DAI Job No. 0539
Document No. 98/052

IDENTIFICATION OF EXISTING FLOOD HAZARDS AND DEVELOPMENT OF INTERIM AND FUTURE DRAINAGE IMPROVEMENT PLANS FOR THE MILL CREEK WATERSHED

CITY OF LUFKIN
ANGELINA COUNTY, TEXAS

Prepared by
Dodson & Associates, Inc.
for
The City of Lufkin, Texas
and the
Texas Water Development Board

STATE OF TEXAS
DUANE BARRETT
63703
REGISTERED
PROFESSIONAL ENGINEER
3/5/99

December 30, 1998

DAI Job No. 0539

Document No. 98/052

IDENTIFICATION OF EXISTING FLOOD HAZARDS AND DEVELOPMENT OF INTERIM AND FUTURE DRAINAGE IMPROVEMENT PLANS FOR THE MILL CREEK WATERSHED

CITY OF LUFKIN
ANGELINA COUNTY, TEXAS

Prepared by

Dodson & Associates, Inc.

for

The City of Lufkin, Texas

and the

Texas Water Development Board

December 30, 1998

TABLE OF CONTENTS

1. INTRODUCTION AND SUMMARY OF CONCLUSIONS

1.1 Purpose of This Report

This report describes the results of hydrologic and hydraulic analyses completed in an effort to identify existing flood hazards in the Mill Creek watershed in Lufkin, Texas and to develop both short-term and long-range plans for mitigating those flood hazards.

1.2 Report Preview

Section 1 (this section) provides a brief overview of the report, including a description of the Mill Creek watershed and a summary of conclusions regarding the flood hazard analysis. Section 2 describes the methods and data used in hydrologic analyses of the Mill Creek watershed and provides a summary of the results obtained. Section 3 presents a summary of hydraulic analyses of Mill Creek and tributary streams. Included in Section 3 are tabulations of computed water surface elevations for each of the studied streams. Section 4 describes an analysis of the effects of long-term development and of the effectiveness of proposed future drainage improvements and policies. Finally, Section 4 describes the development of a plan for completing short-term drainage improvements and the results of an analysis of those improvements.

1.3 Description of the Mill Creek Watershed

The portion of the Mill Creek watershed included in this study covers a total area of approximately 3.42 square miles (2,190 acres). As indicated on Exhibit 1.1, the Mill Creek watershed covers much of the northern portion of the City of Lufkin. The watershed is partially urbanized, especially in the southern portions. The study area is characterized by unimproved drainage channels and open ditch secondary drainage systems, although a few improved channels and underground storm sewer drainage systems do exist.

The downstream limit of the study area is the confluence of Mill Creek with the first significant tributary downstream (north) of the corporate boundaries of the City of Lufkin. From this confluence, Mill Creek extends upstream to Ellen Trout Lake, which is located just to the north of Loop 287. Upstream of the lake, Mill Creek splits into two main branches, designated the West Branch and the East Branch for the purposes of this report. Moving in the upstream direction, the West Branch of Mill Creek passes under Loop 287, then turns westward, passing under FM 2251. A short distance upstream of FM 2251, the West Branch splits into the West Fork and the East Fork. Again moving in the upstream direction, the West Branch, West Fork parallels Loop 287, eventually passing under State Highway 69. West Branch, East Fork extends southward, passing under a railroad spur before splitting into two small streams, both of which extend upstream to U.S. Highway 69. The East Branch of Mill Creek extends to the south and southeast from Ellen Trout Lake, passing under Loop 287, a railroad spur, a private driveway, and Martin Luther King Drive. Two existing impoundments, Jones Lake and Lake Myriad, drain into the East Branch of Mill Creek.

A total of thirteen (13) roads and railroads cross the channels of Mill Creek and its various branches. The existing channels of Mill Creek and its branches are for the most part unimproved. The channel side slopes are steep in many areas, and there is evidence of erosion in some reaches. The banks and bottom of the channel are vegetated with brush and small trees in many areas.

The City of Lufkin is a participant in the National Flood Insurance Program. The Mill Creek watershed was included in the Flood Insurance Study for the City of Lufkin, but only Ellen Trout Lake, a short segment of Mill Creek below the lake, and limited portions of the West

Branch and East Branch upstream of the lake were studied. Exhibit 1.2 illustrates the flood plain and floodway boundaries currently recognized by the Federal Emergency Management Agency for the Mill Creek watershed.

1.4 Objectives of the Analyses Described in this Report

The major objectives of the analyses described in this report are as follows:

1. to develop a HEC-1 computer model of the Mill Creek watershed for the purpose of computing existing conditions runoff hydrographs and peak flow rates at strategic locations within the watershed;
2. to develop HEC-RAS models of Mill Creek and its various branches to reflect recent field-surveyed channel cross-section data;
3. to use the HEC-1 and HEC-RAS models to compute existing conditions peak flow rates and flood profiles for 5-year, 10-year, 25-year, 50-year, 100-year, and 500-year storm events;
4. to develop existing conditions flood plain boundary maps for the watershed;
5. to develop a long-range drainage plan that accommodates future development without exacerbating existing flooding problems and provides relief from existing drainage problems;
6. to develop a plan for implementing short-term drainage (interim) improvements to address the most critical existing flooding problems in the watershed;
7. to develop interim conditions floodway data for each major branch of Mill Creek, as well as the main channel itself;
8. to develop interim conditions flood plain and floodway maps for the Mill Creek watershed.

1.5 Summary of Conclusions

The primary conclusions reached as a result of the Mill Creek study are as follows.

- Existing conditions flood plains are fairly extensive, covering low-lying areas along Mill Creek and its tributaries.
- Under current conditions, overbank flooding will occur in many areas for even a 5-year storm event.
- Existing wetlands and the lack of adequate rights-of-way along many of the streams in the Mill Creek watershed will make channelization projects difficult to permit and expensive to implement.
- Regional detention appears to be the best alternative to widespread channelization.
- Future development in the Mill Creek can be accommodated through a combination of regional detention and limited channelization.
- The proposed combination of detention and channelization will provide relief from existing flooding problems, but will not eliminate the potential for flooding during severe storm events.

2. EXISTING CONDITIONS HYDROLOGIC ANALYSIS

2.1 Method of Analysis

Hydrologic analyses of the Mill Creek watershed are completed using the HEC-1 computer program developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The HEC-1 program provides the means for computing, routing, and combining runoff hydrographs from multiple sub-areas within a watershed. For the purposes of applying the HEC-1 program to the Mill Creek study, the watershed has been subdivided into fifteen (15) sub-areas as indicated on Exhibit 2.1.

Rainfall data used for 10-year, 50-year, and 100-year storm events are developed using depth-duration-frequency data published by the National Weather Service. The HEC-1 program automatically distributes rainfall over a specified storm duration using a set of rainfall depths which correspond to a given storm frequency.

Infiltration losses for pervious areas are calculated using the SCS Curve Number method. This method relates the amount of infiltration to the soil structure and to the type and condition of vegetal cover. Infiltration for impervious areas is assumed by the HEC-1 program to be zero. The overall percent impervious cover for each sub-watershed is computed by estimating the total area covered by impervious materials (streets, parking lots, rooftops, etc.) and dividing by the drainage area.

Hydrographs are relationships between the rate of storm runoff (volume per unit of time, usually cubic feet per second) versus the elapsed time from the beginning of rainfall. In the HEC-1 program, a hydrograph is computed by first establishing a unit hydrograph, which is defined as the response of a watershed to a volume of runoff equivalent to 1 inch of depth over the watershed, then multiplying the ordinates of that unit hydrograph by the actual equivalent depth of storm water runoff. The Clark unit hydrograph method is used for computing runoff hydrographs. Clark unit hydrograph parameters are computed using a methodology developed specifically for this study.

The Modified Puls method is used to route hydrographs from point to point within the watershed. Storage-discharge data for the Modified Puls method are developed using HEC-RAS computer models of Mill Creek and its major tributaries.

2.2 Rainfall Data Development and Utilization

Table 2-1 presents rainfall depth-duration-frequency data developed through statistical analyses of recorded rainfall data and published in two publications: U.S. Weather Bureau Technical Paper No. 40 (*Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*) and National Weather Service Hydrometeorological Report No. 35 (*Five- to 60-Minute Precipitation Frequency for the Eastern and Central United States*). This information represents rainfall data which may be used to generate design storm events for drainage analyses and design studies. As indicated in the table, the 100-year, 24-hour rainfall depth for Lufkin is about 11.5 inches.

TABLE 2-1: HYDRO-35 & TP-40 RAINFALL DATA FOR LUFKIN, TEXAS								
Storm	Rainfall Depth in Inches for Given Storm Duration							
Event	5-Minute	15-Minute	60-Minute	2-Hour	3-Hour	6-Hour	12-Hour	24-Hour
2 year	0.54	1.16	2.18	2.67	2.94	3.48	4.15	4.75
5-year	0.61	1.33	2.65	3.45	3.82	4.54	5.50	6.43
10-year	0.66	1.46	2.99	3.98	4.41	5.39	6.55	7.73
25-year	0.75	1.65	3.48	4.55	5.12	6.33	7.69	9.07
50-year	0.81	1.81	3.87	5.09	5.67	7.05	8.70	10.20
100-year	0.88	1.96	4.25	5.67	6.34	8.00	9.77	11.48

In flood studies of the type completed for the Mill Creek watershed, hypothetical rainfall data are used in conjunction with the HEC-1 program. Rainfall depths are entered by the user to define the relationship between rainfall depth, storm duration, and frequency. The temporal distribution of the rainfall is developed internally by the HEC-1 program using built-in capabilities. The HEC-1 rainfall distribution is "balanced" in that it places the most intense rainfall at the center of the storm duration with decreasing rainfall amounts to either side of the period of maximum intensity. The depth of the rainfall occurring before and after the period of maximum intensity is approximately equal. A 24-hour storm duration is used for all analyses of the Mill Creek watershed.

2.3 Soils Data and Selection of SCS Curve Numbers

Information presented in the *Soil Survey of Angelina County, Texas* indicates that soils within the incorporated boundaries of Lufkin consist of fine sandy loams at slopes of 0 to 15 percent. The major soils present within the Mill Creek watershed include those named in Table 2-2. Exhibit 2.2 illustrates the areal extents of the various soils.

The Curve Number method developed by the U.S. Soil Conservation Service for estimating infiltration losses us used for this study. The Curve Number method involves the classification of soils into one of four hydrologic soil groups. These groups, designated A, B, C, and D, provide a means of indexing soils in terms of infiltration capacity. Soils belonging to hydrologic soil group A have the highest infiltration capacity, while those belonging to group D have the lowest infiltration capacity. As indicated in Table 2-2, each of the four hydrologic soil groups are represented in Lufkin.

TABLE 2-2: SOILS FOUND IN THE MILL CREEK WATERSHED			
Soil Symbol	Soil Name	Soil Description	HSG
AcB	Alazan	Alazan-Urban land complex, 0-4 percent slopes	B
CtD	Cuthbert	Cuthbert fine sandy loam, 5 to 15 percent slopes	C
DaC	Darco	Darco loamy fine sand, 1 to 8 percent slopes	A
Du	Dumps	Dumps (former sanitary landfill sites)	--
FuB	Fuller	Fuller-Urban land complex, 1-4 percent slopes	D
KcB	Keltys	Keltys fine sandy loam, 1-5 percent slopes	B
KcD	Keltys	Keltys fine sandy loam, 5 to 15 percent slopes	B
KdB	Keltys	Keltys-Urban land complex, 1-5 percent slopes	B
KdD	Keltys	Keltys-Urban land complex, 5 to 15 percent slopes	B
KhB	Kirvin	Kirvin soils, graded, 2 to 5 percent slopes	D
Kp	Koury	Koury loam, frequently flooded	C
Ks	Koury	Koury-Urban land complex, occasionally flooded	C
KuB	Kurth	Kurth fine sandy loam, 0-4 percent slopes	C
KwB	Kurth	Kurth-Urban land c omplex, 0-4 percent slopes	C
MsB	Moswell	Moswell loam, 1-5 percent slopes	D
Pa	Pits	Pits (bentonite clay excavation areas)	--
SaB	Sacul	Sacul fine sandy loam, 1 to 5 percent slopes	C
SaD	Sacul	Sacul fine sandy loam, 5 to 15 percent slopes	C
SbB	Sacul	Sacul-Urban land complex, 1-5 percent slopes	C
TnD	Tenaha	Tenaha loamy fine sand, 5 to 15 percent slopes	B

SCS curve numbers reflect the relative ability of water to infiltrate into soils. The maximum curve number is 100. A curve number of 100 indicates that no infiltration can take place. The lower the curve number, the greater the infiltration capacity. Curve numbers are related to the soil type and structure, which are accounted for by assigning soils to one of the four hydrologic soil groups just described, and to the type and condition of vegetal cover. The following table gives curve numbers for a few typical conditions.

TABLE 2-3: SCS CURVE NUMBERS FOR PERVIOUS AREAS				
	Hydrologic Soil Group			
Land Use Description	A	B	C	D
Pasture or Range Land: good condition	39	61	74	80
Wood or Forest Land: good cover	25	55	70	77
Lawns & Parks: good condition, grass on 75% or more of area	49	69	79	84
Meadow: good condition	30	58	71	78

Curve numbers for pasture or range land in good condition are averaged with those for wood or forest land with good cover to obtain values for use in the Mill Creek watershed. This is done to reflect the mixture of wooded and grassed areas found throughout the watershed. The curve numbers used for hydrologic soil groups A, B, C, and D are 32, 58, 72, and 79, respectively. Tables 2-4 and 2-5 present the weighted curve number tabulations for each of the major sub-watersheds in the Mill Creek watershed. These curve numbers are used in HEC-1 models of the Mill Creek watersheds for the major sub-watersheds listed in Table 2-4 and for any smaller subdivisions of those sub-watersheds.

TABLE 2-4: SCS CURVE NUMBERS FOR MAJOR MILL CREEK SUB-WATERSHEDS										
		Area Belonging to Each Hydrologic Soil Group (acres)								
Hydrologic Soil Group	CN	JONES	EBR1A	EBR1B	EBR1C	MYRIAD	EBR2A	EBR2B	WFK1	WFK2
A	32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	6.2
B	58	45.0	37.2	124.1	54.7	48.0	45.2	12.6	227.0	82.0
C	72	48.7	5.9	9.4	11.8	41.1	53.5	112.5	87.0	255.8
D	79	0.0	0.0	23.1	0.2	0.0	0.0	0.0	33.8	0.0
Weighted Curve Number		65	60	62	61	64	65	71	63	68

TABLE 2-5: SCS CURVE NUMBERS FOR MAJOR MILL CREEK SUB-WATERSHEDS										
		Area Belonging to Each Hydrologic Soil Group (acres)								
Hydrologic Soil Group	CN	EFK1	EFK2	EFK3	CITY	DNSTM	-----	-----	-----	-----
A	32	1.1	9.0	0.0	28.1	2.4	-----	-----	-----	-----
B	58	46.9	107.2	24.9	0.0	134.1	-----	-----	-----	-----
C	72	61.3	33.2	47.1	98.6	127.1	-----	-----	-----	-----
D	79	0.0	21.1	0.0	0.0	9.2	-----	-----	-----	-----
Weighted Curve Number		66	62	67	65	65	-----	-----	-----	-----

2.4 Land Use Data & Impervious Cover Calculations

Existing land uses for the Mill Creek watershed have been divided into a number of categories. Recent aerial photographs have been used to determine the area of existing development which falls into each of those categories, each of which has a different average percentage of impervious cover. Exhibit 2.3 illustrates the distribution of existing development over the watershed. Tables of hydrologic parameters included in Appendix A to this report provide details regarding the breakdown of land uses within each sub-area and the computed impervious cover for each sub-area.

2.5 Times of Concentration & Storage Coefficients for the Clark Method

The Clark unit hydrograph method requires that the user specify a time of concentration and a storage coefficient for each sub-area in the HEC-1 model of the Mill Creek watershed. The time of concentration is set equal to the time required for storm runoff to travel from the most hydraulically remote point in the sub-area to the outlet point. The storage coefficient is a relative measure of the amount of storage in the sub-area. Typically, the flatter the slopes in a particular watershed, the greater the surface and depression storage, and the greater the value of the storage coefficient. As slopes increase, the storage coefficient typically decreases. Because this inverse relationship is similar to the relationship between time of concentration and slope, the storage coefficient is frequently computed as follows:

$$R = K \times TC$$

where R is the storage coefficient, TC is the time of concentration, and K is a multiplier. The value of K typically ranges from 2.0 for relatively steep slopes to 3.0 for flatter slopes. For all sub-areas in the Mill Creek watershed, K is set equal to 2.0.

The time of concentration for each sub-area in the Mill Creek watershed is computed by dividing the distance over which storm runoff must travel by the flow velocity. Because flow velocities vary with flow conditions, the longest watercourse in each sub-area is divided into four segments: overland flow, shallow concentrated flow, paved or gully flow, and channel flow. Overland flow represents sheet flow at very shallow depths, and is limited in this study to no more than 300 feet of distance at the upstream end of each watercourse. Shallow concentrated flow takes over as storm runoff collects in shallow rills and swales, and flow depths increase to a few inches. Paved or gully flow reflects flow in curb-and-gutter streets, concrete-lined swales, and small gullies. Finally, channel flow represents the flow of flood waters through relatively large gullies and creeks illustrated on U.S. Geologic Survey 7.5-minute quadrangle maps using blue lines.

Velocities for overland flow, shallow concentrated flow, and paved or gully flow are estimated using the SCS Uplands Method, which relates flow condition and slope to flow velocity. Exhibit 2.4 illustrates the relationships between flow velocity and slope developed for the Uplands Method. For channel flow, an average velocity of 3.0 feet per second is used for all sub-areas.

Detailed time of concentration calculations for each sub-area included in the Mill Creek HEC-1 model may be found in Appendix A to this report.

2.6 Summary of Hydrologic Parameters for Mill Creek Sub-Areas

Table 2-6 provides a summary of the hydrologic modeling data used to represent the fifteen (15) sub-areas included in the Mill Creek existing conditions HEC-1 computer model.

TABLE 2-6: SUMMARY OF HEC-1 PARAMETERS FOR MILL CREEK SUB-AREAS

Sub-Area	Drainage Area (acres)	SCS Curve Number	Impervious Cover (%)	Time of Concentration (hours)	Storage Coefficient (hours)
JONES	94	65	34.6	0.24	0.49
EBR1A	43	60	29.9	0.25	0.51
EBR1B	157	62	23.7	0.44	0.88
EBR1C	113	61	35.8	0.32	0.63
EBR1D	31	63	3.9	0.21	0.42
MYRIAD	89	64	29.4	0.16	0.33
EBR2A	50	65	17.7	0.21	0.42
EBR2B	125	71	5.8	0.58	1.17
WFK1	356	63	13.0	0.31	0.62
WFK2	344	68	5.2	0.71	1.42
EFK1	109	66	8.8	0.46	0.91
EFK2	171	62	12.3	0.54	1.07
EFK3	72	67	7.6	0.32	0.63
CITY	164	65	26.5	0.27	0.54
DNSTM	273	65	10.1	0.64	1.29

2.7 Storage Routing Data for Mill Creek

Exhibit 2.1 illustrates the extents of the routing reaches for which storage-discharge are defined for this study. Tables 2-7 and 2-8 present a summary of the storage routing data developed for each channel routing reach and each of the existing lakes in the watershed. Channel routing volumes are computed using a special multi-profile HEC-RAS model of Mill Creek and its various branches. The number of routing steps used for each reach is determined by using HEC-RAS results to compute the average travel time through the reach and dividing the average travel time by the HEC-1 computation interval of 10 minutes (0.167 hour).

TABLE 2-7: STORAGE ROUTING DATA FOR MILL CREEK										
Reach #1: Jones Lake to East Branch										# Steps
Flow Rate (cfs)	0	40	80	120	160	200	240			
Volume (ac-ft)	0	1	2	3	4	5	6			1
Reach #2: East Branch Confluence to MLK										# Steps
Flow Rate (cfs)	0	120	240	360	480	600	720			
Volume (ac-ft)	0	6	12	17	23	29	33			3
Reach #3: MLK to Ellen Trout Lake										# Steps
Flow Rate (cfs)	0	172	344	516	688	860	1032			
Volume (ac-ft)	0	27	50	56	63	68	73			4
Reach #4: West Branch, West Fork, US 69 to East Fork										# Steps
Flow Rate (cfs)	0	200	400	600	800	1000	1200			
Volume (ac-ft)	0	25	48	69	91	114	139			8
Reach #5: West Branch, East Fork, Confl. to West Fork										# Steps
Flow Rate (cfs)	0	120	240	360	480	600	720			
Volume (ac-ft)	0	11	23	34	44	51	58			2
Reach #6: West Branch, West Fork, Confl. to City Lake										# Steps
Flow Rate (cfs)	0	340	680	1020	1360	1700	2040			
Volume (ac-ft)	0	15	31	46	61	77	86			2
Reach #7: Ellen Trout Lake to Downstream Confluence										# Steps
Flow Rate (cfs)	0	520	1040	1560	2080	2600	3120			
Volume (ac-ft)	0	3	7	10	13	15	17			1

Discharge data for Jones Lake and Lake Myriad is developed using the standard weir equation $Q = CLH^{1.5}$. The principal spillway structure for each lake is a broad-crested weir with sloping ends. A weir coefficient of 2.6 is used for each spillway.

TABLE 2-8: STORAGE ROUTING DATA FOR EXISTING LAKES										
Jones Lake										# Steps
Surface Area (ac.)	8.0	10.3	14.2							
Elevation (feet)	318.8	320.0	322.0							
Flow Rate (cfs)	0	0	45	130	243	473				
Elevation (feet)	318.8	320.0	320.5	321.0	321.5	322.0				1
Lake Myriad										# Steps
Surface Area (ac.)	17.0	18.8	21.7	25.4						
Elevation (feet)	304.3	306.0	308.0	310.0						
Flow Rate (cfs)	0	18	81	190	370	894	1950			
Elevation (feet)	304.3	305.0	306.0	307.0	308.0	309.0	310.0			1
Ellen Trout Lake										# Steps
Surface Area (ac.)	34.9	44.7	49.2							
Elevation (feet)	268.2	270.0	272.0							
Flow Rate (cfs)	0	34	231	582	1065	1665	2360	3144	4077	
Elevation (feet)	268.2	268.5	269.0	269.5	270.0	270.5	271.0	271.5	272.0	1

2.8 Summary of HEC-1 Results

Table 2-9 provides a summary of computed 5-year, 10-year, 25-year, 50-year, and 100-year peak flow rates at a number of strategic points in the Mill Creek watershed. Exhibit 2.1 illustrates the locations of the computation points described in the table.

TABLE 2-9: COMPUTED PEAK FLOW RATES AT GIVEN LOCATIONS

Location	5-Year	10-Year	25-Year	50-Year	100-Year
Jones Lake Inflow	157	200	249	286	326
Jones Lake Discharge	48	87	125	159	195
East Branch, West Fork at East Fork Confluence	62	110	158	201	248
East Branch D/S of West Fork - East Fork Confl.	218	304	408	496	592
East Branch U/S of Martin Luther King Drive	286	401	526	619	731
Lake Myriad Inflow	178	228	284	328	373
Lake Myriad Discharge	26	40	55	67	80
East Branch D/S of Martin Luther King Drive	318	450	600	716	852
East Branch at Railroad Spur	259	385	599	727	891
East Branch at Loop 287	306	467	732	894	1102
West Branch, West Fork at U.S. 69	409	557	722	853	992
West Branch, West Fork at East Fork Confluence	471	657	867	1025	1202
West Branch, East Fork U/S of Confluence	134	185	243	289	339
West Branch, East Fork D/S of Confluence	238	328	428	507	593
West Branch, East Fork at Mouth	194	269	352	420	503
West Branch D/S of West Fork - East Fork Confl.	662	926	1219	1442	1700
Ellen Trout Lake at Upstream End	931	1345	1813	2158	2534
Ellen Trout Lake Inflow	973	1410	1917	2278	2676
Ellen Trout Lake Discharge	918	1321	1804	2174	2587
Downstream Limit of Study	1005	1457	1998	2411	2878

2.9 Comparison of FIS and Updated Peak Flow Rates

Table 2-10 provides a comparison of results from the Flood Insurance Study for Lufkin, Texas and the update study completed by Dodson & Associates, Inc. The comparison of computed 100-year peak flow rates indicates that updated peak flow rates are consistent with Flood Insurance Study values.

TABLE 2-10: COMPARISON OF 100-YEAR FLOW RATES FROM FLOOD INSURANCE STUDY AND UPDATE STUDY

Location	**Flood Insurance Study**		**Update Study**	
	Drainage Area (sq. mi.)	100-Year Peak Flow (cfs)	Drainage Area (sq. mi.)	100-Year Peak Flow (cfs)
Mill Creek at Corporate Limits	3.4	2830	3.42	2878
East Branch at Ellen Trout Lake	1.0	1380	1.10	1102
West Branch at Ellen Trout Lake	1.9	1890	1.64	1700

3. EXISTING CONDITIONS HYDRAULIC ANALYSES

3.1 Method of Analysis

The HEC-RAS computer program developed at the U.S. Army Corps of Engineers Hydrologic Engineering Center is used for all hydraulic analyses of Mill Creek and its tributaries. The HEC-RAS program uses Manning's Equation to compute water surface profiles given cross-section data, roughness coefficients, and flow rates. In addition, the program has a number of special capabilities related to the analysis of culverts and bridges at roadway crossings.

3.2 Hydraulic Conditions Along Mill Creek and Tributaries

3.2.1 Roadway Crossing Structures

Table 3-1 provides brief descriptions of the thirteen (13) existing roadway structures along Mill Creek and its various branches.

TABLE 3-1: EXISTING ROADWAY CROSSING STRUCTURES ALONG MILL CREEK		
Number	Name of Roadway	Description of Structure
Mill Creek		
MC-1	Lake Street	Two 84-Inch Corrugated Steel Pipe Culverts
MC-2	E. Trout Zoo Railroad	Dual Clear-Span Steel Truss Bridges
MC-3	Loop 287	Five 10' x 4' Concrete Box Culverts
East Branch		
EB-1	Railroad Spur	Concrete Bridge
EB-2	Private Road	Three 30-Inch Corrugated Steel Pipe Culverts
East Branch, East Fork		
EBEF-1	Martin Luther King	Eight 48-Inch Corrugated Steel Pipe Culverts
EBEF-2	Martin Luther King	Two 5' x 3' Concrete Box Culverts
West Branch		
WB-1	Loop 287	Five 10' x 4' Concrete Box Culverts
WB-2	FM 2251	Four 7' x 4' Concrete Box Culverts
West Branch, West Fork		
WBWF-1	U.S. 69	One 10' x 6' Box Culvert
West Branch, East Fork		
WBEF-1	Railroad Spur	Timber Bridge
WBEF-2	Minnie Lou	Two 30-Inch Vinyl Pipe Culverts
WBEF-3	U.S. 69	Two 36-Inch Concrete Pipe Culverts

3.3 HEC-RAS Models Used in This Analysis

Three (3) HEC-RAS models are used in this analysis. One is a multi-profile (5-year, 10-year, 25-year, 50-year, 100-year, and 500-year) model representing Mill Creek and its various branches. Another is a floodway model for the same streams. The third is a storage-discharge model used to compute data for Modified Puls streamflow routing in the HEC-1 model of the Mill Creek watershed.

