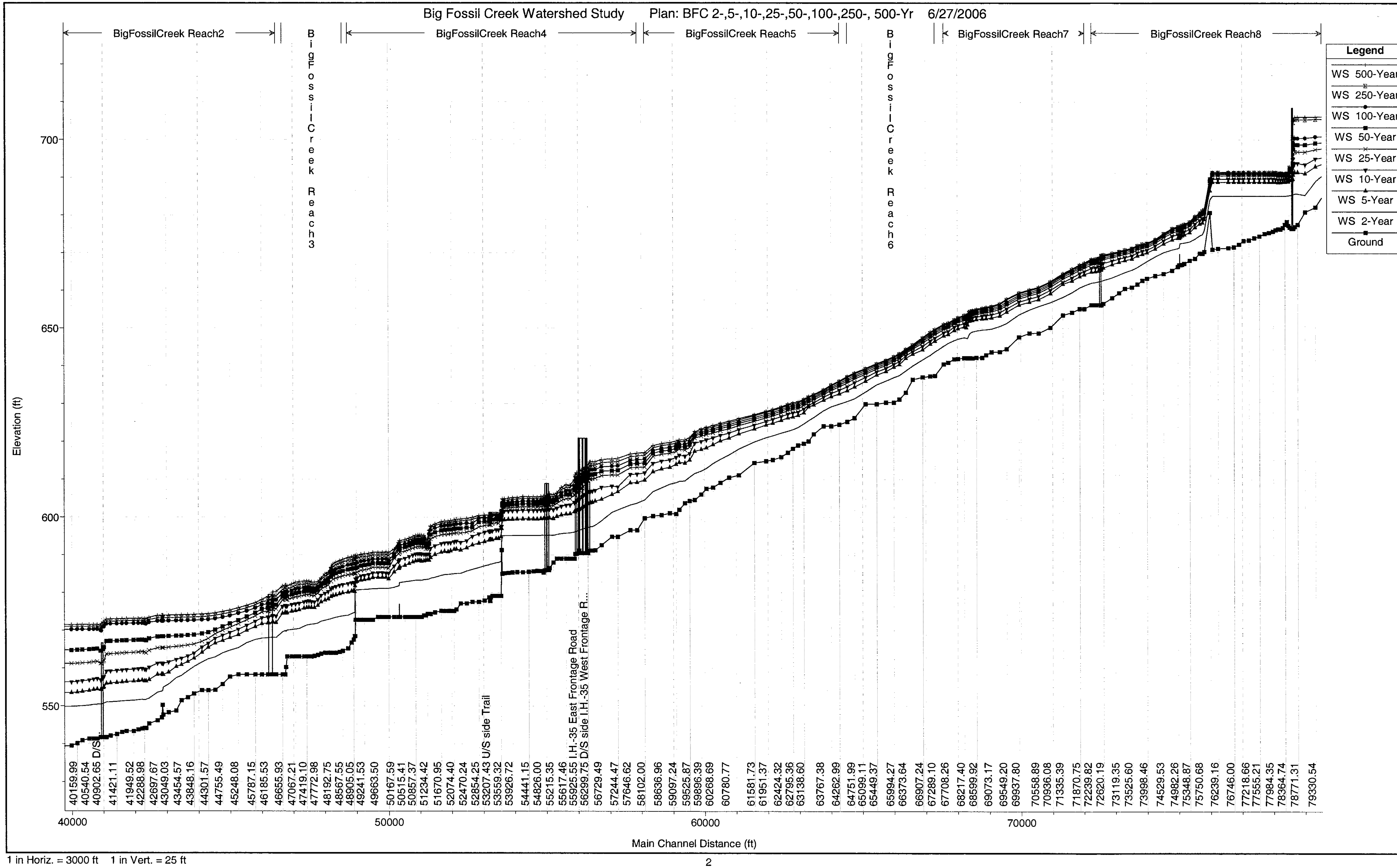
Big Fossil Creek Water Surface Profile Plots

13 July 2006

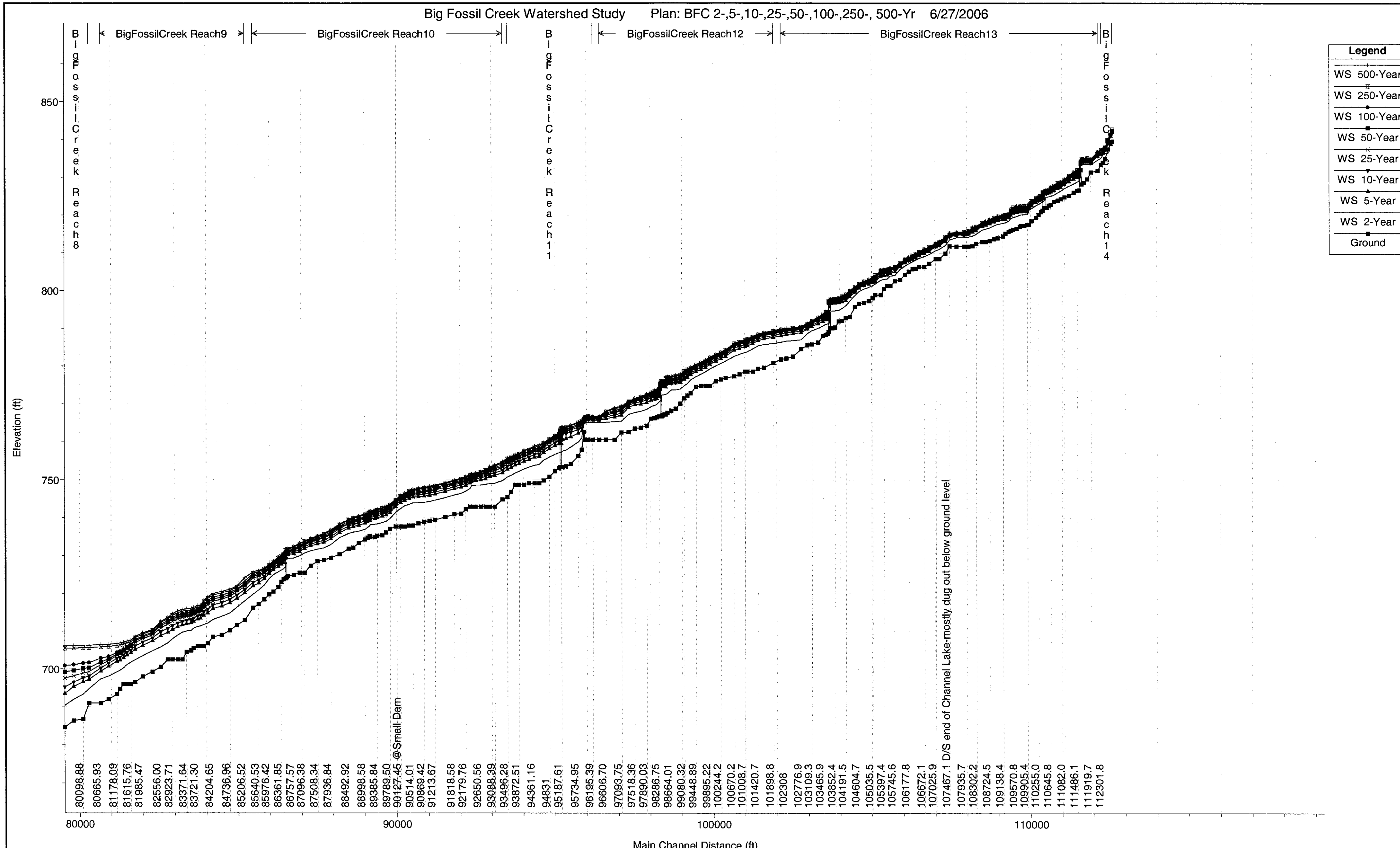


1 in Horiz. = 3000 ft 1 in Vert. = 25 ft

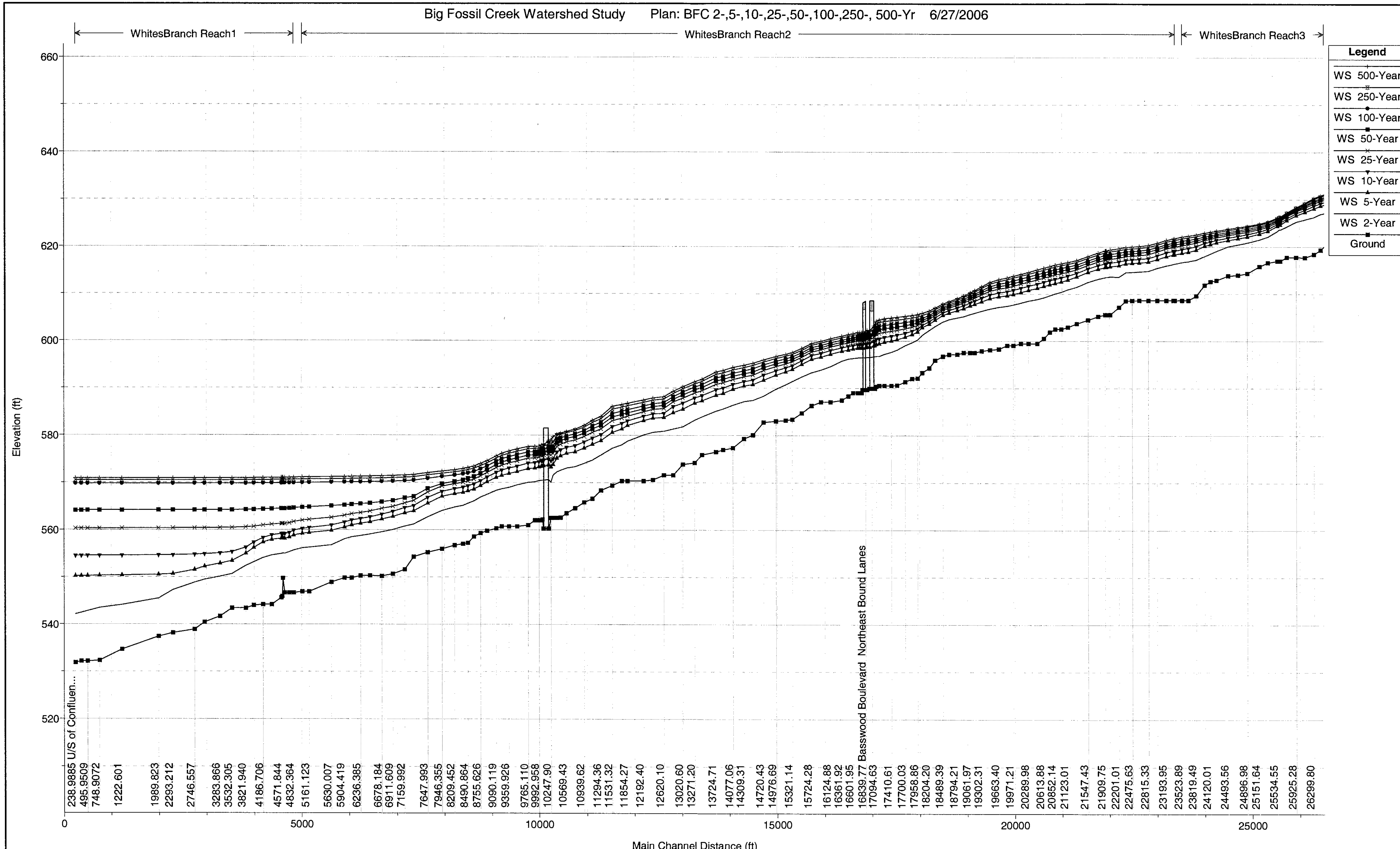
1



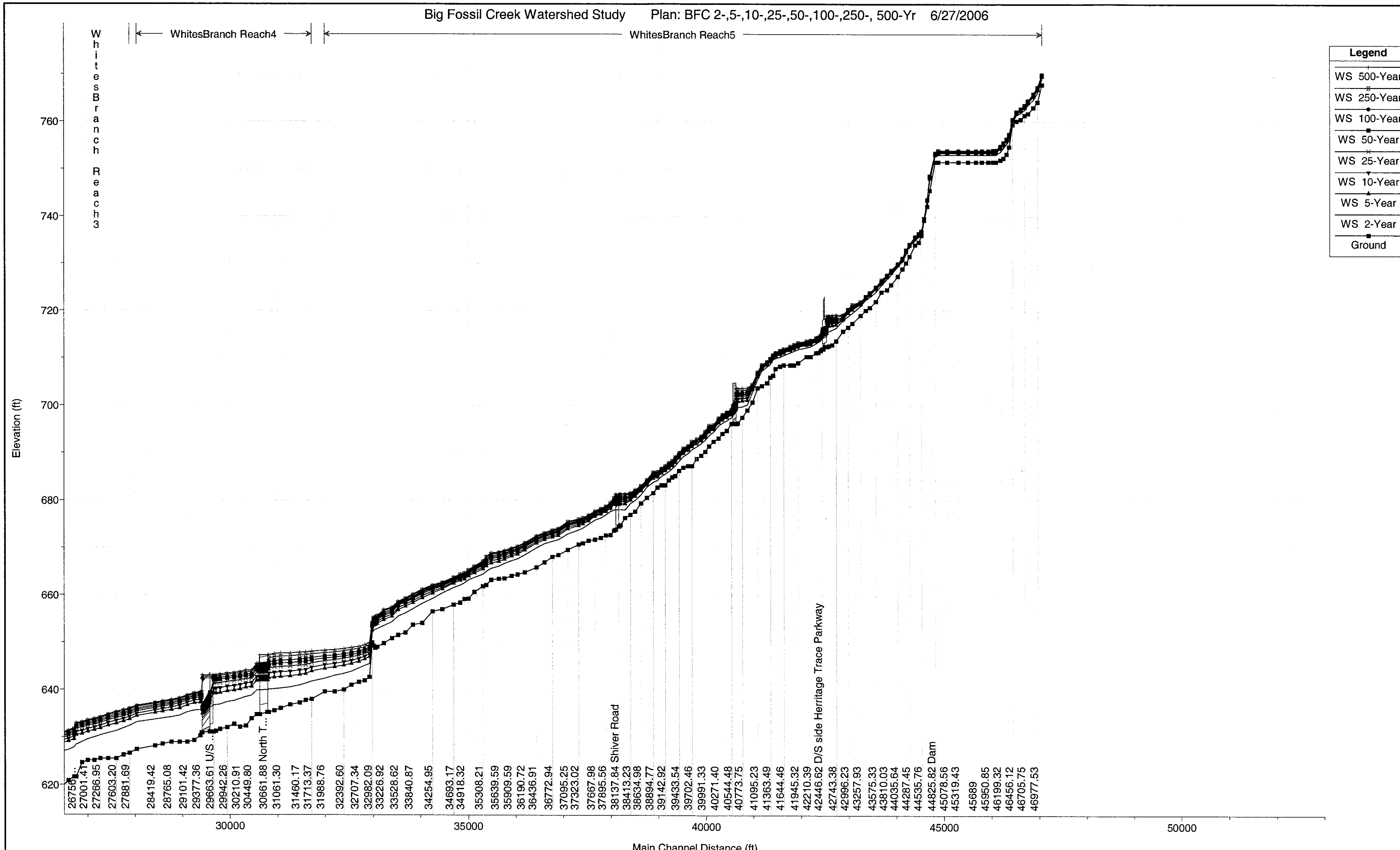
Big Fossil Creek Watershed Study Plan: BFC 2-,5-,10-,25-,50-,100-,250-, 500-Yr 6/27/2006
BigFossilCreek Reach2
BigFossilCreek Reach3
BigFossilCreek Reach4
BigFossilCreek Reach5
BigFossilCreek Reach6
BigFossilCreek Reach7
BigFossilCreek Reach8
Legend
WS 500-Year
WS 250-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 5-Year
WS 2-Year
Ground
Elevation (ft)
700
650
600
550
40159.99
40540.54
40902.65 D/S
41421.11
41949.52
42288.98
42697.67
43049.03
43454.57
43848.16
44301.57
44755.49
45248.08
45787.15
46185.53
46655.93
47067.21
47419.10
47772.98
48192.75
48567.55
48905.05
49241.53
49663.50
50167.59
50515.41
50857.37
51234.42
51670.95
52074.40
52470.24
52854.25
53207.43 U/S side Trail
53559.32
53926.72
54441.15
54826.00
55215.35
55617.46
55925.55 I.H.-35 East Frontage Road
56299.75 D/S side I.H.-35 West Frontage R...
56729.49
57244.47
57646.62
58102.00
58636.96
59097.24
59525.87
59896.39
60268.69
60780.77
61581.73
61951.37
62424.32
62795.36
63138.60
63767.38
64262.99
64751.99
65099.11
65449.37
65994.27
66373.64
66907.24
67289.10
67708.26
68217.40
68599.92
69073.17
69549.20
69937.80
70558.89
70936.08
71335.39
71870.75
72239.82
72620.19
73119.35
73525.60
73998.46
74529.53
74982.26
75348.87
75750.68
76239.16
76746.00
77218.66
77555.21
77984.35
78364.74
78771.31
79330.54
40000
50000
60000
70000
Main Channel Distance (ft)
1 in Horiz. = 3000 ft 1 in Vert. = 25 ft



1 in Horiz. = 3000 ft 1 in Vert. = 25 ft



1 in Horiz. = 2000 ft 1 in Vert. = 20 ft



1 in Horiz. = 2000 ft   1 in Vert. = 20 ft

APPENDIX C

Biological Surveys of Birds in the Big Fossil Creek Corridor

Birds in Big Fossil Creek Corridor
Between Beach Street and HWY 377
Lasted updated – August 14, 2002

Current Count: 67

Common Name	Scientific Name
Cardinal	*Cardinalis cardinalis*
Blue Jay	*Cyanocitta cristata*
Northern Mockingbird	*Mimus polyglottos*
American Robin	*Turdus migratorius*
Swainson's Thrush	*Catharus ustulatus*
Brown Thrasher	*Toxostoma rufum*
Loggerhead Shrike	*Lanius ludovicianus*
Western Kingbird	*Tyrannus verticalis*
Scissor-tailed Flycatcher	*Tyrannus Forticatus*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Phoebe	*Sayonnis phoebe*
Chipping Sparrow	*Spizella passerina*
Harris Sparrow	*Zonotrichia querula*
Lark Sparrow	*Chondestes grammacus*
House Sparrow	*Passer domesticus*
European Starling	*Sturnus vulgaris*
Brown-headed Cowbird	*Molothrus ater*
Gadwall	*Anas strepera*
Wood Duck	*Aix sponsa*
Pied-billed Grebe*	*Podilymbus podiceps*
Great Blue Heron	*Ardea herodias*
Little Blue Heron	*Egretta caerulea*
Green Heron	*Butorides virescens*
Black-crowned Night Heron	*Nycticorax nycticorax*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Great Egret	*Casmerodius albus*
Snowy Egret	*Egretta thula*
Cattle Egret	*Bubulcus ibis*
Killdeer	*Charadrius vociferus*
Spotted Sandpiper	*Actitis macularia*
Chimney Swift	*Chaetura pelagica*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Hirundo pyrrhonota*
Mourning Dove	*Zenaida macroura*
White-winged Dove	*Zenaida asiatica*
House Finch	*Carpodacus mexicanus*
American Crow	*Corvus brachyrhynchos*
Common Grackle	*Quiscalus Quiscula*
Great-tailed Grackle	*Quiscalus mexicanus*
Red-Wing Blackbird	*Agelaius phoeniceus*

Common Name	Scientific Name
Bullock's Oriole	*Icterus bullockii*
Belted Kingfisher	*Ceryle alcyon*
Downy Woodpecker	*Picoides pubescens*
Golden-fronted Woodpecker	*Melanerpes aurifrons*
Red-bellied Woodpecker	*Melanerpes carolinus*
Northern Flicker	*Colaptes auratus*
Tufted Titmouse	*Baeolophus bicolor*
Carolina Chickadee	*Poecile carolinensis*
Ruby-crowned Kinglet	*Regulus calendula*
Blue-gray Gnatcatcher	*Polioptila nigriceps*
Black-throated Green Warbler	*Dendroica virens*
Orange-crowned Warbler	*Vermivora celata*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*
Nashville Warbler	*Vermivora ruficapilla*
Common Yellowthroat	*Geothlypis trichas*
American Redstart	*Setophaga ruticilla*
Carolina Wren	*Thryothorus ludovicianus*
Bewick's Wren	*Thryomanes bewickii*
American Kestrel	*Falco sparverius*
Red-tailed Hawk	*Buteo jamaicensis*
Cooper's Hawk	*Accipiter cooperii*
Long-eared Owl	*Asio flammeus*
Cedar Waxwing	*Bombycilla cedrorum*
Dark-eyed Junco	*Junco hyemalis*
White-throated Sparrows	*Zonotrichia albicollis*
Spotted Towhee	*Pipilo maculates*

* Actually seen near Western Center Blvd

Birds in Big Fossil Creek Corridor
Between Beach Street and HWY 377
Lasted updated – February 27, 2003

Current Count: 78

Common Name	Scientific Name
Cardinal	*Cardinalis cardinalis*
Blue Jay	*Cyanocitta cristata*
Northern Mockingbird	*Mimus polyglottos*
American Robin	*Turdus migratorius*
Swainson's Thrush	*Catharus ustulatus*
Hermit Thrush	*Catharus guttatus*
Brown Thrasher	*Toxostoma rufum*
Loggerhead Shrike	*Lanius ludovicianus*
Western Kingbird	*Tyrannus verticalis*
Scissor-tailed Flycatcher	*Tyrannus Forticatus*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Phoebe	*Sayonnis phoebe*
Chipping Sparrow	*Spizella passerina*
Harris Sparrow	*Zonotrichia querula*
Lark Sparrow	*Chondestes grammacus*
House Sparrow	*Passer domesticus*
White-throated Sparrow	*Zonotrichia albicollis*
White-crowned Sparrow	*Zonotrichia leucophrys*
Fox Sparrow	*Passerella iliaca*
Song Sparrow	*Melospiza melodia*
European Starling	*Sturnus vulgaris*
Brown-headed Cowbird	*Molothrus ater*
Ring-billed Gull***	*Larus delawarensis*
Gadwall	*Anas strepera*
Wood Duck	*Aix sponsa*
Pied-billed Grebe*	*Podilymbus podiceps*
Great Blue Heron	*Ardea herodias*
Little Blue Heron	*Egretta caerulea*
Green Heron	*Butorides virescens*
Black-crowned Night Heron	*Nycticorax nycticorax*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Great Egret	*Casmerodius albus*
Snowy Egret	*Egretta thula*
Cattle Egret	*Bubulcus ibis*
Killdeer	*Charadrius vociferus*
Spotted Sandpiper	*Actitis macularia*
Greater Yellowlegs	*Tringa melanoleuca*
Chimney Swift	*Chaetura pelagica*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Hirundo pyrrhonota*

Common Name	Scientific Name
Purple Martin	*Progne subis*
Mourning Dove	*Zenaida macroura*
White-winged Dove**	*Zenaida asiatica*
House Finch	*Carpodacus mexicanus*
American Goldfinch	*Carduelis tristis*
American Crow	*Corvus brachyrhynchos*
Common Grackle	*Quiscalus Quiscula*
Great-tailed Grackle	*Quiscalus mexicanus*
Red-Wing Blackbird	*Agelaius phoeniceus*
Bullock's Oriole	*Icterus bullockii*
Belted Kingfisher	*Ceryle alcyon*
Downy Woodpecker	*Picoides pubescens*
Golden-fronted Woodpecker	*Melanerpes aurifrons*
Red-bellied Woodpecker	*Melanerpes carolinus*
Northern Flicker	*Colaptes auratus*
Brown Creeper	*Certhia americana*
Tufted Titmouse	*Baeolophus bicolor*
Carolina Chickadee	*Poecile carolinensis*
Ruby-crowned Kinglet	*Regulus calendula*
Golden-crowned Kinglet	*Regulus satrapa*
Blue-gray Gnatcatcher	*Polioptila nigriceps*
Black-throated Green Warbler	*Dendroica virens*
Orange-crowned Warbler	*Vermivora celata*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*
Nashville Warbler	*Vermivora ruficapilla*
Common Yellowthroat	*Geothlypis trichas*
American Redstart	*Setophaga ruticilla*
Carolina Wren	*Thryothorus ludovicianus*
Bewick's Wren	*Thryomanes bewickii*
American Kestrel	*Falco sparverius*
Red-tailed Hawk	*Buteo jamaicensis*
Cooper's Hawk	*Accipiter cooperii*
Long-eared Owl	*Asio flammeus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Cedar Waxwing	*Bombycilla cedrorum*
Dark-eyed Junco	*Junco hyemalis*
Spotted Towhee	*Pipilo maculates*

* Actually seen near Western Center Blvd in area immediately just outside of the area identified above (west of Beach Street).

** Actually seen near Western Center Blvd and White's Branch (tributary to Big Fossil Creek)

*** Creek flyover

Birds in Big Fossil Creek Corridor
Between Beach Street and HWY 377
Lasted updated – March 24, 2003

Current Count: 86

Common Name	Scientific Name
Cardinal	*Cardinalis cardinalis*
Blue Jay	*Cyanocitta cristata*
Northern Mockingbird	*Mimus polyglottos*
American Robin	*Turdus migratorius*
Swainson's Thrush	*Catharus ustulatus*
Hermit Thrush	*Catharus guttatus*
Brown Thrasher	*Toxostoma rufum*
Loggerhead Shrike	*Lanius ludovicianus*
Western Kingbird	*Tyrannus verticalis*
Scissor-tailed Flycatcher	*Tyrannus Forticatus*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Phoebe	*Sayonnis phoebe*
Chipping Sparrow	*Spizella passerina*
Harris Sparrow	*Zonotrichia querula*
Lark Sparrow	*Chondestes grammacus*
House Sparrow	*Passer domesticus*
White-throated Sparrow	*Zonotrichia albicollis*
White-crowned Sparrow	*Zonotrichia leucophrys*
Fox Sparrow	*Passerella iliaca*
Field Sparrow	*Spizella pusilla*
Song Sparrow	*Melospiza melodia*
European Starling	*Sturnus vulgaris*
Brown-headed Cowbird	*Molothrus ater*
Ring-billed Gull***	*Larus delawarensis*
Gadwall****	*Anas strepera*
Ring-necked Duck****	*Aythya collaris*
Greater Scaup****	*Aythya marila*
American Wigeon ****	*Anus americana*
Mallard****	*Anas platyrhynchos*
Northern Shoveler ****	*Anas clypeata*
Ruddy Duck ****	*Oxyura jamaicensis*
American Coot ***/****	*Fulica Americana*
Wood Duck	*Aix sponsa*
Pied-billed Grebe*/***/****	*Podilymbus podiceps*
Great Blue Heron	*Ardea herodias*
Little Blue Heron	*Egretta caerulea*
Green Heron	*Butorides virescens*
Black-crowned Night Heron	*Nycticorax nycticorax*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Great Egret	*Casmerodius albus*

Common Name	Scientific Name
Snowy Egret	*Egretta thula*
Cattle Egret	*Bubulcus ibis*
Killdeer	*Charadrius vociferus*
Spotted Sandpiper	*Actitis macularia*
Greater Yellowlegs	*Tringa melanoleuca*
Chimney Swift	*Chaetura pelagica*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Hirundo pyrrhonota*
Purple Martin	*Progne subis*
Mourning Dove	*Zenaida macroura*
White-winged Dove**	*Zenaida asiatica*
House Finch	*Carpodacus mexicanus*
American Goldfinch	*Carduelis tristis*
American Crow	*Corvus brachyrhynchos*
Common Grackle	*Quiscalus Quiscula*
Great-tailed Grackle	*Quiscalus mexicanus*
Red-Wing Blackbird	*Agelaius phoeniceus*
Bullock's Oriole	*Icterus bullockii*
Belted Kingfisher	*Ceryle alcyon*
Downy Woodpecker	*Picoides pubescens*
Golden-fronted Woodpecker	*Melanerpes aurifrons*
Red-bellied Woodpecker	*Melanerpes carolinus*
Northern Flicker	*Colaptes auratus*
Brown Creeper	*Certhia americana*
Tufted Titmouse	*Baeolophus bicolor*
Carolina Chickadee	*Poecile carolinensis*
Ruby-crowned Kinglet	*Regulus calendula*
Golden-crowned Kinglet	*Regulus satrapa*
Blue-gray Gnatcatcher	*Polioptila nigriceps*
Black-throated Green Warbler	*Dendroica virens*
Orange-crowned Warbler	*Vermivora celata*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*
Nashville Warbler	*Vermivora ruficapilla*
Common Yellowthroat	*Geothlypis trichas*
American Redstart	*Setophaga ruticilla*
Carolina Wren	*Thryothorus ludovicianus*
Bewick's Wren	*Thryomanes bewickii*
American Kestrel	*Falco sparverius*
Red-tailed Hawk	*Buteo jamaicensis*
Cooper's Hawk	*Accipiter cooperii*
Long-eared Owl	*Asio flammeus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Cedar Waxwing	*Bombycilla cedrorum*

Common Name	Scientific Name
Dark-eyed Junco	*Junco hyemalis*
Spotted Towhee	*Pipilo maculates*

* Pond near Western Center Blvd bridge in area immediately east of IH 35 W access road.
** Western Center Blvd and White's Branch (tributary to Big Fossil Creek)
*** Riverine pond in Capp Smith Park, Watauga, east of Denton Hwy
**** Spring Lake Pond south of north Loop 820 and west of Denton Hwy

Birds in Big Fossil Creek Corridor
Lasted updated – April 1, 2003

Current Count: 90

Common Name	Scientific Name
Cardinal	*Cardinalis cardinalis*
Blue Jay	*Cyanocitta cristata*
Northern Mockingbird	*Mimus polyglottos*
American Robin	*Turdus migratorius*
Swainson's Thrush	*Catharus ustulatus*
Hermit Thrush	*Catharus guttatus*
Brown Thrasher	*Toxostoma rufum*
Loggerhead Shrike	*Lanius ludovicianus*
Western Kingbird	*Tyrannus verticalis*
Scissor-tailed Flycatcher	*Tyrannus Forticatus*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Phoebe	*Sayonnis phoebe*
Chipping Sparrow	*Spizella passerina*
Harris Sparrow	*Zonotrichia querula*
Lark Sparrow	*Chondestes grammacus*
House Sparrow	*Passer domesticus*
White-throated Sparrow	*Zonotrichia albicollis*
White-crowned Sparrow	*Zonotrichia leucophrys*
Fox Sparrow	*Passerella iliaca*
Field Sparrow	*Spizella pusilla*
Song Sparrow	*Melospiza melodia*
European Starling	*Sturnus vulgaris*
Brown-headed Cowbird	*Molothrus ater*
Ring-billed Gull***	*Larus delawarensis*
Double-crested Cormorant ***/****	*Phalacrocorax auritus*
Gadwall****	*Anas strepera*
Ring-necked Duck****	*Aythya collaris*
Greater Scaup****	*Aythya marila*
American Wigeon ****	*Anus americana*
Mallard ***/****	*Anas platyrhynchos*
Blue-winged Teal ****	*Anas discors*
Northern Shoveler ****	*Anas clypeata*
Ruddy Duck ****	*Oxyura jamaicensis*
American Coot ***/****	*Fulica Americana*
Wood Duck	*Aix sponsa*
Muscovy Duck ***/****	*Cairina moschata*
Chinese Goose ***	*Anser cygnoides*
Pied-billed Grebe*/***/****	*Podilymbus podiceps*
Great Blue Heron	*Ardea herodias*
Little Blue Heron	*Egretta caerulea*
Green Heron	*Butorides virescens*

Common Name	Scientific Name
Black-crowned Night Heron	*Nycticorax nycticorax*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Great Egret	*Casmerodius albus*
Snowy Egret	*Egretta thula*
Cattle Egret	*Bubulcus ibis*
Killdeer	*Charadrius vociferus*
Spotted Sandpiper	*Actitis macularia*
Greater Yellowlegs	*Tringa melanoleuca*
Chimney Swift	*Chaetura pelagica*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Hirundo pyrrhonota*
Purple Martin	*Progne subis*
Mourning Dove	*Zenaida macroura*
White-winged Dove**	*Zenaida asiatica*
House Finch	*Carpodacus mexicanus*
American Goldfinch	*Carduelis tristis*
American Crow	*Corvus brachyrhynchos*
Common Grackle	*Quiscalus Quiscula*
Great-tailed Grackle	*Quiscalus mexicanus*
Red-Wing Blackbird	*Agelaius phoeniceus*
Bullock's Oriole	*Icterus bullockii*
Belted Kingfisher	*Ceryle alcyon*
Downy Woodpecker	*Picoides pubescens*
Golden-fronted Woodpecker	*Melanerpes aurifrons*
Red-bellied Woodpecker	*Melanerpes carolinus*
Northern Flicker	*Colaptes auratus*
Brown Creeper	*Certhia americana*
Tufted Titmouse	*Baeolophus bicolor*
Carolina Chickadee	*Poecile carolinensis*
Ruby-crowned Kinglet	*Regulus calendula*
Golden-crowned Kinglet	*Regulus satrapa*
Blue-gray Gnatcatcher	*Polioptila nigriceps*
Black-throated Green Warbler	*Dendroica virens*
Orange-crowned Warbler	*Vermivora celata*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*
Nashville Warbler	*Vermivora ruficapilla*
Common Yellowthroat	*Geothlypis trichas*
American Redstart	*Setophaga ruticilla*
Carolina Wren	*Thryothorus ludovicianus*
Bewick's Wren	*Thryomanes bewickii*
American Kestrel	*Falco sparverius*
Red-tailed Hawk	*Buteo jamaicensis*
Cooper's Hawk	*Accipiter cooperii*

Common Name	Scientific Name
Long-eared Owl	*Asio flammeus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Cedar Waxwing	*Bombycilla cedrorum*
Dark-eyed Junco	*Junco hyemalis*
Spotted Towhee	*Pipilo maculates*

* Pond near Western Center Blvd bridge in area immediately east of IH 35 W access road.
** Western Center Blvd and White's Branch (tributary to Big Fossil Creek)
*** Riverine pond in Capp Smith Park, Watauga, east of Denton Hwy & South of Starnes Rd
**** Spring Lake Pond south of North Loop 820 and west of Denton Hwy

APPENDIX D

Big Fossil Creek Existing Cultural Conditions

Cultural Resources

Any proposed undertaking under the responsibility of the US Army Corps of Engineers must follow and account for the responsibilities under Federal and State Cultural Resources laws and regulations, Executive Orders, and US Army Corps of Engineers Regulations. All applicable legislative and regulatory mandates are to be considered in the event that any study provides a basis for a Federal undertaking. Any projects will need to consider the legal responsibilities and obligations of the US Army Corps of Engineers with respect to the National Historic Preservation Act (NHPA) of 1966 (PL 89-665 et seq.), National Environmental Policy Act (NEPA) of 1969 (PL 90-190), Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 (PL 101-601), Executive Order 13007 (Accommodation of Sacred Sites- 24 May 1996), Government-to-Government Relations with Native American Indian Tribal Governments (Presidential Memorandum of 29 April 1994), and Engineer Regulation (ER) 1105-2-100 (Guidance for Conducting Civil Works Planning Studies).

The scale of the relevant study area and the level of effort to collect and prepare detailed information restricted the data collection to that of currently known and recorded cultural resources and a reconnaissance of the drainage area conducted by an archaeologist. Project planning has not progressed to the level of a clear definition of a specific project, therefore impact areas and the nature of those impacts could not be specifically addressed. The proposed study area is extensive and will require definitive project boundaries and descriptions before potential impacts to cultural resources can be assessed and appropriate mandated considerations of impacts described and evaluated.

The potential impacts to cultural resources to be considered include a variety of solutions that could include structural and non-structural flood control and relief systems, easements, pipelines, borrow and disposal areas, mitigation areas, creation of wetland areas, reforestation, and revegetation, among other possibilities. Any of these undertakings would generate a requirement to consider possible impacts to a potentially broad range of cultural resources in areas selected for project locations. These considerations include the completion of archaeological and architectural surveys of project-specific parcels for properties eligible and potentially eligible to the National Register of Historic Places (NRHP) in consultation with the Texas State Historic Preservation Officer (SHPO). Additional consultations with other interested parties and Native American Indian tribal groups is also necessary regarding properties of traditional cultural significance.

Despite best efforts to locate and evaluate all the cultural resources within any given project area, unanticipated subsurface deposits are possible at any ground-breaking undertaking. If previously unknown cultural materials are exposed by construction activities related to the undertaking, work will stop in the immediate vicinity, the resource will be protected, and the SHPO will be notified within 24 hours of discovery. If, in consultation with the SHPO, it is determined that the resource is significant, and cannot be avoided by construction, then a mitigation plan will be prepared in consultation with the SHPO and implemented before construction is allowed to continue in that vicinity.

If unmarked human burials are discovered during construction, work will stop in the immediate vicinity, the remains will be protected, and the local law enforcement agency and SHPO will be notified within 24 hours. The location of the unmarked human burial or burials will be documented and the provisions of the Native American Graves Protection and Repatriation Act will be implemented where applicable. Discovery of human remains will be mitigated, in consultation with SHPO and Federally recognized Native American Tribes if appropriate, before construction will be allowed to continue in the vicinity of the discovery.

Archaeological Resources

A check of state archaeological site records kept at the Texas Archeological Sites Atlas (TASA) online database indicated no recorded sites within the immediate Big Fossil Creek drainage study area. The lack of recorded sites may be due to the dearth of cultural resources surveys that have been conducted in the region. Only two surveys show up in the database, one along Interstate Highway (IH) 35W, north of the interchange with IW 820 and another extending north along Texas state highway 156. Both of these surveys were conducted by the Federal Highway Administration.

The Fort Worth District contracted Geo-Marine, Inc. to investigate the potential for cultural resources within the Big Fossil Creek drainage area. The archaeological field reconnaissance carried out between November 21 and December 5, revealed that the project area has been subject to severe impact and alteration through modern development and construction. Observed creek cut banks showed intact stratigraphic deposits in areas where the creek bank or course had not been altered by construction or channelization. The results of research, field observation, and GIS models were analyzed to create a predictive model for site potential within the Big Fossil Creek drainage (Parrish and Burson 2002).

As project alternatives are developed and evaluated, cultural resources surveys may be needed within the specific project area(s) of potential effect. For example, in the southeastern portion of the drainage, near the confluence of Big Fossil Creek and the West Fork of the Trinity River, backhoe trenching in flood plain areas along with intensive cut bank survey is recommended to locate deeply buried deposits, whereas, no archaeological survey is necessary west of IH 35, in the upland prairie region of the drainage. In areas that cannot be surveyed prior to construction (where pavement prevents excavation, for example), archaeological monitoring may be required if planned project excavation is deeper than modern disturbances. The full need for or extant of survey will not be known until plan formulation progresses.

Architectural Resources

Preliminary indications are that very few, if any, structures in the study area meet age and/or integrity requirements to qualify for the NRHP based upon association with significant people, events, architectural design or information potential. The bridges also initially appear unremarkable for their design and construction values. Once specific project designs have progressed to the point where an area of potential effect can be determined, a more thorough reconnaissance of the structures within that area will need to be conducted to determine if any standing building, bridges or other structures may be eligible for the NRHP.

Parrish, N. A. and E., A. Burson
2002 *Predictive Model for Archaeological and Historic Site Locations Within the Big Fossil Creek Drainage, Tarrant County, Texas*. Miscellaneous Reports of Investigation Number 250. Geo-Marine, Inc., Plano, Texas.

APPENDIX E

An Assessment of the Biological Integrity of the Big Fossil Creek and Trinity River Basin in Tarrant County, TX

Rec'd 2-24-2003
Dr Jenboe has original

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
WinSystems Center Building
711 Stadium Drive, Suite 252
Arlington, Texas 76011

February 24, 2003

Colonel Gordon M. Wells
District Engineer
U.S. Army Corps of Engineers
(Attn: CESWF-EV-EE)
P.O. Box 17300
Fort Worth, Texas 76102-0300

Dear Colonel Wells:

The enclosed report provides planning assistance on the Big Fossil Creek Watershed Interim Feasibility Study, Tarrant County, Texas. This study was initiated by the Fort Worth District Corps of Engineers to develop solutions for flooding associated with the Big Fossil Creek watershed located in the Cities of Richland Hills, Haltom City, North Richland Hills, Fort Worth, Keller, Watauga, Saginaw, and Haslet; and Tarrant County, Texas. It is part of the Upper Trinity River investigations contained in the *Programmatic Environmental Impact Statement* (PEIS), *Upper Trinity River Basin, Trinity River, Texas* dated June 13, 2000. The study sponsor is the North Central Texas Council of Governments with sub-agreements with Tarrant County and the Cities of Fort Worth, Richland Hills, Haltom City, North Richland Hills, Watauga, Keller, Saginaw, and Haslet. Investigations will concentrate on evaluating the feasibility of channel modifications, construction or modification of levees and flood walls, construction of reservoirs, ecosystem restoration, and the creation of recreational opportunities.

The purpose of our report was to identify and describe existing aquatic resources within the proposed project areas and to recommend preliminary measures for aquatic habitat restoration. This planning assistance is provided, in part, pursuant to the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and is intended to assist in the preparation of your detailed project report (DPR). This information does not represent a final report of the Secretary of the Interior within the meaning of Section 2(b) of the Act. This report was prepared in accordance with the Scope of Work agreed to by our agencies, and it is being provided for equal consideration for fish and wildlife conservation in the planning of this project. Additional planning information will be provided pertaining to the terrestrial habitats within the study area at a later date.

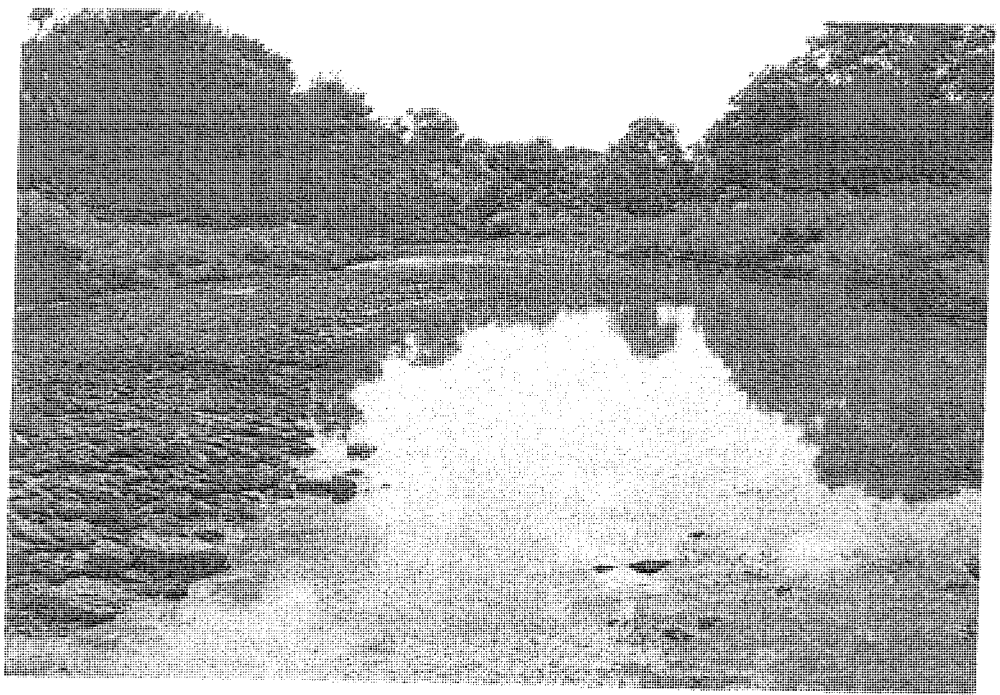
We appreciate the opportunity to participate in the planning of this project. If you have any questions or comments concerning this report, please contact Carol S. Hale of my staff at (817) 277-1100.

Sincerely,

Thomas J. Cloud, Jr.
Field Supervisor

Enclosure

An Assessment of the Biological Integrity of the Big Fossil Creek in the Trinity River Basin in Tarrant County, Texas



Prepared by:
Michael P. Armstrong and Carol S. Hale
Ecological Services Field Office
Arlington, Texas

Reviewed by:
Thomas J. Cloud, Jr.
Field Supervisor

U.S. Fish and Wildlife Service
Region 2
Albuquerque, New Mexico
February 21, 2003

Introduction

Monitoring of physical and chemical characteristics of water is relatively common, but biological monitoring founded on a broadly based concept of biological integrity is rare (Karr and Dudley 1981). This primary dependence on physical and chemical criteria has numerous shortcomings (Thurston et al. 1979; Gosz 1980), and a more valid approach for assessing a system's ecological integrity is to examine properties of the biotic communities that live there (Weber 1981). Movement towards a more comprehensive approach to assessment of water quality was aided by the introduction of an index of biotic integrity (IBI) by Karr (1981). The IBI can be an important tool for assessing the biological integrity of stream resources, and along with information on physical and chemical conditions, should provide a sound basis for management decisions.

The IBI has the potential to aid resource managers, because it is based on attributes of stream fish communities that are relatively easy to measure. As Karr (1981) suggested, fish have numerous advantages as indicator organisms for biological monitoring. These advantages include:

1. Life-history information is extensive for most fish species.
2. Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and include foods of both aquatic and terrestrial origin. Their position at the top of the aquatic food chain in relation to other aquatic organisms also helps to provide an integrative view of the watershed environment.
3. Fish are relatively easy to identify, with most samples being sorted, identified at the sample site, and released after processing.
4. The general public can relate to statements about conditions of the fish community much easier than those about the diatom or invertebrate community.
5. Both acute toxicity (missing taxa) and chronic toxicity (depressed growth and reproductive success) can be evaluated.
6. Fish are typically present, even in the smallest streams and in all but the most polluted waters.
7. Finally, the results of studies using fish can be directly related to the fishable waters mandate of Congress.

A number of disadvantages of monitoring fish can also be cited. These include the selective nature of sampling, fish mobility on diel and seasonal time scales, and manpower needs for field sampling. But these disadvantages are associated with any major taxa.

The U. S. Fish and Wildlife Service (FWS) conducted a fishery survey of the Big Fossil Creek watershed in Tarrant County, Texas to evaluate the existing condition of the aquatic habitat and the potential influences of water quality on fish populations and communities. The FWS's goal for fish sampling in Big Fossil Creek was to collect representative samples of the species present to determine their relative abundances. This assessment had to be completed in a cost-effective manner, while remaining capable of distinguishing the various impacts on the aquatic ecosystem and being scientifically sound. The index of biotic integrity (IBI) utilized statewide, as well as regionally, by the Texas Parks and Wildlife Department (TPWD) were selected as the best means to complete this task (Linam et al. 2002).

Methods

The Big Fossil Creek watershed, which flows through Tarrant County was sampled from July 15 through July18, 2002. The watershed has a drainage basin of approximately 135 square kilometers and empties into the Trinity River just upstream of east Loop 820 near Haltom City, Texas. Sample sites were selected using the following criteria: (1) sites was downstream of the confluences of lower-ranking tributaries; (2) riparian habitat was intact; and (3) convenient access for the sampling crew was available. All available varieties of habitats were sampled in this study, including riffles, runs, and pools. Eight sites were sampled within the watershed. The location of the sample sites are identified in Figure 1. Photographs of the sites are provided in Appendix B to

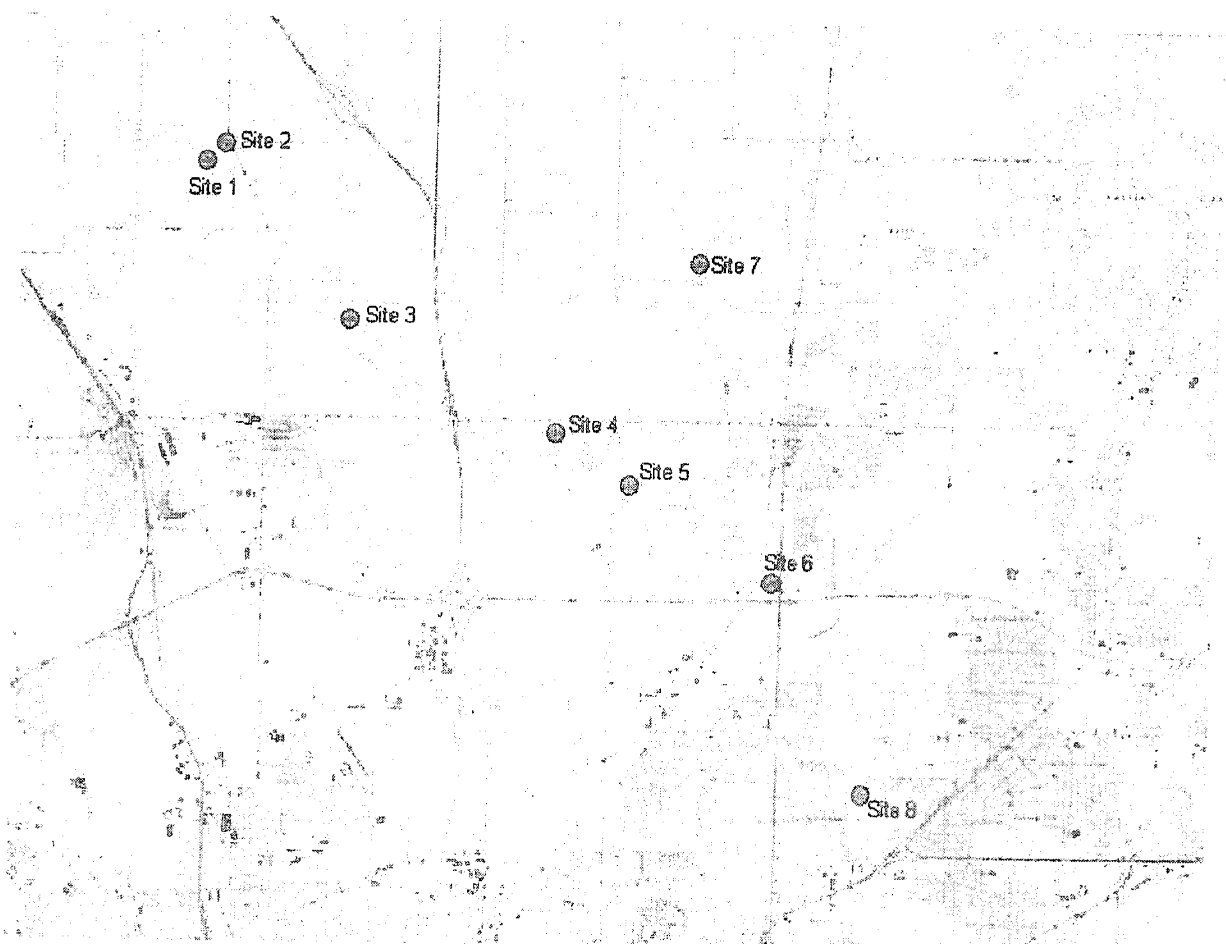


Figure 1. Location of eight IBI sampling sites within the Big Fossil Creek watershed in Tarrant County, Texas.

this report.

The locations of these sites were: Site 1 located on Big Fossil Creek approximately 0.9 km downstream of Walnut Lake; Site 2 located on an unnamed tributary just upstream of Blue Mound Road and its confluence with Big Fossil Creek; Site 3 located on Big Fossil Creek approximately 2.7 km downstream of Site 1; Site 4 located on an unnamed tributary that flows through The Golf Club at Fossil Creek approximately 0.8 km upstream of the confluence with Big Fossil Creek and 4.5 km downstream of Site 3; Site 5 located on Big Fossil Creek within Buffalo Ridge Park approximately 5.6 km downstream of Site 4; Site 6 located on Big Fossil Creek west of U.S. Highway 377 approximately 3.5 km downstream of Site 5 and 0.5 km downstream of the confluence with White's Branch; Site 7 located on White's Branch west of Rushmore at Park Ridge approximately 6 km upstream of the confluence with Big Fossil Creek; and finally, Site 8 located on Big Fossil Creek within Fossil Creek Park approximately 4.3 km downstream of the confluence with White's Branch.

Fish were collected at the sample sites from July 15-18, 2002. Collections were made using a combination of backpack electrofishing and seines. The collector carrying the backpack shocker (Smith-Root type VII Electrofisher) would wade in an upstream direction so that the effects of turbidity caused by disturbed bottom sediment would be eliminated. Two people would follow the shocker with dip nets attempting to net all fish that were stunned, while a fourth person would handle the buckets where the fish were placed. When sampling riffles in strong current, a block seine was set downstream of the persons electrofishing in an attempt to catch additional fish stunned and swept downstream without surfacing. Electrofishing was completed in two riffle and two pool sample runs. The duration of each sampling run was 900 seconds.

Seining was used as a complementary technique to electrofishing in habitats where shocking was not effective. Those habitats included deep pools where wading with a backpack shocker would be difficult, shallow riffles where kick-seining would effectively capture organisms living in and around the substrate, and streams where specific water conductivity was greater than that feasible for effective electrofishing. Several different seines were used depending on habitat conditions. A 30' x 6' x 1/4" mesh straight seine or a 50' x 6' x 3/8" mesh bag seine was used for large deep pools and wide slow-moving channels with minimal obstructions present to cause snagging. A 20' x 4' x 1/8" mesh seine was used in small streams with snags, and for kick seining in small riffles. A 10' x 4' x 1/8" mesh seine was used in shallow, small streams that had several obstructions present. Where possible, an attempt was made to sample at least four riffles and four pools at the site. However, due to the lack of riffle and pool habitat and the large number of obstructions, seine samples varied from 2-10 samples per site. Only successful seine hauls were recorded. Runs where fish could escape the net by out swimming it or when a major snag was encountered were deemed unsuccessful.

Once fish were collected, they were identified to species, enumerated, and released some distance downstream from the sampling area (Lee et al. 1980; Robison and Buchanan 1988; Hubbs et al. 1991; Pflieger 1991; Robins et al. 1991; Etnier and Starnes 1993). Photographs of some of the most common species collected are provided in Appendix C to this report. The utmost care was taken to release fish unharmed. If the identification of a fish collected was questionable, it was preserved in 10% formalin solution and returned to the laboratory for identification and preservation. All fish were examined for external deformities, lesions, or tumors. When an anomaly was found on a fish, it was preserved in 10% formalin solution and returned to the lab for documentation.

The IBI was designed to evaluate the quality or condition of an aquatic resource based on the attributes of the fish assemblage that can be easily derived from a representative sample. The two IBI's applied in this study were initially developed by the Texas Parks and Wildlife Department (TPWD). The statewide IBI has been applied historically in conjunction with water quality, benthic macroinvertebrate, and habitat data to set aquatic life uses in streams. Recently, TPWD conducted a study to regionalize the IBI for Texas' wadeable streams. This study sampled 62 least disturbed reference streams located within 11 of the 12 aquatic ecoregions described for the state. Results of this study displayed that the statewide IBI produced lower overall scores and aquatic life uses. Scores from the statewide IBI demonstrated a geographical trend, declining from east to west, and resulted in no exceptional aquatic life use designations even though the streams were selected through a screening process and were among the least disturbed in a region. These lower IBI values (and aquatic life uses) resulted from using a single index over a large land area comprised of a diversity of land forms, soil types, vegetation, climatic conditions, and zoogeographic factors. Regional criteria consider these natural differences and consequently provide a better representation of the integrity of the fish assemblage. Although the study established that the regional IBI better represents the integrity of the fish assemblage, the TCEQ has requested that both the statewide and regionalized IBI's be included for their regulatory review until the regional IBI can be field verified. We concur with Lyons (1989) that once field verifications are completed the regional IBI's will be used for regulatory and/or resource management decisions, since they delineate geographic areas within which a policy applied to different sites should yield similar results.

The statewide IBI consisted of 12 attributes in three categories: species composition, trophic composition, and health and abundance of fish (Table 1). The regionalized IBI (Subhumid Agricultural Plains) consisted of 11 metrics in the same three categories as the statewide IBI (Table 2). Species composition attributes focus on the overall species richness and richness within major taxonomic groups as well as the occurrences of notably tolerant and intolerant species. Food habits of the fish assemblage, as categorized by trophic composition, are products of the diversity and productivity of the lower trophic levels in the community. The preliminary designation of Texas fishes into trophic and tolerance classifications was designed by Linam and Kleinsasser (1991). Fish abundance and fish health reflect system productivity and habitat stability. A fish sample is assigned one, three, or five points for each attribute by comparison to expectations for a pristine stream of similar size in the same region. Total scores define stream health in four classes ranging from exceptional (pristine) to limited (degraded).

Effective use of the IBI requires a knowledge of the structure and function of regional stream fish communities and of species' tolerances. Species' composition attributes will vary as functions of stream size and region (Fausch et al. 1984). In the statewide IBI, some attributes were adjusted

Table 1. Index of Biotic Integrity Scoring and Evaluation Criteria (TPWD-statewide).

Category	Metric	Scoring		
		5	3	1
Species Richness and Composition	1. Total number of fish species	⋆	⋆	⋆
	2. Total number of darter species	≥3	1-2	0
	3. Total number of sunfish species (excluding bass)	≥2	1	0
	4. Total number of sucker species	≥2	1	0
	5. Total number of intolerant species	≥3	1-2	0
	6. Percentage of individuals as tolerants	<5	5-20	>20
Trophic composition	7. Percentage of individuals as omnivores	<20	20-45	>45
	8. Percentage of individuals as insectivores	>80	>40-80	≤40
	9. Percentage of individuals as piscivores	>5	1-5	<1
Fish abundance and condition	10. Number of individuals in sample	>200	>50-200	≤50
	11. Percentage of individuals as hybrids	0	>0-1	>1
	12. Percentage of individuals with disease or other anomaly	≤2	>2-5	>5

⋆First-second order streams: ≥7(5), 4-6(3), ≤3(1)
Third-fourth order streams: ≥10(5), 5-9(3), ≤4(1)
Fifth-sixth order streams: ≥16(5), 8-15(3), ≤7(1)
Seventh-eighth order streams: ≥22(5), 11-21(3), ≤10(1)

<u>Total Score for Aquatic Life Use Subcategories:</u>

58 - 60 Exceptional
48 - 52 High
40 - 44 Intermediate
≤ 34 Limited

Table 2. Scoring criteria developed to assess stream fish assemblages in the Subhumid Agricultural Plains (Ecoregions 27, 29, and 32).

Category	Metric	Scoring		
		5	3	1
Species Richness and Composition	1. Total number of fish species	See Figure 1		
	2. Number of native cyprinid species	>3	2-3	<2
	3. Number of benthic invertivore species	>1	1	0
	4. Number of sunfish species	>3	2-3	<2
	5. Percentage of individuals as tolerant species (excluding western mosquitofish)	<26	26-50	>50
Trophic composition	6. Percentage of individuals as omnivores	<9	9-16	>16
	7. Percentage of individuals as invertivores	>65	33-65	<33
	8. Percentage of individuals as piscivores	>9	5-9	<5
Fish abundance and condition	9. Number of individuals in sample a. Number of ind./seine haul b. Number of ind./min. electrofishing	 >87 >7.1	 36-87 3.3-7.1	 <36 <3.3
	10. Percentage of individuals as non-native species	<1.4	1.4-2.7	>2.7
	11. Percentage of individuals with disease or other anomaly	<0.6	0.6-1	>1

Total Score for Aquatic Life Use:

≥49	Exceptional
41-48	High
35-40	Intermediate
<35	Limited

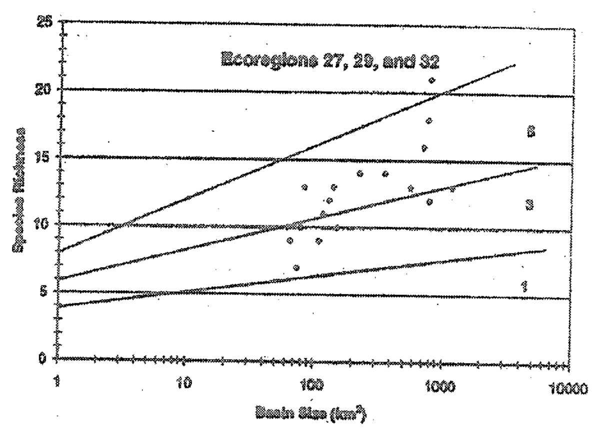


Figure 3. Fish species richness versus drainage basin size in Subhumid Agricultural Plains streams.

by stream order. Stream order adjustments were made following the criterion established by Strahler (1957). A second-order stream is formed where two first-order streams join. When two second-order streams join, a third-order stream is formed and so on. Where a stream of low order enters a higher order stream, but is not a part of the hierarchy of streams used in the classification, the order number of the larger stream is not changed.

General observations of the number of fish species observed but not caught, the surrounding stream and riparian habitat, and the aquatic and terrestrial wildlife were also made for each sample site (Kolbe and Luedke 1993).

Results

A total of 1,607 individuals comprising 9 families and 30 species were represented in the combined samples from seining and electrofishing (Table 3). The highest number of species collected at a sampling site was 22 while the lowest number captured was 7. The average number of fish species captured per site for the study area was 13.63 (n = 8). The family most often represented in this study was the sunfish (Centrarchidae) and minnow (Cyprinidae) family with nine and seven species captured, respectively. Other families collected during this study were the gars (Lepisosteidae), herrings (Clupeidae), suckers (Catostomidae), bullhead catfishes (Ictaluridae), killifishes (Cyprinodontidae), livebearers (Poeciliidae), and the perches (Percidae). The most common species' collected during the sampling efforts were the red shiner (*Cyprinella lutrensis*) and the green sunfish (*Lepomis cyanellus*). Other species collected regularly were the bullhead minnow (*Pimephales vigilax*), yellow bullhead (*Ameiurus natalis*), blackstripe topminnow (*Fundulus notatus*), western mosquitofish (*Gambusia affinis*), bluegill (*Lepomis macrochirus*), Longear sunfish (*Lepomis megalotis*), redear sunfish (*Lepomis microlophus*), and the largemouth bass (*Micropterus salmoides*).

An IBI score, representing the entire fish community, was tabulated for each sample site within the Big Fossil Creek watershed using both the statewide and regionalized IBI's. Results from the eight sites sampled in the Big Fossil Creek watershed are summarized below. Sample sites are discussed beginning with the site farthest upstream and working downstream. Specific data and calculations of both the Statewide and Regional IBI for each site are provided in Appendix A.

Site 1 was given a stream order designation of one. A statewide IBI evaluation score of 36 was calculated for this site, and its aquatic life use class was designated as limited-intermediate. The score was relatively low because no darter, sucker, or intolerant species were present, a high percentage of individuals collected were identified as hybrids, and there was a relatively high percentage of tolerant individuals (~29%) in the sample. Scoring for this site was positively influenced by the relatively large number of species collected, the number of sunfish species collected, low percentage of omnivores collected (10%), the high percentage of piscivores making up the fish community, and the absence of individual fish with disease or other anomalies.

Table 3. Fishes collected from Big Fossil Creek watershed within the Trinity River Basin.

Family	Taxa	Common Name	Tolerance	Trophic Guild
Lepisosteidae				
	Lepisosteus oculatus	Spotted gar	tolerant	piscivore
Clupeidae				
	Dorosoma cepedianum	Gizzard shad	tolerant	omnivore
Cyprinidae				
	Campostoma anomalum	Central stoneroller	intermediate	herbivore
	Cyprinella lutrensis	Red shiner	tolerant	invertivore
	Cyprinus carpio	Common carp	tolerant	omnivore
	Notemigonus crysoleucas	Golden shiner	tolerant	invertivore
	Notropis volucellus	Mimic shiner	intolerant	invertivore
	Pimephales promelas	Fathead minnow	tolerant	omnivore
	Pimephales vigilax	Bullhead minnow	intermediate	invertivore
Catostomidae				
	Carpiodes carpio	River carpsucker	tolerant	omnivore
	Moxostoma poecilurum	Blacktail redhorse	intermediate	invertivore
Ictaluridae				
	Ameiurus melas	Black bullhead	tolerant	omnivore
	Ameiurus natalis	Yellow bullhead	intermediate	omnivore
	Ictalurus punctatus	Channel catfish	tolerant	omnivore
	Noturus nocturnus	Freckled madtom	intolerant	invertivore

Family	Taxa	Common Name	Tolerance	Trophic Guild
	Pylodictis olivaris	Flathead catfish	intermediate	piscivore
Cyprinodontidae				
	Fundulus notatus	Blackstripe topminnow	intermediate	invertivore
	Fundulus olivaceus	Blackspotted topminnow	intolerant	invertivore
Poeciliidae				
	Gambusia affinis	Western mosquitofish	tolerant	invertivore
Centrarchidae				
	Lepomis cyanellus	Green sunfish	tolerant	piscivore
	Lepomis gulosus	Warmouth	tolerant	piscivore
	Lepomis humilus	Orangespotted sunfish	intermediate	invertivore
	Lepomis macrochirus	Bluegill	tolerant	invertivore
	Lepomis megalotis	Longear sunfish	intermediate	invertivore
	Lepomis microlophus	Redear sunfish	intermediate	invertivore
	Lepomis spp.	Hybrid sunfish	intermediate	invertivore
	Micropterus salmoides	Largemouth bass	intermediate	piscivore
	Pomoxis annularis	White crappie	intermediate	piscivore
Percidae				
	Etheostoma spectabile	Orangethroat darter	intermediate	invertivore
	Percina sciera	Dusky darter	intolerant	invertivore

Site 1 received a regional IBI evaluation score of 39 and its aquatic life use class was designated as intermediate within the Subhumid Agricultural Plains ecoregion. The score was relatively low due to a lack of native cyprinid and benthic invertivore species present. It was also negatively affected by the overall small number of individuals collected through seining and electrofishing at the site. Metrics having a positive influence on the overall score were the total number of species and number of sunfish species collected on site, the high percentage of individuals as invertivores (74%), the low percentage of individuals as piscivores (16%), and the absence of non-natives and individuals with disease or other anomaly.

Big Fossil Creek at site 1 had a drainage basin area of approximately 23 square kilometers. A diversity of riffle/pool/run complexes existed at the site, especially downstream of the Hidden Lake Road crossing. Upstream of the crossing was likely influenced by the lake and was one long run/pool habitat. The stream was turbid but had no noticeable odor. No algal blooms were present at the site. The riparian corridor was largely intact. Aquatic invertebrates observed, included Ephemeroptera, Coleoptera, Diptera, and Trichoptera.

Site 2 was located on an intermittent tributary of Big Fossil Creek and was designated as a 1st order stream. A statewide IBI evaluation score of 38 was calculated for this site, and its aquatic life use class was limited-intermediate. The low overall score was mostly influenced by the lack of darter or intolerant species and significant percentages of tolerants and hybrid sunfish collected on site. The overall number of species collected, number of sunfish species collected, low percentage of omnivores, high percentage of insectivores, and lack of individuals with disease or other anomaly were positive influences on the overall score.

Site 2 tallied an overall regional IBI evaluation score of 43 and was designated as having a high aquatic life use. The low percentage of piscivores collected and low number of individuals collected at the site were the only metrics negatively influencing this score. All other metrics received high marks.

The intermittent creek at Site 2 had a drainage basin area of approximately 17 square kilometers. The site was dominated by pool/run habitat approximately 3-4 feet deep. Riffles were present but were very small. The site lacked a significant riparian corridor. Evidence of increased sedimentation from current residential construction was observed immediately downstream from this site. The stream was somewhat turbid with no noticeable odor present. Aquatic invertebrates observed during fish collection included Ephemeroptera, Trichoptera, Odonata, and Diptera.

Site 3 was located on Big Fossil Creek and was given a stream order designation of 2. The sample site was located on private property owned by Mr. Charles Lasater. A statewide IBI evaluation score of 38 was calculated for the site resulting in a limited-intermediate aquatic life use designation. The statewide score was lowered by the absence of sucker and intolerant species, as well as the relatively high percentage of tolerants (59%) and hybrids collected at the site. Five metrics that had a positive influence on the scoring were the high numbers of species (15) and the number of sunfish species (6) collected, the low percentage of individuals as omnivores, the high percentage of individuals as piscivores, and the absence of individuals with disease or other anomaly. All other metrics received an average score of 3.

The regional IBI evaluation score at Site 3 was 39 resulting in a intermediate aquatic life use designation. Metrics negatively influencing the regional score included a high percentage of tolerant species and the overall low number of individuals collected during sampling. The score was positively influenced by the high number of total species and sunfish species collected, the high percentage of piscivores collected and the absence of non-native species and individuals with disease or other anomaly.

Big Fossil Creek at Site 3 has a drainage basin of approximately 50 square kilometers. The site was dominated by large, relatively shallow pools that averaged 2-3 feet in depth. Riffle habitat was lacking at the site and run habitat was non-existent. The site lacked an adequate riparian corridor. Evidence of significant erosion, especially along the outside bank of a meander, was also evident on the site. The stream was slightly turbid. Aquatic invertebrates observed during sampling included Ephemeroptera, Trichoptera, Coleoptera, and Diptera.

Site 4 was located on a 2nd order unnamed tributary of Big Fossil Creek. An intermediate aquatic life use rating of 40 was calculated from the statewide IBI due to the following low scoring metrics: the absence of darter, sucker, and intolerant species in the samples and the high percentage of tolerant individuals collected (92%). The total number of species (7), number of sunfish species (4), low percentage of omnivores (11%), high percentage of piscivores (42%), and the absence of hybrids positively influenced the overall score.

Site 4 received a regional IBI evaluation score of 32. It was designated as a limited aquatic life use class due to the absence of native cyprinids and benthic invertivores, the high percentage of tolerant species present and the low number of individuals collected at the site. It was positively influenced by the number of sunfish species, the high percentage of piscivores, and the absence of any non-native species.

The drainage basin area of Site 4 equals approximately 15 square kilometers. The site was dominated by long narrow run/pools with small riffles between them. The sample site was located on the Fossil Creek Golf Club course and completely lacked a riparian corridor. The creek was modified during construction of the golf course and lacks sinuosity. The creek was relatively clear but did have a noticeable odor. Fish were observed onsite with lesions and scars from heavy predation by wading birds such as herons. Aquatic invertebrates observed during fish sampling included Ephemeroptera, Trichoptera, and Diptera.

Big Fossil Creek at Site 5 was designated as a 3rd order stream. This site received a statewide IBI evaluation score of 40 and an intermediate aquatic life use classification. It was negatively influenced by absence of darter and sucker species, the high percentage of tolerant individuals (40%), and the high percentage of hybrid sunfish (11%) collected at the site. Six metrics positively influenced the classification of the segment of the creek including the high total number of species (14), number of sunfish species (5), number of individuals in sample (375), the low percentage of omnivores (10%), relatively high percentage of piscivores (10%), and the absence of individuals with disease or other anomaly.

A high aquatic use rating of 45 was calculated for Site 5 using the regional IBI. The absence of benthic invertivores from the sampling was the only metric that negatively affected the overall score. All other metrics positively influenced the scoring at Site 5, especially the large number of native cyprinid species (4) collected and the absence of non-native species in the sample.

Site 5 had a drainage basin area of approximately 81 square kilometers. The site had a diversity of riffle/run/pool habitats to sample with riffles averaging 200 feet long and 30 feet wide, runs averaging 215 feet long and 35 feet wide, and pools averaging 150 feet long, 50 feet wide, and 3 feet deep. Some erosion was observed just downstream of the sample site. The creek was relatively clear with no noticeable odor present. Aquatic invertebrates observed during sampling included Ephemeroptera, Trichoptera, Odonata, Hemiptera, Coleoptera, and Diptera.

Big Fossil Creek at Site 6 received a statewide IBI evaluation score of 38 which falls between the limited and intermediate aquatic life use classes. This comparably low score was negatively influenced by the absence of darter, sucker and intolerant species from the sample. The high percentage of tolerant and hybrid individuals collected were also negative metrics. Metrics that positively affected the overall score were the total number of species, individuals, and sunfish species collected, the relatively high percentage of omnivores and piscivores present, and the absence of individuals with disease or other anomaly from the sample

The regional IBI score at Site 6 was calculated at 41 which classified it in the high aquatic life use class. The absence of benthic invertivores from the sample was the only negative metric. All other metrics positively influenced the overall score including the absence of non-native species in the sample and the number of native cyprinid species found.

The drainage basin area at Site 6 was approximately 111 square kilometers in size. This segment of Big Fossil Creek had riffles and pools but lacked run habitat. Riffles on the site averaged 55 feet in length and 15 feet in width, while pool habitat averaged 175 feet in length, 30 feet wide, and 2 feet deep. Severe erosion was observed on the site mainly due to an inadequate riparian buffer zone. The creek was slightly turbid with no noticeable odor. Aquatic invertebrates observed during fish sampling included Ephemeroptera, Trichoptera, Odonata, Coleoptera, and Diptera.

Site 7 was located on Whites Branch, a 2nd order perennial tributary of Big Fossil Creek. A statewide IBI evaluation score of 38 was calculated and this site's aquatic life use class was designated as limited-intermediate. The following factors contributed to this low overall score: absence of sucker and intolerant species, the high percentage of tolerant individuals (55%), a relatively low percentage of piscivores (14%), and a high percentage of hybrid sunfish collected at the site. Conversely, the high total number of species (15), number of sunfish species (6), and absence of individuals with disease or other anomaly had a positive influence on the overall score.

Site 7 had a regional IBI score of 42 and was classified as a stream with a high aquatic life use class. Only two metrics negatively affected this regional score including the high percentage of tolerant individuals sampled and the relatively low number of individuals collected during the sampling period. The regional IBI was scored high due to the large number of overall species and sunfish species collected at the site. The overall balance of the trophic feeding guilds (i.e., omnivores,invertivores and piscivores) and the absence of non-natives and individuals with disease or other anomaly also had a positive influence on the overall score.

Whites Branch has a drainage basin area of approximately 20 square kilometers at Site 7. The site was somewhat dominated by pool habitat (averaging 250 feet long, 30 feet wide, and 3 feet deep), although small riffles (averaging 22 feet long and 4 feet wide) were present. Run habitat was lacking at the site. The riparian corridor adjacent to the creek was non-existent along much of the sampling area. The creek was turbid but no noticeable odor was present. Aquatic invertebrates observed during fish sampling included Ephemeroptera, Trichoptera, Odonata, Coleoptera, and Diptera.

Site 8 was the furthest downstream of all the sample sites. It was located in Big Fossil Creek. This 3rd order stream received a statewide IBI score of 52, resulting in a high aquatic life use classification. The only metric that negatively influenced the overall score at this site was the high percentage of tolerant individuals collected. Two metrics received average scores of 3 including the number of darter species (1) and the percentage of insectivores (78%). All other metrics received the highest score of 5.

The regional IBI score at Site 8 was calculated at 47, also receiving a high aquatic use designation. Again, the only metric to negatively affect this score was the high percentage of tolerant individuals collected. The two metrics receiving an average score of 3 were the percentage of omnivores and the number of individuals collected on site. All other metrics received the highest score of 5.

Site 8 had a drainage basin area of approximately 135 square kilometers. The riparian corridor at this site is intact and is probably one of the most mature stands of hardwoods in the watershed. The stream consisted of a complete riffle/run/pool complex in a diversity of sizes. Riffles averaged 70 feet long and 40 feet wide. Runs averaged 78 feet long, 53 feet wide, and greater than 4 feet deep. Pools averaged 240 feet long, 45 feet wide, and 3 feet deep. The stream was slightly turbid. Aquatic invertebrates observed during fish sampling included Ephemeroptera, Trichoptera, Odonata, Hemiptera, Coleoptera, and Diptera.

At most sites, the regional score was higher than the statewide score due to its ability to recognize natural differences that occur within the fish community of the subhumid agricultural plains ecoregion as compared to differences in other ecoregions within the state. These natural differences include such factors as land form, soil type, vegetation, climatic conditions, and zoogeographic factors. Regional criteria selected to represent the differences in the subhumid agricultural plains include the number of native cyprinid species, number of benthic invertivores, and the percentage of individuals as non-native species. Our results indicate that these regional criteria provided a better representation of the integrity of the fish assemblage within the Big Fossil watershed as compared to the statewide criteria.