3.4 Development of HEC-RAS Modeling Data

3.4.1 Cross-Section Coordinates

The HEC-RAS data used for all analyses described in this report is based on field survey data provided by Everett Griffith Jr. & Associates, Inc. (EGA). Field-surveyed cross-sections obtained by EGA typically includes the channel plus overbank data for a distance of 200 to 300 feet on either side of the channel. Where necessary, field survey data has been supplemented with data from aerial topographic maps developed by United Aerial Mapping, Inc.

3.4.2 Manning Roughness Coefficients

Manning roughness coefficients for channels and flood plains are established for each studied stream in the Mill Creek watershed by comparing hydraulic conditions with those existing along Cedar Creek and its tributaries. Roughness coefficients for Cedar Creek and its tributaries were computed in a 1997 study using the following equation:

$$n = (n_b + n_1 + n_2 + n_3 + n_4)\, m_5$$

where: n = the computed roughness coefficient;

n_b = base roughness coefficient, a function of the channel material;

n_1 = factor to account for the degree of irregularity;

n_2 = factor to account for variations in the channel cross-section (=0.00 for flood plains);

n_3 = factor to account for the effects of obstructions;

n_4 = factor to account for the effects of vegetation;

m_5 = factor to account for the degree of meander in the channel (=1.00 for flood plains).

The range of roughness coefficients computed for Cedar Creek and its tributaries ranged from 0.06 to 0.09 for channels and from 0.14 to 0.19 for overbank areas. In the Mill Creek watershed, base roughness coefficients of 0.08 and 0.17 were adopted for channels and overbank areas, respectively. These values were adjusted upward or downward depending upon conditions encountered in the field. The range of roughness coefficients established for each studied stream in the Mill Creek watershed is summarized in Table 3-2.

TABLE 3-2: MANNING ROUGHNESS COEFFICIENTS

Stream	Channel Coefficient	Overbank Coefficients
Mill Creek	0.08	0.17
East Branch	0.08	0.17
West Branch	0.08	0.17
West Branch, West Fork	0.08	0.17
West Branch, East Fork	0.08	0.17

3.4.3 Flow Rates

Flow rates used in the HEC-RAS models of Mill Creek and tributaries 1 through 7 are determined using the results of HEC-1 analyses for 5-year, 10-year, 25-year, 50-year, and 100-year storm events. Flow rates for the 500-year storm are determined by plotting 10-year and 100-year values on log-probability paper and extrapolating.

3.4.4 Bridge and Culvert Modeling Data

Bridge and culvert modeling data are developed from the field survey data provided by Everett Griffith Jr. & Associates, Inc. and field observations made by representatives of Dodson &

Associates, Inc. Roughness coefficients, minor loss coefficients, roadway elevation profiles, and other data are entered as necessary to provide a complete hydraulic definition for each structure.

3.5 Summary of HEC-RAS Modeling Results

3.5.1 Mill Creek

Table 3-3 provides a summary of computed water surface elevations for Mill Creek. Elevations are given at the upstream side of each of the roadways which cross Mill Creek. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that a flood of 5-year to 10-year magnitude causes flooding at a number of roadway crossings. Exhibits 3.1 through 3.6 illustrate computed flood profiles for existing conditions along Mill Creek and its branches.

TABLE 3-3: SUMMARY OF COMPUTED FLOOD LEVELS ALONG MILL CREEK

Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation				
			5-Year	10-Year	25-Year	50-Year	100-Year
Mill Creek							
Lake Street	60.5	255.50	***256.54***	***257.22***	***257.82***	***258.01***	***258.31***
Ellen Trout Lake Dam	606	-----	269.73	270.09	270.44	270.68	270.91
E. Trout Zoo Railroad	2330.5	273.10	269.81	270.26	270.87	271.29	271.77
Loop 287	3741.5	274.28	271.89	272.50	273.16	273.70	***274.28***
East Branch							
Railroad Spur	818.5	273.80	272.86	***274.33***	***274.68***	***274.79***	***274.90***
Private Road	1784.5	277.60	***278.43***	***278.74***	***278.90***	***278.95***	***279.09***
East Branch, East Fork							
Martin Luther King	1.5	280.40	278.84	279.42	280.15	***280.54***	***280.68***
Martin Luther King	3781	303.00	301.05	301.85	302.42	302.94	***303.15***
West Branch							
FM 2251	2225.5	278.80	277.07	278.47	278.56	278.69	***278.94***
West Branch, West Fork							
Railroad Spur	4333.5	299.00	***299.90***	***300.25***	***300.62***	***300.89***	***301.14***
U.S. 69	4940.5	325.94	305.54	307.11	309.11	310.98	313.51
West Branch, East Fork							
Railroad Spur	461.5	278.00	***278.07***	***279.15***	***279.42***	***279.58***	***279.75***
Minnie Lou	3582.5	296.04	***296.77***	***296.94***	***297.14***	***297.07***	***297.22***
U.S. 69 (Downstream)	3918.5	302.16	299.04	299.37	29967	299.84	299.98

3.6 Comparison of FIS and Updated Flood Levels

Table 3-4 provides a comparision of FIS and updated 100-year flood levels for Mill Creek and Tributaries 1, 3, 5, and 7. As indicated in the table, updated flood levels are similar to or somewhat greater than FIS values at most locations. However, a few updated flood levels are lower than FIS values.

*

TABLE 3-4: COMPARISON OF 100-YEAR FLOOD LEVELS FROM FLOOD INSURANCE STUDY AND UPDATE STUDY

Location	FIS Flood Level (feet)	Updated Flood Level (feet)
Mill Creek (Called "Mill Creek Tributary" in FIS)		
Upstream of Lake Street	258.4	258.31
Upstream of Ellen Trout Lake Spillway	270.8	270.91
Upstream of Loop 287	273.8	274.28
Mill Creek East Branch (Called "Mill Creek Tributary" in FIS)		
Upstream of Railroad	274.3	274.90
Upstream of Martin Luther King Ave. (Called Lake Street in FIS)	281.0	280.68
Mill Creek West Branch (Called "Tributary to Mill Creek Tributary" in FIS)		
Upstream of Loop 287	273.8	274.27
Upstream of FM 2251 (Called "Sayers Street" in FIS)	281.6	278.94

4.

4. FUTURE CONDITIONS ANALYSIS

4.1 Purpose of the Ultimate Conditions Analysis

The purpose of the future conditions HEC-1 analysis described in this section of the report is to assess the effectiveness of regional detention facilities and other flood mitigation measures recommended for the Mill Creek watershed.

4.2 Goals of the Long-Term Drainage Improvement Plan

Major goals of the long-term drainage improvement plan for the Mill Creek watershed include the following.

- Prevent future increases in peak flow rates along Mill Creek and its various branches, thereby preventing future increases in the potential for flooding.
- Wherever possible, reduce the potential for flooding along Mill Creek and its branches by reducing flow rates, replacing inadequate cross-drainage structures, or improving existing waterways.
- Make the plan as cost-effective as possible. Minimize capital improvement costs and long-term maintenance costs.
- Create parks and green spaces wherever possible and where the creation of such areas is consistent with the other goals of the plan.
- Make it possible for future development to occur without undue financial burdens on industrial, commercial, or residential developers.
- Develop a plan that can be implemented in manageable pieces or segments.
- Avoid impacts on environmentally and culturally sensitive areas whenever possible. When this is not possible, mitigate impacts to the greatest extent possible under constraints of cost and time.
- Eliminate structural flooding (homes and businesses) for a 25-year to 100-year storm event.
- To the greatest extent possible, limit the boundaries and base flood elevations (BFEs) of the interim and ultimate 100-year flood plains to the boundaries and BFE's shown on currently effective Flood Insurance Rate Maps (FIRMs) for the City of Lufkin.

4.3 Planning Constraints

A number of planning constraints have been identified in the process of developing a drainage plan for the Mill Creek watershed. These constraints include the following.

- Soils in the area are sandy, and channel side slopes do not hold up well. Erosion will likely be a problem.
- Maintenance of improved channels will likely be expensive due to soil conditions. Side slopes should be no steeper than 4:1 wherever possible.
- Existing development in the southern portion of the watershed is extensive. Large detention sites will be difficult to locate and acquire.
- Existing development will make it difficult to obtain right-of-way along existing streams.
- The City of Lufkin's water plant is located immediately north of Ellen Trout Lake and west of Mill Creek. The plant will be affected by future increases in peak flow rates and flood levels in this area.

- Mill Creek and its various branches pass under Loop 287 and U.S. Highway 69. Coordination with TxDOT will be necessary if improvements to existing crossing structures are required.
- Portions of the Mill Creek watershed are outside the incorporated boundaries of the City of Lufkin. The City may not have complete control over developments, drainage improvements, etc. in these areas.
- Observations made during field visits indicate that there are significant wetlands along Mill Creek and its branches, especially in the areas where channel and overland slopes are relatively flat.

4.4 Cultural Resources and Wetlands Investigations

In order to identify significant natural and historical features in the Mill Creek watershed, cultural resources and wetlands investigations were completed. The cultural resources review, which also covers the Hurricane Creek watershed, was completed by Prewitt & Associates, Inc. of Austin, Texas. A copy of the report prepared by Prewitt & Associates, Inc. in connection with the Mill Creek flood planning study is attached as Appendix B to this report. The results of the cultural resources investigation indicate that the potential for damage to cultural sites in connection with the implementation of a drainage improvement plan in the Mill Creek watershed is minimal.

Wetlands investigations for the Mill Creek and Hurricane Creek watersheds were carried out by Wetland Technologies Corporation of Sugar Land, Texas. The results of the wetlands investigations indicate that there are significant wetlands along Mill Creek and its branches. Even in areas where wetlands may not be found, Mill Creek and its branches are considered to be "waters of the United States" and are subject to regulation by the U.S. Army Corps of Engineers. A copy of the report prepared by Wetland Technologies Corporation is attached as Appendix C to this report.

4.5 General Approach to Drainage Planning

Prior to the development of a drainage plan for the Mill Creek watershed, a number of general principles were developed to guide the planning effort. To the greatest possible extent, these principles have been adhered to in the development of the drainage improvement plan described in this section of the report. The planning principles are described in the following paragraphs.

- Avoid channelization on a large scale because of the difficulty and expense involved in obtaining right-of-way, the likelihood that channels would be difficult to maintain due to soil conditions in the area, the probable damage to existing wetlands, and the difficulty and expense associated with the procurement of the necessary permits.
- Focus on regional detention as the best overall solution for the Mill Creek watershed.
- To the greatest extent possible, create detention storage solely through the construction of dams across natural stream channels. Where necessary, supplement this natural storage through excavation within the boundaries of regional detention facilities.
- Include limited channelization in areas where flooding problems are especially significant and where there is sufficient room for an adequate right-of-way.
- To the greatest degree possible, minimize environmental impacts associated with channelization projects.
- Replace only those cross-drainage structures whose hydraulic capacity is substantially inconsistent with the capacities of upstream and downstream structures or whose physical condition is poor.

- Implement mandatory on-site detention policies only in areas where regional detention sites are not available or where downstream flooding conditions cannot be relieved through channelization.
- Focus drainage planning activities on areas within the incorporated boundaries of the City of Lufkin and areas in which existing drainage problems are significant. Do not attempt to significantly reduce flood plain widths or flood elevations in undeveloped areas.
- To the greatest extent possible, make the plan hydraulically, economically, environmentally, and politically feasible.

4.6 Description of Proposed Long-Term Drainage Improvements

Four (4) potential sites for regional detention facilities have been identified in the Mill Creek watershed. Exhibit 4.1 illustrates the location of each of these sites. Three of these sites are recommended for inclusion in the regional drainage plan. Basin #1 is not included in the plan due to the existence of high-quality wetlands on the proposed detention site and the relatively small amount of detention storage that may be created within the site. is strategically located at the confluence of Mill Creek and Tributary #3. Exhibits 4.2 through 4.5 provide more detailed views of the four potential detention sites.

In addition to regional detention, limited channelization is included in the future conditions drainage plan. Channelization is called for on the West Branch, East Fork of Mill Creek upstream of Regional Detention Basin #3 and on the East Branch of Mill Creek upstream of Regional Detention Basin #4. The extents of each of these channel improvement projects are indicated on Exhibit 4.1. Exhibits 4.6 and 4.7 provide some details on each of the stream segments in which channelization has been recommended as a flood mitigation measure.

New cross-drainage culverts are recommended for the Lake Street crossing of Mill Creek downstream of Ellen Trout Lake and for the Minnie Lou and U.S. 69 crossings of the West Branch, East Fork of Mill Creek. The recommended minimum culvert installation at the Lake Street crossing is three (3) 10' x 7' box culverts. The recommended minimum culvert installations at the Minnie Lou and U.S. 69 crossings are two (2) 54-inch concrete pipes and two (2) 48-inch concrete pipes, respectively.

Additional channel excavation projects originally included in the Mill Creek drainage plan were eliminated due to concerns involving existing wetlands. These projects included improvements to the East Branch of Mill Creek downstream of Martin Luther King Avenue. All channelization and regional detention projects included in the original draft drainage plan were reviewed by Wetland Technologies Corporation. A representative of WTC traveled to Lufkin and visited the locations that would be affected by the various channel improvement projects and detention facilities. Comments on most of the various improvement projects and detention facilities were summarized in a supplement to the original wetlands report prepared by WTC. A copy of the supplemental report is attached as Appendix D.

The final component in the drainage plan for the Mill Creek watershed is an on-site detention policy for the area designated WFK1. This area drains to the West Fork of the West Branch of Mill Creek upstream of U.S. Highway 69. The existing 10' x 6' box culvert under U.S. 69 is very long and is covered by a very high fill, making it extremely difficult and expensive to replace the culvert or to add a culvert at this location. The recommended on-site detention policy for sub-area WFK1 will eliminate the need to replace or upgrade the existing culvert at this location. At the same time, the on-site detention policy will prevent increases in ponding levels at the upstream end of the culvert. Because the culvert is so long, these increases can be significant. It is recommended, therefore, that the detention policy for sub-area WFK1 be strictly enforced and that no increases in peak flow rates be allowed at the U.S. Highway 69 crossing of the West Fork of the West Branch of Mill Creek.

4.7 Sub-Areas Used in the Ultimate Conditions HEC-1 Analysis

For the ultimate conditions HEC-1 analysis of the Mill Creek watershed, a separate sub-area has been established to represent the area draining to each of the ten potential regional detention sites. This is done to allow for an accurate accounting of storm runoff entering each of the regional detention facilities. A total of eighteen (18) sub-areas are included in the future conditions HEC-1 model of the Mill Creek watershed. Exhibit 4.8 illustrates the boundaries of each of the sub-areas included in the model.

4.8 SCS Curve Numbers

As indicated in Section 2 of this report, weighted SCS curve numbers have been determined for the fifteen sub-areas included in the existing conditions HEC-1 model of the Mill Creek watershed. Where one of these original sub-areas has been subdivided to create additional sub-watersheds, the curve number determined for the original sub-area is used for each of the smaller sub-areas. Future conditions curve numbers are identical to those used in the existing conditions analysis of the Mill Creek watershed.

4.9 Land Use Data & Impervious Cover Calculations

Existing land uses for the Mill Creek watershed have been divided into a number of categories. Recent aerial photographs have been used to determine the area of existing development which falls into those categories, each of which has a different average percentage of impervious cover. Assumptions regarding future development patterns have been established using information from the City of Lufkin Comprehensive Plan prepared in 1987 by Bucher Willis Ratliff. Exhibit 4.9 is a copy of the Future Conditions Land Use Map published in the City of Lufkin Comprehensive Plan. For each sub-area included in the future conditions HEC-1 analysis, the area of future development has been determined, and the expected average impervious cover associated with that development has been estimated. Land use breakdowns and impervious cover data for future conditions sub-areas are included in Appendix B to this report.

4.10 Future Conditions Times of Concentration & Storage Coefficients

The Clark unit hydrograph method requires that the user specify a time of concentration and a storage coefficient for each sub-area in the HEC-1 model of the Mill Creek watershed. The time of concentration is set equal to the time required for storm runoff to travel from the most hydraulically remote point in the sub-area to the outlet point. The storage coefficient is a relative measure of the amount of storage in the sub-area. Typically, the flatter the slopes in a particular watershed, the greater the surface and depression storage, and the greater the value of the storage coefficient. As slopes increase, the storage coefficient typically decreases. Because this inverse relationship is similar to the relationship between time of concentration and slope, the storage coefficient is frequently computed as follows:

$$R = K \times TC$$

where R is the storage coefficient, TC is the time of concentration, and K is a multiplier. The value of K typically ranges from 2.0 for relatively steep slopes to 3.0 for flatter slopes. For all sub-areas in the Mill Creek watershed, K is set equal to 2.0.

The time of concentration for each sub-area in the Mill Creek watershed is computed by dividing the distance over which storm runoff must travel by the flow velocity. Because flow velocities vary with flow conditions, the longest watercourse in each sub-area is divided into four segments: overland flow, shallow concentrated flow, paved or gully flow, and channel flow. Overland flow represents sheet flow at very shallow depths, and is limited in this study to no more than 300 feet of distance at the upstream end of each watercourse. Shallow concentrated flow takes over as storm runoff collects in shallow rills and swales, and flow depths increase to a few inches. Paved or gully flow reflects flow in curb-and-gutter streets, concrete-lined swales, and small gullies. Finally, channel flow represents the flow of flood waters through relatively large gullies and creeks illustrated on U.S. Geologic Survey 7.5-minute quadrangle maps using blue lines.

For existing conditions analyses of the Mill Creek watershed, velocities for overland flow, shallow concentrated flow, and paved or gully flow are estimated using the SCS Uplands Method, which relates flow condition and slope to flow velocity. For channel flow, an average flow velocity of 3.0 feet per second is used. For ultimate development conditions, the SCS Uplands Method is again used, but the condition assumed to apply to each segment in the watercourse is altered to reflect higher future flow velocities. The changes made are as follows.

1. For ultimate conditions overland flow, Uplands Method curves representing short grass pasture (or lawns) and paved areas are used for all sub-areas. For existing and interim conditions, curves representing woodland areas and short grass pasture were used. The switch from woodland/pasture to pasture/paved represents assumed changes in the watershed associated with development.
2. For ultimate conditions shallow concentrated flow, the Uplands Method curve representing paved areas was used. For existing and interim conditions shallow concentrated flow, the curve representing a grassed waterway was used.
3. For existing and interim conditions conditions flow in gullies, the Uplands Method curve for paved areas and small gullies was used to estimate flow velocities. For ultimate conditions, the Uplands Method velocities are increased by 2/3 (66%) to reflect assumed improvements to or clean-outs of small gullies and ravines.

Most major channels are assumed to remain in their existing condition. For the unimproved channels, the average future conditions flow velocity is assumed to remain at 3.0 feet per second. For those channel segments where improvements are proposed, the channel velocity is assumed to increase from 3.0 feet per second to 4.0 or 5.0 feet per second, depending on the type and extent of the improvement. The impervious cover of all sub-areas is adjusted to account for future development. Detailed time of concentration calculations for each sub-area included in the ultimate conditions Mill Creek HEC-1 model are provided in Appendix B to this report.

4.11 Summary of Future Conditions Hydrologic Parameters

Table 4-1 provides a summary of the hydrologic modeling data used to represent the forty (40) sub-areas included in the Mill Creek HEC-1 computer model for conditions of ultimate watershed development. Data shown in italicized print indicate sub-areas for which on-site detention is recommended.

TABLE 4-1: FUTURE CONDITIONS HEC-1 PARAMETERS FOR MILL CREEK SUB-AREAS					
Sub-Area	Drainage Area (acres)	SCS Curve Number	Impervious Cover (%)	Time of Concentration (hours)	Storage Coefficient (hours)
JONES	94	65	43.0	0.17	0.35
EBR1A	43	60	45.7	0.23	0.46
EBR1B	157	62	49.5	0.27	0.55
EBR1C1	41	61	75.7	0.18	0.36
EBR1C2	72	61	80.0	0.15	0.31
EBR1D	31	63	20.9	0.15	0.30
MYRIAD	89	64	31.5	0.13	0.25
EBR2A	50	65	68.9	0.09	0.18
EBR2B	125	71	47.4	0.36	0.72
WFK1	***356***	***63***	***13.0***	***0.31***	***0.62***
WFK2A	282	68	78.7	0.46	0.91
WFK2B	62	68	78.0	0.23	0.45
EFK1	109	66	55.4	0.35	0.70
EFK2	171	62	43.4	0.34	0.68
EFK3A	46	67	80.0	0.19	0.37
EFK3B	21	67	80.0	0.15	0.30
CITY	164	65	83.1	0.19	0.39
DNSTM	273	65	79.1	0.48	0.96

4.12 Streamflow Routing Data

Because most of the major streams in the Mill Creek watershed are assumed to remain basically unchanged, the streamflow routing data used in the ultimate conditions analysis is in most cases identical to that used in the existing and interim conditions analyses. However, there are some reaches in which channelization is called for, where an existing cross-drainage structure is proposed to be replaced, or where an adjustment is needed to reflect the presence of a detention facility. Table 4-2 summarizes the future conditions routing data used for Mill Creek and its tributaries.

TABLE 4-2: FUTURE CONDITIONS STORAGE ROUTING DATA FOR MILL CREEK									
Reach #1: Jones Lake to East Branch									# Steps
Flow Rate (cfs)	0	40	80	120	160	200	240		
Volume (ac-ft)	0	1	2	3	4	5	6		1
Reach #2: East Branch, Basin #4 to MLK									# Steps
Flow Rate (cfs)	0	120	240	360	480	600	720		
Volume (ac-ft)	0	4	6	9	13	17	19		2
Reach #3: MLK to Ellen Trout Lake									# Steps
Flow Rate (cfs)	0	172	344	516	688	860	1032		
Volume (ac-ft)	0	27	50	56	63	68	73		4
Reach #4a: West Branch, West Fork, US 69 to Basin #2									# Steps
Flow Rate (cfs)	0	200	400	600	800	1000	1200		
Volume (ac-ft)	0	10	19	29	39	52	67		3
Reach #4b: West Branch, West Fork, Basin #2 to East Fork Confluence									# Steps
Flow Rate (cfs)	0	200	400	600	800	1000	1200		
Volume (ac-ft)	0	4	11	15	22	27	31		2
Reach #5: West Branch, East Fork, Basin 3 to Confl.									# Steps
Flow Rate (cfs)	0	120	240	360	480	600	720		
Volume (ac-ft)	0	9	18	25	32	36	41		1
Reach #6: West Branch, West Fork, Confl. to City Lake									# Steps
Flow Rate (cfs)	0	340	680	1020	1360	1700	2040		
Volume (ac-ft)	0	15	31	46	61	77	86		2
Reach #7: Ellen Trout Lake to Downstream Confluence									# Steps
Flow Rate (cfs)	0	520	1040	1560	2080	2600	3120		
Volume (ac-ft)	0	3	7	10	13	15	17		1

4.13 HEC-1 Analysis of Regional Detention Facilities

Each of the detention facilities included in the Mill Creek drainage plan is represented using a modified Puls storage routing step. Elevation vs. storage volume data for each basin are entered on SE and SV records. Low-level and weir outlet data are entered on SL and SS records, respectively. The low-level outlet option of the HEC-1 program computes discharges using the standard orifice equation:

$$Q = CA(2gH)^{0.5}$$

where: Q = low-level outlet discharge rate (cfs)

C = an orifice flow coefficient

A = the cross-sectional area of the orifice opening (square feet)

g = the acceleration of gravity (32.2 ft/sec^2)

H = the difference between the basin water surface elevation and the elevation at the centroid of the orifice (feet).

The weir option of the program computes discharges using the standard weir equation:

$$Q = CLH^{1.5}$$

where: Q = weir discharge rate (cfs)

L = weir crest length (feet)

H = the difference between the basin water surface elevation and the weir crest elevation (feet).

Tables 4-3 and 4-4 provide a summary of the HEC-1 routing data used to simulate each of the regional detention facilities.

TABLE 4-3: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #2 (With 21 Acre-Feet of Excavation)		***Basin #3 (With 20 Acre-Feet of Excavation)***	
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
278	0.0	278	0.0
280	1.1	280	1.6
282	3.3	282	6
284	10.3	284	20
286	27	286	41
288	52	288	70
290	86	290	110
292	131	-----	-----
294	176	----	-----
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	12.6	Orifice Area (ft^2)	12.6
Centroid Elevation (ft)	280.0	Centroid Elevation (ft)	280.0
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	290.0	Crest Elevation (feet)	287.0
Crest Length (feet)	80	Crest Length (feet)	30
Weir Coefficient	2.6	Weir Coefficient	2.6

TABLE 4-4: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #4 (No Excavation)			
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
278	0.0	-----	-----
280	0.9	-----	-----
282	3.5	-----	-----
284	8.6	-----	-----
286	17.0	-----	-----
288	30.8	-----	-----
290	50.3	-----	-----
292	75.9		
294	109.3	-----	-----
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	12.6	Orifice Area (ft^2)	-----
Centroid Elevation (ft)	280.0	Centroid Elevation (ft)	-----
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	290.0	Crest Elevation (feet)	-----
Crest Length (feet)	30	Crest Length (feet)	-----
Weir Coefficient	2.6	Weir Coefficient	2.6

4.14 Regional Detention Routing Results

Table 4-5 provides a summary of computed routing results for each of the detention facilities included in the ultimate conditions HEC-1 model.

TABLE 4-5: SUMMARY OF COMPUTED DETENTION ROUTING RESULTS			
Parameter	Basin #2	Basin #3	Basin #4
10-Year Storm Event			
Peak Inflow (cfs)	943	684	572
Peak Discharge (cfs)	379	175	184
Maximum Elevation (feet)	290.86	287.24	289.27
100-Year Storm Event			
Peak Inflow (cfs)	1519	1071	966
Peak Discharge (cfs)	1029	405	421
Maximum Elevation (feet)	292.45	288.97	291.94

4.15 Comparison of Existing and Future Conditions HEC-1 Results

Tables 4-6 and 4-7 provide a summary of computed 10-year and 100-year peak flow rates at a number of strategic points in the Mill Creek watershed. Exhibit 4.8 illustrates the locations of the computation points described in the table. As indicated in the tables, the recommended regional detention facilities and on-site detention policy keep future conditions peak flow rates at or below existing conditions levels at nearly all locations along Mill Creek and its tributaries. Increases in peak flow rates above existing conditions values occur at only a few isolated locations. Of the increases in peak flow rates, the only ones of real concern are those occurring on Tributary #6 and Tributary #7. These increases occur in spite of the recommendation for on-site detention in sub-areas HCT6A, HCT6B, HCT7A, and HCT7C. These results indicate that careful regulation of future development in the watersheds of Tributary #6 and Tributary #7 will be necessary.

It is important to note that the implementation of the recommended regional detention plan will not eliminate flooding in Lufkin. It will, however, achieve the following goals.

- It will allow for full development of the Mill Creek watershed without worsening flooding problems.
- It will provide some reductions in existing flood levels along Mill Creek and its tributaries.
- It will allow future development without an on-site detention requirement for much of the watershed.
- Impacts on existing wetlands are minimized to the greatest extent possible.
- It will provide additional park space and recreational areas for the City of Lufkin.

TABLE 4-6: COMPARISON OF COMPUTED 10-YEAR PEAK FLOW RATES

Location	Existing 10-Year	Future 10-Year
Jones Lake Inflow	200	261
Jones Lake Discharge	87	107
East Branch, West Fork at East Fork Confluence	110	141
East Branch D/S of West Fork - East Fork Confl.	304	458
East Branch U/S of Martin Luther King Drive	401	355
Lake Myriad Inflow	228	256
Lake Myriad Discharge	40	41
East Branch D/S of Martin Luther King Drive	450	438
East Branch at Railroad Spur	385	301
East Branch at Loop 287	467	499
West Branch, West Fork at U.S. 69	557	557
West Branch, West Fork at East Fork Confluence	657	384
West Branch, East Fork U/S of Confluence	185	321
West Branch, East Fork D/S of Confluence	328	550
West Branch, East Fork at Mouth	269	169
West Branch D/S of West Fork - East Fork Confl.	926	553
Ellen Trout Lake at Upstream End	1345	856
Ellen Trout Lake Inflow	1410	1299
Ellen Trout Lake Discharge	1321	1010
Downstream Limit of Study	1457	1471

TABLE 4-7: COMPARISON OF COMPUTED 100-YEAR PEAK FLOW RATES

Location	Existing 100-Year	Future 100-Year
Jones Lake Inflow	326	410
Jones Lake Discharge	195	226
East Branch, West Fork at East Fork Confluence	248	291
East Branch D/S of West Fork - East Fork Confl.	592	796
East Branch U/S of Martin Luther King Drive	731	514
Lake Myriad Inflow	373	415
Lake Myriad Discharge	80	84
East Branch D/S of Martin Luther King Drive	852	657
East Branch at Railroad Spur	891	573
East Branch at Loop 287	1102	842
West Branch, West Fork at U.S. 69	992	992
West Branch, West Fork at East Fork Confluence	1202	1039
West Branch, East Fork U/S of Confluence	339	519
West Branch, East Fork D/S of Confluence	593	873
West Branch, East Fork at Mouth	503	367
West Branch D/S of West Fork - East Fork Confl.	1700	1394
Ellen Trout Lake at Upstream End	2534	1961
Ellen Trout Lake Inflow	2676	2052
Ellen Trout Lake Discharge	2587	1985
Downstream Limit of Study	2878	2308

4.16 Comparison of Existing and Future Conditions Flood Levels

4.16.1 Discussion of Future Conditions HEC-RAS Analysis

For future conditions analyses, existing conditions HEC-RAS models are revised to reflect channelization, structure replacements, relief channels, regional detention facilities, and future conditions flow rates. The resulting HEC-RAS models are used to compute future conditions flood levels along Mill Creek and all tributaries. The following sections describe the results of a comparison of existing and future conditions HEC-RAS analyses.

4.16.2 Future Conditions HEC-RAS Results for Mill Creek

Table 4-8 provides a summary of computed future conditions water surface elevations for Mill Creek and its various branches. Elevations are given at the upstream side of each of the roadways which cross Mill Creek and its branches. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. Exhibits 4.10 through 4.15 illustrates computed future conditions stream profiles for Mill Creek and its branches.

TABLE 4-8: SUMMARY OF FUTURE FLOOD LEVELS ALONG MILL CREEK							
Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation 5-Year	10-Year	25-Year	50-Year	100-Year
Mill Creek							
Lake Street	60.5	255.50	***256.28***	***256.73***	***257.13***	***257.54***	***257.94***
Ellen Trout Lake Dam	606	-----	269.47	269.67	269.99	270.23	270.54
E. Trout Zoo Railroad	2330.5	273.10	269.53	269.78	270.22	270.65	271.25
Loop 287	3741.5	274.28	271.40	271.75	272.32	272.79	273.44
East Branch							
Railroad Spur	818.5	273.80	272.74	273.75	***274.12***	***274.23***	***274.40***
Private Road	1784.5	277.60	***278.59***	***278.69***	***278.77***	***278.84***	***278.91***
East Branch, East Fork							
Martin Luther King	1.5	280.40	279.11	279.54	280.16	***280.55***	***280.72***
Martin Luther King	3781	303.00	301.38	302.18	302.79	303.13	303.27
West Branch							
FM 2251	2225.5	278.80	275.81	276.59	278.14	277.54	277.99
West Branch, West Fork							
Railroad Spur	4333.5	299.00	***299.89***	***300.25***	***300.56***	***300.80***	***301.07***
U.S. 69	4940.5	325.94	305.56	307.12	309.13	311.02	313.34
West Branch, East Fork							
Railroad Spur	461.5	278.00	277.75	***278.25***	***279.25***	***279.43***	***279.68***
Minnie Lou	3582.5	296.04	***296.75***	***296.94***	***297.11***	***297.21***	***297.28***
U.S. 69 (Downstream)	3918	302.16	297.51	297.82	298.13	298.34	298.55

Table 4-9 provides a comparison between 10-year and 100-year flood levels computed for existing and future conditions. As indicated, 10-year flood levels along Mill Creek and its various branches are reduced by as much as 1.55 feet with the proposed drainage plan in place. The maximum reduction in 100-year flood levels is 1.43 foot. Small residual increases are computed at only a few locations.

TABLE 4-9: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG MILL CREEK AND ITS VARIOUS BRANCHES

Location	HEC-RAS Cross-Section	Computed Water Surface Elevations					
		Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
Mill Creek							
Lake Street	60.5	257.22	256.73	-0.49	258.31	257.94	-0.37
Ellen Trout Lake Dam	606	270.09	269.67	-0.42	270.91	270.54	-0.37
E. Trout Zoo Railroad	2330.5	270.26	269.78	-0.48	271.77	271.25	-0.52
Loop 287	3741.5	272.50	271.75	-0.75	274.28	273.44	-0.84
East Branch							
Railroad Spur	818.5	274.33	273.75	-0.58	274.90	274.40	-0.50
Private Road	1784.5	278.74	278.69	-0.05	279.09	278.91	-0.18
East Branch, East Fork							
Martin Luther King	1.5	279.42	279.54	**+0.12**	280.68	280.72	**+0.04**
Martin Luther King	3781	301.85	302.18	**+0.33**	303.15	303.27	**+0.12**
West Branch							
FM 2251	2225.5	278.47	276.59	-1.88	278.94	277.99	-0.95
West Branch, West Fork							
Railroad Spur	4333.5	300.25	300.25	0.00	301.14	301.07	-0.07
U.S. 69	4940.5	307.11	307.12	**+0.01**	313.51	313.34	-0.17
West Branch, East Fork							
Railroad Spur	461.5	279.15	278.25	-0.90	279.75	279.68	-0.07
Minnie Lou	3582.5	296.94	296.94	0.00	297.22	297.28	**+0.06**
U.S. 69 (Downstream)	3918	299.37	297.82	-1.55	299.98	298.55	-1.43

4.17 Preliminary Cost Estimates for Drainage Improvements

Preliminary estimates of construction costs for regional detention facilities and channelization projects are included in Appendix G to this report. Cost estimates for detention basins include the following cost items:

- land acquisition;
- excavation, haul and compaction for dam construction;
- principal discharge structure;
- emergency spillway;
- storage excavation and haul;
- engineering and surveying;
- 15% contingency.

Cost estimates for channelization projects include the following items:

- right-of-way acquisition;
- excavation and haul for channel excavation;
- slope stabilization;
- engineering and surveying;
- 15% contingency.

Culvert replacement costs are estimated separately. Potential costs associated with wetlands mitigation requirements are not included in the cost estimates due to uncertainties regarding the actual extent and quality of wetlands that may be impacted by individual improvement projects. Table 4-9 provides a summary of the estimated construction costs associated with each of the major components of the recommended drainage plan for the Mill Creek watershed.

TABLE 4-9: ESTIMATED CONSTRUCTION COSTS FOR RECOMMENDED DRAINAGE PLAN

Drainage Plan Component	***Estimated Cost***
Regional Detention Basin #2	$1,827,400
Regional Detention Basin #3	$1,070,000
Regional Detention Basin #4	$917,300
Channelization, East Branch, East Fork, MLK to Basin #4	$89,500
Channelization, West Branch, East Fork, US 69 to Basin #3	$111,900
Culverts, West Branch, East Fork @ Minnie Lou	$24,000
Culverts, West Branch, East Fork @ U.S. 69	$21,000
Culverts, Mill Creek at Lake Street (Water Plant Access Road)	$94,500

5. INTERIM CONDITIONS ANALYSIS

5.1 Purpose of Interim Conditions Analysis

The purpose of the interim conditions analysis described in this section of the report is to assess the effectiveness of near-term drainage improvements recommended for the Mill Creek watershed.

5.2 Description of Proposed Near-Term Drainage Improvements

The near-term drainage improvement recommended for the Mill Creek watershed consists of a single regional detention facility, Regional Basin #2. This facility has been selected from the four potential regional detention sites identified in the Mill Creek watershed as the site with the g. The location, size, and shape of each of this basin are illustrated on Exhibit 4.3.

For interim conditions, the detention storage in Basin #2 is assumed to be created solely through the construction of a dam. No excavation is called for, with the exception of the earth required to construct the dam.

5.3 Preliminary Construction Cost Estimates for Interim Detention

A preliminary estimate of the construction cost associated with the initial development of Basin #2 is included in Appendix H to this report. The estimate includes the following cost items:

- land acquisition;
- excavation, haul and compaction for dam construction;
- principal discharge structure;
- emergency spillway;
- surveying and engineering;
- 15% contingency.

Potential costs associated with wetlands mitigation requirements are not included in the cost estimates due to uncertainties regarding the actual extent and quality of wetlands that may be impacted by the construction of the Basin #2 dam.

The estimated cost for Basin #2 is $1,603,400 with no storage excavation included. An additional cost not included in this estimate would involve possible adjustments to the railroad spur which passes through the proposed regional detention site. If periodic inundation of the spur is not acceptable, elevation or realignment of the railway embankment may be required.

5.4 HEC-1 Analysis of Near-Term Drainage Improvements

The existing conditions HEC-1 model of the Mill Creek watershed described in Section 2 of this report is used as the basis for the interim conditions analysis. For the purposes of the interim conditions analysis, the existing conditions model is modified through the introduction of storage routing data for the proposed detention basin, the creation of an additional sub-area to accurately reflect the area draining into the detention facility, and adjustments to streamflow routing data to account for detention facility construction. No other changes are made to the existing conditions HEC-1 model.

The proposed detention facility is represented using a modified Puls storage routing step. Elevation vs. storage volume data based on natural ground contours within Basin #2 are entered along with low-level outlet data and weir data on SL and SS records, respectively. The low-level outlet option of the HEC-1 program computes discharges using the standard orifice equation:

$$Q = CA(2gH)^{0.5}$$

where: Q = low-level outlet discharge rate (cfs)

C = an orifice flow coefficient

A = the cross-sectional area of the orifice opening (square feet)

g = the acceleration of gravity (32.2 ft/sec^2)

H = the difference between the basin water surface elevation and the elevation at the centroid of the orifice (feet).

The weir option of the program computes discharges using the standard weir equation:

$$Q = CLH^{1.5}$$

where: Q = weir discharge rate (cfs)

L = weir crest length (feet)

H = the difference between the basin water surface elevation and the weir crest elevation (feet).

Table 5-1 provides a summary of the HEC-1 routing data used to simulate each of the detention facilities.

TABLE 5-1: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #2 (No Excavation for Interim Conditions)			
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
278	0.0	-----	-----
280	1.1	-----	-----
282	3.3	-----	-----
284	10.3	-----	-----
286	24.6	-----	-----
288	46.3	-----	-----
290	73.6	-----	-----
292	109.5	-----	-----
294	155.5	----	-----
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	12.6	Orifice Area (ft^2)	-----
Centroid Elevation (ft)	280.0	Centroid Elevation (ft)	-----
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	290.0	Crest Elevation (feet)	-----
Crest Length (feet)	80	Crest Length (feet)	-----
Weir Coefficient	2.6	Weir Coefficient	2.6

5.5 Summary of Interim Conditions HEC-1 Results

Tables 5-2 and 5-3 provide a comparison of computed existing and interim conditions 10-year and 100-year peak flow rates at a number of strategic points in the Mill Creek watershed. Exhibit 5.1 illustrates the locations of the computation points described in the tables.

TABLE 5-2: COMPARISON OF COMPUTED 10-YEAR PEAK FLOW RATES		
Location	Existing 10-Year	Interim 10-Year
Jones Lake Inflow	200	200
Jones Lake Discharge	87	87
East Branch, West Fork at East Fork Confluence	110	110
East Branch D/S of West Fork - East Fork Confl.	304	304
East Branch U/S of Martin Luther King Drive	401	401
Lake Myriad Inflow	228	228
Lake Myriad Discharge	40	40
East Branch D/S of Martin Luther King Drive	450	450
East Branch at Railroad Spur	385	385
East Branch at Loop 287	467	467
West Branch, West Fork at U.S. 69	557	557
West Branch, West Fork at East Fork Confluence	657	291
West Branch, East Fork U/S of Confluence	185	185
West Branch, East Fork D/S of Confluence	328	328
West Branch, East Fork at Mouth	269	269
West Branch D/S of West Fork - East Fork Confl.	926	496
Ellen Trout Lake at Upstream End	1345	952
Ellen Trout Lake Inflow	1410	1017
Ellen Trout Lake Discharge	1321	964
Downstream Limit of Study	1457	1103

TABLE 5-3: COMPARISON OF COMPUTED 100-YEAR PEAK FLOW RATES		
Location	Existing 100-Year	Interim 100-Year
Jones Lake Inflow	326	326
Jones Lake Discharge	195	195
East Branch, West Fork at East Fork Confluence	248	248
East Branch D/S of West Fork - East Fork Confl.	592	592
East Branch U/S of Martin Luther King Drive	731	731
Lake Myriad Inflow	373	373
Lake Myriad Discharge	80	80
East Branch D/S of Martin Luther King Drive	852	852
East Branch at Railroad Spur	891	891
East Branch at Loop 287	1102	1102
West Branch, West Fork at U.S. 69	992	992
West Branch, West Fork at East Fork Confluence	1202	939
West Branch, East Fork U/S of Confluence	339	339
West Branch, East Fork D/S of Confluence	593	593
West Branch, East Fork at Mouth	503	503
West Branch D/S of West Fork - East Fork Confl.	1700	1403
Ellen Trout Lake at Upstream End	2534	2109
Ellen Trout Lake Inflow	2676	2215
Ellen Trout Lake Discharge	2587	2164
Downstream Limit of Study	2878	2416

Table 5-5 provides a summary of computed routing results for each of the three detention facilities included in the interim conditions HEC-1 model.

TABLE 5-4: SUMMARY OF INTERIM CONDITIONS DETENTION ROUTING RESULTS			
Parameter	Basin #2	Basin #3	Basin #4
10-Year Storm Event			
Peak Inflow (cfs)	769	-----	-----
Peak Discharge (cfs)	284	-----	-----
Maximum Elevation (feet)	290.51	-----	-----
100-Year Storm Event			
Peak Inflow (cfs)	1347	-----	-----
Peak Discharge (cfs)	927	-----	-----
Maximum Elevation (feet)	292.24	-----	-----

5.6 Summary of Interim Conditions HEC-RAS Modeling Results

5.6.1 Discussion of Interim Conditions HEC-RAS Analysis

The proposed interim conditions drainage improvements will affect only Mill Creek and the West Fork of the West Branch. Flow rates for these streams are adjusted to account for the presence of Regional Detention Basin #2. All other data used in the interim conditions analysis for Mill Creek and the West Branch, West Fork are identical to existing conditions data. For the other branches of Mill Creek, all interim conditions HEC-RAS modeling data is identical to existing conditions data.

5.6.2 Interim Conditions HEC-RAS Results for Mill Creek

Table 5-5 provides a summary of computed interim conditions water surface elevations for Mill Creek and its various branches. Elevations are given at the upstream side of each of the roadways which cross Mill Creek and its branches. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. Exhibits 5.2 through 5.4 illustrate computed interim conditions stream profiles for Mill Creek, the West Branch of Mill Creek, and the West Fork of the West Branch.

TABLE 5-5: SUMMARY OF INTERIM FLOOD LEVELS ALONG MILL CREEK							
	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation				
Location			5-Year	10-Year	25-Year	50-Year	100-Year
Mill Creek							
Lake Street	60.5	255.50	255.70	256.73	257.30	257.78	258.02
Ellen Trout Lake Dam	606	-----	269.50	269.75	270.07	270.37	270.68
E. Trout Zoo Railroad	2330.5	273.10	269.54	269.83	270.22	270.75	271.29
Loop 287	3741.5	274.28	271.51	271.92	272.47	273.03	273.70
East Branch							
Railroad Spur	818.5	273.80	272.55	274.38	274.84	274.96	275.08
Private Road	1784.5	277.60	278.44	278.63	278.90	278.94	279.10
East Branch, East Fork							
Martin Luther King	1.5	280.40	278.85	279.34	280.15	280.54	280.70
Martin Luther King	3781	303.00	301.05	301.85	302.42	302.94	303.15
West Branch							
FM 2251	2225.5	278.80	275.88	276.30	278.24	278.45	278.68
West Branch, West Fork							
Railroad Spur	4333.5	299.00	299.91	300.22	300.58	300.89	301.14
U.S. 69	4940.5	325.94	305.54	307.12	309.13	310.98	313.51
West Branch, East Fork							
Railroad Spur	461.5	278.00	277.72	278.29	279.37	279.63	279.73
Minnie Lou	3582.5	296.04	296.72	296.95	297.03	297.20	297.24
U.S. 69 (Downstream)	3918.5	302.16	299.05	299.39	299.69	299.86	300.03

Table 5-6 provides a comparison between 10-year and 100-year flood levels computed for existing and interim conditions. As indicated, 10-year flood levels along Mill Creek and its various branches are reduced by as much as 2.17 feet with the proposed regional detention facilities in place. The maximum reduction in 100-year flood levels is 0.58 foot.

TABLE 5-6: COMPARISON OF EXISTING & INTERIM FLOOD LEVELS ALONG MILL CREEK AND ITS VARIOUS BRANCHES							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Interim 10-Year	Change	Existing 100-Year	Interim 100-Year	Change
Mill Creek							
Lake Street	60.5	257.22	256.73	-0.49	258.31	258.02	-0.29
Ellen Trout Lake Dam	606	270.09	269.75	-0.34	270.91	270.68	-0.23
E. Trout Zoo Railroad	2330.5	270.26	269.83	-0.43	271.77	271.29	-0.48
Loop 287	3741.5	272.50	271.92	-0.58	274.28	273.70	-0.58
East Branch							
Railroad Spur	818.5	274.33	274.38	**+0.05**	274.90	275.08	**+0.18**
Private Road	1784.5	278.74	278.63	-0.11	279.09	279.10	**+0.01**
East Branch, East Fork							
Martin Luther King	1.5	279.42	279.34	-0.08	280.68	280.70	**+0.02**
Martin Luther King	3781	301.85	301.85	0.00	303.15	303.15	0.00
West Branch							
FM 2251	2225.5	278.47	276.30	-2.17	278.94	278.68	-0.26
West Branch, West Fork							
Railroad Spur	4333.5	300.25	300.22	-0.03	301.14	301.14	0.00
U.S. 69	4940.5	307.11	307.12	**+0.01**	313.51	313.51	0.00
West Branch, East Fork							
Railroad Spur	461.5	279.15	278.29	-0.86	279.75	279.73	-0.02
Minnie Lou	3582.5	296.94	296.95	**+0.01**	297.22	297.24	**+0.02**
U.S. 69 (Downstream)	3918.5	299.37	299.39	**+0.02**	299.98	300.03	**+0.05**

5.7 Interim Conditions Floodway Computations

Interim conditions floodway data have been computed for Mill Creek and all studied branches. Floodway method 4, which establishes floodway encroachments based on an equal loss of flow conveyance on each side of a stream channel, is used for preliminary floodway computations. Floodway Method 1, which relies on the modeler to input floodway encroachments, is used for final floodway computations on Mill Creek and all tributary streams. Method 1 floodway encroachments are based on Method 4 results, with adjustments made where appropriate to avoid oscillations in floodway widths, provide consistency in floodway data at roadway crossings, etc. Surcharge values are kept at or below 1.00 foot at all cross-sections.

5.8 Interim Conditions Flood Plain & Floodway Mapping

Flood plain and floodway boundaries for interim conditions are illustrated on Exhibit 5.5. Also illustrated on this exhibit are interim conditions base flood elevations, which are indicated with a "tick" mark across the channel and a number signifying the computed 100-year flood level.

LIST OF EXHIBITS

LIST OF APPENDICES

A. Existing Conditions Hydrologic Parameters for Mill Creek Sub-Areas
B. Cultural Resources Report Prepared by Prewitt & Associates, Inc.
C. Wetlands Investigation Report Prepared by Wetland Technologies Corporation
D. Supplemental Report Prepared by Wetland Technologies Corporation
E. Ultimate Conditions Hydrologic Parameters for Mill Creek Sub-Areas
F. Interim Conditions Hydrologic Parameters for Mill Creek Sub-Areas
G. Preliminary Construction Cost Estimates, Future Conditions Drainage Improvements
H. Preliminary Construction Cost Estimates, Interim Conditions Drainage Improvements

LIST OF REFERENCES AND DATA SOURCES

1. Field Survey Data for Mill Creek and Tributaries, Provided by Everett Griffith Jr. & Associates, Inc. *Soil Survey of Angelina County, Texas*
2. U.S. Geological Survey "Lufkin," "Keltys," "Clawson," and "Redland" 7.5-Minute Quadrangle Maps
3. *Flood Insurance Study for the City of Lufkin, Texas.*
4. Aerial Topographic Maps Developed by United Aerial Mapping, Inc.
5. *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* (U.S. Weather Bureau Technical Paper No. 40)
6. *Five- to 60-Minute Precipitation Frequency for the Eastern and Central United States* (NOAA Technical Memorandum NWS HYDRO-35)
7. *SCS National Engineering Handbook*, Section 4.
8. *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (U.S. Geologic Survey Water-Supply Paper 2339)

CALCULATION OF Tc USING VELOCITY METHOD
MILL CREEK WATERSHED
EXISTING WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	JONES	EBR1A	EBR1B	EBR1C	EBR1D	MYRAD	EBR2A	EBR2B
			Parameter Values for Given Sub-Area Number							
Drainage Area										
Area		ac	94	43	157	113	31	89	50	125
Area		sm	.147	.067	.245	.177	.048	.139	.078	.195
Impervious Cover										
Land Use	I(%)									
Lakes	100%	ac	7.8	.0	.0	.0	.0	14.5	.0	.0
Ind./Comm.	80%	ac	13.4	8.1	20.1	44.3	.0	5.6	7.0	1.4
Multi-Family	70%	ac	.0	7.5	.0	6.2	.0	.0	.0	.0
Highway	60%	ac	.0	.0	.9	.0	.0	.0	5.0	3.7
Community	40%	ac	.0	.0	.0	.0	.0	3.4	.0	.0
S-F (Typical)	30%	ac	46.4	3.8	68.3	2.3	.0	11.7	.0	6.7
S-F (Light)	15%	ac	.0	.0	.0	.0	.0	.0	.0	.0
Golf Course	5%	ac	.0	1.0	.0	.0	24.2	47.8	6.1	39.1
Future Development		ac	26.2	22.8	67.4	60.2	6.5	6.3	32.1	74.4
Future Impervious		%	0%	0%	0%	0%	0%	0%	0%	0%
Total		ac	93.8	43.2	156.7	113.0	30.7	89.3	50.2	125.3
Imperv. Area		ac	32.4	12.9	37.1	40.5	1.2	26.2	8.9	7.3
Imperv. Cover		%	34.6	29.9	23.7	35.8	3.9	29.4	17.7	5.8
Overland		Curve:	C	B	C	C	C	C	C	B
Distance		ft	200	200	100	200	200	200	200	200
Slope		%	1.4	5.0	2.9	1.5	5.0	2.0	6.7	4.0
Velocity		ft/s	.8	1.1	1.2	.9	1.6	1.0	1.8	1.0
Travel Time		min	4.17	3.03	1.39	3.70	2.08	3.33	1.85	3.33
Shallow Concentrated		Curve:	F	F	F	F	F	F	F	F
Distance		ft	0	500	0	500	600	300	400	300
Slope		%	.0	6.0	.0	3.0	5.0	2.0	5.0	4.0
Velocity		ft/s	.0	3.7	.0	2.6	3.4	2.1	3.4	3.0
Travel Time		min	.00	2.25	.00	3.21	2.94	2.38	1.96	1.67
Paved or Gully		Curve:	G	G	G	G	G	G	G	G
Distance		ft	1500	0	3600	400	1100	1000	800	4500
Slope		%	1.4	.0	1.4	5.0	1.5	4.3	4.0	1.5
Velocity		ft/s	2.4	.0	2.4	4.5	2.4	4.1	4.0	2.5
Adjusted Velocity		ft/s	2.40	.00	2.40	4.50	2.40	4.10	4.00	2.50
Travel Time		min	10.42	.00	25.00	1.48	7.64	4.07	3.33	30.00
Improved Drainage Channel										
Distance		ft	0	0	0	0	0	0	0	0
Velocity		ft/s	.0	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel										
Distance		ft	0	1800	0	1900	0	0	1000	0
Velocity		ft/s	.0	3.0	.0	3.0	.0	.0	3.0	.0
Travel Time		min	.00	10.00	.00	10.56	.00	.00	5.56	.00
TC (minutes)			14.58	15.28	26.39	18.95	12.66	9.78	12.70	35.00
TC (hours)			.24	.25	.44	.32	.21	.16	.21	.58
R = 2 x TC (hours)			.49	.51	.88	.63	.42	.33	.42	1.17

CALCULATION OF Tc USING VELOCITY METHOD
MILL CREEK WATERSHED
EXISTING WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	WFK1	WFK2	EFK1	EFK2	EFK3	CITY	DNSTM
			Parameter Values for Given Sub-Area Number						
Drainage Area									
Area		ac	356	344	109	171	72	164	273
Area		sm	.556	.538	.170	.267	.113	.256	.427
Impervious Cover									
Land Use	I(%)								
Lakes	100%	ac	.0	.0	.0	.0	.0	37.2	.0
Ind./Comm.	80%	ac	31.6	6.4	4.6	3.2	5.2	6.1	28.7
Multi-Family	70%	ac	.0	.0	.0	.0	.0	.0	.0
Highway	60%	ac	12.7	18.0	.0	.0	.0	.0	6.5
Community	40%	ac	.0	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	44.4	6.2	20.0	61.4	4.4	4.7	2.4
S-F (Light)	15%	ac	.0	.0	.0	.0	.0	.0	.0
Golf Course	5%	ac	.0	.0	.0	.0	.0	.0	.0
Future Development		ac	267.2	313.6	84.8	106.1	62.3	116.1	235.3
Future Impervious		%	0%	0%	0%	0%	0%	0%	0%
Total		ac	355.9	344.2	109.4	170.7	71.9	164.1	272.9
Imperv. Area		ac	46.2	17.8	9.7	21.0	5.5	43.5	27.6
Imperv. Cover		%	13.0	5.2	8.8	12.3	7.6	26.5	10.1
Overland		Curve:	C	C	B	B	B	C	C
Distance		ft	200	300	300	300	200	300	300
Slope		%	4.0	4.0	2.5	2.0	6.7	2.0	2.0
Velocity		ft/s	1.4	1.4	.8	.7	1.3	1.0	1.0
Travel Time		min	2.38	3.57	6.25	7.14	2.56	5.00	5.00
Shallow Concentrated		Curve:	F	F	F	F	F	F	F
Distance		ft	200	300	300	300	1100	0	0
Slope		%	5.0	8.0	4.0	2.0	8.0	.0	.0
Velocity		ft/s	3.4	4.3	3.0	2.1	4.3	.0	.0
Travel Time		min	.98	1.16	1.67	2.38	4.26	.00	.00
Paved or Gully		Curve:	G	G	G	G	G	G	G
Distance		ft	1200	2300	1600	3400	0	2000	4000
Slope		%	2.0	4.0	1.9	1.6	.0	2.3	1.8
Velocity		ft/s	2.8	4.0	2.8	2.5	.0	3.0	2.7
Adjusted Velocity		ft/s	2.80	4.00	2.80	2.50	.00	3.00	2.70
Travel Time		min	7.14	9.58	9.52	22.67	.00	11.11	24.69
Improved Drainage Channel									
Distance		ft	2400	0	0	0	0	0	0
Velocity		ft/s	5.0	.0	.0	.0	.0	.0	.0
Travel Time		min	8.00	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel									
Distance		ft	0	5100	1800	0	2200	0	1600
Velocity		ft/s	.0	3.0	3.0	.0	3.0	.0	3.0
Travel Time		min	.00	28.33	10.00	.00	12.22	.00	8.89
TC (minutes)			18.50	42.65	27.44	32.19	19.05	16.11	38.58
TC (hours)			.31	.71	.46	.54	.32	.27	.64
R = 2 x TC (hours)			.62	1.42	.91	1.07	.63	.54	1.29

ASSESSMENT OF THE POTENTIAL FOR CULTURAL RESOURCES IN THE HURRICANE AND MILL CREEK WATERSHEDS, ANGELINA COUNTY, TEXAS

by

Ross C. Fields

Principal Investigator: Ross C. Fields

Letter Report No. 421

Submitted to

Dodson and Associates, Inc.
Houston, Texas

by

Prewitt and Associates, Inc.
Consulting Archeologists
Austin, Texas

April 1998

Texas Antiquities Committee Archeology Permit No. 1971

Introduction: This project consists of a files search and reconnaissance field survey to identify known cultural resources within the Hurricane and Mill Creek watersheds and to assess the potential for as-yet-unrecorded resources. These two watersheds are within and adjacent to the City of Lufkin in Angelina County, Texas. The larger of the two, Hurricane Creek, arises within the central and eastern parts of the city and flows southward to join Cedar Creek south-southwest of town. Cedar Creek is a tributary to Jack Creek, which flows into the Neches River. The part of the Mill Creek watershed under consideration here encompasses several generally north-flowing tributaries in the north-central part of the city, with Mill Creek itself being an eastward- and northeastward-flowing tributary of the Angelina River.