Half of the sample sites (Sites 5, 6, 7, and 8) were designated high for Regional aquatic use, three (Sites 1, 2, and 3) were designated as limited intermediate, and Site 4 was designated as limited. Sites 5, 6, 7, and 8 are located in the lower reaches of the creek where there was less urban construction occurring. Sites 3, 5, and 6 had some degree of erosion. Site 2 had a sedimentation problem, Site 5 lacked benthic invertebrates, and Site 4 lacked protective cover for fish. All the sites lacked a significant riparian corridor.

Discussion and Recommendations

The fishery in the upper reaches of the Big Fossil Creek Watershed is impacted by urban construction and nonpoint source pollution. Riparian buffer zones of at least 30 feet on each side of the creek could be used to enhance and protect aquatic resources from adverse impacts of urbanization. Riparian zones provide several benefits for aquatic resources. First, riparian zones stabilize eroding banks by absorbing the erosive force of flowing water while roots hold soil in place. Second, riparian zones filter sediment, nutrients, pesticides, and animal waste from runoff. Finally, riparian zones provide shade, shelter, and food for fish and other aquatic organisms.

Wetlands constructed offstream of small permanent or ephemeral streams could provide nonpoint source pollution control. Wetlands provide several benefits which could contribute to water quality improvements. First the wetlands provide water quality function through solid settling, nutrient transformation, and biological uptake. Second, wetlands provide flood water storage and serve to collect peak flood flows known to carry most of the polluted runoff from nonpoint sources. Finally, wetlands provide diversity in the landscape and supply a unique habitat for many plants and animal species.

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Appendix A. Data from the Statewide and Subhumid Agricultural Plains (Regional) Index of Biotic Integrity (IBI) evaluations and scoring for the Big Fossil Creek Watershed within the Trinity River Basin.

Site:	#1; Big Fossil Creek	**Location:**	Gregg Asikis Leasee;W. of Blue Mound Rd, S. of U.S. 81; Fort Worth; Tarrant County
Date:	15 July 2002	**Collectors:**	M. Armstrong, C. Hale, J. Lewis, & J. Key

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	11(5)	**7.) % of individuals as omnivores:**	10 (5)
2.) Total # of darter species:	0 (1)	**8.) % of individuals as insectivores:**	74 (3)
3.) Total # of sunfish species:	5 (5)	**9.) % of individuals as piscivores:**	16 (5)
4.) Total # of sucker species:	0 (1)	**10.) # of individuals in sample:**	132 (3)
5.) Total # of intolerant species:	0 (1)	**11.) % of individuals as hybrids:**	36 (1)
6.) % of individuals as tolerants:	29 (1)	**12.) % of individuals with disease or anomaly:**	0 (5)
IBI Total Score: 36 (Limited-Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	11(5)	**7.) % of individuals as invertivores:**	74(5)
2.) # of native cyprinid species:	1(1)	**8.) % of individuals as piscivores:**	16(5)
3.) # of benthic invertivore species:	0(1)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	132 22(1) 1.5(1) (1)
4.) # of sunfish species:	5(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	28(3)	**11.) % of individuals with disease or other anomaly:**	0(5)
6.) % of individuals as omnivores:	10(3)		
IBI Total Score: 39 (Intermediate)			

Species Collected:					
Taxa:	**Code:**	**Common Name:**	**#:**	**Trophic:**	**Tolerance:**
Dorosoma cepedianum	21	Gizzard shad	7	O	T
Notemigonus crysoleucas	46	Golden shiner	6	IF	T
Ameiurus natalis	91	Yellow bullhead	6	O	-
Fundulus notatus	120	Blackstripe topminnow	8	IF	-
Gambusia affinis	126	Western mosquitofish	1	IF	T
Lepomis cyanellus	152	Green sunfish	7	P	T
Lepomis gulosus	153	Warmouth	3	P	T
Lepomis macrochirus	155	Bluegill	14	IF	T
Lepomis megalotis	157	Longear sunfish	1	IF	-
Lepomis microlophus	158	Redear sunfish	20	IF	-
Micropterus salmoides	163	Largemouth bass	11	P	-
Lepomis hybrid		Hybrid sunfish	48	IF	-

* Site #1 is on the main stem of Big Fossil Creek and is a 1st Order Stream.

** Drainage Basin Area equals 23.07 square kilometers.

Site: #2; Unnamed trib. of Big Fossil Creek **Location:** @ bridge on Blue Mound Rd, immediately S. of Harmon Rd; Fort Worth; Tarrant County

Date: 15 July 2002 **Collectors:** M. Armstrong, C. Hale, J. Lewis, & J. Key

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	15(5)	**7.) % of individuals as omnivores:**	3(5)
2.) Total # of darter species:	1(3)	**8.) % of individuals as insectivores:**	93(5)
3.) Total # of sunfish species:	7(5)	**9.) % of individuals as piscivores:**	4(3)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	130(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	32(1)
6.) % of individuals as tolerants:	38(1)	**12.) % of individuals with disease or anomaly:**	0(5)
IBI Total Score: 38 (Limited-Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	15(5)	**7.) % of individuals as invertivores:**	93(5)
2.) # of native cyprinid species:	2(3)	**8.) % of individuals as piscivores:**	4(1)
3.) # of benthic invertivore species:	1(3)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	130 21(1) 2.0(1) (1)
4.) # of sunfish species:	7(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	22(5)	**11.) % of individuals with disease or other anomaly:**	0(5)
6.) % of individuals as omnivores:	3(5)		
IBI Total Score: 43 (High)			

Species Collected:					
Taxa:	**Code:**	**Common Name:**	**#:**	**Trophic:**	**Tolerance:**
Dorosoma cepedianum	21	Gizzard shad	2	O	T
Notemigonus crysoleucas	46	Golden shiner	6	IF	T
Pimephales vigilax	72	Bullhead minnow	1	IF	-
Ameiurus natalis	91	Yellow bullhead	2	O	-
Fundulus notatus	120	Blackstripe topminnow	10	IF	-
Gambusia affinis	126	Western mosquitofish	27	IF	T
Lepomis cyanellus	152	Green sunfish	1	P	T
Lepomis gulosus	153	Warmouth	1	P	T
Lepomis humilus	154	Orangespotted sunfish	2	IF	-
Lepomis macrochirus	155	Bluegill	13	IF	T
Lepomis megalotis	157	Longear sunfish	1	IF	-
Lepomis microlophus	158	Redear sunfish	18	IF	-
Micropterus salmoides	163	Largemouth bass	2	P	-
Pomoxis annularis	165	White crappie	1	P	-
Etheostoma spectabile	180	Orangethroat darter	1	IF	-
Lepomis hybrid		Hybrid sunfish	42	IF	-

* Site #2 is on a unnamed tributary of Big Fossil Creek and is a 1st Order Stream.

** Drainage Basin Area equals 16.72 square kilometers.

Site:	#3; Big Fossil Creek	**Location:**	Charles Lasater- owner; E. of Blue Mound Rd, S. of U.S. 81; Fort Worth; Tarrant County
Date:	18 July 2002	**Collectors:**	M. Armstrong, C. Hale, B. Colbert, J. Key & City of Fort Worth

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	15(5)	**7.) % of individuals as omnivores:**	10(5)
2.) Total # of darter species:	1(3)	**8.) % of individuals as insectivores:**	63(3)
3.) Total # of sunfish species:	6(5)	**9.) % of individuals as piscivores:**	27(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	136(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	1(1)
6.) % of individuals as tolerants:	59(1)	**12.) % of individuals with disease or anomaly:**	0 (5)
IBI Total Score: 38 (Limited-Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	15(5)	**7.) % of individuals as invertivores:**	63(3)
2.) # of native cyprinid species:	3(3)	**8.) % of individuals as piscivores:**	27(5)
3.) # of benthic invertivore species:	1(3)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	136 28.5(1) 1.8(1) (1)
4.) # of sunfish species:	6(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	56(1)	**11.) % of individuals with disease or other anomaly:**	0(5)
6.) % of individuals as omnivores:	10(3)		
IBI Total Score: 39 (Intermediate)			

Species Collected:					
Taxa:	Code:	Common Name:	#:	Trophic:	Tolerance:
Dorosoma cepedianum	21	Gizzard shad	2	O	T
Cyprinella lutrensis	31	Red shiner	17	IF	T
Notemigonus crysoleucas	46	Golden shiner	4	IF	T
Pimephales vigilax	72	Bullhead minnow	6	IF	-
Ameiurus natalis	91	Yellow bullhead	11	O	-
Fundulus notatus	120	Blackstripe topminnow	18	IF	-
Gambusia affinis	126	Western mosquitofish	8	IF	T
Lepomis cyanellus	152	Green sunfish	29	P	T
Lepomis gulosus	153	Warmouth	2	P	T
Lepomis macrochirus	155	Bluegill	18	IF	T
Lepomis megalotis	157	Longear sunfish	2	IF	-
Lepomis microlophus	158	Redear sunfish	10	IF	-
Micropterus salmoides	163	Largemouth bass	4	P	-
Pomoxis annularis	165	White crappie	2	P	-
Etheostoma spectabile	180	Orangethroat darter	1	IF	-
Lepomis hybrid		Hybrid sunfish	2	IF	-

* Site #3 is on the main stem of Big Fossil Creek and is a 2nd Order Stream.

** Drainage Basin Area equals 50.11 square kilometers.

Site:	#4; Unnamed trib. of Big Fossil Creek	**Location:**	S. of Watauga St., on Fossil Creek golf course property; Fort Worth; Tarrant County
Date:	17 July 2002	**Collectors:**	M. Armstrong, C. Hale, B. Colbert, J. Key & City of Fort Worth

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	7(5)	**7.) % of individuals as omnivores:**	11(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	47(3)
3.) Total # of sunfish species:	4(5)	**9.) % of individuals as piscivores:**	42(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	92(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	92(1)	**12.) % of individuals with disease or anomaly:**	0(5)
IBI Total Score: 40 (Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	7(3)	**7.) % of individuals as invertivores:**	47(3)
2.) # of native cyprinid species:	0(1)	**8.) % of individuals as piscivores:**	42(5)
3.) # of benthic invertivore species:	0(1)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	92 8(1) 4.6(3) (2)
4.) # of sunfish species:	4(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	88(1)	**11.) % of individuals with disease or other anomaly:**	1(3)
6.) % of individuals as omnivores:	11(3)		
IBI Total Score: 32 (Limited)			

Species Collected:					
Taxa:	**Code:**	**Common Name:**	**#:**	**Trophic:**	**Tolerance:**
Ameiurus melas	90	Black bullhead	10	O	T
Gambusia affinis	126	Western mosquitofish	19	IF	T
Lepomis cyanellus	152	Green sunfish	37	P	T
Lepomis gulosus	153	Warmouth	1	P	T
Lepomis macrochirus	155	Bluegill	18	IF	T
Lepomis megalotis	157	Longear sunfish	6	IF	-
Micropterus salmoides	163	Largemouth bass	1	P	-

* Site #4 is on an unnamed tributary of Big Fossil Creek and is a 2nd Order Stream.

** Drainage Basin Area equals 15.49 square kilometers.

Site:	#5; Big Fossil Creek	**Location:**	E. of Beach Street; Haltom City; Tarrant County
Date:	16 July 2002	**Collectors:**	M. Armstrong, C. Hale, D. Allen, & J. Key

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	14(5)	**7.) % of individuals as omnivores:**	10(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	76(3)
3.) Total # of sunfish species:	5(5)	**9.) % of individuals as piscivores:**	10(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	375(5)
5.) Total # of intolerant species:	1(3)	**11.) % of individuals as hybrids:**	11(1)
6.) % of individuals as tolerants:	40(1)	**12.) % of individuals with disease or anomaly:**	0(5)
IBI Total Score: 40 (Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	14(5)	**7.) % of individuals as invertivores:**	76(5)
2.) # of native cyprinid species:	4(5)	**8.) % of individuals as piscivores:**	10(5)
3.) # of benthic invertivore species:	0(1)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	375 39(3) 5.6(3) (3)
4.) # of sunfish species:	5(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	31(3)	**11.) % of individuals with disease or other anomaly:**	0(5)
6.) % of individuals as omnivores:	10(3)		
IBI Total Score: 45 (High)			

Species Collected:					
Taxa:	Code:	Common Name:	#:	Trophic:	Tolerance:
Campostoma anomalum	26	Central stoneroller	17	H	-
Cyprinella lutrensis	31	Red shiner	54	IF	T
Notropis volucellus	68	Mimic shiner	49	IF	I
Pimephales vigilax	72	Bullhead minnow	28	IF	-
Ameiurus natalis	91	Yellow bullhead	32	O	-
Ictalurus punctatus	94	Channel catfish	4	O	T
Fundulus notatus	120	Blackstripe topminnow	2	IF	-
Gambusia affinis	126	Western mosquitofish	50	IF	T
Lepomis cyanellus	152	Green sunfish	29	P	T
Lepomis gulosus	153	Warmouth	3	P	T
Lepomis macrochirus	155	Bluegill	10	IF	T
Lepomis megalotis	157	Longear sunfish	17	IF	-
Lepomis microlophus	158	Redear sunfish	34	IF	-
Micropterus salmoides	163	Largemouth bass	4	P	-
Lepomis hybrid		Hybrid sunfish	42	IF	-

* Site #5 is on the main stem of Big Fossil Creek and is a 3rd Order Stream.

** Drainage Basin Area equals 81.01 square kilometers.

Site:	#6; Big Fossil Creek	**Location:**	W. of Denton Hwy (IH 377); Haltom City; Tarrant County
Date:	17 July 2002	**Collectors:**	M. Armstrong, C. Hale, B. Colbert, J. Key, & City of Fort Worth

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	10(5)	**7.) % of individuals as omnivores:**	13(5)
2.) Total # of darter species:	0(1)	**8.) % of individuals as insectivores:**	63(3)
3.) Total # of sunfish species:	4(5)	**9.) % of individuals as piscivores:**	11(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	219(5)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	1.4(1)
6.) % of individuals as tolerants:	53(1)	**12.) % of individuals with disease or anomaly:**	0 (5)
IBI Total Score: 38 (Limited-Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	11(5)	**7.) % of individuals as invertivores:**	63(3)
2.) # of native cyprinid species:	2(3)	**8.) % of individuals as piscivores:**	11(5)
3.) # of benthic invertivore species:	0(1)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	219 37(3) 4.0(3) (3)
4.) # of sunfish species:	4(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	49(3)	**11.) % of individuals with disease or other anomaly:**	0(5)
6.) % of individuals as omnivores:	13(3)		
IBI Total Score: 41 (High)			

Species Collected:					
Taxa:	**Code:**	**Common Name:**	**#:**	**Trophic:**	**Tolerance:**
Campostoma anomalum	26	Central stoneroller	29	H	-
Cyprinella lutrensis	31	Red shiner	56	IF	T
Ameiurus natalis	91	Yellow bullhead	26	O	-
Ictalurus punctatus	94	Channel catfish	2	O	T
Fundulus notatus	120	Blackstripe topminnow	15	IF	-
Gambusia affinis	126	Western mosquitofish	16	IF	T
Lepomis cyanellus	152	Green sunfish	23	P	T
Lepomis gulosus	153	Warmouth	1	P	T
Lepomis macrochirus	155	Bluegill	18	IF	T
Lepomis megalotis	157	Longear sunfish	30	IF	-
Lepomis hybrid		Hybrid sunfish	3	IF	-

* Site #6 is on the main stem of Big Fossil Creek and is a 3rd Order Stream.

** Drainage Basin Area equals 111.29 square kilometers.

Site:	#7; Whites Branch of Big Fossil Creek	**Location:**	N. of Watauga Rd,: Fort Worth; Tarrant County
Date:	16 July 2002	**Collectors:**	M. Armstrong, C. Hale, B. Colbert, J. Key, & City of Fort Worth

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	15(5)	**7.) % of individuals as omnivores:**	10(5)
2.) Total # of darter species:	1(3)	**8.) % of individuals as insectivores:**	76(3)
3.) Total # of sunfish species:	6(5)	**9.) % of individuals as piscivores:**	14(5)
4.) Total # of sucker species:	0(1)	**10.) # of individuals in sample:**	170(3)
5.) Total # of intolerant species:	0(1)	**11.) % of individuals as hybrids:**	8(1)
6.) % of individuals as tolerants:	55(1)	**12.) % of individuals with disease or anomaly:**	0 (5)
IBI Total Score: 38 (Limited-Intermediate)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	11(5)	**7.) % of individuals as invertivores:**	76(5)
2.) # of native cyprinid species:	3(3)	**8.) % of individuals as piscivores:**	14(5)
3.) # of benthic invertivore species:	1(3)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	170 53(3) 2.6(1) (2)
4.) # of sunfish species:	6(5)	**10.) % of individuals as non-native species:**	0(5)
5.) % of individuals as tolerant species:	53(1)	**11.) % of individuals with disease or other anomaly:**	0.5(5)
6.) % of individuals as omnivores:	10(3)		
IBI Total Score: 42 (High)			

Species Collected:					
Taxa:	**Code:**	**Common Name:**	**#:**	**Trophic:**	**Tolerance:**
Dorosoma cepedianum	21	Gizzard shad	1	O	T
Cyprinella lutrensis	31	Red shiner	6	IF	T
Notemigonus crysoleucas	46	Golden shiner	15	IF	T
Pimephales vigilax	72	Bullhead minnow	1	IF	-
Ameiurus natalis	91	Yellow bullhead	16	O	-
Fundulus notatus	120	Blackstripe topminnow	8	IF	-
Gambusia affinis	126	Western mosquitofish	9	IF	T
Lepomis cyanellus	152	Green sunfish	17	P	T
Lepomis gulosus	153	Warmouth	2	P	T
Lepomis macrochirus	155	Bluegill	43	IF	T
Lepomis megalotis	157	Longear sunfish	24	IF	-
Lepomis microlophus	158	Redear sunfish	8	IF	-
Micropterus salmoides	163	Largemouth bass	1	P	-
Pomoxis annularis	165	White crappie	4	P	-
Etheostoma spectabile	180	Orangethroat darter	1	IF	-
Lepomis hybrid		Hybrid sunfish	14	IF	-

* Site #7 is on Whites Branch which is a tributary of Big Fossil Creek and is a 2nd Order Stream.

** Drainage Basin Area equals 19.78 square kilometers.

Site:	#8; Big Fossil Creek	**Location:**	N. of Onyx Dr. within Fossil Creek Park; Richland Hills; Tarrant County
Date:	18 July 2002	**Collectors:**	M. Armstrong, C. Hale, B. Colbert, J. Key, & City of Fort Worth

Statewide IBI Metric Calculations (IBI Score):			
1.) Total # of species:	22(5)	**7.) % of individuals as omnivores:**	9.3(5)
2.) Total # of darter species:	1(3)	**8.) % of individuals as insectivores:**	78(3)
3.) Total # of sunfish species:	4(5)	**9.) % of individuals as piscivores:**	13(5)
4.) Total # of sucker species:	2(5)	**10.) # of individuals in sample:**	353(5)
5.) Total # of intolerant species:	4(5)	**11.) % of individuals as hybrids:**	0(5)
6.) % of individuals as tolerants:	55(1)	**12.) % of individuals with disease or anomaly:**	0 (5)
IBI Total Score: 52 (High)			

Subhumid Agricultural Plains IBI Metric Calculations (IBI Score):			
1.) Total # of fish species:	22(5)	**7.) % of individuals as invertivores:**	78(5)
2.) # of native cyprinid species:	4(5)	**8.) % of individuals as piscivores:**	13(5)
3.) # of benthic invertivore species:	3(5)	**9.) # of individuals in sample:** **a. # of ind./ seine haul** **b. # of ind./ min. electrofishing** **c. final average score**	353 37(3) 4.8(3) (3)
4.) # of sunfish species:	4(5)	**10.) % of individuals as non-native species:**	0.3(5)
5.) % of individuals as tolerant species:	55(1)	**11.) % of individuals with disease or other anomaly:**	0(5)
6.) % of individuals as omnivores:	9.3(3)		
IBI Total Score: 47 (High)			

Species Collected:					
Taxa:	**Code:**	**Common Name:**	**#:**	**Trophic:**	**Tolerance:**
Lepisosteus oculatus	9	Spotted gar	1	P	T
Dorosoma cepedianum	21	Gizzard shad	16	O	T
Cyprinella lutrensis	31	Red shiner	122	IF	T
Cyprinus carpio	34	Common carp	1	O	T
Notropis volucellus	68	Mimic shiner	10	IF	I
Pimephales promelas	71	Fathead minnow	1	O	T
Pimephales vigilax	72	Bullhead minnow	61	IF	-
Carpiodes carpio	77	River carpsucker	1	O	T
Moxostoma poecilurum	88	Blacktail redhorse	9	IF	-
Ameiurus natalis	91	Yellow bullhead	12	O	-
Ictalurus punctatus	94	Channel catfish	2	O	T
Noturus nocturnus	96	Freckled madtom	24	IF	I
Pylodictis olivaris	97	Flathead catfish	2	P	-
Fundulus notatus	120	Blackstripe topminnow	2	IF	-
Fundulus olivaceus	121	Blackspotted topminnow	2	IF	I
Gambusia affinis	126	Western mosquitofish	2	IF	T
Lepomis cyanellus	152	Green sunfish	37	P	T
Lepomis macrochirus	155	Bluegill	12	IF	T
Lepomis megalotis	157	Longear sunfish	21	IF	-
Micropterus salmoides	163	Largemouth bass	3	P	-
Pomoxis annularis	165	White crappie	1	P	-
Percina sciera	187	Dusky darter	11	IF	I

* Site #8 is on the main stem of Big Fossil Creek and is a 3rd Order Stream.

** Drainage Basin Area equals 134.60 square kilometers.

Appendix B. Representative photographs of sample sites within the Big Fossil Creek watershed in Tarrant County, Texas completed during the summer of 2002.

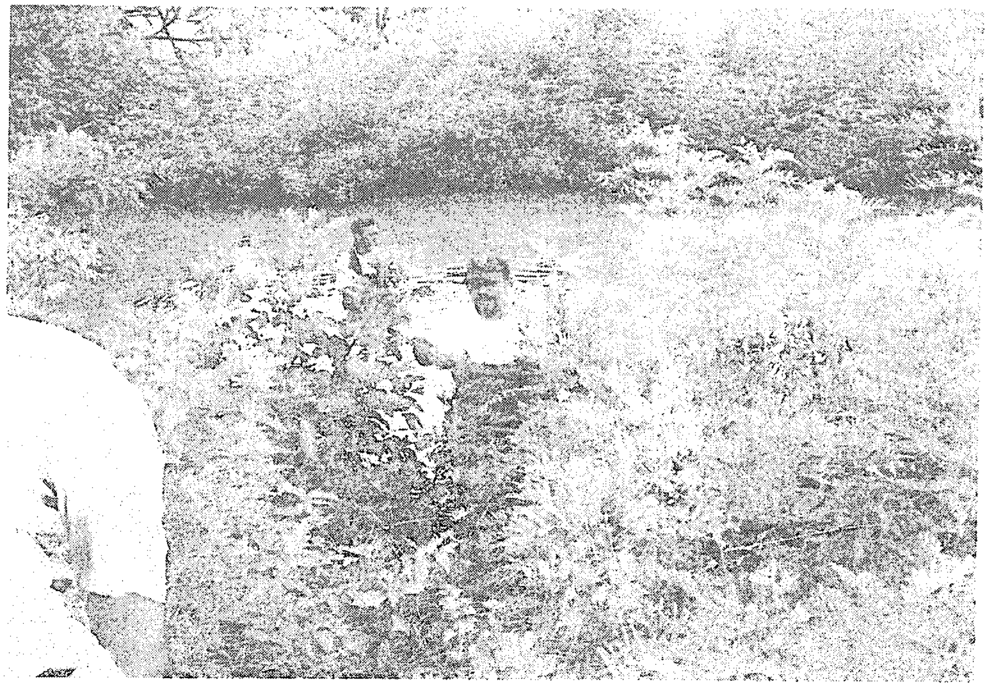

Figure 1. Pool habitat sampled at Site 1.

Figure 2. Run habitat sampled at Site 1.

Figure 3. Pool habitat sampled at Site 2.

Figure 4. Run habitat sampled at Site 2.

Figure 5. Riffle habitat sampled at Site 2.

Figure 6. Pool habitat sampled at Site 3.

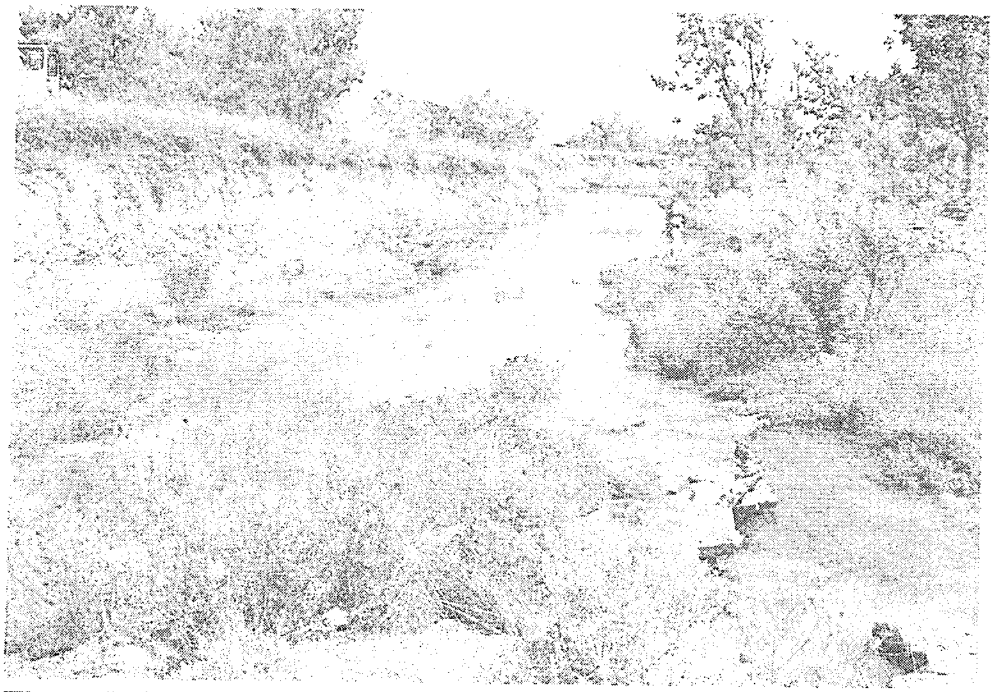

Figure 7. Riffle and Run habitat sampled at Site 3.

Figure 8. Pool Habitat sampled at Site 4.

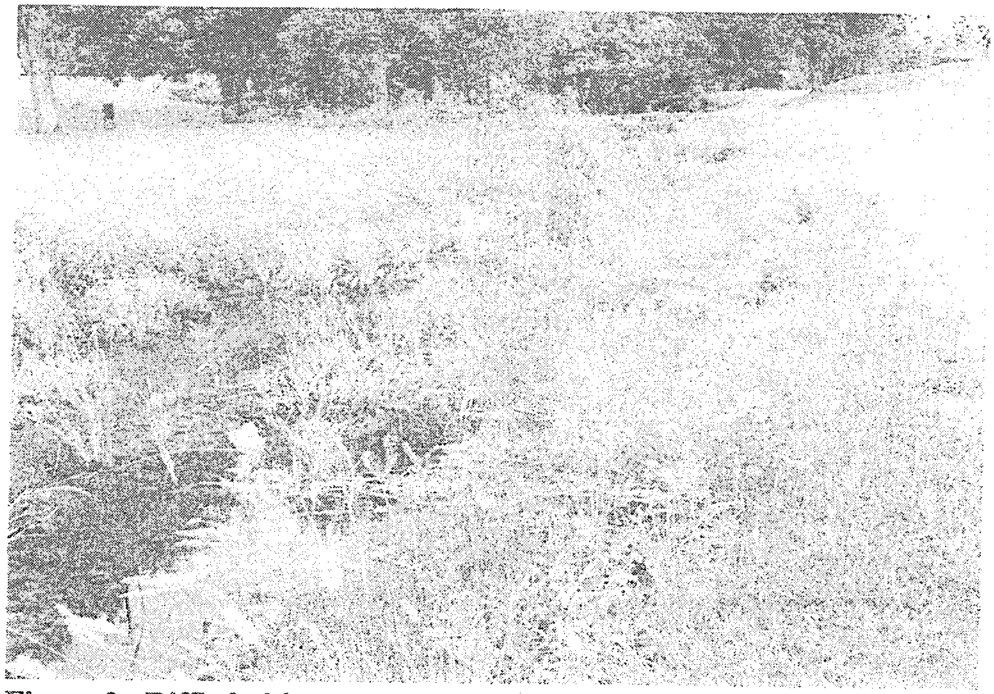

Figure 9. Riffle habitat sampled at Site 4.

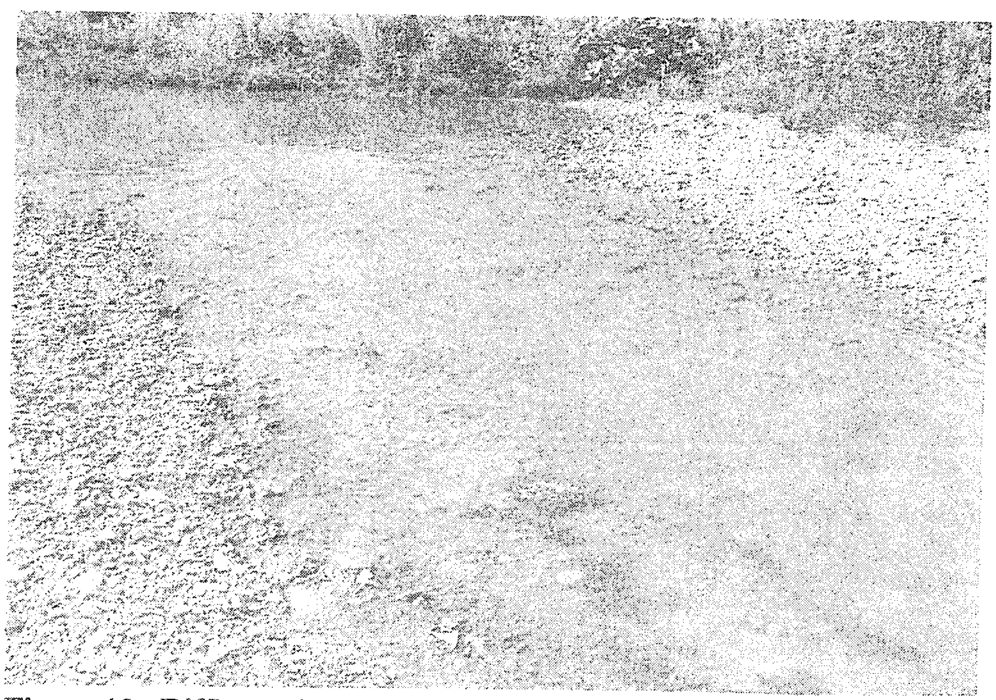

Figure 10. Riffle habitat sampled at Site 5.

Figure 11. Riffle sampled at Site 6.

Figure 12. Pool habitat sampled at Site 6.

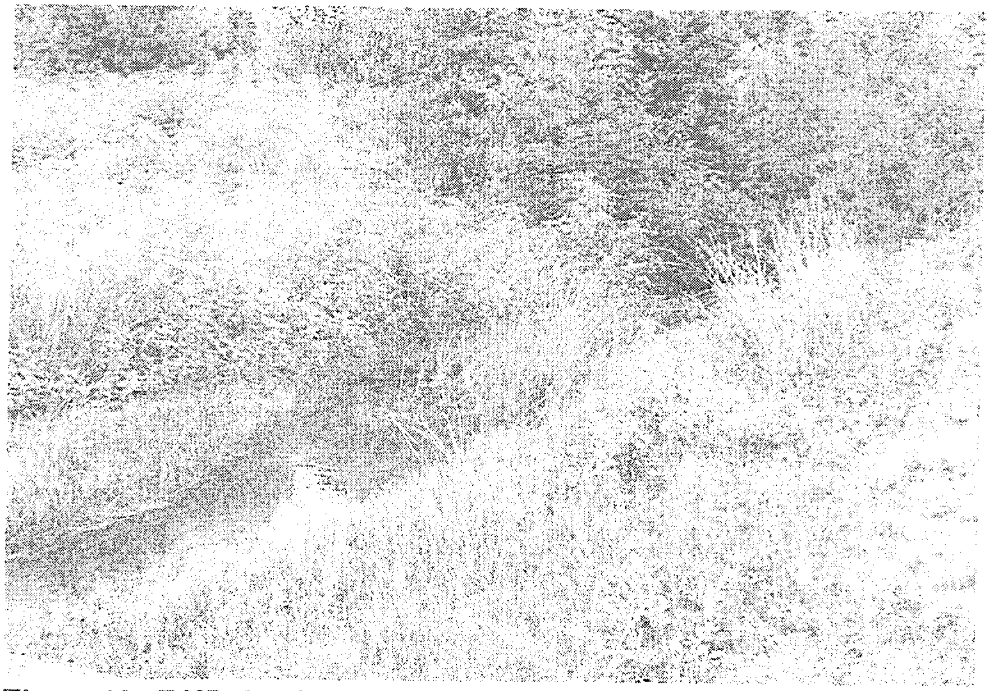

Figure 13. Riffle habitat sampled at Site 7.

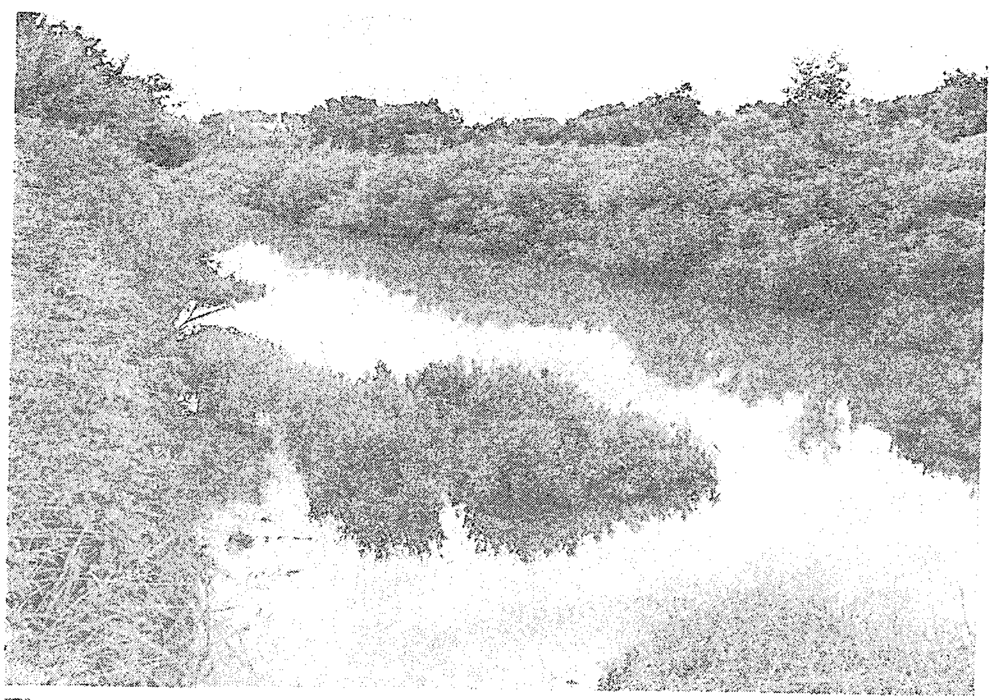

Figure 14. Pool habitat sampled at Site 7.

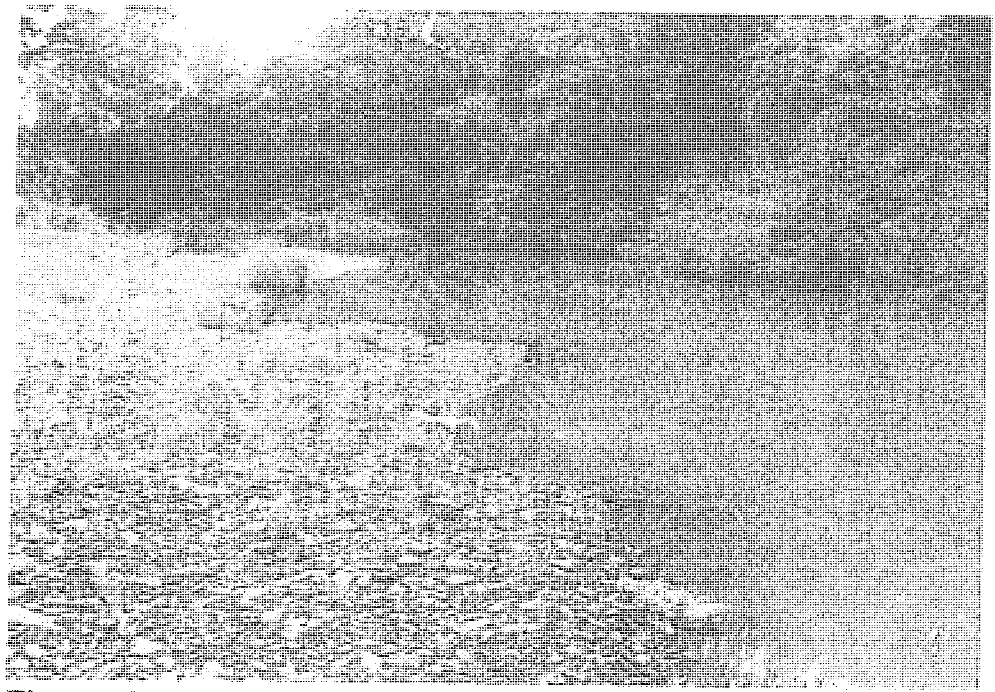

Figure 15. Pool habitat sampled at Site 8.

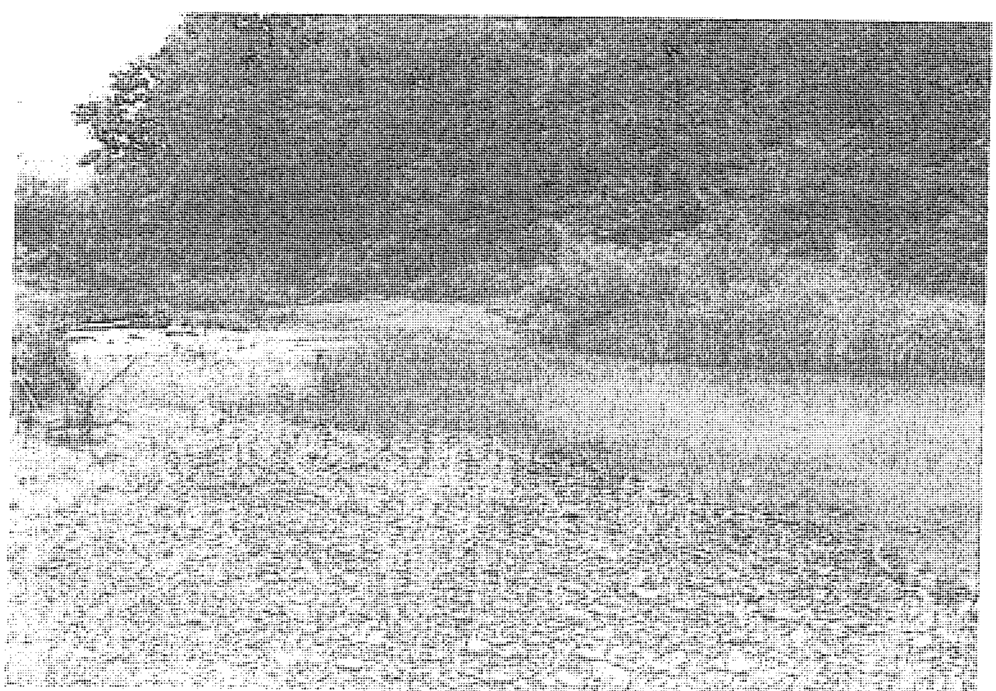

Figure 16. Riffle and run habitat sampled at Site 8.

Appendix C. Photographs of select fishes collected while sampling the Big Fossil Creek watershed during the summer of 2002.

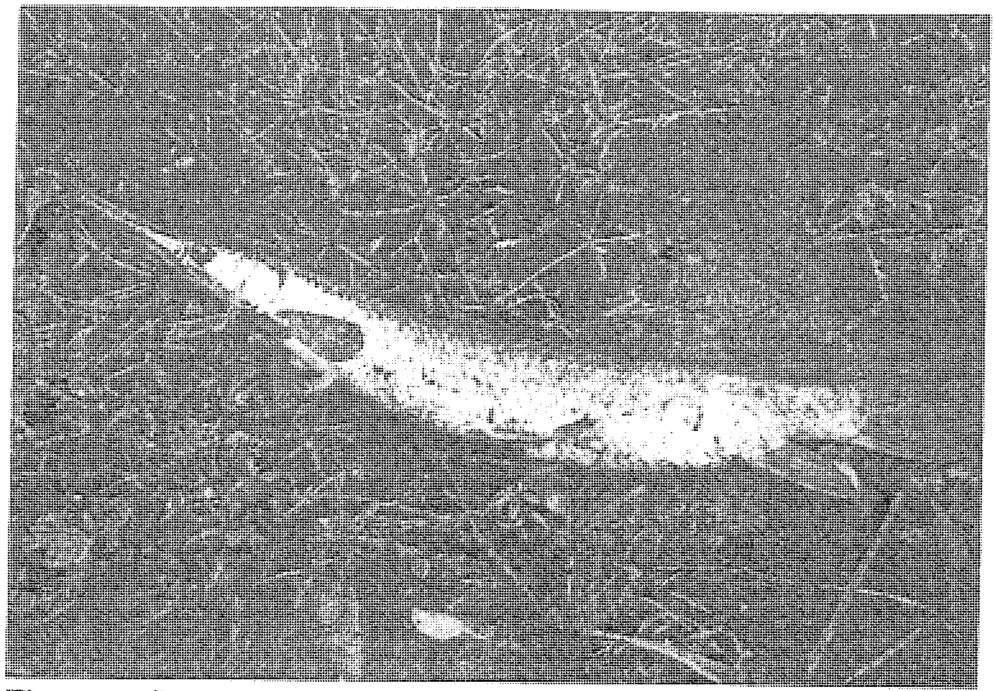

Figure 1. Spotted gar (*Lepisosteus oculatus*)

Figure 2. Gizzard shad (*Dorosoma cepedianum*)

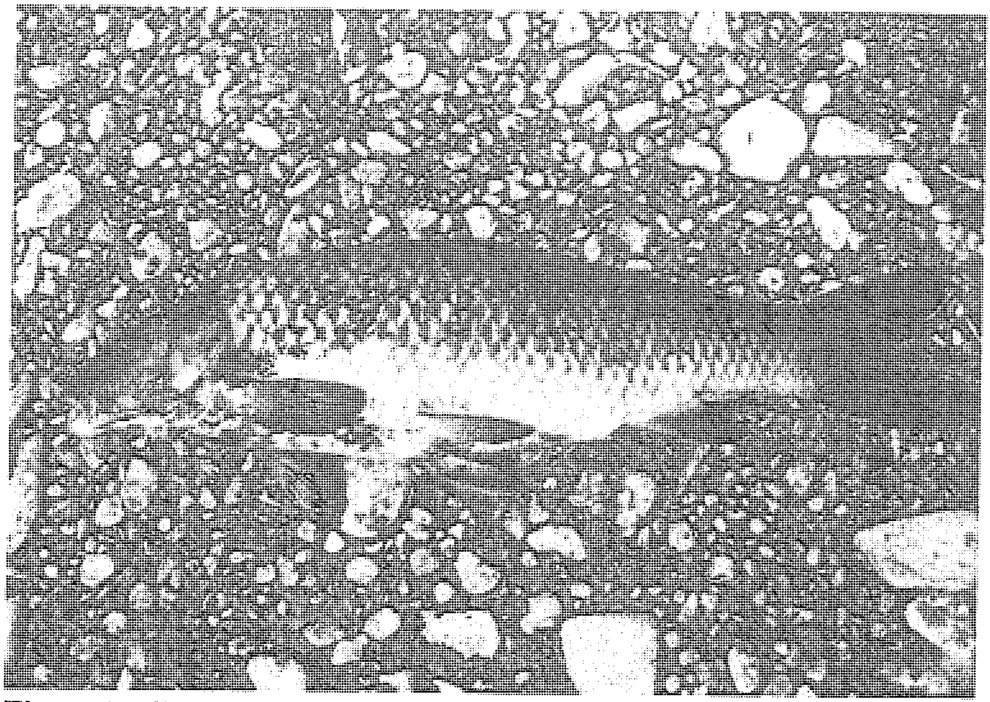

Figure 3. Common carp (*Cyprinus carpio*)

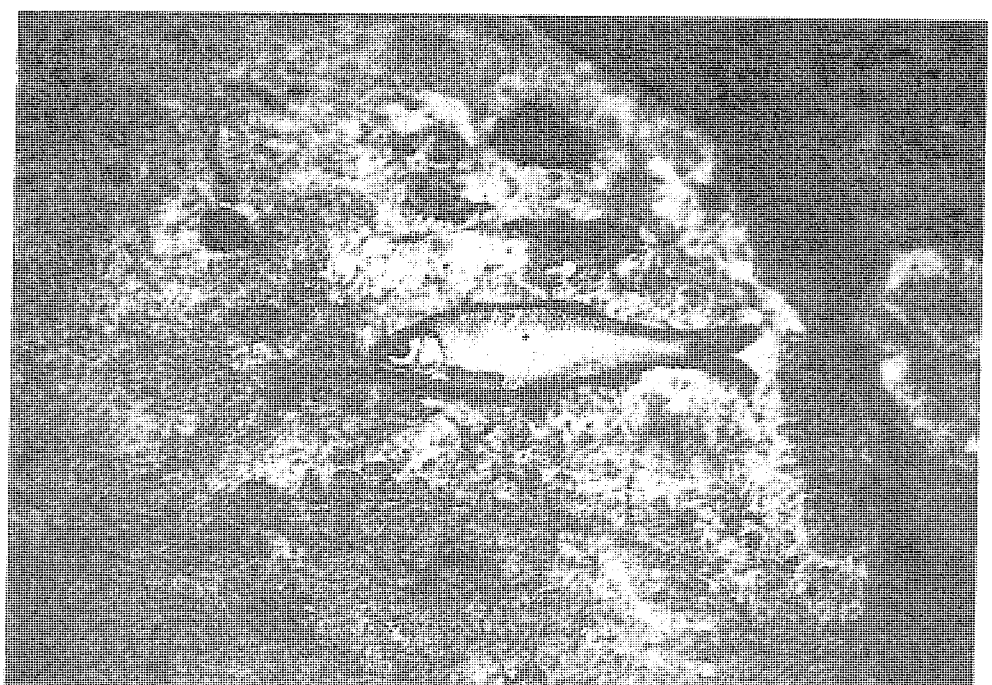

Figure 4. Red shiner (*Cyprinella lutrensis*)

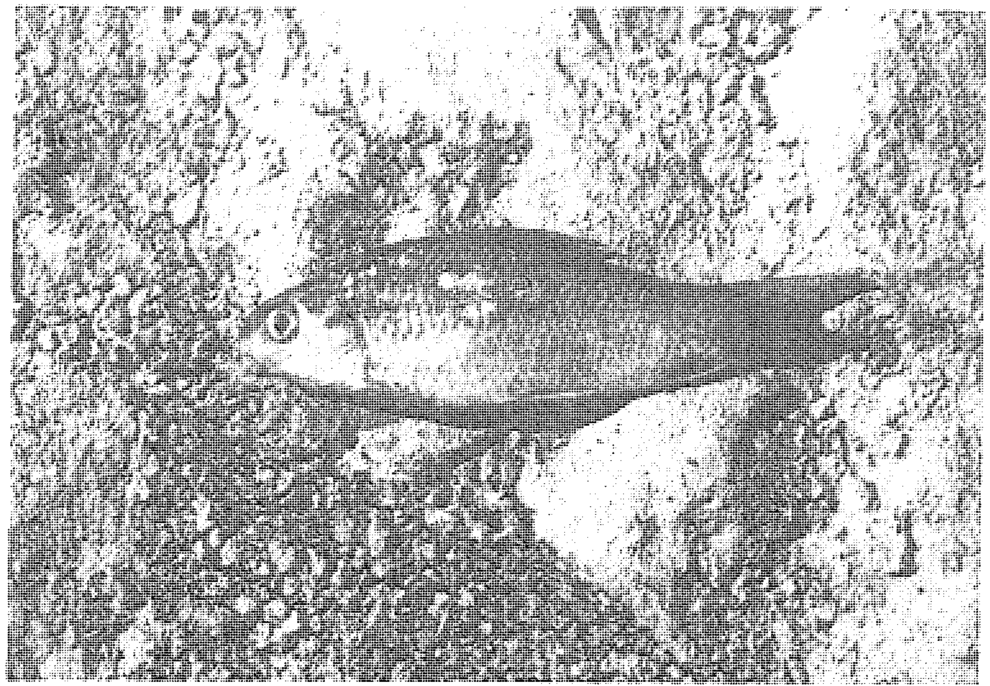

Figure 5. River carpsucker (*Carpiodes carpio*)

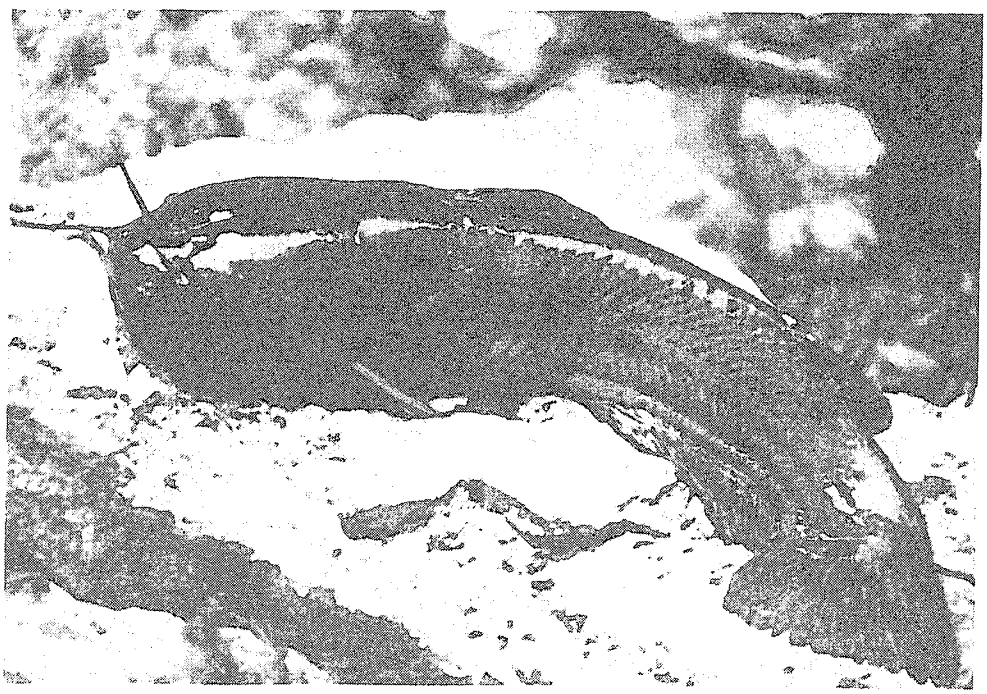

Figure 6. Black bullhead (*Ameiurus melas*)

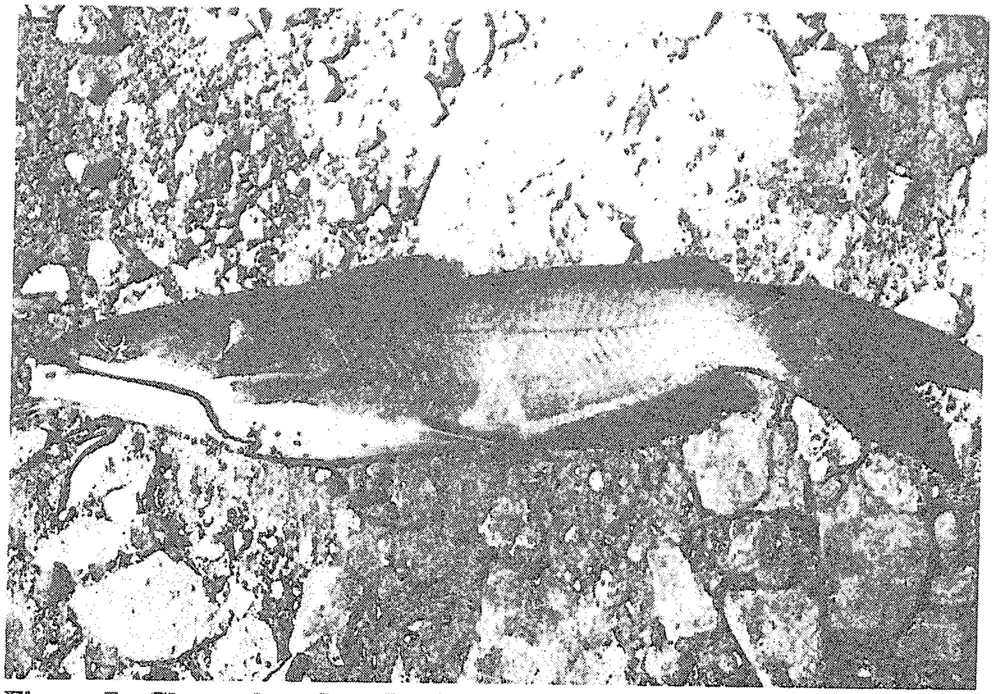

Figure 7. Channel catfish (*Ictalurus punctatus*)

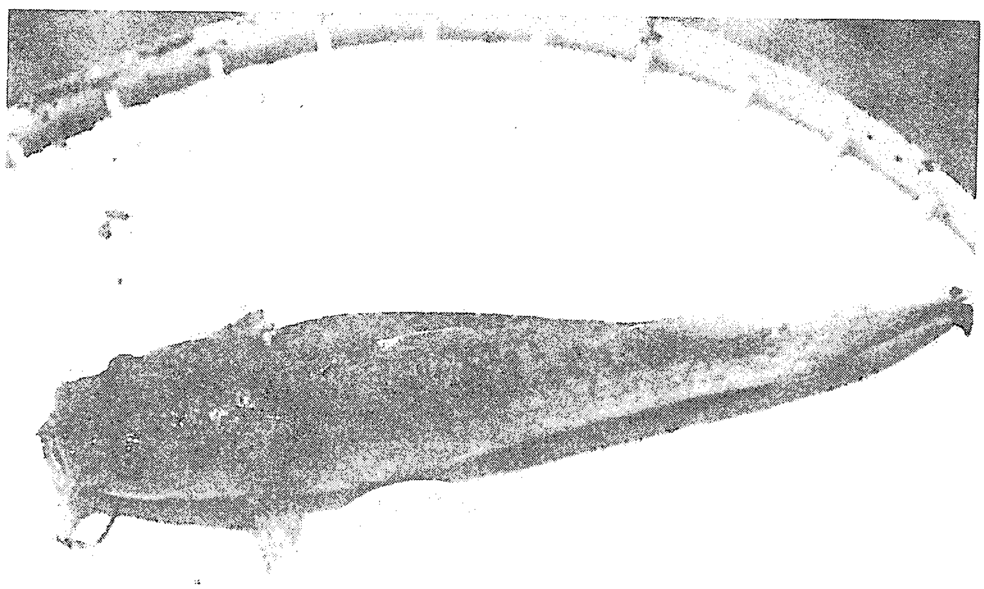

Figure 8. Flathead catfish (*Pylodictus olivaris*)

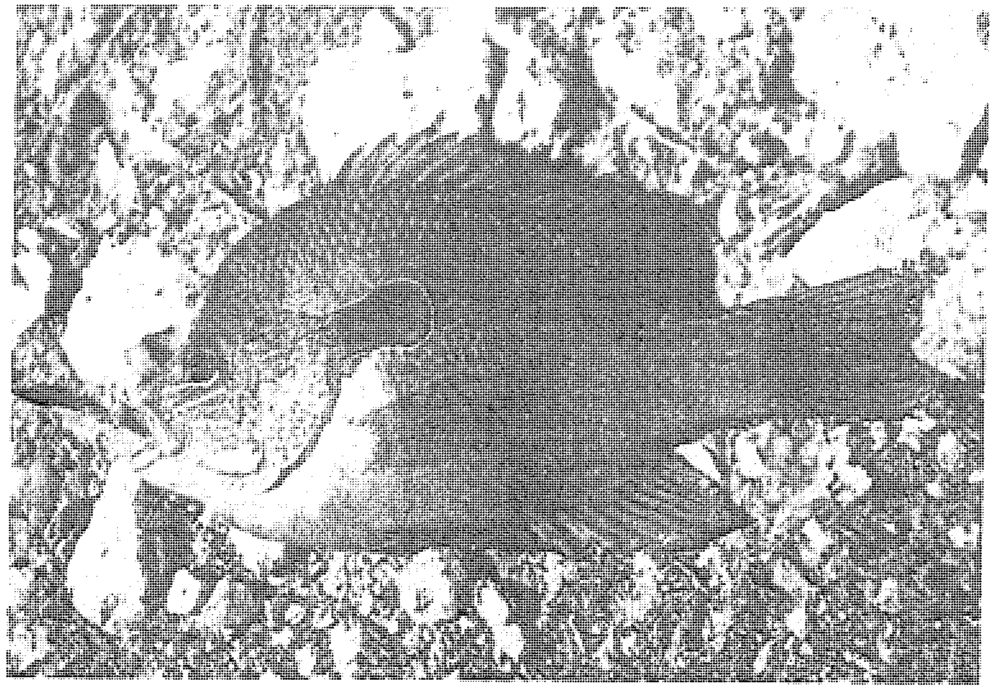

Figure 9. Longear sunfish (*Lepomis megalotis*)

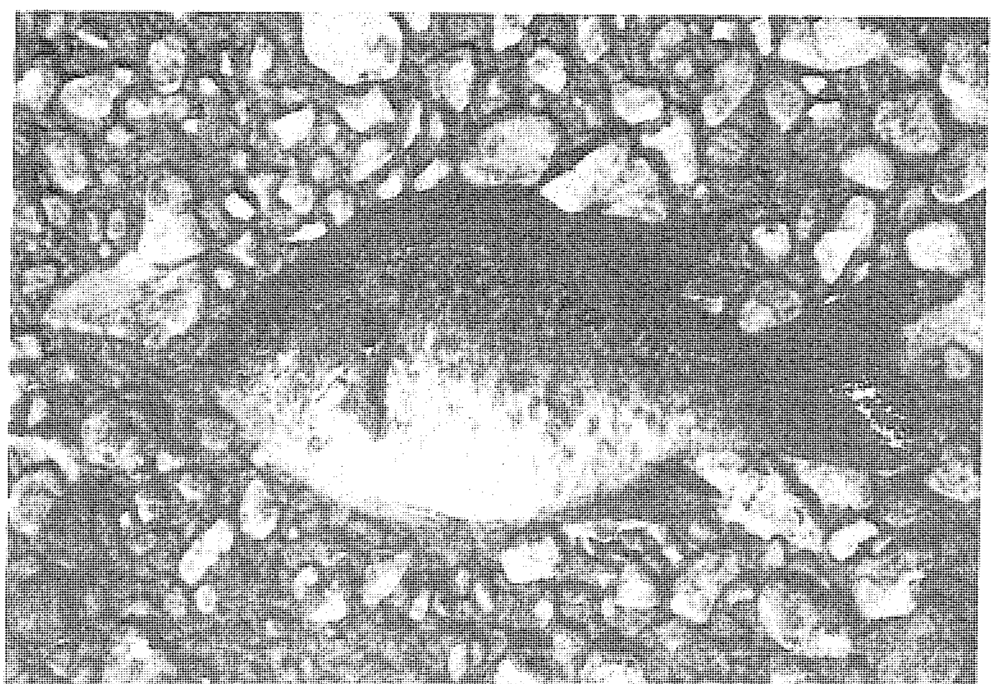

Figure 10. Redear sunfish (*Lepomis microlophus*)

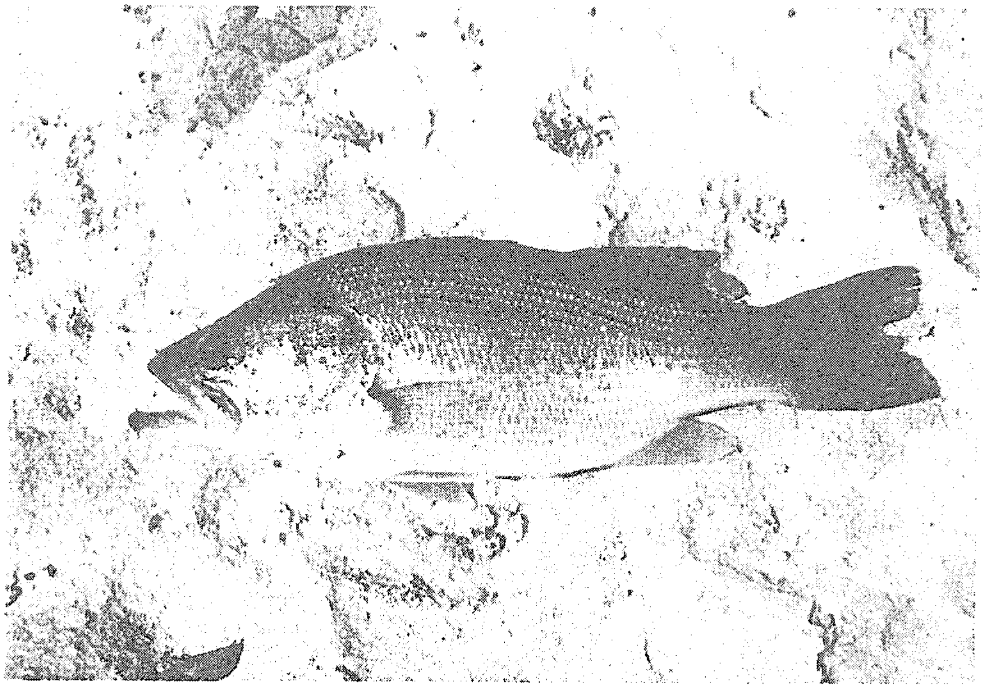

Figure 11. Largemouth bass (*Micropterus salmoides*)

APPENDIX F

Chapter 1 of the iSWM Design Manual for Site Development

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Local Criteria

iSWM™ Design Manual for Site Development

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CHAPTER

1

Table of Contents

Chapter 1 – Storm Water Management System Planning and Design

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STORM WATER MANAGEMENT SYSTEM PLANNING AND DESIGN

Section 1.1 Storm Water Site Planning

1.1.1 Overview

1.1.1.1 Introduction

In order to most effectively and efficiently manage storm water on new development and redevelopment sites, consideration of storm water runoff needs to be fully integrated into the site planning and design process. This involves a more comprehensive approach to site planning and a thorough understanding of the physical characteristics and natural resources of the site. In addition, the management of the quantity and the quality of storm water should be addressed in an integrated approach. The purpose of this manual is to provide design guidance and a framework for incorporating effective and environmentally sensitive storm water management into the site development process and to encourage a greater uniformity in developing plans for storm water management systems that meet the following goals:

- Control conveyance of runoff within and from the site to minimize flood risk to people and properties;
- Assess discharges from the site to minimize downstream bank and channel erosion; and
- Reduce pollutants in storm water runoff to protect water quality;

When designing the storm water management system for a site, a number of questions need to be answered by the site planners and design engineers, including:

- How can the storm water management system be designed to most effectively address the quality of runoff from the site, protect against increased streambank erosion, and meet flood control objectives?
- What are the opportunities for utilizing site design practices to minimize the need for and the size of structural storm water controls?
- What are the development site constraints that preclude the use of certain structural controls?
- What structural controls are most suitable and cost-effective for the site?

1.1.1.2 Five (5) Principles of Storm Water Management Site Planning

The following Five (5) Principles of Storm Water Management Site Planning should be kept in mind in preparing an iSWM Site Plan for a development or redevelopment site:

1. **The site design should utilize an integrated approach to deal with storm water quality protection, streambank protection, and flood control requirements.**

   The storm water management infrastructure for a site should be designed to integrate drainage and flood control, water quality protection, and downstream streambank protection. Site design should be done in unison with the design and layout of storm water infrastructure to better attain storm water management goals. Together, the combination of site design practices and effective infrastructure layout and design can mitigate the worst storm water impacts of most urban developments while preserving stream integrity and aesthetic attractiveness.

2. **Storm water management practices should strive to utilize the natural drainage system and require as little maintenance as possible.**

   Almost all sites contain natural features which can be used to help manage and mitigate runoff from development. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas that can be used to reduce runoff; provide infiltration, and storm water filtering of pollutants and sediment; recycle nutrients; and maximize on-site storage of storm water.

   Site design should seek to supplement the effectiveness of natural systems rather than to ignore or replace them. Further, natural systems typically require low or no maintenance, and will continue to function many years into the future.

3. **Structural storm water controls should be implemented only after all site design and nonstructural options have been exhausted.**

   Operationally, economically, and aesthetically, storm water sensitive site design and the use of natural techniques offer significant benefits over structural storm water controls. Therefore, all opportunities for utilizing these methods should be explored before implementing structural storm water controls such as wet ponds.

4. **Structural storm water solutions should attempt to be multi-purpose and be aesthetically integrated into a site's design.**

   A structural storm water facility need not be an afterthought or ugly nuisance on a development site. A parking lot, soccer field, or city plaza can serve as a temporary storage facility for storm water. In addition, water features such as ponds and lakes, when correctly designed and integrated into a site, can increase the aesthetic value of a development.

5. **"One size does not fit all" in terms of storm water management solutions.**

   Although the basic problems of storm water runoff and the need for its management remain the same, each site, project, and watershed presents different challenges and opportunities. For instance, an infill development in a highly urbanized town center or downtown area will require a much different set of storm water management solutions than a low-density residential subdivision in a largely undeveloped watershed. Therefore, local storm water management needs to take into account differences between development sites, different types of development and land use, various watershed conditions and priorities, the nature of downstream lands and waters, and community desires and preferences.

1.1.2 *integrated* Storm Water Management (iSWM) Site Plans

1.1.2.1 Introduction

To encourage and ensure that the storm water management goals are addressed and that local storm water guidelines and requirements are implemented, communities adopting this manual shall implement a formal *integrated* Storm Water Management Site Plan or iSWM Site Plan preparation, submittal, and review process that facilitates open communication and understanding between the involved parties.

An iSWM Site Plan is a comprehensive report that contains the technical information and analysis to allow a community to determine whether the storm water management system of a proposed new development or redevelopment project meets the general storm water management goals and the local storm water regulatory requirements. This section discusses the typical contents of an iSWM Site Plan, the steps for a site developer to follow in preparing an iSWM Site Plan, and the recommended review and consultation checkpoints between the local government staff and the site developer.

The procedures and guidelines for the preparation of an iSWM Site Plan should be explicitly stated in a local ordinance. The ordinance, in turn, should refer to this Manual for additional detail. Ideally, site storm water plans are developed with open lines of communication between the developer (and developer's engineer) and the plan reviewer. iSWM Site Plans are an enhanced version of traditional drainage plans, and are more than just the preparation of a document and maps. Instead, iSWM Site Plans should be thought of as a subset of the overall development process that occurs throughout the planning and development cycle of a project and then continues after construction is completed via regular inspection and maintenance of the storm water management system.

1.1.2.2 Applicability

iSWM Site Planning is applicable to land disturbing activity of 1 acre or more where total impervious area is increased by more than 5% above the current land development conditions. The Local Criteria section may provide additional definition, restrictions, or exceptions to the applicability of iSWM Site Plans based on the size of the development, specific watershed conditions, or identified hotspots of concern within the local jurisdiction. (Hotspots are land uses or activities that produce higher concentrations of trace metals, hydrocarbons, or other priority pollutants. See page 5.1-8 for examples.)

New development or redevelopment in critical or sensitive areas, or as identified through a watershed study or plan, may be subject to additional performance and/or regulatory criteria. Furthermore, these sites may need to utilize certain structural controls in order to protect a special resource or address certain water quality or drainage problems identified for a drainage area or watershed.

All iSWM Site Plans shall be prepared and sealed by a Licensed Professional Engineer with a valid license from the State of Texas. The Engineer shall attest that the design was conducted in accordance with this integrated Storm Water Management Design Manual.

1.1.2.3 Contents of an iSWM Site Plan

The following elements are typical components of an iSWM Site Plan. Projects could be requested by the local jurisdiction to prepare a site plan that includes a defined subset of the elements outlined below.

1. **Existing Conditions Hydrologic Analysis**
2. **Project Description and Design Considerations**
3. **Post-Development Hydrologic Analysis**
4. **Storm Water Management System Design**
5. **Construction Storm Water Pollution Prevention Plan (SWPPP)**
6. **Landscaping Plan**

7. **Operations and Maintenance Plan**
8. **Evidence of Acquisition of Applicable Federal, State, and Local Permits**
9. **Waiver Requests**

The typical contents of each element are described further in the following sections.

1.1.3 Developer Steps to Prepare an iSWM Site Plan

1.1.3.1 Introduction

An iSWM Site Plan is a comprehensive report that contains the technical information and analysis to allow a local review authority to determine whether a proposed new development or redevelopment project meets the general storm water management goals and the local storm water regulatory requirements. The iSWM site plan shall consist of site layout mapping, narrative, supporting design calculations, and plans that sufficiently represent the proposed storm water management system (recommended scale of 1" = 50' unless otherwise specified).

This section describes the typical contents and general procedure for preparing an iSWM Site Plan. The level of detail involved in the plan will depend on the project size and the individual site and development characteristics.

Prior to beginning the steps to prepare an iSWM Site Plan, the site developer should read and understand the design approach and contents of this manual. Each of the following steps is carried forward and builds upon the previous steps to result in the Final iSWM Site Plan.

Step 1 - Consider the Five (5) Principles of Storm Water Management Site Planning

Step 2 - Review of Local Requirements

Step 3 - Perform Site Analysis and Inventory

Step 4 - Prepare Conceptual iSWM Site Plan

Step 5 - Prepare Preliminary iSWM Site Plan

Step 6 - Complete Final iSWM Site Plan

Worksheets are provided in Appendix E to assist with the development of the iSWM Site Plan.

1.1.3.2 Step 1 - Consider the Five (5) Principles of Storm Water Management Site Planning

The following principles should be kept in mind during all steps of preparing an iSWM Site Plan for a development site:

1. The site design should utilize an integrated approach to deal with storm water quality protection, streambank protection and flood control requirements.
2. Storm water management practices should strive to utilize the natural drainage system and require as little maintenance as possible.
3. Structural storm water controls should be implemented only after all site design and nonstructural options have been exhausted.
4. Structural storm water solutions should attempt to be multi-purpose and be aesthetically integrated into a site's design.
5. "One size does not fit all" in terms of storm water management solutions.

1.1.3.3 Step 2 - Review of Local Requirements

The site developer should become familiar with the local storm water management and development requirements and design criteria that apply to the site. These requirements are identified in the Local Criteria section of this manual and may include:

- Design storm frequencies
- Credits for use of *integrated* Site Design Practices
- Requirements for Water Quality Protection Volume, if applicable
- Requirements for Streambank Protection Volume
- Conveyance design criteria
- Floodplain criteria
- Buffer/setback criteria
- Wetland provisions
- Watershed-based criteria
- Erosion and sedimentation control plan
- Maintenance requirements
- Need for physical site evaluations (infiltration tests, geotechnical evaluations, etc.)
- Grading plan
- Storm Water Pollution Prevention Plan (SWPPP)

Much of this guidance can be obtained at a meeting with the local review authority and should be detailed in various local ordinances (e.g., subdivision regulations, storm water and drainage codes, etc.).

Current land use plans, comprehensive plans, zoning ordinances, road and utility plans, watershed or overlay districts, and public facility plans should all be consulted to determine the need for compliance with other local, state, and federal regulatory requirements. Guidance for applicable regulatory requirements is available in Appendix C.

Opportunities for special types of development (e.g., clustering) or special land use opportunities (e.g., conservation easements or tax incentives) should be investigated. There may also be an ability to partner with a local community for the development of greenways, or other riparian corridor or open space developments.

1.1.3.4 Step 3 - Perform Site Analysis and Inventory

Using approved field and mapping techniques, the site engineer shall collect and review information on the existing site conditions and map the following site features:

- Topography
- Drainage patterns and basins
- Intermittent and perennial streams
- Soils
- Ground cover and vegetation
- Existing development
- Existing storm water facilities

- Adjacent areas
- Property lines and easements

In addition, the site engineer shall identify and map all previously unmapped natural features such as:

- Wetlands
- Critical habitat areas
- Boundaries of wooded areas
- Floodplain boundaries
- Steep slopes
- Required buffers
- Proposed stream crossing locations
- Other required protection areas (e.g., well setbacks)

Some of this information may be available from previously performed studies or from a feasibility study. For example, some of the resource protection features may have been mapped as part of erosion and sediment control activities. Other recommended site information to map or obtain includes utilities information, seasonal groundwater levels, and geologic data.

Individual map or geographic information system (GIS) layers can be designed to facilitate an analysis of the site through what is known as map overlay, or a composite analysis. Each layer (or group of related information layers) is placed on the map in such a way as to facilitate comparison and contrast with other layers. A composite layer is often developed to show all the layers at the same time (see Figure 1.1.3-1). This composite layer can be a useful tool for defining the best buildable areas and delineating and preserving natural feature conservation areas.

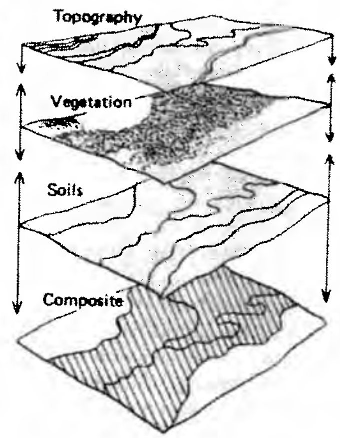

Figure 1.1.3-1
Composite Analysis
(Source: Marsh, 1983)

1.1.3.5 Step 4 - Prepare Conceptual iSWM Site Plan

Based upon the review of existing conditions and site analysis, the design engineer shall develop a Conceptual iSWM Site Plan for the project.

During the concept plan stage the site designer will perform most of the layout of the site including the conceptual storm water management system design and layout. The Conceptual iSWM Site Plan allows the design engineer to propose a potential site layout and gives the developer and local review authority a "first look" at the storm water management system for the proposed development. The Conceptual iSWM Site Plan should be submitted to the local plan reviewer before detailed preliminary site plans are developed.

The following steps shall be followed in developing the Conceptual iSWM Site Plan with the help of the Worksheet for Conceptual iSWM Site Plans found in Appendix E of this manual:

1. Use *integrated* site design practices (Section 1.3) as applicable to develop the site layout, including:
   - Preserving the natural feature conservation areas defined in the site analysis
   - Fitting the development to the terrain and minimizing land disturbance
   - Reducing impervious surface area through various techniques
   - Preserving and utilizing the natural drainage system wherever possible

2. Determine the credits for *integrated* site design (Section 1.3.4), and water quality volume reduction (Section 1.2.3.2) if applicable, to be accounted for in the design of structural and non-structural storm water controls on the site
3. Calculate conceptual estimates of the design requirements for water quality protection, streambank protection, and flood control (Section 1.2) based on the conceptual plan site layout
4. Perform screening and conceptual selection of appropriate structural storm water controls (Section1.4 and Chapter 5) and identification of potential siting locations

It is extremely important at this stage that storm water system design is integrated into the overall site design concept in order to best reduce the impacts of the development to the pre-developed drainage conditions as well as provide for the most cost-effective and environmentally sensitive approach. Using hydrologic calculations, the goal of mimicking pre-development conditions can serve a useful purpose in planning the storm water management system.