This work was done in March–April 1998 by Prewitt and Associates, Inc., for Dodson and Associates, Inc., of Houston, Texas, as part of a planning study concerning future drainage improvements along these streams. The study was done for the City of Lufkin, with partial funding by the Texas Water Development Board. Because of the funding sources, the cultural resources work was done under Texas Antiquities Committee Archeology Permit No. 1971 from the Texas Historical Commission. The overall goal of the cultural resources effort was to provide information on known and potential sites so that areas sensitive in terms of cultural resources can be identified. This will serve as baseline data for the future development of plans for specific drainage improvement projects.

Setting: The mainstem of Hurricane Creek heads in the middle of town near the intersection of Chestnut and Dozier Streets (Figure 1). From there, it flows south along the east side of U.S. Highway 59 to Lufkin Mall where it crosses U.S. Highway 59 and flows southwestward behind Angelina Mall to Loop 287. Three tributaries join the mainstem along this stretch. Tributaries 1 and 2 are westward-flowing streams that join at Kiwanis Park and Lufkin Mall, respectively. Tributary 3 flows to the south and joins just north of Loop 287. Much of this part of the watershed is urbanized, with substantial commercial development along U.S. Highway 59 and Loop 287 and residential development mostly along the upper parts of Tributaries 1 and 3. Relatively undeveloped are the mainstem between Denman Avenue and Lufkin Mall and between Angelina Mall and Grace-Dunn Richardson Park (although this stretch flows through Kiwanis Park and is the route of the Azalea Trail connecting the two parks), Tributary 1 between Chestnut Street and Kiwanis Park, Tributary 2 between Chestnut Street and Tulane Road south of Loop 287, and Tributary 3 in and just north of Grace-Dunn Richardson Park.

Below Loop 287, the mainstem runs south and west through largely undeveloped land before joining Cedar Creek west of FM 324 (Figure 2). Tributaries 4, 5, and 7 are west-flowing streams that join from the east (not far south of Loop 287, southwest of the intersection of U.S. Highway 59 and Daniel McCall Road, and just east of FM 324, respectively), while Tributary 6 flows south and joins the west bank between FM 324 and Daniel McCall Road. Like the mainstem, Tributary 6 and the lower reaches of the three east-bank tributaries have seen limited development. Parts of the middle and upper reaches of the eastern tributaries are more urbanized, with commercial development along U.S. Highway 59 and residential development along the upper reaches of Tributary 4 and both branches of Tributary 7.

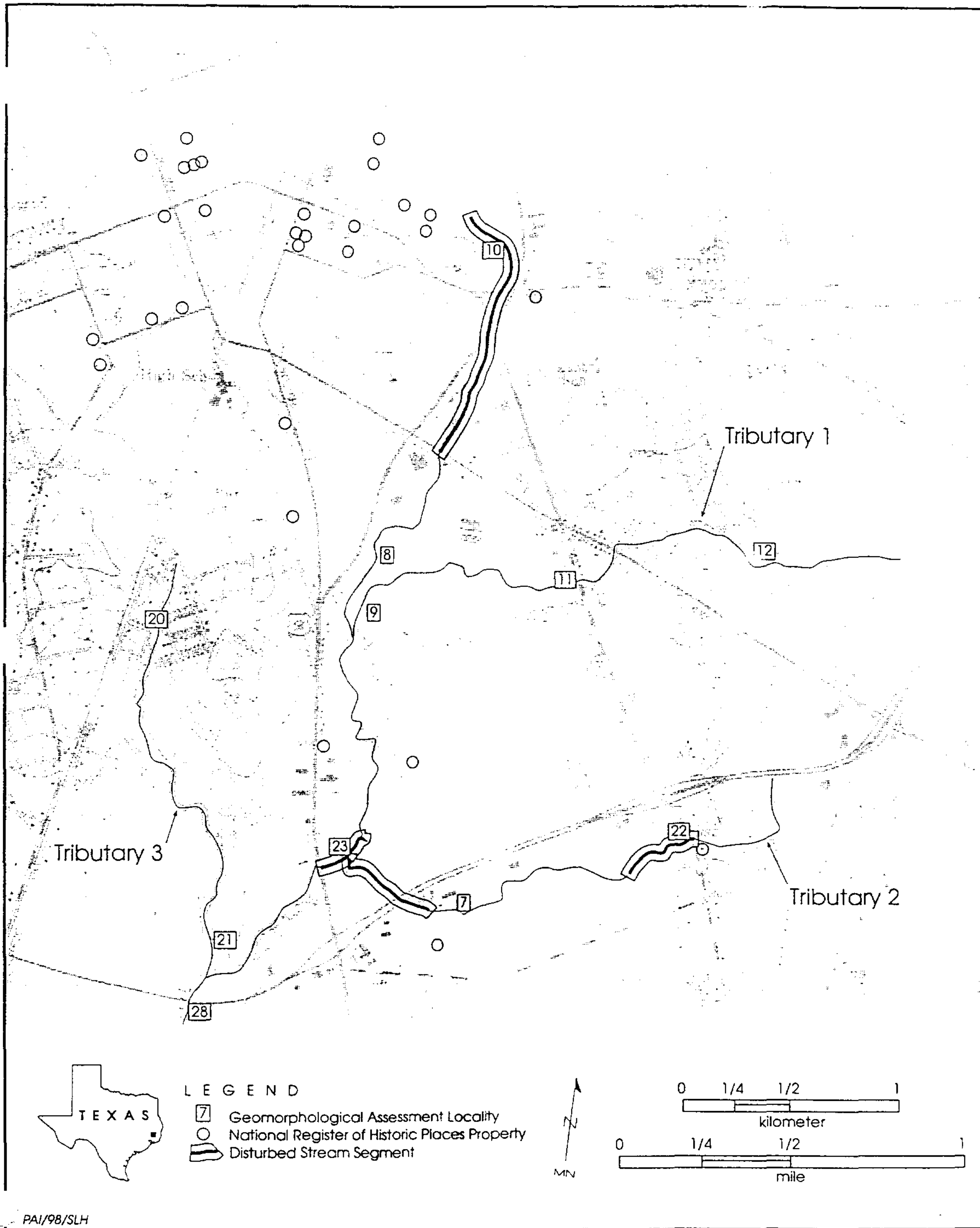


Figure 1. USGS map section (Lufkin quadrangle) showing upper Hurricane Creek watershed.

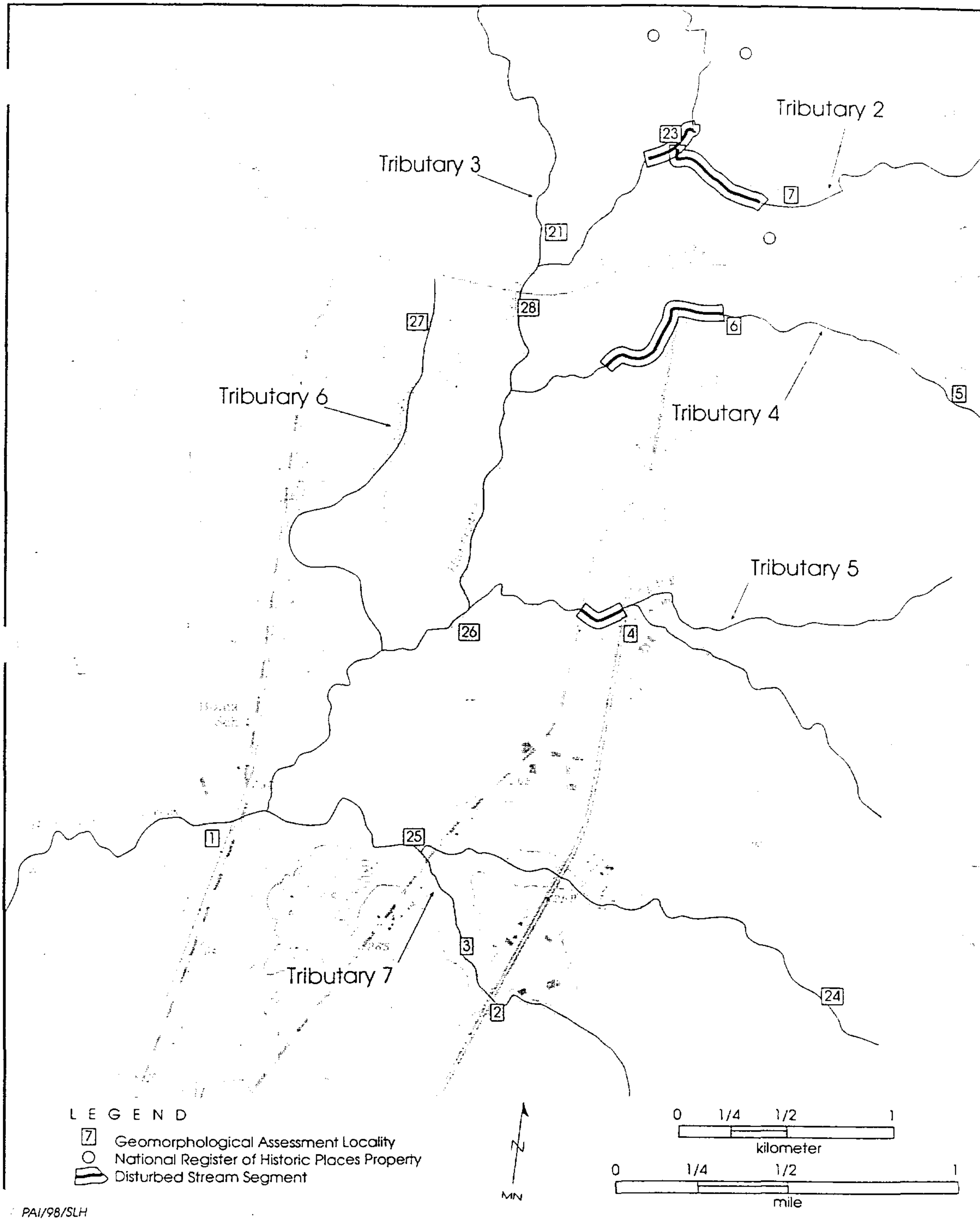


Figure 2. USGS map section (Lufkin and Kelty quadrangles) showing lower Hurricane Creek watershed.

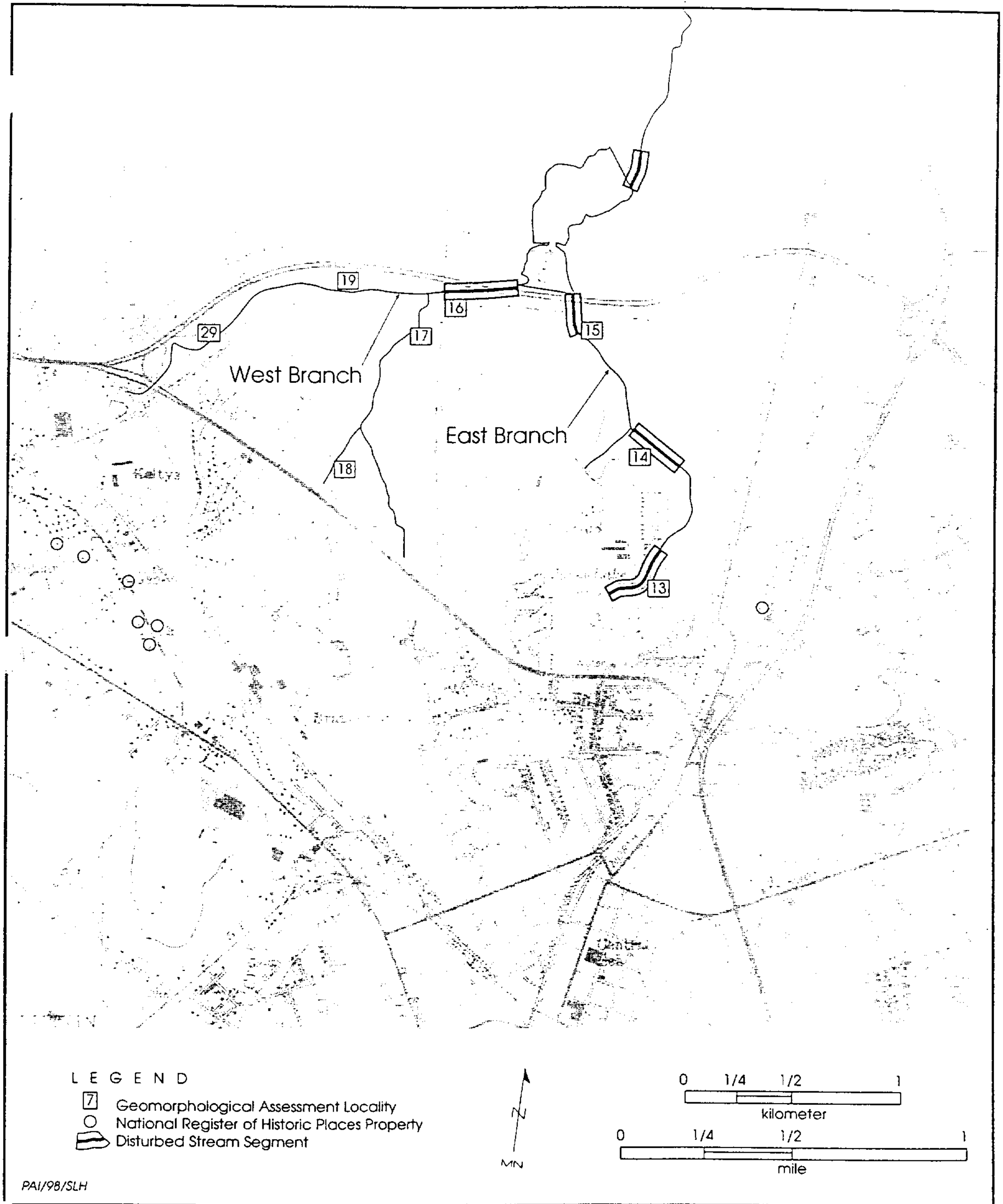
Two branches of Mill Creek are within the project area (Figure 3). The east branch heads just north of Kurth Drive near Martin Luther King Road. Its upper reaches have been affected by recreational development (i.e., Jones Park and the Lufkin Country Club), as well as construction and use of Lufkin Intermediate School and nearby residential development. The stretch north of the country club and south of Loop 287 is less developed. The two forks of the west branch head not far south of Kurth Drive between Sayers Drive and the intersection of Kurth Drive and Loop 287. These streams have not been extensively developed, although the west fork is sandwiched between Loop 287 and the tracks of the Angelina and Neches River Railroad. The east and west branches join just north of Loop 287 where they have been dammed to create Ellen Trout Memorial Lake. This part of the project area has been affected by recreational development around the lake and the construction of a water plant just to the north. The segment of Mill Creek north of the water plant appears to be largely undeveloped.

The project area is on the West Gulf Coastal Plain, where the bedrock geology consists of a series of stacked and tilted units that dip and become progressively younger toward the Gulf. The Eocene Yegua Formation, consisting of fluvial-deltaic sands and clays, crops out in the Lufkin area (Bureau of Economic Geology 1992). The topography generally is gently rolling, with elevations ranging from ca. 210 ft above mean sea level at the confluence of Hurricane and Cedar Creeks to 380 ft on a high hill in the western part of the Mill Creek watershed. The lower and middle reaches of Hurricane Creek have a well-developed floodplain that reaches widths of 1,000–2,000 ft. The upper part of this creek, its tributaries, and Mill Creek have floodplains that are less substantial.

Mapped soils in the uplands belong primarily to the loamy Fuller-Keltys and Keltys-Kurth groups (Dolezel 1988:5–7). They typically consist of fine sandy loam A and E horizons to a depth of 26–39 inches, with sandy clay, sandy clay loam, silty clay loam, loam, or fine sandy loam B or E horizons to 47–56 inches. The Fuller and Keltys soils are underlain by siltstone, while sandstone underlies Kurth soils. Koury floodplain soils are mapped along the lower to middle reaches of Hurricane Creek and consist of a loam and very fine sandy loam A horizon to 17 inches, a silt loam B horizon to 50 inches, and a silt loam C horizon to at least 70 inches. As discussed below, observations made during this project suggest that these alluvial deposits may be quite thick (up to 4–5 m, or 13–16 ft).

Methods: This project consisted of two primary tasks, a files search and a reconnaissance field survey. The following sources were consulted in the files search: (1) the map, county, and site files at the Texas Archeological Research Laboratory at The University of Texas at Austin (for known archeological sites); (2) the county report files at the Texas Historical Commission (for previous archeological surveys); and (3) the National Register and neighborhood surveys files at the Texas Historical Commission (for recorded historic properties).

The reconnaissance field survey was carried out over two days. It consisted of two subtasks. The first involved inspection of 29 locales along Hurricane and Mill Creeks to assess the thickness of the Holocene deposits, and thus the potential for buried archeological sites (see Figures 1–3). The locales were chosen to sample the full lengths of the streams in the study area, with the primary restriction being that most locales had to be accessible via public roads.



gure 3. USGS map section (Lufkin, Kelty and Redlands quadrangles) showing Mill Creek watershed.

Twenty–one locales were in the Hurricane Creek watershed: six on the mainstem, three on Tributary 1, two each on Tributaries 2–4, one each on Tributaries 5 and 6, and four on Tributary 7. Eight locales on Mill Creek were examined, five on the west branch and three on the east branch. Observations made at each locale included approximate cutbank height (estimated, not measured) and visibility, thickness of the Holocene sediments, presence/ absence of bedrock, and extent and kind of disturbance. Formal descriptions of cleaned profiles were not done, and no shovel tests were dug to try to locate archeological sites.

The second subtask involved combining observations made at the 29 locales above with those made during a windshield survey of both watersheds to identify stream segments that obviously are too disturbed to be considered sensitive in terms of cultural resources. This entailed driving all public roads that cross Hurricane and Mill Creeks and their tributaries and noting the extent of development and disturbance. Because not all stream segments were accessible, however, this assessment should not be considered comprehensive.

Files Search: The files search at the Texas Archeological Research Laboratory revealed that there are no recorded archeological sites within the study area. The closest known sites are 41AG12 and 41AG21. Site 41AG12 was recorded by G. E. Arnold, probably in 1939. Local collectors apparently had recovered lithic and ceramic artifacts, and Arnold reported the site as a Native American village covering about 12 acres near the southern limit of the community of Redland. Its plotted location is on the north side of Mill Creek not far west of U.S. Highway 59, ca. 0.5 mile north of the part of the Mill Creek watershed that is within this study area. Site 41AG21 also was recorded by Arnold in 1939 based on stone and ceramic artifacts recovered by a local collector. He reported it as a Native American village covering about 1 acre. It is plotted as being just east of Cedar Creek ca. 0.3 mile north of its confluence with Hurricane Creek. A subsequent survey of the area by personnel from the Texas Water Development Board (see below) was unable to re–locate the site, however, and it is likely that this plotting is in error.

The county report files at the Texas Historical Commission contain information on eight archeological surveys conducted within the study area, none of which found any cultural resources. One, done by D. E. Fox and C. J. Jurgens of the Texas Water Development Board in 1983, consisted of examination of parts of a proposed wastewater line route extending from the wastewater treatment plant on FM 324 just north of Hurricane Creek northward across the Hurricane Creek floodplain and then over the uplands bordering the Cedar Creek valley almost to Loop 287 (Fox and Jurgens 1983). In 1992, J. E. Corbin of Stephen F. Austin State University conducted a survey of the proposed Azalea Trail that follows the mainstem of Hurricane Creek from Kiwanis Park to Grace-Dunn Richardson Park; he also surveyed the latter park, which includes the lower part of Tributary 3 (Corbin 1992). Two years later, Corbin (1994) conducted a survey of a proposed waterline route from the city water plant northward to FM 2021 at the community of Redland; the southern end of this route is just north of Ellen Trout Memorial Lake and runs along Mill Creek and across the adjacent uplands.

The other five surveys were done by personnel from the Texas Department of Transportation. A 1984 survey covered ca. 0.7 mile along Paul Avenue from U.S. Highway 59 to Lubbock

Street; this is in the upper part of the Hurricane Creek watershed, northeast of the head of the mainstem. A 1987 survey covered the ca. 1.7-mile proposed extension of FM 819 northward from U.S. Highway 59 to Loop 287; this route crosses the mainstem of Hurricane Creek in an area with a well-developed floodplain, as well as Tributaries 6 and 7 and adjacent uplands. A 1989 survey covered ca. 0.7 mile along Brentwood Drive from U.S. Highway 59 south and eastward to Chestnut Street; this route crosses Tributary 5 to Hurricane Creek and the uplands north and south of the tributary. A 1993 survey involved coverage of ca. 6 acres around the intersection of Loop 287 and Kurth Drive; this area flanks the head of the western fork of the west branch of Mill Creek. Finally, a 1996 survey covered ca. 2.0 miles along FM 819 from U.S. Highway 59 south to FM 2108; this route crosses Tributary 7 to Hurricane Creek and adjacent uplands, as well as the next drainage to the south (Moccasin Creek).

The National Register files at the Texas Historical Commission contain information on 37 properties within Lufkin that are listed in the National Register of Historic Places. All but one of these are within or very near the Hurricane (n = 29) and Mill Creek (n = 7) watersheds (Table 1; see Figures 1–3). Twenty-five of those within or near the Hurricane Creek watershed are commercial or public buildings (Pines Theater, Fenley Commercial Building, McClendon-Abney Hardware, Corstone Sales Co., and the Old Federal Building) located downtown or residences located just to the north, east, west, and south on Howe, Lufkin, Kerr, and Jefferson Avenues and Paul, Groesbeck, Raguet, Grove, Mantooth, Moore, Bynum and Menefee Streets. The other four are residences located farther south from the center of town on South First Street, Tulane Road (the house at this property has been removed recently, although the barn included in the listing still stands), Harmony Hill Drive, and Chestnut Street.

Six of the seven listed properties in or near the Mill Creek watershed are located on or just off of Old Mill Road. All six are residences associated with the community that was established at the Angelina County Lumber Company sawmill at Keltys, which began operation in the 1880s. The seventh property is the Texas Department of Transportation complex, which is bounded on the west by Forest Park Street and on the east by U.S. Highway 59.

These 36 buildings were listed in the National Register as a result of a Multiple Resource Nomination done in 1986–1988 by Victor and Victor Consultants for the Angelina County Historical Commission. This was part of a larger project to assess the standing architecture across Angelina County as a whole. Over 1,000 buildings and structures were documented (ca. 800 in Lufkin), and 41 were considered to be of sufficient significance to warrant listing in the National Register (including the 36 listed above). These 41 properties date between 1880 and 1940 and were considered significant architecturally or for their association with New Deal programs or the development of transportation networks.

Geomorphological Assessment: Observations made during the geomorphological assessment are summarized in Table 2. While no estimate could be made for the thickness of alluvium at six locations due to the lack of a cutbank or very poor visibility (Localities 10, 11, 13, 19, 24, and 29), all of the other localities yielded some information. Especially useful data came from Localities 1, 7–9, 23, and 28 where the streams are sufficiently incised to expose the underlying bedrock. These localities are on the mainstem of Hurricane Creek (lower,

Table 1. **Properties Listed in the National Register of Historic Places**

Name	Address	Watershed
C. W. Perry/Hallmark Residence	302 Bynum St., South	Hurricane Creek
A. F. Perry/Pitmann Residence	402 Bynum St., South	Hurricane Creek
G. E. Lawrence Residence	2005 Chestnut St., South	Hurricane Creek
Pines Theater	113 First St., South	Hurricane Creek
Rastus Reed Residence	1509 First St., South	Hurricane Creek
Kennedy/Lowrey Residence	519 Groesbeck St., East	Hurricane Creek
Banks/Ogg Residence	602 Groesbeck St., East	Hurricane Creek
A. C. Kennedy/Runnels Residence	603 Groesbeck St., East	Hurricane Creek
Humason/Pinkerton Residence	602 Grove St.	Hurricane Creek (adjacent)
Howard Walker Residence	503 Harmony Hill Dr.	Hurricane Creek
Brookshire/Theatres Residence	304 Howe Ave., East	Hurricane Creek
Walter C. Trout/White Residence	444 Jefferson Ave.	Hurricane Creek
Percy/Abney Residence	466 Jefferson Ave.	Hurricane Creek
Boynton/Kent Residence	107 Kerr St., West	Hurricane Creek
Fenley Commercial Building	112 Lufkin Ave., East	Hurricane Creek
McClendon-Abney Hardware Co.	119 Lufkin Ave., East	Hurricane Creek
Lufkin Land/Log Bell/Buck Residence	1218 Lufkin Ave., East	Hurricane Creek
Binion/Casper Residence	404 Mantooth St.,	Hurricane Creek
Byus/Kirkland Residence	411 Mantooth, St.	Hurricane Creek
Newsom/Moss Residence	420 Mantooth, St.	Hurricane Creek
Russell/Arnold Residence	121 Menefee St., West	Hurricane Creek
Everitt/Cox Residence	418 Moore St.	Hurricane Creek
Abercrombie/Cavanaugh Residence	304 Paul St.	Hurricane Creek
Parker/Bradshaw Residence	213 Raguet St., North	Hurricane Creek
Marsh/Smith Residence	503 Raguet St., North	Hurricane Creek (adjacent)
Corstone Sales Co.	109/111 Shepherd St., East	Hurricane Creek
Behannon/Kenley Residence	317 Shepherd St., East	Hurricane Creek
Old Federal Building	104 Third St., North	Hurricane Creek
Standley Residence	1607 Tulane Rd.	Hurricane Creek
Texas Department of Transportation Complex	110 Forest Park St.	Mill Creek
S. W. Henderson/Bridges Residence	202 Henderson Rd.	Mill Creek (adjacent)
Keltys Worker Housing	109 Medford St.	Mill Creek (adjacent)
Kurth/Glover Residence	1847 Old Mill Rd.	Mill Creek (adjacent)
J. H. Kurth Residence	1860 Old Mill Rd.	Mill Creek
Clark/Whitton Residence	1865 Old Mill Rd.	Mill Creek (adjacent)
McGilbert Residence	1902 Old Mill Rd.	Mill Creek

middle, and upper reaches) and the lower parts of Tributaries 1 and 2. The alluvial deposits at these locations are 3–5 m thick. Elsewhere, only estimates of minimum thickness could be made since bedrock was not exposed. Relatively thick deposits, 4+ m, were documented on lower Hurricane Creek and lower Tributary 7 (Localities 3, 25, and 26), while alluvium of at least moderate thickness, 2–3+ m, was observed in the following areas: upper and lower Tributary 3 (Localities 20 and 21); the middle reaches of Tributaries 4, 5, and 7 (Localities 2, 4, and 6); and lower Mill Creek (Localities 15 and 16). Alluvial deposits at least 0.5–1.5 m thick were noted on the upper parts of Tributaries 1, 2, 4, and 6 (Localities 5, 12, 22, and 27) and the middle and upper parts of Mill Creek (Localities 14, 17, and 18).

Table 2. Localities Examined for Geomorphological Assessment

No.	Location	Cutbank Height/ Visibility	Thickness of Alluvium
1	Hurricane Creek mainstem (lower) at FM 324	4–5 m; fair	3–4 m above bedrock
2	Hurricane Creek Tributary 7 (middle south branch) east of U.S. Highway 59	2–3 m; good	2–3+ m; bedrock not observed
3	Hurricane Creek Tributary 7 (lower south branch) west of U.S. Highway 59	3–4 m; fair	3–4+ m; bedrock not observed
4	Hurricane Creek Tributary 5 (middle) east of U.S. Highway 59	2 m; fair	2+ m; bedrock not observed
5	Hurricane Creek Tributary 4 (upper) off of Hickory Hill Dr.	0.5 m; poor	0.5+ m; bedrock not observed
6	Hurricane Creek Tributary 4 (middle) at Tulane Rd.	2 m; poor	2+ m; bedrock not observed
7	Hurricane Creek Tributary 2 (lower) east of Tulane Rd.	3 m; poor	3 m above bedrock
8	Hurricane Creek mainstem (upper) in Kiwanis Park	3 m; good	3 m above possible bedrock; some introduced fill
9	Hurricane Creek Tributary 1 (lower) in Kiwanis Park	4 m; good	3 m above bedrock; some introduced fill
10	Hurricane Creek mainstem (upper) north of Dozier St.	1 m; very poor	Unknown
11	Hurricane Creek Tributary 1 (middle) west of Chestnut St.	2–3 m; very poor	Unknown
12	Hurricane Creek Tributary 1 (upper) south of Howard Ave.	1 m; poor	1+ m; bedrock not observed
13	Mill Creek east branch (upper east fork) east of Martin Luther King Rd.	No cutbank	Unknown
14	Mill Creek east branch (lower east fork) east of Martin Luther King Rd.	1 m; poor	1+ m; bedrock not observed
15	Mill Creek east branch (lower) south of Loop 287	2.5 m; poor	2.5+ m; bedrock not observed
16	Mill Creek west branch (lower) east of Sayers Dr.	2 m; fair	2+ m; bedrock not observed
17	Mill Creek west branch (lower east fork) west of Sayers Dr.	1.5 m; fair	1.5+ m; bedrock not observed
18	Mill Creek west branch (upper east fork) north of Kurth Dr.	1 m; poor	1+ m; bedrock not observed
19	Mill Creek west branch (middle west fork) south of Loop 287	No cutbank	Unknown
20	Hurricane Creek Tributary 3 (upper) at Morrow St.	3 m; fair	3+ m; bedrock not observed
21	Hurricane Creek Tributary 3 (lower) at Grace-Dunne Richardson Park	3 m; good	3+ m; bedrock not observed
22	Hurricane Creek Tributary 2 (upper) east of Chestnut St.	1 m; poor	1+ m; bedrock not observed
23	Hurricane Creek mainstem (middle) north of Lufkin Mall	4–5 m; good	4–5 m above possible bedrock
24	Hurricane Creek Tributary 7 (upper north branch) at Champions Dr.	0.5 m; very poor	Unknown

date covered small areas and involved little or no shovel testing or other subsurface inspection, however, the lack of known sites is not surprising. Based on the topography and the locations of the few recorded sites nearby, the part of the project area that is considered most likely to contain prehistoric archeological sites is the Hurricane Creek watershed downstream from U.S. Highway 59 to the confluence with Cedar Creek, i.e., the lower part of the valley with a well-developed floodplain. Within this area, sites are most likely on elevated landforms within or adjacent to the floodplains of the mainstem of the creek and the lower parts of Tributaries 3–7; such landforms would include isolated rises probably representing remnants of levees and terraces, as well as terrace and upland margins bordering the floodplains. Sites also could lie buried in the thick (at least 3–5 m) Holocene alluvium in this area, although too little geomorphological work has been done in the Lufkin area and east Texas in general to fully assess this possibility. It is less likely, though certainly not impossible, that prehistoric sites could be present along the smaller stream segments, i.e., the upper parts of Hurricane Creek and its tributaries and along Mill Creek. If so, they probably will occur on elevated landforms near the creeks.

Thirty-six buildings listed in the National Register of Historic Places are within or adjacent to the Hurricane and Mill Creek watersheds. Most are residences, with a small number of commercial and public buildings included as well. Most are privately owned and hence are afforded little protection from disturbance by their National Register listing. Only two—the Rastus Reed Residence at 1509 South First Street (U.S. Highway 59) and the G. E. Lawrence Residence at 2005 South Chestnut Street—are located sufficiently close to creek channels that they are likely to be threatened by drainage improvement projects. Given that the National Register survey was done ca. 10 years ago and did not record all buildings and structures that were 50 years old or older at that time, it is possible that additional historic buildings and structures are located in the study area.

At this point, it is difficult to assess whether significant historic archeological sites might be present. None have been documented, but the National Register survey done in the late 1980s was concerned with architectural rather than archeological resources, and, as noted above, the few archeological surveys have covered only small areas. Lufkin was not founded until 1882, but an earlier settlement called Denman Springs was present before that time (Bowman 1996). Given that the upper part of the Hurricane Creek watershed is within the older part of town, it is possible that archeological remains pertaining to early settlement are present.

As plans for specific drainage improvement projects are developed in the future, the U.S. Army Corps of Engineers, Texas Historical Commission, and Texas Water Development Board may require cultural resources investigations based on the location and nature of the project and extent of prior disturbance. As described above, parts of the study area clearly are too disturbed to be sensitive in terms of cultural resources, and it is recommended that surveys not be required in these areas. Otherwise, some level of survey may be appropriate. Where modifications to existing channels are proposed, this may involve only inspection of cutbanks to ensure that buried prehistoric or historic sites are not present. Where more-extensive impacts are planned (e.g., large detention ponds), three kinds of activities may be needed: (1) historic archival research using old maps and legal records to identify potential early historic sites; (2) archeological survey involving pedestrian coverage, shovel testing, and perhaps

ASSESSMENT OF THE POTENTIAL FOR CULTURAL RESOURCES IN THE HURRICANE AND MILL CREEK WATERSHEDS, ANGELINA COUNTY, TEXAS

by

Ross C. Fields

Principal Investigator: Ross C. Fields

Letter Report No. 421

Submitted to

Dodson and Associates, Inc.
Houston, Texas

by

Prewitt and Associates, Inc.
Consulting Archeologists
Austin, Texas

April 1998

Texas Antiquities Committee Archeology Permit No. 1971

Introduction: This project consists of a files search and reconnaissance field survey to identify known cultural resources within the Hurricane and Mill Creek watersheds and to assess the potential for as-yet-unrecorded resources. These two watersheds are within and adjacent to the City of Lufkin in Angelina County, Texas. The larger of the two, Hurricane Creek, arises within the central and eastern parts of the city and flows southward to join Cedar Creek south-southwest of town. Cedar Creek is a tributary to Jack Creek, which flows into the Neches River. The part of the Mill Creek watershed under consideration here encompasses several generally north-flowing tributaries in the north-central part of the city, with Mill Creek itself being an eastward- and northeastward-flowing tributary of the Angelina River.

This work was done in March–April 1998 by Prewitt and Associates, Inc., for Dodson and Associates, Inc., of Houston, Texas, as part of a planning study concerning future drainage improvements along these streams. The study was done for the City of Lufkin, with partial funding by the Texas Water Development Board. Because of the funding sources, the cultural resources work was done under Texas Antiquities Committee Archeology Permit No. 1971 from the Texas Historical Commission. The overall goal of the cultural resources effort was to provide information on known and potential sites so that areas sensitive in terms of cultural resources can be identified. This will serve as baseline data for the future development of plans for specific drainage improvement projects.

Setting: The mainstem of Hurricane Creek heads in the middle of town near the intersection of Chestnut and Dozier Streets (Figure 1). From there, it flows south along the east side of U.S. Highway 59 to Lufkin Mall where it crosses U.S. Highway 59 and flows southwestward behind Angelina Mall to Loop 287. Three tributaries join the mainstem along this stretch. Tributaries 1 and 2 are westward-flowing streams that join at Kiwanis Park and Lufkin Mall, respectively. Tributary 3 flows to the south and joins just north of Loop 287. Much of this part of the watershed is urbanized, with substantial commercial development along U.S. Highway 59 and Loop 287 and residential development mostly along the upper parts of Tributaries 1 and 3. Relatively undeveloped are the mainstem between Denman Avenue and Lufkin Mall and between Angelina Mall and Grace-Dunn Richardson Park (although this stretch flows through Kiwanis Park and is the route of the Azalea Trail connecting the two parks), Tributary 1 between Chestnut Street and Kiwanis Park, Tributary 2 between Chestnut Street and Tulane Road south of Loop 287, and Tributary 3 in and just north of Grace-Dunn Richardson Park.

Below Loop 287, the mainstem runs south and west through largely undeveloped land before joining Cedar Creek west of FM 324 (Figure 2). Tributaries 4, 5, and 7 are west-flowing streams that join from the east (not far south of Loop 287, southwest of the intersection of U.S. Highway 59 and Daniel McCall Road, and just east of FM 324, respectively), while Tributary 6 flows south and joins the west bank between FM 324 and Daniel McCall Road. Like the mainstem, Tributary 6 and the lower reaches of the three east-bank tributaries have seen limited development. Parts of the middle and upper reaches of the eastern tributaries are more urbanized, with commercial development along U.S. Highway 59 and residential development along the upper reaches of Tributary 4 and both branches of Tributary 7.

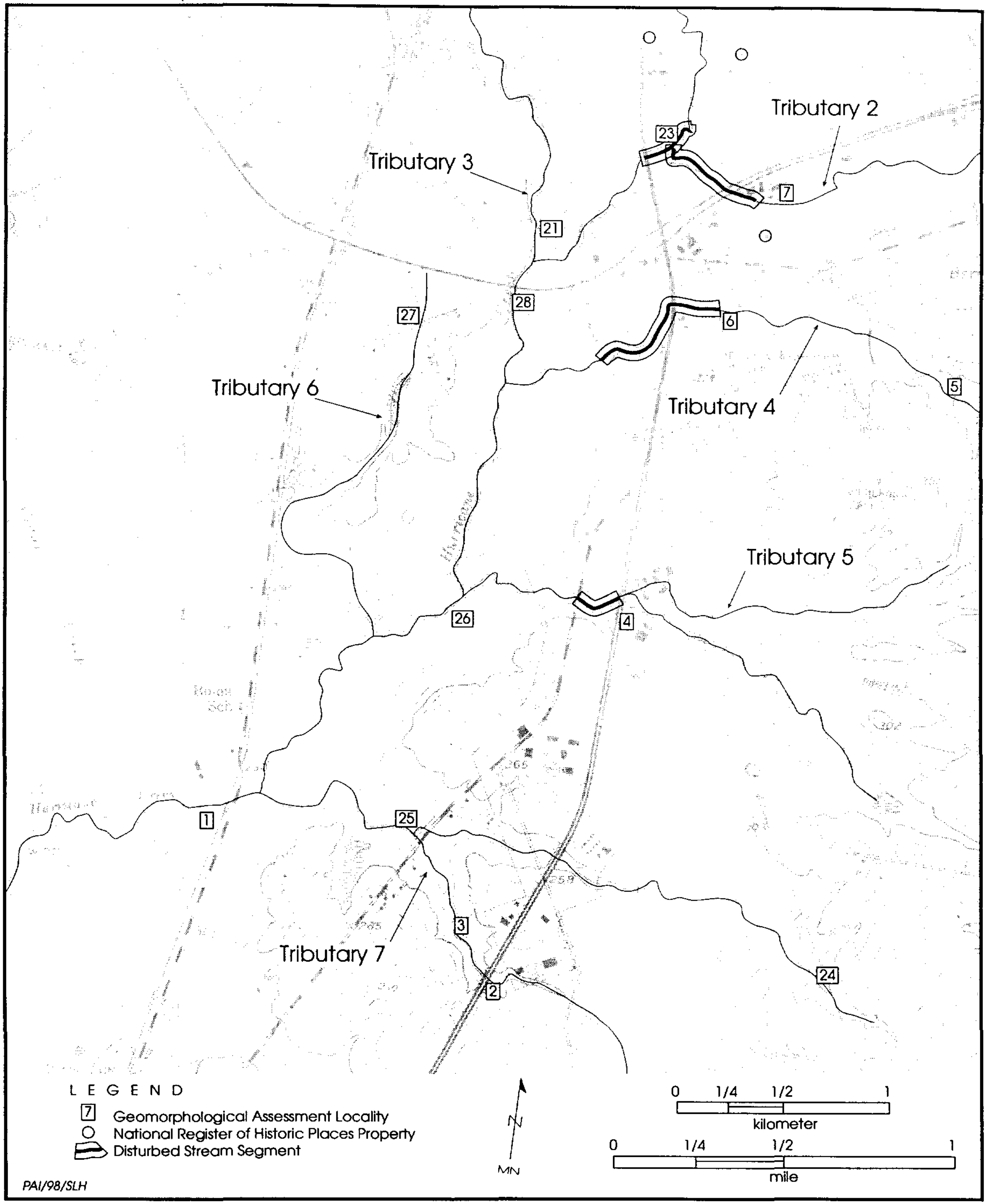


Figure 2. USGS map section (Lufkin and Kelty quadrangles) showing lower Hurricane Creek watershed.

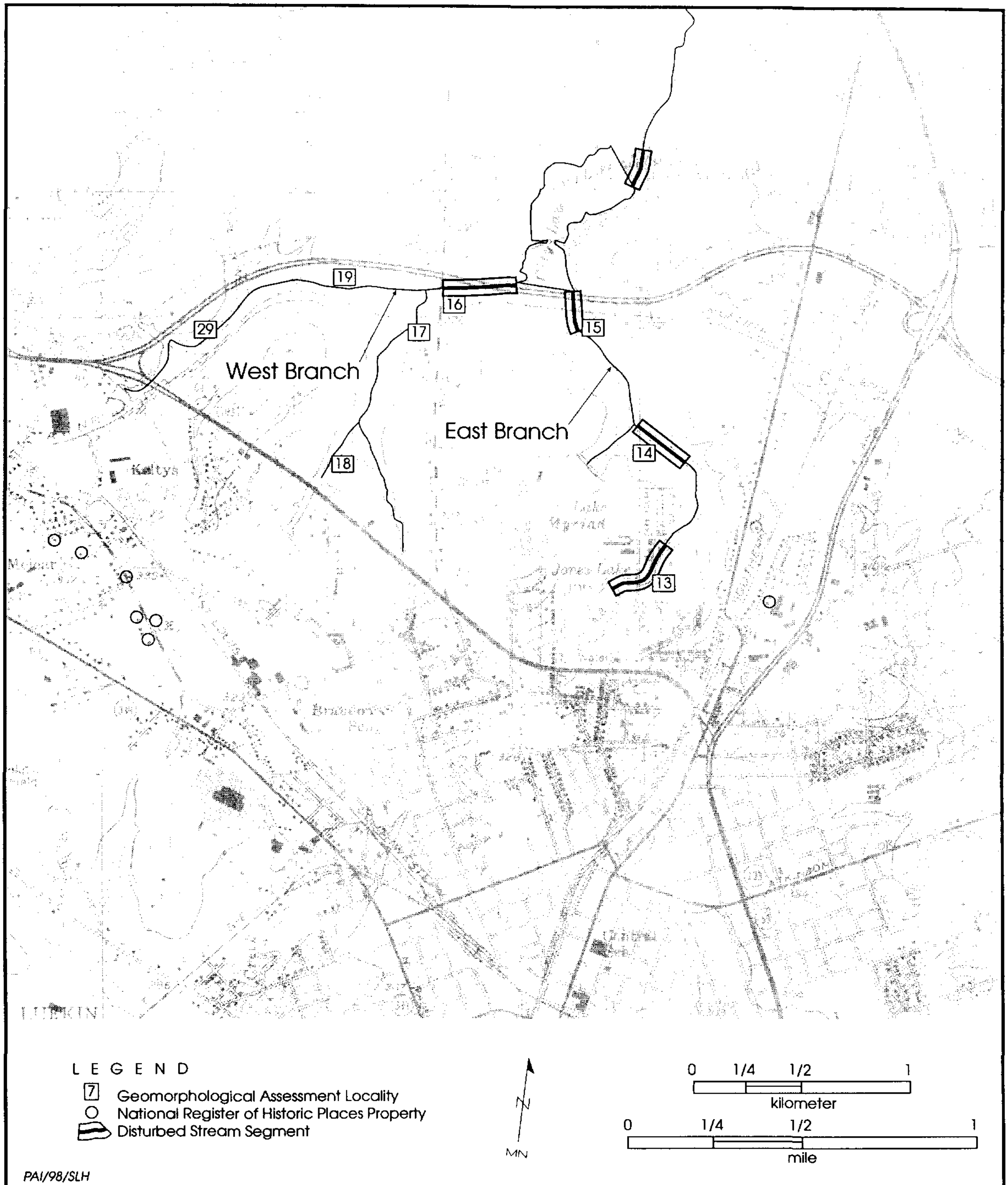


Figure 3. USGS map section (Lufkin, Kelty and Redlands quadrangles) showing Mill Creek watershed.

Twenty–one locales were in the Hurricane Creek watershed: six on the mainstem, three on Tributary 1, two each on Tributaries 2–4, one each on Tributaries 5 and 6, and four on Tributary 7. Eight locales on Mill Creek were examined, five on the west branch and three on the east branch. Observations made at each locale included approximate cutbank height (estimated, not measured) and visibility, thickness of the Holocene sediments, presence/absence of bedrock, and extent and kind of disturbance. Formal descriptions of cleaned profiles were not done, and no shovel tests were dug to try to locate archeological sites.

The second subtask involved combining observations made at the 29 locales above with those made during a windshield survey of both watersheds to identify stream segments that obviously are too disturbed to be considered sensitive in terms of cultural resources. This entailed driving all public roads that cross Hurricane and Mill Creeks and their tributaries and noting the extent of development and disturbance. Because not all stream segments were accessible, however, this assessment should not be considered comprehensive.

Files Search: The files search at the Texas Archeological Research Laboratory revealed that there are no recorded archeological sites within the study area. The closest known sites are 41AG12 and 41AG21. Site 41AG12 was recorded by G. E. Arnold, probably in 1939. Local collectors apparently had recovered lithic and ceramic artifacts, and Arnold reported the site as a Native American village covering about 12 acres near the southern limit of the community of Redland. Its plotted location is on the north side of Mill Creek not far west of U.S. Highway 59, ca. 0.5 mile north of the part of the Mill Creek watershed that is within this study area. Site 41AG21 also was recorded by Arnold in 1939 based on stone and ceramic artifacts recovered by a local collector. He reported it as a Native American village covering about 1 acre. It is plotted as being just east of Cedar Creek ca. 0.3 mile north of its confluence with Hurricane Creek. A subsequent survey of the area by personnel from the Texas Water Development Board (see below) was unable to re–locate the site, however, and it is likely that this plotting is in error.

The county report files at the Texas Historical Commission contain information on eight archeological surveys conducted within the study area, none of which found any cultural resources. One, done by D. E. Fox and C. J. Jurgens of the Texas Water Development Board in 1983, consisted of examination of parts of a proposed wastewater line route extending from the wastewater treatment plant on FM 324 just north of Hurricane Creek northward across the Hurricane Creek floodplain and then over the uplands bordering the Cedar Creek valley almost to Loop 287 (Fox and Jurgens 1983). In 1992, J. E. Corbin of Stephen F. Austin State University conducted a survey of the proposed Azalea Trail that follows the mainstem of Hurricane Creek from Kiwanis Park to Grace-Dunn Richardson Park; he also surveyed the latter park, which includes the lower part of Tributary 3 (Corbin 1992). Two years later, Corbin (1994) conducted a survey of a proposed waterline route from the city water plant northward to FM 2021 at the community of Redland; the southern end of this route is just north of Ellen Trout Memorial Lake and runs along Mill Creek and across the adjacent uplands.

The other five surveys were done by personnel from the Texas Department of Transportation. A 1984 survey covered ca. 0.7 mile along Paul Avenue from U.S. Highway 59 to Lubbock

Street; this is in the upper part of the Hurricane Creek watershed, northeast of the head of the mainstem. A 1987 survey covered the ca. 1.7-mile proposed extension of FM 819 northward from U.S. Highway 59 to Loop 287; this route crosses the mainstem of Hurricane Creek in an area with a well-developed floodplain, as well as Tributaries 6 and 7 and adjacent uplands. A 1989 survey covered ca. 0.7 mile along Brentwood Drive from U.S. Highway 59 south and eastward to Chestnut Street; this route crosses Tributary 5 to Hurricane Creek and the uplands north and south of the tributary. A 1993 survey involved coverage of ca. 6 acres around the intersection of Loop 287 and Kurth Drive; this area flanks the head of the western fork of the west branch of Mill Creek. Finally, a 1996 survey covered ca. 2.0 miles along FM 819 from U.S. Highway 59 south to FM 2108; this route crosses Tributary 7 to Hurricane Creek and adjacent uplands, as well as the next drainage to the south (Moccasin Creek).

The National Register files at the Texas Historical Commission contain information on 37 properties within Lufkin that are listed in the National Register of Historic Places. All but one of these are within or very near the Hurricane (n = 29) and Mill Creek (n = 7) watersheds (Table 1; see Figures 1–3). Twenty-five of those within or near the Hurricane Creek watershed are commercial or public buildings (Pines Theater, Fenley Commercial Building, McClendon-Abney Hardware, Corstone Sales Co., and the Old Federal Building) located downtown or residences located just to the north, east, west, and south on Howe, Lufkin, Kerr, and Jefferson Avenues and Paul, Groesbeck, Raguet, Grove, Mantooth, Moore, Bynum and Menefee Streets. The other four are residences located farther south from the center of town on South First Street, Tulane Road (the house at this property has been removed recently, although the barn included in the listing still stands), Harmony Hill Drive, and Chestnut Street.

Six of the seven listed properties in or near the Mill Creek watershed are located on or just off of Old Mill Road. All six are residences associated with the community that was established at the Angelina County Lumber Company sawmill at Keltys, which began operation in the 1880s. The seventh property is the Texas Department of Transportation complex, which is bounded on the west by Forest Park Street and on the east by U.S. Highway 59.

These 36 buildings were listed in the National Register as a result of a Multiple Resource Nomination done in 1986–1988 by Victor and Victor Consultants for the Angelina County Historical Commission. This was part of a larger project to assess the standing architecture across Angelina County as a whole. Over 1,000 buildings and structures were documented (ca. 800 in Lufkin), and 41 were considered to be of sufficient significance to warrant listing in the National Register (including the 36 listed above). These 41 properties date between 1880 and 1940 and were considered significant architecturally or for their association with New Deal programs or the development of transportation networks.