For local review purposes, following the Checklist found in Appendix E of this manual, the Conceptual iSWM Site Plan shall include site layout mapping and plans (recommended scale of 1" = 50' unless otherwise specified), which illustrate at a minimum:

Project Description

- Address and legal description of site
- Vicinity map
- Land use

Existing conditions

- Copy of applicable digital orthophotos showing proposed project boundaries
- A topographic map of existing site conditions (no greater than a 2-foot contour interval recommended) with drainage basin boundaries indicated and project boundaries shown
- Total size area (acres)
- Total impervious area as percentage (%) of total area
- Benchmarks used for site control
- Perennial and intermittent streams
- Mapping of predominant soils from USDA soil surveys
- Boundaries of existing predominant vegetation
- Location and boundaries of other natural feature protection and conservation areas such as wetlands, lakes, ponds, floodplains, stream buffers and other setbacks (e.g., drinking water well setbacks, septic setbacks, etc.)
- Location of existing roads, buildings, parking areas and other impervious surfaces
- Existing utilities (e.g., water, sewer, gas, electric) and easements
- Location of existing conveyance systems such as grass channels, swales, and storm drains
- Flow paths
- Location of floodplain/floodway limits and relationship of site to upstream and downstream properties and drainages
- Location and dimensions of existing channels, bridges or culvert crossings

Conceptual Site Layout

- Complete the iSWM Conceptual Plan Worksheet
- Hydrologic analysis to determine conceptual runoff rates, volumes, and velocities to support selection of Storm Water Controls
- Conceptual site design identifying *integrated* site design practices used

- Identification of storm water site design credits
- Identification and calculation of water quality volume reduction, if applicable
- Conceptual estimates of the three (3) storm design approach (Section 1.2) requirements
- Conceptual selection, location, and size of proposed structural storm water controls
- Conceptual limits of proposed clearing and grading
- Total proposed impervious area, as a percentage (%) of total area

The completed Conceptual iSWM Site Plan shall be submitted to the local review authority for review and comment.

1.1.3.6 Step 5 - Prepare Preliminary iSWM Site Plan

The Preliminary iSWM Site Plan ensures that requirements and criteria are being complied with and opportunities are being taken to minimize adverse impacts from the development. This step builds upon the data developed in the Conceptual iSWM Site Plan by refining and providing more detail to the concepts identified. The Worksheet for Preliminary iSWM Site Plan in Appendix E outlines the data that shall be included in the preliminary iSWM Site Plan.

The Preliminary iSWM Site Plan shall consist of maps, narrative, and supporting design calculations (hydrologic and hydraulic) for the proposed storm water management system, and shall include the following sections:

Existing Conditions Hydrologic Analysis

Provide an existing condition hydrologic analysis for storm water runoff rates, volumes, and velocities, which includes:

- Existing conditions data developed in the Conceptual iSWM Plan
- All existing storm water conveyances and structural control facilities
- Direction of flow and exits from the site
- Analysis of runoff provided by off-site areas upstream of the project site
- Methodologies, assumptions, site parameters and supporting design calculations used in analyzing the existing conditions site hydrology

Project Description and Design Considerations Provide an updated description of the project and the considerations and factors affecting the design approach that have changed between the conceptual and preliminary plans, including:

- A description of the overall project and the site plan showing facility locations, roadways, etc.
- A discussion of the applicable local criteria and how it will be integrated into the design of the project (see Local Criteria section)
- Identify the *integrated* Site Design Practices and their applicability to this site (see Section 1.3)
- If applicable, a discussion of Credits for *integrated* Site Design and their applicability to this site (see Section 1.3.4)
- A discussion of the water quality treatment techniques (pollution prevention practices) that are to be utilized on this site, if applicable
- A determination of groundwater recharge considerations, if applicable, for this site
- Identify hotspot land uses, if applicable, and how runoff will be addressed (see page 5.1-8 for examples of hotspots)

Post-Development Hydrologic Analysis

Provide a post-development hydrologic analysis using appropriate methods from Chapter 2 for storm water runoff rates, volumes, and velocities, which includes:

- A topographic map of developed site conditions (no greater than a 2-foot contour interval recommended) with the post-development basin boundaries indicated
- Total area of post-development impervious surfaces and other land cover areas for each subbasin affected by the project
- Runoff calculations for flood control and streambank protection for each subbasin, as well as any applicable water quality calculations
- Location and boundaries of proposed natural feature protection and conservation areas
- Documentation and calculations for any applicable site design credits or water quality volume reduction methods being utilized
- Methodologies, assumptions, site parameters and supporting design calculations used in analyzing the post-development conditions site hydrology
- Supporting documentation that there is existing streambank protection/reinforcement or that the planned development will provide such streambank protection downstream
- Supporting calculations for a downstream peak flow analysis to show safe passage of post-development design flows downstream. Document point downstream at which analysis ends, and how it was determined

In calculating runoff volumes and discharge rates, consideration may need to be given to any planned future upstream land use changes. Depending on the site characteristics and given local design criteria, upstream lands may need to be modeled as "existing condition" or "projected buildout/future condition" when sizing and designing on-site conveyances and storm water controls.

Storm Water Management System Design

Provide drawings and design calculations for the proposed storm water management system, including:

- A drawing or sketch of the storm water management system including the location of non-structural site design features and the placement of existing and proposed structural storm water controls. This drawing shall show design water surface elevations, storage volumes available from zero to maximum head, location of inlet and outlets, location of bypass and discharge systems, and all orifice/restrictor sizes.
- Narrative describing that appropriate and effective structural storm water controls from Chapter 5 have been selected
- Cross-section and profile drawings and design details for each of the structural storm water controls in the system. This should include supporting calculations to show that the facility is designed according to the applicable design criteria
- Hydrologic and hydraulic analysis of the storm water management system for all applicable design storms (should include stage-storage or outlet rating curves, and inflow and outflow hydrographs), refer to Chapters 2,3 and 4
- Documentation and supporting calculations to show that the storm water management system adequately meets the *integrated* Design Approach (Section 1.2)
- Drawings, design calculations and elevations for all existing and proposed storm water conveyance elements including storm water drains, pipes, culverts, catch basins, channels, swales and areas of overland flow, using guidance from Chapters 3 and 4

The completed Preliminary iSWM Site Plan shall be submitted to the local review authority for review and comment.

1.1.3.7 Step 6 - Complete Final iSWM Site Plan

The Final iSWM Site Plan adds further detail to the Preliminary iSWM Site Plan and reflects changes that are requested or required by the local review authority. The Final iSWM Site Plan, as outlined in the final iSWM Site Plan Worksheet in Appendix E, should include all of the revised elements of the Preliminary iSWM Site Plan as well as the following items:

Construction Storm Water Pollution Prevention Plan (SWPPP)

- Must contain all the elements specified in the iSWM Design Manual for Construction, local ordinances, and State regulations
- Sequence/phasing of construction and temporary stabilization measures
- Temporary structures that will be converted into permanent storm water controls

Landscaping Plan

- Arrangement of planted areas, natural areas, and other landscaped features on the site plan
- Information necessary to construct the landscaping elements shown on the plan drawings
- Descriptions and standards for the methods, materials, and vegetation that are to be used in the construction

Operations and Maintenance Plan

- Description of maintenance tasks, frequency of maintenance, responsible parties for maintenance, funding, access, and safety issues
- Reviewed and approved maintenance agreements

Evidence of Acquisition of Applicable Federal, State, and Local Permits

Description and copies of any applicable federal, state, and/or local environmental permits such as USACE Regulatory Program permits, 401 water quality certification, or construction TPDES permits. Permits must be obtained prior to or in conjunction with final plan submittal, including:

- Notice of Intent (NOI) or Construction Site Notice, as appropriate, for TPDES permits
- Permits obtained for any other storm water related development requirements (i.e. USACE Regulatory Program permits, erosion control, grading, water rights permits, TCEQ dam safety, etc.)

Waiver Requests

- Description of waiver requests

The completed Final iSWM Site Plan shall be submitted to the local review authority for final approval prior to any construction activities on the development site.

1.1.4 Local Community Plan Review Responsibilities

The iSWM Site Plans are to be reviewed by the local community. The approach recommended herein should be adopted by a community to adapt to its current plan review procedure. In most communities, part of their overall project approval process includes reviews of (1) Concept Plans, (2) Preliminary Plans, and (3) Final Plans.

The recommended approach is to incorporate the review of iSWM Site Plans into a community's current process, in an attempt to complement, not replace their overall process. Following is a brief discussion of each step with references to checklists that complement that procedure:

1. **Concept Plan Stage**

   Review of the Conceptual iSWM Site Plan – During the concept plan stage the site designer will perform most of the layout of the site including the conceptual storm water management system design and layout. The Conceptual iSWM Site Plan allows the design engineer to propose a potential site layout and gives the developer and local review authority a "first look" at the storm water management system for the proposed development. The Conceptual iSWM Site Plan shall be submitted to and approved by the local plan reviewer before detailed preliminary site plans are developed.

   It is in the Concept Plan Stage that the site developer is best able to integrate the storm water system design into the overall site design concept in order to reduce the impacts of the development, as well as provide for the most cost-effective and environmentally sensitive approach. This is done, in part, by evaluating and integrating as appropriate Credits for *integrated* Site Designs and Water Quality Protection Volume reduction. A recommended checklist for the Conceptual iSWM Site Plan Review is included in Appendix E of this Manual.

2. **Preliminary Plan Stage**

   Review of Preliminary iSWM Site Plan - The preliminary plan ensures that local requirements and criteria are being complied with and opportunities are being taken to minimize adverse impacts from the development.

   The Preliminary iSWM Site Plan shall consist of maps, narrative, and supporting design calculations (hydrologic and hydraulic) for the proposed storm water management system, and shall include the preliminary versions of the following iSWM Site Plan components:

   a. Existing Conditions Hydrologic Analysis

   b. Project Description and Design Considerations

   c. Post-Development Hydrologic Analysis

   d. Storm Water Management System Design

   A recommended checklist for the Preliminary iSWM Site Plan Review is included in Appendix E of this Manual.

   It shall be demonstrated that appropriate and effective storm water controls have been selected and adequately designed. The preliminary plan shall also include, among other things, street and site layout, delineation of natural feature protection and conservation areas, soils data, existing and proposed topography, relation of site to upstream drainage, limits of clearing and grading, and proposed methods to manage and maintain conservation areas (e.g., easements, maintenance agreements/responsibilities, etc.)

3. **Final Plan Stage**

   Review Final iSWM Site Plan - The Final iSWM Site Plan adds further detail to the preliminary plan and reflects changes that are requested or required by the local review authority. The Final iSWM Site Plan shall include all of the revised elements from the preliminary plan as well as the following remaining items:

   a. Construction Storm Water Pollution Prevention Plan (SWPPP)

   b. Landscaping Plan

   c. Operations and Maintenance Plan

   d. Evidence of Acquisition of Applicable Federal, State, and Local Permits

e. Waiver Requests

A recommended checklist for the Final iSWM Site Plan Review is included in Appendix E of this Manual.

This process should be iterative. The reviewer should ensure that all submittal requirements have been satisfactorily addressed and permits, easements, and pertinent legal agreements (e.g., maintenance agreements, performance bond, etc.) have been obtained and/or executed.

The approved Final iSWM Site Plan shall be submitted during the platting development process to the local review authority for final approval. The iSWM Site Plan must be approved prior to the preliminary plat approval and prior to any construction activities on the development site. Approval of the Final iSWM Plan is the last major milestone in the storm water planning process. The remaining steps are to ensure the plan is installed, implemented, and maintained properly.

1.1.5 Local Community Responsibilities during Construction and Operation

After the iSWM Site Plan and the final plat have been prepared and approved, the project will move into construction and the ongoing operation of related facilities and storm water treatment areas. Again, most communities have as part of their overall process, steps to ensure that approved facilities are installed as approved and are appropriately maintained after construction. The approach recommended herein can be adopted by a community to adapt to its construction and facility review procedures. In most communities, part of their overall project process will include: (1) Construction Inspections and (2) Ongoing Maintenance Inspections.

The recommended approach is to incorporate the above steps into a community's current process, in an attempt to complement, not replace their overall process. The following steps are intended to provide a community with a review process and checklist that complement their current procedures:

1. **Construction Inspections**

   Where possible, a pre-construction meeting shall occur before any clearing or grading is initiated on the site. This is the appropriate time to ensure that natural feature protection areas and limits of disturbance have been adequately staked and adequate erosion and sediment control measures are in place. This step ensures that the owner/developer, contractor, engineer, inspector, and plan reviewer can be sure that each party understands how the plan will be implemented on the site.

   Project sites should periodically be inspected during construction by local agencies to ensure that conservation areas have been adequately protected and that storm water control and conveyance facilities are being constructed as designed. Inspection frequency may vary with regard to site size and location; however, monthly inspections are a minimum target. In addition, it is recommended that some inspections occur after larger storm events (e.g., 0.5 inches and greater to assure compliance with the TPDES Construction General Permit). The inspection process can prevent later problems that result in penalties and added cost to developers.

   An added benefit of a formalized and regular inspection process is that it should help to motivate contractors to internalize regular maintenance of sediment controls as part of the daily construction operations and not disturb water quality area "set-asides." If necessary, a community can consider implementing a penalty system whereby things such as stop work orders could be issued.

   A final inspection is needed to ensure that the construction conforms to the intent of the approved design. Prior to accepting the infrastructure components, issuing an occupancy permit, and releasing any applicable bonds, the review authority should ensure that: (1) temporary erosion control measures have been removed; (2) storm water controls are unobstructed and in good working order;

(3) permanent vegetative cover has been established in exposed areas; (4) any damage to natural feature protection and conservation areas has been mitigated; (5) conservation areas and buffers have been adequately marked or signed; and (6) any other applicable conditions have been met.

Record drawings of the structural storm water controls, drainage facilities, and other infrastructure components should also be acquired by the community, as they are important in the long-term maintenance of the facilities. The review authority should keep copies of the drawings and associated documents and develop a local storm water control inventory and data storage system. With geographic information systems (GIS) becoming more widely used, much of this data can be stored electronically.

2. **Ongoing Maintenance Inspections**

Ongoing inspection and maintenance of a project site's storm water management system is often the weakest component of storm water plans. It needs to be clearly detailed in the iSWM Site Plan which entity has responsibility for operation and maintenance of all structural storm water controls and drainage facilities. Often, the responsibility for maintenance is transferred from the developer and contractor to the owner. Communication about this important responsibility is usually inadequate. Therefore, communities may need to consider ways to notify property owners of their responsibilities. For example, notification can be made through a legal disclosure upon sale or transfer of property or public outreach programs may be instituted to describe the purpose and value of maintenance.

Ideally, preparation of maintenance plans should be a requirement of the iSWM Site Plan preparation and review process. A maintenance plan should outline the scope of activities, schedule, costs, funding source, and responsible parties. Vegetation, sediment management, access, and safety issues should also be addressed. In addition, the plan should address the testing and disposal of sediments that will likely be necessary and the ultimate replacement of structures as needed.

Annual inspections of storm water management facilities should be conducted by an appropriate local agency. Where chronic or severe problems exist, the local government should have the authority to remedy the situation and charge the responsible party for the cost of the work. This authority should be well established in an ordinance.

1.1.6 iSWM Site Plan Design Tools

There are several design tools that can be used by the developer, planner, and engineer in the development of an iSWM Site Plan for a specific project. The tools include the following, which are discussed in more detail in subsequent sections of this Manual:

***integrated* Planning and Design Approach** (Section 1.2)

- Design requirements to achieve water quality protection, streambank protection, and flood control goals

***integrated* Site Design Practices** (Section 1.3)

- Nonstructural approaches to be used during site planning

***integrated* Storm Water Controls** (Section 1.4)

- Controls to remove pollutants, regulate discharge, and/or convey storm water

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CHAPTER
1

Section 1.2
integrated Planning and Design Approach

1.2.1 Introduction

This section presents an integrated approach for meeting the storm water runoff quality and quantity management goals by addressing the key adverse impacts of development on storm water runoff. The purpose is to provide guidance for designing a comprehensive storm water management system as part of the iSWM Site Plan to:

- Remove pollutants in storm water runoff to protect water quality;
- Assess discharge from the site to minimize downstream bank and channel erosion; and
- Control conveyance of runoff within and from the site to minimize flood risk to people and property.

The *integrated* Design Approach is a coordinated set of design standards that allow the site engineer to design and size storm water controls to address these goals. Each of the *integrated* Design Steps should be used in conjunction with the others to address the overall storm water impacts from a development site. When used as a set, the *integrated* Design Approach controls the entire range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100-year, 24-hour storm. Through the *integrated* Design Approach, each community receives standardized options while retaining the flexibility to define their own program. The Local Criteria section of this manual specifies the options allowed and/or required by the community.

The design approach for each of the goals above is summarized in Table 1.2.1-1 below:

Table 1.2.1-1 Steps for *integrated* Design Approach for Storm Water Control and Impact Mitigation

Steps	Approach
Step 1: Downstream Assessment	Conduct a downstream assessment to the point at which the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. The assessment shall analyze downstream impacts from a development for three (3) storm events based on Local Criteria: (1) a "Streambank Protection" storm, either the 1- or 2-year, 24-hour event, (2) a "Conveyance" storm, either the 5-, 10-, or 25-year, 24-hour event, and (3) the "100-year" storm, a 100-year 24-hour storm event.
Step 2: Water Quality Protection	Achieve by conserving natural features, reducing impervious cover, and using the natural drainage system by applying the *integrated* Site Design Practices; as approved by the local jurisdiction. For enhanced water quality protection use one or both of the following options: (1) If required by the Local Criteria, treat the Water Quality Protection Volume (WQ_V) by reducing total suspended solids from the development site for runoff resulting from rainfalls of up to 1.5 inches (85th percentile storm); (2) Assist in implementing off-site community storm water pollution prevention programs/activities as designated in an approved storm water master plan or TPDES Storm Water permit.

Table 1.2.1-1 Steps for *integrated* Design Approach for Storm Water Control and Impact Mitigation	
Step 3: Streambank Protection	Provide streambank protection from erosion due to increased storm water volumes and velocities caused by development using one or more of the following options: (1) Determine acceptable downstream conditions; (2) Reinforce/stabilize downstream conditions; (3) Install storm water controls to maintain existing downstream conditions; (4) Provide on-site controlled release of the 1-year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SP_V).
Step 4: Flood Control	Flood impact reduction may be achieved by a combination of on-site control, downstream protection, floodplain management, and/or other mitigation measures. Onsite: Minimize localized site flooding of streets, sidewalks, and properties by a combination of on-site storm water controls and conveyance systems. These systems will be designed for the "Streambank Protection" and "Conveyance" storm event frequencies. Depending upon their location, function, and the requirements of the local jurisdiction, the full build-out "100-year" storm event is to be conveyed on-site such that no resulting habitable structural flooding occurs. Downstream: Based on the downstream assessment, manage downstream flood impacts caused by the increase of storm water discharges from the development using one or more of following options: (1) Determine acceptable downstream conditions; (2) Provide adequate downstream conveyance systems, (3) Install storm water controls on-site to maintain existing downstream conditions; (4) In lieu of a downstream assessment, maintain existing on-site runoff conditions.

Figure 1.2.1-1 graphically illustrates the relative volume requirements of each of the *integrated* Design Steps and demonstrates that the pieces typically overlay one another. If the downstream assessment for flood control indicated upstream detention was needed to limit the discharge from a development, the volume requirement to achieve the downstream flood control requirement could also contain the volume needed to provide for Streambank Protection and, if required, Water Quality Protection. The appropriate type of detention facility could be designed with outlet controls to address each of the steps of the Design Approach. Obviously, detention may not be required in all situations, but consideration of site design practices and storm water controls that work together to meet all the requirements is what is important. The following sections describe the *integrated* Design Approach in more detail.

Figure 1.2.1-1 Representation of the *integrated* Design Approach

1.2.2 Downstream Assessment

As part of the iSWM Site Plan development, the downstream impacts of development must be carefully evaluated. The purpose of the downstream assessment is to protect downstream properties from increased flooding and downstream channels from increased erosion potential due to upstream development. The importance of the downstream assessment is particularly evident for larger sites or developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic and, as such, following the *integrated* Design Approach is just as important for the smaller sites as it is for the larger sites.

The assessment should extend from the outfall of a proposed development to a point downstream where the discharge from a proposed development no longer has a significant impact on the receiving stream or storm drainage system. The assessment should be a part of the concept, preliminary, and final iSWM site plans, and should include the following properties:

- Hydrologic analysis of the pre- and post-development on-site conditions
- Drainage path which defines extent of the analysis.
- Capacity analysis of all existing constraint points along the drainage path, such as existing floodplain developments, underground storm drainage systems culverts, bridges, tributary confluences, or channels
- Offsite undeveloped areas are considered as "full build-out" for both the pre- and post-development analyses
- Evaluation of peak discharges and velocities for three (3) 24-hour storm events
  - Small-frequency storm for "Streambank Protection", either the 1- or 2-year event
  - A "Conveyance" storm of either the 5-, 10-, or 25-year event
  - A "100-year" storm event
- Separate analysis for each major outfall from the proposed development

Once the analysis is complete, the designer should ask the following three questions at each determined junction downstream:

- Are the post-development discharges greater than the pre-development discharges?
- Are the post-development velocities greater than the pre-development velocities?
- Are the post-development velocities greater than the velocities allowed for the receiving system?

These questions should be answered for each of the three storm events. The answers to these questions will determine the necessity, type, and size of non-structural and structural controls to be placed on-site or downstream of the proposed development. Section 2.1 gives additional guidance on calculating the discharges and velocities, as well as determining the downstream extent of the assessment.

1.2.3 Water Quality Protection

iSWM requires the use of *integrated* Site Design Practices as the primary means to protect the water quality of our streams, lakes, and rivers from the negative impacts of storm water runoff from development. A community should provide adequate water quality protection for development sites by specifying in their Local Criteria the acceptable *integrated* Site Design Practices for the local community. Enhanced water quality protection shall only be required as identified by the Local Criteria section of this manual.

<u>Use of *integrated* Site Design Practices</u>

Through the consideration and use of *integrated* Site Design practices, as discussed in Section 1.3, natural drainage and treatment systems can be preserved. With conservation of natural features, reduced imperviousness, and the use of the natural drainage system, the generation of storm water runoff and pollutants from the site is reduced.

Enhanced water quality protection can be achieved by use of one or both of the following two options:

Option 1: Treat the Water Quality Protection Volume

A municipality may identify specific watersheds with documented poor water quality and require design enhancements as a part of the on-site controls to address water quality protection. Therefore, using the Water Quality Protection Volume as required by the Local Criteria, storm water runoff generated from sites can be treated using a variety of on-site structural and nonstructural techniques with the goal of removing a target percentage of the average annual total suspended solids.

A system has been developed by which the Water Quality Protection Volume can be reduced, thus requiring less structural control. This is accomplished through the use of certain reduction methods, where affected areas can be deducted from the site area ("A") in the formula, thereby reducing the amount of runoff to be treated ("WQ_v"). For more information on the Water Quality Volume Reduction Methods see Section 1.2.3.2.

Option 2: Assist with Off-site Pollution Prevention Activities/Programs

Some communities may implement pollution prevention programs/activities in certain areas to remove pollutants from the runoff after it has been discharged from the site. This may be especially true in intensely urbanized areas facing site redevelopment where many of the BMP criteria would be difficult to apply. These programs will be identified in the local jurisdiction's approved TPDES storm water permit. In lieu of on-site treatment, the developer may be requested to simply assist with the implementation of these off-site pollution prevention programs/activities.

Through iSWM, each community receives standardized tools while retaining the flexibility to define their own program. The Local Criteria section of this manual allows for this flexibility.

1.2.3.1 Water Quality Protection Volume

Hydrologic studies show smaller, frequently occurring storms account for the majority of rainfall events. Consequently, the runoff from the many smaller storms also accounts for a major portion of the annual pollutant loadings. By treating these frequently-occurring, smaller rainfall events and the initial portion of the storm water runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area.

Studies have shown the 85th percentile storm event (i.e., the storm event that is greater than 85% of the storms that occur) is a reasonable target event to address the vast majority of smaller, pollutant-loaded storms. Based on a rainfall analysis, 1.5 inches of rainfall has been identified as the average depth corresponding to the 85th percentile storm for the NCTCOG region. The runoff from these 1.5 inches of rainfall is referred to as the Water Quality Protection Volume (WQ_v). Thus, a storm water management system designed for the WQ_v will treat the runoff from all storm events of 1.5 inches or less, as well as a portion of the runoff for all larger storm events. The Water Quality Protection Volume is directly related to the amount of impervious cover and is calculated using the formula below:

$$WQ_V = \frac{1.5R_VA}{12}$$

where:

WQ_v = Water Quality Protection Volume (in acre-feet)

R_v = 0.05 + 0.009(I) where I is percent impervious cover

A = site area in acres remaining after reduction

Determining the Water Quality Protection Volume (WQ_v)

- *Measuring Impervious Area*: The area of impervious cover can be taken directly off a set of plans or appropriate mapping. Where this is impractical, NRCS TR-55 land use/impervious cover relationships can be used to estimate impervious cover. I is expressed as a percent value not a fraction (e.g., I = 30 for 30% impervious cover)
- *Multiple Drainage Areas*: When a development project contains or is divided into multiple outfalls, WQ_v should be calculated and addressed separately for each outfall.
- *Water Quality Volume Reduction*: The use of certain *integrated* site design practices may allow the WQ_v to be reduced. These volume reduction methods are described in Section 1.2.3.3.
- *Determining the Peak Discharge for the Water Quality Storm:* When designing off-line structural control facilities, the peak discharge of the water quality storm (Q_{wq}) can be determined using the method provided in Section 2.1.10.2.
- *Extended Detention of the Water Quality Volume:* The water quality treatment requirement can be met by providing a 24-hour drawdown of a portion of WQ_v in a storm water pond or wetland system (as described in Chapter 5). Referred to as water quality ED (extended detention), it is different than providing extended detention of the 1-year storm for the streambank protection volume (SP_v). The ED portion of the WQ_v may be included when routing the SP_v.
- *Permanent Pool:* Wet ponds and wetlands will have permanent pools, the volume of which may be used to account for up to 50% of the WQ_v.
- WQ_v can be expressed in cubic feet by multiplying by 43,560. WQ_v can also be expressed in watershed-inches by removing the area (A) and the "12" in the denominator.

This approach to control pollution from storm water runoff treats the WQ_v from a site to reduce a target percentage of post-development total suspended solids (TSS). TSS was chosen as the representative storm water pollutant for measuring treatment effectiveness for several reasons:

- The measurement standard of using TSS as an "indicator" pollutant is well established.
- Suspended sediment and turbidity, as well as other pollutants of concern adhere to suspended solids, and are a major source of water quality impairment due to urban development in the region's watersheds.
- A large fraction of many other pollutants of concern are removed either along with TSS, or at rates proportional to the TSS removal.

Even though TSS is a good indicator for many storm water pollutants, there are special cases that warrant further consideration including:

- The removal performance for pollutants that are soluble or that cannot be removed by settling must be specifically designed for. For pollutants of specific concern, individual analyses of specific pollutant sources should be performed and the appropriate removal mechanisms implemented.
- Runoff, which is atypical in terms of normal TSS concentrations, will be treated to a higher or lesser degree. For example, treatment of highly turbid waters would attain a higher removal percentage but still may not attain acceptable water quality without additional controls or a higher level of BMP maintenance.
- Bed and bank-material sediment loads not accurately measured by the TSS standard are also typically removed using this approach.
- Site, stream, or watershed specific criteria, different from the TSS standard, may be developed through a state or federal regulatory program necessitating a tailored approach to pollution prevention.

1.2.3.2 Water Quality Volume Reduction Methods

A set of storm water "volume reduction methods" is presented to provide developers and site designers an incentive to implement site designs that can reduce the volume of storm water runoff and minimize the pollutant loads from a site. The reduction directly translates into cost savings to the developer by reducing the size of structural storm water control and conveyance facilities.

The basic premise of the system is to recognize the water quality benefits of certain site design practices by allowing for a reduction in the water quality protection volume (WQ_v). If a developer incorporates one or more of the methods in the design of the site, the requirement for capture and treatment of the water quality protection volume will be reduced.

The methods by which the water quality volume can be reduced are listed in Table 1.2.3-1. Site-specific conditions will determine the applicability of each method. For example, the stream buffer reduction cannot be taken on upland sites that do not contain perennial or intermittent streams. Perennial streams flow 365 days a year in a normal year. Intermittent streams have short or lengthy periods of time when there is no flow in a normal year.

Table 1.2.3-1 Methods to Reduce the Water Quality Volume

Practice	Description
Natural area conservation	Undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics.
Stream buffers	Storm water runoff is treated by directing sheet flow runoff through a naturally vegetated or forested buffer as overland flow.
Use of vegetated channels	Vegetated channels are used to provide storm water treatment.
Overland flow filtration/infiltration zones	Overland flow filtration/infiltration zones are incorporated into the site design to receive runoff from rooftops and other small impervious areas.
Environmentally sensitive large lot subdivisions	A group of site design techniques are applied to low and very low density residential development.

Site designers are encouraged to use as many volume reduction methods as they can on a site. Greater reductions in storm water storage volumes can be achieved when many methods are combined (e.g., disconnecting rooftops and protecting natural conservation areas). However, volume reduction cannot be claimed twice for an identical area of the site (e.g. claiming a reduction for stream buffers and disconnecting rooftops over the same site area).

Due to local safety codes, soil conditions, and topography, some of these volume reduction methods may be restricted. Designers are encouraged to consult with the appropriate approval authority to ensure if and when a reduction is applicable and to determine restrictions on non-structural strategies.

The methods by which the water quality volume can be reduced are detailed below. For each volume reduction method, there is a minimum set of criteria and requirements that identify the conditions or circumstances under which the reduction may be applied. The intent of the suggested numeric conditions (e.g., flow length, contributing area, etc.) is to avoid situations that could lead to a volume reduction being granted without the corresponding reduction in pollution attributable to an effective site design modification.

Volume Reduction Method #1: Natural Area Conservation

A water quality volume reduction can be taken when undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics. Under this method, a designer would be able to subtract the conservation areas from the total site area when computing the water quality protection volume. An added benefit is that the post-development peak discharges will be smaller, and hence, water quantity control volumes will be reduced due to lower post-development curve numbers or rational formula "C" values.

Rule: Subtract conservation areas from total site area when computing water quality protection volume requirements.

Criteria:

- Conservation area cannot be disturbed during project construction and must be protected from sediment deposition.
- Shall be protected by limits of disturbance clearly shown on all construction drawings
- Shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management]
- Shall have a minimum contiguous area requirement of 10,000 square feet
- R_v is kept constant when calculating WQ_v
- Must be forested or have a stable, natural ground cover.

Example:

Residential Subdivision
Area = 38 acres
Natural Conservation Area = 7 acres
Impervious Area = 13.8 acres

$R_v = 0.05 + 0.009\ (I) = 0.05 + 0.009\ (36.3\%) = 0.38$

Reduction:

7.0 acres in natural conservation area

New drainage area = 38 – 7 = 31 acres

Before reduction:
$WQ_v = (1.5)(0.38)(38)/12 = 1.81$ ac-ft

With reduction:
$WQ_v = (1.5)(0.38)(31)/12 = 1.47$ ac-ft

(19% reduction in water quality protection volume)

Volume Reduction Method #2: Stream Buffers

This reduction can be taken when a stream buffer effectively treats storm water runoff. Effective treatment constitutes treating runoff through overland flow in a naturally vegetated or forested buffer. Under the proposed method, a designer would be able to subtract areas draining via overland flow to the buffer from total site area when computing water quality protection volume requirements. In addition, the volume of runoff draining to the buffer can be subtracted from the streambank protection volume. The design of the stream buffer treatment system must use appropriate methods for conveying flows above the annual recurrence (1-yr storm) event.

Rule: **Subtract areas draining via overland flow to the buffer from total site area when computing water quality protection volume requirements.**

Criteria:

- The minimum undisturbed buffer width shall be 50 feet
- The maximum contributing length shall be 150 feet for pervious surfaces and 75 feet for impervious surfaces
- The average contributing slope shall be 3% maximum unless a flow spreader is used
- Runoff shall enter the buffer as overland sheet flow. A flow spreader can be installed to ensure this
- Buffers shall remain as naturally vegetated or forested areas and will require only routine debris removal or erosion repairs
- R_v is kept constant when calculating WQ_v
- Not applicable if overland flow filtration/groundwater recharge reduction is already being taken

Example:

Residential Subdivision
Area = 38 acres
Impervious Area = 13.8 acres
Area Draining to Buffer = 5 acres

$R_v = 0.05 + 0.009\,(I) = 0.05 + 0.009\,(36.3\%) = 0.38$

Reduction:

5.0 acres draining to buffer

New drainage area = 38 – 5 = 33 acres

Before reduction:
$WQ_v = (1.5)(0.38)(38)/12 = 1.81$ ac-ft

With reduction:
$WQ_v = (1.5)(0.38)(33)/12 = 1.57$ ac-ft

(13% reduction in water quality protection volume)

Volume Reduction Method #3: Enhanced Swales

This reduction may be taken when enhanced swales are used for water quality protection. Under the proposed method, a designer would be able to subtract the areas draining to an enhanced swale from total site area when computing water quality protection volume requirements. An enhanced swale can fully meet the water quality protection volume requirements for certain kinds of low-density residential development (see Volume Reduction Method #5). An added benefit is the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule: Subtract the areas draining to an enhanced swale from total site area when computing water quality protection volume requirements.

Criteria:

- This method is typically only applicable to moderate or low density residential land uses (3 dwelling units per acre maximum)
- The maximum flow velocity for water quality design storm shall be less than or equal to 1.0 feet per second
- The minimum residence time for the water quality storm shall be 5 minutes
- The bottom width shall be a maximum of 6 feet. If a larger channel is needed use of a compound cross section is required
- The side slopes shall be 3:1 (horizontal:vertical) or flatter
- The channel slope shall be 3 percent or less
- R_v is kept constant when calculating WQ_v

Example:

Residential Subdivision
Area = 38 acres
Impervious Area = 13.8 acres

R_v = 0.05 + 0.009 (I) = 0.05 + 0.009 (36.3%) = 0.38

Reduction:

12.5 acres meet enhanced swale criteria

New drainage area = 38 – 12.5 = 25.5 acres

Before reduction:
WQ_v = (1.5)(0.38)(38)/12 = 1.81 ac-ft

With reduction:
WQ_v = (1.5)(0.38)(25.5)/12 = 1.21 ac-ft

(33% reduction in water quality protection volume)

Volume Reduction Method #4: Overland Flow Filtration/Groundwater Recharge Zones

This reduction can be taken when "overland flow filtration/infiltration zones" are incorporated into the site design to receive runoff from rooftops or other small impervious areas (e.g., driveways, small parking lots, etc). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or "rain garden" areas. If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality protection volume requirements. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule: If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality protection volume requirements.

Criteria:

- Relatively permeable soils (hydrologic soil groups A and B) should be present
- Runoff shall not come from a designated hotspot
- The maximum contributing impervious flow path length shall be 75 feet
- Downspouts shall be at least 10 feet away from the nearest impervious surface to discourage "re-connections"
- The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or structural storm water control
- The length of the "disconnection" shall be equal to or greater than the contributing length
- The entire vegetative "disconnection" shall be on a slope less than or equal to 3 percent
- The surface imperviousness area to any one discharge location shall not exceed 5,000 square feet
- For those areas draining directly to a buffer, reduction can be obtained from either overland flow filtration *-or-* stream buffers (See Method #2)
- R_v is kept constant when calculating WQ_v

Example:

Site Area = 3.0 acres
Impervious Area = 1.9 acres (or 63.3% impervious cover)
"Disconnected" Impervious Area = 0.5 acres

$R_v = 0.05 + 0.009 (I) = 0.05 + 0.009 (63.3\%) = 0.62$

Reduction:

0.5 acres of surface imperviousness hydrologically disconnected

New drainage area = 3 – 0.5 = 2.5 acres

Before reduction:
$WQ_v = (1.5)(0.62)(3)/12 = 0.23$ ac-ft

With reduction:
$WQ_v = (1.5)(0.62)(2.5)/12 = 0.19$ ac-ft

(17% reduction in water quality protection volume)

Volume Reduction Method #5: Environmentally Sensitive Large Lot Subdivisions

This reduction can be taken when a group of environmental site design techniques are applied to low and very low density residential development (e.g., 1 dwelling unit per 2 acres [du/ac] or lower). The use of this method can eliminate the need for structural storm water controls to treat water quality protection volume requirements. This method is targeted towards large lot subdivisions and will likely have limited application.

Rule: Targeted towards large lot subdivisions (e.g. 2 acre lots and greater). The requirement for structural practices to treat the water quality protection volume shall be waived.

Criteria:

For Single Lot Development:

- Total site impervious cover is less than 15%
- Lot size shall be at least two acres
- Rooftop runoff is disconnected in accordance with the criteria in Method #4
- Grass channels are used to convey runoff versus curb and gutter

For Multiple Lots:

- Total impervious cover footprint shall be less than 15% of the area
- Lot areas should be at least 2 acres, unless clustering is implemented. Open space developments should have a minimum of 25% of the site protected as natural conservation areas and shall be at least a half-acre average individual lot size
- Grass channels should be used to convey runoff versus curb and gutter (see Method #3)
- Overland flow filtration/infiltration zones should be established (see Method #4)

1.2.4 Streambank Protection

The increase in the frequency and duration of bankfull flow conditions in stream channels due to urban development is the primary cause of accelerated streambank erosion and the widening and downcutting of stream channels. Therefore, streambank protection criterion applies to all development sites for which there is an increase in the natural flows to downstream feeder streams, channels, ditches, and small streams.

There are four options by which a community can provide adequate streambank protection downstream of a proposed development. The local jurisdiction should specify in their Local Criteria which of these options are acceptable, as well as any other alternatives for streambank protection. If on-site or downstream improvements are required for streambank protection, easements or right-of-entry agreements may need to be obtained in accordance with the Local Criteria.

Option 1: Determine Acceptable Downstream Conditions

The developer should first determine if existing downstream streambank protection is adequate to convey storm water velocities for post-development conditions. This is accomplished by first obtaining post-developed velocities for the "Streambank Protection" storm event from the downstream assessment, as described in Section 1.2.2. These velocities are then compared to the allowable velocity of the downstream receiving system. Allowable velocities can be found in Chapter 4 in Tables 4.4-2 and 4.4-3. If the downstream system is designed to handle the increase in velocity, the developer should provide all supporting calculations and/or documentation to show that the stream integrity will not be compromised.

Option 2: Reinforce/Stabilize Downstream Conditions

If the increased velocities are higher than the allowable velocity of the downstream receiving system, then the developer may choose to reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream post-development velocities (for the 3 storm events described in Section 1.2.2) are less than or equal to either the allowable velocity of the downstream receiving system or the pre-development velocities, whichever is higher. The developer must provide supporting calculations and/or documentation that the downstream velocities do not exceed the allowable range once the downstream modifications are installed. (See Tables 4.4-2 and 4.4-3 for allowable velocities.)

Option 3: Install Storm Water Controls On-site to Maintain Existing Downstream Conditions

The developer may also choose to use on-site controls to keep downstream post-development discharges at or below allowable velocity limits described in Option 2. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed such that downstream velocities for the three (3) storm events described in Section 1.2.2 are within an allowable range once the controls are installed.

Option 4: Provide On-site Controlled Release of the Streambank Protection Volume

Another approach to streambank protection is to specify that 24 hours of extended detention be provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume for extended detention is referred to as the Streambank Protection Volume (denoted SP_v). The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the SP_v will reduce the bank scour rate and severity.

Determining the Streambank Protection Volume (SP_v)

- *SP_v Calculation Methods:* Several methods can be used to calculate the SP_v storage volume required for a site. Subsection 2.1.11 illustrates the recommended average outflow method for volume calculation.
- *Hydrograph Generation:* The SCS TR-55 hydrograph methods provided in Section 2.1.5 can be used to compute the runoff hydrograph for the 1-year, 24-hour storm.
- *Rainfall Depths:* The rainfall depth of the 1-year, 24-hour storm will vary depending on location and can be determined from the rainfall tables included in Appendix A for various locations across North Central Texas.
- *Multiple Drainage Areas*: When a development project contains or is divided into multiple outfalls, SP_v should be calculated and addressed separately for each outfall.
- *Off-site Drainage Areas:* A structural storm water control located "on-line" will need to safely bypass any off-site flows. Maintenance agreements may be required.
- *Routing/Storage Requirements:* The required storage volume for the SP_v must lie above the permanent pool elevation in storm water ponds. Wet ponds and wetlands will have permanent pools. The portion of the WQ_v above the permanent pool may be included when routing the SP_v.
- Hydraulic control structures appropriate for each storage requirement may be needed.
- *Control Orifices:* Orifice diameters for SP_v control of less than 3 inches are not recommended without adequate clogging protection (see Section 4.6). Clogging protection must be provided on all orifices.

1.2.5 Flood Control

Flood control analyses are based on the following three (3) storm events. The storm frequencies for each event shall be established in the Local Criteria section.

- *"Streambank Protection":* Either the 1- or 2-year, 24-hour storm event
- *"Conveyance":* Either the 5-, 10-, or 25-year, 24-hour storm event
- "100-year" the 100-year, 24-hour storm event

The intent of the flood control criteria is to provide for public safety; minimize on-site and downstream flood impacts from the "Streambank Protection", "Conveyance", and "100-year" storm events; maintain the boundaries of the mapped 100-year floodplain; and protect the physical integrity of the on-site storm water controls and the downstream storm water and flood control facilities.

Flood control must be provided for on-site conveyance, as well as downstream outfalls as described in the following sections.

1.2.5.1 On-Site Conveyance

The "Conveyance" storm event is used to design standard levels of flood protection for streets, sidewalks, structures, and properties within the development. This is typically handled by a combination of conveyance systems including street and roadway gutters, inlets and drains, storm drain pipe systems, culverts, and open channels. Other storm water controls may affect the design of these systems.

The design storms used to size the various on-site conveyance systems will vary depending upon their location and function. For example, open channels, culverts, and street rights-of way are generally designed for larger events (25- to 100-year storm), whereas inlets and storm drain pipes are designed for smaller events (5- to 25-year storm). The requirements of the local jurisdiction should be obtained and utilized as shown in the Local Criteria section of this manual.

It is recommended that once the initial set of controls are selected in the iSWM Site Plan design, the full build-out 100-year, 24-hour storm be routed through the on-site conveyance system and storm water controls to determine the effects on the systems, adjacent property, and downstream areas. Even though the conveyance systems may be designed for smaller storm events, overall, the site should be designed appropriately to safely pass the resulting flows from the full build-out 100-year storm event with no flood waters entering habitable structures.

On-site flood control has many considerations for the safeguarding of people and property. On residential streets, for the "Conveyance" storm event, the safe passage of vehicular traffic is an important concern. For the 100-year storm events, traffic may be limited in order to utilize all or portions of the right-of-way for storm water conveyance in order to protect properties. As such, the effective management of storm water throughout the development for the full range of storm events is needed.

1.2.5.2 Downstream Flood Control

The downstream assessment is the first step in the process to determine if a specific development will have a flooding impact on downstream properties, structures, bridges, roadways, or other facilities. This assessment should be conducted downstream of a development to the point where the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system.. Hydrologic and hydraulic evaluations must be conducted to determine if there are areas of concerns, i.e. an increase of the Base Flood Elevations. The local jurisdiction should be consulted to obtain records and maps related to the National Flood Insurance Program and the availability of Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs) which will be helpful in this assessment.

The downstream flood control criterion is based on an analysis of the "Streambank Protection" and "Conveyance" storm events, as well as the "100-year", defined as the 100-year, 24-hour storm event (denoted Q_{p100}). The local jurisdiction should quantify the frequency of the "Streambank Protection" and "Conveyance" storm events, as well as other events that may be required based on local policy or site-specific conditions, as identified in the Local Criteria section of this manual. If on-site or downstream modifications are required for downstream flood control, easements or right-of-entry agreements may need to be obtained in accordance with the Local Criteria.

Initially, the assessment will determine if the downstream receiving system has adequate capacity in its "full build-out" floodplain. To make this determination, Q_f, the runoff which the stream can handle without having an impact on downstream properties, structures, bridges, roadways, or other facilities, must be determined. There are four options by which a community can address downstream flood control. The local jurisdiction should specify in their Local Criteria which of these options are acceptable, as well as any other alternatives for downstream flood control. These options closely follow the four options for Streambank Protection.

<u>Option 1: Determine Acceptable Downstream Conditions</u>

The developer should provide all supporting calculations and/or documentation to show that the existing downstream conveyance system has capacity (Q_f) to safely pass the full build-out Q_{p100} discharge. Systems shown to be adequate are reflective of areas where attempts have been made to keep flood-susceptible development out of the "full build-out" floodplain through a combination of regulatory controls, storm water master planning, and incentives. This includes communities that have regulated floodplains for fully-developed conditions. This approach recognizes that the impacts of new development might not be completely mitigated at the extreme flood level and provides a much greater assurance that local flooding will not be a problem because people and structures are kept out of harm's way.

<u>Option 2: Provide Adequate Downstream Conveyance Systems</u>

If the downstream receiving system does not have adequate capacity, then the developer may choose to provide modifications to the off-site, downstream conveyance system. If this option is chosen the proposed modifications must be designed to adequately convey the full build-out storm water peak discharges for the three (3) storm events. The modifications must also extend to the point at which the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. The developer must provide supporting calculations and/or documentation that the downstream peak discharges and water surface elevations are safely conveyed by the proposed system, without endangering downstream properties, structures, bridges, roadways, or other facilities.

<u>Option 3: Install Storm Water Controls to Maintain Existing Downstream Conditions</u>

If the downstream receiving system does not have adequate capacity, then the developer may also choose to provide storm water controls to reduce downstream flood impacts. These controls include on-site controls such as detention, regional controls, and, as a last resort, local flood protection such as levees, floodwalls, floodproofing, etc. Storm water master plans are a necessity to attempt to ensure public safety for the extreme storm event. The developer must provide supporting calculations and/or documentation that the controls will be designed and constructed so that there is no increase in downstream peak discharges or water surface elevations due to development.

<u>Option 4: In lieu of a Downstream Assessment, Maintain Existing On-Site Runoff Conditions</u>

Lastly, on-site controls may be used to maintain the pre-development peak discharges from the site. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed and constructed to maintain on-site existing conditions.

It is important to note that Option 4 does not require a downstream assessment. It is a detention-based approach to addressing downstream flood control after the application of the *integrated* site design practices. For many developments however, the results of a downstream assessment may show that significantly less flood control is required than "detaining to pre-development conditions". This method may also exacerbate downstream flooding problems due to timing of flows as discussed in Section 2.1.9. Therefore, it is strongly recommended that a downstream assessment be performed for all developments, and that Option 4 only be used when Options 1, 2, and 3 are not feasible.

The following items should be considered when providing downstream flood control.

- *Peak-Discharge and Hydrograph Generation:* Hydrograph methods provided in Section 2.1 can be used to compute the peak discharge rate and runoff for the three (3) storm events ("Streambank Protection", "Conveyance", and 100-year).
- *Rainfall Depths:* The rainfall depth of the three storm events will vary depending on location and can be determined from rainfall tables included in Appendix A for various locations across North Central Texas.
- *Off-site Drainage Areas:* Off-site drainage areas should be modeled as "full build-out" for the three storm events to ensure safe passage of future flows.
- *Downstream Assessment:* If flow is being detained on-site, downstream areas should be checked to ensure there is no peak flow or water surface increase above pre-development conditions to the point where the undetained discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. More detail on Downstream Assessments is given in Section 2.1.9.

1.2.6 *integrated* Watershed Planning

1.2.6.1 Introduction

Storm water master planning is an important tool used to assess and prioritize both existing and potential future storm water problems and to consider alternative storm water management solutions. A storm water master plan is prepared to consider, in detail, what storm water management practices and measures are to be provided for an urban drainage area or a large development project.

Storm water master plans are most often used to address specific single functions such as drainage provision, flood mitigation, cost/benefit analysis, or risk assessment. These plans prescribe specific management alternatives and practices. Multi-objective storm water master planning broadens this traditional definition to potentially include land use planning and zoning, water quality, habitat, recreation, and aesthetic considerations. The broadest type of storm water master plan is the comprehensive watershed plan which is described in detail in this chapter.

For any storm water master plan, it is important at the outset to: (1) clearly identify and quantify the objectives and issues the plan will address; (2) recognize the constraints (technical, political, legal, financial, social, physical) that limit the possible solutions; and (3) develop a clear technical approach that will address the key issues and needs while staying within the constraints to potential solutions.

1.2.6.2 Types of Storm Water Master Planning

There are several basic types of storm water master plans that can be prepared. The Local Criteria section should specify whether and how master planning is applicable within the local jurisdiction. Below are descriptions of representative types of master plans.

Flood Assessment Master Plans

Flood assessment is the simplest form of storm water master planning where only the essential components, alignments, and functions of a drainage system are analyzed. The focus of these studies is on water quantity control and flood prevention and/or mitigation.

Frequently, a flood assessment study analyzes both existing conditions and projected future build-out conditions. The study is based upon estimates (usually modeled) of peak and total discharges for selected return period runoff events. The selected events should be based on local standards. Both the hydrology and hydraulics of the system are analyzed to determine water surface profiles and elevations. This, in turn, assists in determining probable locations where impacts can be expected to occur. Frequently, an alternatives analysis will be performed as part of the master plan to provide potential solutions to mitigating the flood impacts. This typically involves the modeling of proposed modifications or development scenarios.

Examples include examining the effects of detention on flooding and providing improved flood protection (e.g., flood proofing structures, levies, etc). A local community might develop HEC-HMS and HEC-RAS models for the hydrology and hydraulics of a watershed for the purposes of estimating the full build-out floodplain and regulating new development on this basis rather than the ever-changing "existing conditions" approach.

Flood Study Cost/Benefit Analysis Master Plans

Another type of master planning builds on a flood assessment master plan to determine acceptable risks and the associated costs. Using information developed in the flood analysis, economic and/or environmental impacts can be assessed. This initially entails establishing a relation between water surface elevation and associated damage (often referred to as stage-damage curves). Based on this relationship, an acceptable level of risk is determined, from which design discharges and associated water surface profiles and elevations are established. Acceptable levels of risk might be based upon the likelihood of loss of human life, impacts to residences, impacts to non-residential structures, or damage to utilities. This information then is used to determine the ultimate drainage infrastructure that will be needed to achieve the planning goals. Both a formal benefit-cost analyses and a more subjective "cost-effectiveness" approach could be used. Based on the design criteria, preliminary designs can be developed which in turn yield initial cost estimates for the infrastructure.

For example, a community might look at different flood protection strategies along a stream and estimate the costs and flood damage savings for each alternative in an effort to select the most appropriate solution(s) for that community.

Water Quality Master Plans

Master planning for storm water quality is becoming increasingly important, as nonpoint source loads are a critical component of watershed-wide water quality assessments. It may become necessary to estimate pollutant loads from storm water runoff to determine Total Maximum Daily Loads (TMDL's), as well as for the expansion of wastewater treatment facilities. A water quality master plan can provide the foundation from which to develop broader water quality assessments. Storm water quality studies will typically analyze water quality impacts to receiving waters (and groundwater) and develop structural and nonstructural strategies to reduce or minimize the pollutant loads. Studies usually involve the development, calibration, and verification of a water quality model. The level of model sophistication can vary from simple to complex. Often, a cost/benefit analysis will be performed as a component of the water quality study to quantify the efficacy of various strategies.

For example, a community might develop a simple spreadsheet-based loading model to perform planning level analyses of loadings of pollutants, potential removal by storm water controls, and the impacts of development strategies—or they may use a more complex continuous simulation water quality model and supporting monitoring to develop a combination of point and non-point source loading estimates in support of a watershed assessment or TMDL.

Biological/Habitat Master Plans

Biological/habitat master planning is similar to a water quality master plan. However, rather than focusing on water chemistry, the focus is on the aquatic biological communities and supporting habitats. Biological assessments are being implemented on a more frequent basis to assess overall water body health. Biological studies provide the ability to assess both acute and long-term effects of nonpoint source impacts to a receiving water in the absence of continuous monitoring data. The resulting data can be used in the design and development of habitat improvements, stream restoration projects, riparian buffers, structural control retrofits, etc.

For example, a community may desire to improve the quality and aesthetics of a stream. Biological monitoring and habitat assessment establishes the baseline health of the stream and can be compared to a reference stream in the area. This information is assessed to determine causes of impairment (often paired with chemical monitoring) and methods to reduce impairment are investigated. The plan might then include riparian corridor planning, land use zoning changes, and planned habitat restoration.

Comprehensive Watershed Master Plans

The comprehensive watershed approach is the most general type of storm water master planning as well as the most extensive. The intent of a comprehensive watershed plan is to assess the health of the existing water resources and to make informed land use and storm water planning decisions. These decisions are based on the current and projected land use and development within the targeted watershed and its associated subwatersheds. Watershed-based water quantity and water quality goals are typically aimed at maintaining the pre-development hydrologic and water quality conditions to the extent practicable through peak discharge control, volume reduction, groundwater recharge, channel protection, and flood protection. In addition, watershed plans may also promote a wide range of additional goals including streambank and stream corridor restoration, habitat protection, protection of historical and cultural resources, and enhancement of recreational opportunities, aesthetic, and quality of life issues.

Watershed-based studies often involve a holistic approach to master planning, where hydrology, geomorphology, habitat, water quality, and biological community impacts are analyzed and solutions are developed.

CHAPTER 1

Section 1.3 *integrated* Site Design Practices

1.3.1 Overview

1.3.1.1 Introduction

The first step in addressing storm water management begins with the site planning and design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to conserve natural areas, reduce impervious cover, and better integrate storm water treatment. By implementing a combination of these nonstructural approaches collectively known as *integrated* site design practices, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff. The goals of *integrated* site design include:

- Managing storm water (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing storm water impacts rather than mitigating them
- Utilizing simple, nonstructural methods for storm water management that are lower cost and lower maintenance than structural controls
- Creating a multifunctional landscape
- Using hydrology as a framework for site design
- Reducing the peak runoff rates and volumes, therefore, reducing the size and cost of drainage infrastructure and structural storm water controls

Integrated site design for storm water management includes a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site for storm water management. The aim is to reduce the environmental impact "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the *integrated* site design practices can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

Reduction of adverse storm water runoff impacts through the use of *integrated* site design should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of *integrated* site design practices offers significant benefits over treating and controlling runoff downstream. Therefore, all opportunities for using these methods should be explored and all options exhausted before considering structural storm water controls.

The reduction in runoff and pollutants using *integrated* site design can reduce the required runoff peak and volumes that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural storm water controls. In some cases, the use of *integrated* site design practices may eliminate the need for structural controls entirely. Hence, *integrated* site design practices can be viewed as both a water quantity and water quality management tool.

To provide an incentive for the use of the *integrated* Site Design Practices, point values may be assigned to each practice. Depending on the amount of points accumulated for a particular development, various types of credits can be granted by the local jurisdiction. Section 1.3.4 describes an example point system and credits in more detail. Furthermore, several of the site design practices described in this section provide a calculable reduction in the volume requirements for Water Quality Protection. Section 1.2.3.2 discusses these reduction opportunities and provides examples of their application.

The use of storm water *integrated* site design also has a number of other ancillary benefits including:

- Reduced construction costs
- Increased property values
- More open space for recreation
- More pedestrian friendly neighborhoods
- Protection of sensitive forests, wetlands, and habitats
- More aesthetically pleasing and naturally attractive landscape
- Easier compliance with wetland and other resource protection regulations

1.3.1.2 List of *integrated* Site Design Practices and Techniques

The *integrated* site design practices and techniques covered in this manual are grouped into four categories and are listed below:

- **Conservation of Natural Features and Resources**
  - Preserve Undisturbed Natural Areas
  - Preserve Riparian Buffers
  - Avoid Floodplains
  - Avoid Steep Slopes
  - Minimize Siting on Porous or Erodible Soils
- **Lower Impact Site Design Techniques**
  - Fit Design to the Terrain
  - Locate Development in Less Sensitive Areas
  - Reduce Limits of Clearing and Grading
  - Utilize Open Space Development
  - Consider Creative Designs
- **Reduction of Impervious Cover**
  - Reduce Roadway Lengths and Widths
  - Reduce Building Footprints
  - Reduce the Parking Footprint
  - Reduce Setbacks and Frontages
  - Use Fewer or Alternative Cul-de-Sacs
  - Create Parking Lot Storm Water "Islands"
- **Utilization of Natural Features for Storm Water Management**
  - Use Buffers and Undisturbed Areas
  - Use Natural Drainageways Instead of Storm Sewers
  - Use Vegetated Swale Instead of Curb and Gutter
  - Drain Rooftop Runoff to Pervious Areas

More detail on each site design practice is provided in the *integrated* Site Design Practice Summary Sheets in subsection 1.3.2. The Summary Sheets are after the work of the Center for Watershed Protection found in its 1998 publication **Better Site Design: A Handbook for changing Development Rules in Your Community**. These summaries provide the key benefits of each practice, examples, and details on how to apply them in site design.

1.3.1.3 Using *integrated* Site Design Practices

Site design should be done in unison with the design and layout of storm water infrastructure in attaining storm water management goals. Figure 1.3.1-1 illustrates the *integrated* site design process that utilizes the four *integrated* site design categories.

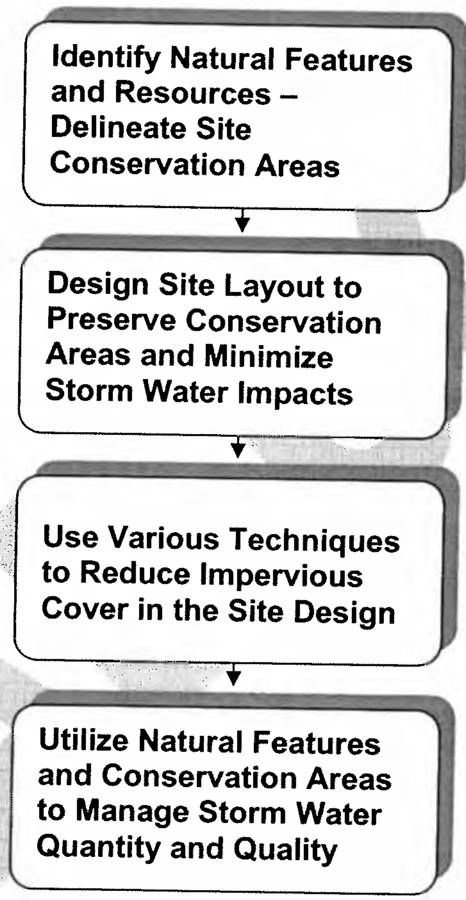


Figure 1.3.1-1 *integrated* Site Design Process

The first step in *integrated* site design involves identifying significant natural features and resources on a site such as undisturbed forest areas, stream buffers and steep slopes that should be preserved to retain some of the original hydrologic function of the site.

Next, the site layout is designed such that these conservation areas are preserved and the impact of the development is minimized. A number of techniques can then be used to reduce the overall imperviousness of the development site.

Finally, natural features and conservation areas can be utilized to serve storm water quantity and quality management purposes.

1.3.2 *integrated* Site Design Practices

1.3.2.1 Conservation of Natural Features and Resources

Conservation of natural features is integral to *integrated* site design. The first step in the *integrated* site design process is to identify and preserve the natural features and resources that can be used in the protection of water resources by reducing storm water runoff, providing runoff storage, reducing flooding, preventing soil erosion, promoting infiltration, and removing storm water pollutants. Some of the natural features that should be taken into account include:

- Areas of undisturbed vegetation
- Floodplains and riparian areas
- Ridge tops and steep slopes
- Natural drainage pathways
- Intermittent and perennial streams
- Wetlands
- Aquifers and recharge areas
- Soils
- Shallow bedrock or high water table
- Other natural features or critical areas

Some of the ways used to conserve natural features and resources described over the next several pages include the following methods:

- Preserve Undisturbed Natural Areas
- Preserve Riparian Buffers
- Avoid Floodplains
- Avoid Steep Slopes
- Minimize Siting on Porous or Erodible Soils

Delineation of natural features is typically done through a comprehensive site analysis and inventory before any site layout design is performed (see Subsection 1.1.3.4). From this site analysis, a concept plan for a site can be prepared that provides for the conservation and protection of natural features. Figure 1.3.2-1 shows an example of the delineation of natural features on a base map of a development parcel.

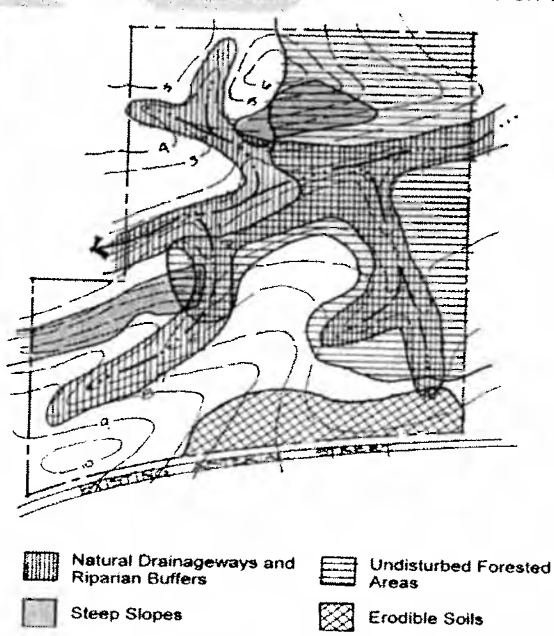


Figure 1.3.2-1 Example of Natural Feature Delineation
(Source: MPCA, 1989)

integrated Site Design Practice #1:

Preserve Undisturbed Natural Areas

Conservation of Natural Features and Resources

Description: Important natural features and areas such as undisturbed forested and vegetated areas, natural drainageways, stream corridors, wetlands and other important site features should be delineated and placed into conservation areas.

KEY BENEFITS

- Helps to preserve a portion of the site's natural predevelopment hydrology
- Can be used as nonstructural storm water filtering and infiltration zones
- Helps to preserve the site's natural character and aesthetic features
- May increase the value of the developed property
- A storm water site design credit can be taken if allowed by the local review authority

USING THIS PRACTICE

- ☑ Delineate natural areas before performing site layout and design
- ☑ Ensure that conservation areas are protected in an *undisturbed state* throughout construction and occupancy

Discussion

Preserving natural conservation areas such as undisturbed forested and vegetated areas, natural drainageways, stream corridors and wetlands on a development site helps to preserve the original hydrology of the site and aids in reducing the generation of storm water runoff and pollutants. Undisturbed vegetated areas also stabilize soils, provide for filtering and infiltration, decreases evaporation, and increases transpiration.

Natural conservation areas are typically identified through a site analysis using maps and aerial/satellite photography, or by conducting a site visit. These areas should be delineated before any site design, clearing or construction begins. When done before the concept plan phase, the planned conservation areas can be used to guide the layout of the site. Figure 1.3.2-2 shows a site map with undisturbed natural areas delineated.

Conservation areas should be incorporated into site plans and clearly marked on all construction and grading plans to ensure equipment is kept out of these areas and native vegetation is kept in an undisturbed state. The boundaries of each conservation area should be mapped by carefully determining the limit that should not be crossed by construction activity.

Once established, natural conservation areas must be protected during construction and managed after occupancy by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements. Permanent signage and fences should be required.

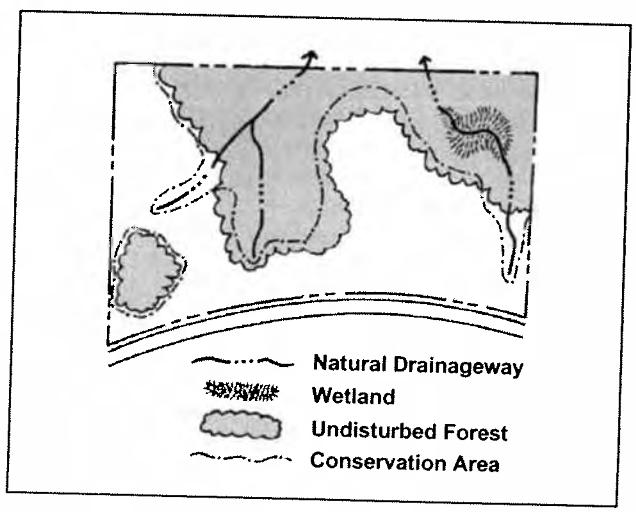


Figure 1.3.2-2 Delineation of Natural Conservation Areas

integrated Site Design Practice #2:
Preserve Riparian Buffers

Conservation of Natural Features and Resources

Description: Naturally vegetated buffers should be delineated and preserved along perennial streams, rivers, lakes, and wetlands.

KEY BENEFITS	USING THIS PRACTICE
• Can be used as nonstructural storm water filtering and infiltration zones • Keeps structures out of the floodplain and provides a right-of-way for large flood events • Helps to preserve riparian ecosystems and habitats • A storm water site design reduction credit can be taken if allowed by the local review authority	☑ Delineate and preserve naturally vegetated riparian buffers ☑ Ensure buffers and native vegetation are protected throughout construction and occupancy

Discussion

A riparian buffer is a special type of natural conservation area along a stream, wetland or shoreline where development is restricted or prohibited. The primary function of buffers is to protect and physically separate a stream, lake or wetland from future disturbance or encroachment. If properly designed, a buffer can provide storm water management functions, can act as a right-of-way during floods, and can sustain the integrity of stream ecosystems and habitats. An example of a riparian stream buffer is shown in Figure 1.3.2-3.

Forested riparian buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Proper restoration should include all layers of the forest plant community, including understory, shrubs and groundcover, not just trees. A riparian buffer can be of fixed or variable width, but should be continuous and not interrupted by impervious areas that would allow storm water to concentrate and flow into the stream without first flowing through the buffer.

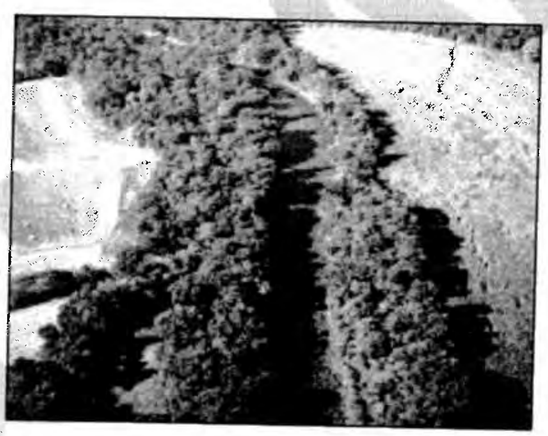


Figure 1.3.2-3 Riparian Stream Buffer

Ideally, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and wetlands. The buffer depth needed to perform properly will depend on the size of the stream and the surrounding conditions, but a minimum 25-foot undisturbed vegetative buffer is needed for even the smallest perennial streams and a 50-foot or larger undisturbed buffer is ideal. Even with a 25-foot undisturbed buffer, additional zones can be added to extend the total buffer to at least 75 feet from the edge of the stream. The three distinct zones within the 75-foot depth are shown in Figure 1.3.2-4. The function, vegetative target and allowable uses vary by zone as described in Table 1.3.2-1.

These recommendations are minimum standards to apply to most streams. Some streams and watershed may require additional measures to achieve protection. In some areas, specific state laws or local ordinances already require stricter buffers than are described here. The buffer widths discussed are not intended to modify or supercede deeper or more restrictive buffer requirements already in place.

As stated above, the streamside or inner zone should consist of a minimum of 25 feet of undisturbed mature forest. In addition to runoff protection, this zone provides bank stabilization as well as shading and protection for the stream. This zone should also include wetlands and any critical habitats, and its width should be adjusted accordingly. The middle zone provides a transition between upland development and the inner zone and should consist of managed woodland that allows for infiltration and filtration of runoff. An outer zone allows more clearing and acts as a further setback for impervious surfaces. It also functions to prevent encroachment and filter runoff. In the outer zone, flow into the buffer should be transformed from concentrated flow into sheet flow to maximize ground contact with the runoff.

Development within the riparian buffer should be limited only to those structures and facilities that are absolutely necessary. Such limited development should be specifically identified in any codes or ordinances enabling the buffers. When construction activities do occur within the riparian corridor, specific mitigation measures should be required, such as larger buffers or riparian buffer improvements.

Generally, the riparian buffer should remain in its natural state. However, some maintenance is periodically necessary, such as planting to minimize concentrated flow, the removal of exotic plant species when these species are detrimental to the vegetated buffer and the removal of diseased or damaged trees.

Figure 1.3.2-4 Three-Zone Stream Buffer System

Table 1.3.2-1 Riparian Buffer Management Zones

	Streamside Zone	Middle Zone	Outer Zone
Width	Minimum 25 feet plus wetlands and critical habitat	Variable depending on stream order, slope, and 100-year floodplain (min. 25 ft)	25-foot minimum setback from structures
Vegetative Target	Undisturbed mature forest. Reforest if necessary.	Managed forest, some clearing allowed.	Forest encouraged, but turf grass at a minimum
Allowable Uses	**Very Restricted** e.g., flood control, utility easements, footpaths	**Restricted** e.g., some recreational uses, some storm water controls, bike paths	**Unrestricted** e.g., residential uses including lawn, garden, most storm water controls

integrated Site Design Practice #3:

Avoid Floodplains

Conservation of Natural Features and Resources

Description: Floodplain areas should be avoided for homes and other structures to minimize risk to human life and property damage, and to allow the natural stream corridor to accommodate flood flows.

KEY BENEFITS	USING THIS PRACTICE
• Provides a natural right-of-way and temporary storage for large flood events • Keeps people and structures out of harm's way • Helps to preserve riparian ecosystems and habitats • Can be combined with riparian buffer protection to create linear greenways	☑ Obtain maps of the 100-year floodplain from the local review authority ☑ Ensure all development activities do not encroach on the designated floodplain areas

Discussion

Floodplains are the low-lying lands that border streams and rivers. When a stream reaches its capacity and overflows its channel after storm events, the floodplain provides for storage and conveyance of these excess flows. In their natural state they reduce flood velocities and peak flow rates by the passage of flows through dense vegetation. Floodplains also play an important role in reducing sedimentation by filtering runoff, and provide habitat for both aquatic and terrestrial life. Development in floodplain areas can reduce the ability of the floodplain to convey storm water, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties. Most communities regulate the use of floodplain areas to minimize the risk to human life as well as to avoid flood damage to structures and property.

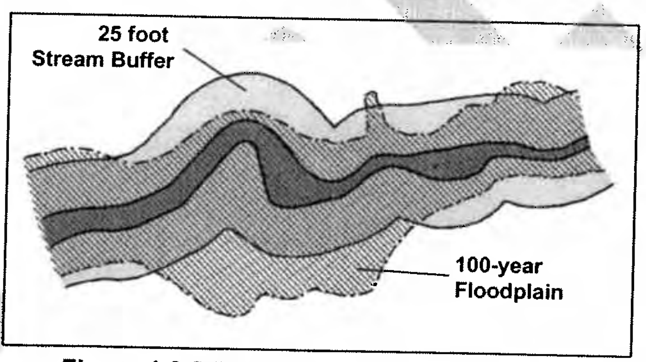


Figure 1.3.2-5 Floodplain Boundaries in Relation to a Riparian Buffer

As such, floodplain areas should be avoided on a development site. Ideally, the entire 100-year full-buildout floodplain should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Floodplain protection is complementary to riparian buffer preservation. Both of these *integrated* site design practices preserve stream corridors in a natural state and allow for the protection of vegetation and habitat. Depending on the site topography, 100-year floodplain boundaries may lie inside or outside of a preserved riparian buffer corridor, as shown in Figure 1.3.2-5.

Maps of the 100-year floodplain can typically be obtained through the local review authority. Developers and builders should also ensure their site designs comply with any other relevant local floodplain and FEMA requirements.

Integrated Site Design Practice #4:
Avoid Steep Slopes

Conservation of Natural Features and Resources

Description: Steep slopes should be avoided due to the potential for soil erosion and increased sediment loading. Excessive grading and flattening of hills and ridges should be minimized.

KEY BENEFITS	USING THIS PRACTICE
• Preserving steep slopes helps to prevent soil erosion and degradation of storm water runoff quality • Steep slopes can be kept in an undisturbed natural condition to help stabilize hillsides and soils • Building on flatter areas will reduce the need for cut-and-fill and grading	☑ Avoid development on steep slope areas, especially those with a grade of 15% or greater. ☑ Minimize grading and flattening of hills and ridges

Discussion

Developing on steep slope areas has the potential to cause excessive soil erosion and increased storm water runoff during and after construction. Past studies by the SCS (now NRCS) and others have shown that soil erosion is significantly increased on slopes of 15% or greater. In addition, the nature of steep slopes means that greater areas of soil and land area are disturbed to locate facilities on them compared to flatter slopes as demonstrated in Figure 1.3.2-6.

Therefore, development on slopes with a grade of 15% or greater should be avoided if possible to limit soil loss, erosion, excessive storm water runoff, and the degradation of surface water. Excessive grading should be avoided on all slopes, as should the flattening of hills and ridges. Steep slopes should be kept in an undisturbed natural condition to help stabilize hillsides and soils. If slopes are already bare and eroding, controls to stabilize and revegetate the slopes must be considered.

On slopes greater than 25%, no development, regrading, or stripping of vegetation should be considered unless the disturbance is for roadway crossings or utility construction and it can be demonstrated that the roadway or utility improvements are absolutely necessary in the sloped area.

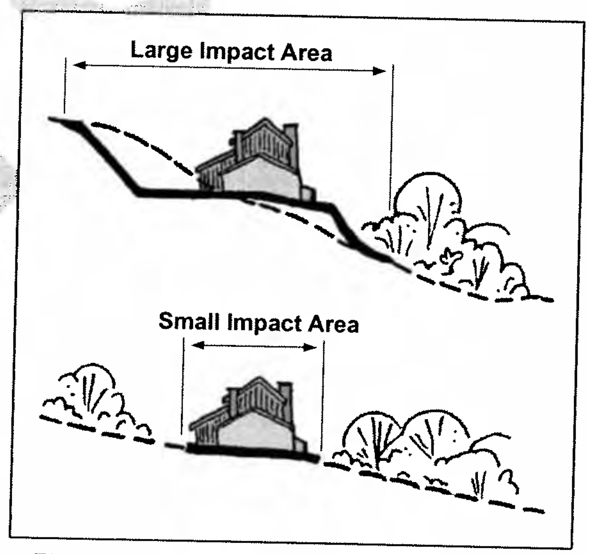


Figure 1.3.2-6 Flattening Steep Slopes for Building Sites Uses More Land Area than Building on Flatter Slopes
(Source: MPCA, 1989)

integrated Site Design Practice #5:
Minimize Siting on Permeable or Erodible Soils

Conservation of Natural Features and Resources

Description: Permeable soils such as sand and gravels provide an opportunity for groundwater recharge of storm water runoff and should be preserved as a potential storm water management option. Unstable or easily erodible soils should be avoided due to their greater erosion potential.

KEY BENEFITS

- Areas with highly permeable soils can be used as nonstructural storm water infiltration zones. A storm water site design credit can be taken if allowed by the local review authority
- Avoiding highly erodible or unstable soils can prevent erosion and sedimentation problems and water quality degradation

USING THIS PRACTICE

- ☑ Use soil surveys to determine site soil types
- ☑ Leave areas of porous or highly erodible soils as undisturbed conservation areas

Discussion

Infiltration of storm water into the soil reduces both the volume and peak discharge of runoff from a given rainfall event, and also provides for water quality treatment and groundwater recharge. Soils with maximum permeabilities (hydrologic soil group A and B soils such as sands and sandy loams) allow for the most infiltration of runoff into the subsoil. Thus, areas of a site with these soils should be conserved as much as possible and these areas should ideally be incorporated into undisturbed natural or open space areas. Conversely, buildings and other impervious surfaces should be located on those portions of the site with the *least* permeable soils to the extent that soil stability, shrink-swell potential, and other soil characteristics allow.