Geomorphological Assessment: Observations made during the geomorphological assessment are summarized in Table 2. While no estimate could be made for the thickness of alluvium at six locations due to the lack of a cutbank or very poor visibility (Localities 10, 11, 13, 19, 24, and 29), all of the other localities yielded some information. Especially useful data came from Localities 1, 7–9, 23, and 28 where the streams are sufficiently incised to expose the underlying bedrock. These localities are on the mainstem of Hurricane Creek (lower,

Table 2. Localities Examined for Geomorphological Assessment

No.	Location	Cutbank Height/ Visibility	Thickness of Alluvium
1	Hurricane Creek mainstem (lower) at FM 324	4–5 m; fair	3–4 m above bedrock
2	Hurricane Creek Tributary 7 (middle south branch) east of U.S. Highway 59	2–3 m; good	2–3+ m; bedrock not observed
3	Hurricane Creek Tributary 7 (lower south branch) west of U.S. Highway 59	3–4 m; fair	3–4+ m; bedrock not observed
4	Hurricane Creek Tributary 5 (middle) east of U.S. Highway 59	2 m; fair	2+ m; bedrock not observed
5	Hurricane Creek Tributary 4 (upper) off of Hickory Hill Dr.	0.5 m; poor	0.5+ m; bedrock not observed
6	Hurricane Creek Tributary 4 (middle) at Tulane Rd.	2 m; poor	2+ m; bedrock not observed
7	Hurricane Creek Tributary 2 (lower) east of Tulane Rd.	3 m; poor	3 m above bedrock
8	Hurricane Creek mainstem (upper) in Kiwanis Park	3 m; good	3 m above possible bedrock; some introduced fill
9	Hurricane Creek Tributary 1 (lower) in Kiwanis Park	4 m; good	3 m above bedrock; some introduced fill
10	Hurricane Creek mainstem (upper) north of Dozier St.	1 m; very poor	Unknown
11	Hurricane Creek Tributary 1 (middle) west of Chestnut St.	2–3 m; very poor	Unknown
12	Hurricane Creek Tributary 1 (upper) south of Howard Ave.	1 m; poor	1+ m; bedrock not observed
13	Mill Creek east branch (upper east fork) east of Martin Luther King Rd.	No cutbank	Unknown
14	Mill Creek east branch (lower east fork) east of Martin Luther King Rd.	1 m; poor	1+ m; bedrock not observed
15	Mill Creek east branch (lower) south of Loop 287	2.5 m; poor	2.5+ m; bedrock not observed
16	Mill Creek west branch (lower) east of Sayers Dr.	2 m; fair	2+ m; bedrock not observed
17	Mill Creek west branch (lower east fork) west of Sayers Dr.	1.5 m; fair	1.5+ m; bedrock not observed
18	Mill Creek west branch (upper east fork) north of Kurth Dr.	1 m; poor	1+ m; bedrock not observed
19	Mill Creek west branch (middle west fork) south of Loop 287	No cutbank	Unknown
20	Hurricane Creek Tributary 3 (upper) at Morrow St.	3 m; fair	3+ m; bedrock not observed
21	Hurricane Creek Tributary 3 (lower) at Grace-Dunne Richardson Park	3 m; good	3+ m; bedrock not observed
22	Hurricane Creek Tributary 2 (upper) east of Chestnut St.	1 m; poor	1+ m; bedrock not observed
23	Hurricane Creek mainstem (middle) north of Lufkin Mall	4–5 m; good	4–5 m above possible bedrock
24	Hurricane Creek Tributary 7 (upper north branch) at Champions Dr.	0.5 m; very poor	Unknown

Table 2, continued

No.	Location	Cutbank Height/ Visibility	Thickness of Alluvium
25	Hurricane Creek Tributary 7 (lower) west of Daniel McCall Rd.	4 m; good	4+ m; bedrock not observed
26	Hurricane Creek mainstem (lower) at FM 819	5 m; fair	5+ m; bedrock not observed
27	Hurricane Creek Tributary 6 (upper) at Sandy Lane	0.5 m; poor	0.5+ m; bedrock not observed
28	Hurricane Creek mainstem (middle) south of Loop 287	4 m; poor	4 m above possible bedrock
29	Mill Creek west branch (upper west fork) south of Loop 287	No cutbank	Unknown

Windshield Survey: While the issue of the extent of disturbance could not be addressed in a comprehensive fashion, combining observations made at the 29 localities listed in Table 2 with those made during a windshield survey of the project area allowed identification of some areas that clearly are too disturbed to contain intact cultural resources (see Figures 1–3). These areas are as follows: (1) the upper end of the mainstem of Hurricane Creek above Denman Avenue, where the creek flows through and beneath commercial developments; (2) the mainstem of Hurricane Creek flanking U.S. Highway 59 and just north of Lufkin Mall, as well as the adjoining lower part of Tributary 2 beneath the mall and across Loop 287 eastward to Tulane Road; (3) the upper part of Tributary 2 west of Chestnut Street, which flows beneath the Lowe's Home Center parking lot; (4) Tributary 4 west of Tulane Road across U.S. Highway 59 to south of Scenic Acres Drive; (5) Tributary 5 west of U.S. Highway 59 to Daniel McCall Road; (6) Mill Creek below Ellen Trout Memorial Lake through the water plant; (7) the east and west branches of Mill Creek south of Ellen Trout Memorial Lake and across Loop 287; (8) the east fork of the east branch of Mill Creek from Jones Lake across Martin Luther King Road and behind; and (9) part of the east fork of the east branch of Mill Creek east of Martin Luther King Road and north of Lufkin Intermediate School.

A number of areas are less obviously disturbed but may have a limited potential to contain intact cultural resources, compared to the more-rural parts of the project area, because they are in developed parts of the city. Included are the following: (1) the mainstem of Hurricane Creek and the lower part of Tributary 1 within Kiwanis Park, as introduced fill was observed at both localities recorded there; (2) the mainstem of Hurricane Creek between Kiwanis Park (Tulane Road) and Lufkin Mall, as this area backs up to extensive commercial development along U.S. Highway 59; and (3) segments of the Hurricane Creek tributaries that flow through residential areas, including Tributary 1 east of Chestnut Street, Tributary 3 north of Jane-Way Avenue, and most of Tributary 7 east of U.S. Highway 59. These are not shown on Figures 1–3 because it is not certain that these areas are too disturbed to be sensitive in terms of cultural resources.

Conclusions and Recommendations: There are no recorded archeological sites within the Hurricane or Mill Creek watersheds. Given that the only archeological surveys completed to

date covered small areas and involved little or no shovel testing or other subsurface inspection, however, the lack of known sites is not surprising. Based on the topography and the locations of the few recorded sites nearby, the part of the project area that is considered most likely to contain prehistoric archeological sites is the Hurricane Creek watershed downstream from U.S. Highway 59 to the confluence with Cedar Creek, i.e., the lower part of the valley with a well-developed floodplain. Within this area, sites are most likely on elevated landforms within or adjacent to the floodplains of the mainstem of the creek and the lower parts of Tributaries 3–7; such landforms would include isolated rises probably representing remnants of levees and terraces, as well as terrace and upland margins bordering the floodplains. Sites also could lie buried in the thick (at least 3–5 m) Holocene alluvium in this area, although too little geomorphological work has been done in the Lufkin area and east Texas in general to fully assess this possibility. It is less likely, though certainly not impossible, that prehistoric sites could be present along the smaller stream segments, i.e., the upper parts of Hurricane Creek and its tributaries and along Mill Creek. If so, they probably will occur on elevated landforms near the creeks.

Thirty-six buildings listed in the National Register of Historic Places are within or adjacent to the Hurricane and Mill Creek watersheds. Most are residences, with a small number of commercial and public buildings included as well. Most are privately owned and hence are afforded little protection from disturbance by their National Register listing. Only two—the Rastus Reed Residence at 1509 South First Street (U.S. Highway 59) and the G. E. Lawrence Residence at 2005 South Chestnut Street—are located sufficiently close to creek channels that they are likely to be threatened by drainage improvement projects. Given that the National Register survey was done ca. 10 years ago and did not record all buildings and structures that were 50 years old or older at that time, it is possible that additional historic buildings and structures are located in the study area.

At this point, it is difficult to assess whether significant historic archeological sites might be present. None have been documented, but the National Register survey done in the late 1980s was concerned with architectural rather than archeological resources, and, as noted above, the few archeological surveys have covered only small areas. Lufkin was not founded until 1882, but an earlier settlement called Denman Springs was present before that time (Bowman 1996). Given that the upper part of the Hurricane Creek watershed is within the older part of town, it is possible that archeological remains pertaining to early settlement are present.

As plans for specific drainage improvement projects are developed in the future, the U.S. Army Corps of Engineers, Texas Historical Commission, and Texas Water Development Board may require cultural resources investigations based on the location and nature of the project and extent of prior disturbance. As described above, parts of the study area clearly are too disturbed to be sensitive in terms of cultural resources, and it is recommended that surveys not be required in these areas. Otherwise, some level of survey may be appropriate. Where modifications to existing channels are proposed, this may involve only inspection of cutbanks to ensure that buried prehistoric or historic sites are not present. Where more-extensive impacts are planned (e.g., large detention ponds), three kinds of activities may be needed: (1) historic archival research using old maps and legal records to identify potential early historic sites; (2) archeological survey involving pedestrian coverage, shovel testing, and perhaps

trenching or augering to locate prehistoric and historic sites; (3) architectural survey to identify historic buildings and structures, if removal of buildings and structures is planned. Surveys aimed at finding prehistoric archeological sites are more likely to be necessary in the lower Hurricane Creek watershed, while surveys for historic resources, both archeological and architectural, will be more of an issue in the upper Hurricane Creek watershed. With the information gathered to date, the Mill Creek watershed does not appear to be especially sensitive in terms of either prehistoric or historic resources.

REFERENCES CITED

Bowman, Bob

1996 Lufkin, Texas. In *The New Handbook of Texas*, vol. 4, pp. 331–332. The Texas State Historical Association, Austin.

Bureau of Economic Geology

1992 *Geologic Map of Texas*. Bureau of Economic Geology, The University of Texas at Austin.

Corbin, James E.

1992 *Archaeological Survey of the Proposed Azalea Fitness Trail and Grace Dunne Richardson Park, City of Lufkin, Angelina County, Texas*. Archaeological Survey Report No. 92-25. On file, Texas Historical Commission, Austin.

1994 *Archaeological Survey of the Proposed Raw Waterline Replacement Project (HUD, CDBG, F2, F13) for the City of Lufkin, Angelina County, Texas*. Archaeological Survey Report No. 94-34. On file, Texas Historical Commission, Austin.

Dolezel, Raymond

1988 *Soil Survey of Angelina County, Texas*. United States Department of Agriculture, Soil Conservation Service, in cooperation with the Texas Agriculture Experiment Station.

Fox, Daniel E., and Christopher J. Jurgens

1983 *An Archeological Reconnaissance at City of Lufkin, Angelina County, Texas, C-48-1553*. Texas Department of Water Resources, Austin.

Preliminary Wetlands Survey

for the:

City of Lufkin Watershed Study

prepared by:

Wetland Technologies Corp.

in association with:

Dodson & Associates, Inc.

Date:

September 15, 1998

Preliminary Wetland Study of Hurricane Creek and Mill Creek

located within and near:

The City of Lufkin, Angelina County, Texas

Introduction:

Wetland Technologies Corporation (Wet Tech) was engaged to perform this preliminary wetland study according to the current requirements of the U.S. Army Corps of Engineers (Corps) by Dodson & Associates, Inc. (Dodson) on behalf of the City of Lufkin (City) in order to assess potential environmental impacts from future flood control projects that may be planned for the Hurricane Creek and Mill Creek watersheds.

A preliminary cultural history study has been concurrently prepared by Prewitt & Associates, Inc. (Prewitt). These two reports meet the requirements of the Texas Water Development Board for preliminary project planning.

The report(s) serve the purpose of describing areas of potential impacts to wetlands, endangered species and cultural resources should they be selected for future project planning and development. Those areas chosen as potential development project locations will require more definitive environmental and archeological study at that time. We have provided some general suggestions for potential development as the results of this study.

Methods:

Pre-mapping- A U.S.G.S. Quad Survey was used as the primary mapping unit to locate proposed project area(s) and the attached map enclosures are prepared from the same materials. The primary quad map utilized consisted of the northwest section of the Lufkin Quadrangle, 7.5 minute series; along with a small part of the Keltys and Redland Quadrangles.

A copy of the *Soil Survey of Angelina County, Texas* soils map and it's associated hydric soil list was obtained from the Natural Resources Conservation Service (NRCS) Lufkin office and compared to the quad map in order to determine potential hydric soil conditions before site inspections were performed.

As a part of pre-mapping studies, we examined a series of aerial photos flown on 3/2/96, scale ratio of 1:9996, which were provided by Dodson. Wet Tech was also provided a streambank and watershed location map by Dodson; along with a set of detailed 2 foot topological drawings of the Hurricane Creek study area.

Site inspections- After noting areas of potential concern during the pre-mapping; the Mill Creek streambank was examined for one full day, and three full days were expended inspecting Hurricane Creek streambank(s).

About 30% of the study area(s) consisted of fully developed urban land, about 30% of partially developed urban land, and about 40% of rural land impacted by certain agricultural practices (timber management and clearing for cattle pastures).

Conditions during site investigations were influenced by a major thunderstorm that traversed study area(s) at the beginning of our trip. Violent high winds downed many large trees and sudden (but short duration) heavy rainfall produced a visible high-water mark for the entire inspection period. Several homes reported as flood-prone on the upper Hurricane Creek experienced stormwater rising in their yards, and most large downstream channels overflowed their banks.

Agency Comments:

Prior to preparation of this report we obtained a copy of *Guidelines for the Preparation of Environmental Assessments* (ed-1, 10/10/97) from the Texas Water Development Board (Water Board). We subsequently contacted the Corps' Dallas Division office regarding persons responsible for the Lufkin area at the Corps' Ft. Worth District. We then contacted the Chief of Enforcement (regarding 404 Determinations) and the Chief of Evaluation (regarding 404 Permitting) of the Corps' Ft. Worth District. The Chief of Evaluation is currently involved in developing recommendations for alternatives to streambank modifications with other interested agencies similar to those in this report, and is planning a series of workshops to present these criteria to concerned parties.

The biologist responsible for East Texas for the U.S. Fish & Wildlife Service (USF&WS) was contacted regarding endangered species, as well as the Texas Parks & Wildlife Department (TP&WD) Tyler office.

Background Information:

Our primary focus in this study is to assess overall environmental liability according to directives of the Water Board in order to aid in potential site selection for detention facilities and other flood control measures, as well as potential sites for 404 mitigation of those projects. Although other environmental concerns are addressed herein, the primary regulatory area that will be involved is Corps 404 jurisdictional authority.

A part of that jurisdiction is determined by the Corps according to the current definition of wetlands (whether associated with a stream or not); whereas another part is determined by them according to whether projects are located in "waters of the U.S." (in association with a wetland or not).

These two major parts of a 404 jurisdictional determination are (separately) then considered in several sub-parts before a combined decision is rendered by the Corps Enforcement biologists. Once 404 jurisdiction is determined, they will notify the Corps Permit Evaluation project managers (and the proposing entity) that an application for a 404 permit to impact them is required.

Section 404 of the Clean Water Act: Each of the many Sections of the Clean Water Act (the Act, as passed by Congress [and in various revisions] in the early and mid 1970's) addressed some individual public concern by establishing regulations over pollutants contaminating the public water supply. The water quality concern referenced within Section 404 was primarily related to dredge spoils from channelization, and fill materials from upland construction being deposited into "waters of the U.S".

Congress had determined that functions desirable to the public interest currently being performed by waters of the U.S. were seriously degraded by deposition of these materials; therefore, public waters were to be protected from such pollutants in order to achieve clean water goals along with "end of pipe" regulations established in other Sections of the Act. As soil-based materials dissolve into sediments, they pollute public waters, and fill materials greatly restrict the amount of public water. Consequently in both cases, the filling entity was "taking " that "non-productive" public water area for it's own use.

Therefore, Section 404 was promulgated primarily to protect exsisting water quality (for both drinking water and recreational uses) to be improved by other Sections of the Act, and to reserve available water capacity for future public use(s).

Although the Sections regulating end of pipe discharges were assigned to the States and (a federal authority that became) the Environmental Protection Agency (EPA); Section 404 was assigned to the Corps of Engineers as it had an existing regulatory permit program in place. The Corps had previously maintained a long term permit authority over placement of obstructions into or excavations from "navigable waters of the United States" per Section 10 of the Rivers and Harbors Act of 1899.

As a matter of practice, the Corps combines Section 10 authority and Section 404 authority into one consideration when "determining" whether a proposed activity requires a permit. A number of permit requirements thought by project proponents to be Section 404 wetland related are actually Section 10 rules.

Although flood storage capacity and water cleansing functions of wetlands (both adjacent to and isolated from waters of the U.S.) were well known by scientists advising Congress during the drafting of the Act, these functions (and other desirable functions) were not well defined in (the Act's) early drafts and revisions. Consequently, when the Corps began releasing rules in 1976 to add Section 404 to their existing Section 10 permit program, they ignored the intention of preserving water quality and capacity functions of the Act and focused on the narrow definition of regulating deposition of fill material into "navigable waters" (only).

Subsequent revisions were passed by Congress that included regulation of other desirable functions (other than water quality and quantity) and special aquatic habitats, including wetlands. Early in the 1980's wetlands were recognized by Congress to provide all of the water quality and flood capacity functions intended by the Act (as well as special habitat functions). As a consequence, the Corps was required to develop regulations for impacts to both adjacent and isolated wetlands separate from consideration of any "navigability" considerations.

The Corps began to introduce these "404 only" rules in the mid 1980's and considers the end of 1985 in most cases as the cut-off date for grandfathering any un-intentional impacts. Any intentional circumvention of Corps rules already considered inadequate by Act supporters was not then, and is not now protected by grandfathering.

During this same mid 1980's period the Corps developed a definition of wetlands which was issued in 1987 as *Technical Report Y-87-1* and refered to as the Corps' Wetland Delineation Manual. Lands existing at a higher elevation than a line "delineated" as described by the '87 Method were defined as uplands and therefore not regulated; whereas, all elevations below the line were regulated wetlands, whether adjacent to or isolated from U.S. waters.

404 Wetland Definition: The wetland manual known as *Y-87-1* immediately was considered scientifically faulty for the purpose of providing the protection intended by Act proponents; that is, the Corps was attempting to establish a permit program as instructed by Congress, not protect the functional benefit interests of the public. As a result, various scientific groups and a number of affected federal agencies formed a large national committee to achieve a consensus regarding a national definition of wetlands that would be regulated.

In 1989 the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* was issued jointly by the Corps, the EPA, the USF&WS, and the Soil Conservation Service (SCS) to be known as the '89 Wetland Manual. Although the national lists of hydric plants, hydric soils and the list of hydrologic indicators were not changed, the way in which the three required parameters were calculated was changed in a number of ways, the result of which defined wetlands that had previously been defined as uplands. Congress subsequently rejected the '89 Manual and all parties and the Corps have agreed to return to the '87 Manual.

However, project proponents have desired that 404 wetlands be classified as "good, better, and best" in quality in order to negotiate mitigation requirements with resource agencies somewhat predictably. The development groups have agreed that they will accept the Act's supporters' desire for recognition of wetlands according to function in order to achieve a "good, better, best" classification. Accordingly, the Corps has committed to scientific classification of wetlands (both existing and mitigation to be built) with adoption of a method titled the *Hydrogeomorphic Assessment Method* known as HGM with a focus on wetland functional values.

1.) data points (DP's)- Are selected by the inspecting biologist as being typical of the site and their locations are mapped on his report. Each DP should be located entirely within one (1) occurrence of either a typical upland or wetland, not on a dividing line between them. If a typical delineation line is to be established as a part of the work, it should be selected between the wetland DP and the upland DP, and flagged a reasonable distance in each direction.

2.) hydric plants- National Plant List- The *National List of Plant Species That Occur in Wetlands: yr. pub. National Summary* is compiled and published by the U.S.F.&W.S. with the year published denoting a particular edition (revision). For example the '88 edition is noted as *Biological Report 88(24), September 1988.* The hydric status of individual plant species is negotiated and agreed on before publishing between the National and Regional Interagency Review Panels. The list divides known U.S. plant species into five (5) categories in descending order from upland to wetland with three (3) intermediate categories designated as "facultative". The four (4) categories that are known to grow in wetlands are provided (there are very few upland only species listed within this publication).

The four ratings are:

a.) facultative upland (FACU) species- mostly upland, occasionally found in a wetland, and
b.) facultative (FAC) species- found either in upland or wetland, and
c.) facultative wetland (FACW) species- mostly wetland, occasionally found in an upland, and
d.) obligate (OBL) species- found only in wetlands.

The three facultative designations are further modified with either a (+) or a (-) for some species that "weight" the numerical score somewhat.

Species within the designated DP inspection area are identified and those that are dominant noted first; with individuals of occasional species noted last onto the accepted Corps Determination form for the '87 Method. If a delineation line (the Line) is to be marked, a species known locally by the biologist to dominate at the edge (such as FACW + species *Andropogon glomeratus* [bushy bluestem] within open-sun prairie areas) is selected for closer examination. The soils are shovel tested for wetness on either side of the proposed Line in order to confirm the species selection. The Line is then marked in both directions along the plant species/soils gradient until a change is noted.

3.) hydric soils- National\County Soils List- The list titled *Hydric Soils of the United States* is prepared and published by the NRCS (previously the SCS) in cooperation with the National Technical Committee for Hydric Soils. The local county soils map of the NRCS (such as the *Soil Survey of Angelina County, Texas*) is provided with a list of hydric soils found in that county, including a breakdown of hydric soil type inclusions found in upland soils.

Soil types are described and their locations mapped within the NRCS county handbook to the extent that field identification (of a soil type) is possible by a properly trained individual. Such detailed NRCS soil descriptions also include landform, position on the landscape and frequency of flooding; which should (also) be observed at each DP, and noted as to whether they conform to hydrological indicators found at the same DP (more fully described below).

The hydric list(s) were prepared for agricultural uses only; consequently many wet soils that will qualify as 404 hydric soils are not listed as such by the NRCS. It is important to note that NRCS determination of a soil type as hydric is only one of a number of hydric soil indicators listed (as qualified) by the '87 Method. Therefore, if the soil type identified during site inspection is not NRCS listed (as hydric) ; but other indicators are present sufficient to meet '87 Method requirements, the soil type is then classified as hydric for 404 purposes.

Some biologists extensively trained in the '87 Method are able to identify various soil types sufficient to report on the '87 DP form. However, the additional expertise of soil scientists or technicians may be required to make the soil determination when soil classification is the deciding factor, or a soil type not described in the NRCS county soil survey is present.

On agricultural lands, NRCS soil scientists trained in the '87 Method will make a determination according to Swampbuster Act rules. At the limits of rural communities where agricultural lands encroach into 404 jurisdictions, there is a necessary cooperation between the Corps and the NRCS, as the '87 Manual is the basis for the Method to be utilized by all parties.

4.) hydrology- hydrologic indicators- There are no national or county lists of true hydrologic indicators provided to practioners of 404 determinations. Certain "wetness" indicators are described in the '87 Method which may or may not be present on-site. These are more visual, less technical in nature, such as "blackened leaves" accumulated in deposits up to the high water mark. Each is ranked as either a primary or a secondary indicator in order to "weight" the numerical finding. These indicators are noted on the DP form where required and are calculated into the finding which determines whether available water source(s) are sufficient (or not).

As most trained 404 practioners have biology backgrounds, and a few have soils backgrounds, these visual "clues" allow a 404 determination to be made without an opinion of a wetland hydrologist. However, a proper observation of the depressional nature of the landform, size of the upslope watershed, and the probable frequency and duration of flooding is a superior indicator of sufficient hydrology.

In urban areas, hydrological expertise is available from practioners who make such observations in order to design construction of mitigation wetlands into previously upland sites. In rural areas, NRCS personnel are skilled in hydrology calculations as a consequence of determining the hydric nature of soils, and calculation of upslope watershed(s) for farm pond designs.

The driving force for adoption of the HGM Method described previously is it's rating of functional values for use by all entities participating in 404 rulemaking. However, HGM is based on a true technical observation of a site's actual hydrologic characteristics. If the HGM Method does replace the '87 Method, the '87 Manual's visual clue indicators will not be sufficient to determine a site's hydrology (or lack of) for 404 purposes.

5.) 404 determinations- All three hydric indicators (plants, soils and hydrology) must be present and determined to be sufficiently wet in order to qualify a DP as a wetland site. If any one of the three indicators is judged to be lacking by the '87 Method, then the DP is not a qualified 404 wetland.

A typical example would be documenting by the on-site observer of a previously ditched and drained (before the end of 1985) wetland site; whose wet soils continued to germinate wet plants from normal rainfall (only), but the necessary hydrology is no longer present according to the '87 Method. Over a long period of time the soil would lose it's hydric nature, and FACU plant species would eventually dominate such a habitat (FAC species such as *Pinus taeda* [loblloly pine] are classified as wetland species for 404 qualification purposes).

Conversely, a non-hydric soil can be provided more hydrology than historically available by development activities wherein the soil would develop wet characteristics and thereby begin to germinate seeds of wet species within it's local area. This happens when a flat or concave surface is cut into a previously sloped surface over a slowly permeable soil type; or upstream development begins to flood an area not historically a floodplain.

As any determination by the observer of a lack of one type of hydric indicator will remove a DP (and all similar habitat on-site) from Corps Jurisdiction, then all other considerations required by the '87 Method are rigorously enforced (hence the Corps designation Enforcement Section). There is considerable lattitude for use of "best professional judgement" by all parties practicing in the 404 field which can lead to disagreement as to the meaning of a particular indicator.

Therefore, Corps Enforcement Section confirmation of a private practioner's 404 determination (and delineation lines if a part of the work) is required in order to be accepted by all parties. That is, an incorrect determination of a qualified 404 wetland area as technically too dry according to the '87 Method by a wetland consultant will not protect a project developer from Act penalties if the Corps does not agree.

U.S. Army Corps of Engineers 404 Enforcement Program: Any public complaint that construction work is impacting a 404 wetland must be investigated by qualified Corps biologists within 24 hours of the call. Concurrence by the inspecting biologist that 404 impacts are in progress will bring an immediate on-the-spot "cease work" order. An investigation ensues that lasts about one year which concludes with a finding of the monetary fine to be paid, and a requirement to re-construct the impacted wetland on it's original site and to it's original state.

Considerable effort is expended in order to determine whether a development impact was intentional (or not). If "intent" is discovered, the case may be referred by the Corps to the EPA for prosecution under penalties of the current revision of the Clean Water Act.

At the time of the initial finding, a project developer may negotiate a settlement agreeable to all parties by proposing suitable mitigation (more fully described below) to offset existing project impacts, and mitigation for future impacts of the site's development plan. If the Corps agrees (and the EPA, if involved), the Enforcement Action will be put on hold while an after-the-fact permit is negotiated with the Evaluation Section. If an after-the-fact permit is negotiated between the parties (which also takes about one year), the project is allowed to proceed along with simultaneous construction of the mitigation agreed to.

However, on a daily basis the Corps Enforcement Section's work consists mainly of inspection of proposed wetland impacts by qualified biologists in order to determine their 404 wetland status. If the Corps' biologist agrees with the findings presented by the developer's consultant regarding the number of acres and location of jurisdictional impacts planned, the proposed project is forwarded to the Corps Evaluation Section to process the developer's request.

U. S. Army Corps of Engineers' 404 Permit Evaluation Program: The 404 program consists of a separate review of 404 permit requirements by Corps Evaluation Section permit specialists; who may be, but are not necessarily biologists themselves.

Corps evaluation of an application to permit proposed 404 Wetland impacts will include consideration of qualification for various components of the Nationwide Permit program for small impacts or the Individual Permit program for larger impacts. The Nationwide Permit program will be modified (the Nationwide #26 Permit will be dropped altogether) before any actual projects are constructed in the Hurricane Creek or Mill Creek watersheds, or elsewhere within the City of Lufkin. Individual Permits include all 404 impacts in a single project permit and require public notice.

All Corps rulemaking must meet the requirements of the *National Environmental Policy Act* (NEPA) and include co-ordination with the USF&WS for Endangered Species review, and co-ordination with the State Historic Preservation Officer (SHPO) for cultural resources review.

1.) mitigation of wetland impacts- An application to the Corps for a 404 permit to impact wetlands must contain an offer to mitigate (offset) such impacts by creation or restoration of new wetland areas. Certain poor quality wetlands may be replaced at the rate of 1:1; however, most mitigation ratios will be 2:1 (2 new acres constructed for every acre impacted) or higher.

Due to the cost of land acquisition, design, construction and maintenance of mitigation wetlands, avoidance of wetland impacts whenever possible is the lowest project cost alternative.

2.) mitigation sequencing- To be granted mitigation, a project applicant must first actively practice a series of sequential actions during preliminary planning wherein the first is avoidance of all 404 impacts, then minimization of as many 404 impacts as is possible; and finally, if any 404 impacts are determined to be not avoidable, then mitigation may be offered by applicant. Avoidance of the best quality wetlands also will result in lowering the mitigation ratio, thereby lowering hard costs of mitigation to applicant.

Wetland Types: Two primary wetland habitat types occur within the watersheds described in the Results section of this report; as follows:

1.) braided channel- Typical floodway configuration where storm surges regularly overflow the main channel. Such overflow cuts many smaller channels into the floodplain above the main channel's normal bank level. This type of habitat is more complex than a backwater floodplain wetland due to a considerable amount of edge effect, whether open-sun or forested.

2.) flooded forest- Typical forested wetland whether lying in the active floodway or on the backwater floodplain above. All of the effects of shade dominance that occur in upland forests are also a factor in forested wetlands, along with selection for tree and shrub species tolerant of wet soil conditions. Where standing pool levels prevents wet tree and shrub species from invading (except for bald cypress [*Taxodium distichum*], black gum [*Nyssa sylvatica*], and buttonbush [*Cephalanthus occidentalis*]), an open-sun prairie wetland may exist within a forested area. However, at the edge of standing water, a water oak (*Quercus nigra*) -willow oak (*Quercus phellos*) forest will invade the floodpool unless managed by fire or mowing.

U.S. Fish & Wildlife Service's Endangered Species Program: The USF&WS maintains a permanent program for Threatened and Endangered Species (T & E Species) that includes identification and listing of species at risk of extinction, development of recovery plans for those species, and implementation of such plans to attempt recovery and de-listing of T & E Species. The TP&WD also operates a similar program for species identification and state listing, which may include other species not listed by USF&WS.

State Historic Preservation Officer's Cultural Resources Program: The Corps co-ordinates with the SHPO's office in Austin, Texas to determine whether any potential project areas may have cultural significance. If so, an intensive cultural resources survey may be required. Such a survey would entail pedestrian coverage accompanied by shovel testing and trenching/augering, perhaps followed by test excavations, to identify and evaluate archeological sites, while historic buildings and structures would be recorded and evaluated through an architectural survey. Adverse effects to significant resources can be mitigated, usually through data recovery excavations at archeological sites and Historic American Buildings Survey (HABS) or Historic American Engineering Record (HAER) documentation of buildings and structures, or the project can be designed to avoid the resources. The Corps' Fort Worth District maintains on staff an archeologist for preliminary determinations and co-ordination with the SHPO's office.

Discussion of Study Area 404 Considerations:

Corps' 404 Jurisdictional Program: Several factors are a part of current 404 rules in effect that are directly related to whether the Corps' Ft. Worth District exercises jurisdictional authority over the City's proposed watershed projects within areas appearing to be non-jurisdictional; as follows:

1.) NRCS Soils List- A critical part of the definition of a wetland is a sub-part determination of whether a site's soil type can be considered hydric (wet) in any particular area being examined. As is more fully described above, consideration is given in the '87 Method to the soil type's listing on the NRCS county hydric soil list. However, as a practical matter, a listed soil can be drained sufficiently to prevent it's being hydric; conversely a non-listed soil can have sufficient hydrology to cause it to develop definite hydric characteristics.

We note that the NCRS has not listed as hydric soil types within the Mill Creek streambanks, and also Hurricane Creek streambanks until about a mile south of Loop 287. Though soil types described within Mill Creek and upper Hurricane Creek are not listed as such, the soils are very wet as described, consequently any area flooded sufficiently enough to meet the 404 hydrology criterion will also meet the Corps hydric soil requirements.

2.) Small Urbanized Channels- When considering determination of "waters of the US" that are jurisdictional, wetland vegetation is not necessary, as the high-water mark is the primary determining factor. Consequently, on-site observation of this high-water mark invokes Corps authority in small streams where there may be no plants existing.

This is important to the City of Lufkin as all of the urban tributaries share this regulatory qualification.

Jurisdictional Corps authority ceases above the high-water mark, provided no associated wetland exists (above the high-water mark). Exemption from jurisdiction of "above the headwaters" (5cfs streamflow) only applies to Nationwide Permit #26, which will not be available shortly.

Corps 404 Mitigation Program: Where the Corps requires mitigation to offset impacts to regulated wetland habitats, certain rules are in effect that control criteria of the proposed design.

The specified mitigation-

a.) must be located nearby (preferably directly adjacent to the impacted area), and
b.) must be "like kind" (same type of habitat as is destroyed by development project), and
c.) must be at least a mitigation ratio of one new acre created to one existing acre destroyed (but may be a higher ratio agreed to by applicant in order to proceed).

Potential Mitigation Projects: We have identified a number of areas in the following report where detention ponds could be installed along with (or rather than) channelization in order to reduce flood hazard. These could be detention areas with a permanently wet bottom that may also be designed to serve as mitigation sites for un-avoidable 404 impacts, thereby reducing costs of mitigation by as much as 50%. We have denoted these areas as potential detention/mitigation sites in the following material and as **Sites** on the attached maps.

As permanently wet bottom projects, these combined project designs would require natural pond type sedimentation traps to prevent mitigated wetlands from becoming uplands due to accretion of sediments. Accordingly, State and Federal requirements for control of in-stream sediments to be enacted in the future would also be provided for.

Typical Mitigation Design: These wetland design details are typical (only) such that most of the following proposed project sites would be constructed in a similar manner. They do not represent the level of detail required in order to successfully construct a mitigation quality wetland.

Within a typical detention/wetland project, the site's fertile topsoils would be stripped and set aside for subsequent construction of wetland planting shelves, and topsoiling sideslopes. The major excavation contractor would cut away sterile subsoil down to slightly below the Creek's bottom elevation and haul it away from the project. A berm about 5' wide and 2' high of natural ground would be left along the Creek bank to prevent small flows from entering until completion.

The detail contractor would shape bottom configurations according to the agreed on design, and then lay saved topsoils onto wetland planting areas up to final elevation. Naturally shaped large capacity (deep) sedimentation pools would be excavated at the designated infall area. Plants would be taken from storm ditches nearby and installed within on prepared planting shelves at the correct elevation for their particular species. Plants would be watered by pump from the Creek every day it does not rain until final flooding. On completion the inlet channel and outlet channel would be dug through the separation berm to connect with the streambed.

Discussion of Other Considerations:

T & E Species Program: The national and state regulations governing T & E Species primarily address identification of unique habitat with potential for utilization by such species. Biologists trained in T & E Species inspections must prepare their reports identifying potential habitats as described in specific laws passed at the national and state level (as well as whether any animals or plants are actually observed by them). However, agencies involved which will review the inspecting biologist's report have determined the actual location (or lack thereof) of most of these species. Consequently, the appropriate method of determining future comments of resource agencies is to submit areas under consideration for potential project locations to them prior to beginning any definitive environmental studies.

If either agency replies that it has mapped one or more listed species in a potential project area a qualified biologist must be engaged to determine whether any individual listed animal or plant actually inhabits the area.

USF&WS and TP&WD biologists have stated to us that no T & E Species are a concern within urbanized areas of the City. Where lower Hurricane Creek becomes a major stream about one mile south of Loop 287, there may begin to be a concern regarding some of the fishes as well as the alligator snapping turtle (*Macreclemys temminchii*). At the extreme remote end of Hurricane Creek west of Hwy. 324, the timber rattlesnake (*Croatalus horridus horridus*) may or may not be a concern until they consider a particular proposed project site. We recommend that early in planning a specific project (that) a proposed site be submitted to them for their comments; which comments would then (if negative) be provided the Corps and Water Board, and if positive, necessary avoidance or mitigation agreements negotiated with them in advance of any 404 Permit or Water Board application.

It must be noted that such a T & E Species restriction may prevent developing a specific project site completely. Mitigation for T & E Species is much more complex than 404 wetland mitigation and in some cases impossible to construct. An example would be an attempt to re-create a particular flowing stream habitat for fishes in lower Hurricane Creek which would not be possible without access to a similar floodflow pattern.

Cultural Resources Program: All preliminary comments regarding Cultural Resources has been provided in a report by Prewitt. Such report completes our combined requirements (scope of work) for this contract.

We noted a potential project site at the north end of Hunter's Creek street that is also identified as a **Site** on the attached map. It is about three acres of vacant residential land directly adjacent to a pink house that is shown as a repetitive flood loss property, located on the northeast corner of the deadend of Hunter's Creek street. Water had risen in the yard of the pink house during the recent storm event, and also in the lower corner of the prospective project site. Excavation of additional flood capacity into that lower corner may hydrologically benefit the pink house and several nearby repetitive flood loss properties.

Tributary Two: The short length of channel located in a residential neighborhood above the Lowe's store is sited on Fuller fine sandy loam (FfB) and Fuller-Urban land complex (FuB) soils. Fullers' description of saturation in winter and frequent high water table, location in interstream divides, and poor suitability for urban development indicate the potential to be hydric where regularly flooded (though not listed as hydric).

We observed that the new Lowe's has installed behind the store a small detention pond for collection of their runoff directly adjacent to (but not within) the streambed. A potential project **Site** shown is (recommended to be) expansion of Lowe's existing small pond into the vacant land surrounding it, in order to capture upstream runoff within the enlarged detention volume.

Tributary Three: Most of the upper section runs through residential yards as is described above. It's soil type is the Koury soil also more fully described above. Immediately on falling out of the last neighborhood, it enters a large, remote, un-developed area described in Section Two below. We did not observe any potential project sites directly adjacent to the small channel within the developed Section; however, flood capacity could be excavated at the outfall from the neighborhood into un-developed land as is shown on the enclosed map.

Tributary Four: Only a very small section is urbanized as the stream is semi-urbanized above and below Hwy. 59 as is described in Section Two below. It is developed into an apartment complex directly east of Hwy. 59 that does not offer opportunities for flood detention projects. The soil type is Alazan very fine sandy loam (AaB) of 0 to 4 percent slopes. It is another loamy soil limited from most uses due to wetness, but is not listed on the NRCS hydric soils list.

Tributary Five: The upper section flowing through the Crown Colony subdivision is residential and does not appear to contain a potential project site within it. The soil type is Alazan described in Tributary Four above.

We observed that where the stream outfalls from the tankcar culvert under Edmund Grey Road that the streambed has recently been channelized behind the Church Retreat property. We have not noted the area on our map, but perhaps the vacant land adjacent to the east of the new channel would serve as a project site.

Summary of Section One Report:

1.) Most of Upper Hurricane Creek that is significantly developed occurs in the upper parts of the Main Stem and Tributaries One, Two, Three and Five. The soil types identified for the Main Stem and all of the Tributaries are not listed on the Angelina County- NRCS hydric soil list; however, each type is sufficiently wet in composition to qualify as a 404 hydric soil where frequently flooded or depressional.

This factor is of little consequence in Section One (but becomes a major factor in Section Two reported below) as very few wetlands are associated with small channels located within residential backyards.

2.) Such small channels are regulated up to the historical high water mark on their streambank, and small impacts (such as stream crossings) may be allowed by various Nationwide Permits.

Channelization of the small streams will require complete 404 Individual Permits that include public notice and comment, and mitigation of those impacts. All of the tributaries within the City share this regulatory concern.

3.) Care has been taken during field work to identify and characterize sites within floodprone areas that have potential to provide flood capacity through temporary detention, and to mitigate small 404 impacts on-site.

Section Two- semi urbanized- Middle Hurricane Creek:

This Section is comprised of the Main Stem and Tributary One below Denman Avenue to the Main Stem junction with Tributary Four, Tributary Two below the Lowe's store, Tributary Three below the residential neighborhood, most of Tributary Four except within the apartment complex, and Tributary Five below Crown Colony to (but not including) it's junction with the Main Stem. This Section is also shown on **Exhibit 1**, except for that area south of Loop 287.

All of these are described as semi-urban stream segments whether large or small in size within this Section. The Main Stem's junction with Tributary Four about one mile downstream of Loop 287 marks Section Three where the area becomes very remote and rural in nature.

Generally the difference(s) between these areas and Section One reported on previous pages relates to their lower position on the landscape which must contain larger flows and have developed larger channels, some of which overflow their banks during heavy rainfall events. These floodplains adjacent to and above the main channels consist of complex, high quality wetlands that would be difficult to 404 permit complete development of as would be a part of in-stream channelization projects. Due to established high water marks, lack of NRCS hydric listing of soil types would have no effect on qualification as a Corps regulated area.

A second difference with Section One is the existing un-developed land above the high water mark directly adjacent to some parts of these channels. Such non-regulated uplands offer the opportunity for location of diversion channels and/or detention areas provided some remaining floodflow was allowed to continue to provide hydrology to existing Creek channels and adjacent floodpools.

Upper Main Stem and Tributary One: The upper Main Stem and Tributary One fall downslope toward each other below Denman Avenue, turn parallel for a short distance below the high school, and then run together within the Kiwanis City Park. A braided channel, flooded forest type of high quality wetland habitat begins within the area behind the high school and continues completely to the end of Hurricane Creek. All of the area consists of the Koury soil type more fully described in Section One above, which is flooded sufficiently throughout to qualify as hydric, and would be regulated up to the high water mark in any case. Consequently, the interstream divide and most of the streambank to either side will qualify as high quality 404 wetland.

1.) Denman Avenue South- A short distance south of Denman Avenue both the Main Stem and Tributary One begin to exhibit adjacent floodplains from frequent overflows. These are small pocket wetlands that could allow a channel to be excavated between them to intersect with the existing channel for diversion with very little wetland impact from construction activities. The existing main channels and small wetlands would require full Corps permitting to impact.

Small areas of uplands directly adjacent could site flood control projects accessed by diversion channels from and to either of the main channels.

2.) East of High School- In the area behind the high school, the Main Stem and Tributary One turn almost parallel to each other and run southward toward the Kiwanis City Park. Where the interstream divide eventually falls below the established high water mark for both channels, a good quality forested wetland is reletively intact. This quality of forested wetland would be difficult to permit 404 impacts to; and if allowed, would be a mitigation ratio in excess of one-to-one. Channelization and/or detention on adjacent upland outside wetland floodpools would be prefered, provided sufficient hydrology was available to both segments downstream.

3.) High School to Kiwanis City Park- From directly below the high school downstream to the park lies the <u>least impacted high quality wetland</u> along the Main Stem within the City of Lufkin. Within the interstream divide, large loblolly pines stand on mounded areas less frequently flooded, and floodplain hardwoods from saplings to mature large trees inhabit lower areas. Between large trees a typical scrub/shrub habitat provides very dense cover for wildlife. Evidently the loblolly pine timber has been thinned, but not clearcut in perhaps 50 or 60 years, and the floodplain hardwoods may be somewhat older than the pines.

Most likely, impacts from <u>flood control projects would not be allowed</u>, including reduction of upstream floodflow by bypassing the area within an uplands with a channelization project. Excessive ponding more than is currently existing may or may not be allowed.

4.) Kiwanis City Park- Most of the park lies within an established floodplain between the Main Stem and Tributary One flowing to their junction at the lower park boundary, except for a small amount of high ground along the eastern edge. This naturally formed floodpool acts as a small volume detention basin when the two channels overflow their banks and pond against the roadbed along the southern edge of the park. However, during smaller rainfall events that do not cause overflow, water drains quickly off into both bordering channels, which enables the interstream divide to dry faster than nearby poorly drained areas. Large pines and hardwoods provide extensive shade cover for the park, but all small shruby species that would normally live between them are prevented by park maintenance.

As the park is currently impacted by development, additional development for flood control may be more acceptable to wildlife agencies than the area directly upstream. However, the City may not desire loss of any park area to flood control. Mitigation would be required for any type of development actvity that is more intrusive than existing park facilities.

5.) Summary of Upper Main Stem/Tributary One- There appear to be opportunities for small flood control projects within uplands directly adjacent to both stream segment(s) described in item **1.)**. Some projects may be allowed within Corps regulated wetlands in both stream segments identified as items **1.)**, **2.)** and **4.)** above. Such impacts would require suitable mitigation nearby and to be like-kind habitat replacement.

Most likely, development impacts would not be allowed to either stream segment and/or their interstream divide within item **3.)**, including negatively affecting their flooding regime.

Lower Main Stem: The Main Stem flows through an active floodplain along the Azalea Trail to Richardson Park where it is joined by Tributary Three. Their combined flow continues as the lower Main Stem of Hurricane Creek to it's junction with Tributary Four. All of the Main Stem below Tributary Four is reported on in the following Section Three due to it's considerable change in character from that point. That part inside Loop 287 is shown on **Exhibit 1**, and that part below the Loop is shown on **Exhibit 2**.

The area from the City Park to Tributary Four consists of frequently flooded Koury soil that qualifies as a 404 wetland. The high quality flooded forest type of habitat described previously continues throughout the area and is not described in detail here.

1.) Azalea Trail Segment- Hurricane Creek flowing from the City Park along the Azalea Trail flooded it's streamside zone from the storm event occurring during our field work. The small amount of rainfall during the event indicates that the zone is frequently flooded. The available hydrology causes the Koury soil type to be considered hydric, except where new deposits of sand changes it's nature. At the end of the Azalea Trail, the stream is joined with Tributary Three in Richardson Park and turns southward under Loop 287.

The narrow floodway is constrained by development all it's length to the park junction limiting potential for projects outside the floodway. The floodway zone would be Corps regulated and difficult to permit development projects within that are more intrusive than the Azalea Trail.

2.) Segment below Loop 287- As the Creek emerges from under the Loop, it's channel widens considerably in order to allow larger flows from the addition of Tributary Three. It begins to curve sinuously in a manner that continues on an increasingly larger scale through Section Three described below to it's junction with Cedar Creek. The soil type is the Koury soil which is sufficiently flooded to be hydric below the stream's regulated high water mark. A short distance downstream at the junction with Tributary Four, the soil type changes to Pophers (Po) silty clay loam, which is a NRCS listed hydric soil.

Due to the soil type change, additional floodflows of Tributary Four, and remote nature of the landscape, we have selected the boundary between Section Two and Section Three to be at that junction. Accordingly, this small segment noted as item **2.)** is shown on the map identified as **Exhibit 2**, rather than with the balance of Section Two on **Exhibit 1**.

a.) potential flood control project(s)- This segment is unique due to it's potential for location of flood control projects for the City, provided that it is not too far downstream from problem areas in the center of the city to be effective. This is the last segment of Koury soil such that any area not frequently flooded will not qualify as a wetland. Those areas under the high water marks are limited by high banks and small flood zones across the inside of curves in the streambed. This presents a much narrower regulated zone to Corps permit than the broad floodways prevalent both upstream and downstream. Channels could be cut from an outside bank curve through uplands to the next outside bank, bypassing the lower regulated riparian wetland on the inside curve with only minor 404 permitting.

b.) <u>other considerations</u>- Small amounts of mitigation would be required for areas where cuts were made into the bank. However, the inner loop wetland will be required to have as much access to floodwater as before project construction for this strategy to be easily approved. The abandoned inner loop will provide some additional flood capacity, but may cause undesirable turbulence. Also, future siltation may cause the Creek to leave the new channel and return to the old sinuous configuration.

c.) <u>potential detention/mitigation project(s)</u>- This area appears to be the first un-developed land along the Main Stem of Hurricane Creek where acreage may be available for large scale detention projects (there are some large raw land tracts upstream along Tributaries Two and Three described below). Within such a large detention project, there are opportunites for landscape scale 404 mitigation.

Large wetland projects may be operated as mitigation banks where other City project 404 impacts could be mitigated, and/or space may be sold to a private developer. Along the gulf coast, the Texas Department of Transportation has participated in a number of mitigation banks operated by other entities.

Tributary Two: The semi-urban area starts directly below the Lowes' store and flows westward outside of and parallel to Loop 287 until it falls beneath the Loop and mall parking lot. At about the Lowes' store the soil type changes from Fuller fine sandy loam (Ffb) to Alazan very fine sandy loam (Aab) of 0 to 4 percent slopes. It is another loamy soil limited from most uses due to wetness, but is not listed on the NRCS hydric soil list. The stream segment is shown on the map attached as **Exhibit 1**.

A short distance downslope from Lowes' the channel splits into a braided multi-channel flooded forest configuration. The high quality of forested wetland active flood zone would be difficult to 404 permit. The narrow landform between the floodway and the Loop does not seem suitable for flood control projects. As described more fully in Section One above, a large upland area is located directly adjacent to the south of Lowes' small detention pond that may have potential for expansion into a large detention project.

Alternatively, a channel could be cut into the upland running parallel, but bypassing entirely around the floodway zone downslope to the main culvert under the Loop, provided that sufficient flow continued to be available to the avoided wetland area.

Tributary Three: This segment falls out of the developed neighborhoods and flows through a large un-developed area in a large curving stream southward to Grace Dunn Richardson Park where it joins the Main Stem. It is located on Koury soil it's entire length and is shown on the map attached as **Exhibit 1**.

At the upper end it is a small channel with raw land tracts on both sides that has the potential for 404 permitting for flood control. This short reach of low quality mostly in-channel streamflow has the potential to be one of very few in the City that may be allowed in-stream channelization with appropriate mitigation proposed for it's 404 impacts.

A short distance downstream several large flows are introduced that widen the channel into a major stream with frequent overflows similar to other streams within Loop 287. This larger channel would be difficult to 404 permit impacts to as is previously described several places.

We noted that the City owns and is actively developing land on the western shoreline above the park. This tract happens to lie within the inside curve of the stream that maintains a large floodway across the lower elevations when flowing above the inner bank. Due to previous landclearing activities, the floodzone is changing into an open-sun wet prairie habitat rarely observed within the City.

There may be potential for location of a channel within the upland lying above wetland level. It could cut across the inner loop directly southward to the next outer loop segment within Richardson Park, but allow the inner zone to continue to flood.

Tributary Four: A different profile begins with Tributary Four in that it's located entirely outside of the central City of Lufkin (outside the Loop). East of the apartment project at HWY 59 the channel is reletively small and rarely overflows into 404 wetlands. Below HWY 59, the channel widens from larger inflows and many adjacent forested wetlands are associated with the channel. It is shown on the map titled **Exhibit 2**.

The soil type is the Alazan (Aab) loam type described previously on page 22, except for a small area prior to infall into the Main Stem of Moten-Multey complex (Mx), gently undulating, nearly level stream terraces. Although Moten-Multey is not listed on the hydric soils list, it's description is wet enough that where sufficient hydrology was available, it would be considered a 404 hydric soil. The lower floodpool at the junction of Tributary Four begins the Pophers soil type which <u>is a listed hydric soil type</u>.

East of HWY 59 the small channel exhibits vacant land on either or both sides for most of it's length, although there is a considerable amount of development upslope on the higher ridgelines. It falls out of a large lake flowing westward, and mostly remains within the small channel. This may be another of those segments that would be able to permit in-stream channelization with an appropriate amount of mitigation offered for it's un-avoidable impacts. West of HWY 59 the larger stream would be difficult to permit in-stream projects. However, adjacent vacant uplands on both sides of the segment offer project opportunities.

Tributary Five: The northernmost reach falls out of Crown Colony through a recently channelized area behind the Church Retreat development and joins it's southern arm in a very good quality forested floodpool between their junction and HWY 59. It's soil type is the Alazan (Aab) loam described above east of HWY 59, west of 59 the Pophers hydric soil begins as a part of the Main Stems' upper floodpool down to it's junction with the Main Stem.

The southern segment above the junction is a very small channel that would have a minor amount of 404 permitting requirement as is more fully described in Section One above, including the rare possibility of in-stream channelization. The floodpool east of HWY 59 and all of the main channel west of 59 would be difficult to permit impacts to.

Summary of Section Two Report:

1.) The segment defined as Middle Hurricane Creek lies within a highly developed floodplain that constricts floodflow between well drained commercial land directly adjacent. Most of the Main Stem is currently utilized as public park area and stormwater is allowed to overflow the main channel(s) through the minimally developed floodplain.

2.) The Main Stem and it's floodplain wetlands consist of high quality forested wetland habitat, such that major development projects would be difficult to permit with wildlife agencies that are more intrusive than existing park facilities.

3.) The Main Stem south/outside of Loop 287 does have potential for 404 permitting of large scale flood control projects provided adequate mitigation is proposed to offset wetland/stream impacts. If the project were a detention basin excavated from uplands, it would have flooded land available sufficient to mitigate it's own 404 impacts, and additional area to mitigate impacts from other City projects nearby.

4.) Tributaries Two, Three, Four and Five are adjacent to large tracts of land which have potential for flood control projects to be 404 permitted for construction within their upland areas outside of existing floodways.

5.) The eastern upstream channels of Tributaries Four and Five, and a short segment below developed neighboods of Tributary Three are small in size and rarely overflow into adjacent wetlands. They may be allowed in-stream channelization by wildlife agencies with appropriate mitigation proposed.

Section Three- semi rural- Lower Hurricane Creek:

This Section is described as that part of the Main Stem of Hurricane Creek below it's juncture with Tributary Four throughout it's length to Cedar Creek, and all of the streambanks of Tributaries Six and Seven. The difference(s) between these areas and Section(s) One and Two reported on previous pages relates to their considerably larger stormflows. The Main Stem has developed a large riverine channel that overflows its' banks during heavy rainfall conditions. Similar to Section Two within the City, these floodplains consist of complex, high quality wetlands that would be difficult to 404 permit complete development of.

In addition, the streambank(s) and associated floodplain of the Main Stem at and downstream from Tributary Four is located on soils that are listed as hydric by the NRCS. From the City Treatment Plant at FM 324 downstream to Cedar Creek there may be (or may not be) endangered species associated with either the streambed or the streambanks. All of Section Three is shown on the map attached as **Exhibit 2**, with suggested project locations described below marked as a **Site**.

Main Stem: The hydric soil Pophers (Po) is mapped in a floodpool configuration around the the junction with Tributary Four along with a less hydric soil Moten-Multey complex (Mx) upstream within Tributary Four. The Pophers soil type is mapped by the NRCS along the Main Stem completely to Cedar Creek, and is mapped to extend up the floodpools of junctions with Tributaries Five, Six and Seven. It is mapped upstream on both banks of Tributary Five eastward to HWY 59.

Pophers is described as "deep, slowly permeable, somewhat poorly drained soils on bottomlands. These soils formed in loamy and silty alluvium. They are subject to flooding mainly in winter and spring. Slopes are generally less than 1 percent" according to the NRCS.