Similarly, areas on a site with highly erodible or unstable soils should be avoided for land disturbing activities and buildings to prevent erosion and sedimentation problems as well as potential future structural problems. These areas should be left in an undisturbed and vegetated condition.

Soils on a development site should be mapped in order to preserve areas with permeable soils, and to identify those areas with unstable or erodible soils as shown in Figure 1.3.2-7. Soil surveys can provide a considerable amount of information relating to all relevant aspects of soils. Appendix B of this Manual provides permeability, shrink-swell potential and hydrologic soils group information for all North Central Texas soil series. General soil types should be delineated on concept site plans to guide site layout and the placement of buildings and impervious surfaces.

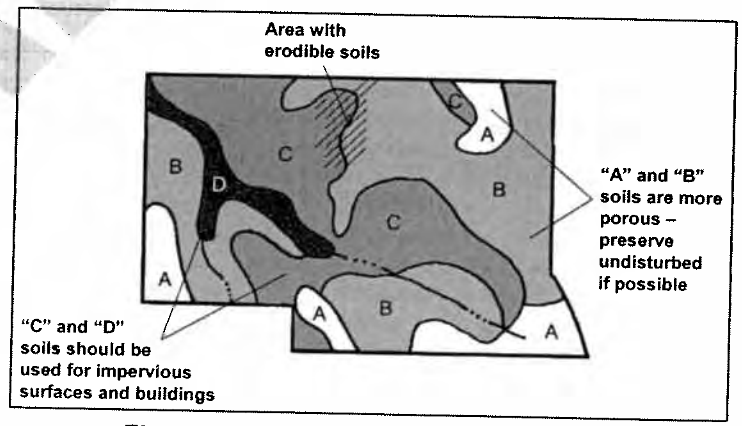


Figure 1.3.2-7 Soil Mapping Information Can Be Used to Guide Development

1.3.2.2 Lower Impact Site Design Techniques

After a site analysis has been performed and conservation areas have been delineated, there are numerous opportunities in the site design and layout phase to reduce both water quantity and quality impacts of storm water runoff. These primarily deal with the location and configuration of impervious surfaces or structures on the site and include the following practices and techniques covered over the next several pages:

- Fit the Design to the Terrain
- Locate Development in Less Sensitive Areas
- Reduce Limits of Clearing and Grading
- Utilize Open Space Development
- Consider Creative Development Design

The goal of lower impact site design techniques is to lay out the elements of the development project in such a way that the site design (i.e. placement of buildings, parking, streets and driveways, lawns, undisturbed vegetation, buffers, etc.) is optimized for effective storm water management. That is, the site design takes advantage of the site's natural features, including those placed in conservation areas, as well as any site constraints and opportunities (topography, soils, natural vegetation, floodplains, shallow bedrock, high water table, etc.) to prevent both on-site and downstream storm water impacts.

Figure 1.3.2-8 shows a development that has utilized several lower impact site design techniques in its overall layout and design.

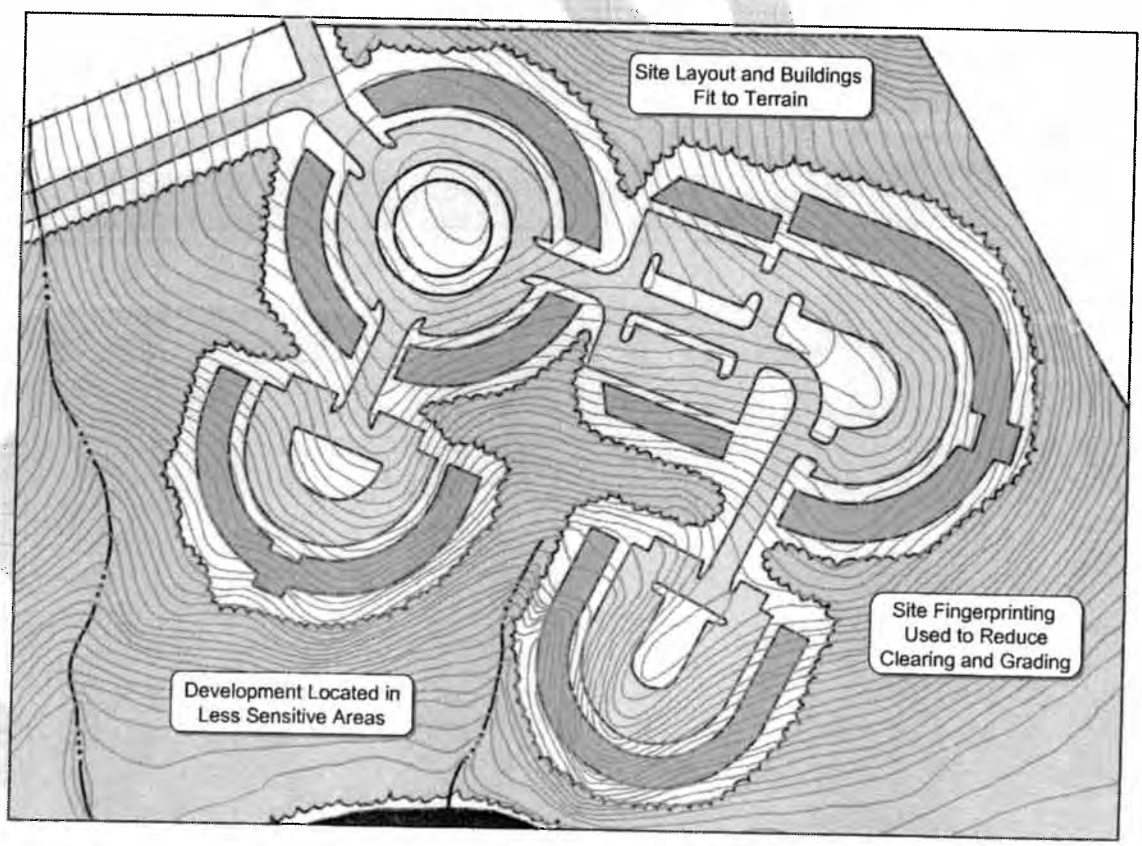


Figure 1.3.2-8 Development Design Utilizing Several Lower Impact Site Design Techniques

integrated Site Design Practice #6:
Fit Design to the Terrain

Lower Impact Site Design Techniques

Description: The layout of roadways and buildings on a site should generally conform to the landforms on a site. Natural drainageways and stream buffer areas should be preserved by designing road layouts around them. Buildings should be sited to utilize the natural grading and drainage system and avoid the unnecessary disturbance of vegetation and soils.

KEY BENEFITS

- Helps to preserve the natural hydrology and drainageways of a site
- Reduces the need for grading and land disturbance
- Provides a framework for site design and layout

USING THIS PRACTICE

- ☑ Develop roadway patterns to fit the site terrain.
- ☑ Locate buildings and impervious surfaces away from steep slopes, drainageways and floodplains

Discussion

All site layouts should be designed to conform with or "fit" the natural landforms and topography of a site. This helps to preserve the natural hydrology and drainageways on the site, as well as reduces the need for grading and disturbance of vegetation and soils. Figure 1.3.2-9 illustrates the placement of roads and homes in a residential development.

Roadway patterns on a site should be chosen to provide access schemes which match the terrain. In rolling or hilly terrain, streets should be designed to follow natural contours to reduce clearing and grading. Street hierarchies with local streets branching from collectors in short loops and cul-de-sacs along ridgelines help to prevent the crossing of streams and drainageways as shown in Figure 1.3.2-10. In flatter areas, a traditional grid pattern of streets or "fluid" grids which bend and may be interrupted by natural drainageways may be more appropriate (see Figure 1.3.2-11). A grid pattern may also allow for narrower streets and less imperviousness as having more than one route for emergency vehicles makes it easier to relax minimum street width requirements. In either case, buildings and impervious surfaces should be kept off of steep slopes, away from natural drainageways, and out of floodplains and other lower lying areas. In addition, the major axis of buildings should be oriented parallel to existing contours.

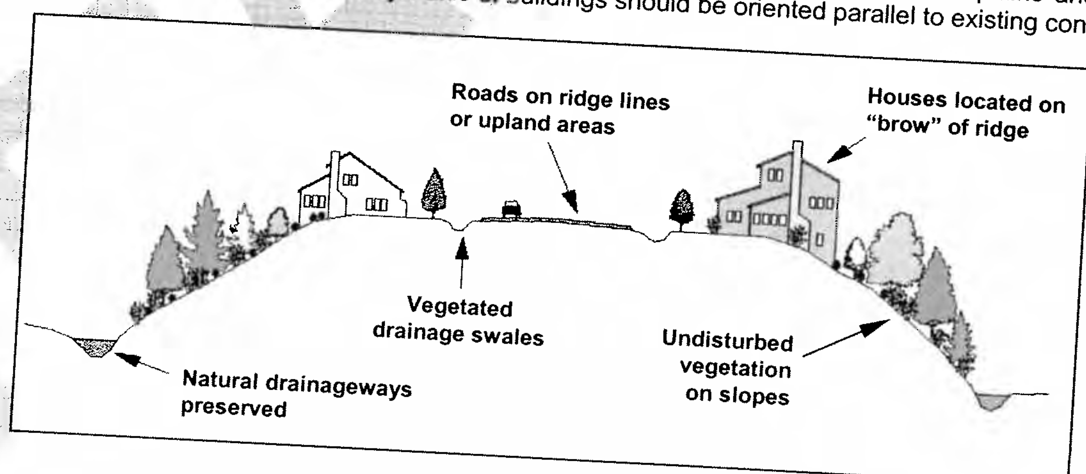


Figure 1.3.2-9 Preserving the Natural Topography of the Site
(Adapted from Sykes, 1989)

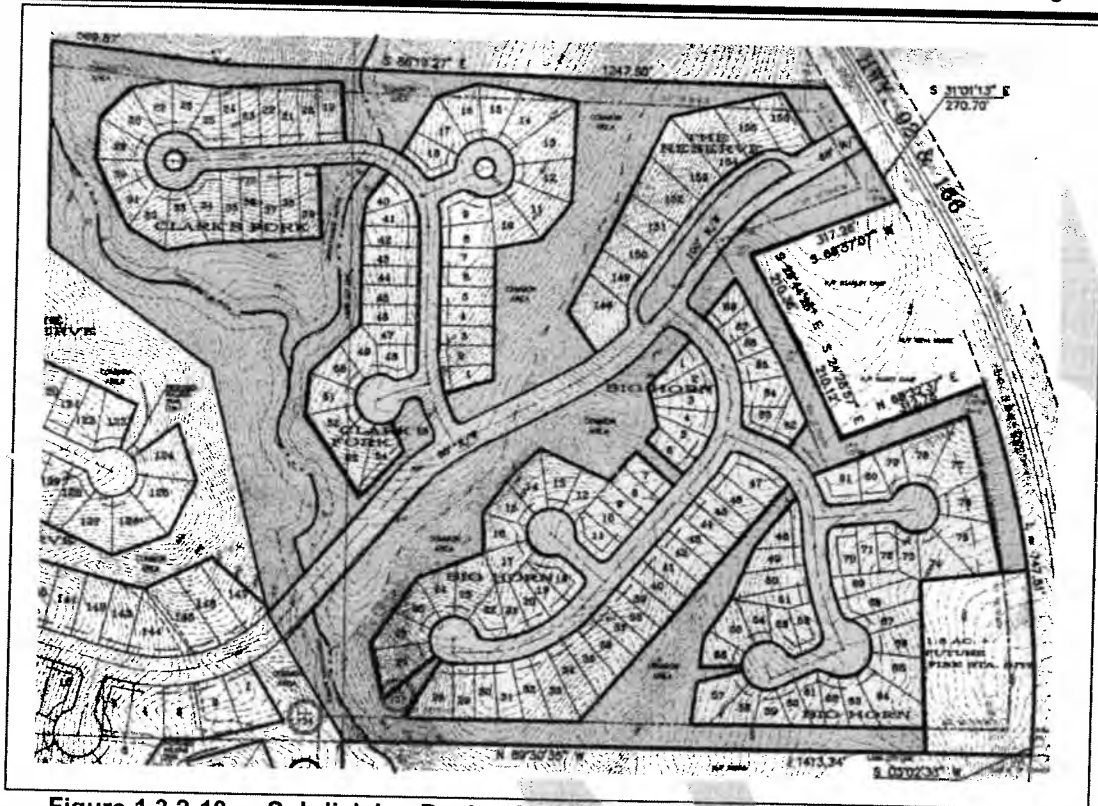


Figure 1.3.2-10 Subdivision Design for Hilly or Steep Terrain Utilizes Branching Streets from Collectors that Preserves Natural Drainageways and Stream Corridors

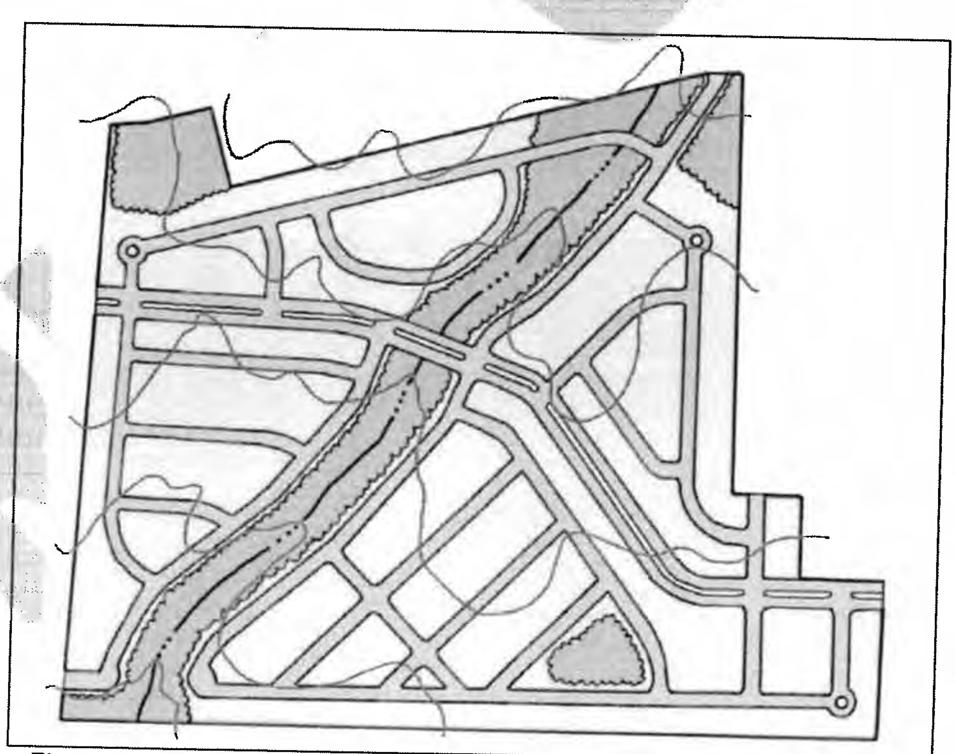


Figure 1.3.2-11 A Subdivision Design for Flat Terrain Uses a Fluid Grid Layout that is Interrupted by the Stream Corridor

integrated Site Design Practice #7:
Locate Development in Less Sensitive Areas

Lower Impact Site Design Techniques

Description: To minimize the hydrologic impacts on the existing site land cover, the area of development should be located in areas of the site that are less sensitive to disturbance or have a lower value in terms of hydrologic function.

KEY BENEFITS	USING THIS PRACTICE
• Helps to preserve the natural hydrology and drainageways of a site • Makes most efficient use of natural site features for preventing and mitigating storm water impacts • Provides a framework for site design and layout	☑ Lay out the site design to minimize the hydrologic impact of structures and impervious surfaces

Discussion

In much the same way that a development should be designed to conform to terrain of the site, a site layout should also be designed so the areas of development are placed in the locations of the site that minimize the hydrologic impact of the project. This is accomplished by steering development to areas of the site that are less sensitive to land disturbance or have a lower value in terms of hydrologic function using the following methods:

Locate buildings and impervious surfaces away from stream corridors, wetlands and natural drainageways. Use buffers to preserve and protect riparian areas and corridors.

Areas of the site with permeable soils should left in an undisturbed condition and/or used as storm water runoff infiltration zones. Buildings and impervious surfaces should be located in areas with less permeable soils.

Figure 1.3.2-12 Guiding Development to Less Sensitive Areas of a Site
(Source: Prince George's County, MD, 1999)

- Avoid land disturbing activities or construction on areas with steep slopes or unstable soils.
- Minimize the clearing of areas with dense tree canopy or thick vegetation, and ideally preserve them as natural conservation areas.
- Ensure natural drainageways and flow paths are preserved, where possible. Avoid the filling or grading of natural depressions and ponding areas.

Figure 1.3.2-12 shows a development site where the natural features have been mapped in order to delineate the hydrologically sensitive areas. Through careful site planning, sensitive areas can be set aside as natural open space areas (see *integrated* Site Design Practice #9). In many cases, such areas can be used as buffer spaces between land uses on the site or between adjacent sites.

integrated Site Design Practice #8:

Reduce Limits of Clearing and Grading

Lower Impact
Site Design Techniques

Description: Clearing and grading of the site should be limited to the minimum amount needed for the development and road access. Site footprinting should be used to disturb the smallest possible land area on a site.

KEY BENEFITS	USING THIS PRACTICE
• Preserves more undisturbed natural areas on a development site • Techniques can be used to help protect natural conservation areas and other site features	☑ Establish limits of disturbance for all development activities ☑ Use site footprinting to minimize clearing and land disturbance

Discussion

Minimal disturbance methods should be used to limit the amount of clearing and grading that takes place on a development site, preserving more of the undisturbed vegetation and natural hydrology of a site. These methods include:

- Establishing a limit of disturbance (LOD) based on maximum disturbance zone radii/lengths. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils. LOD distances may vary by type of development, size of lot or site, and by the specific development feature involved.
- Using site "footprinting" which maps all of the limits of disturbance to identify the smallest possible land area on a site which requires clearing or land disturbance. Examples of site footprinting are illustrated in Figures 1.3.2-13 and 1.3.2-14.
- Fitting the site design to the terrain.
- Using special procedures and equipment which reduce land disturbance.

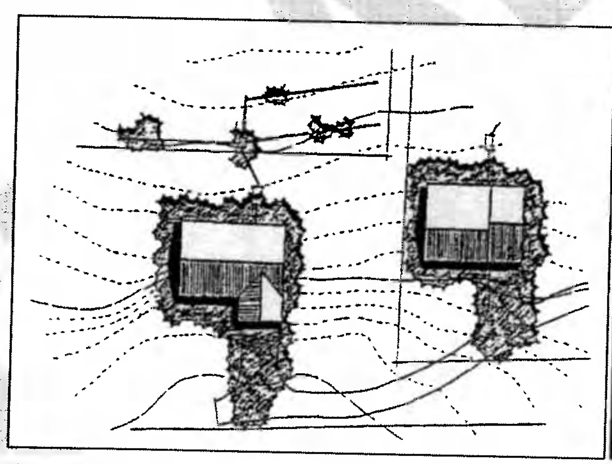


Figure 1.3.2-13 Establishing Limits of Clearing
(Source: DDNREC, 1997)

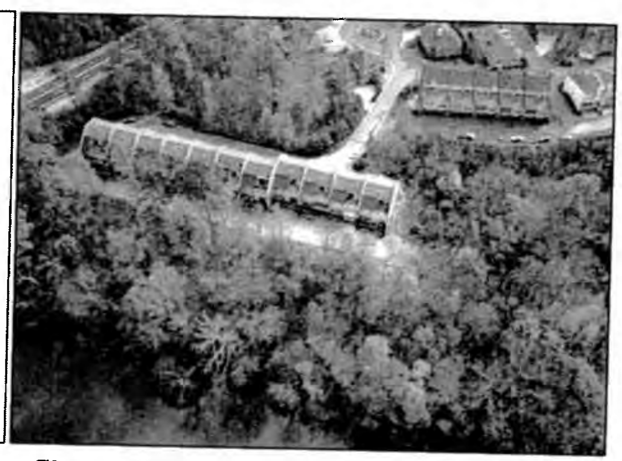


Figure 1.3.2-14 Example of Site Footprinting

integrated Site Design Practice #9:
Utilize Open Space Development

Lower Impact Site Design Techniques

Description: Open space site designs incorporate smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources.

KEY BENEFITS

- Preserves conservation areas on a development site
- Can be used to preserve natural hydrology and drainageways
- Can be used to help protect natural conservation areas and other site features
- Reduces the need for grading and land disturbance
- Reduces infrastructure needs and overall development costs

USING THIS PRACTICE

☑ Use a site design which concentrates development and preserves open space and natural areas of the site

Discussion

Open space development, also known as *conservation development* or *clustering*, is an *integrated* site design technique that concentrates structures and impervious surfaces in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. Typically, smaller lots and/or nontraditional lot designs are used to cluster development and create more conservation areas on the site.

Open space developments have many benefits compared with conventional commercial developments or residential subdivisions: they can reduce impervious cover, storm water pollution, construction costs, and the need for grading and landscaping, while providing for the conservation of natural areas. Figures 1.3.2-15 and 1.3.2-16 show examples of open space developments.

Along with reduced imperviousness, open space designs provide a host of other environmental benefits lacking in most conventional designs. These developments reduce potential pressure to encroach on conservation and buffer areas because enough open space is usually reserved to accommodate these protection areas. As less land is cleared during the construction process, alteration of the natural hydrology and the potential for soil erosion are also greatly diminished. Perhaps most importantly, open space design reserves 25 to 50 percent of the development site in conservation areas, which would not otherwise be protected.

Open space developments can also be significantly less expensive to build than conventional projects. Most of the cost savings are due to reduced infrastructure cost for roads and storm water management controls and conveyances. While open space developments are frequently less expensive to build, developers also find these properties often command higher prices than those in more conventional developments. Several studies estimate that residential properties in open space developments garner premiums higher than conventional subdivisions resulting in higher selling or leasing rates.

Once established, common open space and natural conservation areas must be managed by a responsible party, typically a municipality, to maintain the areas in a natural state in perpetuity. Typically, the conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements.

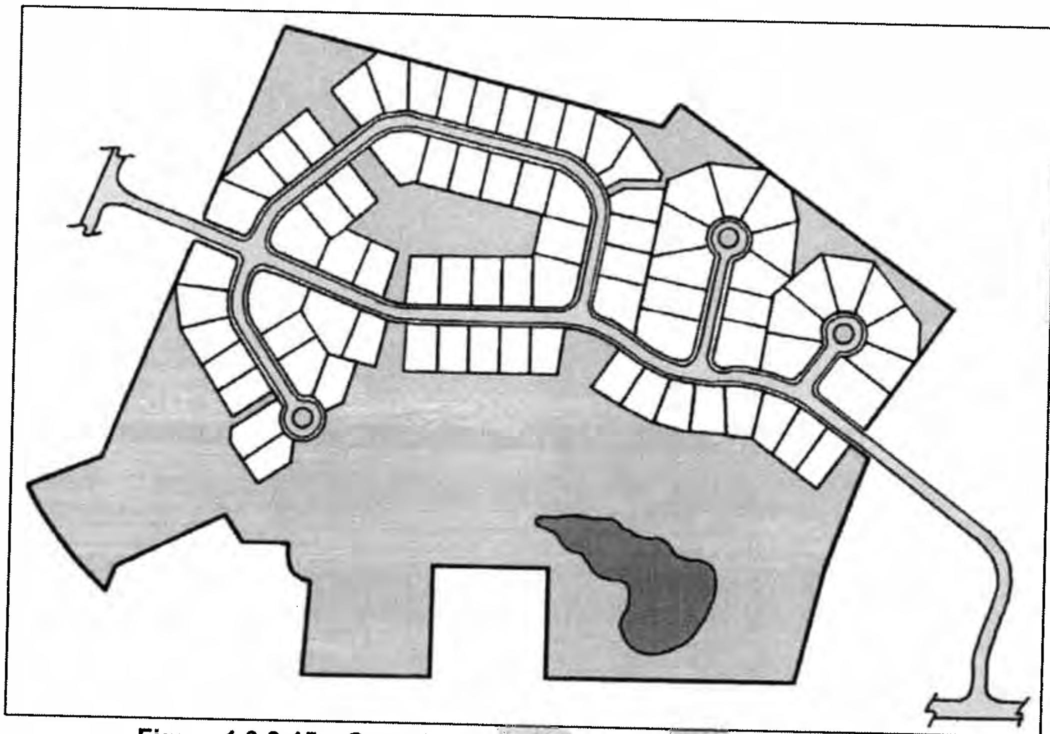


Figure 1.3.2-15 Open Space Subdivision Site Design Example

Figure 1.3.2-16 Aerial View of an Open Space Subdivision

integrated Site Design Practice #10:
Consider Creative Development Design

Lower Impact Site Design Techniques

Description: Planned Unit Developments (PUDs) allow a developer or site designer the flexibility to design a residential, commercial, industrial, or mixed-use development in a fashion that best promotes effective storm water management and the protection of environmentally sensitive areas.

KEY BENEFITS

- Allows flexibility to developers to implement creative site designs which include *integrated* site design practices
- May be useful for implementing an open space development

USING THIS PRACTICE

- ☑ Check with your local review authority to determine if the community supports PUDs
- ☑ Determine the type and nature of deviations allowed and other criteria for receiving PUD approval

Discussion

A Planned Unit Development (PUD) is a type of planning approval available in some communities which provides greater design flexibility by allowing deviations from the typical development standards required by the local zoning code with additional variances or zoning hearings. The intent is to encourage better designed projects through the relaxation of some development requirements, in exchange for providing greater benefits to the community. PUDs can be used to implement many of the other *integrated* site design practices covered in this Manual and to create site designs that maximize natural nonstructural approaches to storm water management.

Examples of the types of zoning deviations which are often allowed through a PUD process include:

- Allowing uses not listed as permitted, conditional or accessory by the zoning district in which the property is located
- Modifying lot size and width requirements
- Reducing building setbacks and frontages from property lines
- Altering parking requirements
- Increasing building height limits

Many of these changes are useful in reducing the amount of impervious cover on a development site (see *integrated* Site Design Practices #11 through #16).

A developer or site designer should consult the local review authority to determine whether the community supports PUD approvals. If so, the type and nature of deviations allowed from individual development requirements should be obtained from the review authority in addition to any other criteria that must be met to obtain a PUD approval.

1.3.2.3 Reduction of Impervious Cover

The level of impervious cover, i.e. rooftops, parking lots, roadways, sidewalks and other surfaces that do not allow rainfall to infiltrate into the soil, is an essential factor to consider in *integrated* site design for storm water management. Increased impervious cover means increased storm water generation and increased pollutant loadings.

Thus by reducing the area of total impervious surface on a site, a site designer can directly reduce the volume of storm water runoff and associated pollutants that are generated. It can also reduce the size and cost of necessary infrastructure for storm water drainage, conveyance, and control and treatment. Some of the ways impervious cover can be reduced in a development include:

- Reduce Roadway Lengths and Widths
- Reduce Building Footprints
- Reduce the Parking Footprint
- Reduce Setbacks and Frontages
- Use Fewer or Alternative Cul-de-Sacs
- Create Parking Lot Storm Water Islands

Figure 1.3.2-17 shows an example of a residential subdivision that employed several of these principles to reduce the overall imperviousness of the development. The next several pages cover these methods in more detail.

Figure 1.3.2-17 Example of Reducing Impervious Cover (clockwise from upper left): (a) Cul-de-sac with Landscaped Island; (b) Narrower Residential Street; (c) "Green" Parking Lot with Landscaped Islands; and (d) Landscape Median in Roadway.

integrated Site Design Practice #11:
Reduce Roadway Lengths and Widths

Reduction of Impervious Cover

Description: Roadway lengths and widths should be minimized on a development site where possible to reduce overall imperviousness.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated • Reduces the costs associated with road construction and maintenance	☑ Consider different site and road layouts that reduce overall street length ☑ Minimize street width by using narrower street designs

Discussion

The use of alternative road layouts that reduce the total linear length of roadways can significantly reduce overall imperviousness of a development site. Site designers are encouraged to analyze different site and roadway layouts to see if they can reduce overall street length. The length of local cul-de-sacs and cross streets should be shortened to a maximum of 200 ADT (average trips per day) to minimize traffic and road noise so shorter setbacks may be employed.

In addition, residential streets and private streets within commercial and other development should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency access. Figure 1.3.2-18 shows a number of different options for narrower street designs. One-way single-lane loop roads are another way to reduce the width of lower traffic streets.

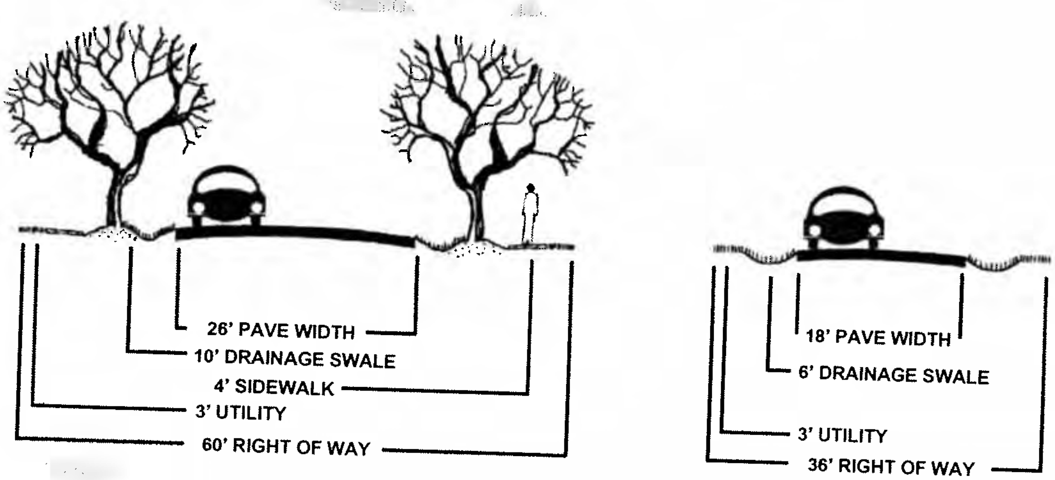


Figure 1.3.2-18 Potential Design Options for Narrower Roadway Widths
(Source: VPISU, 2000)

integrated Site Design Practice #12:
Reduce Building Footprints

Reduction of Impervious Cover

Description: The impervious footprint of commercial buildings and residences can be reduced by using alternate or taller buildings while maintaining the same floor to area ratio.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated	☑ Use alternate or taller building designs to reduce the impervious footprint of buildings

Discussion

In order to reduce the imperviousness associated with the footprint and rooftops of buildings and other structures, alternative and/or vertical (taller) building designs should be considered. Consolidate functions and buildings, as required, or segment facilities to reduce the footprint of individual structures. Figure 1.3.2-19 shows the reduction in impervious footprint by using a taller building design.

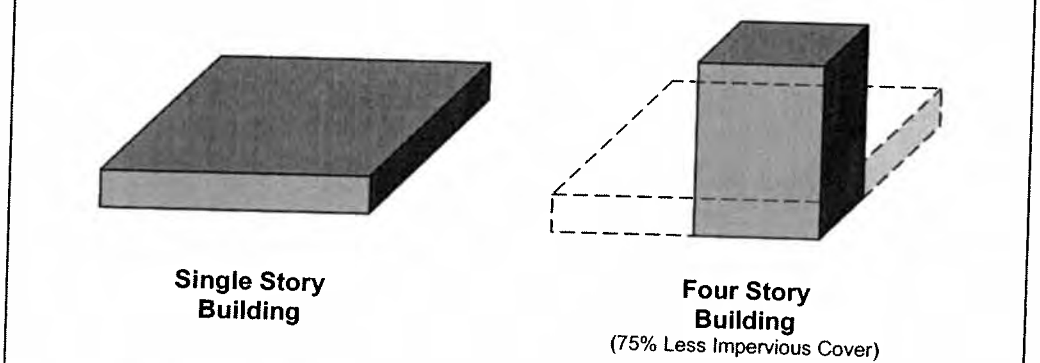


Figure 1.3.2-19 Building Up Rather Than Out Can Reduce the Amount of Impervious Cover

integrated Site Design Practice #13:
Reduce the Parking Footprint

Reduction of Impervious Cover

Description: Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, parking decks, and using porous paver surfaces or porous concrete in overflow parking areas where feasible and where soils allow for infiltration.

KEY BENEFITS

- Reduces the amount of impervious cover and associated runoff and pollutants generated

USING THIS PRACTICE

- ☑ Reduce the number of parking spaces
- ☑ Minimize stall dimensions
- ☑ Consider parking structures and shared parking
- ☑ Use alternative porous surface for overflow areas

Discussion

Setting maximums for parking spaces, minimizing stall dimensions, using structured parking, encouraging shared parking and using alternative porous surfaces can all reduce the overall parking footprint and site imperviousness.

Sometimes parking lot designs result in far more spaces than actually required. This problem may be caused by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand. Table 1.3.2-2 provides examples of conventional parking requirements and compares them to average parking demand.

Table 1.3.2-2 Conventional Minimum Parking Ratios
(Source: ITE, 1987; Smith, 1984; Wells, 1994)

Land Use	Parking Requirement		Actual Average Parking Demand
	Parking Ratio	Typical Range	
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0–6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0–10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5–2.0	1.48 per 1000 ft^2 GFA
Medical/ dental office	5.7 spaces per 1000 ft^2 GFA	4.5–10.0	4.11 per 1000 ft^2 GFA

GFA = Gross floor area of a building without storage or utility spaces.

Another technique to reduce the parking footprint is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall. Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier to implementing stall minimization techniques, stall width requirements in most local parking codes are much larger than the widest SUVs.

Structured parking decks are one method to significantly reduce the overall parking footprint by minimizing surface parking. Figure 1.3.2-20 shows a parking deck used for a commercial development.

Figure 1.3.2-20 Structured Parking at an Office Park Development

Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings.

Utilizing alternative surfaces such as porous pavers or porous concrete is an effective way to reduce the amount of runoff generated by parking lots. They can replace conventional asphalt or concrete in both new developments and redevelopment projects. Figure 1.3.2-21 is an example of porous paver used at an overflow lot. Alternative pavers can also capture and treat runoff from other site areas. However, porous pavement surfaces are generally more costly to construct and require more maintenance than conventional asphalt or concrete. For more specific information using these alternative surfaces, see the sections in Chapter 5 on (Modular Porous Paver Systems) and (Porous Concrete). These surfaces can only be used if the soils allow for adequate infiltration.

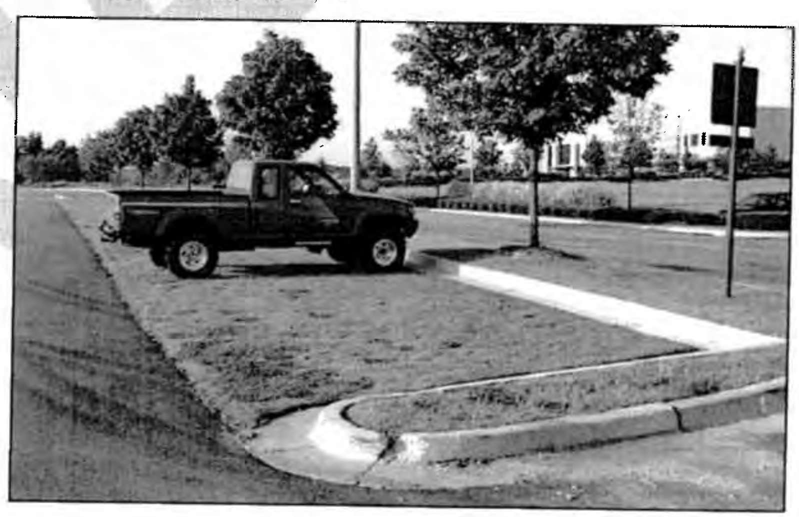


Figure 1.3.2-21 Grass Paver Surface Used for Parking

integrated Site Design Practice #14:
Reduce Setbacks and Frontages

Reduction of Impervious Cover

Description: Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths. This would not apply to rear access (i.e. alleys) home developments.

KEY BENEFITS	**USING THIS PRACTICE**
• Reduces the amount of impervious cover and associated runoff and pollutants generated	☑ Reduce building and home front and side setbacks ☑ Consider narrower frontages

Discussion

Building and home setbacks should be shortened to reduce the amount of impervious cover from driveways and entry walks. A setback of 20 feet is more than sufficient to allow a car to park in a driveway without encroaching into the public right of way, and reduces driveway and walk pavement by more than 30% compared with a setback of 30 feet (see Figure 1.3.2-22).

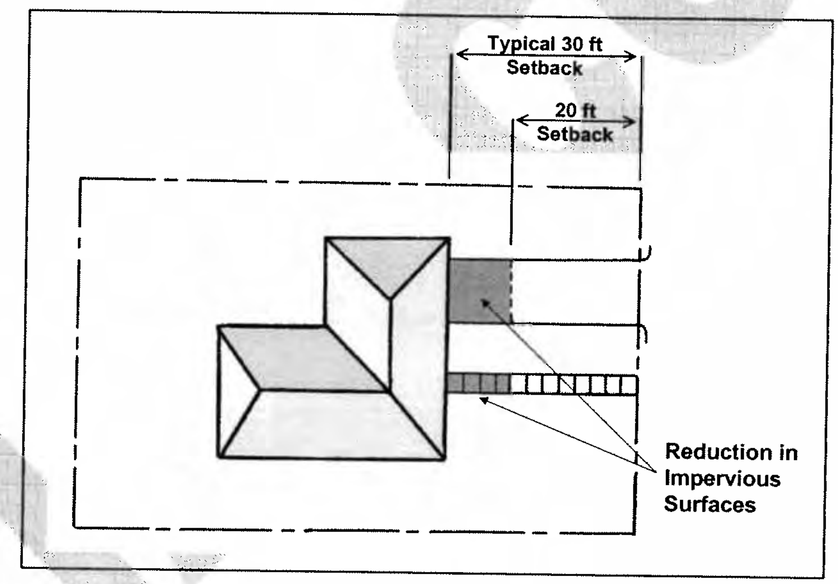


Figure 1.3.2-22 Reduced Impervious Cover by Using Smaller Setbacks
(Adapted from: MPCA, 1989)

Further, reducing side yard setbacks and using narrower frontages can reduce total street length when the same number of lots are used, especially in cluster and open space designs. Figure 1.3.2-23 shows examples of reduced front and side yard setbacks and narrow frontages.

Flexible lot shapes and setback and frontage distances allow site designers to create attractive and unique lots, which provide homeowners with enough space while allowing for the preservation of natural areas in a residential subdivision. Figure 1.3.2-24 illustrates various nontraditional lot designs.

Figure 1.3.2-23 Examples of Reduced Frontages and Side Yard Setbacks

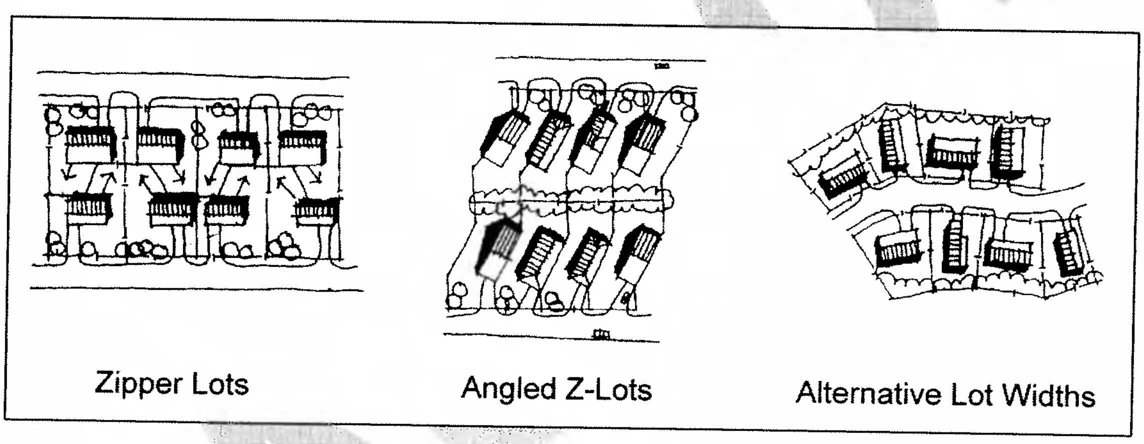


Figure 1.3.2-24 Nontraditional Lot Designs
(Source: ULI, 1992)

integrated Site Design Practice #15:
Use Fewer or Alternative Cul-de-Sacs

Reduction of Impervious Cover

Description: Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should also be considered.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated	☑ Consider alternative cul-de-sac designs

Discussion

Alternative turnarounds are designs for end-of-street vehicle turnarounds that replace cul-de-sacs and reduce the amount of impervious cover created in developments. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a storm water perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center (see Figure 1.3.2-25).

Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. Fire trucks, service vehicles and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and many school buses usually do not enter individual cul-de-sacs.

Implementing alternative turnarounds will require addressing local regulations and marketing issues. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds that need to be modified.

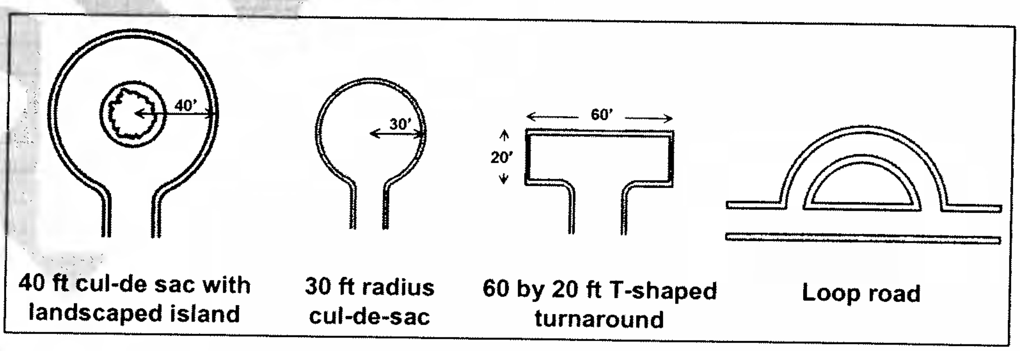


Figure 1.3.2-25 Four Turnaround Options for Residential Streets
(Source: Schueler, 1995)

integrated Site Design Practice #16:
Create Parking Lot Storm Water "Islands"

Reduction of Impervious Cover

Description: Provide storm water treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated • Provides an opportunity for the siting of structural control facilities • Trees in parking lots provide shading for cars and are more visually appealing	☑ Integrate porous areas such as landscaped islands, swales, filter strips and bioretention areas in a parking lot design.

Discussion

Parking lots should be designed with landscaped storm water management "islands" which reduce the overall impervious cover of the lot as well as provide for runoff treatment and control in storm water facilities.

When possible, expanses of parking should be broken up with landscaped islands which include shade trees and shrubs. Fewer large islands will sustain healthy trees better than more numerous very small islands. The most effective solutions in designing for tree roots in parking lots is to use a long planting strip at least 8 feet wide, constructed with sub-surface drainage and compaction resistant soil.

Structural control facilities such as filter strips, dry swales and bioretention areas can be incorporated into parking lot islands. Storm water is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the facility and is infiltrated into the subsurface or collected for discharge into a stream or another storm water facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of filter strips, enhanced swales and bioretention areas, refer to Chapter 5.

Figure 1.3.2-26 Parking Lot Storm Water "Island"

1.3.2.4 Utilization of Natural Features for Storm Water Management

Traditional storm water drainage design tends to ignore and replace natural drainage patterns and often results in overly efficient hydraulic conveyance systems. Structural storm water controls are costly and often can require high levels of maintenance for optimal operation. Through use of natural site features and drainage systems, careful site design can reduce the need and size of structural conveyance systems and controls.

Almost all sites contain natural features that can be used to help manage and mitigate runoff from development. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas that can be used to reduce runoff; provide infiltration and storm water filtering of pollutants and sediment; recycle nutrients; and maximize on-site storage of storm water. Site design should seek to utilize the natural and/or nonstructural drainage system and improve the effectiveness of natural systems rather than to ignore or replace them. These natural systems typically require low or no maintenance and will continue to function many years into the future.

Some of the methods of incorporating natural features into an overall *integrated* storm water management site plan include the following practices:

- Use Buffers and Undisturbed Areas
- Use Natural Drainageways Instead of Storm Sewers
- Use Vegetated Swales Instead of Curb and Gutter
- Drain Runoff to Pervious Areas

The following pages cover each practice in more detail.

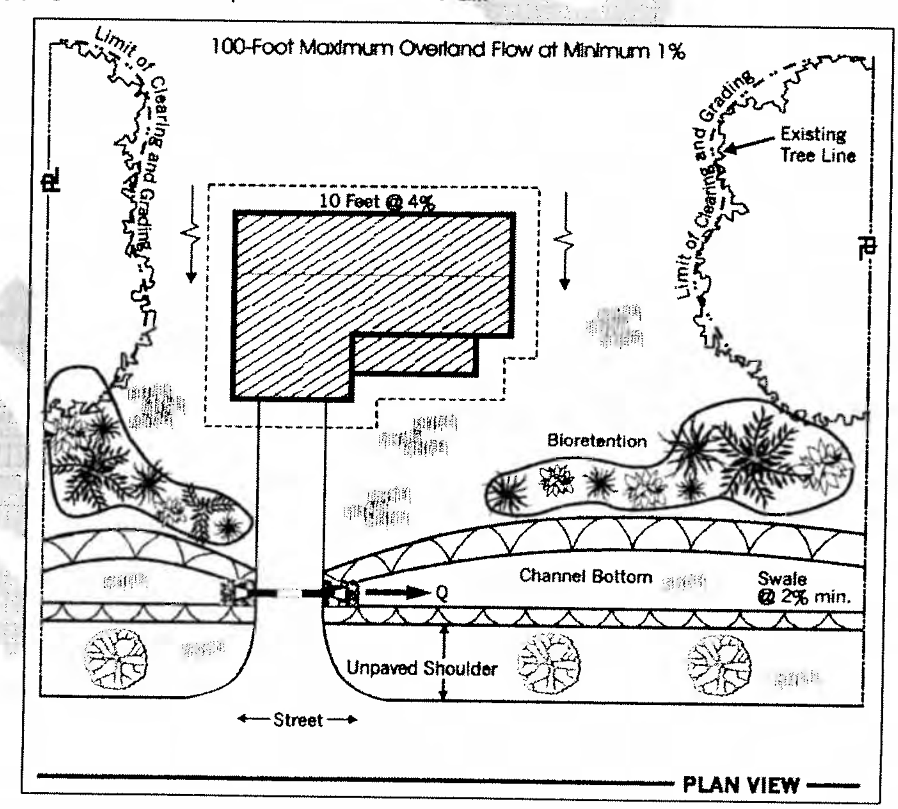


Figure 1.3.2-27 Residential Site Design Using Natural Features for Storm Water Management
(Source: Prince George's County, MD, 1999)

integrated Site Design Practice #17:
Use Buffers and Undisturbed Areas

Utilization of Natural Features for Storm Water Management

Description: Undisturbed natural areas such as forested conservation areas and stream buffers can be used to treat and control storm water runoff from other areas of the site with proper design.

KEY BENEFITS	USING THIS PRACTICE
• Riparian buffers and undisturbed vegetated areas can be used to filter and infiltrate storm water runoff • Natural depressions can provide inexpensive storage and detention of storm water flows • A storm water site design credit can be taken if allowed by the local review authority	☑ Direct runoff towards buffers and undisturbed areas using a level spreader to ensure sheet flow ☑ Utilize natural depressions for runoff storage

Discussion

Runoff can be directed towards riparian buffers and other undisturbed natural areas delineated in the initial stages of site planning to infiltrate runoff, reduce runoff velocity and remove pollutants. Natural depressions can be used to temporarily store (detain) and infiltrate water, particularly in areas with permeable (hydrologic soil group A and B) soils.

The objective in utilizing natural areas for storm water infiltration is to intercept runoff before it has become substantially concentrated and then distribute this flow evenly (as sheet flow) to the buffer or natural area. This can typically be accomplished using a level spreader, as seen in Figure 1.3.2-28. A mechanism for the bypass of higher flow events should be provided to reduce erosion or damage to a buffer or undisturbed natural area.

Carefully constructed berms can be placed around natural depressions and below undisturbed vegetated areas with pervious soils to provide for additional runoff storage and/or infiltration of flows. See the section on bioretention areas as a storm water control with a similar goal.

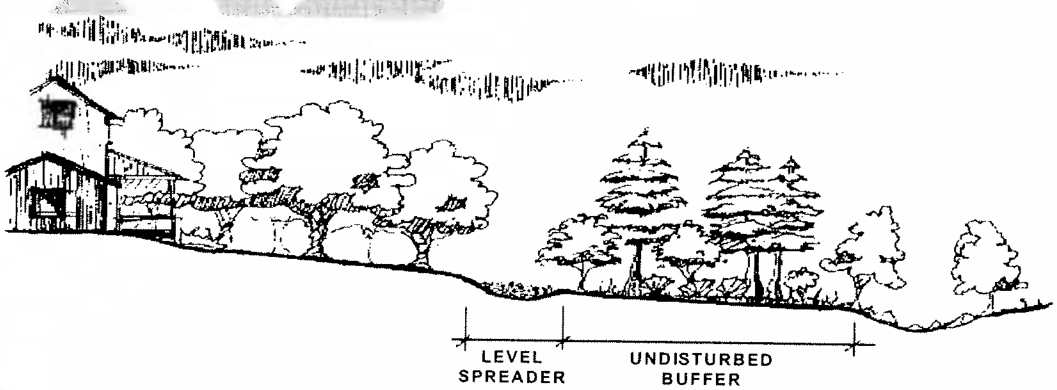


Figure 1.3.2-28 Use of a Level Spreader with a Riparian Buffer
(Adapted from NCDENR, 1998)

integrated Site Design Practice #18: Use Natural Drainageways Instead of Storm Sewers

Utilization of Natural Features for Storm Water Management

Description: The natural drainage paths of a site can be used instead of constructing underground storm sewers or concrete open channels.

KEY BENEFITS

- Use of natural drainageways reduces the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading
- Natural drainage paths are less hydraulically efficient than man-made conveyances, resulting in longer travel times and lower peak discharges
- Can be combined with buffer systems to allow for storm water filtration and infiltration

USING THIS PRACTICE

- ☑ Preserve natural flow paths in the site design
- ☑ Direct runoff to natural drainageways, ensuring peak flows and velocities will not cause channel erosion

Discussion

Structural drainage systems and storm sewers are designed to be hydraulically efficient in removing storm water from a site; however, in doing so, these systems tend to increase peak runoff discharges, flow velocities and the delivery of pollutants to downstream waters. An alternative is the use of natural drainageways and vegetated swales (where slopes and soils permit) to carry storm water flows to their natural outlets, particularly for low-density development and residential subdivisions.

The use of natural open channels (see Figure 1.3.2-29) allows for more storage of storm water flows on-site, lower storm water peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of storm water pollutants. It is critical that natural drainageways be protected from higher post-development flows by applying downstream streambank protection methods (including the SP_v criteria) to prevent erosion and degradation.

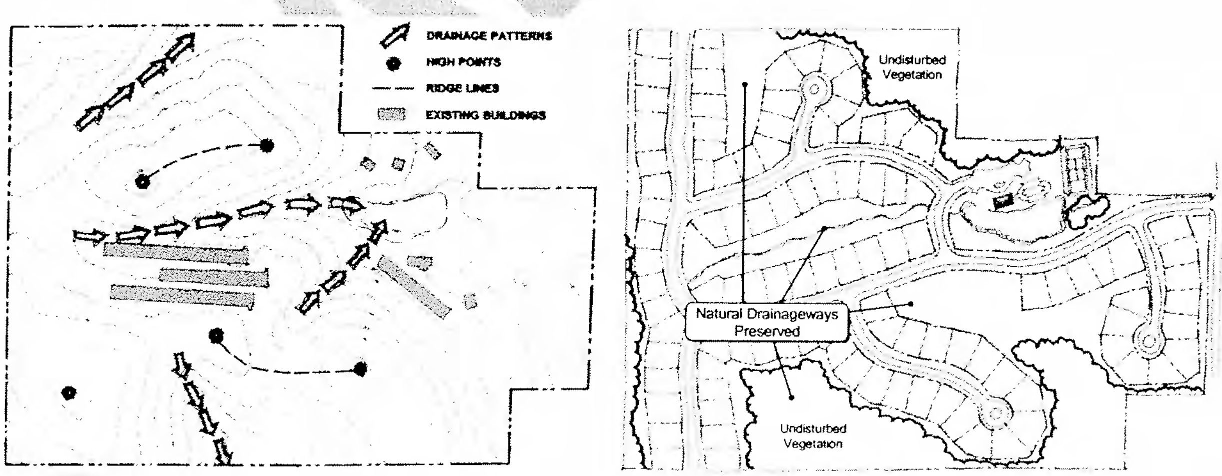


Figure 1.3.2-29 Example of a Subdivision Using Natural Drainageways for Storm Water Conveyance and Management

integrated Site Design Practice #19:
Use Vegetated Swales Instead of Curb and Gutter

Utilization of Natural Features for Storm Water Management

Description: Where density, topography, soils, slope, and safety issues permit, vegetated open channels can be used in the street right-of-way to convey and treat storm water runoff from roadways.

KEY BENEFITS

- Reduces the cost of road and storm sewer construction
- Provides for some runoff storage and infiltration, as well as treatment of storm water
- A storm water site design reduction credit can be taken if allowed by the local review authority

USING THIS PRACTICE

☑ Use vegetated open channels (enhanced wet or dry swales or grass channels) in place of curb and gutter to convey and treat storm water runoff

Discussion

Curb and gutter and storm drain systems allow for quicker transport of storm water from a site to a drainageway, which results in increased peak flow and flood volumes and reduced runoff infiltration. Curb and gutter systems also do not provide treatment of storm water that is often polluted from vehicle emissions, pet waste, lawn runoff and litter.

Open vegetated channels along a roadway (see Figure 1.3.2-30) remove pollutants by allowing infiltration and filtering to occur, unlike curb and gutter systems which move water with virtually no treatment. Older roadside ditches which have not been maintained suffer from erosion, standing water, and break up of the road edge. Grass channels and enhanced dry swales are two alternatives when properly installed and maintained under the right site conditions, are excellent methods for treating storm water on-site. In addition, open vegetated channels can be less expensive to install than curb and gutter systems. Further design information and specifications for grass channels/enhanced swales can be found in Chapter 5.

Figure 1.3.2-30 Using Vegetated Swales Instead of Curb and Gutter

integrated Site Design Practice #20:
Drain Runoff to Pervious Areas

Utilization of Natural Features for Storm Water Management

Description: Where possible, direct runoff from impervious areas such as rooftops, roadways and parking lots to pervious areas, open channels or vegetated areas to provide for water quality treatment and infiltration. Avoid routing runoff directly to the structural storm water conveyance system.

KEY BENEFITS	USING THIS PRACTICE
• Sending runoff to pervious vegetated areas increases overland flow time and reduces peak flows • Vegetated areas can often filter and infiltrate storm water runoff • A storm water site design credit can be taken if allowed by the local review authority	☑ Minimize directly connected impervious areas and drain runoff as sheet flow to pervious vegetated areas

Discussion

Storm water quantity and quality benefits can be achieved by routing the runoff from impervious areas to pervious areas such as lawns, landscaping, filter strips and vegetated channels. Much like the use of undisturbed buffers and natural areas (*integrated* Site Design Practice #17), revegetated areas such as lawns and engineered filter strips and vegetated channels can act as biofilters for storm water runoff and provide for infiltration in pervious (hydrologic group A and B) soils. In this way, the runoff is "disconnected" from a hydraulically efficient structural conveyance such as a curb and gutter or storm drain system.

Some of the methods for disconnecting impervious areas include:

- Designing roof drains to flow to vegetated areas or infiltration areas
- Directing flow from paved areas such as driveways to stabilized vegetated areas
- Breaking up flow directions from large paved surfaces (see Figure 1.3.2-31)
- Carefully locating impervious areas and grading landscaped areas to achieve sheet flow runoff to the vegetated pervious areas

For maximum benefit, runoff from impervious areas to vegetated areas must occur as sheet flow and vegetation must be stabilized. See Chapter 5 for more design information and specifications on filter strips and vegetated channels.

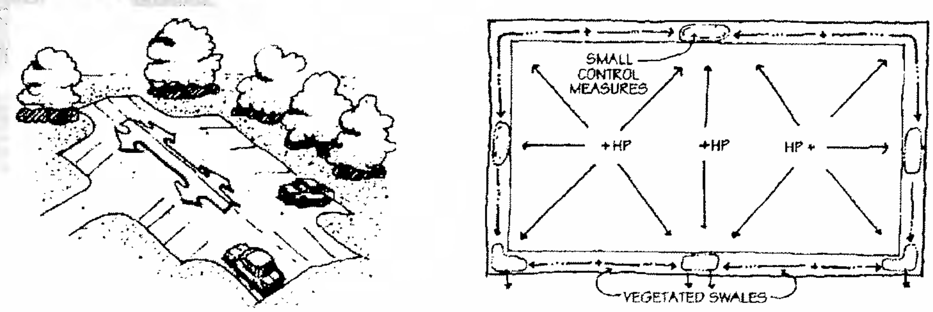


Figure 1.3.2-31 Design Paved Surfaces to Disperse Flow to Vegetated Areas
Source: NCDENR, 1998

1.3.3 *integrated* Site Design Examples

1.3.3.1 Residential Subdivision Example 1

A typical residential subdivision design on a parcel is shown in Figure 1.3.3-1 (a). The entire parcel except for the subdivision amenity area (clubhouse and tennis courts) is used for lots. The entire site is cleared and mass graded, and no attempt is made to fit the road layout to the existing topography. Because of the clearing and grading, all of the existing tree-cover, vegetation and topsoil are removed dramatically altering both the natural hydrology and drainage of the site. The wide residential streets create unnecessary impervious cover and a curb and gutter system that carries storm water flows to the storm sewer system. No provision for non-structural storm water treatment is provided on the subdivision site.

A residential subdivision employing *integrated* site design practices is presented in Figure 1.3.3-1 (b). This subdivision configuration preserves a quarter of the property as undisturbed open space and vegetation. The road layout is designed to fit the topography of the parcel, following the high points and ridgelines. The natural drainage patterns of the site are preserved and are utilized to provide natural storm water treatment and conveyance. Narrower streets reduce impervious cover and grass channels provide for treatment and conveyance of roadway and driveway runoff. Landscaped islands at the ends of cul-de-sacs also reduce impervious cover and provide storm water treatment functions. Where possible, constructing and building homes, only the building envelopes of the individual lots are cleared and graded, further preserving the natural hydrology of the site.

1.3.3.2 Residential Subdivision Example 2

Another typical residential subdivision design is shown in Figure 1.3.3-2 (a). Most of this site is cleared and mass graded, with the exception of a small riparian buffer along the large stream at the right boundary of the property. Almost no buffer was provided along the small stream that runs through the middle of the property. In fact, areas within the 100-year floodplain were cleared and filled for home sites. As is typical in many subdivision designs, this one has wide streets for on-street parking and large cul-de-sacs.

The *integrated* site design subdivision can be seen in Figure 1.3.3-2 (b). This subdivision layout was designed to conform to the natural terrain. The street pattern consists of a wider main thoroughfare, which winds through the subdivision along the ridgeline. Narrower loop roads branch off of the main road and utilize landscaped islands. Large riparian buffers are preserved along both the small and large streams. The total undisturbed conservation area is close to one-third of the site.

1.3.3.3 Commercial Development Example

Figure 1.3.3-3 (a) shows a typical commercial development containing a supermarket, drugstore, smaller shops and a restaurant on an outlot. The majority of the parcel is a concentrated parking lot area. The only pervious area is a small replanted vegetation area acting as a buffer between the shopping center and adjacent land uses. Storm water quality and quantity control are provided by a wet extended detention pond in the corner of the parcel.

An *integrated* site design commercial development can be seen in Figure 1.3.3-3 (b). Here the retail buildings are dispersed on the property, providing more of an "urban village" feel with pedestrian access between the buildings. The parking is broken up, and bioretention areas for storm water treatment are built into parking lot islands. A large bioretention area which serves as open green space is located at the main entrance to the shopping center. A larger undisturbed buffer has been preserved on the site. Because the bioretention areas and buffer provide water quality treatment, only a dry extended detention basin is needed for water quantity control.

1.3.3.4 Office Park Example

An office park with a conventional design is shown in Figure 1.3.3-4 (a). Here the site has been graded to fit the building layout and parking area. All of the vegetated areas of this site are replanted areas.

The *integrated* site design layout, presented in Figure 1.3.3-4 (b), preserves undisturbed vegetated buffers and open space areas on the site. Both the parking areas and buildings have been designed to fit the natural terrain of the site. In addition, a modular porous paver system is used for the overflow parking areas.

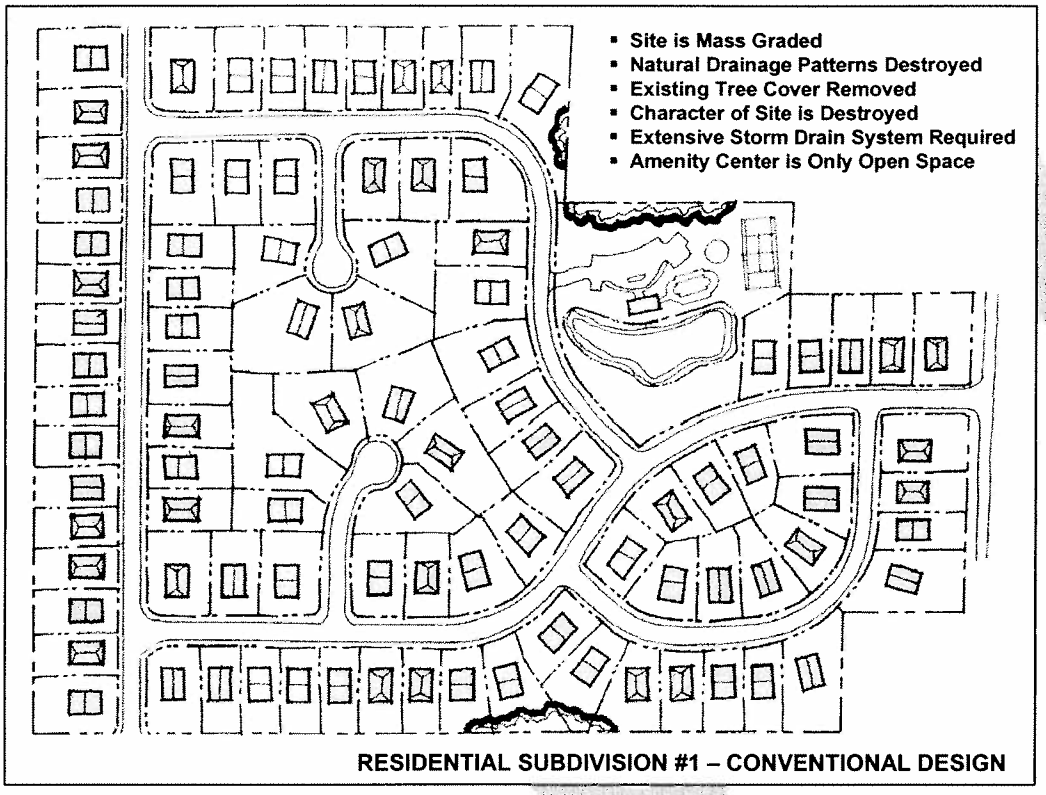
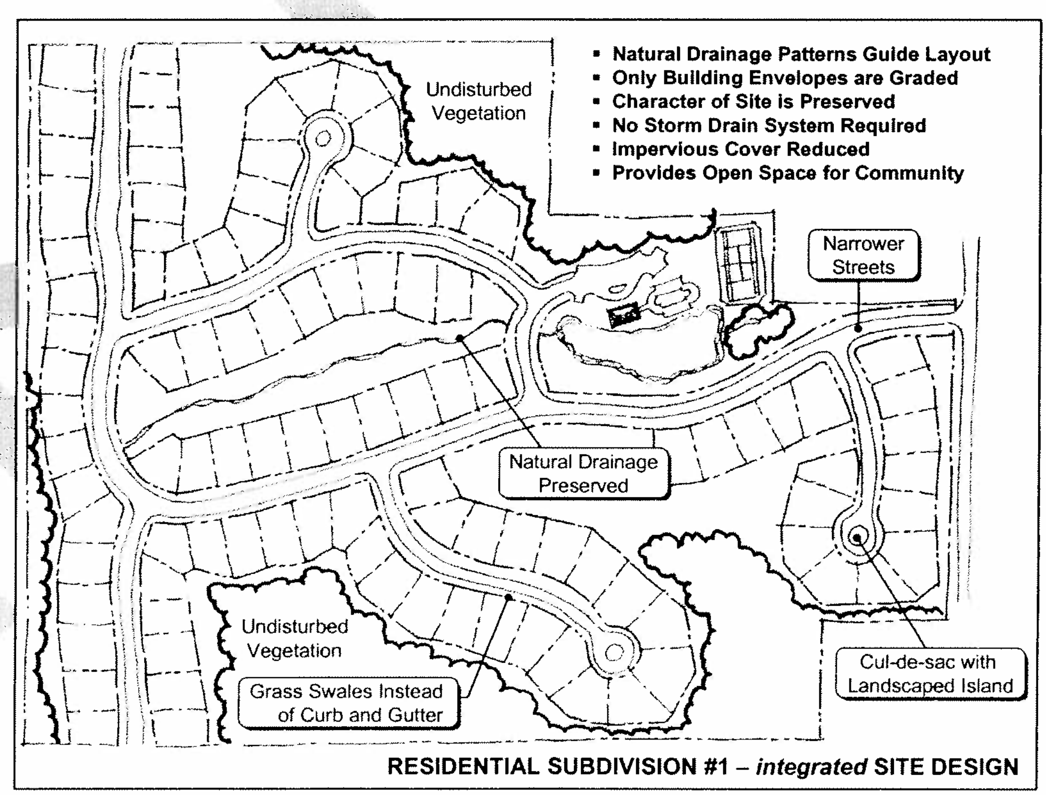


Figure 1.3.3-1 Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



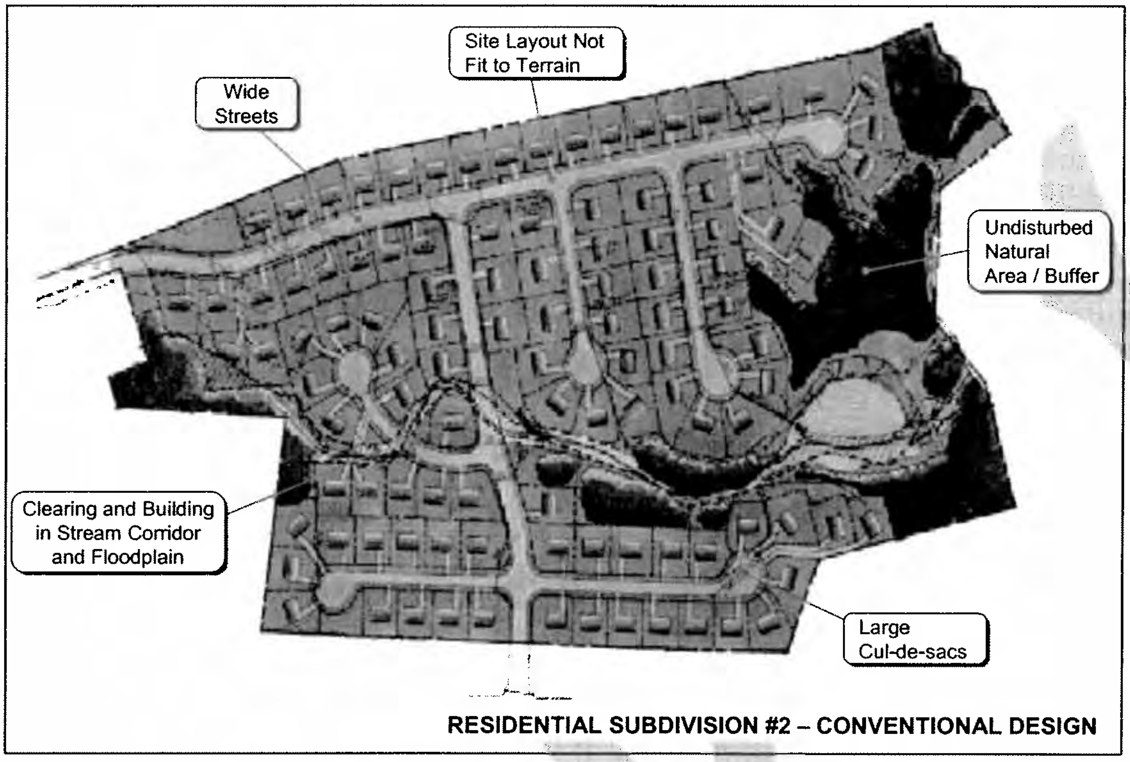
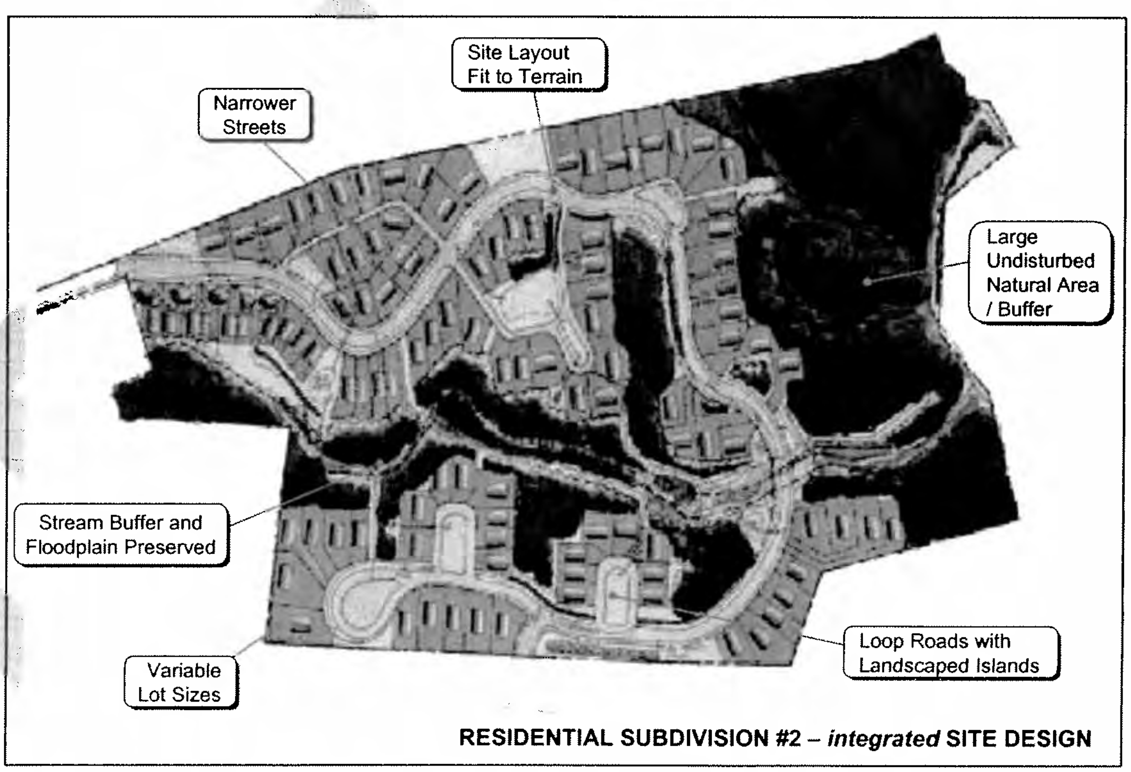


Figure 1.3.3-2 Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



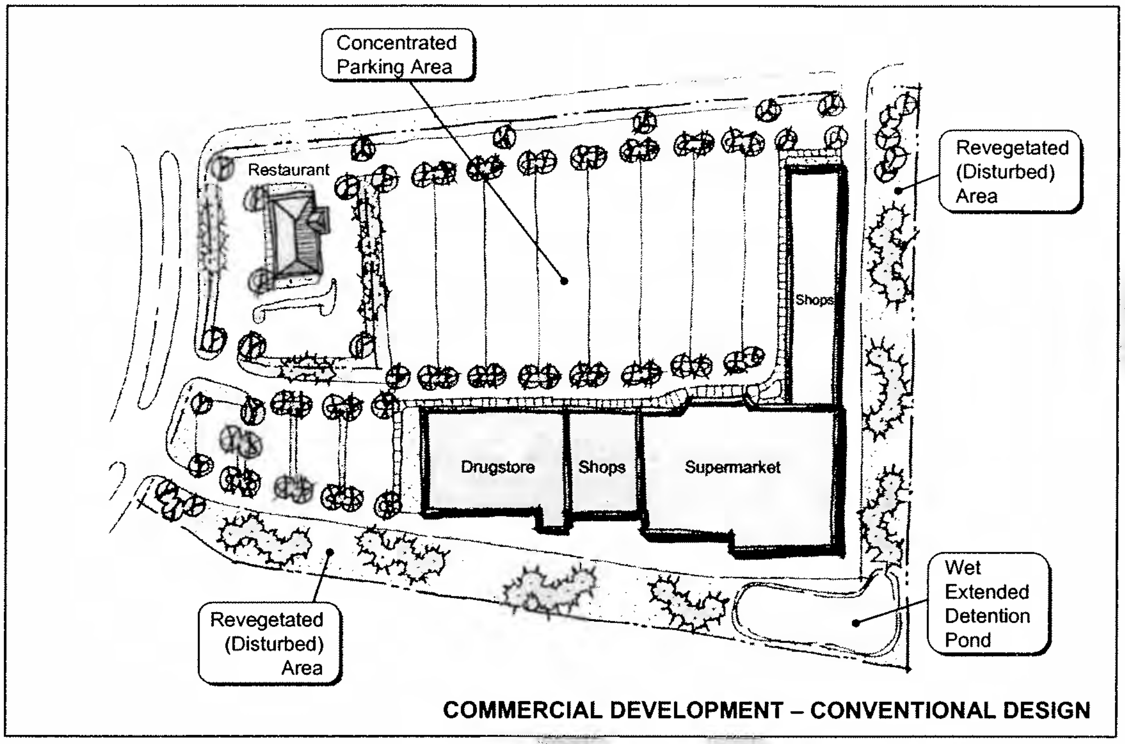
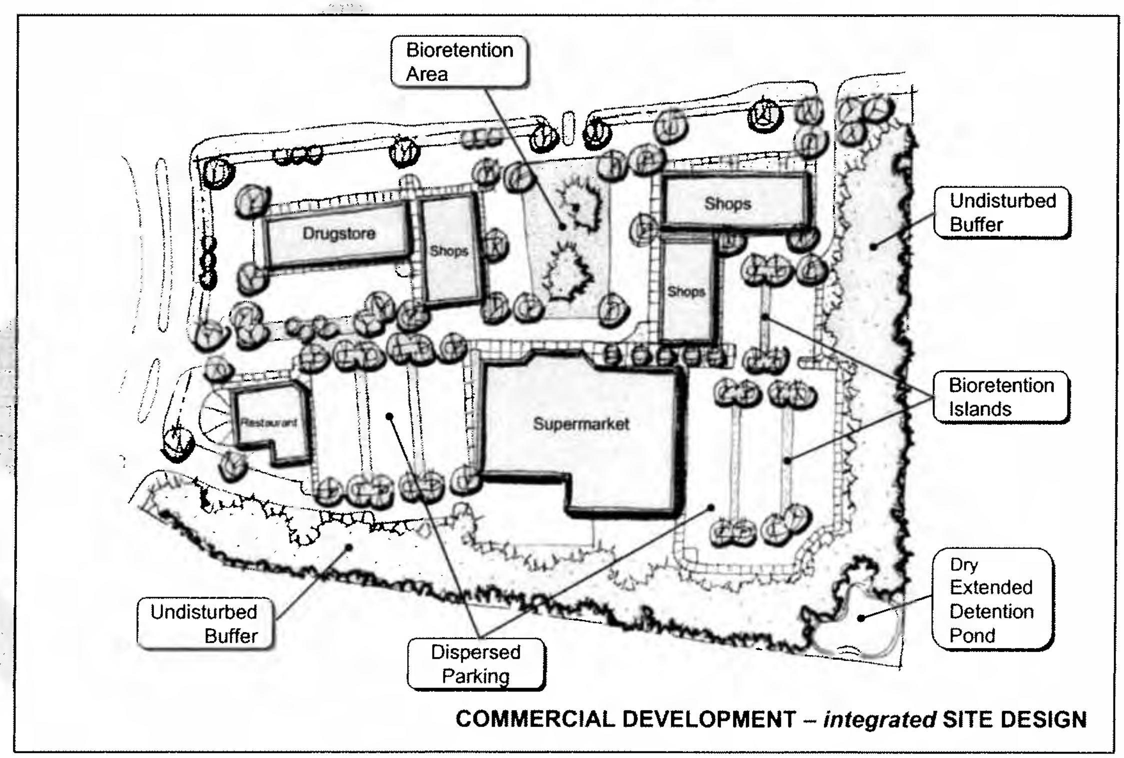


Figure 1.3.3-3 Comparison of a Traditional Commercial Development (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



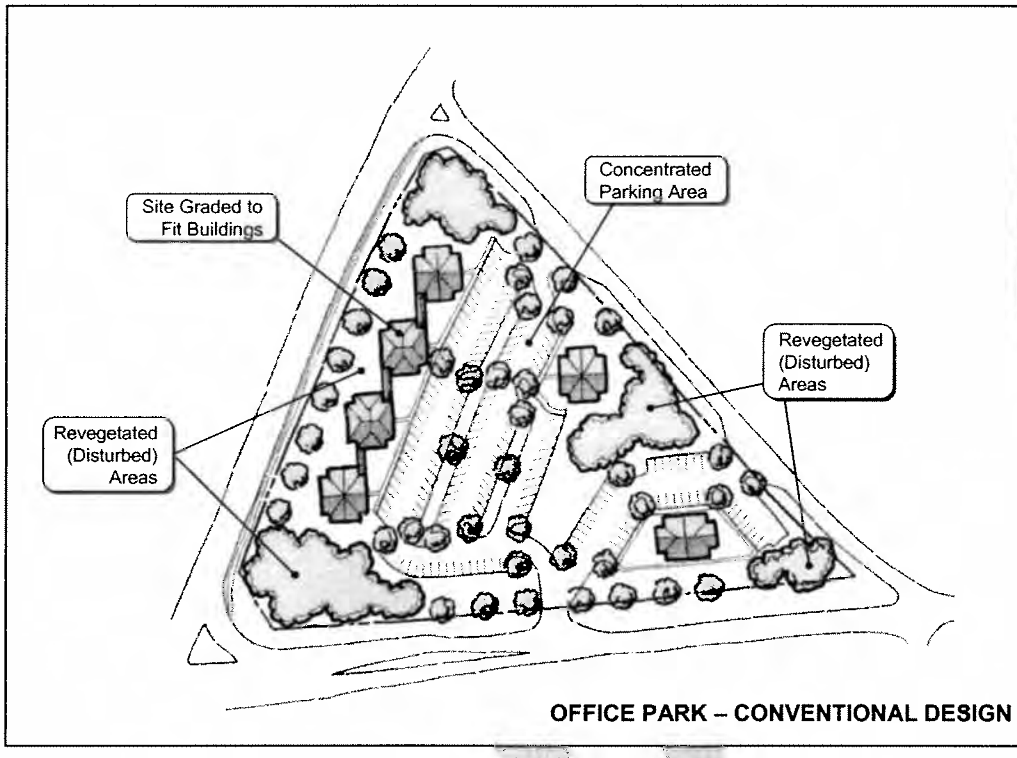
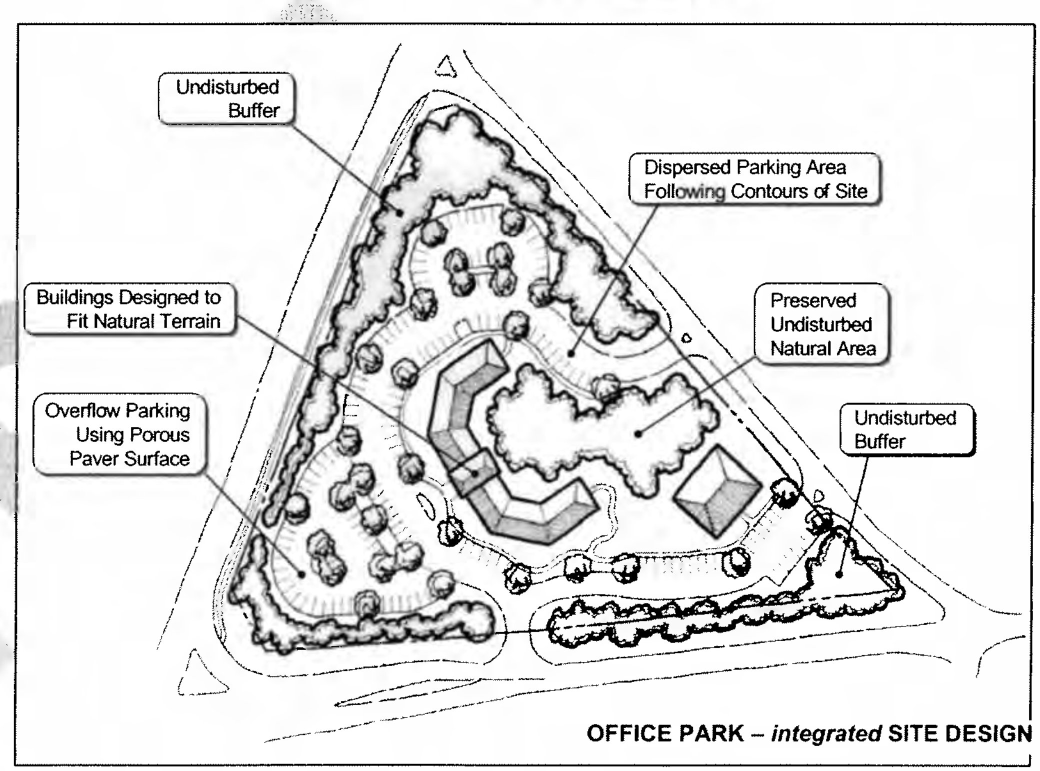


Figure 1.3.3-4 Comparison of a Traditional Office Park Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



1.3.4 *integrated* Site Design Credits

1.3.4.1 Introduction

Non-structural storm water control practices are increasingly recognized as a critical feature in every site design. As such, a set of storm water "credits" has been developed to provide developers and site designers an incentive to implement *integrated* site design practices that can minimize the pollutant loads from a site.

Site designers are encouraged to utilize as many site design practices as they can on a site. Greater reductions in storm water pollutant loading can be achieved when many practices are combined (e.g., disconnecting rooftops and protecting natural conservation areas).

The type and amount of credit that is available for a development will depend on the amount of points it has accumulated, or its total "score". Multiple points can be obtained by applying one or multiple practices. Points are accumulated based on the implementation of various site design practices.

During the site planning process described in Section 1.1, there are several steps involved in site layout and design, each more clearly defining the location and function of the various components of the storm water management system. The site design practices can be integrated with this process as shown in Table 1.3.4-1.

Table 1.3.4-1 Integration of Site Design Practices with Site Development Process

Site Development Phase	Site Design Practice Activity
Feasibility Study	• Determine storm water management requirements • Perform site reconnaissance to identify potential areas for and types of credits
Site Analysis	• Identify and delineate natural feature conservation areas (natural areas and stream buffers)
Concept Plan	• Preserve natural areas and stream buffers during site layout • Reduce impervious surface area through various techniques • Identify locations for use of vegetated channels and groundwater recharge • Look for areas to disconnect impervious surfaces • Document the use of site design practices.
Preliminary and Final Plan	• Perform layout and design of credit areas – integrating them into treatment trains • Ensure *integrated* Design Approach is satisfied • Ensure appropriate documentation of site design credits according to local requirements.
Construction	• Ensure protection of key areas • Ensure correct final construction of areas needed for credits
Final Inspection	• Develop maintenance requirements and documents • Ensure long term protection and maintenance • Ensure credit areas are identified on final plan and plat if applicable

1.3.4.2 Point System

To appropriately allocate credit for using the integrated site design practices, a guideline point system has been presented. This system assigns a point value to each practice, as shown in Table 1.3.4-2. The total number of points for a given development becomes the score for the development. The score determines the type and amount of credit available to that particular development. The local jurisdiction should, as part of their Local Criteria, determine which practices (if any) they wish to give credit for. The local jurisdiction should also determine the number of points, or point weighting, assigned to each practice, and which criteria must be met in order to obtain the credit.

Table 1.3.4-2 Example Point System for *integrated* Site Design Practices

Practice	Maximum Points	Point Allocation Based on % of Practice Utilized					
		0%	<15	<30	<50	<75	>75
Conservation of Natural Features and Resources							
Preserve Undisturbed Natural Areas	5	0	1	2	3	4	5
Preserve Riparian Buffers	5	0	1	2	3	4	5
Avoid Floodplains	5	0	1	2	3	4	5
Avoid Steep Slopes	5	0	1	2	3	4	5
Minimize Siting on Porous or Erodible Soils	5	0	1	2	3	4	5
Lower Impact Site Design Techniques							
Fit Design to the Terrain	5	0	1	2	3	4	5
Locate Development in Less Sensitive Areas	5	0	1	2	3	4	5
Reduce Limits of Clearing and Grading	5	0	1	2	3	4	5
Utilize Open Space Development	5	0	1	2	3	4	5
Consider Creative Design	5	0	1	2	3	4	5
Reduction of Impervious Cover							
Reduce Roadway Lengths and Widths	5	0	1	2	3	4	5
Reduce Building Footprints	5	0	1	2	3	4	5
Reduce the Parking Footprint	5	0	1	2	3	4	5
Reduce Setbacks and Frontages	5	0	1	2	3	4	5
Use Fewer or Alternative Cul-de-Sacs	5	0	1	2	3	4	5
Create Parking Lot Storm Water "Islands"	5	0	1	2	3	4	5
Utilization of Natural Features for Storm Water Management							
Use Buffers and Undisturbed Areas	5	0	1	2	3	4	5
Use Natural Drainageways Instead of Storm Sewers	5	0	1	2	3	4	5
Use Vegetated Swale Instead of Curb and Gutter	5	0	1	2	3	4	5
Drain Rooftop Runoff to Pervious Areas	5	0	1	2	3	4	5
Total Points	100						

1.3.4.3 Example Design Credits

There are various areas of credit available for use in a storm water management program. The list below is only an example of areas of credit and should not be considered comprehensive.

- Reduction in Storm Water Utility fees
- Reduction in Park dedication requirements
- Reduction in Open space dedication requirements
- Reduction in Landscape requirements
- Decrease in plan approval process time
- Simplified planning and variance process for implementing storm water practices
- Ability to receive variance in parking or lot size requirements
- Reduction in Storm Water Quality Volume (see Section 1.2.3.3)
- Other City-Developer Agreements

Depending on the local storm water management program, some of these site design credits may be restricted, or no credits may be available. It is up to the local jurisdiction to define the types and amounts of credit they will offer to a development. Designers are encouraged to consult with the appropriate approval authority to ensure if and when a credit is applicable and to determine restrictions and guidelines on non-structural strategies.

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CHAPTER
1

Section 1.4
integrated Storm Water Controls

1.4.1 Introduction

The impacts of storm water runoff from development cannot always be completely mitigated by land use and nonstructural approaches. Therefore, the use of appropriate structural storm water controls on development sites is sometimes necessary as an integrated part of the storm water management system. Storm water controls (sometimes referred to as *best management practices* or *BMPs*) are constructed storm water management facilities designed to treat storm water runoff and/or mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization.

Chapter 5 recommends a number of structural storm water controls that can be used for meeting the *integrated* design approach including very specific performance and design criteria. The next several pages provide a brief overview of the range of storm water controls recommended for use in North Central Texas communities. Clearly not every control is applicable for every site or goal.

1.4.2 Recommended Storm Water Control Practices for North Central Texas Communities

Bioretention Areas

- Bioretention areas are shallow storm water basins or landscaped areas that utilize engineered soils and vegetation to capture and treat storm water runoff. Runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.

Channels

- *Enhanced Swale:* A vegetated open channel that is explicitly designed and constructed to capture and treat storm water runoff within wet or dry cells formed by check dams or other means.
- *Grass Channel:* A vegetated open channel designed to filter storm water runoff and meet velocity targets for the water quality and streambank protection design storm events.
- *Open Conveyance Channel:* Includes such conveyance systems as drainage ditches, grass channels, dry and wet enhanced swales, riprap channels, and concrete channels.

Chemical Treatment

- *Alum Treatment System:* This chemical treatment provides for the injection of liquid alum into storm water runoff on a flow-weighted basis during rain events as it enters a settling basin. The alum precipitate or 'floc' that is formed during coagulation combines with nutrients, suspended solids, and heavy metals and settles in the settling basin.

Conveyance Components

- *Culverts:* Typically, short, closed (covered) conduits that convey storm water runoff under an embankment, usually a roadway. The primary purpose of a culvert is to convey surface water, but it may also be used to restrict flow and reduce downstream peak flows.

- *Energy Dissipators:* Energy dissipaters are engineered devices such as riprap or concrete baffles placed at the outlet of a storm water conveyance for the purpose of reducing the velocity, energy, and turbulence of the discharged flow.
- *Inlets/Street Gutters:* Drainage elements that remove runoff from sidewalks, streets, and sumps for public safety purposes and function to input storm water to the storm drain pipe systems.
- *Pipe Systems:* A branching system of closed conduits that accumulate storm water runoff and convey it to an open channel, natural stream, or storage facility.

Detention

- **Dry Detention:* Dry detention basins are surface storage basins or facilities typically designed to provide water quantity control through detention or extended detention of storm water runoff.
- **Extended Dry Detention Basins:* Extended dry detention basins are surface storage basins or facilities that can be designed to provide water quality and quantity control through extended detention of storm water runoff.
- *Multi-Purpose Detention Areas:* Multi-purpose detention areas are facilities designed primarily for another purpose, such as parking lots and rooftops, that can provide water quantity control through detention of storm water runoff.
- *Underground Detention:* Underground detention storage is provided by underground tanks or vaults designed to provide water quantity control through detention and/or extended detention of storm water runoff.

Filtration

- *Filter Strip:* Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration.
- *Organic Filter:* Organic filters are design variant of the surface sand filter using organic materials such as peat or compost in the filter media.
- *Planter Boxes:* Planter boxes are used on impervious surfaces to collect and detain/infiltrate rainfall and runoff. They usually contain growing plants.
- *Surface Sand Filter / Perimeter Sand Filter:* Sand filters are multi-chamber structures designed to treat storm water runoff through filtration, using a sand bed as the primary filter media. Filtered runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.
- *Underground Sand Filter:* The underground sand filter is a design variant of the surface sand filter located in an underground vault designed for high density land use where there is not enough space for a surface sand filter or other storm water controls.

Hydrodynamic Devices

- *Gravity (Oil-Grit) Separator:* The gravity (oil-grit) separator is a hydrodynamic separation device designed to remove settleable solids, oil, grease, debris, and floatables from storm water runoff through gravitational settling and trapping of pollutants.

Infiltration

- *Downspout Drywells:* Downspout Drywells are essentially perforated manholes, but they can be manufactured in various sizes. Located underground, they allow storm water infiltration even in highly urbanized areas. They should be used in conjunction with some type of pretreatment devices where there are minimal risks of groundwater contamination.
- *Infiltration Trench:* Infiltration trenches are excavated trenches filled with stone aggregate used to

capture and allow infiltration of storm water runoff into the surrounding soils from the bottom and sides of the trench.

- *Soakage Trench:* Soakage trenches are a variation of infiltration trenches. Soakage trenches drain through a perforated pipe buried in gravel. They are used in highly impervious areas where conditions do not allow surface infiltration and where pollutant concentrations in runoff are minimal (i.e. non-industrial rooftops). They may be used in conjunction with other storm water devices, such as draining downspouts or planter boxes.

*Ponds

There are two storm water storage functions: detention and retention. Detention ponds are designed to store water and release it over time to empty the basin. Retention basins have a permanent pool (or micropool) of water. Some basins are designed to include both detention and retention. Runoff from each rain event is detained and treated in the pool. Pond design variants include:

- Micropool Extended Detention Pond
- Multiple Pond Systems
- Wet Extended Detention Pond
- Wet Pond

Porous Surfaces

- *Green Roofs:* A green roof uses a small amount of substrate over an impermeable membrane to support a covering of plants. The green roof slows down runoff from the otherwise impervious roof surface as well as moderating rooftop temperatures. With the right plants, a green roof will also provide aesthetic or habitat benefits. Green roofs have been used in Europe for decades.
- *Modular Porous Paver Systems:* Modular porous paver systems are pavement surfaces composed of structural units with void areas that are filled with pervious materals such as sand or grass turf. Porous pavers are installed over a gravel base course to provide storage as runoff infiltrates through the porous paver system into underlying permeable soils.
- *Porous Concrete:* Porous concrete is the term for a mixture of coarse aggregate, Portland cement, and water that allows for rapid infiltration of water and overlays a stone aggregate reservoir. The reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system.

Proprietary Structural Controls

There are numerous manufactured structural control systems available from commercial vendors designed to treat storm water runoff and/or provide water quantity control.

Re-Use

- *Rain Harvesting (Tanks/Barrels):* A rain harvesting system is a container or system designed to capture and store rainwater discharged from a roof. The rain harvesting system consists of a storage container, a downspout diversion, a sealed lid, and an overflow system. Typical rain harvesting systems hold between 50 and 500 gallons of water, and may work in series to provide larger volumes of storage. For larger roof tops an underground storage tank and pump system can provide water for irrigation purposes on site.

Wetlands

- **Storm Water Wetlands:* Storm water wetlands are constructed wetland systems used for storm water management. Storm water wetlands consist of a combination of shallow marsh areas, open water areas, and semi-wet areas above the permanent water surface. Wetland design variants include:

  - Extended Detention Shallow Wetland
  - Pocket Wetland
  - Pond/Wetland Systems
  - Shallow Wetland
- *Submerged Gravel Wetlands:* Submerged gravel wetlands are also known as subsurface flow wetlands and consist of one or more cells filled with crushed rock designed to support wetland plants. Storm water runoff flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

* *Consideration must be given in the design of storm water ponds, wetlands, and detention basins to minimize potential mosquito breeding areas. This can be accomplished in a variety of ways including aquatic and chemical techniques which should be utilized as appropriate for the situation.*

1.4.3 Suitability of Storm Water Controls to Meet Storm Water Management Goals

Table 1.4.3-1 summarizes the storm water management suitability of the various storm water controls in addressing the *integrated* Design Approach. Given that some storm water controls cannot alone meet all of the design requirements, typically two or more controls are used in series to form what is known as a storm water "treatment train." Chapter 5 provides guidance on the use of a treatment train as well as how to calculate the pollutant removal efficiency for storm water controls in series. Chapter 5 also provides guidance for choosing the appropriate storm water control(s) for a site as well as the basic considerations and limitations on the use of a particular storm water control.

Table 1.4.3-1 Suitability of Storm Water Controls to Meet *integrated* Design Approach

Category	*integrated* Storm Water Controls	Water Quality Protection	Streambank Protection	On-Site Flood Control	Downstream Flood Control
Bioretention Areas	Bioretention Areas	P	S	S	-
Channels	Enhanced Swales	P	S	S	S
	Channels, Grass	S	S	P	S
	Channels, Open	-	-	P	S
Chemical Treatment	Alum Treatment System	P	-	-	-
Conveyance Components	Culverts	-	-	P	P
	Energy Dissipation	-	P	S	S
	Inlets/Street Gutters	-	-	P	-
	Pipe Systems	-	P	P	P
Detention	Detention, Dry	S	P	P	P
	Detention, Extended Dry	S	P	P	P
	Detention, Multi-purpose Areas	-	P	P	P
	Detention, Underground	-	P	P	P
Filtration	Filter Strips	S	-	-	-
	Organic Filters	P	-	-	-
	Planter Boxes	P	-	-	-
	Sand Filters, Surface/Perimeter	P	S	-	-
	Sand Filters, Underground	P	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	S	-	-	-
Infiltration	Downspout Drywell	P	-	-	-
	Infiltration Trenches	P	S	-	-
	Soakage Trenches	P	S	-	-
Ponds	Ponds, Storm Water	P	P	P	P
Porous Surfaces	Green Roof	P	S	-	-
	Modular Porous Paver Systems	S	S	-	-
	Porous Concrete	S	S	-	-
Proprietary Systems	Proprietary Systems *	S	S	S	S
Re-Use	Rain Barrels	P	-	-	-
Wetlands	Wetlands, Storm Water	P	P	P	P
	Wetlands, Submerged Gravel	P	P	S	-

P = **Primary Control:** Able to meet design criterion if properly designed, constructed and maintained.

S = **Secondary Control:** May partially meet design criteria. May be a Primary Control but designated as a Secondary due to other considerations. For Water Quality Protection, recommended for limited use in approved community-designated areas.

- = Not typically used or able to meet design criterion.

***** = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data.

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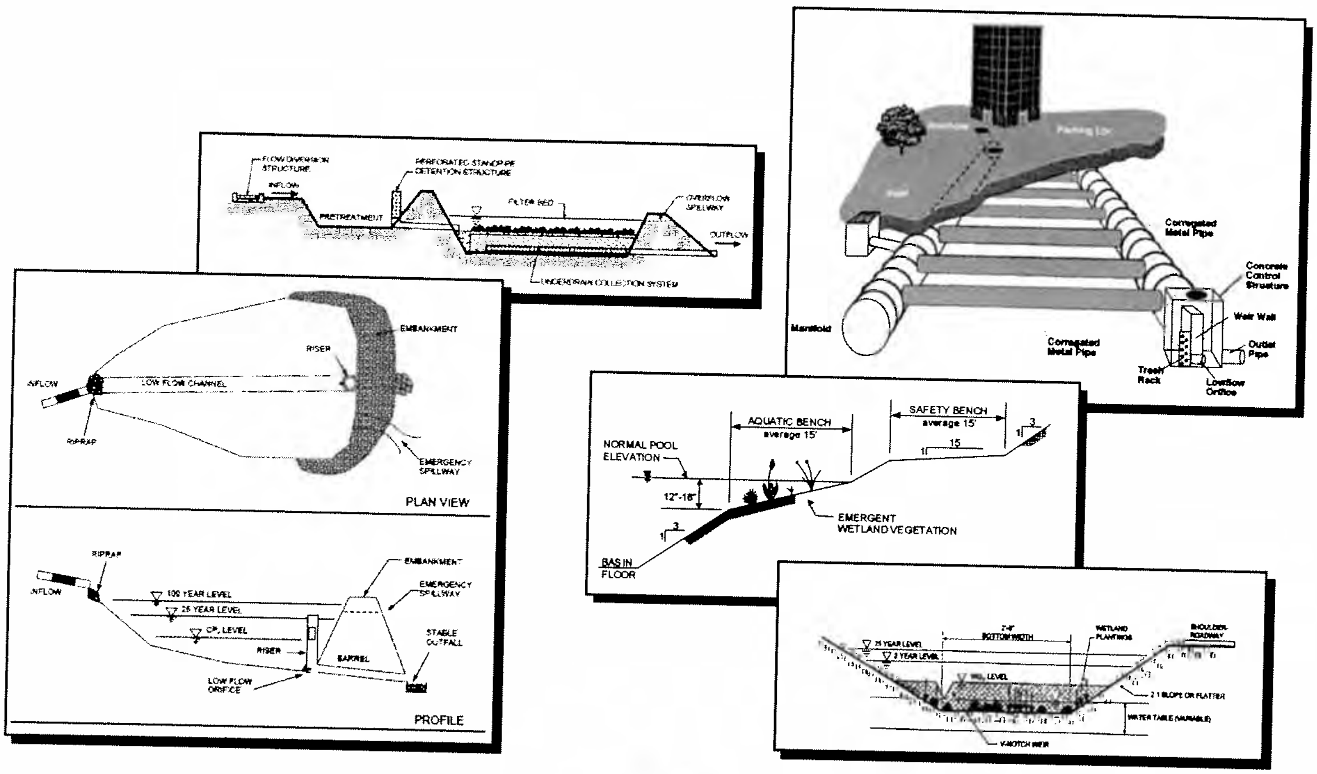
APPENDIX G

iSWM Big Fossil Creek Watershed Study

integrated Storm Water Management

Big Fossil Creek Watershed Study



iSWM

February 2005

This report was prepared by AMEC for the North Central Texas Council of Governments. The purpose of this study is to provide a quantitative analysis to determine the impacts of implementing iSWM for development in North Texas. The report was reviewed by the Technical Review Team as well as the iSWM Steering Committee.

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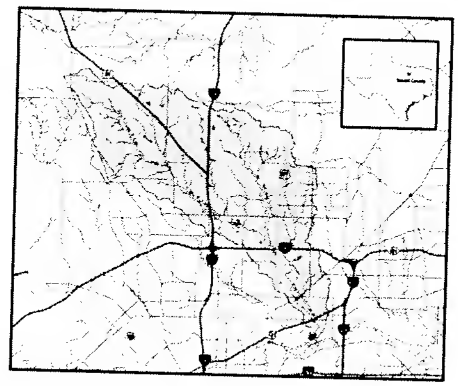
Executive Summary

The benefits of integrated Storm Water Management (iSWM) may be extended beyond the individual site planning level to the watershed level when applied consistently throughout the development of a watershed. The Big Fossil Creek Watershed, located in the northwestern portion of the North Central Texas Council of Governments (NCTCOG) region, was selected to apply simulated development utilizing the iSWM design criteria and watershed models (see figure below). The purpose was to test the potential impacts of iSWM application to the remaining undeveloped portions of Big Fossil Creek compared to development without iSWM practices.

The Big Fossil Creek Watershed covers an area of approximately 56 square miles and encompasses Big Fossil Creek, four un-named tributaries, and Whites Branch. Residential, commercial, and industrial development has primarily occurred in the lower portion of the watershed, leaving the undeveloped upper portion a prime location to simulate iSWM design criteria and verify watershed wide benefits.



Big Fossil Creek Watershed

The iSWM simulation within the Big Fossil Creek Watershed focused on the analysis of the iSWM design criteria in achieving the goals of flood control, water quality, and streambank protection for three watershed scenarios:

- existing watershed conditions;
- future conditions *without* the application of iSWM design criteria; and
- future conditions *with* the application of iSWM design criteria.

Results

The table below compares the results of the three watershed scenarios for each of the four iSWM design criteria goals: (1) runoff quantity flood control; (2) floodplain impact flood control; (3) water quality; and (4) streambank protection. It can be noted the increase from existing conditions to future conditions is consistently reduced with the application of iSWM design practices.

iSWM Design Goals	Watershed Conditions					
	Existing	Future without iSWM	Increase from Existing to Future	Future *with* iSWM	Increase from Existing to Future *with* iSWM	Increase from Future to Future *with* iSWM
Flood Control Analysis – Runoff Quantity						
100-Yr Peak Discharge Upstream of SH 121	34,204 cfs	38,026 cfs	+ 11%	34,639 cfs	+ 1%	- 9%
1-Yr Peak Discharge Upstream of SH 121	5,742 cfs	8,576 cfs	+ 49%	5,054 cfs	- 12%	- 41%
Flood Control Analysis – Floodplain Impact						
Flood Elevation Cross Section # 1	512.66 ft	513.98 ft	1.32 ft	512.81 ft	0.15 ft	- 1.17 ft
Flood Elevation Cross Section # 2	564.77 ft	567.49 ft	2.72 ft	565.47 ft	0.70 ft	- 2.02 ft
Water Quality Analysis						
Total Annual TSS Loading	7,692,556 lbs	11,395,189 lbs	+ 32%	9,714,227 lbs	+18%	-17%
Streambank Protection Analysis (ft)						
Channel Width (ft)	73.00 ft	96.97 ft	+ 33%	63.21 ft	- 13%	- 35%
Channel Depth (ft)	7.60 ft	10.99 ft	+ 45%	7.42 ft	- 2%	- 33%

Value-added Benefits

Developers in North Central Texas can effectively implement storm water management practices to address the impacts of new development and redevelopment, and to prevent and mitigate problems associated with urban storm water runoff. Within the limits of the study approach, the analyses of runoff quantity, floodplain impact, water quality, and streambank protection verified the benefits of iSWM design criteria at the watershed level for future conditions:

- Reduction in future runoff quantities to near existing conditions;
- Reduction in the increase of water surface elevations;
- Reduction in the increase of TSS loadings; and
- Reduction in the increase of erosion to channel depths and widths.

While the water quality analysis primarily focused on the simulated application of structural BMPs to reduce the pollutant loading to the stream, it can also be noted that water quality benefits are achieved through streambank protection. With bed and bank erosion as a primary source of TSS loadings within the North Central Texas region, a reduction in the amount of channel erosion, through streambank protection, will also result in a reduction in TSS loadings.

Summary of Big Fossil Creek Watershed Study

The benefits of iSWM may be extended beyond the individual site planning level to the watershed level when applied consistently throughout the development of a watershed. The Big Fossil Creek Watershed, located in the northwestern portion of the North Central Texas Council of Governments (NCTCOG) region, was selected for conceptual development utilizing the iSWM design criteria and watershed models (See Figure 1). The purpose was to test the potential impacts of iSWM application to the remaining undeveloped portions of Big Fossil Creek compared to development without ISWM practices.

The Big Fossil Creek Watershed covers an area of approximately 56 square miles and encompasses Big Fossil Creek, four un-named tributaries, and Whites Branch. Residential, commercial, and industrial development has primarily occurred in the lower portion of the watershed, leaving the undeveloped upper portion a prime location to simulate iSWM design criteria and verify watershed wide benefits.

The iSWM simulation within the Big Fossil Creek Watershed focused on the analysis of the iSWM design criteria in achieving the goals of flood control, water quality, and streambank protection for three watershed scenarios: existing watershed conditions, future conditions *without* the application of iSWM design criteria, and future conditions *with* the application of iSWM design criteria.

Flood Control Analysis – Runoff Quantity

The analysis of runoff quantity required the development of a hydrologic model. An existing conditions hydrologic model was first created, using the HEC-1 computer program, to reflect the current types of land use, soil conditions, and runoff parameters within the watershed. The Big Fossil Creek Watershed was divided into six basins, representing Big Fossil Creek, the four un-named tributaries, and Whites Branch. Each basin was comprised of varying numbers of sub-basins, ranging in area from 0.25 to 1.0 square miles. Figure 2 presents the computed existing conditions curve numbers for each sub-basin in the watershed. Curve numbers are a numerical description of the impermeability of the land in the watershed. This number varies from 0 (100% rainfall infiltration) to 100 (0% infiltration - i.e., pavement). This gives an indication for the potential for runoff.

The hydrologic model was then modified to reflect future developed conditions. Future developed conditions for the year 2025 were determined from land use projections provided by the NCTCOG and the City of Fort Worth. Increased impervious areas due to projected residential, commercial, and industrial growth are reflected in the increased curve numbers and somewhat reduced lag times computed throughout the watershed. Figure 3 presents the developed future curve numbers for each sub-basin in the watershed.

A second modified model was created to reflect the application of iSWM design criteria in the currently undeveloped areas of the upper portion of the watershed. Figure 4 highlights the undeveloped sub-basins selected for iSWM model application.

The hydrologic model was modified to reflect the iSWM design standard known as the ten percent rule. The ten percent rule recognizes the fact that a structural control providing detention has a "zone of influence" downstream where its effectiveness can be felt. Beyond this zone of influence the structural control becomes relatively insignificant compared to the runoff from the total drainage area.

Due to the limited budget and large number of sub-basins within the hydrologic model, a target range of acceptable peak flow reduction from 5 percent less than existing conditions peak flow to

25 percent less than existing conditions peak flow was assumed. This would allow for an average reduction in the 100-year peak flow to achieve the ten percent rule within the selected sub-basins. Table 1 presents the peak runoff values for the three watershed scenarios throughout the lower portion of the watershed, specifically from the stream crossing at Blue Mound Road to the base of the watershed, just upstream of State Highway 121. The application of iSWM design criteria in the upper portion of the watershed would almost maintain the runoff quantity of the existing conditions scenario. A detailed discussion of the hydrologic model development and modifications is presented in Appendix A.

Table 1. Summary of Conceptual Development Analysis – Runoff Quantity

Area of Big Fossil Creek Watershed (sq.mi.)	100 Year Peak Flow (cfs)					
	Existing Watershed Conditions	Future without iSWM Watershed Conditions	Percent Increase from Existing to Future	Future *with* iSWM Watershed Conditions	Percent Increase from Existing to Future *with* iSWM	Percent Increase from Future to Future *with* iSWM
16.64	16955	19259	13.6%	16963	0.0%	-11.9%
17.57	17355	19754	13.8%	17574	1.3%	-11.0%
18.18	17617	20030	13.7%	17967	2.0%	-10.3%
19.31	18603	21150	13.7%	19166	3.0%	-9.4%
19.98	18534	21100	13.8%	19368	4.5%	-8.2%
20.75	18832	21406	13.7%	19783	5.0%	-7.6%
21.76	19089	21683	13.6%	20296	6.3%	-6.4%
22.40	19176	21734	13.3%	20496	6.9%	-5.7%
28.63	24273	27668	14.0%	25724	6.0%	-7.0%
28.74	24132	27438	13.7%	25599	6.1%	-6.7%
31.06	25470	29011	13.9%	26737	5.0%	-7.8%
31.77	25308	28755	13.6%	26512	4.8%	-7.8%
32.32	23788	26648	12.0%	24731	4.0%	-7.2%
42.94	32280	36166	12.0%	33153	2.7%	-8.3%
43.44	31717	35501	11.9%	32668	3.0%	-8.0%
44.35	31756	35507	11.8%	32681	2.9%	-8.0%
49.84	33654	37495	11.4%	34175	1.5%	-8.9%
50.63	33805	37650	11.4%	34294	1.4%	-8.9%
51.17	33587	37420	11.4%	34119	1.6%	-8.8%
51.94	33715	37553	11.4%	34229	1.5%	-8.9%
52.57	33786	37628	11.4%	34313	1.6%	-8.8%
53.60	34016	37880	11.4%	34488	1.4%	-9.0%
54.31	33984	37800	11.2%	34443	1.4%	-8.9%
55.88	34204	38025	11.2%	34639	1.3%	-8.9%
56.63	33934	37678	11.0%	34398	1.4%	-8.7%

Flood Control Analysis - Floodplain Impact

The flood impact analysis applied the computed runoff quantities of the three watershed scenarios to a hydraulic model, previously created by the U.S. Army Corps of Engineers, Fort Worth District, along a defined stream reach, Interstate 35 to State Highway 121. This stream reach, located within the developed lower portion of the watershed, was selected because of identified flooding problems. As development occurs in the upper portion of the watershed, maintaining or lessening the impact of a flood event in the existing lower, developed area is important.

Flood elevations were determined at multiple cross sections within the stream reach for the 100-year storm event. A detailed discussion of the hydraulic model and modifications is presented in Appendix B. Table 2 presents 100-year water surface elevations (WSEL) for the same three development scenarios as the hydrologic model discussed above at several locations within the stream reach. It can be seen that the flood elevation increase from existing conditions to future conditions without iSWM is greater than the increase from existing conditions to future conditions *with* iSWM.

Table 2. Summary of Conceptual Development Analysis – Flood Impact

Location	**100-Year Water Surface Elevation (ft)**				
	Existing Watershed Conditions	**Future without iSWM Watershed Conditions**	**Increase in Future WSEL from Existing Conditions**	**Future *with* iSWM Watershed Conditions**	**Increase in Future iSWM WSEL from Existing Conditions**
Flood Elevation (ft) Cross Section # 17130 Upstream of Hwy 183	512.66	513.98	1.32	512.81	0.15
Flood Elevation (ft) Cross Section # 35870/36000 Upstream of T&P RR	564.77	567.49	2.72	565.47	0.70
Flood Elevation (ft) Cross Section # 57920 Upstream of Western Ctr Blvd	605.84	607.84	2.00	606.47	0.63

The application of iSWM holds the flow elevation increase to an average increase of 0.27 feet throughout the reach, while uncontrolled development in just the currently undeveloped portion allows the 100-year flow elevation to increase by an average of 1.2 feet throughout the reach, with a maximum increase of 2.72 feet.

While this increase does not create problems in developed areas remote from the flood increases, in currently flooded areas would create increasingly dangerous flood depths and velocities for those homes currently flooded, a further reduction in property values, and would inundate several additional structures in the neighborhood. For example, Exhibits 1 and 2 show two neighborhoods where significant new portions of streetside flooding occurs. New flooding is indicated by the dark blue areas, while the light blue areas indicate existing 100-year floodplain limits. Actual planimetric structure footprint information was not assessed to verify actual structure locations. On a larger scale, figures 5 and 6 present the 100-year floodplain in the upper and lower portions of the watershed, respectively.

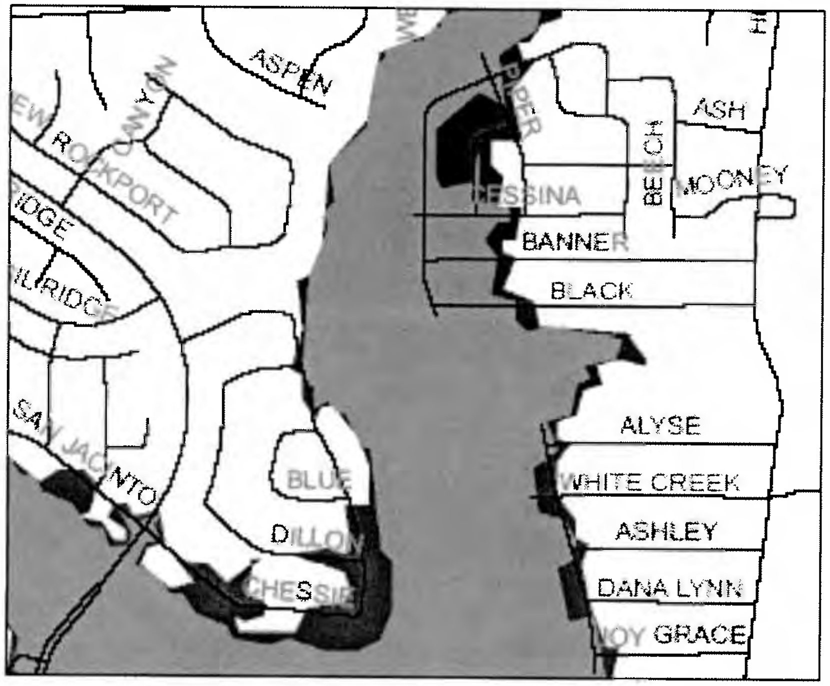


Exhibit 1. Neighborhood Flooding in Study Reach Example 1

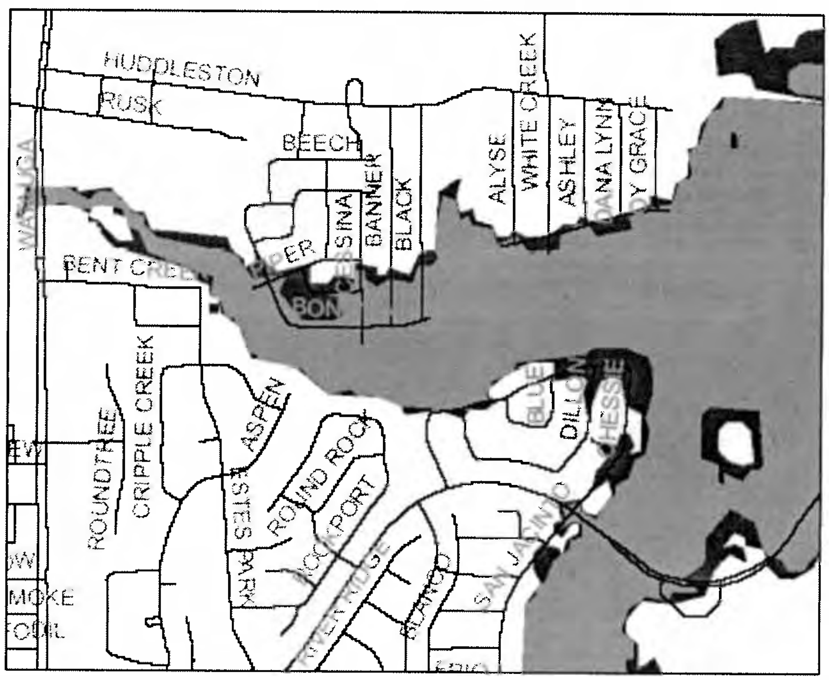


Exhibit 2. Neighborhood Flooding in Study Reach Example 2

Water Quality Analysis

The amount of total suspended solids (TSS) in a stream is a fair indicator of the overall water quality of the stream. But it is not without its problems especially in drier climates. Urban pollutants, such as oils and grease, attach themselves to the suspended solids and are transported downstream. Additionally, sediment in Texas streams is seen as a significant problem. Excess sediment in streams causes the following problems:

- Lost property or conveyance and adjacent structural damage;
- Safety concerns for crossing structures and steep or caving banks;
- Increased flooding due to channel siltation;
- Reservoir filling reducing storage capability;
- Water quality degradation;
- Ecological damage from turbid waters;
- Aesthetics & quality of life; and
- Property value preservation.

For the water quality analysis, TSS was selected as the indicator pollutant used to compare water quality impacts for the watershed scenarios. TSS pollutant loadings were computed for each sub-basin developed within the hydrologic model using a land use approach to estimate the annual and/or seasonal non-point source loads based upon the event mean concentrations (EMCs) and runoff volumes. Event mean concentrations were determined through a qualitative in-stream monitoring program completed by the NCTCOG. Table 3 presents the EMC values for TSS.

Table 3. Event Mean Concentrations, TSS (mg/l)

Type of Land Use	Season 1 (Sep – Oct)	Season 2 (Nov – Feb)	Season 3 (Mar – Jun)	Season 4 (Jul – Aug)
Commercial	41.5	37.5	46	37
Highway	62	142	134	142
Industrial	54	86	135	86
Open	118	332	118	332
Residential	90	73	116	73

"Open Space" has the highest TSS concentration per unit of runoff. But, when coupled with the much greater total volume of runoff per acre from more impervious areas, and the fact that other pollutants that attach to TSS are more highly concentrated in urbanized runoff, it is clear that urban development increases pollution to streams and channels.

Additionally, it can be surmised from data from the monitoring program that often the largest component of TSS loadings downstream are the result of bed and bank erosion within the channel itself (see discussion on stream erosion below). Thus the control of channel erosion through the channel protection criteria would also significantly improve the TSS loading reductions and associated stream water quality, though reduced channel erosion would not reduce other kinds of pollution.

Similar to the hydrologic and hydraulic model scenarios, water quality models were created for existing conditions, future conditions *without* iSWM, and future conditions *with* iSWM design criteria. In order to simulate the future conditions *with* iSWM scenario, a 70 percent reduction in TSS loadings was applied to each of the selected iSWM sub-basins, previously identified in the hydrologic model development. This application was done to reflect the design recommendations of the iSWM structural Best Management Practices (BMPs). The recommended water quality BMPs, if designed and installed properly and maintained, will remove 70-80 percent of the average annual TSS load in typical urban post-development runoff and a proportional removal of other pollutants.

While this assumption of 70-80 percent removal is true for sites with well designed and newly constructed controls, as we saw above, it may not be true for the whole watershed or for individual sub-basins. This is true, in part, because of bed and bank erosion, erosion along unprotected roadways, and general erosion in areas not protected by structural controls. Also, without proper maintenance, controls can lose effectiveness over time. No effort was made in this brief study to quantify these other sources of TSS and other pollutants.

Table 4 presents the TSS loadings determined for the entire watershed for the three watershed scenarios. A detailed discussion of the water quality model and TSS loading results for individual sub-basins is presented in Appendix C.

Table 4. Summary of Conceptual Development Analysis – Water Quality

Season	TSS LOADING (lbs)					
	Existing Watershed Conditions	**Future without iSWM Watershed Conditions**	**Percent Difference from Existing to Future**	**Future *with* iSWM Watershed Conditions**	**Percent Difference from Existing to Future *with* iSWM**	**Percent Difference from Future to Future *with* iSWM**
Sep- Oct	935,230	1,536,896	39%	1,311,525	24%	-17%
Nov – Feb	2,504,454	2,916,779	14%	2,515,762	0.4%	-16%
Mar – Jun	3,148,510	5,655,309	44%	4,777,553	29%	-18%
Jul – Aug	1,104,361	1,286,205	14%	1,109,387	0.4%	-16%
TOTAL ANNUAL LOADING	**7,692,556**	**11,395,189**	**32%**	**9,714,227**	**18%**	**-17%**

The focus of the water quality analysis on TSS loadings reveals that urbanization does not necessarily increase the concentration of TSS from existing to future conditions. The EMC values determined for TSS within open space were significantly high, contributing to high TSS loadings for existing conditions. On a national level, the TSS concentrations for stabilized open space ranges between 150 and 250 mg/l.

Urbanization, however, does increase the volume of runoff, as well as the concentration of urban pollutants, such as oil and grease, attached to the suspended solids. It is the application of structural BMPs, which does reduce the TSS loading for future conditions *with iSWM* from future conditions without iSWM.

Streambank Protection Analysis

For the channel impact analysis, the computed runoff quantities from the three watershed scenarios were applied to a locally derived regression equation for computing channel erosion. Channel erosion and incision have both environmental and physical effects. As listed above, these effects range from undermining bridges, undermining pipeline crossings, lowering local ground water tables, filling reservoirs and detention ponds, loss of property (along with property value), and creating a safety problem with vertical cliffs to loss of wildlife habitats and biodiversity. The equation used in this study of Big Fossil Creek was derived in the technical paper *Erodibility of Urban Bedrock and Alluvial Channels, North Texas* (Allen, Peter M., et.al.). This technical paper identified and quantified the erosion processes and erosion potential of stream channel types specific to North Texas.

According to the technical paper, major erosion of urban stream channels in North Texas is found in smaller basins with contributing drainage areas of less than ten square miles. For these basins, four basic channel types have been identified based on bed and bank lithologies: alluvial banks and bottoms, alluvial banks and gravel bottoms, alluvial banks and rock bottoms, and rock banks and rock bottoms. Most channels, approximately 75 percent, have alluvial banks with gravel or rock bottoms. Channel slopes are steep and rock consists predominantly shale and limestone.

For the study of Big Fossil Creek, representative cross sections were identified in the stream reach from Interstate 35 to State Highway 121. From these cross sections it was possible to categorize the channel type as alluvial banks with rock bottom. For this specific channel type, a channel erosion equation derived in the technical paper was used to estimate the changes in channel shape due to the increased shear forces along channel side slopes and bottom width. A detailed discussion of the channel impact analysis is presented in Appendix D.

To illustrate the impacts of urban development on channel widths and depths, the equation is plotted against C factor. This exhibit was developed by calculating required peak flows for the channel size equation using the Rational Method. It is assumed that the initial undeveloped C Factor is 0.2. The exhibit illustrates what happens to a channel in terms of the ratio of stream width and depth compared to the “natural” width and depth for a C Factor of 0.20.

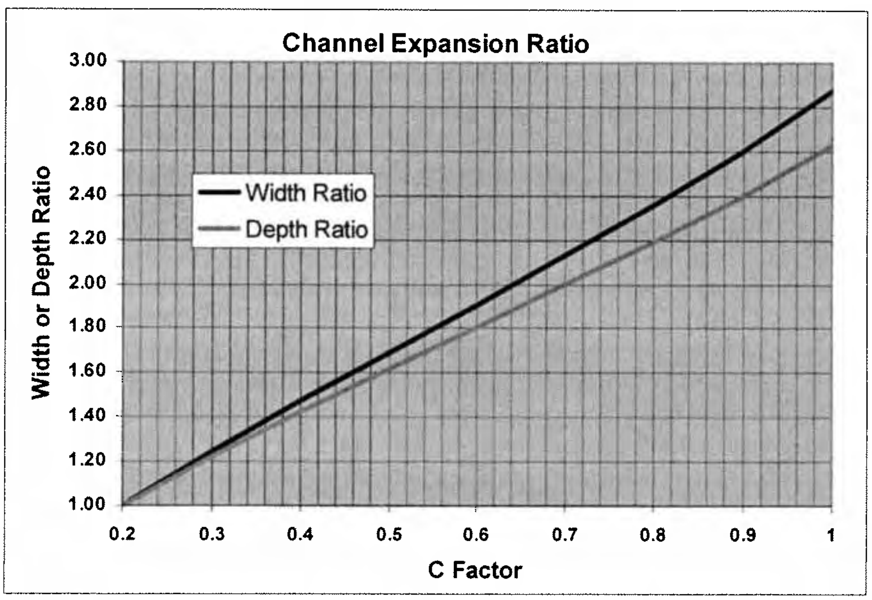


Exhibit 3. Channel Expansion Ratio versus Rational C Factor

When this equation is applied over the 9.5-mile study reach from Interstate 35 to State Highway 121, approximately 20,000,000 ft^3 (460 acre-feet) of sediment are anticipated to be removed from Big Fossil Creek under future conditions without the application of iSWM design criteria. When the watershed as a whole is considered with more than 85 miles of streams the total sediment load and potential for damage is enormous.

Table 5 presents the reduction in channel erosion between the future conditions without and *with* iSWM application for the specific cross section. Notice that the iSWM cross section is actually smaller than the existing condition. This indicates, within the margin of error of the equations, that the channel would have been less than its currently impacted shape had iSWM been used throughout the upstream area from the beginning. Exhibit 4 presents the specific channel cross sections for existing, future, and future *with* iSWM conditions.

Table 5. Summary of Conceptual Development Analysis – Streambank Protection

Type of Analysis	Existing Conditions from HEC-2 Model	Future Conditions without iSWM	Percent Difference from Existing to Future	Future Conditions *with* iSWM	Percent Difference from Existing to Future *with* iSWM	Percent Difference from Future to Future *with* iSWM
Channel Width (ft)	73.00	96.97	32.84%	63.21	-13.41%	-34.8%
Channel Depth (ft)	7.60	10.99	44.61%	7.42	-2.37%	-32.5%
Channel Area (ft^2)	429	824[1]	---	359[1]	---	---

[1]Trapezoidal channels with 2:1 side slopes were assumed for both of the future conditions scenarios.

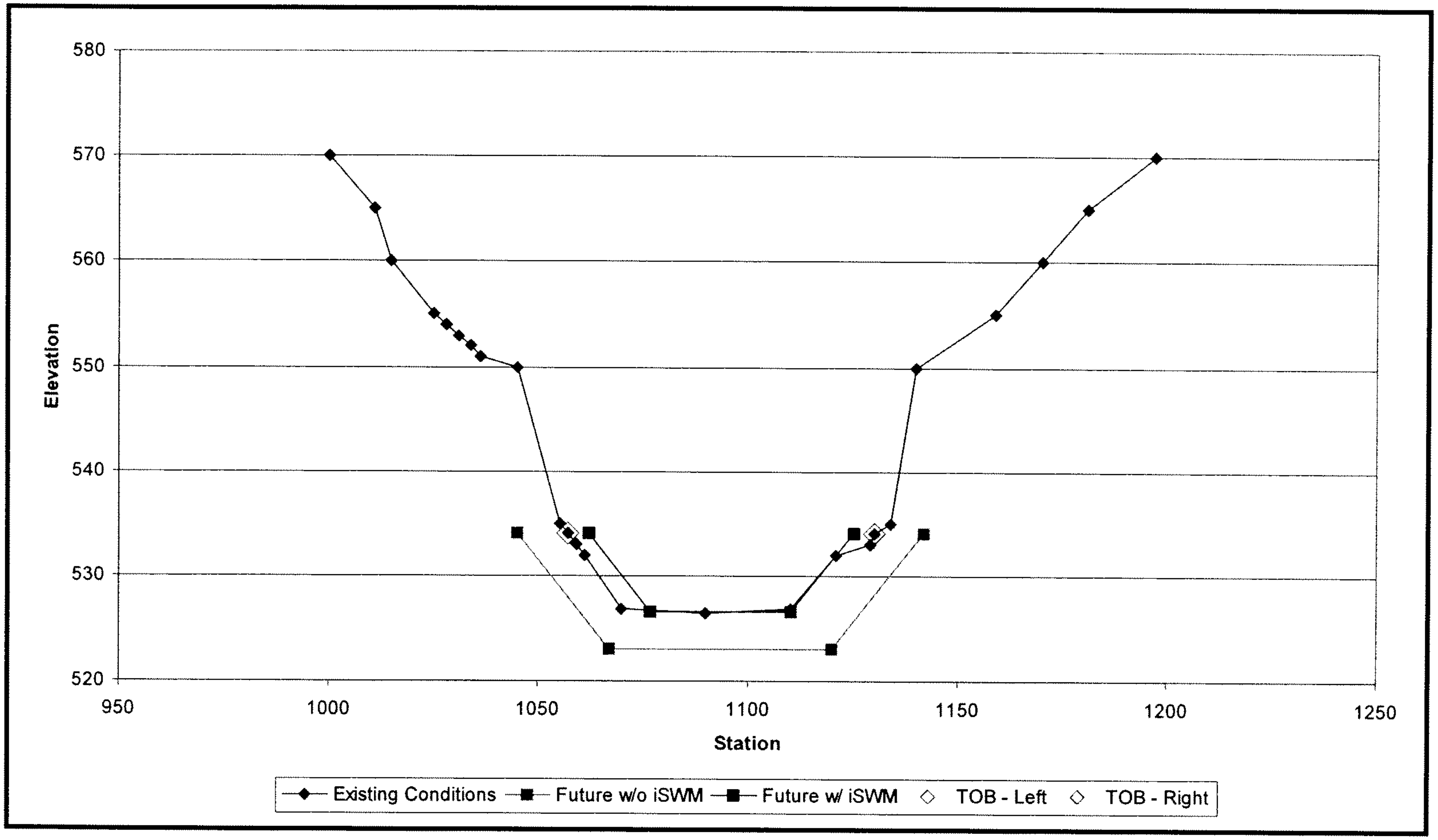


Exhibit 4. Computed Streambank Erosion on Sample Cross Section

Conclusion

Developers in North Central Texas can effectively implement storm water management practices to address the impacts of new development and redevelopment, and to prevent and to mitigate problems associated with urban storm water runoff. Within the limits of the study approach, the analyses of runoff quantity, floodplain impact, water quality, and streambank protection verified the benefits of iSWM design criteria at the watershed level for future conditions:

- Reduction in future runoff quantities to near existing conditions;
- Reduction in the increase of water surface elevations;
- Reduction in the increase of TSS loadings; and
- Reduction in the increase of erosion to channel depths and widths.

While the water quality analysis primarily focused on the simulated application of structural BMPs to reduce the pollutant loading to the stream, it can also be noted that water quality benefits are achieved through streambank protection. With bed and bank erosion as a primary source of TSS loadings within the North Central Texas region, a reduction in the amount of channel erosion, through streambank protection, will also result in a reduction in TSS loadings.

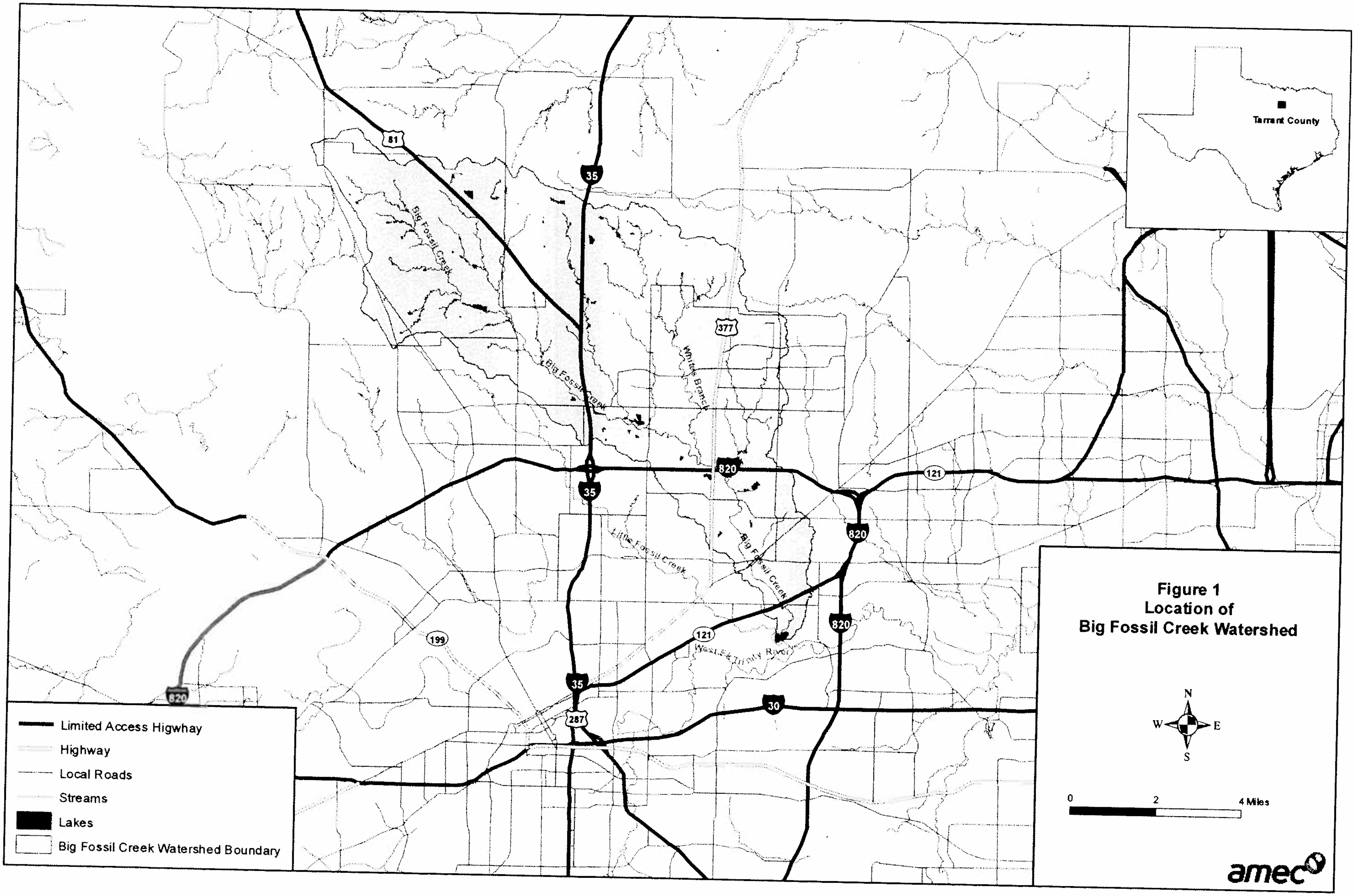
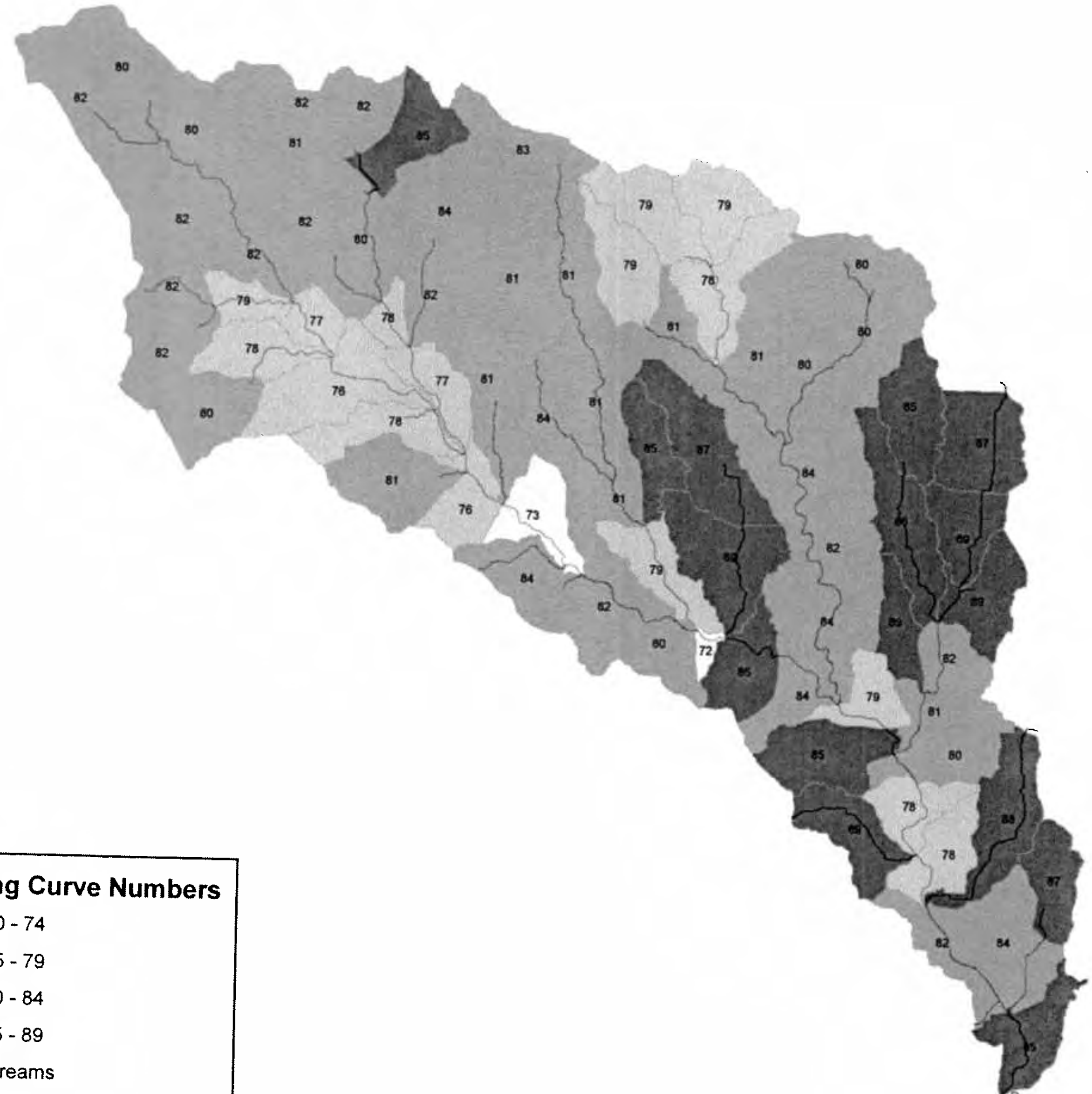


Figure 1
Location of
Big Fossil Creek Watershed



Existing Curve Numbers

- 70 - 74
- 75 - 79
- 80 - 84
- 85 - 89
- Streams

Figure 2
Existing Conditions Curve Numbers

N W E S

0 6,500 13,000 Feet

amec

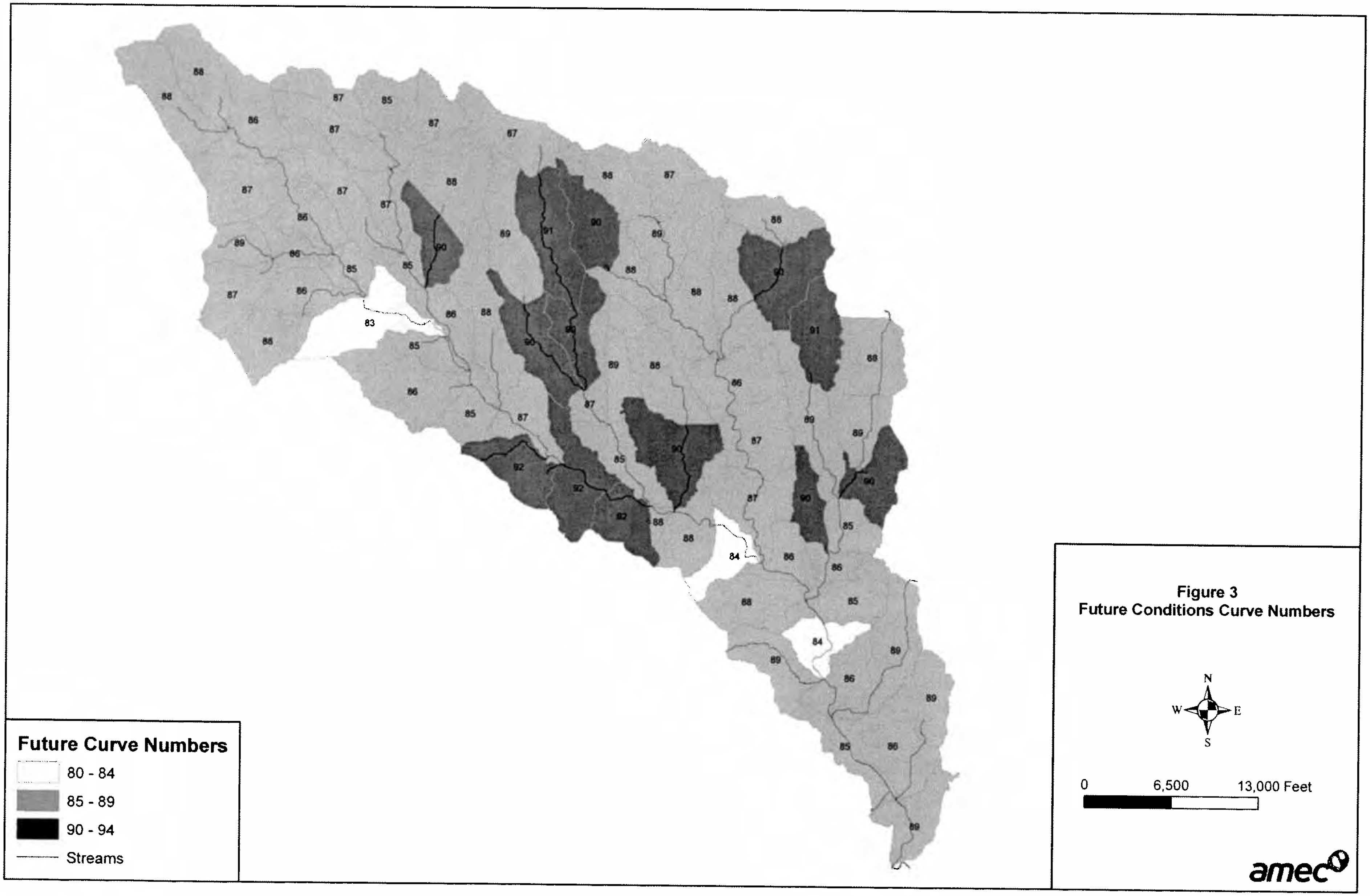


Figure 3
Future Conditions Curve Numbers

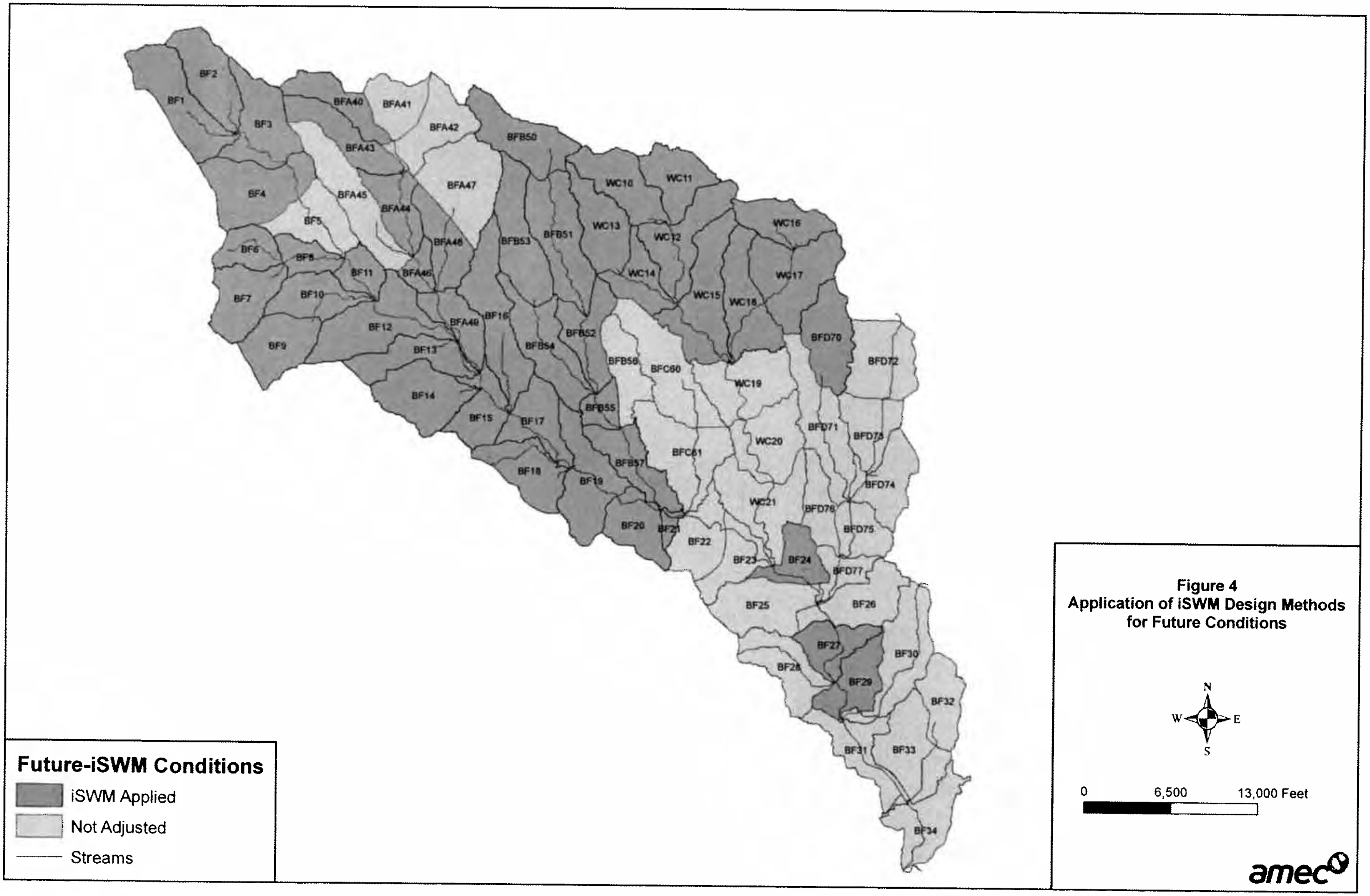


Figure 4
Application of iSWM Design Methods for Future Conditions

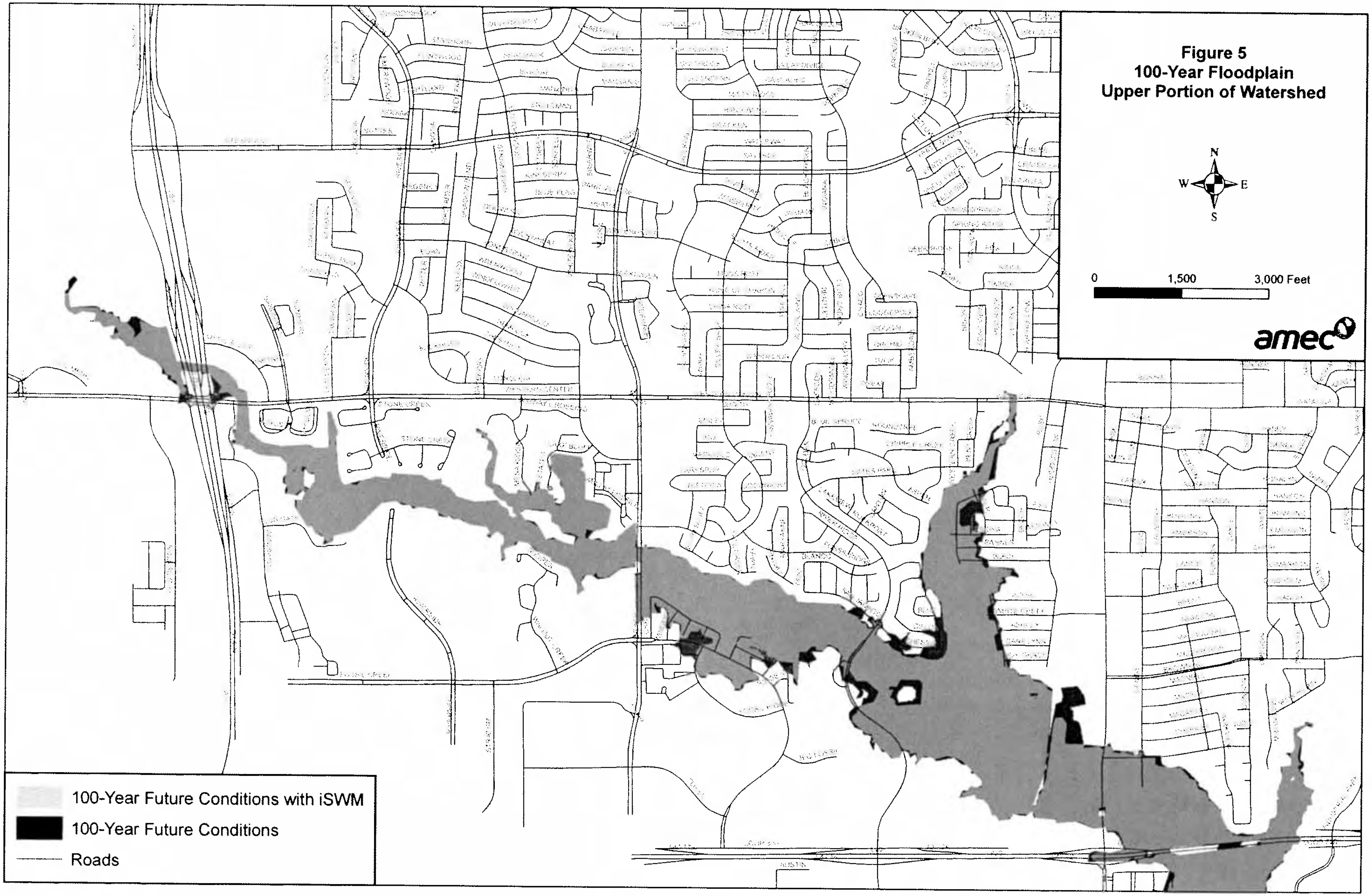


Figure 5
100-Year Floodplain
Upper Portion of Watershed
N
W
E
S
0
1,500
3,000 Feet
amec
100-Year Future Conditions with iSWM
100-Year Future Conditions
Roads

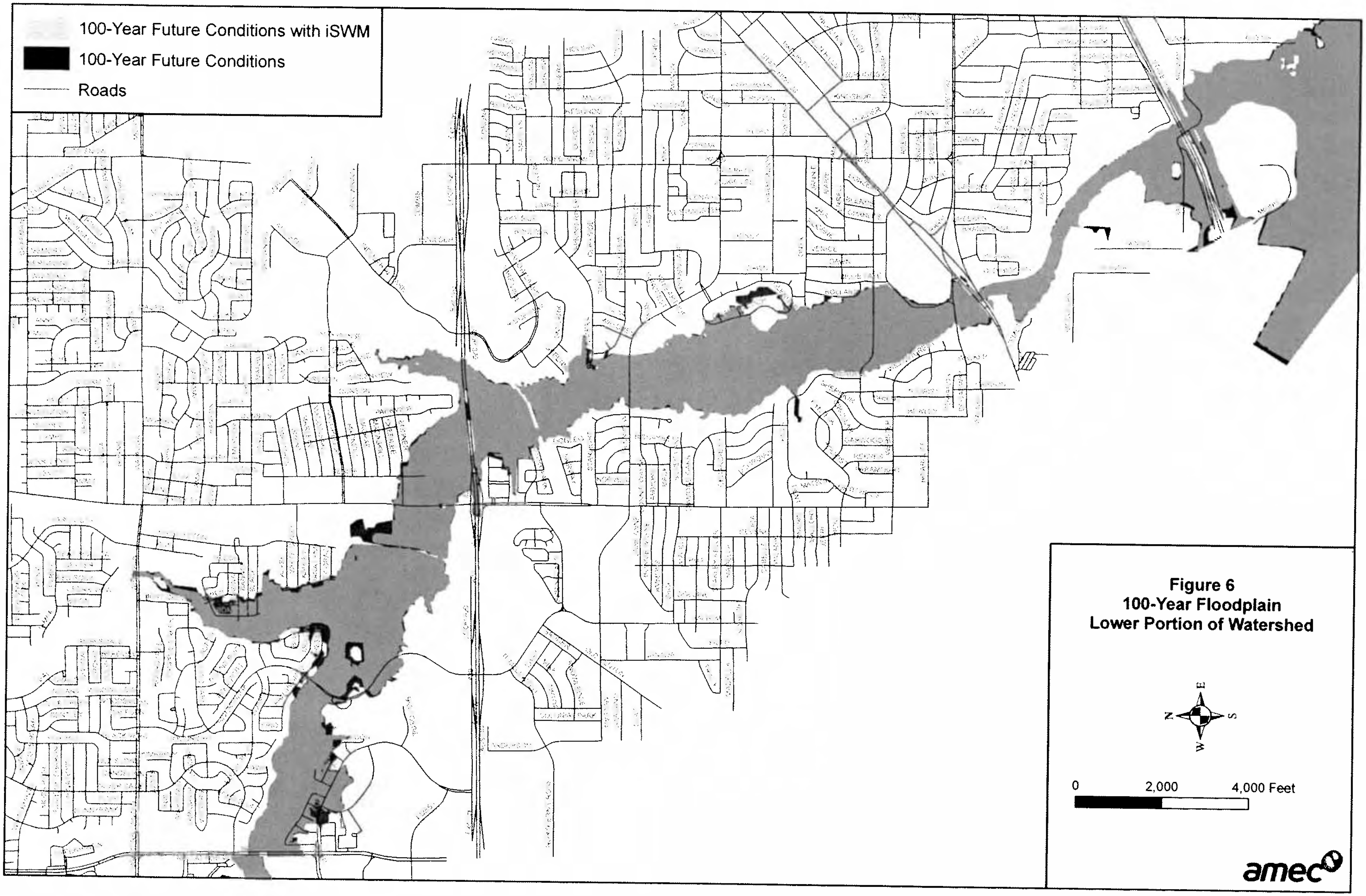


Figure 6
100-Year Floodplain
Lower Portion of Watershed

Appendix A – Runoff Quantity Analysis

A hydrologic model of Big Fossil Creek was created in order to estimate the flow rate of storm water runoff for the watershed. The model was developed from data including precipitation, basin characteristics, and types of soil and land uses. The model produced results that can be used to predict flows from a wide range of storm events.

The primary method of flow rate computation used was the Snyder's Unit Hydrograph. The HEC-1 Flood Hydrograph Package (USACE, 1990) computer model was used to facilitate the calculations. The following sections detail the procedures for developing the model, and present the results of the model.

Model Development
Input for the hydrologic model includes precipitation data, basin characteristic data (area, SCS runoff curve number, lagtime t_p and peaking coefficient C_p), and stream data (channel length, slope, roughness value, and/or storage-elevation/volume-discharge relationship).

Precipitation
A 24-hour balanced storm was used to simulate the design rainfall in the Big Fossil Creek hydrologic model. Table A-1 presents the 1-year and 100-year frequency rainfall depths for various durations used to develop the balanced storm for hydrologic modeling in the Big Fossil Creek Watershed.

Table A-1. Rainfall Depth-Duration-Frequency Data for Tarrant County

Frequency (years)	Rainfall Depths (inches)							
	5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
1	0.44	0.83	1.36	1.62	1.77	2.04	2.28	2.64
100	0.92	2.00	3.84	4.84	5.43	6.54	7.68	9.12

Rainfall depths are presented in Appendix A of the *iSWM Design Manual for Development/Redevelopment.*

Unit Hydrograph
The HEC-1 model supports several unit hydrograph methods to transform rainfall excess into surface runoff. The method selected for this study was the Snyder's unit hydrograph method, which is the method used by the US Army Corps of Engineers, Fort Worth District, for the majority of hydrologic studies in the region. It is similar to the Soil Conservation Service (SCS) method, in that it considers the time distribution of the rainfall, the initial losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm.

Areal Reduction and Computational Interval
The average rainfall depth over a watershed for a given frequency decreases with increasing drainage area. Areal reduction of point rainfall is necessary to reduce rainfall depths applied to a sub-basin by the HEC-1 model. The area of the Big Fossil Creek Watershed is over 56 square miles, therefore areal reduction of point rainfall was performed using the depth-area option in the HEC-1 model. A computation interval of 6 minutes (0.1 hrs) was chosen for the HEC-1 model of the Big Fossil Creek Watershed.

Drainage Boundary Delineation
Sub-basin boundaries in the Big Fossil Creek Watershed were automatically delineated using the digital mapping tool, ArcHydro, and two-foot contour information obtained from the NCTCOG. ArcHydro is an extension tool in the ArcMap digital mapping software program.
Adjustments were made to individual sub-basins in order to limit each sub-basin area to approximately one square mile. ArcHydro was used to estimate the longest flow path (L); to

estimate the length of the flow path from the centroid of sub-basin to the sub-basin's outlet (L_{ca}); and to extract elevations for both the highest and lowest points along the flow path. Table A-2 summarizes the hydraulic data used in the hydrologic analysis of Big Fossil Creek Watershed.

The Big Fossil Creek Watershed was divided into six basins, each comprised of varying numbers of sub-basins, for a total of 74 sub-basins within the watershed. Basins and sub-basin boundaries of the watershed are shown in Figure A-1. Sub-basins located in the Big Fossil Creek Watershed range in size from 150 acres to 770 acres, with an average size of approximately 500 acres. All sub-basin boundaries were utilized, without adjustment, for the existing and future conditions scenarios.

Table A-2. Hydrologic Data Summary

Sub-basin	Area (acres)	Area (sq.mi.)	Length of Longest Flow Path (L, ft)	Elevation Difference Along Longest Flow Path (ft)	Length of Flow Path from Sub-basin's Centroid to Outlet (L_{ca}, ft)	Slope (ft/mi)
BF1	679.1	1.06	13864	94	6555	35.8
BF10	407.9	0.64	9657	107	5625	58.5
BF11	223.0	0.35	6641	52	3032	41.3
BF12	768.5	1.20	16653	122	7822	38.7
BF13	432.4	0.68	13548	116	8111	45.2
BF14	594.0	0.93	10556	112	6475	56.0
BF15	390.7	0.61	7595	85	2595	59.1
BF16	722.7	1.13	17346	129	8490	39.3
BF17	429.2	0.67	10814	89	5260	43.5
BF18	492.7	0.77	8283	83	3404	52.9
BF19	647.6	1.01	10804	109	3332	53.3
BF2	530.7	0.83	10961	70	6187	33.7
BF20	410.4	0.64	7549	88	3200	61.5
BF21	69.7	0.11	3897	87	1909	117.9
BF22	454.4	0.71	6000	100	2597	88.0
BF23	353.7	0.55	7937	113	4002	75.2
BF24	317.7	0.50	5405	80	3645	78.2
BF25	585.1	0.91	10979	122	5286	58.7
BF26	508.7	0.79	9242	106	3983	60.6
BF27	348.2	0.54	8035	88	4000	57.8
BF28	490.6	0.77	9663	107	4956	58.5
BF29	403.2	0.63	10381	128	4025	65.1
BF3	597.5	0.93	10529	72	4316	36.1
BF30	660.9	1.03	14958	116	8828	40.9
BF31	453.2	0.71	12034	113	5576	49.6

Table A-2. Hydrologic Data Summary

Sub-basin	Area (acres)	Area (sq.mi.)	Length of Longest Flow Path (L, ft)	Elevation Difference Along Longest Flow Path (ft)	Length of Flow Path from Sub-basin's Centroid to Outlet (L_{ca}, ft)	Slope (ft/mi)
BF32	386.0	0.60	7618	68	3959	47.1
BF33	618.4	0.97	8946	122	4167	72.0
BF34	482.6	0.75	12039	66	4571	28.9
BF4	722.6	1.13	9301	96	4744	54.5
BF5	466.0	0.73	8735	86	4221	52.0
BF6	285.6	0.45	6868	72	3329	55.4
BF7	496.7	0.78	10529	72	4971	36.1
BF8	222.7	0.35	7189	70	3649	51.4
BF9	485.7	0.76	7306	58	3781	41.9
BFA40	356.7	0.56	10425	66	5424	33.4
BFA41	358.0	0.56	6536	128	3316	103.4
BFA42	484.7	0.76	9685	138	5241	75.2
BFA43	437.1	0.68	12515	81	6245	34.2
BFA44	372.2	0.58	9517	73	5029	40.5
BFA45	659.5	1.03	16563	104	8353	33.2
BFA46	152.3	0.24	5390	44	2313	43.1
BFA47	749.3	1.17	8680	120	4090	73.0
BFA48	405.1	0.63	9088	54	4370	31.4
BFA49	344.3	0.54	9534	78	4881	43.2
BFB50	577.2	0.90	11262	96	4911	45.0
BFB51	732.2	1.14	13153	144	7892	57.8
BFB52	438.2	0.68	10621	93	5524	46.2
BFB53	628.5	0.98	14069	151	6346	56.7
BFB54	621.8	0.97	13122	97	5911	39.0
BFB55	177.7	0.28	4819	58	2440	63.6
BFB56	376.8	0.59	10163	94	4843	48.8
BFB57	441.4	0.69	10377	88	4748	44.8
BFC60	735.6	1.15	13926	96	6037	36.4
BFC61	745.9	1.17	12760	71	6725	29.4
BFD70	526.9	0.82	8944	74	4080	43.7
BFD71	659.1	1.03	15938	136	7410	45.1
BFD72	622.5	0.97	6671	44	4038	34.8
BFD73	408.9	0.64	8623	76	4414	46.5
BFD74	468.0	0.73	6804	52	4284	40.4

Table A-2. Hydrologic Data Summary

Sub-basin	Area (acres)	Area (sq.mi.)	Length of Longest Flow Path (L, ft)	Elevation Difference Along Longest Flow Path (ft)	Length of Flow Path from Sub-basin's Centroid to Outlet (L_{ca}, ft)	Slope (ft/mi)
BFD75	319.5	0.50	6284	94	3517	79.0
BFD76	303.6	0.47	9944	117	4621	62.1
BFD77	214.3	0.33	6915	135	3766	103.1
WC10	508.5	0.79	11653	120	5865	54.4
WC11	429.3	0.67	8250	96	4330	61.4
WC12	597.4	0.93	14325	176	6688	64.9
WC13	492.8	0.77	11682	123	4737	55.6
WC14	347.7	0.54	8187	104	3934	67.1
WC15	765.7	1.20	15374	192	6855	65.9
WC16	408.9	0.64	4899	42	2855	45.3
WC17	745.9	1.17	10329	96	3630	49.1
WC18	586.9	0.92	12134	203	5775	88.3
WC19	654.9	1.02	9028	94	4173	55.0
WC20	576.0	0.90	10785	119	4944	58.3
WC21	681.9	1.07	12210	97	7286	41.9

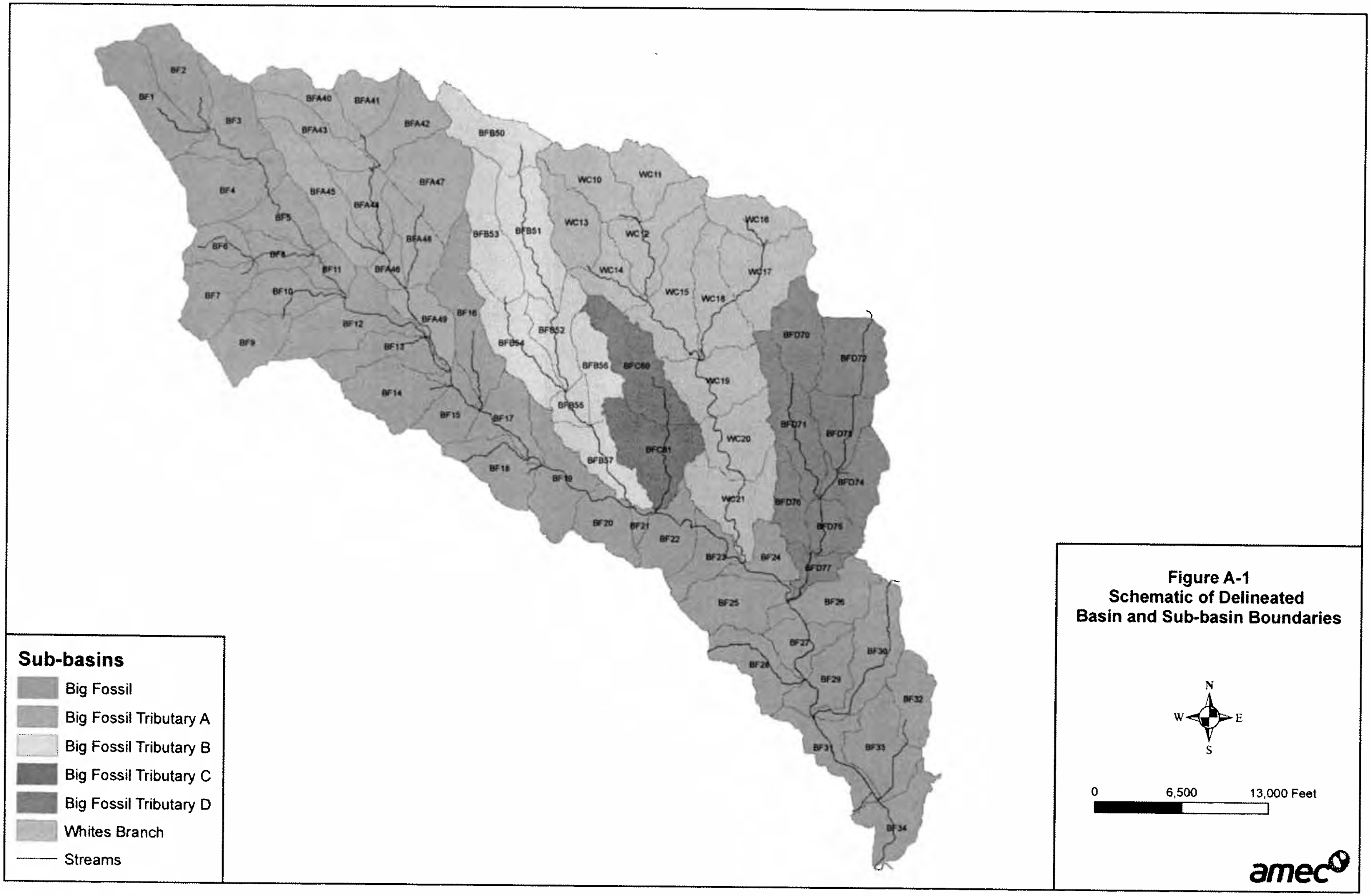


Figure A-1
Schematic of Delineated Basin and Sub-basin Boundaries

Soils Data

Soils information was provided by the NCTCOG in an ArcView shape file format. However the associated data table lacked the hydrological soil group definition. In order to populate this field, SURGO data were used to populate the hydrologic soil group. Soils delineation was utilized, without adjustment, for the existing and future conditions scenarios. The type of soil is a major factor in determining the amount of runoff that will occur during the event. Sandy soils will allow significant infiltration while rock formations tend to allow no infiltration. Soil types were matched to a specific hydrologic soil group (A, B, C, D) as used to compute curve numbers in the SCS method. The definition of each hydrologic soil group is given in Table A-3.

Table A-3. Definition of Hydrologic Soil Groups

Hydrologic Soil Group	Soil Group Characteristics
A	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well-to-excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impeded downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils have very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Curve Numbers

The SCS runoff curve number (CN) is an index developed to represent the combined hydrologic effect of soil type, land use, and antecedent soil moisture condition. Using this index to determine the amount of available storage (and subsequent precipitation excess) in a drainage basin is a standard hydrologic analysis technique developed by the SCS.

In watersheds that are delineated into numerous sub-basins, such as the Big Fossil Creek Watershed, GIS software is well suited for curve number estimation because it can manipulate the large amounts of spatial data (e.g., soil and land use coverage). Area-weighted curve numbers were determined for each sub-basin by combining the soil, land use, and sub-basin boundary maps in ArcView, through use of a script (i.e., program) developed specifically for curve number generation.

Since future land use designations were developed with the stipulation that runoff potential could not decrease from existing to future conditions, future curve numbers for each sub-basin will be equal to or greater than existing curve numbers.

Land Use

Land use was classified into 25 categories as designated by the *iSWM Design Manual for Development/Redevelopment*. Table A-4 presents these categories and the corresponding curve numbers. The curve numbers shown in Table A-4 are assumed to correspond to antecedent moisture condition II (AMC II).

Land use data for this study was provided by both the NCTCOG and the City of Fort Worth in ArcView shape file formats. Land use data for the year 2000 and 2003 was provided by the

NCTCOG. Future conditions land use data for the year 2025 was provided by the City of Fort Worth. For the existing conditions hydrologic model, the 2000 land use data was used. For future conditions hydrologic modeling, a combination of the NCTCOG and Fort Worth data was used. That is, the 2003 land use data was used to complete the portions of the watershed not included within the Fort Worth 2025 future land use information.

The 2000 and 2003 land use mapping from the NCTCOG defined land use through a numbered code field that ranged from 111 to 500. The future land use information from the City of Fort Worth defined land use through a descriptive code field. Table A-5 assigns a new land use code for both the NCTCOG and Fort Worth data that corresponds to the 25 land use categories designated by iSWM (See Table A-4).

Table A-4. Curve Number Look-Up Table

Cover Description	Land Use Code for Correlation	Curve Number by hydrological soil group				Cp Value
		A	B	C	D	
Cultivated Land w/o conservation treatment	1a	72	81	88	91	0.58
Cultivated Land w/ conservation treatment	1b	62	71	78	81	0.58
Pasture or Range land: Poor Condition	2a	68	79	86	89	0.58
Pasture or Range land: Good Condition	2b	39	61	74	80	0.58
Meadow: Good Condition	3	30	58	71	78	0.58
Wood or Forest Land: Thin Stand; Poor Cover	4a	45	66	77	83	0.58
Wood or Forest Land: Good Cover	4b	25	55	70	77	0.58
Open Space: Poor Condition (<50%)	5a	68	79	86	89	0.58
Open Space: Fair Condition (50% to 75%)	5b	49	69	79	84	0.58
Open Space: Good Condition (<75%)	5c	39	61	74	80	0.58
Impervious Areas	6	98	98	98	98	0.73
Streets and Roads: Paved excluding ROW	7a	98	98	98	98	0.73
Streets and Roads: Paved including ROW	7b	83	89	92	93	0.73
Streets and Roads: Gravel	7c	76	85	89	91	0.73
Streets and Roads: Dirt	7d	72	82	87	89	0.73
Urban Districts: Commercial and Business	8a	89	92	94	95	0.73
Urban Districts: Industrial	8b	81	88	91	93	0.73
Residential: 1/8 acre or less	9a	77	85	90	92	0.73
Residential: 1/4 acre	9b	61	75	83	87	0.66
Residential: 1/3 acre	9c	57	72	81	86	0.66
Residential: 1/2 acre	9d	54	70	80	85	0.66
Residential: 1 acre	9e	51	68	79	84	0.66
Residential: 2 acres	9f	46	65	77	82	0.66
Developing Urban Areas	10	77	86	91	94	0.66
Water	11	100	100	100	100	1.00

Curve Number data presented in the *iSWM Design Manual for Development/Redevelopment*.

Table A-5. Land Use Codes

NCTCOG Land Use Codes (2000 and 2003)	Corresponding Land Use Code		City of Ft. Worth Land Use Codes (2025)	Corresponding Land Use Code
111	9b		AG	1b
112	9a		NC	8b
113	9a		GC	8b
114	9f		HI	8a
121	8a		LI	8b
122	8a		IGC	8a
123	8a		MUGC	8b
131	8b		INFRA	7a
141	6		INST	9f
142	6		PRIPK	5c
143	3		PUBPK	5c
144	6		LDR	9e
171	5c		MDR	9d
171	5c		MH	9a
172	5b		RURAL	9f
173	5a		SF	9b
181	10		SUB	9b
300	5c			
308	7b			
500	11			

Lagtimes and Peaking Coefficient

Snyder's Unit Hydrograph method was used to calculate a runoff hydrograph for the development of the HEC-1 model of the Big Fossil Creek Watershed. This method requires specification of a lagtime (t_p) and peaking coefficient (C_p) for each sub-basin. The lagtime, specified in hours, is defined as the lag (time) between the center of mass of rainfall excess and the peak of the unit hydrograph.

The *iSWM Design Manual for Development/Redevelopment* describes the lagtime and peak flow (q_p) as:

$$t_p = C_t(L\ L_{ca})^{0.33}/S^{1/2}$$
$$q_p = C_p\ 640/t_p$$

The coefficient C_t is a regional coefficient for variations in slopes within the watershed. L is the river mileage from the sub-basin outlet to the upstream limits of the drainage area. L_{ca} is the river mileage from the outlet of the sub-basin into the center of gravity of the drainage area. S is the slope of the longest flow-path (ft/mi).

The coefficient C_p is the peaking coefficient, typically ranges from 0.3 to 1.2 with an average value of 0.8, and is related to the flood wave and storage coefficients of the watershed (See Table A-6). Larger values of C_p are generally associated with smaller values of C_t.

Table A-6. Typical Values of Cp

Typical Drainage Area Characteristics	Value of Cp
Undeveloped Area w/Storm Drains	
Flat Basin Slope <0.5%	0.55
Moderate Basin Slope 0.5% to 0.8%	*0.58*
Steep Basin Slope >0.8%	0.61
Moderately Developed Area	
Flat Basin Slope <0.5%	0.63
Moderate Basin Slope 0.5% to 0.8%	*0.66*
Steep Basin Slope >0.8%	0.69
Highly Developed/Commercial Area	
Flat Basin Slope <0.5%	0.7
Moderate Basin Slope 0.5% to 0.8%	*0.73*
Steep Basin Slope >0.8%	0.77

Cp values are presented in the *iSWM Design Manual for Development/Redevelopment.*

The lagtime for each sub-basins was calculated using the ArcHydro tools in the ArcMap environment. Automated utilities of Arc Hydro expedited the process of determining the parameters of the t_p equation: L , $L_{ca,}$ and slope.

After preliminary analysis, it was determined that the initial slope term in the equation for lagtime causes the lagtime to be too small for the size of watershed under consideration. In addition, the original format of Snyder's equation does not contain the slope (S) term. The addition of the slope S in the iSWM Design Manual refers to the U.S. Army Corps of Engineers Manual (EM 1112-2-1405). However, this reference states that in some instances, other measurable characteristics of basins maybe included in the original Snyder's methodology if regression analysis on the effect of the regressed parameter is developed for a region. Thus, the original format of Snyder's equation was used in this study.

For the determination of C_t, the iSWM Design Manual suggests that average values range from 0.4 to 2.3 with an average value of 1.1. Review of previous hydrologic modeling efforts of Big Fossil Creek by the U.S. Army Corps of Engineers indicated an average value of 0.45 was used for Little and Big Fossil Creek Watersheds. In order to estimate the C_t value, a regression formula was developed between the slope of each basin (ft/mile) and the C_t value used in the previous hydrologic model. The resulting equation:

$$C_t = (-0.0032 * \text{Slope}) + 0.5718$$

was used to estimate the C_t value, then it was increased uniformly by 0.1 for all sub-basins to adjust the t_p value.

In determining the C_p value, the iSWM Design Manual was used as a guide. Three levels of development; undeveloped, moderately developed, and highly developed categories were associated with different levels of land use. Due to the level of detailed delineated land use the median values of 0.58, 0.66, and 0.73 were assigned to C_p for the three respective levels of development. Subsequently, in the curve number lookup table (Table A-4) the appropriate C_p value was assigned to different categories of land use. C_p values within each sub-basin were area weighted and a composite C_p value was calculated for each sub-basin, Table A-7.

Future Conditions without iSWM

New development in the Big Fossil Creek Watershed is anticipated to be primarily residential or commercial. Changes in the curve numbers and subsequently C_p values were the only differences considered between the existing and the future condition models. No further adjustment in the C_t value was made for the future condition, see Table A-7.

Future Conditions with iSWM

A systematic procedure was used to simulate the effectiveness of the proposed best management practices in the iSWM manual. iSWM design criteria were applied only to selected sub-basins in the watershed; the undeveloped areas of the upper portion of the watershed. Sub-basins, for which the future curve number had the potential to increase more that 6 points from the existing conditions land use, were selected for iSWM application. Thus, iSWM design criteria was applied only to those sub-basins that were currently undeveloped but were anticipated to be developed in the future.

It was assumed that the iSWM design criteria would reduce the 100-year peak flow to a level approximately 15 percent below the existing condition's peak. Inferring that this will account for the ten-percent rule as presented in the *iSWM Design Manual for Development/Redevelopment.* Due to the large number of sub-basins within the hydrologic model, a target range of acceptable peak flow reduction from 5 percent less than existing conditions peak flow to 25 percent less than existing conditions peak flow was assumed. This would allow for an average reduction in the 100-year peak flow to achieve the ten-percent rule within the Big Fossil Creek Watershed.

The ten-percent rule recognizes the fact that a structural control providing detention has a "zone of influence" downstream where its effectiveness can be felt. Beyond this zone of influence the structural control becomes relatively insignificant compared to the runoff from the total drainage area. Based on studies and master planning results for a large number of sites, that zone of influence is considered to be the point where the drainage area controlled by the detention or storage facility comprises 10 percent of the total drainage area. For example, if the structural control drains 10 acres, the zone of influence ends at the point where the total drainage area is 100 acres or greater.

In order to decrease the iSWM selected sub-basins' outflow by target of 15 percent lower than the existing condition the C_t value was uniformly increased by 0.4. For those sub-basins that did not reach this target value, subsequent further modifications were made to the Ct values.

Table A-7 Hydrologic Variable Parameters for the Three Watershed Scenarios (iSWM application noted as Highlighted Sub-basins)

Sub-basin	Existing Conditions				Future Conditions *without* iSWM				Future Conditions *with* iSWM		
	CN	C_p	C_t	t_p	CN	C_p	C_t	t_p	CN	C_t	t_p
BF1	82	0.61	0.56	0.82	88	0.68	0.56	0.82	88	0.90	1.33
BF10	78	0.59	0.48	0.60	86	0.67	0.48	0.60	86	0.86	1.07
BF11	77	0.58	0.54	0.48	85	0.66	0.54	0.48	85	0.98	0.88
BF12	76	0.60	0.55	0.91	83	0.66	0.55	0.91	83	0.94	1.56
BF13	78	0.59	0.53	0.83	85	0.64	0.53	0.83	85	0.89	1.40
BF14	81	0.60	0.49	0.66	86	0.63	0.49	0.66	86	0.77	1.04
BF15	76	0.60	0.48	0.43	85	0.67	0.48	0.43	85	0.89	0.79
BF16	81	0.60	0.55	0.95	88	0.68	0.55	0.95	88	0.95	1.64
BF17	73	0.59	0.53	0.67	87	0.69	0.53	0.67	87	1.20	1.52
BF18	84	0.63	0.50	0.50	92	0.72	0.50	0.50	92	0.88	0.88
BF19	82	0.62	0.50	0.55	92	0.72	0.50	0.55	92	0.93	1.01
BF2	80	0.59	0.56	0.76	88	0.68	0.56	0.76	88	0.99	1.33
BF20	80	0.62	0.47	0.45	92	0.73	0.47	0.45	92	0.95	0.91
BF21	72	0.61	0.29	0.19	88	0.73	0.29	0.19	88	0.79	0.51
BF22	85	0.66	0.39	0.32	88	0.68	0.39	0.32	88	0.39	0.32
BF23	84	0.68	0.43	0.45	84	0.65	0.43	0.45	84	0.43	0.45
BF24	79	0.65	0.42	0.38	86	0.67	0.42	0.38	86	0.71	0.63
BF25	85	0.66	0.48	0.62	88	0.67	0.48	0.62	88	0.48	0.62
BF26	80	0.67	0.48	0.52	85	0.69	0.48	0.52	85	0.48	0.52
BF27	78	0.64	0.49	0.51	84	0.66	0.49	0.51	84	0.74	0.78
BF28	89	0.68	0.48	0.58	89	0.68	0.48	0.58	89	0.48	0.58
BF29	78	0.65	0.46	0.53	86	0.68	0.46	0.53	86	0.77	0.88
BF3	80	0.59	0.56	0.65	86	0.66	0.56	0.65	86	0.94	1.10
BF30	88	0.68	0.54	0.90	89	0.68	0.54	0.90	89	0.54	0.90
BF31	82	0.66	0.51	0.69	85	0.66	0.51	0.69	85	0.51	0.69
BF32	87	0.67	0.52	0.53	89	0.68	0.52	0.53	89	0.52	0.53
BF33	84	0.67	0.44	0.49	86	0.68	0.44	0.49	86	0.44	0.49
BF34	85	0.67	0.58	0.72	89	0.69	0.58	0.72	89	0.58	0.72
BF4	82	0.62	0.50	0.58	87	0.67	0.50	0.58	87	0.80	0.93
BF5	82	0.62	0.51	0.55	86	0.66	0.51	0.55	86	0.51	0.55
BF6	82	0.62	0.49	0.46	89	0.68	0.49	0.46	89	0.84	0.79
BF7	82	0.61	0.56	0.68	87	0.67	0.56	0.68	87	0.89	1.10
BF8	79	0.60	0.51	0.50	86	0.66	0.51	0.50	86	0.86	0.84

Table A-7 Hydrologic Variable Parameters for the Three Watershed Scenarios (iSWM application noted as Highlighted Sub-basins)

Sub-basin	Existing Conditions				Future Conditions *without* iSWM				Future Conditions *with* iSWM		
	CN	C_p	C_t	t_p	CN	C_p	C_t	t_p	CN	C_t	t_p
BF9	80	0.60	0.54	0.54	88	0.66	0.54	0.54	88	0.95	0.95
BFA40	82	0.62	0.56	0.71	87	0.67	0.56	0.71	87	0.86	1.09
BFA41	82	0.61	0.34	0.31	85	0.64	0.34	0.31	85	0.34	0.31
BFA42	85	0.64	0.43	0.53	87	0.65	0.43	0.53	87	0.43	0.53
BFA43	81	0.59	0.56	0.79	87	0.66	0.56	0.79	87	0.95	1.33
BFA44	80	0.58	0.54	0.65	87	0.66	0.54	0.65	87	0.94	1.13
BFA45	82	0.59	0.57	0.96	87	0.66	0.57	0.96	87	0.57	0.96
BFA46	78	0.59	0.53	0.41	85	0.66	0.53	0.41	85	0.93	0.72
BFA47	84	0.62	0.44	0.47	88	0.67	0.44	0.47	88	0.44	0.47
BFA48	82	0.62	0.57	0.64	90	0.70	0.57	0.64	90	0.98	1.10
BFA49	77	0.61	0.53	0.63	86	0.68	0.53	0.63	86	0.98	1.16
BFB50	83	0.64	0.53	0.66	87	0.67	0.53	0.66	87	0.78	0.98
BFB51	81	0.60	0.49	0.75	91	0.71	0.49	0.75	91	0.92	1.42
BFB52	81	0.60	0.52	0.67	90	0.70	0.52	0.67	90	0.97	1.24
BFB53	81	0.60	0.49	0.72	89	0.68	0.49	0.72	89	0.86	1.26
BFB54	84	0.62	0.55	0.77	90	0.69	0.55	0.77	90	0.90	1.26
BFB55	81	0.59	0.47	0.35	87	0.67	0.47	0.35	87	0.87	0.65
BFB56	85	0.63	0.52	0.62	89	0.69	0.52	0.62	89	0.52	0.62
BFB57	79	0.65	0.53	0.64	85	0.70	0.53	0.64	85	0.87	1.05
BFC60	87	0.66	0.56	0.80	88	0.68	0.56	0.80	88	0.56	0.80
BFC61	89	0.68	0.58	0.84	90	0.68	0.58	0.84	90	0.58	0.84
BFD70	85	0.63	0.53	0.58	91	0.69	0.53	0.58	91	0.87	0.95
BFD71	86	0.65	0.53	0.85	89	0.68	0.53	0.85	89	0.53	0.85
BFD72	87	0.67	0.56	0.55	88	0.67	0.56	0.55	88	0.56	0.55
BFD73	89	0.67	0.52	0.58	89	0.67	0.52	0.58	89	0.52	0.58
BFD74	89	0.68	0.54	0.55	90	0.69	0.54	0.55	90	0.54	0.55
BFD75	82	0.64	0.42	0.39	85	0.65	0.42	0.39	85	0.42	0.39
BFD76	89	0.67	0.47	0.56	90	0.67	0.47	0.56	90	0.47	0.56
BFD77	81	0.65	0.34	0.33	86	0.67	0.34	0.33	86	0.34	0.33
WC10	79	0.60	0.50	0.67	88	0.69	0.50	0.67	88	0.92	1.24
WC11	79	0.59	0.48	0.52	87	0.67	0.48	0.52	87	0.88	0.95
WC12	78	0.59	0.46	0.70	89	0.67	0.46	0.70	89	0.86	1.30
WC13	79	0.60	0.49	0.62	90	0.72	0.49	0.62	90	0.96	1.20

Table A-7 Hydrologic Variable Parameters for the Three Watershed Scenarios (iSWM application noted as Highlighted Sub-basins)

Sub-basin	Existing Conditions				Future Conditions *without* iSWM				Future Conditions *with* iSWM		
	CN	C_p	C_t	t_p	CN	C_p	C_t	t_p	CN	C_t	t_p
WC14	81	0.59	0.46	0.48	88	0.67	0.46	0.48	88	0.83	0.87
WC15	81	0.60	0.46	0.71	88	0.66	0.46	0.71	88	0.72	1.12
WC16	80	0.63	0.53	0.42	88	0.69	0.53	0.42	88	0.93	0.74
WC17	80	0.60	0.51	0.57	90	0.69	0.51	0.57	90	0.98	1.08
WC18	80	0.61	0.39	0.53	88	0.66	0.39	0.53	88	0.67	0.91
WC19	84	0.65	0.50	0.55	86	0.67	0.50	0.55	86	0.50	0.55
WC20	82	0.63	0.49	0.60	87	0.67	0.49	0.60	87	0.49	0.60
WC21	84	0.66	0.54	0.79	87	0.67	0.54	0.79	87	0.54	0.79

Hydrograph Routing

For those routing reaches where a HEC-2 model had been developed previously by the USACE Ft. Worth and could be located on associated USACE work maps, the Modified Puls Routing methodology was used for storage-routing analysis. Otherwise, Muskingum-Cunge channel routing method was used to represent the reach. An initial outflow equal to initial inflow was used for the initial condition. Table A-8 presents the storage routing reaches information obtained from previous HEC-2 models and used in HEC-1.

The Muskingum-Cunge channel routing method was used for stream reaches located at the upstream limits of the HEC-2 models or where no previous study was available. To perform Muskingum-Cunge routing, the HEC-1 model requires reach length, slope, Manning's n value, channel shape (trapezoidal, rectangular or circular), bottom width, and side slopes. Reach length, slope, Manning's n value and channel geometry parameters were determined using aerial photography and two-foot topographic maps. A sample cross section of flow within the routing reach was digitized in GIS and elevations along this cross section were extracted from the terrain data. HEC-1 requires an eight point cross section representing the routing reach, thus the extracted cross section was simplified to an eight point cross section representing the over banks and the channel geometry.

Table A-8. Routing Reaches developed from previous HEC-2 models

HEC-1 Routing Reach	HEC-2 Model	Downstream and Upstream Stations	SV and SQ cards						Reach Length (ft)	Avg Velocity (ft/s)	Time Steps
BFC61	K20BFC1	DS - 1150	SV	0	98	121	133	169	5790	8.0	2
		US - 6940	SQ	0	3550	4700	5200	6550			
WC14	K20WB	DS - 31190	SV	0	76	98	107	130	3760	4.0	3
		US – 34950	SQ	0	5150	6900	7600	9550			
WC15	K20WB	DS – 24700	SV	0	253	321	346	417	6490	5.5	3
		US – 31190	SQ	0	5950	8200	9100	11700			
WC19	K20WB	DS - 18140	SV	0	312	394	425	510	6560	8.5	2
		US – 24700	SQ	0	9100	12450	13850	17700			
WC20	K20WB	DS - 9850	SV	0	296	421	474	587	8290	8.0	3
		US – 18140	SQ	0	7200	10100	11500	14700			
WC21	K20WB	DS - 2310	SV	0	360	469	520	629	7540	8.0	3
		US - 9850	SQ	0	7200	10100	11500	14700			
BFD73	X20SINGH	DS - 13730	SV	0	95	118	133	160	6070	7.0	2
		US – 19800	SQ	0	3900	5200	5800	7200			
BFD74	X20SINGH	DS - 11230	SV	0	48	63	69	84	2430	7.0	1
		US – 13660	SQ	0	3900	5200	5800	7200			
BFD75	X20SINGH	DS - 6070	SV	0	141	183	200	240	4540	6.0	2
		US – 10610	SQ	0	5900	8000	8900	11200			
BFD77	X20SINGH	DS - 2310	SV	0	110	133	141	161	2540	7.0	1
		US – 4850	SQ	0	5900	8000	8900	11200			
BF4	K20BF0S3	DS - 94660	SV	0	41	59	67	83	2170	10.0	1
		US – 96830	SQ	0	4550	6150	6900	8600			
BF5	K20BF0S3	DS - 87800	SV	0	307	365	390	441	6860	7.0	3
		US – 94660	SQ	0	6100	8300	9250	11550			
BF11	K20BF0S3	DS - 83550	SV	0	160	209	228	273	4250	7.0	2
		US – 87800	SQ	0	5350	8700	9950	12800			
BF12	K20BF0S3	DS - 75720	SV	0	753	1031	1110	1293	6980	7.0	3
		US – 82700	SQ	0	10400	16200	18600	24450			
BFA49X	K20BF0S3	DS - 72900	SV	0	108	153	170	208	1750	7.0	1
		US – 74650	SQ	0	10400	16200	18600	24500			
BF15	K20BF0S3	DS - 71390	SV	0	2	3	4	5	1500	7.0	1
		US – 71430	SQ	0	10850	16700	19350	25350			
BF15	K20BF0S3	DS - 67930	SV	0	253	355	397	484	3460	7.0	1
		US – 71390	SQ	0	10350	16200	18800	24800			
BF17	K20BF0S3	DS - 60540	SV	0	297	472	543	688	6350	8.0	2
		US – 66890	SQ	0	10300	16250	18950	25150			

Table A-8. Routing Reaches developed from previous HEC-2 models

HEC-1 Routing Reach	HEC-2 Model	Downstream and Upstream Stations	SV and SQ cards	Reach Length (ft)	Avg Velocity (ft/s)	Time Steps
BF19	K20BF0S3	DS - 57110 US – 59260	SV 0 75 149 180 237 SQ 0 10300 16100 18800 25000	2150	7.5	1
BF20	K20BF0S3	DS - 51410 US – 54410	SV 0 128 202 231 290 SQ 0 14600 22000 25400 33450	3000	10.0	1
BF21	J20BFC	DS - 47270 US – 51410	SV 0 127 223 275 388 SQ 0 14590 22420 26620 34950	4140	10.0	1
BF22	J20BFC	DS - 42430 US – 47100	SV 0 307 422 526 708 SQ 0 13700 20040 23070 29360	4670	6.5	2
BF23	J20BFC	DS - 37340 US – 42020	SV 0 875 1661 2029 2912 SQ 0 20020 28590 32840 41080	4680	6.0	2
BF24	J20BFC	DS - 33400 US – 36970	SV 0 460 763 890 1155 SQ 0 19640 28020 31770 39400	3570	7.0	1
BF25	J20BFC	DS - 31080 US – 33180	SV 0 316 470 544 685 SQ 0 20670 29320 33570 41300	2100	6.0	1
BF26	J20BFC	DS - 29400 US – 30830	SV 0 130 176 197 232 SQ 0 20670 29320 33570 41300	1430	8.0	0
BF27	J20BFC	DS - 20430 US – 28300	SV 0 1299 1766 1978 2350 SQ 0 20300 29230 33820 42080	7870	7.0	3
B29	J20BFC	DS - 19110 US – 20230	SV 0 153 226 258 318 SQ 0 20300 29230 33820 42080	1120	6.0	1
BF31	J20BFC	DS - 10730 US – 18140	SV 0 727 974 1106 1411 SQ 0 19470 28620 33440 42000	7410	7.5	3
BF34	J20BFC	DS - 940 US – 10610	SV 0 2451 3188 3476 4059 SQ 0 26000 36750 41250 51750	9670	7.0	4
BF33	C20BF5	DS - 2170 US – 5470	SV 0 38 46 50 61 SQ 0 2100 2700 2900 3800	3300	7.0	1
BFB52	K20BFC2A	DS - 840 US – 6570	SV 0 138 174 189 223 SQ 0 2500 3400 3800 4750	5730	5.0	3
BFB54	K20BFC2	DS - 12600 US – 20920	SV 0 153 264 286 338 SQ 0 2000 2850 3150 3950	8320	6.5	4
BFB55	K20BFC2	DS - 8220 US – 11630	SV 0 128 164 179 214 SQ 0 5350 7500 8400 10600	3410	7.0	1
BFB57	K20BFC2	DS - 1140 US – 8130	SV 0 237 318 351 426 SQ 0 5350 7500 8400 10600	6990	7.0	3
WC12	K20WB1	DS - 1610 US – 4855	SV 0 69 87 94 115 SQ 0 3400 4550 5050 6550	3245	6.5	1
BFA49R	K20BFC4	DS - 1960 US – 4525	SV 0 120 152 167 203 SQ 0 7100 9900 11200 14200	2565	7.0	1

Table A-8. Routing Reaches developed from previous HEC-2 models

HEC-1 Routing Reach	HEC-2 Model	Downstream and Upstream Stations	SV and SQ cards	Reach Length (ft)	Avg Velocity (ft/s)	Time Steps
BFA46	K20BFC4	DS - 4650 US – 7900	SV 0 100 126 137 163 SQ 0 7150 9800 11000 13850	3250	6.5	1
BFA44	K20BFC4	DS - 9300 US – 16800	SV 0 170 217 236 286 SQ 0 3550 4900 5500 7050	7500	6.0	3
BFC48	K20BFC4A	DS - 730 US – 6960	SV 0 182 214 228 262 SQ 0 2600 3500 3900 4900	6230	7.0	2

Peak Discharge Determination

The HEC-1 models for the three scenarios: existing conditions, future conditions *without* iSWM application and future conditions *with* iSWM application were executed for the 1-year and 100-year storm events to determine the peak discharges. Table A-9 presents the peak discharges of each of the individual sub-basins for three scenarios for each storm event. For the future conditions *with* iSWM application 1-year event it was not feasible to simulate detention by adjusting the unit hydrograph parameters as was performed for the 100-year condition. Therefore the total volume beneath each selected sub-basins hydrograph for future condition 1-year event was taken and a constant rate flow hydrograph was developed in such a way that the sub-basin outlet would discharge the same volume over 24-hour period. Table A-9 also presents the future conditions *with* iSWM peak flows for selected sub-basins where the sub-basin C_t values were changed to accomplish reduction of future flows to produces peak flows approximately 15 percent lower than existing peak flows.

Table A-9. Comparison of Peak Discharges for the Three Watershed Scenarios (iSWM Application noted as Highlighted Sub-Basins)

Sub-basin	Flow 100-year (cfs)			Flow 1-year (cfs)			% Difference Existing Future-iSWM Peak Flow
	Existing	Future	Future iSWM	Existing	Future	Future iSWM	
BF1	1703	1985	1447	316	488	42	-15%
BF10	1139	1399	978	178	326	23	-14%
BF11	680	847	591	103	191	12	-13%
BF12	1586	1913	1341	212	373	36	-15%
BF13	978	1167	821	147	249	23	-16%
BF14	1636	1826	1383	294	413	33	-15%
BF15	1272	1607	1113	181	370	21	-13%
BF16	1581	1928	1336	275	464	44	-15%
BF17	991	1418	838	114	338	25	-15%
BF18	1753	2100	1498	379	633	37	-15%
BF19	2065	2591	1798	395	774	49	-13%
BF2	1299	1631	1134	219	401	33	-13%
BF20	1424	1853	1234	251	565	31	-13%
BF21	337	474	290	43	137	5	-14%
BF22	2142	2267	2267	509	613	613	
BF23	1405	1350	1350	307	292	292	
BF24	1239	1404	1068	217	337	18	-14%
BF25	1916	2000	2000	424	504	504	
BF26	1738	1905	1905	310	432	432	
BF27	1132	1263	970	182	274	18	-14%
BF28	1789	1789	1789	469	469	469	
BF29	1300	1506	1101	206	354	23	-15%
BF3	1603	1919	1375	273	438	33	-14%
BF30	1807	1827	1827	437	460	460	
BF31	1334	1392	1392	255	304	304	
BF32	1440	1482	1482	353	395	395	
BF33	2309	2404	2404	503	569	569	
BF34	1455	1558	1558	318	404	404	
BF4	2247	2540	1907	433	611	42	-15%
BF5	1495	1674	1674	286	390	390	
BF6	1021	1200	870	199	323	19	-15%
BF7	1386	1602	1180	262	380	29	-15%
BF8	721	846	620	121	201	13	-14%

Table A-9. Comparison of Peak Discharges for the Three Watershed Scenarios (iSWM Application noted as Highlighted Sub-Basins)

Sub-basin	Flow 100-year (cfs)			Flow 1-year (cfs)			% Difference Existing Future-iSWM Peak Flow
	Existing	Future	Future iSWM	Existing	Future	Future iSWM	
BF9	1486	1797	1271	257	456	30	-14%
BFA40	998	1121	854	189	268	21	-14%
BFA41	1579	1709	1709	325	408	408	
BFA42	1718	1784	1784	383	436	436	
BFA43	1055	1260	894	187	295	26	-15%
BFA44	989	1214	850	168	289	22	-14%
BFA45	1429	1689	1689	259	388	388	
BFA46	536	646	462	87	150	8	-14%
BFA47	2688	2999	2999	575	770	770	
BFA48	1183	1436	1019	223	391	28	-14%
BFA49	935	1164	791	137	269	19	-15%
BFB50	1719	1886	1470	341	450	34	-14%
BFB51	1857	2399	1594	329	669	52	-14%
BFB52	1185	1498	1023	213	405	30	-14%
BFB53	1655	2012	1405	295	521	41	-15%
BFB54	1669	1942	1424	341	517	42	-15%
BFB55	702	834	595	133	213	11	-15%
BFB56	1206	1343	1343	265	354	354	
BFB57	1286	1488	1092	211	329	24	-15%
BFC60	2103	2169	2169	493	531	531	
BFC61	2176	2198	2198	552	581	581	
BFD70	1721	1958	1459	380	556	38	-15%
BFD71	1777	1908	1908	395	484	484	
BFD72	2267	2293	2293	552	582	582	
BFD73	1475	1475	1475	386	386	386	
BFD74	1755	1795	1795	464	495	495	
BFD75	1277	1348	1348	260	314	314	
BFD76	1108	1119	1119	291	306	306	
BFD77	920	1004	1004	180	248	248	
WC10	1330	1690	1148	217	420	31	-14%
WC11	1310	1621	1120	216	399	25	-15%
WC12	1495	1908	1287	229	492	39	-14%
WC13	1388	1823	1207	227	502	34	-13%
WC14	1133	1370	965	212	350	22	-15%

Table A-9. Comparison of Peak Discharges for the Three Watershed Scenarios (iSWM Application noted as Highlighted Sub-Basins)

Sub-basin	Flow 100-year (cfs)			Flow 1-year (cfs)			% Difference Existing Future-iSWM Peak Flow
	Existing	Future	Future iSWM	Existing	Future	Future iSWM	
WC15	2045	2386	1787	366	593	47	-13%
WC16	1511	1801	1297	272	474	26	-14%
WC17	2205	2800	1894	384	767	51	-14%
WC18	1850	2200	1570	322	561	36	-15%
WC19	2243	2356	2356	476	549	549	
WC20	1788	1989	1989	346	482	482	
WC21	1903	1998	1998	393	469	469	

Hydrologic Model Results

The hydrologic model of the Big Fossil Creek Watershed provides peak discharge estimates at numerous locations in the watershed. Table A-9 presents a comparison of the peak discharges of the three proposed scenarios for the two flood events, 1-year and 100-year. The tabulated values are the individual sub-basins' hydrograph peaks. In order to analyze the aggregate effect of best management practices suggested in iSWM manual, a single location was chosen for comparison of peak flow from the three scenarios. The chosen comparison location was just upstream of State Highway 121, the most downstream location of Big Fossil Creek before receiving flow from Little Fossil Creek.

Runoff from the existing conditions scenario (34,204 cfs) as compared to the future conditions *without* iSWM scenario (38,026 cfs) increases by 11.2 percent while the increase to the future conditions *with* iSWM scenario (34,634 cfs) is 1.3 percent. The application of iSWM design criteria in the upper portion of the watershed would almost maintain the runoff quantity of the existing conditions scenario.

For the future conditions with iSWM, the assumption was made that application of best management practices recommended through the iSWM manual at a sub-basin level could potentially reduce peak flow by 15 percent, thus reducing the effect downstream. This assumption was put to test through simulation. Sub-basins for which future curve number had the potential to increase more that 6 points were selected. The time to peak of their corresponding hydrograph were altered in such a way that the peak discharge would be reduced by approximately 15 percent relative to the existing 100-year peak flow. The result of this analysis indicated that the discharge at the junction just upstream of State Highway 121 would equal 34634 cfs. This is equivalent to a 1.26 percent increase in discharge relative to the existing condition.

Although the hydrologic model developed and analyzed for this study was used for comparative runoff quantity purposes only, it is encouraging to note the similarities with an existing USACE Ft. Worth hydrologic model of the Big Fossil Creek Watershed. This previous hydrologic model, SWFHYD, Southwest Fort Worth Hydrology (USACE 1986), was developed for a drainage area of 55.0 square miles. For existing conditions the SWFHYD model produces a flow of 33,813 cfs. For future conditions, or as it is titled in the SWFHYD model "projected urbanization (fully developed) runoff condition", flow is predicted as 37,228 cfs.

The HEC-1 model developed for the Big Fossil Creek Watershed Study was developed for a drainage area of 55.88 square miles. For future conditions the HEC-1 model produces a flow of 34,204 cfs. For future conditions without iSWM design criteria, flow is calculated at 38,026 cfs. The HEC-1 model predicts a 11.2 percent increase in existing versus future flow, whereas SWFHYD predicts an increase of 10.1 percent.

Appendix B – Flood Impact Analysis

The flood impact analysis applied the computed runoff quantities of the three watershed scenarios to a HEC-2 (USACE, 1989) hydraulic model along a defined stream reach between Interstate 35 and State Highway 121. The hydraulic model for this study was developed through the combination of several hydraulic models previously created by the U.S. Army Corps of Engineers, Fort Worth District (USACE, Ft. Worth).

Two USACE Ft. Worth HEC-2 models, identified as J20BFC and K20BFOS3, previously modeled the selected stream reach. The appropriate cross sections from upstream of Interstate Highway 35 to downstream of State Highway 121, including bridge and culvert information, were extracted from the USACE models and combined into a single HEC-2 model. The flows (identified as QT cards) were updated to reflect the three watershed scenarios: existing conditions, future conditions *without* iSWM, and future conditions *with* iSWM, for the 1- and 100-year storm events (see Table B-1).

The combined HEC-2 model was executed to produce the water surface elevations (see Table B-2). The centerline of the study reach of Big Fossil Creek was calibrated by positioning the HEC-2 stations over the digital stream information. The calculated water surface elevations were digitally plotted using a floodplain routine scripted in Visual Basic in the ArcMap environment. Figures 5 and 6, presented in the Summary Portion of this Study, display the floodplains graphically for comparative purposes.

Table B-1. Updated Flow Change Points within HEC-2 Model.

HEC-2 Station	HEC-1 Sub-Basin	Flow 100-year (cfs)			Flow 1-year (cfs)		
		Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
60540	BF18C	18832	21406	19783	2769	4049	1906
57110	BF19C	19089	21683	20296	2821	4109	1948
51410	BF20D	24273	27668	25724	3631	5446	2275
49300	BF21D	25470	29011	26737	3908	5793	2552
47220	BF22C	25308	28753	26512	3916	5798	2564
38200	BF23D	32280	36169	33153	5351	8354	3416
35870	BF24C	31717	35503	32668	5293	8231	3375
31080	BF25D	33654	37496	34175	5738	8744	4924
28980	BF26C	33805	37652	34294	5759	8765	5034
22920	BF28C	33715	37554	34229	5677	8547	4836
20850	BF30C	34016	37881	34488	5727	8598	4992
16340	BF31D	34204	38026	34639	5742	8576	5054
3180	BF31D	34204	38026	34639	5742	8576	5054

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
940	498.75	499.3	498.82	488.6	491.33	487.84
3180	499.70	500.24	499.77	489.76	492.49	489.00
6790	501.55	502.08	501.61	492.76	495.06	492.13
8510	503.48	504.13	503.56	494.01	496.24	493.38
9950	504.99	505.69	505.07	494.57	497.07	493.88
10000	505.00	505.73	505.08	494.41	496.83	493.74
10020	505.15	505.88	505.24	494.51	496.96	493.82
10100	505.49	506.17	505.57	495.04	497.79	494.28
10340	505.75	506.44	505.83	495.19	497.99	494.42
10390	505.44	506.07	505.51	495.19	497.97	494.43
10430	505.68	506.36	505.76	495.21	498.00	494.44
10520	505.90	506.67	505.99	495.22	498.01	494.45
10610	505.91	506.65	505.99	495.23	498.02	494.46
10730	505.97	506.72	506.06	495.23	498.03	494.46
10780	506.08	506.91	506.17	495.24	498.03	494.46
11180	506.51	507.36	506.61	495.28	498.09	494.50
11910	506.67	507.53	506.77	495.33	498.15	494.55
12380	506.70	507.52	506.79	495.37	498.20	494.58
13120	507.02	507.87	507.12	495.44	498.29	494.65
14120	507.60	508.49	507.70	495.60	498.46	494.81
14780	508.06	508.97	508.16	495.76	498.62	494.96
15660	508.90	509.87	509.02	496.14	498.95	495.36
16000	509.48	510.43	509.59	496.81	499.53	496.08
16340	510.17	511.15	510.29	497.43	500.04	496.74
16680	510.32	511.26	510.43	497.91	500.39	497.24
16920	510.68	511.62	510.79	498.32	500.72	497.68
16960	511.04	512.02	511.16	498.53	500.91	497.88
17000	511.63	512.77	511.77	498.73	501.04	498.11
17030	511.01	511.98	511.12	498.67	500.97	498.04
17080	511.58	512.62	511.70	498.92	501.22	498.29
17130	512.66	513.98	512.81	499.21	501.47	498.59
17700	513.62	514.90	513.77	501.51	503.61	500.91
17750	513.63	514.82	513.66	501.80	503.91	501.19
17790	513.92	514.82	514.01	502.04	504.25	501.40
17840	515.08	515.63	515.15	502.31	504.55	501.65

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
18140	516.71	517.28	516.78	503.5	505.86	502.80
19110	519.00	519.65	519.08	507.22	509.68	506.44
19920	520.44	521.06	520.52	509.54	511.97	508.75
19970	520.45	521.07	520.53	510.00	512.56	509.18
20020	520.49	521.11	520.57	510.04	512.60	509.22
20060	520.51	521.13	520.59	510.07	512.64	509.24
20120	520.65	521.27	520.73	510.10	512.67	509.27
20160	520.65	521.27	520.73	511.94	513.27	510.85
20230	520.69	521.31	520.77	511.96	513.29	510.87
20430	520.71	521.33	520.79	512.06	513.44	510.98
20610	520.83	521.45	520.91	512.14	513.57	511.05
20850	521.14	521.76	521.21	512.32	513.87	511.24
22920	524.03	524.60	524.10	516.39	518.76	515.42
24720	527.70	528.18	527.76	520.95	523.00	520.05
24750	527.91	528.40	527.98	520.40	522.77	520.12
24780	527.91	528.39	527.97	521.83	523.34	521.48
25750	529.61	530.08	529.67	522.84	524.64	522.37
25790	529.68	530.15	529.74	522.98	524.83	522.49
25800	529.71	530.19	529.77	522.90	524.13	522.44
25810	529.77	530.24	529.83	522.87	524.06	522.34
25820	529.83	530.28	529.89	523.46	526.26	522.76
26450	530.68	531.14	530.74	524.75	526.82	524.11
26520	530.84	531.29	530.90	524.88	526.88	524.57
26550	530.88	531.33	530.93	525.59	526.95	525.41
26860	531.27	531.73	531.33	525.84	527.17	525.63
28050	532.94	533.45	533.01	526.94	528.20	526.62
28165	533.23	533.74	533.29	527.01	528.36	526.69
28235	533.47	533.95	533.53	527.10	528.46	526.76
28300	533.61	534.09	533.67	527.26	528.86	526.88
28720	533.67	534.19	533.74	527.68	529.13	527.28
28980	536.46	537.01	536.53	528.33	530.14	527.84
29400	537.35	537.91	537.43	529.04	531.06	528.48
29422	537.76	538.34	537.84	528.95	531.05	528.39
29434	537.83	538.41	537.91	529.16	531.22	528.61
29512	537.88	538.45	537.96	529.68	531.59	529.12
30230	539.05	539.65	539.14	530.35	532.38	529.72

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
30620	538.93	539.47	539.00	530.59	532.60	529.97
30830	540.72	541.34	540.81	531.10	533.21	530.44
30860	540.79	541.40	540.88	531.17	533.29	530.51
30890	540.65	541.22	540.73	531.18	533.28	530.52
30910	541.97	543.25	542.12	531.25	533.39	530.58
30960	546.65	548.31	546.88	531.88	534.36	531.11
31080	547.97	549.72	548.21	531.99	534.49	531.22
31360	548.25	549.98	548.48	532.45	534.92	531.68
32500	548.54	550.24	548.78	533.86	536.28	532.52
32780	548.55	550.24	548.79	534.28	536.56	532.80
32880	548.58	550.26	548.82	534.41	536.72	532.89
32980	548.61	550.28	548.85	534.58	536.92	533.00
33080	548.66	550.29	548.89	534.78	537.15	533.15
33130	548.69	550.29	548.91	534.90	537.27	533.24
33180	548.85	550.68	549.08	535.04	537.49	533.34
33400	549.13	551.22	549.51	535.12	537.60	533.40
33480	550.75	552.61	551.17	535.47	538.06	533.66
33630	550.76	552.62	551.18	535.46	537.88	533.74
33960	550.81	552.66	551.23	536.58	539.14	534.58
34430	551.01	552.82	551.42	537.41	540.11	535.27
34480	551.15	552.91	551.55	537.50	540.21	535.33
34570	551.76	553.11	552.04	537.54	540.27	535.37
34630	551.77	553.12	552.05	537.16	539.79	535.16
35050	551.90	553.20	552.17	539.70	542.33	537.39
35510	552.39	553.60	552.65	540.48	543.11	538.13
35710	552.55	553.71	552.80	540.61	543.27	538.25
35755	552.87	554.07	553.14	540.66	543.34	538.28
35780	552.56	553.71	552.81	540.64	543.30	538.27
35820	561.44	563.75	562.03	540.72	543.44	538.32
35870	563.52	566.24	564.22	540.91	543.76	538.44
36000	564.77	567.49	565.47	540.70	543.78	538.14
36130	565.14	567.83	565.83	542.23	545.13	539.83
36720	565.31	567.99	566.00	543.62	546.28	541.35
36970	565.34	568.02	566.02	544.10	546.59	542.01
37340	565.38	568.05	566.06	544.59	546.92	542.56
37960	565.42	568.09	566.10	545.21	547.40	543.26

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
38200	565.44	568.11	566.12	545.65	548.05	544.45
39350	565.52	568.17	566.20	551.21	552.14	550.37
39640	565.53	568.17	566.20	551.30	552.22	550.46
40020	565.55	568.18	566.22	551.35	552.30	550.50
40230	565.55	568.17	566.22	551.58	552.71	550.63
40410	565.76	568.31	566.41	551.82	553.07	550.78
40620	565.97	568.48	566.62	551.97	553.28	550.88
40840	566.11	568.58	566.77	552.09	553.44	550.95
41030	566.25	568.71	566.91	552.23	553.61	551.06
41220	566.65	569.03	567.29	552.53	554.06	551.25
41250	566.68	569.04	567.32	552.54	554.07	551.26
41280	566.71	569.05	567.34	552.56	554.10	551.28
41310	566.72	569.06	567.36	552.59	554.13	551.30
41340	566.73	569.06	567.36	552.62	554.17	551.32
41350	566.73	569.05	567.36	552.63	554.18	551.33
41405	566.55	568.91	567.18	552.65	554.19	551.35
41450	568.30	570.08	568.82	552.69	554.26	551.37
41500	569.47	571.03	569.96	552.93	554.64	551.51
41825	569.60	571.14	570.09	553.13	554.89	551.67
42020	569.70	571.23	570.19	553.25	555.03	551.76
42230	569.81	571.35	570.30	553.38	555.17	551.87
42430	569.89	571.42	570.38	553.56	555.35	552.03
42630	569.99	571.51	570.48	553.78	555.59	552.24
42740	570.16	571.77	570.69	555.38	557.20	553.76
42810	570.65	572.12	571.13	559.06	561.43	556.80
43310	570.73	572.18	571.20	559.80	561.74	558.05
44540	570.84	572.28	571.31	561.21	562.05	560.35
45480	571.57	572.82	571.98	565.32	566.28	563.92
45860	571.87	572.99	572.23	566.06	567.04	564.57
46200	573.39	574.21	573.65	567.45	568.63	566.29
46500	574.74	575.41	574.96	569.55	570.35	568.39
46650	574.91	575.57	575.13	569.72	570.54	568.55
46980	576.67	577.26	576.88	570.20	571.32	568.86
47100	576.75	577.33	576.95	570.22	571.36	568.88
47220	577.29	578.01	577.54	570.28	571.45	568.92
47270	577.88	578.85	578.23	570.08	571.12	568.8

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
49300	578.40	579.25	578.7	570.81	572.05	569.42
50210	580.69	581.17	580.88	573.24	574.89	571.68
51410	585.43	585.97	585.69	576.21	578.12	574.27
52950	590.67	591.33	590.96	580.40	582.36	578.47
53820	593.92	594.54	594.22	583.81	585.76	582.13
54410	595.32	595.98	595.63	586.18	587.81	584.91
57110	599.45	600.06	599.74	591.29	592.53	590.25
57780	602.71	603.88	603.28	592.85	594.17	591.80
57830	602.05	602.99	602.54	593.89	594.85	593.21
57870	602.84	604.73	603.34	593.99	595.00	593.27
57920	605.84	607.84	606.47	594.43	595.58	593.59
58420	606.53	608.27	607.08	595.87	597.13	594.84
58620	606.79	608.46	607.32	596.22	597.54	595.13
58670	607.86	609.07	608.27	596.29	597.64	595.18
58770	607.93	609.13	608.34	596.43	597.81	595.31
58970	607.96	609.15	608.37	596.48	597.88	595.34
59070	607.96	609.16	608.37	596.65	598.05	595.51
59110	608.73	609.57	609.01	596.82	598.26	595.64
59160	608.74	609.58	609.01	597.09	598.48	595.99
59260	608.92	609.75	609.19	597.87	599.20	596.82
60540	612.16	612.81	612.31	604.16	605.42	603.05

Hydraulic Modeling Results

Review of table B-2 and the plots of floodplain maps for the 1- and 100-year storm events (Figures 5 and 6) indicate good agreement with the expectation of the modeling effort. The hydraulic modeling effort developed a comparison of the three watershed scenarios. Review of Table B-2 reveals a decrease in the water surface elevations of both the 1- and 100-year storm events between the future *without* iSWM conditions and the future *with* iSWM conditions scenarios. The plots of the floodplain maps reveal the width of the 100-year floodplain is reduced between the future *without* iSWM conditions and the future *with* iSWM conditions scenarios (see Figures 5 and 6 of the Summary).

Appendix C – Water Quality Analysis

The amount of total suspended solids (TSS) in a stream is a fair indicator of the overall water quality of the stream. Other pollutants attach themselves to the suspended solids and are transported downstream. Suspended solids interfere with the transmission of light and settle out in receiving streams and lakes. Turbid water is a result of excessive suspended solids in a stream. Reduction of TSS values in a stream has long been considered the best way to improve a stream's water quality and thus increase its potential uses.

The Simple Method was used to determine seasonal TSS loadings for the Big Fossil Creek Watershed. The Simple Method, developed by the Center for Watershed Protection, incorporates a land-use approach to estimating annual and/or seasonal non-point source loads from direct runoff based upon the event mean concentrations (EMCs) and runoff volumes. The approach is based on the fact that the type and concentration of pollutants in storm water is related to the amount of imperviousness and type of land use contributing to the runoff. Data required to execute the Simple Method water quality model include EMCs for TSS, land use, average annual/seasonal precipitation, and estimates for percent imperviousness on the sub-basin level. In summary, the Simple Method provides a basis for planning level evaluations of the long-term (annual or seasonal) non-point pollution loads and the relative benefits of non-point source pollution management strategies to reduce these loads.

During a storm event, the concentration of pollutants in the runoff varies considerably over time. For example, the concentration of oily substances on roadways are highest during the first part of the storm, and then decline quickly when the bulk of the material is washed off. This is known as the first-flush phenomenon. However, the concentration in the first-flush runoff is not representative of the entire storm. In order to estimate the loading from a storm, the flow-weighted average concentration is needed. Known as the Event Mean Concentration (EMC), the flow-weighted concentration is found by dividing the average of total loading by total runoff for a series of storm events.

The EMCs used in the Simple Method water quality model for the Big Fossil Creek Watershed were based upon a qualitative in-stream monitoring program completed by the NCTCOG. The NCTCOG completed a comprehensive sampling program of 22 separate outfalls for a wide range of pollutants, including total suspended solids. The sampling was conducted from September 1997 to August 2000. Although many other pollutants were included in the analysis, TSS is the pollutant of concern for this study. In order to model TSS values in the watershed, sampling sites were classified into five separate land use categories in order to differentiate water quality from diverse sources. For each sampling interval, the concentration and the quantity of runoff were combined to determine a TSS loading for the interval. At the end of the storm event, the results were used to develop the EMC (total mass/total runoff), which describes the average concentration for the storm. These results were combined with the results from several storm events and statistically evaluated to arrive at a representative EMC for each land use on a seasonal or average annual basis. Storm water loadings tend to be highly variable from one storm event to another, even for the same sampling site. This is attributable to variable antecedent weather conditions, which affect the amount of runoff; variable rainfall for a given event; seasonal variations in land use (e.g., spring fertilization of lawns); and other factors. Consequently, it is desirable to obtain a good statistical representation of the EMC.

A summary of the EMCs used in the Simple Method water quality model are presented in Table C-1.

Table C-1. Event Mean Concentrations, TSS (mg/l)

Type of Land Use	Season 1 (Sep – Oct)	Season 2 (Nov – Feb)	Season 3 (Mar – Jun)	Season 4 (Jul – Aug)
Commercial	41.5	37.5	46	37
Highway	62	142	134	142
Industrial	54	86	135	86
Open	118	332	118	332
Residential	90	73	116	73

Rainfall

The rainfall data used in the Simple Method water quality model were the long-term records of the National Weather Service recording station at Dallas/Fort Worth International Airport. Annual/Seasonal precipitation values were obtained from the National Oceanic and Atmospheric Association (NOAA).

Pollutant Data

As previously discussed, EMCs were derived from actual wet weather samples taken from 22 sites across the area. These sites were located within five different land uses types: commercial, industrial, highway, open, and residential.

Mapping

All mapping data was obtained from NCTCOG geographic information system. Digital base data included contours, orthophotographs, and existing and future land use. Basin and sub-basin boundaries were delineated during the development of the hydrologic models.

Model Development

The Simple Method water quality model was incorporated into a spreadsheet format for evaluation of the impacts on water quality from traditional non-point sources. The model is a user-friendly database model that simulates the generation and outcome of pollutant loads from a number of watershed pollutant sources. The model's primary function is to estimate pollutant loads from storm water runoff (non-point source pollution). For simulation of storm water runoff pollutant loads, the model uses land use and the associated runoff volume and event mean concentrations (EMCs) for total suspended solids.

Designated sub-basins within the Big Fossil Creek Watershed were simulated using existing and future land uses. The developed model is beneficial to NCTCOG future planning efforts because it can provide a forecast of the approximate impact of planned actions or alternatives on water quality and pollutant loads. The model may also be used to estimate and analyze trade-offs between planning objectives through the management of all watershed pollution sources (including non-point sources, such as storm water runoff, and point sources, such as wastewater treatment plant discharges, CSOs, etc.)

Land Use

The pollutant loading calculation is derived from land uses. Existing and future land use data, provided by the NCTCOG and the City of Fort Worth, were used as the basis for determining the land use classes employed in the water quality calculations. The provided land use was classified into the five land use types, as determined in the monitoring study completed by the NCTCOG; by grouping similar land use types. For example, regional commercial uses, office commercial uses, community commercial uses, and heavy commercial uses were all combined into a larger "commercial" category. Table C-2 displays the land uses from the model and their corresponding percent imperviousness.

Table C-2.
Land Use Designations

Number	Description	Percent Imperviousness
1	Commercial	85
2	Highway	90
3	Industrial	72
4	Open	3
5	Residential	30

Pollutant Loads

Pollutant load is simply the product of runoff volume and event mean concentration. In order to generate the input data, land use-based runoff coefficients, land use-based EMCs, and rainfall depths are needed. Rainfall/runoff relationships are needed to estimate non-point pollution load factors (lbs/acre/year) for the various land use categories. The load factors are then used to calculate the annual load of a certain parameter from a drainage basin (lbs/year) based on the area of that land use.

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$L = 0.226 * R * C * A$$

L = Annual load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration or Event Mean Concentration (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

Annual Runoff

The Simple Method calculates annual runoff as a product of annual runoff volume, and a runoff coefficient (Rv). Runoff volume is calculated as:

$$R = P * P_j * Rv$$

R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

For the modeling, a runoff coefficient of (0.05 + 0.009(I)) was used to predict runoff, where I is the percent of impervious area. For completely pervious surfaces, the R_v would be 0.05. For completely impervious surfaces, the R_v would be 0.95.

iSWM Application

In order to simulate the future conditions *with* iSWM scenario, a 75 percent reduction in TSS loadings was applied to each sub-basin. This application was made to reflect the design recommendations of the iSWM structural Best Management Practices (BMPs). Recommended water quality BMPs will remove 80 percent of the average annual TSS load in typical urban post-development runoff and a proportional removal of other pollutants, if designed and installed properly.

Model Results

Table C-3 presents the TSS loadings computed for each sub-basin for the existing conditions scenario and the future conditions scenarios, both *without* and *with* iSWM design criteria. Red text denotes application of iSWM design criteria for Future Conditions.

Table C-3. Comparison of TSS Loadings

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	580	745	1,440	328	308	395	765	174	231	297	574	131
BF1	Highway	5,137	16,953	24,889	7,477	6,186	20,417	29,975	9,004	4,640	15,313	22,481	6,753
	Industrial	570	1,307	3,193	577	3,525	8,091	19,760	3,568	2,644	6,068	14,820	2,676
	Open	6,815	27,629	15,278	12,185	158	642	355	283	158	642	355	283
	Residential	672	786	1,942	346	19,177	22,415	55,415	9,885	14,383	16,811	41,561	7,414
	Total	**13,772**	**47,420**	**46,743**	**20,913**	**29,355**	**51,960**	**106,269**	**22,915**	**22,055**	**39,130**	**79,790**	**17,257**
	Commercial	0	348	0	0	0	348	1	0	0	261	1	0
BF2	Highway	1,087	3,588	5,267	1,582	955	3,153	4,629	1,391	717	2,365	3,472	1,043
	Industrial	0	0	0	0	5,277	12,111	29,578	5,341	3,958	9,083	22,183	4,006
	Open	6,219	25,215	13,943	11,120	3	13	7	6	3	13	7	6
	Residential	0	0	0	0	15,741	18,399	45,486	8,114	11,806	13,799	34,115	6,086
	Total	**7,306**	**29,151**	**19,210**	**12,703**	**21,977**	**34,024**	**79,701**	**14,852**	**16,484**	**25,521**	**59,778**	**11,140**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF3	Highway	681	2,246	3,298	991	662	2,185	3,209	964	497	1,639	2,406	723
	Industrial	0	0	0	0	166	380	929	168	124	285	697	126
	Open	6,699	27,161	15,019	11,979	25	100	55	44	25	100	55	44
	Residential	1,254	1,466	3,624	647	22,293	26,058	64,420	11,492	16,720	19,543	48,315	8,619
	Total	**8,634**	**30,873**	**21,941**	**13,616**	**23,146**	**28,724**	**68,613**	**12,668**	**17,366**	**21,568**	**51,473**	**9,512**
	Commercial	0	0	0	0	888	1,141	2,207	503	666	856	1,655	377
BF4	Highway	1,041	3,436	5,044	1,515	1,006	3,319	4,873	1,464	754	2,489	3,655	1,098
	Industrial	2,648	6,078	14,844	2,680	9,101	20,886	51,010	9,211	6,826	15,665	38,257	6,909
	Open	5,979	24,241	13,404	10,691	709	2,873	1,588	1,267	709	2,873	1,588	1,267
	Residential	6,106	7,137	17,644	3,147	17,143	20,038	49,538	8,837	12,858	15,029	37,154	6,628
	Total	**15,774**	**40,891**	**50,936**	**18,034**	**28,847**	**48,257**	**109,216**	**21,282**	**21,812**	**36,911**	**82,309**	**16,279**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	116	149	288	66	116	149	288	66
BF5	Highway	436	1,437	2,110	634	1,131	3,733	5,480	1,646	1,131	3,733	5,480	1,646
	Industrial	152	348	850	154	0	0	0	0	0	0	0	0
	Open	2,843	11,528	6,374	5,084	148	599	331	264	148	599	331	264
	Residential	8,461	9,890	24,449	4,362	16,647	19,458	48,104	8,581	16,647	19,458	48,104	8,581
	Total	**11,891**	**23,203**	**33,784**	**10,233**	**18,042**	**23,938**	**54,203**	**10,557**	**18,042**	**23,938**	**54,203**	**10,557**
	Commercial	0	0	0	0	221	285	550	125	166	213	413	94
BF6	Highway	781	2,578	3,785	1,137	2,304	7,603	11,163	3,353	1,728	5,703	8,372	2,515
	Industrial	2,471	5,670	13,847	2,501	2,605	5,978	14,599	2,636	1,954	4,483	10,950	1,977
	Open	2,718	11,021	6,094	4,861	72	293	162	129	72	293	162	129
	Residential	0	0	0	0	7,274	8,502	21,018	3,749	5,455	6,376	15,764	2,812
	Total	**5,970**	**19,269**	**23,727**	**8,498**	**12,476**	**22,661**	**47,493**	**9,994**	**9,375**	**17,069**	**35,660**	**7,528**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF7	Highway	1,895	6,255	9,183	2,758	1,940	6,402	9,399	2,823	1,455	4,802	7,049	2,118
	Industrial	2,554	5,861	14,313	2,585	2,466	5,660	13,822	2,496	1,850	4,245	10,367	1,872
	Open	4,378	17,749	9,814	7,828	290	1,174	649	518	290	1,174	649	518
	Residential	2,151	2,514	6,215	1,109	15,151	17,710	43,782	7,810	11,363	13,282	32,836	5,858
	Total	**10,977**	**32,378**	**39,526**	**14,279**	**19,847**	**30,946**	**67,652**	**13,648**	**14,958**	**23,503**	**50,902**	**10,365**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF8	Highway	135	444	652	196	890	2,938	4,314	1,296	668	2,204	3,235	972
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	2,200	8,918	4,931	3,933	7	30	17	13	7	30	17	13
	Residential	1,476	1,725	4,264	761	8,016	9,369	23,163	4,132	6,012	7,027	17,372	3,099
	Total	**3,810**	**11,087**	**9,848**	**4,890**	**8,913**	**12,337**	**27,493**	**5,441**	**6,687**	**9,260**	**20,624**	**4,084**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	1	1	0	774	994	1,922	438	580	745	1,442	329
BF9	Highway	2,596	8,569	12,580	3,779	1,528	5,044	7,405	2,225	1,146	3,783	5,554	1,668
	Industrial	0	0	0	0	537	1,232	3,008	543	403	924	2,256	407
	Open	5,048	20,466	11,317	9,026	877	3,555	1,966	1,568	877	3,555	1,966	1,568
	Residential	1,174	1,373	3,393	605	13,904	16,252	40,178	7,167	10,428	12,189	30,134	5,376
	Total	**8,819**	**30,408**	**27,292**	**13,411**	**17,620**	**27,076**	**54,480**	**11,941**	**13,434**	**21,196**	**41,351**	**9,348**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF10	Highway	479	1,580	2,320	697	674	2,225	3,267	981	506	1,669	2,450	736
	Industrial	0	0	0	0	1,355	3,109	7,593	1,371	1,016	2,332	5,695	1,028
	Open	4,116	16,687	9,227	7,359	1	3	2	2	1	3	2	2
	Residential	2,300	2,688	6,646	1,186	14,203	16,601	41,041	7,321	10,652	12,451	30,780	5,491
	Total	**6,895**	**20,955**	**18,193**	**9,242**	**16,232**	**21,938**	**51,902**	**9,675**	**12,175**	**16,455**	**38,927**	**7,257**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF11	Highway	46	152	223	67	210	692	1,016	305	157	519	762	229
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	2,600	10,543	5,830	4,650	5	21	11	9	5	21	11	9
	Residential	265	309	765	136	8,402	9,821	24,279	4,331	6,302	7,366	18,209	3,248
	Total	**2,911**	**11,004**	**6,818**	**4,853**	**8,617**	**10,533**	**25,306**	**4,645**	**6,464**	**7,905**	**18,982**	**3,486**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF12	Highway	2,234	7,374	10,827	3,252	599	1,977	2,903	872	449	1,483	2,177	654
	Industrial	0	0	0	0	2,326	5,338	13,036	2,354	1,744	4,003	9,777	1,766
	Open	8,893	36,057	19,938	15,902	283	1,146	634	506	283	1,146	634	506
	Residential	0	0	0	0	26,399	30,856	76,284	13,608	19,799	23,142	57,213	10,206
	Total	**11,128**	**43,431**	**30,765**	**19,154**	**29,607**	**39,318**	**92,857**	**17,340**	**22,276**	**29,775**	**69,801**	**13,131**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	300	385	745	170	618	794	1,535	350	463	595	1,151	262
BF13	Highway	946	3,123	4,585	1,377	989	3,263	4,790	1,439	741	2,447	3,593	1,079
	Industrial	19	44	107	19	580	1,332	3,252	587	435	999	2,439	440
	Open	4,972	20,159	11,147	8,891	2,193	8,892	4,917	3,922	2,193	8,892	4,917	3,922
	Residential	0	0	0	0	8,408	9,827	24,296	4,334	6,306	7,371	18,222	3,251
	Total	**6,237**	**23,711**	**16,583**	**10,457**	**12,788**	**24,108**	**38,790**	**10,632**	**10,139**	**20,304**	**30,322**	**8,955**
	Commercial	387	498	962	219	2,376	3,052	5,903	1,346	1,782	2,289	4,428	1,010
BF14	Highway	1,517	5,007	7,350	2,208	4,147	13,688	20,095	6,037	3,110	10,266	15,072	4,527
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	5,681	23,032	12,736	10,158	4,122	16,712	9,241	7,370	4,122	16,712	9,241	7,370
	Residential	3,567	4,170	10,308	1,839	5,674	6,632	16,395	2,925	4,255	4,974	12,296	2,193
	Total	**11,152**	**32,706**	**31,357**	**14,424**	**16,318**	**40,083**	**51,634**	**17,677**	**13,269**	**34,240**	**41,036**	**15,101**
	Commercial	33	42	81	19	771	991	1,917	437	578	743	1,438	328
BF15	Highway	1,614	5,327	7,821	2,349	2,039	6,729	9,880	2,968	1,529	5,047	7,410	2,226
	Industrial	0	0	0	0	2,878	6,605	16,131	2,913	2,159	4,954	12,099	2,185
	Open	3,940	15,974	8,833	7,045	3,610	14,638	8,094	6,456	3,610	14,638	8,094	6,456
	Residential	1,557	1,820	4,499	803	9,987	11,674	28,860	5,148	7,490	8,755	21,645	3,861
	Total	**7,144**	**23,163**	**21,234**	**10,215**	**19,286**	**40,637**	**64,882**	**17,922**	**15,367**	**34,137**	**50,685**	**15,055**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF16	Highway	2,202	7,267	10,669	3,205	2,783	9,184	13,483	4,050	2,087	6,888	10,112	3,038
	Industrial	1,920	4,407	10,764	1,944	7,083	16,256	39,702	7,169	5,313	12,192	29,776	5,377
	Open	7,883	31,963	17,674	14,096	3,516	14,254	7,882	6,286	3,516	14,254	7,882	6,286
	Residential	0	0	0	0	20,479	23,937	59,178	10,557	15,360	17,953	44,384	7,918
	Total	**12,006**	**43,637**	**39,107**	**19,245**	**33,861**	**63,631**	**120,244**	**28,063**	**26,275**	**51,287**	**92,154**	**22,619**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	8,759	11,254	21,767	4,963	6,569	8,440	16,325	3,722
BF17	Highway	0	0	0	0	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	5,179	20,998	11,611	9,261	5,159	20,918	11,567	9,225	5,159	20,918	11,567	9,225
	Residential	0	0	0	0	8,958	10,470	25,884	4,617	6,718	7,852	19,413	3,463
	Total	**5,179**	**20,998**	**11,611**	**9,261**	**22,876**	**42,642**	**59,218**	**18,806**	**18,447**	**37,211**	**47,305**	**16,411**
	Commercial	4,217	5,418	10,480	2,390	5	7	13	3	4	5	10	2
BF18	Highway	2,122	7,005	10,284	3,089	2,656	8,767	12,872	3,867	1,992	6,576	9,654	2,900
	Industrial	818	1,877	4,585	828	21,242	48,749	119,057	21,499	15,931	36,562	89,293	16,125
	Open	3,766	15,269	8,443	6,734	3,159	12,807	7,082	5,648	3,159	12,807	7,082	5,648
	Residential	1,546	1,807	4,468	797	1,552	1,813	4,483	800	1,164	1,360	3,362	600
	Total	**12,470**	**31,377**	**38,261**	**13,838**	**28,614**	**72,144**	**143,507**	**31,817**	**22,250**	**57,310**	**109,401**	**25,275**
	Commercial	1,544	1,984	3,838	875	681	876	1,694	386	511	657	1,270	290
BF19	Highway	8,105	26,751	39,275	11,798	9,452	31,195	45,798	13,757	7,089	23,396	34,348	10,318
	Industrial	0	0	0	0	22,699	52,095	127,228	22,975	17,025	39,071	95,421	17,231
	Open	5,361	21,735	12,019	9,586	1,386	5,621	3,108	2,479	1,386	5,621	3,108	2,479
	Residential	2,086	2,438	6,026	1,075	1,704	1,992	4,924	878	1,278	1,494	3,693	659
	Total	**17,096**	**52,909**	**61,158**	**23,334**	**35,923**	**91,777**	**182,752**	**40,476**	**27,289**	**70,238**	**137,841**	**30,976**
	Commercial	545	701	1,355	309	2,717	3,490	6,751	1,539	2,037	2,618	5,063	1,154
BF20	Highway	1,331	4,392	6,448	1,937	1,351	4,457	6,544	1,966	1,013	3,343	4,908	1,474
	Industrial	1,435	3,293	8,042	1,452	16,452	37,756	92,209	16,651	12,339	28,317	69,157	12,488
	Open	3,665	14,860	8,217	6,553	27	109	60	48	27	109	60	48
	Residential	1,801	2,105	5,204	928	0	0	0	0	0	0	0	0
	Total	**8,777**	**25,350**	**29,266**	**11,180**	**20,545**	**45,812**	**105,564**	**20,204**	**15,416**	**34,386**	**79,188**	**15,165**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	150	192	372	85	112	144	279	64
BF21	Highway	83	273	401	121	130	428	628	189	97	321	471	141
	Industrial	74	169	412	74	3,229	7,409	18,096	3,268	2,421	5,557	13,572	2,451
	Open	805	3,265	1,805	1,440	0	1	1	1	0	1	1	1
	Residential	12	14	34	6	0	0	1	0	0	0	1	0
	Total	**974**	**3,721**	**2,654**	**1,641**	**3,508**	**8,031**	**19,097**	**3,542**	**2,631**	**6,024**	**14,323**	**2,657**
	Commercial	2,779	3,571	6,907	1,575	4,680	6,013	11,630	2,652	4,680	6,013	11,630	2,652
BF22	Highway	2,984	9,847	14,457	4,343	4,268	14,087	20,682	6,213	4,268	14,087	20,682	6,213
	Industrial	1,872	4,297	10,494	1,895	1,330	3,053	7,455	1,346	1,330	3,053	7,455	1,346
	Open	2,135	8,658	4,787	3,818	1,337	5,422	2,998	2,391	1,337	5,422	2,998	2,391
	Residential	5,206	6,085	15,044	2,684	5,838	6,823	16,869	3,009	5,838	6,823	16,869	3,009
	Total	**14,977**	**32,458**	**51,690**	**14,315**	**17,453**	**35,398**	**59,635**	**15,611**	**17,453**	**35,398**	**59,635**	**15,611**
	Commercial	6,936	8,911	17,236	3,930	4,106	5,275	10,202	2,326	4,106	5,275	10,202	2,326
BF23	Highway	2,278	7,517	11,036	3,315	2,416	7,975	11,709	3,517	2,416	7,975	11,709	3,517
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,503	6,093	3,369	2,687	2,088	8,466	4,681	3,734	2,088	8,466	4,681	3,734
	Residential	1,631	1,906	4,713	841	2,112	2,468	6,102	1,088	2,112	2,468	6,102	1,088
	Total	**12,347**	**24,427**	**36,354**	**10,773**	**10,721**	**24,184**	**32,694**	**10,665**	**10,721**	**24,184**	**32,694**	**10,665**
	Commercial	821	1,055	2,041	465	5,658	7,269	14,060	3,206	4,243	5,452	10,545	2,404
BF24	Highway	3,704	12,224	17,947	5,391	2,896	9,558	14,032	4,215	2,172	7,168	10,524	3,161
	Industrial	1,956	4,490	10,966	1,980	0	0	0	0	0	0	0	0
	Open	1,920	7,785	4,305	3,433	1,148	4,653	2,573	2,052	1,148	4,653	2,573	2,052
	Residential	1,872	2,189	5,411	965	2,134	2,495	6,168	1,100	1,601	1,871	4,626	825
	Total	**10,274**	**27,743**	**40,669**	**12,235**	**11,836**	**23,974**	**36,832**	**10,573**	**9,164**	**19,144**	**28,267**	**8,443**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	2,650	3,405	6,587	1,502	5,569	7,155	13,839	3,155	5,569	7,155	13,839	3,155
BF25	Highway	9,750	32,179	47,243	14,191	7,908	26,099	38,317	11,510	7,908	26,099	38,317	11,510
	Industrial	1,910	4,384	10,708	1,934	702	1,611	3,934	710	702	1,611	3,934	710
	Open	3,307	13,406	7,413	5,912	2,554	10,353	5,725	4,566	2,554	10,353	5,725	4,566
	Residential	2,917	3,409	8,428	1,504	4,737	5,537	13,688	2,442	4,737	5,537	13,688	2,442
	Total	**20,534**	**56,784**	**80,378**	**25,043**	**21,469**	**50,754**	**75,502**	**22,384**	**21,469**	**50,754**	**75,502**	**22,384**
	Commercial	2,229	2,863	5,538	1,263	7,905	10,156	19,644	4,479	7,905	10,156	19,644	4,479
BF26	Highway	7,775	25,662	37,675	11,317	5,935	19,589	28,760	8,639	5,935	19,589	28,760	8,639
	Industrial	70	160	390	70	0	0	0	0	0	0	0	0
	Open	1,797	7,288	4,030	3,214	715	2,900	1,603	1,279	715	2,900	1,603	1,279
	Residential	7,610	8,895	21,991	3,923	7,255	8,479	20,963	3,740	7,255	8,479	20,963	3,740
	Total	**19,481**	**44,868**	**69,624**	**19,788**	**21,810**	**41,124**	**70,970**	**18,137**	**21,810**	**41,124**	**70,970**	**18,137**
	Commercial	207	265	514	117	3,048	3,916	7,575	1,727	2,286	2,937	5,681	1,295
BF27	Highway	3,678	12,138	17,820	5,353	3,385	11,173	16,403	4,927	2,539	8,379	12,302	3,696
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,680	6,810	3,766	3,004	1,065	4,319	2,388	1,905	1,065	4,319	2,388	1,905
	Residential	5,833	6,818	16,855	3,007	5,520	6,452	15,951	2,846	4,140	4,839	11,963	2,134
	Total	**11,397**	**26,032**	**38,955**	**11,481**	**13,019**	**25,859**	**42,317**	**11,405**	**10,030**	**20,474**	**32,335**	**9,030**
	Commercial	1,453	1,867	3,611	823	2,914	3,744	7,242	1,651	2,914	3,744	7,242	1,651
BF28	Highway	8,571	28,287	41,529	12,475	6,907	22,796	33,468	10,054	6,907	22,796	33,468	10,054
	Industrial	1,978	4,541	11,089	2,002	1,646	3,777	9,223	1,666	1,646	3,777	9,223	1,666
	Open	538	2,180	1,206	962	486	1,972	1,091	870	486	1,972	1,091	870
	Residential	9,685	11,320	27,986	4,993	9,757	11,404	28,193	5,029	9,757	11,404	28,193	5,029
	Total	**22,225**	**48,195**	**85,422**	**21,255**	**21,710**	**43,693**	**79,217**	**19,270**	**21,710**	**43,693**	**79,217**	**19,270**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	86	111	214	49	4,781	6,142	11,880	2,709	3,586	4,607	8,910	2,032
BF29	Highway	4,474	14,765	21,677	6,512	4,014	13,248	19,450	5,843	3,011	9,936	14,588	4,382
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,701	6,896	3,813	3,041	365	1,479	818	652	365	1,479	818	652
	Residential	7,543	8,817	21,798	3,888	8,029	9,385	23,201	4,139	6,022	7,039	17,401	3,104
	Total	**13,804**	**30,589**	**47,502**	**13,490**	**17,189**	**30,254**	**55,350**	**13,343**	**12,983**	**23,060**	**41,717**	**10,170**
	Commercial	3,280	4,214	8,151	1,858	6,416	8,244	15,945	3,636	6,416	8,244	15,945	3,636
BF30	Highway	10,576	34,906	51,247	15,394	8,247	27,219	39,961	12,004	8,247	27,219	39,961	12,004
	Industrial	1,342	3,079	7,520	1,358	231	531	1,296	234	231	531	1,296	234
	Open	661	2,682	1,483	1,183	661	2,681	1,482	1,182	661	2,681	1,482	1,182
	Residential	13,653	15,958	39,451	7,038	13,089	15,299	37,823	6,747	13,089	15,299	37,823	6,747
	Total	**29,512**	**60,839**	**107,852**	**26,831**	**28,645**	**53,973**	**96,508**	**23,803**	**28,645**	**53,973**	**96,508**	**23,803**
	Commercial	3,617	4,647	8,988	2,049	5,854	7,522	14,549	3,317	5,854	7,522	14,549	3,317
BF31	Highway	6,360	20,990	30,816	9,257	4,312	14,230	20,892	6,276	4,312	14,230	20,892	6,276
	Industrial	1,005	2,307	5,634	1,017	0	0	0	0	0	0	0	0
	Open	2,116	8,579	4,744	3,783	2,065	8,372	4,629	3,692	2,065	8,372	4,629	3,692
	Residential	3,347	3,912	9,671	1,725	3,478	4,065	10,049	1,793	3,478	4,065	10,049	1,793
	Total	**16,444**	**40,434**	**59,852**	**17,832**	**15,708**	**34,188**	**50,118**	**15,078**	**15,708**	**34,188**	**50,118**	**15,078**
	Commercial	2,114	2,716	5,254	1,198	2,498	3,209	6,207	1,415	2,498	3,209	6,207	1,415
BF32	Highway	4,397	14,513	21,307	6,400	4,330	14,291	20,981	6,302	4,330	14,291	20,981	6,302
	Industrial	57	130	317	57	0	0	0	0	0	0	0	0
	Open	812	3,292	1,820	1,452	549	2,227	1,232	982	549	2,227	1,232	982
	Residential	7,973	9,319	23,039	4,110	8,558	10,003	24,729	4,411	8,558	10,003	24,729	4,411
	Total	**15,353**	**29,970**	**51,737**	**13,217**	**15,935**	**29,730**	**53,148**	**13,111**	**15,935**	**29,730**	**53,148**	**13,111**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	2,776	3,566	6,898	1,573	4,169	5,357	10,361	2,362	4,169	5,357	10,361	2,362
BF33	Highway	9,673	31,924	46,869	14,079	9,073	29,946	43,966	13,207	9,073	29,946	43,966	13,207
	Industrial	284	651	1,591	287	52	118	289	52	52	118	289	52
	Open	1,143	4,635	2,563	2,044	590	2,392	1,323	1,055	590	2,392	1,323	1,055
	Residential	12,227	14,291	35,331	6,303	13,295	15,539	38,416	6,853	13,295	15,539	38,416	6,853
	Total	**26,102**	**55,068**	**93,252**	**24,286**	**27,179**	**53,352**	**94,355**	**23,529**	**27,179**	**53,352**	**94,355**	**23,529**
	Commercial	467	600	1,160	264	11,109	14,273	27,608	6,295	11,109	14,273	27,608	6,295
BF34	Highway	6,365	21,008	30,843	9,265	4,960	16,369	24,031	7,219	4,960	16,369	24,031	7,219
	Industrial	4,323	9,922	24,232	4,376	545	1,250	3,053	551	545	1,250	3,053	551
	Open	3,273	13,272	7,339	5,853	1,558	6,317	3,493	2,786	1,558	6,317	3,493	2,786
	Residential	947	1,107	2,736	488	968	1,131	2,797	499	968	1,131	2,797	499
	Total	**15,376**	**45,909**	**66,310**	**20,247**	**19,140**	**39,340**	**60,982**	**17,350**	**19,140**	**39,340**	**60,982**	**17,350**
	Commercial	0	0	0	0	0	1	1	0	0	0	1	0
BFA40	Highway	4,965	16,387	24,059	7,227	4,467	14,744	21,646	6,502	3,350	11,058	16,235	4,877
	Industrial	239	548	1,338	242	0	0	0	0	0	0	0	0
	Open	3,400	13,787	7,624	6,080	30	122	68	54	30	122	68	54
	Residential	0	0	0	0	11,134	13,014	32,172	5,739	8,350	9,760	24,129	4,304
	Total	**8,604**	**30,722**	**33,021**	**13,549**	**15,632**	**27,881**	**53,888**	**12,296**	**11,731**	**20,941**	**40,433**	**9,235**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA41	Highway	126	416	611	183	268	886	1,301	391	268	886	1,301	391
	Industrial	734	1,685	4,116	743	0	0	0	0	0	0	0	0
	Open	3,133	12,704	7,025	5,603	1,166	4,730	2,615	2,086	1,166	4,730	2,615	2,086
	Residential	3,135	3,664	9,058	1,616	9,853	11,517	28,473	5,079	9,853	11,517	28,473	5,079
	Total	**7,129**	**18,470**	**20,810**	**8,145**	**11,288**	**17,132**	**32,389**	**7,556**	**11,288**	**17,132**	**32,389**	**7,556**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	88	113	219	50	96	124	239	54	96	124	239	54
BFA42	Highway	2,694	8,891	13,054	3,921	2,811	9,277	13,620	4,091	2,811	9,277	13,620	4,091
	Industrial	0	0	0	0	120	276	673	122	120	276	673	122
	Open	2,190	8,881	4,911	3,917	1,345	5,453	3,015	2,405	1,345	5,453	3,015	2,405
	Residential	10,068	11,767	29,092	5,190	12,586	14,711	36,369	6,488	12,586	14,711	36,369	6,488
	Total	**15,040**	**29,653**	**47,275**	**13,078**	**16,958**	**29,840**	**53,917**	**13,160**	**16,958**	**29,840**	**53,917**	**13,160**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA43	Highway	1,423	4,698	6,897	2,072	1,246	4,114	6,040	1,814	935	3,085	4,530	1,361
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	5,032	20,402	11,282	8,998	1	3	2	1	1	3	2	1
	Residential	0	0	0	0	16,043	18,752	46,360	8,270	12,033	14,064	34,770	6,203
	Total	**6,455**	**25,100**	**18,179**	**11,070**	**17,291**	**22,869**	**52,401**	**10,086**	**12,968**	**17,152**	**39,301**	**7,565**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA44	Highway	562	1,854	2,721	817	486	1,603	2,354	707	364	1,203	1,766	530
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	4,396	17,822	9,855	7,860	5	21	12	9	5	21	12	9
	Residential	0	0	0	0	13,957	16,314	40,331	7,195	10,468	12,235	30,248	5,396
	Total	**4,957**	**19,676**	**12,576**	**8,677**	**14,448**	**17,938**	**42,697**	**7,911**	**10,837**	**13,459**	**32,025**	**5,936**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA45	Highway	624	2,059	3,023	908	552	1,821	2,673	803	552	1,821	2,673	803
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	7,334	29,737	16,444	13,115	83	337	186	148	83	337	186	148
	Residential	1,644	1,921	4,750	847	24,668	28,833	71,282	12,716	24,668	28,833	71,282	12,716
	Total	**9,602**	**33,718**	**24,217**	**14,870**	**25,303**	**30,991**	**74,141**	**13,667**	**25,303**	**30,991**	**74,141**	**13,667**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA46	Highway	35	117	172	52	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,832	7,427	4,107	3,276	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	5,825	6,809	16,833	3,003	4,369	5,107	12,625	2,252
	Total	**1,867**	**7,544**	**4,279**	**3,327**	**5,825**	**6,809**	**16,833**	**3,003**	**4,369**	**5,107**	**12,625**	**2,252**
	Commercial	403	517	1,000	228	62	80	154	35	62	80	154	35
BFA47	Highway	4,383	14,466	21,238	6,380	4,117	13,589	19,951	5,993	4,117	13,589	19,951	5,993
	Industrial	1,079	2,477	6,050	1,092	3,612	8,288	20,242	3,655	3,612	8,288	20,242	3,655
	Open	5,385	21,833	12,073	9,629	571	2,313	1,279	1,020	571	2,313	1,279	1,020
	Residential	8,060	9,421	23,290	4,155	21,818	25,502	63,046	11,247	21,818	25,502	63,046	11,247
	Total	**19,310**	**48,714**	**63,650**	**21,484**	**30,179**	**49,773**	**104,673**	**21,951**	**30,179**	**49,773**	**104,673**	**21,951**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA48	Highway	2,525	8,333	12,234	3,675	2,989	9,866	14,485	4,351	2,242	7,400	10,864	3,263
	Industrial	2,778	6,377	15,573	2,812	9,964	22,867	55,847	10,085	7,473	17,150	41,885	7,564
	Open	3,788	15,359	8,493	6,774	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	6,266	7,324	18,107	3,230	4,700	5,493	13,580	2,423
	Total	**9,091**	**30,069**	**36,300**	**13,261**	**19,219**	**40,058**	**88,439**	**17,666**	**14,415**	**30,043**	**66,329**	**13,250**
	Commercial	0	0	0	0	5	6	12	3	4	5	9	2
BFA49	Highway	1,356	4,476	6,571	1,974	2,414	7,968	11,698	3,514	1,811	5,976	8,774	2,636
	Industrial	2,042	4,685	11,443	2,066	4,154	9,533	23,281	4,204	3,115	7,150	17,461	3,153
	Open	3,432	13,913	7,693	6,136	1,078	4,371	2,417	1,928	1,078	4,371	2,417	1,928
	Residential	0	0	0	0	8,310	9,713	24,014	4,284	6,233	7,285	18,010	3,213
	Total	**6,829**	**23,074**	**25,708**	**10,176**	**15,961**	**31,591**	**61,422**	**13,932**	**12,240**	**24,786**	**46,671**	**10,931**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	639	821	1,589	362	0	0	0	0	0	0	0	0
BFB50	Highway	1,819	6,002	8,812	2,647	1,313	4,333	6,362	1,911	985	3,250	4,772	1,433
	Industrial	1,470	3,373	8,238	1,488	6,449	14,801	36,146	6,527	4,837	11,100	27,110	4,896
	Open	3,332	13,508	7,470	5,957	631	2,559	1,415	1,129	631	2,559	1,415	1,129
	Residential	8,870	10,367	25,630	4,572	14,443	16,881	41,735	7,445	10,832	12,661	31,301	5,584
	Total	**16,129**	**34,072**	**51,739**	**15,027**	**22,836**	**38,575**	**85,658**	**17,012**	**17,285**	**29,571**	**64,597**	**13,041**
	Commercial	289	371	718	164	0	0	0	0	0	0	0	0
BFB51	Highway	4,471	14,756	21,664	6,508	5,619	18,545	27,226	8,179	4,214	13,909	20,420	6,134
	Industrial	307	705	1,723	311	22,759	52,232	127,562	23,035	17,069	39,174	95,671	17,276
	Open	7,923	32,122	17,762	14,167	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	7,583	8,863	21,912	3,909	5,687	6,648	16,434	2,932
	Total	**12,990**	**47,954**	**41,867**	**21,149**	**35,961**	**79,640**	**176,701**	**35,123**	**26,971**	**59,730**	**132,526**	**26,342**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB52	Highway	2,800	9,242	13,569	4,076	3,049	10,065	14,776	4,439	2,287	7,549	11,082	3,329
	Industrial	0	0	0	0	10,938	25,103	61,307	11,071	8,204	18,827	45,981	8,303
	Open	4,702	19,062	10,541	8,407	0	0	0	0	0	0	0	0
	Residential	347	405	1,001	179	6,757	7,898	19,525	3,483	5,068	5,923	14,644	2,612
	Total	**7,848**	**28,709**	**25,111**	**12,661**	**20,745**	**43,066**	**95,609**	**18,993**	**15,559**	**32,300**	**71,707**	**14,245**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB53	Highway	1,385	4,572	6,712	2,016	1,217	4,016	5,895	1,771	913	3,012	4,422	1,328
	Industrial	2,058	4,722	11,532	2,083	9,851	22,608	55,213	9,970	7,388	16,956	41,410	7,478
	Open	6,572	26,645	14,734	11,751	102	412	228	182	102	412	228	182
	Residential	889	1,039	2,568	458	15,533	18,156	44,885	8,007	11,650	13,617	33,664	6,005
	Total	**10,903**	**36,978**	**35,546**	**16,308**	**26,702**	**45,191**	**106,221**	**19,930**	**20,052**	**33,997**	**79,723**	**14,993**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB54	Highway	9,895	32,658	47,946	14,403	9,615	31,734	46,591	13,996	7,211	23,801	34,943	10,497
	Industrial	553	1,268	3,098	559	6,127	14,061	34,339	6,201	4,595	10,545	25,754	4,651
	Open	5,684	23,047	12,744	10,164	4,334	17,574	9,718	7,750	4,334	17,574	9,718	7,750
	Residential	0	0	0	0	13,861	16,202	40,055	7,145	10,396	12,151	30,041	5,359
	Total	**16,132**	**56,973**	**63,788**	**25,126**	**33,938**	**79,571**	**130,702**	**35,092**	**26,537**	**64,072**	**100,456**	**28,257**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB55	Highway	728	2,403	3,528	1,060	326	1,075	1,579	474	244	806	1,184	356
	Industrial	0	0	0	0	821	1,883	4,599	830	615	1,412	3,449	623
	Open	2,020	8,190	4,529	3,612	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	5,993	7,004	17,316	3,089	4,494	5,253	12,987	2,317
	Total	**2,748**	**10,593**	**8,056**	**4,672**	**7,139**	**9,963**	**23,494**	**4,394**	**5,354**	**7,472**	**17,620**	**3,295**
	Commercial	1,637	2,103	4,067	927	236	303	586	134	236	303	586	134
BFB56	Highway	2,108	6,956	10,212	3,068	4,473	14,763	21,674	6,511	4,473	14,763	21,674	6,511
	Industrial	0	0	0	0	4,866	11,168	27,274	4,925	4,866	11,168	27,274	4,925
	Open	2,406	9,757	5,395	4,303	63	254	141	112	63	254	141	112
	Residential	4,254	4,972	12,291	2,193	8,164	9,543	23,591	4,209	8,164	9,543	23,591	4,209
	Total	**10,404**	**23,787**	**31,966**	**10,491**	**17,802**	**36,031**	**73,266**	**15,890**	**17,802**	**36,031**	**73,266**	**15,890**
	Commercial	7	9	17	4	55	70	136	31	41	53	102	23
BFB57	Highway	2,955	9,752	14,317	4,301	4,145	13,681	20,085	6,033	3,109	10,260	15,064	4,525
	Industrial	0	0	0	0	9,516	21,840	53,338	9,632	7,137	16,380	40,004	7,224
	Open	3,031	12,289	6,795	5,420	176	715	396	315	176	715	396	315
	Residential	5,675	6,633	16,398	2,925	6,768	7,911	19,558	3,489	5,076	5,933	14,669	2,617
	Total	**11,667**	**28,682**	**37,527**	**12,649**	**20,661**	**44,218**	**93,513**	**19,501**	**15,540**	**33,342**	**70,234**	**14,705**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	3,407	4,377	8,467	1,930	3,067	3,941	7,623	1,738	3,067	3,941	7,623	1,738
BFC60	Highway	8,025	26,485	38,883	11,680	9,062	29,909	43,911	13,190	9,062	29,909	43,911	13,190
	Industrial	0	0	0	0	6,445	14,791	36,124	6,523	6,445	14,791	36,124	6,523
	Open	2,083	8,446	4,670	3,725	767	3,111	1,720	1,372	767	3,111	1,720	1,372
	Residential	14,300	16,715	41,322	7,372	17,809	20,817	51,463	9,180	17,809	20,817	51,463	9,180
	Total	**27,815**	**56,023**	**93,343**	**24,707**	**37,151**	**72,569**	**140,840**	**32,004**	**37,151**	**72,569**	**140,840**	**32,004**
	Commercial	3,203	4,115	7,959	1,815	1,280	1,645	3,182	725	1,280	1,645	3,182	725
BFC61	Highway	12,368	40,820	59,929	18,002	11,650	38,450	56,450	16,957	11,650	38,450	56,450	16,957
	Industrial	0	0	0	0	3,989	9,156	22,361	4,038	3,989	9,156	22,361	4,038
	Open	**777**	3,150	1,742	1,389	306	1,241	686	547	306	1,241	686	547
	Residential	16,663	19,476	48,149	8,589	17,131	20,024	49,503	8,831	17,131	20,024	49,503	8,831
	Total	**33,010**	**67,560**	**117,779**	**29,795**	**34,357**	**70,515**	**132,181**	**31,099**	**34,357**	**70,515**	**132,181**	**31,099**
	Commercial	1,819	2,338	4,521	1,031	7,903	10,153	19,639	4,478	5,927	7,615	14,729	3,358
BFD70	Highway	4,910	16,205	23,791	7,147	6,186	20,417	29,975	9,004	4,640	15,313	22,481	6,753
	Industrial	440	1,010	2,466	445	1,492	3,424	8,362	1,510	1,119	2,568	6,271	1,132
	Open	3,578	14,506	8,021	6,397	700	2,837	1,569	1,251	700	2,837	1,569	1,251
	Residential	4,276	4,998	12,356	2,204	6,725	7,860	19,432	3,466	5,044	5,895	14,574	2,600
	Total	**15,023**	**39,056**	**51,156**	**17,224**	**23,005**	**44,692**	**78,977**	**19,710**	**17,429**	**34,228**	**59,625**	**15,095**
	Commercial	1,910	2,454	4,746	1,082	4,968	6,382	12,345	2,815	4,968	6,382	12,345	2,815
BFD71	Highway	8,656	28,567	41,941	12,599	9,015	29,755	43,684	13,122	9,015	29,755	43,684	13,122
	Industrial	66	151	368	66	387	888	2,169	392	387	888	2,169	392
	Open	3,090	12,527	6,927	5,525	649	2,630	1,455	1,160	649	2,630	1,455	1,160
	Residential	9,068	10,599	26,203	4,674	13,762	16,085	39,766	7,094	13,762	16,085	39,766	7,094
	Total	**22,789**	**54,297**	**80,184**	**23,946**	**28,780**	**55,741**	**99,419**	**24,583**	**28,780**	**55,741**	**99,419**	**24,583**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	142	182	352	80	1,664	2,138	4,135	943	1,664	2,138	4,135	943
BFD72	Highway	10,098	33,329	48,931	14,699	9,224	30,442	44,693	13,425	9,224	30,442	44,693	13,425
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,104	4,475	2,475	1,974	670	2,718	1,503	1,199	670	2,718	1,503	1,199
	Residential	14,738	17,226	42,587	7,597	15,288	17,869	44,176	7,881	15,288	17,869	44,176	7,881
	Total	**26,081**	**55,212**	**94,344**	**24,349**	**26,846**	**53,167**	**94,507**	**23,448**	**26,846**	**53,167**	**94,507**	**23,448**
	Commercial	513	659	1,275	291	1,116	1,434	2,773	632	1,116	1,434	2,773	632
BFD73	Highway	7,137	23,554	34,580	10,388	6,187	20,419	29,978	9,005	6,187	20,419	29,978	9,005
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	533	2,160	1,195	953	407	1,650	913	728	407	1,650	913	728
	Residential	9,663	11,294	27,922	4,981	10,061	11,760	29,074	5,187	10,061	11,760	29,074	5,187
	Total	**17,845**	**37,667**	**64,972**	**16,612**	**17,771**	**35,264**	**62,738**	**15,552**	**17,771**	**35,264**	**62,738**	**15,552**
	Commercial	3,341	4,293	8,304	1,893	5,189	6,667	12,895	2,940	5,189	6,667	12,895	2,940
BFD74	Highway	8,000	26,403	38,763	11,644	6,697	22,102	32,449	9,748	6,697	22,102	32,449	9,748
	Industrial	649	1,489	3,637	657	670	1,538	3,757	678	670	1,538	3,757	678
	Open	587	2,379	1,316	1,049	250	1,015	561	448	250	1,015	561	448
	Residential	8,379	9,793	24,212	4,319	8,560	10,005	24,734	4,412	8,560	10,005	24,734	4,412
	Total	**20,956**	**44,358**	**76,231**	**19,563**	**21,366**	**41,328**	**74,397**	**18,226**	**21,366**	**41,328**	**74,397**	**18,226**
	Commercial	35	45	87	20	1,147	1,474	2,851	650	1,147	1,474	2,851	650
BFD75	Highway	4,163	13,739	20,171	6,059	2,632	8,686	12,752	3,831	2,632	8,686	12,752	3,831
	Industrial	1,271	2,916	7,122	1,286	1,028	2,360	5,763	1,041	1,028	2,360	5,763	1,041
	Open	1,919	7,782	4,303	3,432	1,589	6,444	3,563	2,842	1,589	6,444	3,563	2,842
	Residential	2,889	3,377	8,348	1,489	4,000	4,675	11,558	2,062	4,000	4,675	11,558	2,062
	Total	**10,277**	**27,858**	**40,030**	**12,286**	**10,396**	**23,639**	**36,487**	**10,425**	**10,396**	**23,639**	**36,487**	**10,425**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	861	1,106	2,140	488	1,558	2,002	3,873	883	1,558	2,002	3,873	883
BFD76	Highway	5,027	16,593	24,361	7,318	4,173	13,772	20,219	6,074	4,173	13,772	20,219	6,074
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	455	1,847	1,021	814	321	1,301	719	574	321	1,301	719	574
	Residential	6,721	7,856	19,422	3,465	7,015	8,200	20,272	3,616	7,015	8,200	20,272	3,616
	Total	**13,065**	**27,402**	**46,944**	**12,085**	**13,067**	**25,275**	**45,083**	**11,147**	**13,067**	**25,275**	**45,083**	**11,147**
	Commercial	237	304	588	134	2,388	3,068	5,933	1,353	2,388	3,068	5,933	1,353
BFD77	Highway	4,484	14,800	21,729	6,527	3,020	9,969	14,636	4,396	3,020	9,969	14,636	4,396
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,307	5,301	2,931	2,338	780	3,164	1,749	1,395	780	3,164	1,749	1,395
	Residential	1,428	1,670	4,127	736	2,058	2,405	5,947	1,061	2,058	2,405	5,947	1,061
	Total	**7,457**	**22,075**	**29,376**	**9,735**	**8,246**	**18,606**	**28,265**	**8,206**	**8,246**	**18,606**	**28,265**	**8,206**
	Commercial	62	79	153	35	545	700	1,354	309	409	525	1,016	232
WC10	Highway	1,448	4,780	7,018	2,108	3,185	10,511	15,432	4,636	2,389	7,883	11,574	3,477
	Industrial	785	1,803	4,403	795	9,695	22,250	54,340	9,813	7,271	16,688	40,755	7,360
	Open	5,684	23,046	12,743	10,164	64	261	144	115	64	261	144	115
	Residential	0	0	0	0	9,655	11,285	27,900	4,977	7,241	8,464	20,925	3,733
	Total	**7,979**	**29,707**	**24,317**	**13,102**	**23,144**	**45,008**	**99,171**	**19,850**	**17,374**	**33,821**	**74,414**	**14,916**
	Commercial	0	0	0	0	13	17	33	8	10	13	25	6
WC11	Highway	647	2,134	3,133	941	2,227	7,351	10,792	3,242	1,670	5,513	8,094	2,431
	Industrial	31	71	174	31	1,038	2,382	5,817	1,050	778	1,786	4,363	788
	Open	4,895	19,845	10,974	8,752	235	951	526	419	235	951	526	419
	Residential	532	622	1,538	274	13,669	15,977	39,497	7,046	10,251	11,982	29,623	5,284
	Total	**6,104**	**22,672**	**15,818**	**9,999**	**17,182**	**26,678**	**56,666**	**11,765**	**12,945**	**20,246**	**42,631**	**8,929**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	2	3	6	1	2	2	4	1
WC12	Highway	885	2,919	4,286	1,288	1,858	6,131	9,001	2,704	1,393	4,598	6,751	2,028
	Industrial	0	0	0	0	5,584	12,815	31,298	5,652	4,188	9,611	23,473	4,239
	Open	6,910	28,015	15,491	12,355	208	845	467	373	208	845	467	373
	Residential	471	551	1,362	243	16,918	19,775	48,887	8,721	12,689	14,831	36,666	6,541
	Total	**8,265**	**31,485**	**21,139**	**13,886**	**24,570**	**39,569**	**89,659**	**17,451**	**18,480**	**29,888**	**67,361**	**13,181**
	Commercial	0	0	0	0	15	19	37	8	11	14	28	6
WC13	Highway	1,916	6,325	9,286	2,789	2,972	9,810	14,402	4,326	2,229	7,357	10,802	3,245
	Industrial	390	895	2,186	395	19,423	44,576	108,866	19,659	14,567	33,432	81,649	14,744
	Open	5,526	22,405	12,389	9,881	55	222	123	98	55	222	123	98
	Residential	0	0	0	0	2,216	2,591	6,404	1,142	1,662	1,943	4,803	857
	Total	**7,832**	**29,625**	**23,861**	**13,065**	**24,681**	**57,217**	**129,832**	**25,234**	**18,525**	**42,969**	**97,404**	**18,950**
	Commercial	39	50	96	22	59	76	146	33	44	57	110	25
WC14	Highway	182	601	882	265	2,288	7,552	11,087	3,331	1,716	5,664	8,316	2,498
	Industrial	0	0	0	0	3,132	7,188	17,554	3,170	2,349	5,391	13,166	2,377
	Open	3,835	15,551	8,599	6,858	621	2,518	1,393	1,111	621	2,518	1,393	1,111
	Residential	1,013	1,184	2,928	522	8,599	10,051	24,848	4,433	6,449	7,538	18,636	3,325
	Total	**5,069**	**17,385**	**12,505**	**7,667**	**14,699**	**27,385**	**55,029**	**12,077**	**11,180**	**21,168**	**41,620**	**9,336**
	Commercial	1,805	2,319	4,486	1,023	1,911	2,455	4,749	1,083	1,433	1,841	3,562	812
WC15	Highway	996	3,289	4,828	1,450	5,845	19,293	28,324	8,508	4,384	14,469	21,243	6,381
	Industrial	0	0	0	0	3,750	8,607	21,019	3,796	2,813	6,455	15,765	2,847
	Open	8,186	33,190	18,353	14,637	1,648	6,682	3,695	2,947	1,648	6,682	3,695	2,947
	Residential	1,266	1,479	3,658	652	18,818	21,995	54,377	9,700	14,113	16,496	40,782	7,275
	Total	**12,253**	**40,277**	**31,324**	**17,763**	**31,973**	**59,032**	**112,164**	**26,034**	**24,391**	**45,945**	**85,047**	**20,262**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	35	44	86	20	476	612	1,183	270	357	459	888	202
WC16	Highway	2,127	7,021	10,308	3,097	1,610	5,315	7,803	2,344	1,208	3,986	5,853	1,758
	Industrial	3,963	9,096	22,215	4,012	7,633	17,518	42,782	7,726	5,725	13,138	32,087	5,794
	Open	3,411	13,829	7,647	6,099	99	403	223	178	99	403	223	178
	Residential	623	728	1,801	321	8,259	9,653	23,865	4,257	6,194	7,240	17,898	3,193
	Total	**10,159**	**30,719**	**42,057**	**13,548**	**18,078**	**33,501**	**75,856**	**14,774**	**13,583**	**25,226**	**56,948**	**11,125**
	Commercial	15	20	38	9	1,345	1,729	3,344	762	1,009	1,296	2,508	572
WC17	Highway	1,941	6,407	9,406	2,825	3,385	11,173	16,403	4,927	2,539	8,379	12,302	3,696
	Industrial	1,587	3,643	8,898	1,607	16,925	38,842	94,861	17,130	12,693	29,131	71,146	12,848
	Open	8,099	32,837	18,158	14,482	839	3,402	1,881	1,500	839	3,402	1,881	1,500
	Residential	586	685	1,692	302	9,959	11,640	28,777	5,133	7,469	8,730	21,583	3,850
	Total	**12,229**	**43,592**	**38,192**	**19,225**	**32,453**	**66,785**	**145,265**	**29,453**	**24,549**	**50,939**	**109,419**	**22,465**
	Commercial	0	0	0	0	16	20	39	9	12	15	29	7
WC18	Highway	735	2,426	3,562	1,070	5,246	17,315	25,421	7,636	3,935	12,986	19,066	5,727
	Industrial	0	0	0	0	1,261	2,893	7,065	1,276	945	2,170	5,299	957
	Open	5,124	20,774	11,487	9,162	1,039	4,212	2,329	1,858	1,039	4,212	2,329	1,858
	Residential	5,811	6,792	16,791	2,995	15,428	18,033	44,581	7,953	11,571	13,525	33,436	5,965
	Total	**11,670**	**29,992**	**31,841**	**13,227**	**22,989**	**42,473**	**79,436**	**18,731**	**17,502**	**32,908**	**60,159**	**14,513**
	Commercial	700	899	1,739	397	50	64	124	28	50	64	124	28
WC19	Highway	6,816	22,495	33,026	9,921	9,959	32,868	48,255	14,495	9,959	32,868	48,255	14,495
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	2,365	9,588	5,302	4,228	933	3,783	2,092	1,668	933	3,783	2,092	1,668
	Residential	13,280	15,523	38,376	6,846	16,674	19,489	48,182	8,595	16,674	19,489	48,182	8,595
	Total	**23,161**	**48,505**	**78,442**	**21,391**	**27,616**	**56,204**	**98,653**	**24,787**	**27,616**	**56,204**	**98,653**	**24,787**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	1,126	1,447	2,799	638	1,495	1,921	3,715	847	1,495	1,921	3,715	847
WC20	Highway	3,367	11,114	16,317	4,902	7,479	24,683	36,238	10,886	7,479	24,683	36,238	10,886
	Industrial	1,113	2,554	6,238	1,126	1,499	3,441	8,404	1,518	1,499	3,441	8,404	1,518
	Open	3,509	14,227	7,867	6,274	952	3,860	2,134	1,702	952	3,860	2,134	1,702
	Residential	7,284	8,513	21,047	3,755	12,558	14,679	36,289	6,474	12,558	14,679	36,289	6,474
	Total	**16,399**	**37,855**	**54,267**	**16,695**	**23,983**	**48,583**	**86,780**	**21,426**	**23,983**	**48,583**	**86,780**	**21,426**
	Commercial	2,288	2,940	5,686	1,296	6,143	7,893	15,266	3,481	6,143	7,893	15,266	3,481
WC21	Highway	8,551	28,221	41,433	12,446	8,622	28,457	41,780	12,550	8,622	28,457	41,780	12,550
	Industrial	624	1,433	3,499	632	0	0	0	0	0	0	0	0
	Open	2,382	9,657	5,340	4,259	2,084	8,449	4,672	3,726	2,084	8,449	4,672	3,726
	Residential	11,492	13,432	33,208	5,924	9,593	11,213	27,720	4,945	9,593	11,213	27,720	4,945
	Total	**25,337**	**55,683**	**89,166**	**24,557**	**26,442**	**56,011**	**89,438**	**24,702**	**26,442**	**56,011**	**89,438**	**24,702**
	TOTAL WATERSHED	**935,230**	**2,504,454**	**3,148,510**	**1,104,361**	**1,536,896**	**2,916,779**	**5,655,309**	**1,286,205**	**1,311,525**	**2,515,762**	**4,777,553**	**1,109,387**

Appendix D – Streambank Protection Analysis

Channel erosion is effected by such factors as flow regime, climate, and types of channel beds and bank material. Within a specific stream reach, change in flow rate can be considered to be the determining factor when comparing erosion losses subject to different flow conditions. The channel erosion concepts presented in the technical paper *Erodibility of Urban Bedrock and Alluvial Channels, North Texas* (Allen, Peter M., et.al. Journal of The American Water Resources Association, Vol.38, No. 5, October 2002) were used to quantify the degree of potential channel erosion in the study portion of Big Fossil Creek for future conditions *without* and *with* iSWM design criteria.

The technical paper found that approximately 75 percent of channels in North Texas basins have alluvial banks with gravel or rock bottoms and the active channel width and depth could be determined through regression analysis. From the extensive field survey results, regression equations were developed to determine the active channel width (ACW) and active channel depth (ACD) based on the flow rate of the channel. These relationships are as follows:

$$ACW = 1.28 * Q^{0.48} \quad , \quad R^2 = 0.83$$
$$ACD = 0.208 * Q^{0.44} \quad , \quad R^2 = 0.91$$

(R= regression coefficient, Q expressed as 1-year event)

To determine the relative effects of future conditions *without* iSWM and future conditions *with* iSWM scenarios on erosion losses of the channel, two cross section locations along the main stem of Big Fossil Creek within the hydraulic study area were selected (See Figure D-1). Cross Section location 1 is located 500 feet upstream of Glenview Drive. Cross Section location 2 is located approximately 1700 feet upstream of Haltom Road. Figures D-2 and D-3 were obtained during field visits to Cross Section 1 and 2, respectively. The bed and bank materials show a dominance of gravel bed and alluvial channel bank. Figure D-3 shows existing channel erosion.

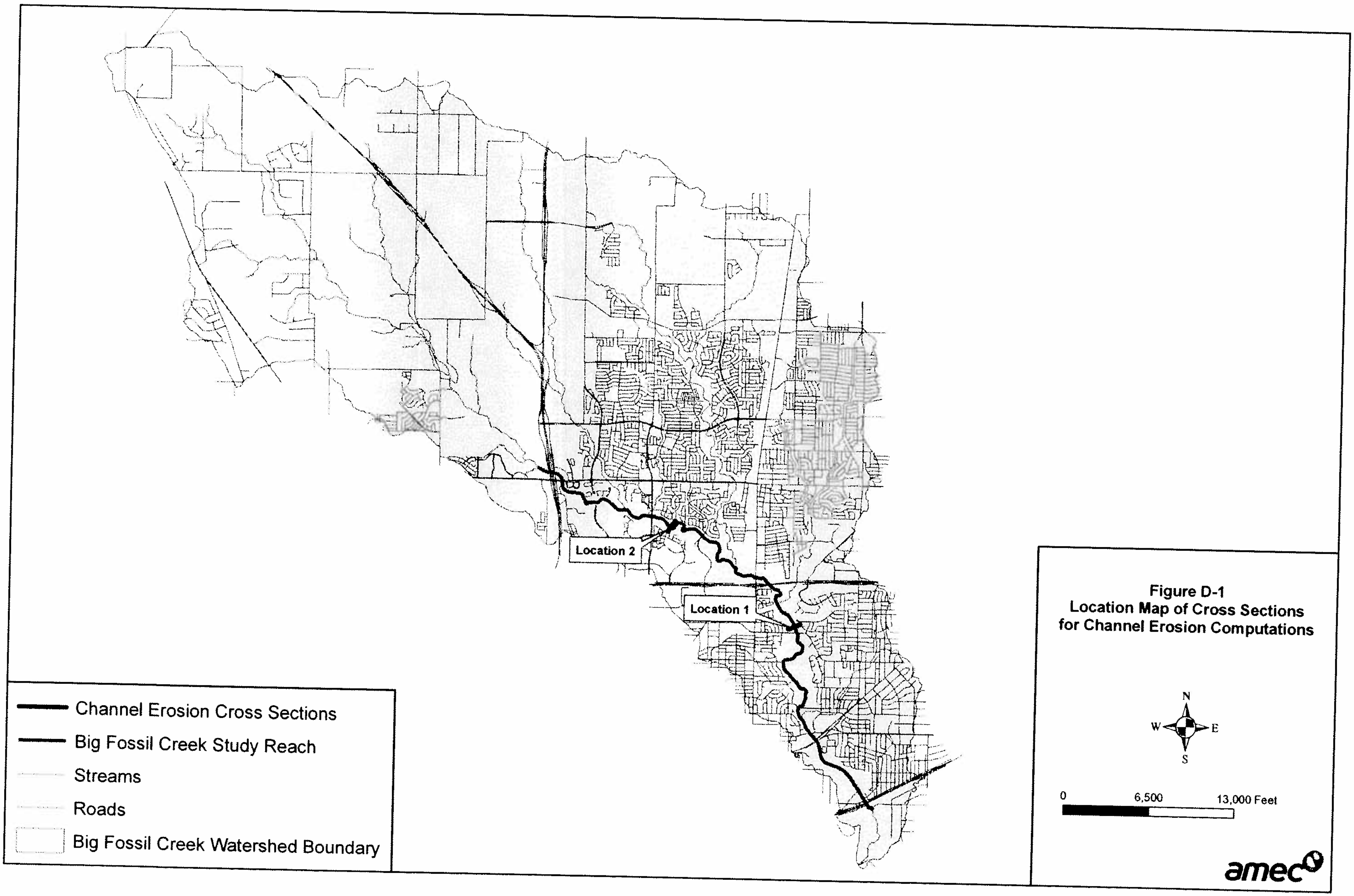

Location 2
Location 1
Channel Erosion Cross Sections
Big Fossil Creek Study Reach
Streams
Roads
Big Fossil Creek Watershed Boundary
Figure D-1
Location Map of Cross Sections
for Channel Erosion Computations
N
W
E
S
0
6,500
13,000 Feet
amec

Figure D-2. Cross Section location 1 - 500 feet upstream of Glenview Drive

Figure D-3. Cross Section location 2 - 1,700 feet upstream of Haltom Road

The drainage area and corresponding frequency discharges for the 1-year storm event for the three watershed scenarios, at each cross section location, were determined from the hydrologic analysis. The cross sections were located in the field and photographed and the channel sections in the available hydraulic models were identified. The regression equations outlined above were used to calculate active channel width (ACW) and active channel depth (ACD) for the three watershed scenarios. Results of the analysis are presented in Table D-1.

Table D-1. Potential Channel Erosion for Future, and Future-iSWM condition

Description	Parameters	1-Yr Event Future	1-Yr Event Future-iSWM
Location 1 Drainage Area, 50.63 (mi^2)	Discharge (cfs)	8,765	5,034
	Active channel Width (ft)	99.9	76.6
	Active Channel Depth (ft)	11.3	8.8
	Area of Channel (ft^2)	1129	678
Location 2 Drainage Area, 31.77 (mi^2)	Discharge (cfs)	5,798	2,564
	Active channel Width (ft)	82.0	55.4
	Active Channel Depth (ft)	9.4	6.6
	Area of Channel (ft^2)	772	364

Channel Impact Model Results

The data from the analysis in Table D-1 can be used to quantify the potential increase in channel erosion in the study reach. It is clear that applying iSWM design criteria would mitigate the potential for channel erosion, since the model shows that the active channel size without iSWM conditions is significantly greater than the active channel size with application of iSWM design criteria. However, if iSWM design criteria are not applied, the potential for erosion in the study area is significant. Assuming cross section locations 1 and 2 are typical of the 4.75 miles of the upper and lower portion of the study reach (total study reach length of 9.5 miles), and the channel sections could be represented accurately for this calculation as a rectangles, the potential increase in channel erosion under future conditions without iSWM compared to future conditions with iSWM is equal to 797,916 cu yards of material, or 83,991 cu yards per linear mile of stream.

APPENDIX H

Trend Analysis of Air & Water Quality in the Big Fossil Creek Watershed

A Trend Analysis of Air and Water Quality

In the Big Fossil Creek Watershed

July 2002

North Central Texas Council of Governments

Introduction to Air Quality

The Big Fossil Creek watershed, located in northern Tarrant County in the heart of the Dallas-Fort Worth Metroplex, encompasses nearly 37,000 acres and drains into the West Fork of the Trinity River. The watershed is one of the fastest growing urban areas in the country. The entire downstream half of the watershed is almost fully developed, and similar growth is anticipated for the upper half of the watershed in the coming years. Because urbanization in the lower half of the watershed over the last few decades has produced great expanses of sprawling single-family residential developments, it has undoubtedly contributed to a significant share of the region's transportation-related air quality problems. With urbanization expected to continue into the upper portion of the watershed, conditions such as a growing population and an expanding road network may exacerbate the region's air quality problems. Working from the notion that "however the region goes, so go all the parts of it," this report presents the historical and current air quality conditions of the Big Fossil Creek watershed vis-à-vis air quality conditions throughout the entire DFW region.

Clean Air Act

With passage of the 1990 Clean Air Act Amendments (CAAA) the Dallas-Fort Worth region was classified as a "moderate nonattainment" area for ozone. The area receiving the classification was Collin, Dallas, Denton, and Tarrant counties collectively. The U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) for six air pollutants: ozone, lead, carbon monoxide, sulfur dioxide, nitrogen dioxide, and respirable particulate matter. The Dallas Fort Worth region is in attainment for all these pollutants except ozone. Compliance with the CAAA required no more than 3 exceedances of the one-hour average of 125 ppb at any single monitoring station over a 3-year period by 1996. The DFW region did not achieve attainment before 1996, with six of its eight monitoring stations recording exceedances in the 1994 – 1996 monitoring period, and was then reclassified as "serious nonattainment" (see Figure 1). Reclassification meant that the region was required to develop a demonstration of attainment State Implementation Plan (SIP) for submittal to the EPA by 2000.

Ozone

For the DFW area, weather and on-road transportation are the two largest factors determining whether a monitoring station will exceed the one hour standard. Because ozone forms when volatile organic compounds and nitrogen oxides mix with sunlight, weather conditions such as clouds, wind and rain affect where, when and if ozone forms. Wind plays an important role, with calm winds favoring the concentration of ozone, and light winds that can carry a base level of ozone into the region. In 2001, the Dallas-Fort Worth area enjoyed a relatively mild, wet summer, which is considered to account for much of the reduction in the ground-level ozone concentrations for the year. Additionally, the entire state recorded low levels of ozone transported by wind from surrounding states, and this also contributed to the lower concentrations.

According to 1996 base line measurements, transportation in the DFW area accounts for at least 50% of the nitrogen oxides (NOx) that are generated annually (see Figure 2). Area and non-road sources are the next largest contributor, at about 23%. Reduction in NOx emissions is the primary method for control of ozone generation spelled out in the SIP, with volatile organics controlled to a lesser degree. One reason for this strategy is that the volume of plant life in the region contributes a significant amount of biogenic volatile organics to the atmosphere, requiring larger reductions in man made volatile organics to achieve significant reductions.

Areas of the country that are currently in attainment are required to meet the eight hour NAAQS of 85 ppb for ozone. The DFW area will continue to be measured against the one-hour standard until the goals of the current SIP are met. Once the SIP goals are met, then the eight-hour standard will apply.

NAAQS

The National Ambient Air Quality Standard for Ozone

Air Pollution Concentrations Required to Exceed the NAAQS

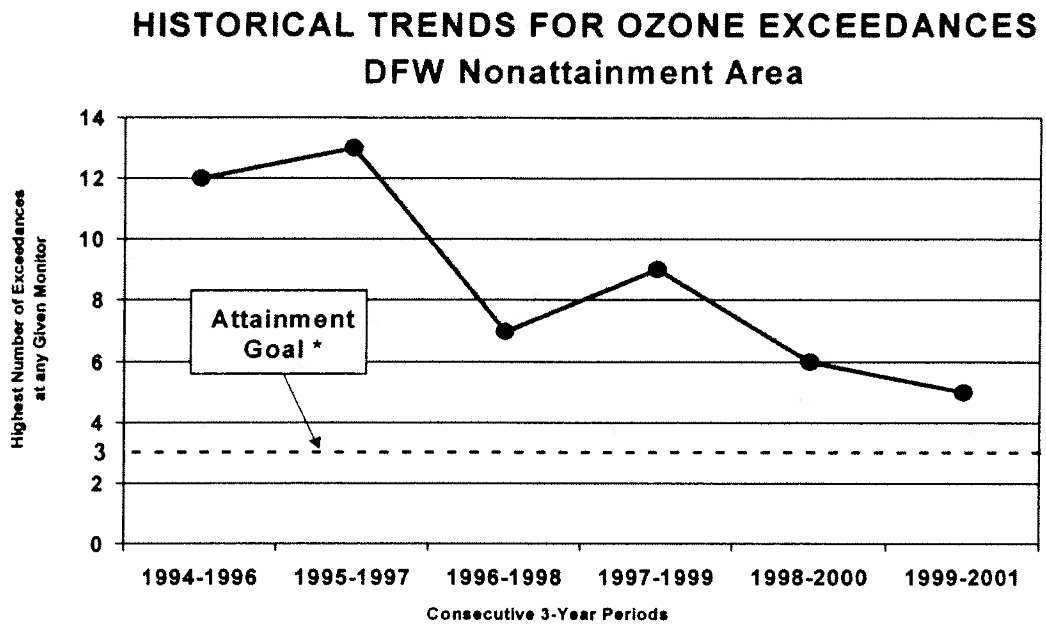
Standard	Primary NAAQS	Secondary NAAQS	Primary NAAQS
1-hr	Not to be at or above this level on more than three days over three years at any single monitoring point.	125 ppb	125 ppb
8-hr	The average of the annual fourth highest daily eight-hour maximum over a three-year period is not to be at or above this level.	85 ppb	85 ppb
Annual	The three-year average of annual arithmetic mean concentrations at each monitor within an area is not to be at or above this level.	51 $\mu g/m^3$	51 $\mu g/m^3$

STATE IMPLEMENTATION PLAN

EPA requires that a serious nonattainment area prepare a State Implementation Plan (SIP) containing a schedule to come into attainment. The DFW area SIP is a plan prepared by the TNRCC cooperatively with a locally developed steering committee. It specifically describes targets, plans, and control strategies calculated to achieve NAAQS for the region.

The control strategies section of the SIP is dynamic and has been modified several times since the SIP was initially sent to the EPA for approval in 2000. Modifications consist of removing control measures or adding new ones. Each of the controls in the SIP must provide a calculated reduction in ozone formation, and the total reduction contained in the SIP must provide a 44% reduction in NOx from 1996 levels by 2007. Therefore, as a control measure is removed, one of equal NOx reduction must replace it. Many of the control methods are controversial in that they restrict activities of the business community and the public. An example of a control proposed in the original SIP and later replaced was the construction operation time shift, which was to ban operation of construction equipment between 6:00 a.m. and 10:00 a.m. from June 1 to October 31. This measure was removed and replaced by the 77th Texas Legislature in 2001. The replacement measure was a combination of methods based on economic incentives that included reductions from the public transpiration sector, large off road diesel engine operations, on road diesel fuel controls, and residential and commercial building efficiency management.

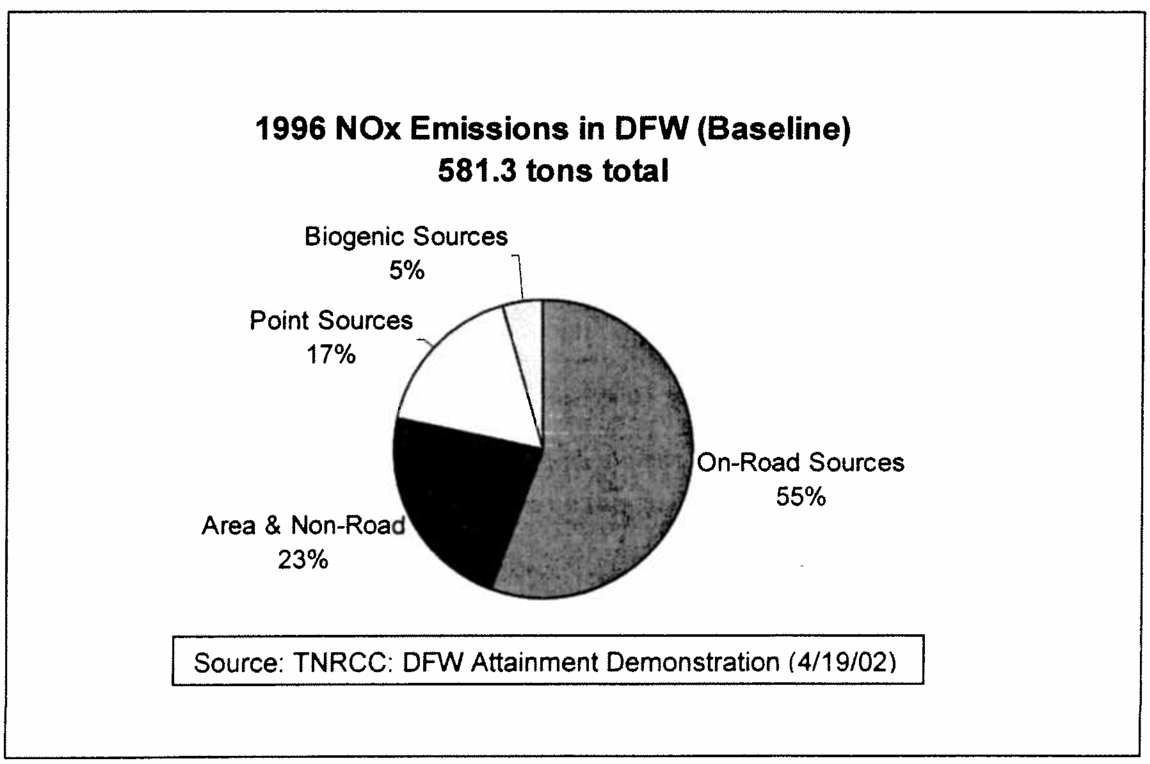
Figure 1



*Attainment Goal - According to the US EPA National Ambient Air Quality Standards, attainment is reached when there are no more than 3 exceedances per monitor within a consecutive 3-year period.

Source NCTCOG Transportation Dept – October 2001

Figure 2



MONITORING

Air Quality Monitoring Stations in the northeast Tarrant County area **(see map in Appendix)**

Station Keller C17

- EPA site number: 48-439-2003
- Address: Alta Vista Rd.
- City: Fort Worth
- County: Tarrant
- Site coordinates:
  - Latitude: 32° 55' 21" North (32.922500°)
  - Longitude: 97° 16' 55" West (97.281944°)
  - Elevation: 232 m (761 ft)
- Maintained by: City of Fort Worth for the TNRCC
- Real-time monitoring since: Wednesday, July 16, 1997
- Current status: Active
- Parameters currently being monitored:
  - Pollution parameters:
    - Ozone
  - Meteorological parameters:
    - Wind Speed
    - Resultant Wind Speed
    - Resultant Wind Direction
    - Maximum Wind Gust
    - Standard Deviation of Horizontal Wind Direction
    - Outdoor Temperature
    - Solar Radiation

Station Ft. Worth Northwest C13

- EPA site number: 48-439-1002
- Address: 3317 Ross Ave
- City: Fort Worth
- County: Tarrant
- Site coordinates:
  - Latitude: 32° 48' 21" North (32.805833°)
  - Longitude: 97° 21' 24" West (97.356667°)
  - Elevation: 189 m (620 ft)
- Maintained by: TNRCC DFW Regional Office
- Real-time monitoring since: Tuesday, August 12, 1997
- Current status: Active
- Parameters currently being monitored:
  - Pollution parameters:
    - Carbon Monoxide
    - Nitric Oxide
    - Nitrogen Dioxide
    - Oxides of Nitrogen
    - Ozone
  - Meteorological parameters:
    - Wind Speed
    - Resultant Wind Speed
    - Resultant Wind Direction
    - Maximum Wind Gust
    - Standard Deviation of Horizontal Wind Direction
    - Outdoor Temperature
    - Dew Point Temperature
    - Relative Humidity
    - Solar Radiation

Number of Ozone Exceedances near the Big Fossil Creek Watershed: 1994-2001
(An ozone level of 125 parts per billion or greater is an exceedance of the ozone standard)

	Keller C17	Fort Worth Northwest C13
1994	7	0
1995	3	2
1996	2	2
1997	0	2
1998	2	1
1999	4	3
2000	0	0
2001	1	2

Source: TNRCC

Introduction to Water Quality

With its watershed encompassing nearly 37,000 acres in northern Tarrant County, Big Fossil Creek is a major tributary of the West Fork of the Trinity River. Located in the heart of the Dallas-Fort Worth Metroplex, the Big Fossil Creek watershed is experiencing one of the highest rates of urbanization in the country. The entire downstream half of the watershed is almost fully developed, and similar growth is anticipated for the upper half of the watershed in the coming years.

As the headwaters experience increasing development, downstream communities face a growing risk of deteriorating environmental quality, especially in terms of water quality. This report presents an assessment of the general historical trends in water quality for the Big Fossil Creek watershed by analyzing both the conditions in the watershed as well as by extrapolating conditions from the larger West Trinity Forks watershed.

Physical and Geographic Characteristics

Based on NCTCOG water quality information, the Big Fossil Creek watershed is one of fourteen subwatersheds that drain into the West Trinity Forks watershed. Out of these fourteen subwatersheds, the Big Fossil Creek watershed (36,941 acres) comprises the largest percentage of land area (20%) within the West Trinity Forks watershed (188,658 acres). The West Trinity Forks watershed contains State stream segment 0806 (a 33 mile stretch of the West Fork of the Trinity River below Lake Worth from a point immediately upstream of the confluence of Village Creek in Tarrant County to Lake Worth Dam in Tarrant County).

Regional Watershed Perspective

Within a regional context, Big Fossil Creek is an important regional resource that affects the overall public health, safety, welfare, and quality of life of all residents in the North Central Texas region. Of the 54.1 miles of streams that make up the Big Fossil Creek watershed, the North Central Texas Council of Governments has identified 40.4 miles as Regional Environmental Corridors. In other words, Regional Environmental Corridors make up approximately 74% of all drainages presently identified in the Big Fossil Creek watershed. Regional Environmental Corridors are the focus of NCTCOG's initiative to work with local governments and others in the region to establish a vision of success for watershed management whereby the values of the Trinity River COMMON VISION program are adopted in the Mainstem, East Fork, West Fork, and Elm Fork watersheds of the MPA-Trinity. This vision has taken the shape of a broad **Sustainable Environmental Excellence (SEE)** initiative that, among other things, aims to translate the Trinity River COMMON VISION values of safe, clean, enjoyable, natural, & diverse into **SAFE CLEAN & GREEN**. For the purpose of the ***SEE SAFE CLEAN & GREEN Initiative***, regional environmental corridors are those corridors that meet any one of the following criteria:

- stream segments or water bodies that are multi-jurisdictional (segments that traverse more that one government entity within the MPA - Trinity),
- state designated stream segments (including reservoirs), or
- ecologically significant stream segments identified by the state.

The major surface waters of the state are classified as segments for purposes of water quality management and designation of site-specific standards. Stream segments designated by the state for site-specific standards are selected for recognition as regional environmental corridors.

The SEE vision can be summarized as **Safe** corridors where flooding risk is reduced, **Clean** corridors where water quality meets or exceeds state standards, and **Green** corridors where greenways are connected for ecological benefits, recreational and mobility opportunities. NCTCOG's new strategic plan lays the foundation to achieve the **SEE** vision through a series of long-term objectives and short-term action recommendations to be undertaken beginning in 2003 to 2007. This initiative includes more than 2,400 miles of stream corridors that meet the definition of "regional" and will require the participation of more than 115 local governments as well as many state and federal partners to fulfill this vision. Individual goals can only be achieved through cooperative management and a comprehensive approach addressing flood damage reduction, recreation, and environmental quality in the Big Fossil Creek watershed. With 74% of the corridors in the Big Fossil Creek watershed having been identified by NCTCOG as "regional," the nine local governments in the Interim Feasibility Study will have to undertake substantial cooperative roles in implementing the **SEE SAFE CLEAN & GREEN** objectives and action recommendations.

POINT SOURCES

There are no wastewater treatment facilities which discharge to the West Trinity Forks watershed or to the Big Fossil Creek watershed. All flows generated from the 6 State permitted wastewater facilities in the West Trinity Forks watershed are transported to another watershed for treatment and discharge. However, according to EPA's water discharge permits database (PCS), there are 2 non-municipal permitted facilities that discharge to the Big Fossil Creek watershed. The US Bureau of Engraving and Printing facility, located at 9000 Blue Mound Road in Fort Worth, holds National Pollution Discharge Elimination System (NPDES) permit TXR00F900, which allows the discharge of storm water associated with industrial activity; and the Redi-Mix LP facility, located at 5517 Denton Highway in Haltom City, holds NPDES permit TXG110157, which allows the discharge of facility wastewater and contact storm water from ready-mixed concrete plants. For this permit, Big Fossil Creek is listed as the receiving water body.

NONPOINT SOURCES

Historical nationwide water quality summaries have long suggested that over 40 percent of the nation's assessed water bodies are being impaired by nonpoint source pollution, particularly during storm events. Nonpoint source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and coastal waters, including underground sources of drinking water. These pollutants include: excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks; bacteria and nutrients from livestock, pet wastes, and faulty septic systems.

STORM WATER POLLUTION MANAGEMENT

Storm water runoff is one of the leading threats to public health and the environment today. In an effort to address these concerns, the Environmental Protection Agency (EPA) issued NPDES (Nationwide Pollution Discharge Elimination System) Phase I rules (1990) to address storm water discharges from large and medium (>100,00 population) municipal separate storm sewer systems (MS4), and Phase II rules for small MS4s (<100,000 in urbanized areas). These rules place all MS4s in urbanized areas as defined by the latest census under permit coverage affecting almost 60 cities and counties in North Central Texas (1990 census). Under the Phase II rules, affected small Municipal Storm Sewer Systems (MS4s) will be required to obtain permits by March 2003 and will have the initial five-year permit term to develop and implement management programs aimed at reducing urban storm water impacts to local streams and water bodies. Fort Worth is the only city in this watershed operating under a Phase I storm water permit, which requires pollution prevention activities aimed at curbing nonpoint source pollution. The following Phase II cities (per 1990 census) in the Big Fossil Creek watershed will be required to implement pollution prevention measures as part of the permit requirement: Haltom City, Keller, North Richland Hills, Richland Hills, Saginaw, Watauga and Tarrant County. For over a decade, NCTCOG has been assisting regulated local governments through its Regional Storm Water Management Program in order to educate local governments on the storm water regulatory requirements as well as to identify cooperative management opportunities aimed at improving local water quality.

Residential and Commercial Runoff

A primary element of the NPDES Phase I storm water permit applications is the characterization of storm water quality for specific land use categories. The U.S.

Geological Survey was engaged to monitor wet-weather storm water discharges from 30 regional monitoring sites. The goal of the wet-weather monitoring program was to provide data on storm water quality to characterize typical runoff quality from residential, commercial and industrial land use cover. The final set of monitoring sites included 11 residential, 6 commercial, and 9 industrial basins plus 4 highway sites. Of the 186 constituents which were sampled for, 86 have not been detected in any of the storm water samples to date. Of the remaining 100 constituents, only 48 have been detected in 10 percent of more of the samples. As part of the regional program, an extensive effort has been made to determine what water quality parameters have been reported to cause "problems" or "concerns" in streams in the Dallas-Fort Worth area.

The results of these investigations have been reported in three technical reports and a final analysis document. In order to determine the priority of storm water quality concerns, the following key factors were considered: 1) which constituents have been detected most frequently; 2) which constituents have State of Texas Water Quality Standards numerical criteria for surface water (not storm water); 3) which constituents have occasionally exceeded the most stringent water quality standards for surface water (not storm water), and 4) which constituents have been reported as being potential water quality problems in the upper Trinity River and its tributaries. Based on these factors, the constituents were rated as being of high, medium or low priority concern. Based upon these ratings, and on an individual city's local priorities, the sampling parameters for continuing studies can be targeted by the cities as they develop their local management programs.

In assigning priorities, constituents which were detected in more than 10 percent of the samples were rated as either "medium" or "high" priority. If these constituents also had a "yes" for all three other factors, they were judged to be of "high" priority. If a dissolved metal was judged to be of "high" priority, then the total metal was also rated as "high". Diazinon was judged to be of "high" priority because of known high local interest in this pesticide. Constituents occurring in less than 10 percent of the samples were rated as "medium" if they also met at least two of the three key factors; otherwise they were given a "low" priority rating. These criteria were reviewed by the Storm Water Quality Subcommittee and the Regional Storm Water Task Force.

The high priority constituents of local concern in the Dallas-Fort Worth region are:

STORM WATER CONSTITUENTS OF LOCAL CONCERN HIGH Priority	
Metals	**Others**
Cadmium (R)	Chlordane
Chromium	Diazinon
Copper (R)	Fecal coliform
Lead (R)	Fecal streptococcus
Zinc (R)	TSS (R)
(R) = Annual Loading estimates required by EPA	

Concerns regarding pesticides and excessive nutrients may best be approached initially through education and training. Suspended solids and sediments can be controlled to some extent by construction site management and erosion prevention practices. The sources of fecal coliform and fecal streptococcus bacteria need to be determined through specifically designed monitoring programs. Sources may be sanitary sewer overflows, illicit connections, or animal wastes. Insight could be gained by starting with sampling a very small, "clean" portion of a watershed and then sampling increasingly larger portions of this watershed. Through this stepwise approach, it could be determined where the bacteria tend to increase substantially.

Urban impacts do not portray the complete picture of nonpoint source loading to a watershed; however, rural impacts have not yet been adequately assessed for the region. Water pollution generated during storm events, whether it is referred to as urban storm water or nonpoint source pollution, will continue to be the focus of water quality regulations.

HYDROLOGY

Subwatersheds of the West Trinity Forks Watershed	Area (in acres)
Undefined	215
West Fork above Fossil Creek	15,176
West Fork above Sycamore Creek	9,006
West Fork above Clear Fork	9,574
[redacted]	[redacted]
Lower Little Fossil Creek	3,852
Upper Little Fossil Creek	7,702
Dry Branch	1,493
Lower Sycamore Creek	11,500
Upper Sycamore Creek	11,555
Sycamore Tributary	845
Marine Creek	13,082
King's Branch	6,983
Mary's Creek	35,384
Clear Fork	25,350

CLIMATE

Climate data were taken from the Natural Resources Conservation Service's (NRCS) Climate web page. Data were acquired by county for the time period ranging from 1961 to 1990 and averaged for all stations reporting. For Tarrant County, which contains the Big Fossil Creek watershed, the average annual precipitation was 33.9 inches, and the average annual temperature was 64.0 degrees.

LAND USE

According to NCTCOG, the major land use categories in the Big Fossil Creek watershed in 1995 included commercial and industrial (6.65%), parks and open space (71.61%), residential (19.22%), water (0.41%), and roadways (2.11%). In 2000, the major land use categories within the Big Fossil Creek watershed included commercial and industrial (7.4%), parks and open space (60.3%), residential (20.97%), water (1.07%), and roadways (10%). Analysis of the change in land use percentages from 1995 to 2000 reveals several indicators of increased urbanization of the watershed. For the commercial and industrial, residential, water, and roadway land use categories, the percentages of land being used for these purposes increased. The biggest increase occurred for roadways (7.89%). This trend is significant not only because roadways contribute to the imperviousness of the watershed but also because they typically signal an increase in future urbanization. Another indication that urbanization is well underway in the watershed is the significant loss of lands classified as parks, open space, or vacant (11.31%).

Major Land Use Percentages in the Big Fossil Creek watershed (1995 and 2000)

Land Use	1995	2000	% change
Commercial and industrial	6.65%	7.40%	+ 0.75
Parks and open space	71.61%	60.30%	-- 11.31
Residential	19.22%	20.97%	+ 1.75
Water	0.41%	1.07%	+ 0.66
Roadways	2.11%	10.00%	+ 7.89

LAND COVER

Rapid urban growth alters existing land use patterns by increasing the impervious cover of a watershed, resulting in dramatic water quality impacts brought upon by increased nonpoint sources of pollution. The amount of impervious cover cannot, in itself, be an indicator of potential water quality problems, but the influences of high impervious cover, high population density, high traffic levels, and a shrinking percentage of open or rural land suggest that this watershed is in danger of negatively impacting the water bodies to which it drains. As the percentage of impervious cover increases, surface water volumes and velocities will also increase. Additionally, erosion, sedimentation, floatables and other nonpoint source problems will intensify. Special attention is due to this watershed given these factors and the potential for increased impacts as population densities increase.

Using 1995 land use data from NCTCOG, approximately 25% of the Big Fossil Creek watershed was impervious cover. Using 2000 land use data, approximately 28% was impervious cover. Major impervious transportation routes which pass through the Big Fossil Creek watershed include: Interstate 35W, Interstate 820, US Highway 287, US Highway 377, State Highway 26, and State Highway 183.

DEMOGRAPHICS

In 1995, the population of the Big Fossil Creek watershed accounted for about 17% of the total population of the West Trinity Forks watershed. In 2000, the population of the Big Fossil Creek watershed, again, accounted for 17% of the total population of the West Trinity Forks watershed. In 2025, the forecasted population of the Big Fossil Creek watershed will account for nearly 26% of the forecasted population of the West Trinity Forks watershed. The largest concentrations of people are currently in the lower half of the watershed on the east side of Interstate 35W, but, over the next 25 years, population forecasts by NCTCOG show increasing densities of people in the upper half of the watershed.

	West Trinity Forks watershed			Big Fossil Creek watershed		
Year	1995	2000	Forecasted 2025	1995	2000	Forecasted 2025
Population	516,171	597,603	719,551	88,684	101,926	185,355

WATER QUALITY MONITORING DATA

Federal, state, regional and local governmental agencies all have a role in assessing the water quality of our region's waters. The extent to which any given agency participates in these assessment activities varies greatly by watershed. Some of these activities address a special condition or project while others are routine monitoring efforts designed to keep track of changes in water quality over the long term. While water quality data gathering efforts are conducted in other parts of the West Trinity Forks watershed as well as throughout the region, few if any water quality monitoring activities have been conducted in the Big Fossil Creek watershed. As a result, an accurate water quality assessment of the Big Fossil Creek watershed is not entirely feasible given the lack of data. Although there are no current data gathering efforts underway, the City of Fort Worth plans to initiate sampling activities in Big Fossil Creek in the near future. An approximate water quality assessment of Big Fossil Creek will be based on available regional water quality monitoring activities and the corresponding findings conducted at the federal, state, regional and local levels.

Monitoring in the Big Fossil Creek Watershed

Name	Level	Number of Sites
NAWQA	Federal	0
USGS (water quality)	Federal	0
USGS (flow data only)	Federal	1 (inactive)
State Water Quality Monitoring Network (SWQM)	State	0
Texas Watch	State/Regional	0
Trinity River Authority (TRA)	Regional	0
Storm Water Monitoring Network	Regional	0

Federal agencies such as the U.S. Geological Survey (USGS) conduct both routine water quality monitoring as well as special water quality studies. The USGS routinely conducts water flow monitoring for the Trinity River Basin. Although the USGS sites primarily conduct water flow monitoring, water quality sampling is also performed at some sites. This water quality monitoring samples for conventional parameters such as water temperature, dissolved oxygen, pH, and specific conductivity. There are 8 USGS monitoring sites in the West Trinity Forks watershed, one of which is in the Big Fossil Creek area. USGS Gage 08048800 is located in Big Fossil Creek, just north of S.H. 121 (Latitude 32°48'26", Longitude 97°14'54" NAD27). According to USGS data, this station measured daily streamflow from 1959 until 1973 and peak streamflow from 1959 until 2000 (and even measured water quality for 7 months in 1964). The gage is currently inactive but is slated for reactivation in the USGS National Streamflow Information Program (NSIP). Early discussions among some participants in the Big Fossil Creek Watershed Interim Feasibility Study have already identified the reactivation of this gage as a potential action to come out of the Study.

The USGS also works in conjunction with regional and local entities to conduct special water quality studies such as fish tissue sampling and storm water monitoring. At the State level, the Texas Natural Resource Conservation Commission (TNRCC) implements monitoring programs under the State Water Quality Monitoring network (SWQM). Data from monitoring conducted by the SWQM program is elemental in supporting targeted water quality assessments, establishing limits for wastewater treatment facilities, locating point and nonpoint sources of pollution, and determining wildlife conditions. SWQM is also responsible for updating the annual Water Quality Inventory Report, and coordinating with other entities to establish a watershed-based strategic monitoring plan in each river basin. There are 28 SWQM monitoring sites in the West Trinity Forks watershed, but none are located in the Big Fossil Creek watershed.

The Clean Rivers Program (CRP) is a statewide program to collect and assess water quality data throughout the river basins. The CRP program addresses both basin and state monitoring objectives through collaboration and coordination with SWQM, other governmental agencies, and the private and public sectors. The CRP conducts routine, periodic, and targeted monitoring activity comparable to the SWQM program. The compatibility of monitoring efforts facilitates collaboration between these programs to assess, manage and disseminate water quality data used in developing basin-specific monitoring plans. The Trinity River Authority (TRA) implements the CRP program for the Trinity River Basin.

As part of TRA's regional implementation of the Clean Rivers Program, various monitoring activities and special studies are conducted in the West Trinity Forks watershed to assess and prioritize water quality issues. The TRA conducts baseline monitoring and coordinates with other regional and local monitoring entities to compile and transfer monitoring data of the Trinity River Basin to the TNRCC. The TNRCC will use this information to help carry out future regulatory activity, such as Total Maximum Daily Load (TMDL) development, where necessary. In addition to baseline monitoring, TRA conducts systematic monitoring at the request of local governments interested in obtaining water quality data at specified locations. Currently, there is 1 TRA monitoring site in the West Trinity Forks watershed, but it is not located in the Big Fossil Creek watershed.

Under the CRP program, the TRA also provides the support framework for monitoring activities conducted by the Texas Watch Volunteer Citizens' program. Texas Watch began in the spring of 1991 and initially operated as part of the Federal Clean Lakes Program. The Texas Watch program is a partnership of the US EPA and TNRCC. The TNRCC has recently enlisted the cooperation of Southwest Texas State University to administer the program statewide. One of the goals of this program is to involve citizens in water monitoring for the purpose of increasing public awareness and education of water quality issues. In each river basin, Texas Watch seeks to involve various institutions and governmental entities as local Texas Watch Partners that provide support and training for volunteers, thereby fostering communication and cooperation. In the Big Fossil Creek watershed, 12 monitoring sites were requested by Texas Watch in 1997, but no sampling data have been reported to TNRCC for these sites. Currently, the best available information indicates that no Texas Watch activities are underway in the Big Fossil Creek watershed.

Annual monitoring activities are also conducted as part of the Regional Storm Water Management Program. Under the National Pollutant Discharge Elimination System (NPDES) municipal storm water permit program, Phase I entities are required to monitor their storm water quality. The NPDES permit program requires that wet weather monitoring be conducted on representative outfalls, internal sampling stations, and/or instream monitoring locations to characterize the quality of storm water discharges from the Municipal Separate Storm Sewer System. The monitoring program consists of 22 monitoring location sites. Fifteen of these stations are original single land use outfall sites used during the application phase. Six of the remaining seven sites are newer mixed land use sites that assess a more typical land use composition. Three are in-stream stations and three are mixed land use outfall stations. The final station is characterized as an outfall site that drains a predominately undeveloped watershed. Under this regional program, storm water samples are analyzed for twenty-two constituents, and the data is reported annually to EPA. In the West Trinity Forks watershed, the City of Fort Worth participated in this program with five monitoring sites described below.

Regional Storm Water Monitoring Stations in the City of Fort Worth , EPA permit TXS000901

Although there are no regional storm water monitoring sites located in the Big Fossil Creek watershed, the regional monitoring sites are representative of typical land use throughout the region. The following stations located in the City of Fort Worth are part of the North Central Texas Regional Monitoring Program.

Outfall 001S, USGS 08048700 - Eastern Hills High School outfall at Weiler Dr. [Station EH1] is representative of residential land use in Fort Worth. The station is located 30 ft. upstream of the outfall of a 60-in. diameter circular concrete pipe. The pipe is one of two that discharges into a square drop box inlet. Flow from the two pipes is then carried to a natural channel via a 50-ft. length of 6 x 6-ft. concrete box culvert. The pipe drains the Eastern Hills area of Fort Worth, which consists of medium density single family residences along with some multi-family residences. The drainage area is approximately 151 acres (57.2% Residential; 27.9% Commercial; 13.9% Undeveloped; 1.0% Other).

Outfall 002S, USGS 08048505 - Pylon Street outfall at Meacham Road [Station PY1] is representative of industrial land use in Fort Worth, and is comprised of mostly newer light industrial, primarily manufacturing, warehousing, and distribution. The station is located approximately 20 ft. upstream of the outfall of the 60-in. diameter circular pipe discharging into a concrete-lined trapezoidal channel. The pipe drains an industrial area of Fort Worth with a drainage area of approximately 152 acres (22.0% Industrial; 75.0% Undeveloped; 1.1% Highway; 1.9% Other).

Outfall 003S, USGS 08048545 - Dry Branch outfall at 33rd Avenue [Station CRA1] is representative of industrial land use in Fort Worth. The station is located 15 ft. upstream from the outfall of the 54-in. circular concrete pipe. The pipe discharges into an 8-ft. wide trapezoidal channel that has a natural bottom with concrete side slopes of approximately 2 to 1. The area is completely industrialized with a mixture of light, medium and heavy industry. The drainage area is approximately 74 acres (98.9% Industrial; 1.1% Undeveloped).

Outfall 004S, USGS 08048920 - I-35 at Deer Creek is a TxDOT Fort Worth District highway site (TxDOT Fort Worth District is a co-permittee with the City of Fort Worth). The site drains I-35W and some abutting property from just north of Garden Acres to Deer Creek within the Fort Worth city limits. Its drainage area landuse includes both highway and vacant land. The total drainage area is 63.13 acres (65.9% Highway; 10.8% Industrial; 23.3% Undeveloped).

Outfall 005S, USGS 08048542 – Sycamore Creek at Scott Ave [Station SYC1] is an in-stream site on Sycamore Creek and is representative of mixed land uses within the City of Fort Worth. The site is located approximately 1/3 mile upstream of the confluence of Sycamore Creek with the West Fork Trinity River. The Creek drains approximately 23,897 acres (49.2% Residential; 13.5% Commercial; 5.4% Industrial; 29.2% Undeveloped; 2.7% Highway; 0.1% Other).

Additional water quality assessments may take place at the local level. For instance, the City of Fort Worth conducts one or more extensive stream bioassays annually to assess the status of water quality. This bioassay is a component of the Regional Storm Water

Monitoring program. Fort Worth is scheduled to start a joint program in July 2002 with the US Fish and Wildlife Service to perform bioassays and water quality monitoring on 8 sites within the Big Fossil Creek watershed. The combined efforts of the local, regional, state and federal monitoring programs assist in determining the water quality conditions of the watershed.

Possible Causes of Water Quality Degradation

The results of water quality monitoring are used to assess the health of each water body. The TNRCC has established standards or criteria to determine if a water body falls short of meeting the State's goal of maintaining its beneficial uses, such as drinking, fishing and swimming. The Clean Rivers Program produces an annual assessment report that identifies "constituents of concern" for each stream segment based on screening criteria established by the State for purposes of developing future monitoring programs. State stream standards are established for each stream segment at levels necessary to achieve designated uses. Streams that do not meet established standards are required to be identified on a list of impaired waters [303(d)], reported to EPA and scheduled for remediation through the Total Maximum Daily Loads (TMDL) program. A TMDL is the maximum amount of a pollutant that a water body can receive without seriously harming its beneficial uses. This program requires the identification and quantification of all point and nonpoint pollutant inputs to a stream and subsequent regulation of these inputs such that stream standards are achieved.

The Clean Rivers Program assessment identified chlordane and fecal coliform bacteria as the constituents of concern for State stream segment (0806) West Trinity Forks below Lake Worth. The State's adopted 1999 303(d) List contained segment (0806) for elevated levels of chlordane and elevated fecal coliform bacteria levels. The North Central Texas Regional Storm Water Monitoring Program conducted for compliance with NPDES permits has also detected these pollutants in urban storm water runoff. Chlordane is a banned pesticide with no known current uses. It is possible that stockpiles of this chemical are currently being used without any knowledge by the State, but a more likely explanation could be that the chemical is resident in soils from past application as termite control for building foundations. Fecal coliform bacteria are found in the feces of warm-blooded animals and could be a result of sanitary sewer overflows, cattle ranching, direct discharge of sewage, or leaking sewage pipes.

Segment Number	Segment Name	Reason for Impairment or Threat
0806	West Fork Trinity River below Lake Worth	In a 17-mile portion from 5 miles upstream to 12 miles downstream of Beach Street, bacteria concentrations sometimes exceed the criterion established to assure the safety of contact recreation (L/NS). The fish consumption use is not supported through the lower 22 miles, based on an aquatic-life closure issued by the Texas Department of Health in 1990 due to elevated levels of chlordane in fish tissue (M/NS).

Pollutant Loadings for Watershed

The Phase I NPDES permit application required an estimate of "the annual pollutant load of the cumulative discharges to waters of the United States from all identified municipal outfalls and the event mean concentration of the cumulative discharges to waters of the United States from all identified municipal outfalls during a storm event: for 12 selected constituents." These constituents include 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), total nitrogen (TN), total ammonia plus organic nitrogen (or total Kjeldahl nitrogen—TKN), total phosphorus (TP), dissolved phosphorus (DP), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn). In 1993, two computer watershed models were used to compute estimates of the pollutant loads for each regional watershed in North Central Texas. Computer modeling provides a means to predict impacts from storm water pollution. Models can also facilitate evaluation of alternative management strategies.

The CDM Watershed Management Model

The first model was developed by the regional consultant, Camp Dresser & McKee, and is a user-friendly spreadsheet-based model which simulates the generation and fate of pollutant loads resulting from storm water runoff. The model, called the Watershed Management Model (WMM), uses 12 land use categories, each with an associated Event Mean Concentration (EMC) for each pollutant type, average annual precipitation, percent imperviousness, and acres of each land use type. The model simulates annual or seasonal pollutant loads carried in storm water runoff for the required parameters. It is a *planning level* model that provides a basis for evaluation of the long-term nonpoint pollution loads and the relative costs of nonpoint pollution management strategies.

Models depend on the quality of data input into them. Preliminary estimates of watershed loadings were initially computed by the regional storm water cities using default EMC values obtained from the National Urban Runoff Program (NURP) dataset. This dataset was compiled from 1978 to 1983 on 1,690 storms for 75 urban stations in 15 metropolitan areas and represents the single most extensive *national* dataset on urban runoff to date. These default values were used to estimate pollutant loadings, but the NURP values do not adequately describe storm water quality in north central Texas. As more local wet weather data became available, local event mean concentrations were calculated. These revised values were used in the WMM computer model to recalculate loading estimates. Annual loading estimates of the 12 selected constituents (COD, BOD_5, SS, DS, TN, TKN, TP, DP, Cd, Cu, Pb, Zn) for the Big Fossil Creek watershed are listed in the accompanying table at the end of this section.

The USGS Regression Equation Model

The second model, the USGS Regression Equation Model, was developed by the USGS from statistical regression equations developed earlier by Driver and Tasker of the USGS (Driver and Tasker, 1990). As the wet weather data were collected, USGS began to use these values to estimate event mean concentrations and loadings for the 12 conventional pollutants by these statistical methods. In their report (Driver and Tasker, 1990) the USGS had developed regression equations based on nationwide urban storm water runoff databases including NURP and other USGS studies to related storm water runoff loads and volumes to easily measured physical, land use, and climatic characteristics. Since regression equations are only statistically valid within the range of values upon which they were computed, these equations cannot be used directly to predict pollutant loadings for watersheds greater than 500 acres. In addition, storm water quality estimates derived form these Nationwide Regression Equations, when used without local data, are subject to large standard errors of estimate varying from about 60 to more than 200 percent, depending on the constituent. In consideration of this limitation, the characterization of the wet-weather data was undertaken in three phases. In the first phase, the statistical equations were initially standardized with data from the NURP study, and default EMCs were used with NCTCOG land use data to calculate preliminary estimates of pollutant loading.

In the next phase, local data were input into the multivariable equations to reduce the error or variability. The statistics used to measure this variability is the standard error of estimate. The standard error of estimate of the mean is an estimate of the standard deviation about the regression. The smaller the standard error of estimate, the more precise will be the predictions of pollutant loads. Local loading data are more similar to each other because of similar rainfall patterns, topographic characteristics, and land use practices; therefore, using these data rather than the national data reduces the inherent variability and increases the precision of the estimates. The accompanying table illustrates the success of this approach, as the average standard errors for local data are approximately 64% less than the average standard errors for the national data.

COMPARISONS WITH OTHER STORM WATER DATA (mean values in mg/L)			
Parameters	**NPDES Application Data (reported Sept. 1993)**	**1978 TRA Data**	**NURP Data**
BOD_5	7.2	12.0	10.2
COD	84.5	106	77
TN	1.77	2.8	2.8
TKN	1.14	-	1.96
$NO_2 + NO_3 - N$	0.65	-	0.84
TP	0.3	0.9	0.4
DP	0.18	-	0.13
TSS	145.9	663	123
Cu	0.04	0.04	0.05
Pb	0.04	0.33	0.17
Zn	0.13	0.54	0.22

This process continued as the third phase until all the wet-weather data were collected and final loading estimates were computed. Local USGS staff devised a method to use the local regression equations for the larger Metroplex watersheds. The median *drainage area of the monitored sites used to calculate the local regression equations* was determined to be 0.0803 sq. mi. This value is divided into a given watershed to determine the number of subwatersheds of this median size it contains. Physical characteristics other than drainage area of this large watershed are used in the regression equation. The median drainage area value is used instead to compute the annual loads for each constituent. These loading values are then multiplied by the number of median subwatersheds contained in the larger watershed to determine the annual load for the entire watershed. A loading equation was not developed for total recoverable cadmium because cadmium was only measured above detection limits for a small number of storm events. Loading estimates were provided for the pesticide diazinon. Overall, both the WMM and the USGS data sets show a reduction in the loading estimates from those predicted by the NURP data. This would indicate that the Metroplex has less pollutant loading in its storm water than the NURP studies would predict.

Conclusions on Parameter Concentrations

The data have been statistically analyzed by the regional consultant and compared with data from the Nationwide Urban Runoff Program (NURP) study and from a 1976-1978 runoff study conducted by the Trinity River Authority (TRA) for NCTCOG. Only 8 of the 12 conventional pollutants are addressed in all three studies. These are BOD_5, COD, total nitrogen, total phosphorus, TSS, copper, lead and zinc. Overall, concentrations of current data are somewhat lower than comparable values from both of the previous studies. Exceptions include TSS and COD values, which are both slightly higher than the NURP values. These lower concentrations may indicate improved water quality or they may be a result of the higher than average rainfall which may serve as a diluting factor. Values for lead may be lower because of the increased use of unleaded gasoline. In general, recent data values appear to be more similar to values collected during the NURP studies than those collected in 1978. However, with the notable exception of suspended solids (TSS), the local values are generally significantly lower than the NURP concentrations. The conventional constituent averages for the current data are 25 to 40 percent lower than the NURP data. The average concentration values of metals for the current data are 20 to 80 percent lower than the NURP data.

Characterization of Storm Water Quality From Selected Land Uses

There do seem to be some anticipated distinctions in pollutant levels between the three land use types. The pesticides, diazinon and chlordane, were found in higher concentrations in residential land use areas. Arsenic, which is a major component of some pesticides and herbicides (e.g. DMSA), was found in residential areas at levels 132 and 159 percent higher than industrial and commercial land use levels respectively. Fecal coliform and fecal streptococcus bacteria levels were also higher in residential areas. Nutrient levels were higher as well in residential areas, possibly from the improper application of fertilizers. For example, total phosphorus levels were 36 to 111 percent higher in residential areas than in industrial and commercial land use areas, respectively. Dissolved phosphorus levels were 79 to 178 percent higher in residential land use areas than industrial and commercial land use areas. Total Kjeldahl nitrogen concentration levels also tended to be higher in residential areas. Total nitrogen levels were approximately 34 percent higher for residential land use than for industrial and commercial land use. Conversely, total suspended solid concentrations were approximately 68 percent higher in industrial land use areas than for residential areas and approximately 270 percent higher than commercial land use areas. Metal concentrations were found to be generally higher in industrial areas. In particular, cadmium, chromium, copper, mercury, nickel, lead and zinc were all highest for industrial land uses. Lead levels in industrial areas were more than twice those found in residential areas. Chloride and sulfate were highest for industrial land uses as well.

Annual Nonpoint Source Urban Loading Estimates

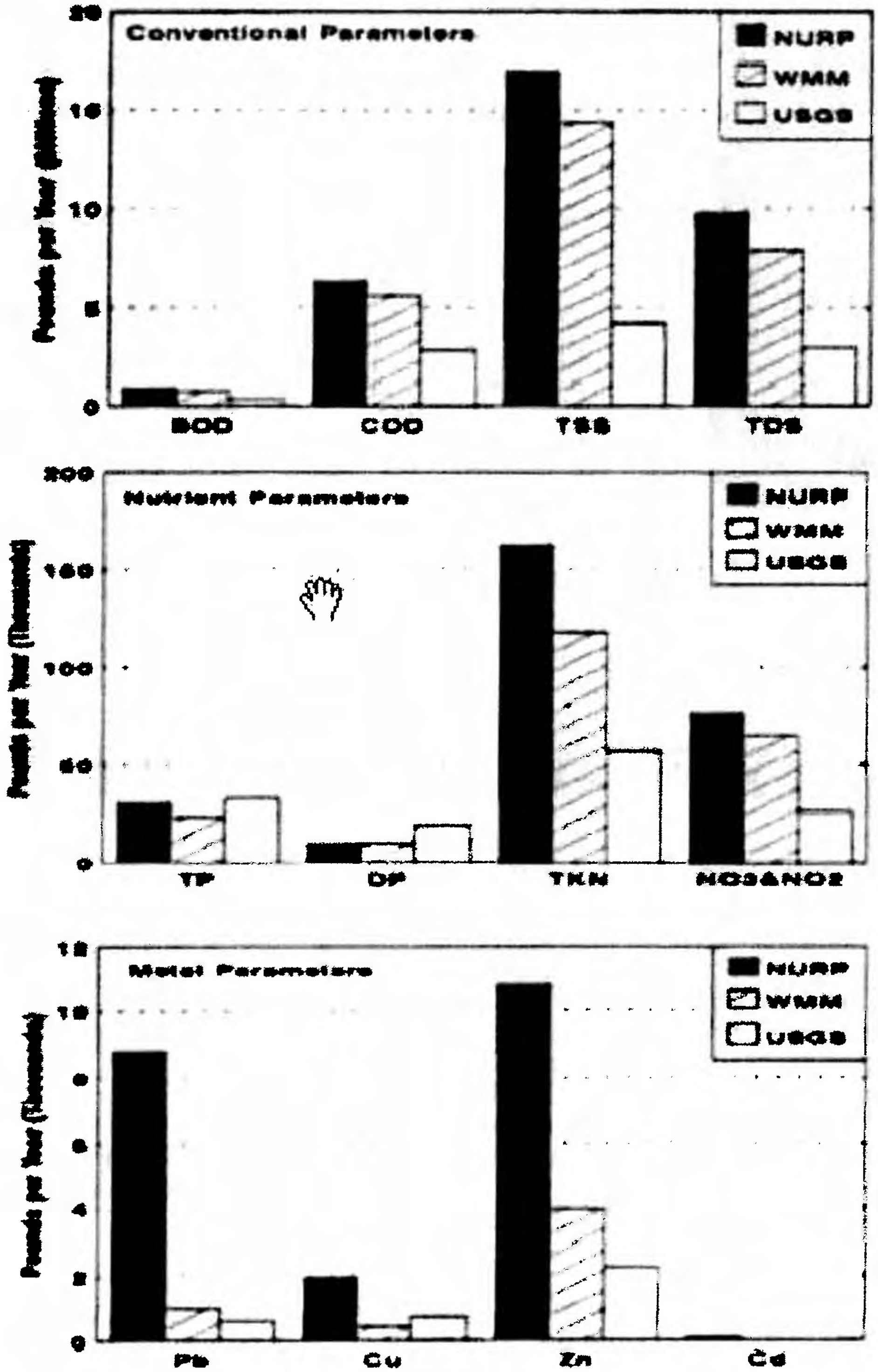
(pounds per year)

Big Fossil Creek Based on WMM Model Calculations 1990 Land Use With EMC's From Local Land Data	**BOD**	**COD**	**TSS**	**TDS**	**TP**	**DP**
	738,866	5,640,838	14,289,940	7,813,083	23,888	10,046
	TKN	**NO_2+NO_3**	**Lead**	**Copper**	**Zinc**	**Diaz**
	118,721	66,062	963	419	3,953	3,953

Big Fossil Creek Based on *USGS Regression Equations* 1990 Land Use With USGS EMC's From Local Land Data	**BOD**	**COD**	**TSS**	**TDS**	**TP**	**DP**
	365,819	2,777,917	4,203,640	2,891,731	32,963	19,629
	TKN	**NO_2+NO_3**	**Lead**	**Copper**	**Zinc**	**Diaz**
	57,731	83,990	582	709	2,247	46

The evaluation of the two loading methodologies is still preliminary. In comparing the two methods, the WMM model generally predicts higher loads, but this is constituent dependent since it does predict lower loads for some. The models are based on different approaches, which may account for the different results. Some of this difference may be due to the use of calculated local runoff coefficients in the USGS model loading calculations, whereas the WMM model retained the NURP default values. It is clear that, in every case, both methods predict improved loading estimates in contrast to the original NURP values. A direct comparison of the three models is shown below. No striking differences are apparent between the WMM estimates and the NURP estimates for the conventional parameters, but, in most cases, the USGS estimates are less than half the NURP values. For the nutrient parameters, little or no difference is seen among the phosphorus estimates for all three models; however, the USGS estimates for the nitrogen parameters are, again, almost half those of the NURP model, which are relatively comparable to the WMM estimates. For all four metals, the NURP model predicts much higher values than either the WMM or the USGS model. For these parameters, the WMM and the USGS model estimates are very similar. Note that little or no cadmium was found in the local storm water samples and so a local EMC value for the parameter could not be derived. These comparisons are preliminary and visual. A statistical comparison should be done to determine if they are valid, and the details of each model should be compared to obtain a better understanding of their differences. The relative impact of runoff coefficients and percent imperviousness needs to be considered when selecting and using models.

Comparison of Loading Calculation Methodologies
Big Fossil Creek



OTHER PROBLEMS: SEPTIC SYSTEMS COMPLAINT REPORTS

In order to identify and characterize recent problems with septic systems in the Big Fossil Creek watershed, particularly in the unincorporated areas of the upper watershed, the North Central Texas Council of Governments (NCTCOG) has acquired all pertinent data available from the Tarrant County Public Health Department during the period from 1/1/2000 to 4/3/2002. No data were readily available for any time prior to 1/1/2000. It should be noted that these data are derived from a database of septic system complaints. Thus, they are "soft" data and are only intended to provide qualitative evidence of potential fecal coliform bacteria contamination of ground and surface water. Twenty-two complaints were registered within the Big Fossil Creek watershed during the specified time period, and the spatial allocation of these complaints reveals a few areas of environmental concern (see map).

Area of Concern #1 is the Hicks Airfield industrial area located in the uppermost portion of the watershed near the origins of Big Fossil Creek. This area is currently in unincorporated Tarrant County. Several complainants have alleged that septic systems are overburdened and are failing. There are numerous reports from citizens of surfacing effluent near the hangars and taxiways.

Area of Concern #2 is the Fossil Creek Estates subdivision, also located in unincorporated Tarrant County. Having been built over the last 3 to 4 years, this subdivision is a relatively new development. There are numerous complaints of malfunctioning and improperly maintained septic systems within this subdivision. This area is of particular concern because Big Fossil Creek flows through the southwest corner of the subdivision.

Area of Concern #3 is the North Fork Estates subdivision, also located in unincorporated Tarrant County along the western boundary of the Big Fossil Creek watershed. This subdivision is also relatively new. There are several complaints of leaking and improperly maintained septic systems. Many reports describe unbearable odors and observed effluent on the surface of the ground. There are also reports of possible contamination of water wells by septic systems in this area.

Area of Concern #4 is the Ranchette Estates subdivision, an older residential development in unincorporated Tarrant County near the western boundary of the City of Keller. In this area, there are reports of surfacing sewage effluent. This effluent is apparently affecting the natural drainage of the area. In one particular spot, a complainant has alleged that a creek has even formed from the septic run-off.

Closed and Abandoned Landfill Inventory Report

The North Central Texas Council of Governments (NCTCOG) is currently conducting an inventory of closed and abandoned landfills located within the north central Texas region. Southwest Texas State University, under a contract with The Texas Natural Resource Conservation Commission (TNRCC), and in cooperation with the 24 regional Council of Governments in the State, has completed an initial statewide identification of closed and abandoned landfills. A total of 623 sites are located within the north central Texas region. Of these sites, 136 were permitted by the State, and 487 were unauthorized and are now considered abandoned.

Over the past two years, the NCTCOG has been researching each of these sites to obtain more detailed information about site location, current land use and ownership. NCTCOG has identified seven sites in the Big Fossil Creek watershed (see map). They are:

P464 Tarrant County—Laidlaw/Fort Worth
This is the only permitted landfill in the watershed and is located 300 feet south of SH121 and four miles north of Elliot-Reeder Road in Fort Worth and Haltom City. The site straddles the boundary between the Little Fossil Creek and Big Fossil Creek watersheds and is largely in the floodplain of the confluence of Big Fossil and Little Fossil Creeks. The landfill is approximately 177 acres and closed in 1995. It is under 30-year post-closure care per TNRCC. During its operation, it received 1100 tons per day of municipal solid waste. A 1980 Texas Department of Health report defined waste characteristics as toxic and corrosive and described "barrels of industrial materials that are toxic." The same report referred to a 1977 County Health Department report of stagnant water at the site and recommendation that the areas be drained and filled. A 1996 quarterly methane gas report indicated a violation. The landfill is extensively documented and continues to be monitored.

U820 Tarrant County—Old Haltom Site
This site is described as being at Midway Road and Big Fossil Creek. It was serving Haltom City and the vicinity and closed in 1968. Site visit and review of historical aerials did not facilitate a more exact assessment of its location.

U1353 Tarrant County—Midway Road Landfill
This site location description places the site 0.2 miles north of 6609 Midway Road, east of Wilson Road, north of Airport Freeway. It was never authorized and closed in 1975. Materials deposited are unknown, but a 1991 Texas Department of Health report describes household waste, construction and demolition debris, and indications of groundwater or surface water contamination. A 1992 letter from the Texas Water Commission refers to "two piles of used railroad ties." Documentation described the site as 17-25 acres in size. Site visit and review of historical aerials did not facilitate a more exact assessment of its location, but hummocks are visible east of Minnis dirt road and west of Big Fossil Creek.

U1172 Tarrant County—Fossil Springs
This site is described as being along Haltom Road south of Western Center. It is reported in a 1992 list of Resolution Trust Corporation sites, and the responsible party is listed by RTC as AMRESCO, Inc. with AMDA Contract Number 76190102001 and RTC

REOMS Property Number 932690209. RTC listed possible environmental hazards as including asbestos. Site visit showed ponds, possibly from springs, northeast of the church parking lot at the south end of Haltom Road. Site visit and review of historical aerials did not facilitate a more exact assessment of its location. There is no information on file at NCTCOG as to dates of operation, size, or materials received.

U851 Tarrant County—Real-Tex
This site is described as being 1.5 miles north of Watauga and 0.25 miles east of Denton Highway along US 377. It was opened and closed in 1974 with a fill area dimension of 200 feet by 50 feet by 4 feet. Site visit did not facilitate a more exact assessment of its location, but review of a 1975 aerial showed possible excavation and cover of described location at Greenfield and Jerri Lynn. There is no information on file at NCTCOG on the materials received.

U1183 Tarrant County—Highland Station Subdivision
This site is described as being at Blue Mound Road and Basswood Boulevard with no quadrant indicated. However, the site address is recorded as 1251 Basswood, which is in the southwest quadrant. It was reported in a 1992 list of Resolution Trust Corporation sites, and the responsible party is listed as Coastal Realty Partners with AMDA Contract Number 763910008002 and RTC REOMS Property Number 512049539. Site visit showed the area as an open field adjacent to the Highland Station subdivision and across Blue Mound Road from the Carter property. There is no information on file at NCTCOG as to dates of operation, size, or materials received.

U1267 (U1270, U1271, U1273, U1275, U1276) Tarrant County—Town & Country
The sites at this location are described as being at NW US Highway 377 and Wall Price; however, no quadrant is specified. This location is an old Resolution Trust Corporation site that was reported in 1992. The responsible party is listed by RTC as Sunbelt Federal Savings with RTC REOMS Property Number 87861840. Site visit showed an elevated area of the southwest quadrant at tracts 11B, Deerfield 9617, and 11B2 with a discernable ridge. New residential development is taking place atop the ridge north of the Kroger Distribution Center. Review of historical photographs showed a subdivision grid with dirt roads in 1975 in the area where the three tracts and Distribution Center are now located. There is no information on file at NCTCOG as to dates of operation, size, or materials received.

Recent Municipal Solid Waste Activities in the Big Fossil Creek watershed

In an effort to maintain updated municipal solid waste flow information in the North Central Texas region, NCTCOG has recently queried solid waste haulers and municipalities. Within the recent past, there have been no active landfills in the Big Fossil Creek watershed. Nevertheless, for purposes of general environmental quality, it is important to track the different destinations of all the solid wastes generated by residents of the Big Fossil Creek watershed. The following table shows, for each participating city in the Big Fossil Creek Watershed Interim Feasibility Study, the municipal solid waste hauler and landfill.

City	Hauler	Landfill Name
Fort Worth	Waste Management—Fort Worth	WMI Fort Worth Westside Landfill
Haltom City	IESI	WMI Fort Worth Westside Landfill
Haslet	Allied Waste Industries, Inc.	Camelot Landfill
Keller	Allied Waste Industries, Inc.	Camelot Landfill
North Richland Hills	Allied Waste Industries, Inc.	Turkey Creek Landfill
Richland Hills	Allied Waste Industries, Inc.	Turkey Creek Landfill
Saginaw	Allied Waste Industries, Inc.	Turkey Creek Landfill
Watauga	Allied Waste Industries, Inc.	Turkey Creek Landfill

The WMI Fort Worth Westside Landfill is a Type I landfill and has a TNRCC Permit # 1019 held by Waste Management of Texas, Inc. This landfill is located in far west Tarrant County at Linkcrest Drive and Interstate 30, 3 miles west of Loop 820. As of 2000, this landfill had a remaining capacity of 3,882,674 tons and a projected lifetime of 5.34 years.

Camelot Landfill is a Type I landfill and has a TNRCC Permit # 1312 held by the City of Farmers Branch and Camelot Landfill Texas, LP. This landfill is located in Denton County on the east bank of the Elm Fork of the Trinity River, approximately 4000 feet south of Business Highway 121. As of 2000, this landfill had a remaining capacity of 7,121,203 tons and a projected lifetime of 25.35 years.

The Turkey Creek Landfill is a Type I landfill and has a TNRCC Permit # 1417 held by Turkey Creek Landfill Texas, LP. This landfill is located in Johnson County, 2.5 miles south of Alvarado on the west side of Interstate 35W. As of 2000, this landfill had a remaining capacity of 10,736,270 tons and a projected lifetime of 47.33 years.

Other Solid Waste Facilities

Since 1990, a number of Material Recovery Facilities (MRFs), or processing centers for recyclables and centralized composting facilities, have been sited throughout the North Central Texas region to support municipal recycling and landscape waste diversion efforts. Trinity Waste Services of Fort Worth does operate a Material Recovery Facility near Big Fossil Creek. This facility, located at 2550 Austin Road in Richland Hills, processes mixed residential recyclables. It is designed to support a capacity of 60,000 tons per year, and its operating capacity for 2000 was 40,000 tons per year.

Additionally, EPA and TNRCC records indicate that an industrial hazardous solid waste management facility is located near the boundary line of the Big Fossil Creek watershed at 6529 Midway Road in Haltom City. The permit (#50228) is held by Safety Kleen Systems Inc. for the recycling, storage, and transfer of solvents.

EPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database reveals no National Priority List (NPL) Superfund sites in the Big Fossil Creek watershed, and TNRCC's State Superfund Registry includes no sites in the watershed. Nevertheless, CERCLIS does identify the Hicks Field Sewer Corporation site (EPA ID TX0000605382) as a hazardous waste site discovered in 1976. Per EPA records, this site is not on the NPL, and no further remedial action is planned.

Objectives for Water Quality Management

Solutions to water quality challenges in the Big Fossil Creek watershed are complex and will require the concerted effort of all stakeholders as rapid growth in the watershed continues. There is a national trend towards a watershed-based approach to solving water quality issues. The Water Resources Development Act of 2000 broadened the federal watershed perspective to include the full range of water resources, which includes storm water, non-point source pollution, water supply, and other issues. Such an integrated watershed approach that combines best management practices with various regional and local strategies and objectives can serve to improve current conditions and prevent further water quality degradation in the Big Fossil Creek watershed. The following nine objectives come directly from NCTCOG's **SEE SAFE CLEAN & GREEN** planning initiative to improve regional environmental corridors throughout the region. All of these objectives are applicable to the Big Fossil Creek Watershed Interim Feasibility Study.

Objective 1:

Encourage local NCTCOG member governments, as stewards of the regional environmental corridors, to incorporate SAFE CLEAN & GREEN visions and objectives into their local comprehensive plans, drainage master plans, ordinances, resolutions, and other officially adopted documents. Local governments have the inherent responsibilities as stewards to safely manage floodplains, protect water quality, and provide adequate green spaces within their jurisdictions. Therefore, in recognition of these responsibilities, local governments that have regional corridors traversing their jurisdictions should incorporate the concepts of regional corridors as an essential component of local master plans and other officially adopted documents. Furthermore, these local governments should work in cooperation with their neighbors to effectively carry out mutual responsibilities and ensure that there are no upstream and downstream adverse impacts.

Objective 2:

Foster consistency in the collection, distribution, and interpretation of water quality data throughout the region. Baseline water quality data prior to implementation of water quality programs followed by periodic and strategic monitoring can provide a measure of water quality program performance. Several monitoring efforts are currently underway in the Metropolitan Planning Area - Trinity, including the Phase I regional monitoring program, TRA sampling under the Clean Rivers Program, state evaluation of TMDL impacted streams and other efforts. However, a comprehensive source of water quality monitoring data for this region is lacking.

Objective 3: **Expand partnerships with state and federal stakeholders to address mutual challenges and opportunities for SAFE CLEAN & GREEN regional environmental corridors.** A new era of multi-level partnerships must be developed among the governmental entities of the North Central Texas region to implement the visions and objectives of the SEE initiative. Each partner at the local, state, and federal levels has appropriate roles and responsibilities that will need to be identified and carried out with respect to achieving SAFE CLEAN & GREEN regional environmental corridors.

Current examples of ongoing partnerships include cost-share agreements with the U.S. Army Corps of Engineers (USACE) for the multi-year, multi-million dollar "feasibility study" of the Upper Trinity River that has been hailed as a model across the nation. This massive effort is guided by an executive committee composed of representatives of local governments in cooperation with the Fort Worth District USACE senior leadership. It serves as the foundation on which new opportunities can be explored, with 50 percent federal cost-share.

At the state partnership level, examples include cost-shared projects between the Texas Water Development Board and local governments, as well as funding provided by the Texas Parks & Wildlife Department directly to various local governments for park and trail activities along the Trinity River. Multi-level stakeholder partnerships will continue to be vital in addressing current challenges and future opportunities.

Objective 4: **Explore various funding approaches and innovative techniques to help local communities in the region implement SAFE CLEAN & GREEN objectives and action recommendations.** Several financing methods are available to aid local governments in implementing these objectives and actions. Rather than looking at a single funding solution, multiple financing techniques should be explored to determine how they might be combined to create broad-based funding options. NCTCOG should work with all concerned partners to determine current funding sources and explore innovative alternatives for financing cooperative initiatives.

Objective 5: **Join regional educational programs to raise awareness of the needs, benefits, functions, and desirability of making regional environmental corridors SAFE CLEAN & GREEN.** Education programs targeted at city leaders, staff, stakeholders, and the general public are critical in facilitating awareness, understanding, and support of environmental management strategies aimed at improving water quality, reducing flooding risks, and creating and maintaining green space. Education programs help to clarify common misconceptions of flooding hazards and raise awareness of the valuable functions that floodplains provide to a community. For example, public education facilitates pollution prevention at the source, which is preferable to the high costs of pollution treatment downstream. Thus, it can be one of the most effective and less costly water quality best management practices that cities can undertake. In addition, the necessities and benefits of having linked green spaces throughout the region need to be promoted to local leaders and the general public to raise awareness and support for a regional green infrastructure.

A regional approach to public education should focus on developing programs and outreach tools that instill a basic understanding of SAFE CLEAN & GREEN issues. A regional public outreach strategy should clearly identify targeted audiences and stress practical, everyday tips that can improve environmental corridors.

Objective 6: **Explore coalitions/associations that work together to address mutual challenges and opportunities at a watershed level.** Local case studies, such as the successful Trinity River COMMON VISION and other national examples, can provide guidance on creating effective partnerships to work at the watershed level to meet mutual needs and achieve common resource management goals. The growing national trend in the development and utilization of watershed associations reveals new strategies to achieve meaningful public participation and education, successful interaction across sectors and political boundaries, and increased opportunity to expand technical assistance and financing options. Ongoing and emerging watershed planning efforts can be enhanced by the development and institutionalization of an associated and inclusive body of stakeholders, allied agencies, and environmental professionals to provide multidisciplinary guidance, as well as knowledge transfer.

Objective 7: **Promote watershed planning that seeks to prevent further degradation of functional riparian ecosystems such as streams, wetlands, and native vegetation along regional environmental corridors.** The concept of a functional riparian ecosystem takes into account the valuable natural processes that such ecosystems provide to a community. Naturally vegetated riparian corridors function to supply clean water by filtering excess nutrients and pollutants. Riparian ecosystems also protect natural habitat areas, provide air quality improvements, and reduce the magnitude of floods by regulating water storage and conveyance.

All partners will need to work together to assess the current functionality of riparian ecosystems in the Big Fossil Creek watershed and determine opportunities to conduct restoration activities and preservation initiatives. For example, a program known as the Stream Team offers public and private entities technical advice on flooding, streambank erosion, and similar issues prior to regulatory review at no cost. The Stream Team brings together interdisciplinary members from local, state, and federal agencies including the EPA, USACE, Texas Parks & Wildlife, Federal Emergency Management Agency (FEMA), Natural Resource Conservation Service, and NCTCOG. The Stream Team is an example of the type of interagency partnership that will facilitate the caliber of watershed planning needed to achieve these goals.

Objective 8: **Continue this region's strong commitment to implement the policies of the *Regional Strategy for Managing Storm Water Quality.*** In response to emerging water quality regulations, participating local governments in the Regional Storm Water Management Program have been working to implement the management strategies set forth in the regional policy position that was formally adopted in 1999 by NCTCOG's Executive Board. Seven local governments in the Big Fossil Creek watershed must comply with federal storm water regulations that aim to reduce urban storm water impacts to local streams and water bodies by March 2003. The policy position calls for a comprehensive and cooperative approach to managing regional water quality issues. The continuing strong commitment by all regulated entities to implement the policies of the Regional Strategy will facilitate the success to clean up local waters.

Objective 9: **Continue to develop and promote best management practices for this region to achieve water quality improvements.** Implementation of sound, effective and economical best management practices (BMPs) for pollution prevention and reduction will move this watershed closer to achieving CLEAN regional environmental corridors and avoid pressure to consider "end of the pipe" effluent limits. Where practicable, emphasis should be placed on implementing non-structural BMPs along regional environmental corridors to minimize land disturbance and avoid the high costs typically associated with construction and maintenance of those hard structures. Besides a strong public education program, additional effective non-structural management options should be explored and implemented. This includes the use of riparian buffers, which intercept and reduce the concentrations of undesirable contaminants (such as sediment, nutrients, pesticides, and other pollutants) before runoff reaches adjacent receiving waters. Buffers also slow the velocity of water, which allows the settling out of suspended soil particles and decreases erosion potential while enhancing the GREEN benefits of a corridor.

CONCLUSION

As indicated in this report, it is evident that air and water quality are under increasing pressure in the North Central Texas region. As the region's watersheds, including the Big Fossil Creek watershed, become more urbanized over time, this pressure will continue to place air and water quality at risk. Of particular concern for air quality has been the Dallas-Fort Worth region's failure to meet ozone standards primarily because of nitrogen oxides generated by on-road transportation sources. Of particular concern for water quality has been runoff pollution, erosion, and sedimentation stemming from increases in imperviousness and decreases in important green spaces and functional riparian ecosystems. What this report confirms is that there is an inherent and fundamental link between land use, transportation, and environmental quality. It is imperative that the next phases of the Big Fossil Creek Watershed Interim Feasibility Study explore the relationships between these elements when identifying projects, processes and alternatives for flood damage reduction, ecosystem restoration, and recreation and open space planning. Only by finding a balance between these three elements can sustainable solutions be realized.

Resources

Listed in Alphabetical Order:

Closed and Abandoned Municipal Solid Waste Landfill Inventory website
http://www.dfwinfo.com/envir/sw/abndfill/ablandfill.html

Environmental Protection Agency (EPA) Office of Water STORET Database
http://www.epa.gov/storet/dbtop.html

Environmental Protection Agency (EPA) Permit Compliance System (PCS)
http://www.epa.gov/enviro/html/pcs/index.html

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North Central Texas Council of Governments. *Information and Resource Inputs to the Watershed Action Plan for State Stream Segment 0806 Draft.* August 1998.

North Central Texas Council of Governments. *Results of NPDES Storm Water Monitoring In North Central Texas.* August 1993.

Spath, Kevin (interviewer). Telephone interview and email communication with Mike Veazey, Texas Natural Resource Conservation Commission. April 24, 2002.

Spath, Kevin (interviewer). Email communication with Barbara Landry, Texas Natural Resource Conservation Commission, April 24, 2002.

Spath, Kevin (interviewer). Email communication with John Schutz, Texas Watch. April 25, 2002.

Spath, Kevin (interviewer). Email communication with Steve Rothwell, University of Texas at Arlington. April 29, 2002.

Spath, Kevin (interviewer). Email communication with Brian Camp, City of Fort Worth. June 05, 2002.

Tarrant County Public Health Department. Complaint Status Report. April 03, 2002.

Trinity River Authority Clean Rivers Program website
http://www.trinityra.org/BasinPlan/basin_clean_rivers.htm

United States Geological Survey (USGS) Water Resources website
http://water.usgs.gov/nwis

APPENDICES

Maps

a. DFW Air Pollution Monitoring Sites
b. Regional Environmental Corridors
c. 1995 Land Use
d. 2000 Land Use
e. 2000 Population
f. 2025 Forecasted Population
g. Septic Tank Complaints
h. Closed and Abandoned Landfill Inventory

APPENDIX I

Big Fossil Creek COE Feasibility Study:
Macroinvertibrate Assessment &
Physicochemical Analysis

Big Fossil Creek COE Feasibility Study:
Macroinvertebrate Assessment and Physico-chemical Analysis

Preliminary Report: 14 October 2002

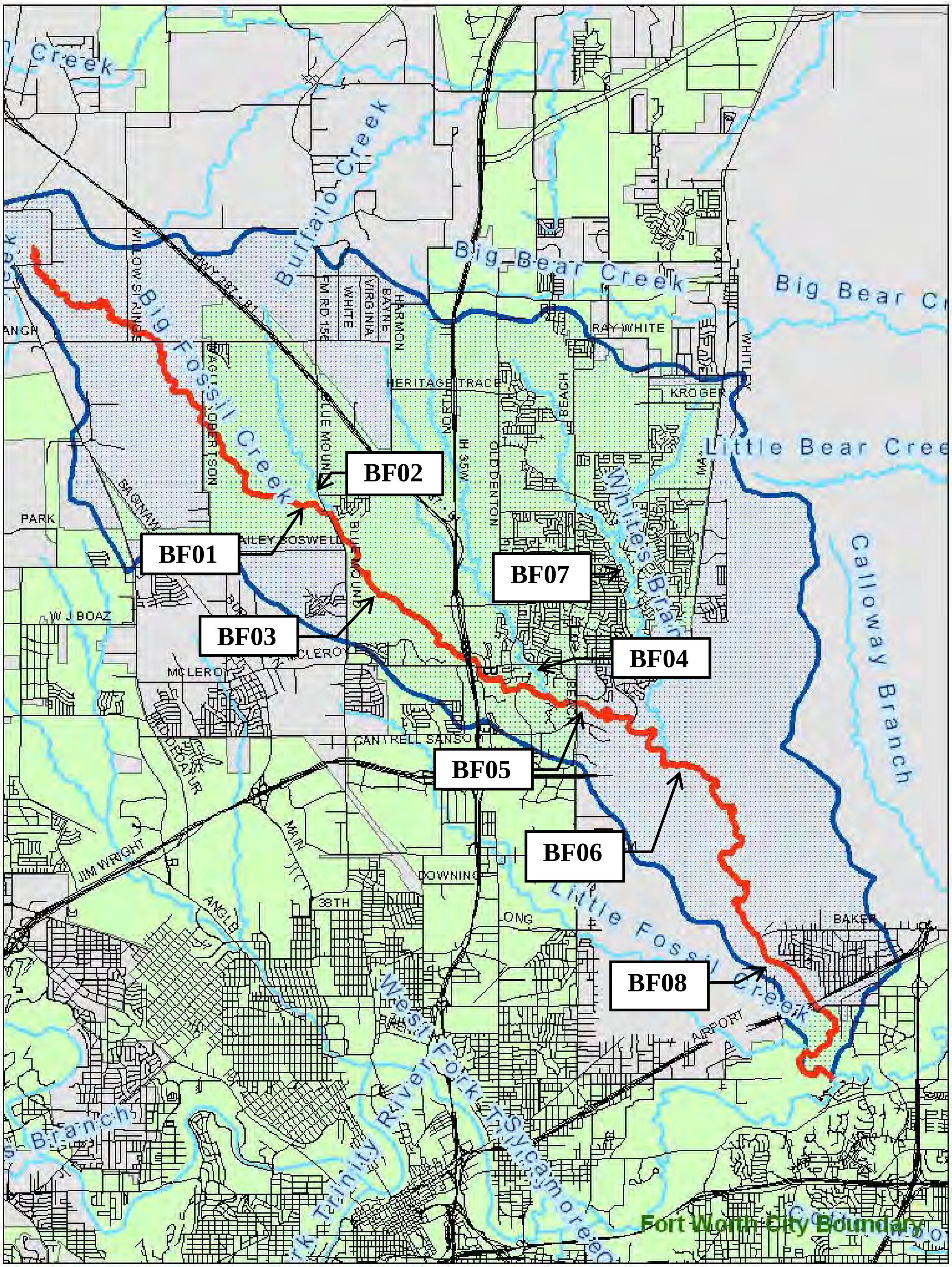
As part of a Corps of Engineers feasibility study of Big Fossil Creek in Tarrant County, Texas, the City of Fort Worth Environmental Management Department is collecting macroinvertebrate and physico-chemical data at eight locations along the creek and its tributaries. Macroinvertebrate samples are being collected at quarterly intervals (July 2002, October 2002, January 2003, and April 2003) and physico-chemical data will be collected monthly from July 2002 through June 2003. This report includes a preliminary assessment of data collected from July through September 2002.

Site Description

Figure 1 is a map showing the location of the eight sample sites. Below are brief descriptions of each site.

- BF01 Channel crossing on Hidden Lake Road SW of 8300 Blue Mound Road (Mapsco 34G) approximately 0.9 km downstream of Walnut Lake. This site is on private property and we have secured permission from the property caretaker to enter the property for sampling.
- BF02 Small Tributary to Big Fossil west of Blue Mound Road at Harmon E. (Mapsco 34G). This channel crosses Blue Mound south of Harmon E. before merging with Big Fossil.
- BF03 7200 Blue Mound Road (Mapsco 34R). This stretch of Big Fossil Creek is on private property and we have secured permission from the property owner to enter the property for sampling. This sample site is approximately 2.7 km downstream of BF01.
- BF04 This tributary flows southward between Inerstate-35 and Riverside Drive. The sample site is located on The Golf Club at Fossil Creek south of Western Center Blvd. (Mapsco 35Z) about 0.8 km before it merges with Big Fossil Creek. This confluence is approximately 4.5 km downstream of BF03.
- BF05 Buffalo Ridge Park west of Beach Street in Haltom City (Mapsco 50A). This site is approximately 5.6 km downstream of BF03.
- BF06 Big Fossil Creek west of 377 at 820 (Mapsco 50H) in Haltom City approximately 3.5 km downstream of BF05 and 0.5 km downstream of the confluence of White's Branch.
- BF07 White's Branch west of Rushmore at Park Ridge (Mapsco 36Q). This tributary is sampled approximately 6 km upstream of its confluence with Big Fossil Creek.
- BF08 Fossil Creek Park, 6101 Onyx Drive (Mapsco 51S) in North Richland Hills approximately 4.3 km downstream of the creek's confluence with White's Branch.

Figure 1: Map of sampling locations along Big Fossil Creek and its tributaries



Methods

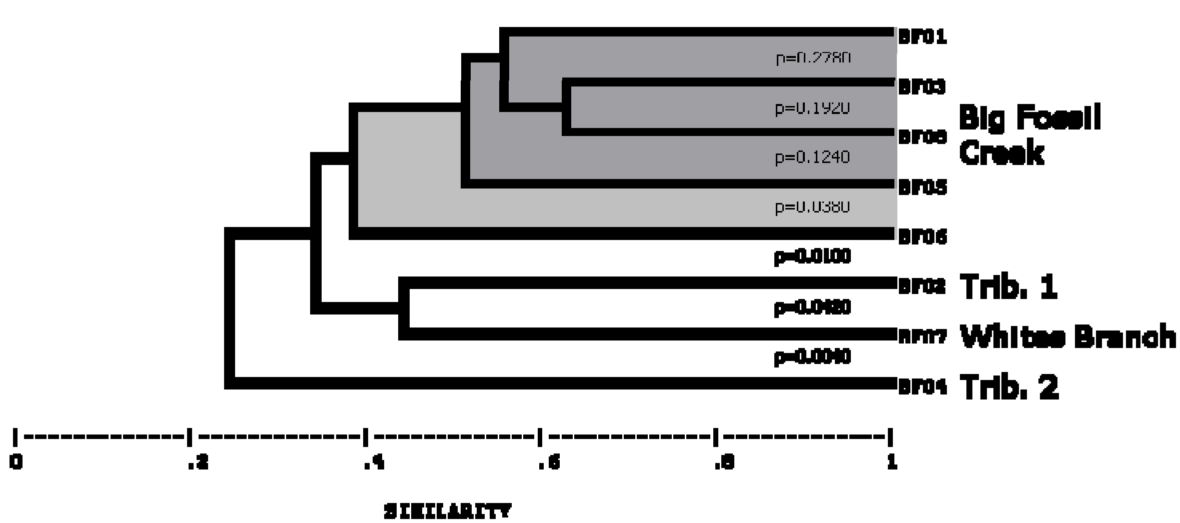
Macroinvertebrates were collected from riffle areas using a Surber sampler with 500µm mesh. Substrate in the 12 X 12 inch area ($0.09m^2$) confined by the sampler was agitated to a depth of approximately 10cm to dislodge organisms. Samples were collected from three separate riffle areas at each site. The captured organisms and debris were preserved in the field with 95% ethyl alcohol. Organisms were sorted from the sample debris and then counted and identified. Most identifications were to the family level; however, Chironomidae were identified to subfamily and Turbellaria, Nematoda, and Hirudinea were not identified any lower.

Water temperature, pH, turbidity, dissolved oxygen, and specific conductance were measured in the field with portable meters. Laboratory analysis of ammonia (Nessler method), nitrate + nitrite (cadmium reduction method), and phosphate (ascorbic acid method) concentrations was conducted using a LaMotte Smart Colorimeter. *E. coli* levels were determined by a chromogenic substrate test using the Colilert system produced by Idexx Laboratories.

Results and Discussion

Macroinvertebrate data for the 24 samples (three replicates at each of eight stations) collected in July are reported in Tables 1 and 2. Hierarchical cluster analysis of the macroinvertebrate community data was performed using the Bray-Curtis similarity coefficient[1] to compare sites. A bootstrap technique was then used on the replicate data to estimate statistical significance ($\alpha=0.05$) of the resulting clusters[2]. This analysis successfully distinguishes between Big Fossil Creek and the three tributaries sampled (Figure 2).

Figure 2: Cluster analysis dendrogram of macroinvertebrate community data at eight locations along Big Fossil Creek and its tributaries.



[1] Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monograph. 27:325-349.
[2] Nemec, A.F.L. and R.O. Brinkhurst. 1988. Using the bootstrap to assess statistical significance in the cluster analysis of species abundance data. Can. J. Fish. Aquat. Sci. 45:965-970.

A general observation of the data shows that there are very few riffle beetles, more oligochaetes, and more Caenid mayflies in the tributaries compared to Big Fossil Creek. The cluster analysis also separates BF06 from the other Big Fossil Creek locations. The major difference here appears to be that far fewer Hydropsychid caddisflies were collected at BF06. Some community metrics, such as Hilsenhoff's Family Level Biotic Index (HBI)[3] and the ratio of Ephemeroptera and Trichoptera (ET) to Chironomidae+ET[4] tend to indicate more stressful conditions in the tributaries but no major trends between the Big Fossil Creek locations (Figures 3 and 4).

E. coli shows a slight increasing trend moving downstream in Big Fossil Creek, with somewhat higher values seen in the tributaries (Figure 5). Other water chemistry values are within expected ranges and there are no distinct trends with one exception; nitrate is notably higher at sites BF05-BF08 compared to the four upstream sites. Physico-chemical data are reported in Table 3.

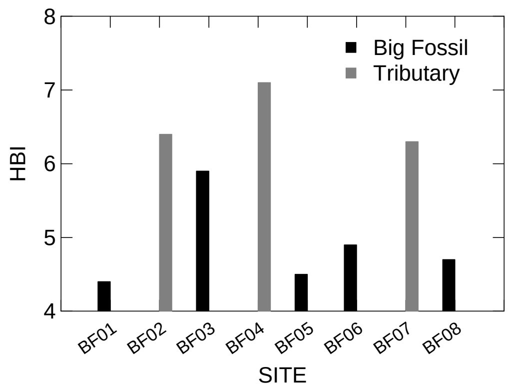


Figure 3: Hilsenhoff's Biotic Index (Family) for macroinvertebrate communities sampled at eight sites along Big Fossil Creek and its tributaries.

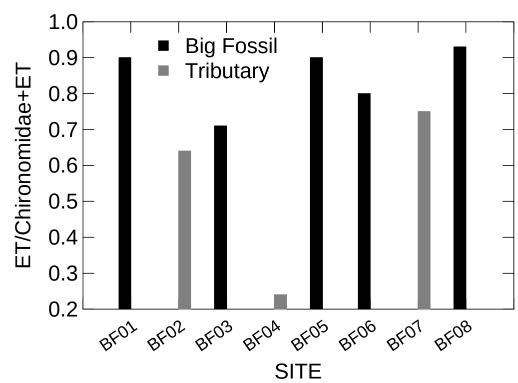


Figure 4: Ratio of Ephemeroptera and Trichoptera (ET) to Chironomidae+ET for macro-invertebrate communities sampled at eight sites along Big Fossil Creek and its tributaries.

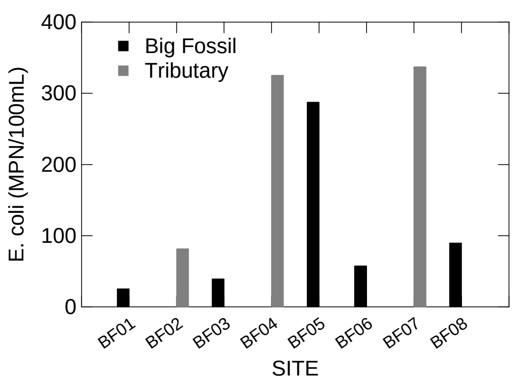


Figure 5: Geometric mean of E. coli levels for eight sites along Big Fossil Creek and its tributaries.

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[3] This index should increase along a gradient of increased stress. It is calculated using abundances of individual taxa (x_i) weighted by their pollution tolerance level (t_i): $\sum x_i t_i/n$ (n=total number of organisms in sample). The tolerance values used are reported in Table 1.

[4] This index should decrease along a gradient of increased stress as the Chironomidae increase in abundance relative to the more sensitive groups Ephemeroptera and Trichoptera. This index usually includes Plecoptera (EPT), however none have been collected in this study.

Table 1: Sum of individual macroinvertebrate abundances for three replicate samples collected at each of eight sample sites along Big Fossil Creek and its tributaries.

Order	Tol	Family	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Turbellaria	6		128	15	0	26	124	10	0	21
Nematoda	6		0	0	0	0	0	0	2	0
Oligochaeta	8	Lumbriculidae	0	0	0	3	0	0	9	0
	10	Tubificidae	7	40	0	21	0	3	9	3
	6	Naididae	0	25	1	0	0	0	1	5
Hirudinea	8		0	13	18	4	4	3	17	1
Gastropoda	9	Physidae	0	12	39	78	6	4	12	0
	6	Planorbidae	0	1	5	1	25	0	1	0
	7	Ancylidae	4	2	28	195	3	1	1	0
Bivalvia	4	Corbiculidae	40	0	160	0	351	71	63	66
	5	Unionidae	0	0	1	0	0	0	0	0
	8	Sphaeridae	56	27	42	3	1	0	7	85
Decapoda	5	Astacidae	1	0	2	0	0	0	0	0
Amphipoda	7	Talitridae	1	2	0	0	0	0	6	0
Ephemeroptera	4	Baetidae	468	221	123	336	698	167	57	192
	7	Caenidae	1	800	33	320	167	24	300	67
	4	Heptageniidae	33	6	0	0	4	1	0	2
	4	Tricorythidae	0	0	0	7	0	0	0	0
Trichoptera	4	Helicopsychidae	0	0	0	0	409	32	0	1
	4	Hydropsychidae	675	356	753	439	1193	78	120	731
	4	Hydroptilidae	9	44	4	301	14	4	6	1
	3	Philopotamidae	593	8	0	0	2	0	0	0
	3	Polycentropodidae	0	0	0	19	0	0	0	0
Anisoptera	1	Gomphidae	0	0	0	0	2	0	0	0
	9	Libellulidae	0	1	0	1	0	2	0	0
Zygoptrera	9	Coenagrionidae	35	43	398	30	90	20	24	19
	5	Calopterygidae	0	0	1	0	4	1	0	1
Hemiptera	5	Corixidae	1	0	0	0	0	0	0	0
	5	Gerridae	0	1	0	0	0	0	0	4
	5	Hebridae	1	0	0	1	0	0	0	0
	5	Mesoveliidae	0	1	0	0	0	0	1	4
	5	Naucoridae	0	4	0	1	0	0	0	0
	5	Veliidae	1	0	0	0	0	0	0	0
Coleoptera	5	Dytiscidae	0	0	0	2	0	0	0	0
	5	Elmidae	391	8	249	7	87	317	8	60
	5	Helophoridae	0	1	0	0	0	0	0	0
	5	Hydrophilidae	0	5	5	17	2	1	0	1
Megaloptera	2	Corydalidae	0	0	0	0	1	1	0	0
Lepidoptera	5	Pyralidae	0	2	6	8	20	1	0	0
Diptera	5	Ceratopogonidae	1	56	15	26	0	1	3	0
	6	Culicidae	0	1	0	1	0	0	0	0
	6	Empididae	1	0	0	7	0	0	0	0
	6	Simuliidae	287	1	156	2	1	5	0	25
	5	Stratiomyidae	0	0	0	2	0	0	0	0
	8	Chironominae	173	655	291	4205	185	48	114	41
	6	Tanypodinae	12	66	35	266	72	8	36	19
	6	Orthocladiinae	17	78	49	91	28	19	9	12
Number of Individuals			2936	2495	2414	6420	3493	822	806	1361

Table 2: Macroinvertebrate abundances for samples collected at eight sites along Big Fossil Creek and its tributaries (three replicate samples per site).

Order	Family	BF01 01A	BF01 01B	BF01 01C	BF02 01A	BF02 01B	BF02 01C	BF03 01A	BF03 01B	BF03 01C	BF04 01A	BF04 01B	BF04 01C	BF05 01A	BF05 01B	BF05 01C	BF06 01A	BF06 01B	BF06 01C	BF07 01A	BF07 01B	BF07 01C	BF08 01A	BF08 01B	BF08 01C
Turbellaria		66	12	50	6	8	1				9	7	10	55	39	30	9		1				6		15
Nematoda																				2					
Oligochaeta	Lumbriculidae											2	1							2	6	1			
	Tubificidae	7			12	8	20				2	6	13				2		1	9			1	1	1
	Naididae				24	1				1											1		1	4	
Hirudinea					5	4	4	14		4		1	3	3	1		1		2	8	5	4			1
Gastropoda	Physidae						12	24		15	2	69	7	5	1		1	2	1	1	3	8			
	Planorbidae				1			2		3			1	13	12						1				
	Ancylidae	3	1				2	19	1	8	8	67	120	3			1			1					
Bivalvia	Corbiculidae	6	1	33				127	24	9				14	138	199	12	49	10	10	7	46	44	2	20
	Unionidae									1															
	Sphaeridae	44	3	9	11	10	6	26	9	7			3	1						2		5		1	84
Decapoda	Astacidae		1						1	1															
Amphipoda	Talitridae	1					2														5	1			
Ephemeroptera	Baetidae	281	49	138	26	126	69	61	52	10	178	141	17	338	109	251	102	40	25	11	34	12	93	31	68
	Caenidae	1			269	61	470	7	8	18	35	190	95	80	62	25	11	9	4	62	109	129		67	
	Heptageniidae	7	16	10	1	1	4							3		1	1							2	
	Tricorythidae										2	2	3												
Trichoptera	Helicopsychidae													75	215	119	3	28	1						1
	Hydropsychidae	333	65	277	70	165	121	246	459	48	201	86	152	373	295	525	40	23	15	65	18	37	274	70	387
	Hydroptilidae	7		2	16	1	27	1		3	80	172	49	3	2	9	2	1	1	5	1			1	
	Philopotamidae	306	36	251	5	2	1							2											
	Polycentropodidae										10	9													
Anisoptera	Gomphidae														2										
	Libellulidae						1						1				1		1						
Zygoptrera	Coenagrionidae	26	5	4	18	12	13	143	167	88	3	20	7	25	29	36	9	7	4	11	5	8	3	14	2
	Calopterygidae							1							2	2	1								1
Hemiptera	Corixidae			1																					
	Gerridae						1																	4	
	Hebridae	1									1														
	Mesoveliidae				1															1				4	
	Naucoridae					3	1					1													
	Veliidae	1																							
Coleoptera	Dytiscidae											2													
	Elmidae	213	9	169	3	1	4	109	108	32	1		6	20	36	31	159	120	38	5		3	22	13	25
	Helophoridae						1																		
	Hydrophilidae				2	1	2	1	3	1	2	8	7			2			1					1	
Megaloptera	Corydalidae															1	1								
Lepidoptera	Pyralidae					2		3	2	1	4	3	1	1	9	10		1							
Diptera	Ceratopogonidae	1			21		35	5		10	2	10	14				1			2		1			
	Culicidae						1					1													
	Empididae	1									1	2	4												
	Simuliidae	194	35	58	1			93	51	12	2					1	3	1	1				16	2	7
	Stratiomyidae												2												
	Chironominae	136	6	31	334	25	296	127	104	60	991	2181	1033	67	55	63	39	4	5	54	17	43	7	11	23
	Tanypodinae	9	2	1	17	12	37	18	7	10	43	146	77	27	24	21	4	3	1	5	12	19	6	6	7
	Orthocladiinae	13	1	3	29	11	38	13	17	19	64	15	12	13	6	9	7	12		2		7		6	6
Total Number of Individuals		1657	242	1037	872	454	1169	1040	1013	361	1641	3141	1638	1121	1037	1335	410	300	112	258	224	324	473	240	648

Table 3: Results of physico-chemical analyses conducted on Big Fossil Creek and its tributaries in July, August, and September 2002.

	Station							
	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
pH								
Jul-02	8.10	7.00	7.90	7.00	7.10	7.80	7.70	7.00
Aug-02	7.92	7.09	7.44	6.77	7.16	7.02	7.13	7.61
Sep-02	8.00	7.90	7.50	7.50	8.10	7.90	7.80	7.60
Geometric Mean	8.01	7.32	7.61	7.08	7.44	7.56	7.54	7.40
Conductance (μS)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	510	790	540	560	590	500	660	390
Aug-02	460	380	390	880	440	400	650	410
Sep-02	490	490	680	550	690	490	720	490
Mean	487	553	537	663	573	463	677	430
Turbidity (NTU's)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	15	5	32	9	8	23	29	49
Aug-02	19	17	44	30	5	14	40	30
Sep-02	12	9	3	40	3	3	30	17
Mean	15	10	26	27	5	13	33	32
DO (mg/L)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	5.60	3.70	6.80	4.50	7.00	8.70	4.00	7.30
Aug-02	3.81	1.91	6.87	2.60	8.90	7.52	2.48	5.20
Sep-02	3.60	5.80	3.80	5.40	9.70	9.20	4.80	6.30
Mean	4.34	3.80	5.82	4.17	8.53	8.47	3.76	6.27
Temperature (°C)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	28.5	22.8	30.6	26.1	26.9	28.5	26.7	27.9
Aug-02	28.6	27.1	28.1	28.7	27.5	28.5	27.5	29.5
Sep-02	20.6	20.7	21.4	22.6	20.4	24.9	22.3	20.3
Mean	25.9	23.5	26.7	25.8	24.9	27.3	25.5	25.9
Total Alkalinity (mg/L)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	134	304	179	196	182	150	210	133
Aug-02	112	142	138	166	147	102	180	128
Sep-02	126	146	246	140	204	106	60	200
Mean	124	197	188	167	178	119	150	154
Total Hardness (mg/L)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	140	324	202	193	211	173	324	139
Aug-02	143	142	142	362	172	134	215	138
Sep-02	160	170	235	180	218	158	215	150
Mean	147	212	193	245	200	155	251	142
Ammonia (mg/L-N)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	0.10	0.20	0.27	0.24	0.11	<0.05	0.08	<0.05
Aug-02	0.06	0.17	<0.05	0.27	0.20	0.06	0.18	0.32
Sep-02	0.25	0.30	0.29	0.33	0.28	0.17	0.27	0.16
Mean	0.14	0.22	0.20	0.28	0.20	0.09	0.18	0.17
NO_3+NO_2 (mg/L-N)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	0.11	0.10	0.17	0.08	0.55	0.61	0.39	0.59
Aug-02	0.06	0.08	0.08	<0.05	0.30	0.48	0.32	0.35
Sep-02	0.08	0.17	<0.05	<0.05	0.76	0.11	0.18	0.25
Mean	0.08	0.12	0.09	0.04	0.54	0.40	0.30	0.40
PO_4 (mg/L)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	<0.10	<0.10	0.13	<0.10	<0.10	<0.10	0.15	<0.10
Aug-02	<0.10	<0.10	0.05	<0.10	<0.10	<0.10	<0.10	<0.10
Sep-02	<0.10	<0.10	0.48	<0.10	<0.10	<0.10	<0.10	<0.10
Mean	<0.10	<0.10	0.22	<0.10	<0.10	<0.10	0.08	<0.10
E. coli (MPN/100mL)	BF01	BF02	BF03	BF04	BF05	BF06	BF07	BF08
Jul-02	24	291	19	7270	19863	138	488	145
Aug-02	79	117	192	172	26	65	816	162
Sep-02	9	16	17	28	46	21	96	31
Geometric Mean	25	82	39	325	288	57	337	90