This mapping of broad areas of Pophers hydric soil along both streambanks of the Main Stem, and even wider flood zones at tributary junctions, is important to consideration of potential for 404 permitting of flood control projects on adjacent lands. Upstream the non-hydric listing of soils allowed classification of most areas outside the high water mark technically as uplands, consequently such uplands have been suggested as having potential for development of City projects. This downstream segment and associated wider floodpools have no uplands directly adjacent to propose projects within (that may be easily permitted by wildlife agencies).

From it's junction with Tributary Four downstream to Cedar Creek there may be a T & E Species consideration of small fishes. Downstream of FM 324 there may be a concern for timber rattlesnakes along streambanks on either side of the channel.

Directly south of Loop 287, Tributary Six runs parallel to and west of the Main Stem almost to their junction before flowing westward under FM 324. Above their junction floodpool, there is an upland ridgeline area suitable for 404 permitting between the tributary and main channel that may (or may not) have potential as a flood control project area shown as a **Site** on the attached map.

West of FM 324 the large floodway resulting from joining of the Main Stem and Tributary Six continues downstream to Cedar Creek. This habitat is a large scale flooded forest similar to a major river floodplain. The highest flood elevation is somewhat lower than the base of the adjacent City Treatment Plant. Except for that small area around the plant that is regularly mowed, tracts of land on both sides of the Creek consist of floodplain hardwood tree species. It would be difficult to 404 permit any type of development project adjacent to the Creek west of FM 324 any more intrusive than the timber harvesting currently practiced by private landowners.

Tributary Six: The headwaters of Tributary Six begin at the edge of Loop 287 and flow southward a short distance to the Main Stem. The soil type is Fuller fine sandy loam (FfB), 1 to 4 percent slopes. Fuller is a soil that is not wet enough to be classified as hydric above any channel high water marks. For a short distance below Loop 287 it flows within it's banks to the extent that this segment may be allowed in-stream channelization. Large tracts of uplands to either side may have potential for detention projects, also shown as a **Site** on **Exhibit 2**.

Several thousand feet south of Loop 287 the channel widens into a major stream, and floodflows above the bankside have established a floodway wetland on both sides. Although the Fuller soil type continues downstream, it is flooded suficiently to be hydric, and is regulated as being below the streams' high water mark.

Tributary Seven: The north and south branches of Tributary Seven are located on Alazan (AaB) and Fuller (FfA) soils more fully described above, as well as a short reach of Herty very fine sandy loam (HeB), 1 to 5 percent slopes along the north branch between HWY 59 and Daniel McCall Road. All three soil types are not wet enough to be listed as hydric by the NRCS.

Both branches east of HWY 59 are small enough that in-stream channelization may be permitted, except where they pond against the highway. From the floodpool formed at the junction of the north and south branches west to the Main Stem, the flooded forest habitat is such that permitting direct impacts to the habitat by wildlife agencies would be difficult.

<u>Results: Mill Creek</u>

We have organized our report on the watersheds of Mill Creek into details regarding it's east and west branches, which larger streams are further divided into east and west forks upstream. A number of technical descriptions are similar to those described at length in the previous report on Hurricane Creek and are not re-described in great detail here. The nature of Mill Creek is considerably different from Hurricane Creek, due to it's character consisting of at least 50% of prairie wetlands.

All of the area within Mill Creek watersheds are as is shown on the enclosed **Exhibit 3**, and suggested project locations are marked as a **Site**. The area is reported on as follows:

East Branch: The East Fork begins to flow northward from the outfall of Jones Lake within Jones Park under Martin Luther King. It's upper segment is located on Keltys-Urban land complex (KdD), 5 to 15 percent slopes that is a well drained upland fine sandy loam. The only hydric soils are those located directly under constant streamflow and associated wetland floodpools. The floodway below the outfall of Jones Lake is a good quality prairie (open-sun) wetland varying in width from 20' to 50'.

East of Martin Luther King the stream mostly remains in the small channel as it curves northward around the apartment complex. It enters an area of small trees at the edge of the apartments where the soil changes to the Koury type reported on previously. An in-stream channelization project may be allowed in this segment. As the channel emerges from under the trees, it widens out into an established floodpool that supports a very good quality prairie wetland.

A small area directly adjacent, parallel to Martin Luther King (located under powerlines) may have potential for a small detention/mitigation project as is marked as a **Site** on the attached map. We suggest that it would be <u>an excellent area for location of a small 404 mitigation project</u> if it were not suitable for flood control.

At this point, the East Fork flows northwestward under Martin Luther King again. The West Fork joins it immediately after flowing from Lake Myriad. The combined flow of the East Branch runs alternatively through flooded forest and back into the open sun to and under the railroad tracks and Loop 287 to the City Lake. Wetlands associated with the floodway (both forested and prairie) are 50' to 200' wide, establishing a large regulated area that will be difficult to permit impacts to. A separate floodpool between the railroad tracks and the Loop has established a large prairie wetland that is mowed regularly during dry weather periods.

West Brànch: The East Fork consists of two small arms falling steeply downslope from HWY 103 northward, parallel and west of FM 2251 to it's junction with the West Fork. The upper channels are located on soils of Alazan-Urban land complex (AcB), 0 to 4 percent slopes and the lower elevations cross the Koury soil type. The channels of the East Fork and their associated wetlands are small at this time, which may have potential for in-stream channelization or detention/mitigation projects. Where it joins the West Fork, a large floodpool is formed that would be difficult to permit impacts to.

The West Fork has established a major floodway that runs parallel to and between the Loop and railroad tracks, eastward towards City Lake. It is also located on the Koury soil type. The floodplain alternates between forested and prairie depending on which different ownerships mow their land regularly. All of the West Fork and it's floodplain wetlands are large and of very good quality. They would be difficult to permit (any type of development activity to) with wildlife agencies.

Main Stem: We observed the large floodpool between the railroad tracks and Loop 287 during flood conditions, in which the flood storage capacity (of) was impressive. It receives all of the combined flows from the East Branch and West Branch, and outfalls below the Loop northward into City Lake (Ellen Trout Memorial Lake).

Directly northward of the Loop culvert is a forested floodpool at the head of the Lake. This particular wetland area resembles the description of habitat typical of that utilized by the alligator snapping turtle. However, the USF&WS and the TP&WD did not express a concern about the area for T & E Species. Whether or not any snapping turtles may inhabit the area, as potential habitat it may be very difficult to construct any type of projects within.

Downstream of the Lake, Mill Creek flows northward within a large channel through a large pasture area towards HWY 59. It is also located on the Koury (Ko) soil type described previously. Within the short reach inside the City of Lufkin, it mainly stays within the large channel. Where it is not associated with a wetland floodpool, flood control projects may be allowed within or at least adjacent to the stream. Whether or not it is suitable for flood control projects, the large area of cleared pasture would be suitable for constructing a large wetland mitigation project, which is shown as a **Site** on **Exhibit 3**.

City of Lufkin Map Exhibits

Three (3) map exhibits are presented on following pages in support of Wet Tech's Preliminary Wetlands Survey as a part of the City of Lufkin Watershed Study.

Exhibit 1- **illustrates material from the report on Upper and Middle Hurricane Creek.**

Exhibit 2- **maps the areas described within Lower Hurricane Creek; and**

Exhibit 3- **maps areas identified within Mill Creek watersheds.**

Legend:

1.) **Tributary Number**---------------------------------- **5**
Identifying Tributary number as assigned by Dodson & Associates on the map of Stream Names of Lufkin, Texas.

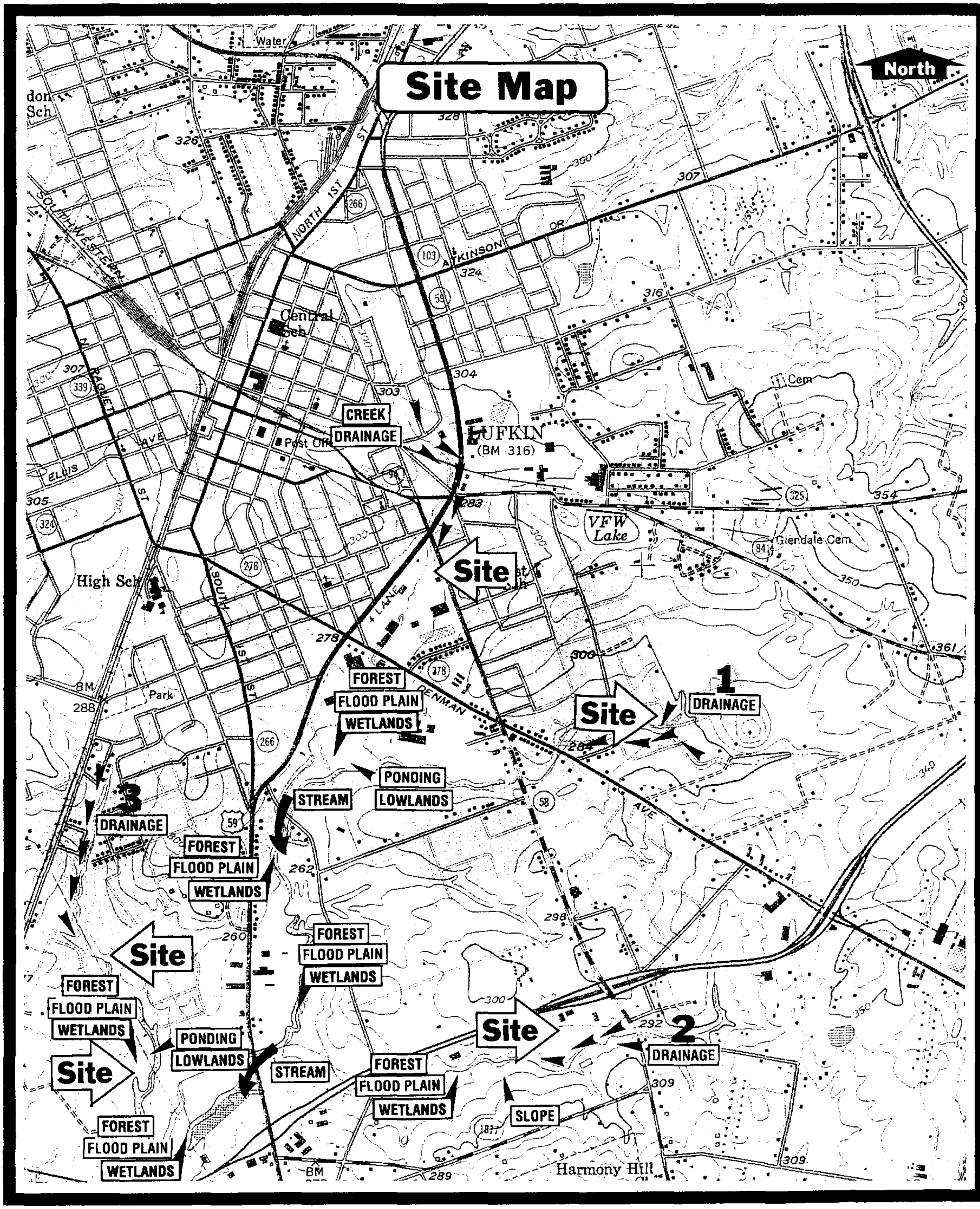
2.) **Potential Flood Control Project Site**--------------- **Site**
A partial mapping of suggested project sites described in report text, proposed to be located in uplands adjacent to stream.

3.) **Upper Tributary Flow**------------------------------- DRAINAGE
Direction of flow of tributary toward Main Stem of Hurricane Creek or Mill Creek.

4.) **Major Stream Overflow Areas (at Junctions)**------ PONDING LOWLANDS
Typical areas of long term ponding during floodflow at junctions between tributaries or with main stem.

5.) **Typical Wetland Areas in vicinity**----------------- WETLANDS
Location of wetlands typical (of wetlands) nearby as is described in report.

6.) **Typical Wetland Type in vicinity**------------------ FOREST FLOOD PLAIN
Type of wetlands typical of those indicated in area as is described in report.



Site Map
North
CREEK
DRAINAGE
LUFKIN
(BM 316)
Site
1
DRAINAGE
Site
FOREST
FLOOD PLAIN
WETLANDS
PONDING
LOWLANDS
STREAM
3
DRAINAGE
FOREST
FLOOD PLAIN
WETLANDS
FOREST
FLOOD PLAIN
WETLANDS
Site
FOREST
FLOOD PLAIN
WETLANDS
PONDING
LOWLANDS
Site
STREAM
FOREST
FLOOD PLAIN
WETLANDS
Site
2
DRAINAGE
SLOPE
FOREST
FLOOD PLAIN
WETLANDS
VFW Lake
Central Sch
High Sch
Post Off
Park
Glendale Cem
Harmony Hill
ATKINSON DR
DENMAN AVE
NORTH 1ST ST
SOUTH 1ST ST
RAGUET ST

Exhibit 1

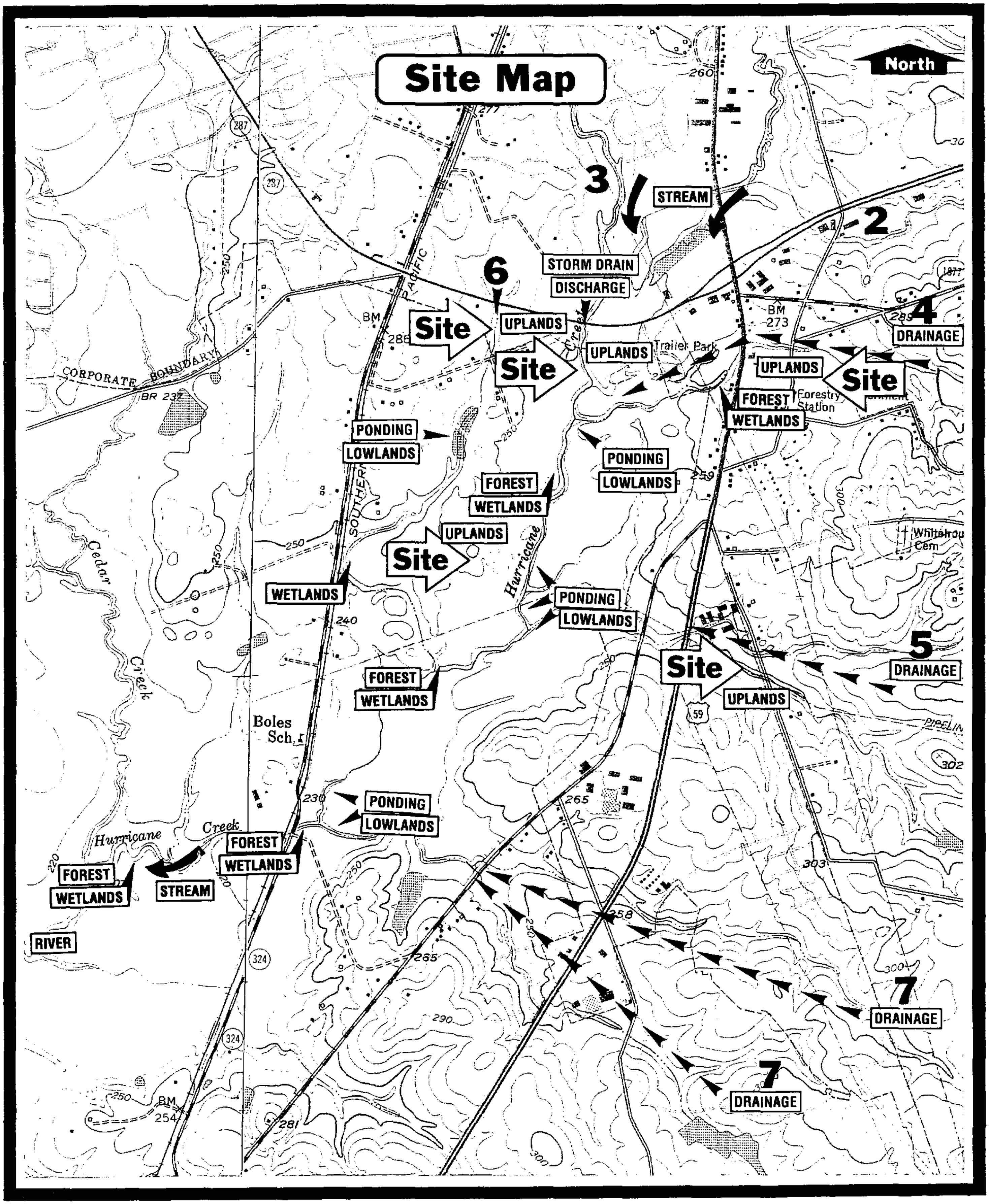
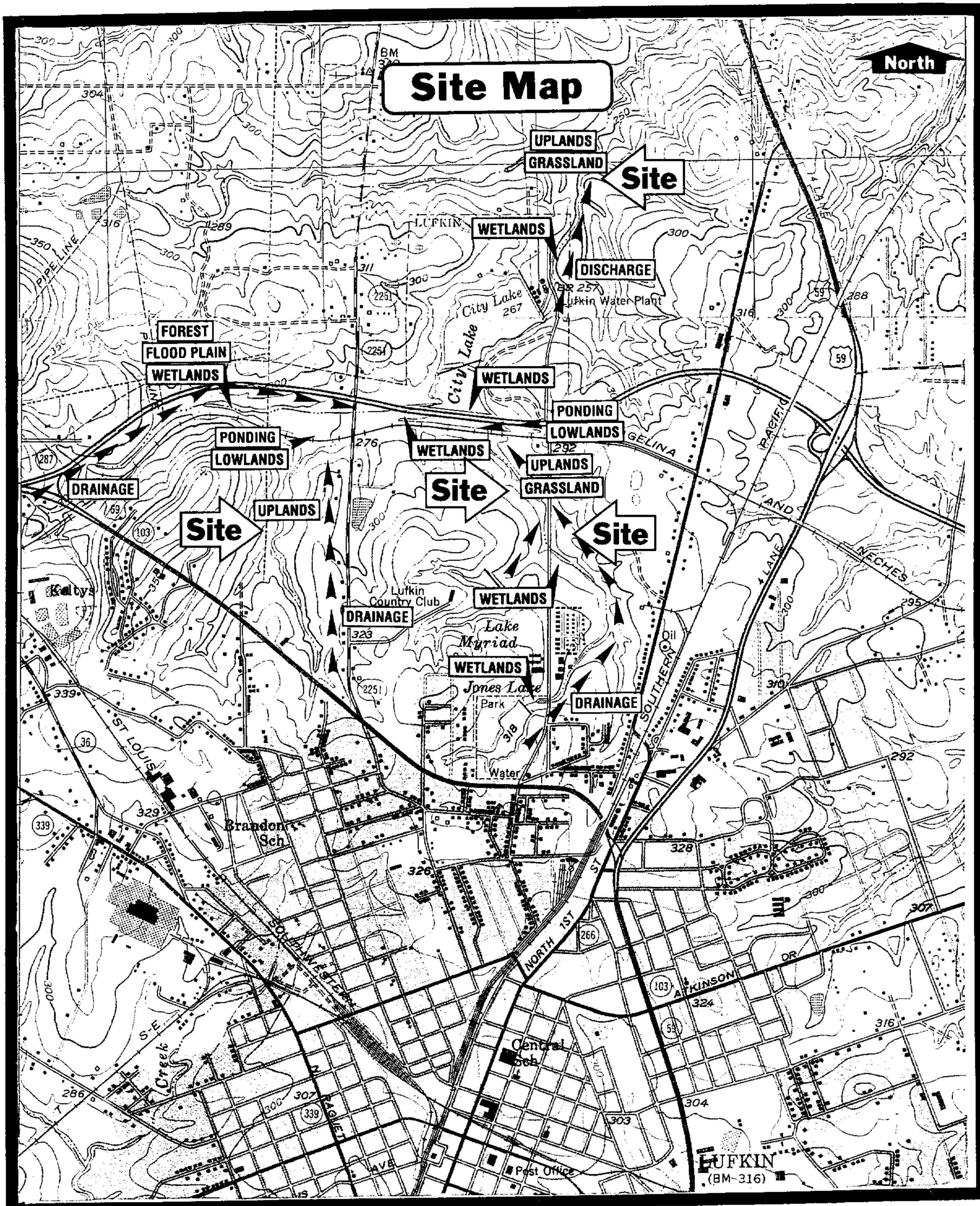

Site Map
North
3
STREAM
2
6
STORM DRAIN
DISCHARGE
Site
UPLANDS
Site
UPLANDS
Trailer Park
UPLANDS
Site
4
DRAINAGE
FOREST
WETLANDS
Forestry Station
PONDING
LOWLANDS
PONDING
LOWLANDS
FOREST
WETLANDS
UPLANDS
Site
WETLANDS
Hurricane
PONDING
LOWLANDS
5
DRAINAGE
Site
UPLANDS
FOREST
WETLANDS
Boles Sch.
PONDING
LOWLANDS
Hurricane
Creek
FOREST
WETLANDS
STREAM
FOREST
WETLANDS
RIVER
Cedar
Creek
CORPORATE BOUNDARY
SOUTHERN PACIFIC
7
DRAINAGE
7
DRAINAGE
Whitehouse Cem
PIPELINE

Exhibit 2



Site Map
North
UPLANDS
GRASSLAND
Site
WETLANDS
DISCHARGE
Lufkin Water Plant
City Lake
FOREST
FLOOD PLAIN
WETLANDS
WETLANDS
PONDING
LOWLANDS
PONDING
LOWLANDS
WETLANDS
UPLANDS
GRASSLAND
DRAINAGE
Site
UPLANDS
Site
Site
Lufkin Country Club
DRAINAGE
WETLANDS
Lake Myriad
WETLANDS
Jones Lake
Park
DRAINAGE
Brandon Sch
Central Sch
Post Office
LUFKIN
(BM-316)

Exhibit 3

Wet Tech

Wetland Technologies Corporation

... providing watershed assessment, design, and construction supervision services.

November 16, 1998

Mr. Duane Barrett, P.E.
Dodson & Associates, Inc.
5629 FM 1960 West, Suite 314
Houston, Tx. 77069-4216

Re: Interim Project Review- Proposed City of Lufkin Stormwater Project(s)

Subject: Hurricane Creek and Mill Creek Watershed(s)

Dear Mr. Barrett;

Please find following our Report detailing findings regarding the proposed project sites. This material was developed during an inspection the afternoon of November 4, 1998, all day of the 5th, and the early morning of the 6th. A recent storm had flooded some of the lower areas several days before.

We noted that certain placement guidelines had been developed from our previous Report and employed to greatly reduce potential conflicts with regulatory agencies; however, where these are not appropriate for a particular site is described herein.

Please let us know if there are any questions regarding the enclosed material.

Sincerely;

WETLAND TECHNOLOGIES CORPORATION

Glenn Jarrett,
General Manager

1831 Pinewood Ct. • Sugar Land, TX 77478 • off: ~~713~~ 281-242-8734 • fax: ~~713~~ 281-491-0825

Additional Comments regarding:

Project Site Selection & Design Criteria

Location of Flood Control Structure(s):

Most proposed projects consist primarily of a berm type dam/spillway sited across a small channel that would detain stormwater a required period of time, and then drain slowly to a "dry-bottom" configuration. As these berms have a small footprint of impact across a regulated streambed, and no permanent impoundment is created, then resource agency objections will be minor to the extent mitigation should be allowed by them (in most cases). This criteria would not constitute a "small impact" within major channels, and we note that none are proposed to do so (Project's #1 and #2 on Mill Creek are close).

However, several proposals specify excavate-and-haul-away which impacts an entire site permanently. Those that would be minimal impact and those that would not are differentiated to the extent possible below without extensive on-site work.

Where an improvement in re-locating a site a short distance is appropriate, we have so described in the following material.

Design Criteria:

Where the **purpose of a project** would not incorporate construction of mitigation within, the berm's "footprint impact" will be required to be the smallest possible to achieve the desired storage capacity. Where mitigation is planned within, mitigation requirements will be required to be **primary** over capacity considerations.

Mitigation Criteria:

Certain proposed project sites that appear to be more suitable for mitigation meet a specific criteria that generally floods a large area (that) currently qualifies as upland. In some cases we recommend re-locating a structure in order to flood a flatter area now currently proposed to be avoided. An example would be our comments regarding Mill Creek Watershed's Project #3 wherein a part of the avoided area may be suitable to be incorporated within. Where upland sites are excavated for retention, opportunities exist for mitigation projects to be specified. **It is important to note that all of the projects proposed will require some amount of mitigation offset.**

Review of Proposed Hurricane Creek Project(s)

Introduction:

Inspection of major projects proposed inside Loop 287 and Project's #5 & #6 outside the Loop revealed no major impediment to regulatory approval for sturctures or excavation (except for #2 more fully described below). Where upstream channelization may be allowed varies with each stream and is described to the extent possible in this work.

Project #1:

This project appears from Cunningham and Ford Chapel Rd. to be a large, well drained site. There is an undeveloped area to the south that does not have an approach (is not easily viewed). It appears to flood a large volume with the proposed berm location such that excavation would not be needed for additional capacity. Such criteria may indicte a potential for location of a suitable mitigation site. If so, Wet Tech is of the opinion that **necessary mitigation required** for this project and others nearby be incorporated within.

Mitigation would specify little or no landclearing; rather the shallow excavations should be specified to be constructed between groups of trees with inter-connecting swales. The fertile topsoils would be cut out and set aside for re-installation and planting after shallow excavation work is complete. If the underlying subsoils are suitable, they would be used for berm construction; thereby saving the cost of hauling them away, and the cost of materials importation (for berm construction).

Most likely the improvements proposed for the small channel would be allowed (with suitable mitigation) downstream to Denman Avenue.

Project #2

This project may not be feasible as proposed. It is specified to be over-excavation of an existing depressional site for additional stormwater capacity (it currently holds and slowly releases a large volume of run-off). The existing forested over-bank depressions surrounding the confluence of several small channels is of very high habitat quality.

The site's **only potential** would be in delineating existing wetlands and excavating outer edges of available un-developed land up to, but not within the specified "avoid area". Final outfall elevation must remain as currently exists, only capacity would be increased.

Project #3:

The channelization proposed above and under Chestnut St. would most likely be allowed, while that proposed south of Chestnut would not.

The area designated behind Kurth Elementary school currently floods, consequently increasing the floodpool footprint would be acceptable provided little or no impact occurred from berm construction. Care must be taken to select an upland area for the specific berm location; otherwise, the site is excellent as proposed.

Additionally, there is a vacant land tract directly adjacent east of the school ballfields that (if available) would be suitable for excavation of a regional retention project with mitigation incorporated within (see drawing on next page). It may be appropriate to install paths and decks across the permanent wet bottom areas as a neighborhood park in the same manner as Kiwanis Park/Azalea Trail nearby (warning signs of danger during major floods would be required for the school's ballfields and the public use area).

Project #4:

This project is proposed to be specified in a similar manner as Project #3 in the southeast corner of Tulane and York Streets. Again, provided the specific berm location is carefully selected for least habitat impact, this is an excellent project location. Additionally, an un-developed area above the intended floodpool directly to the southeast would be suitable for mitigation. Upon closer on-site inspection it may prove acceptable for significant excavation also. As a large volume of material will be required to construct the berm, a cost off-set from balance of cut-and-fill may be possible.

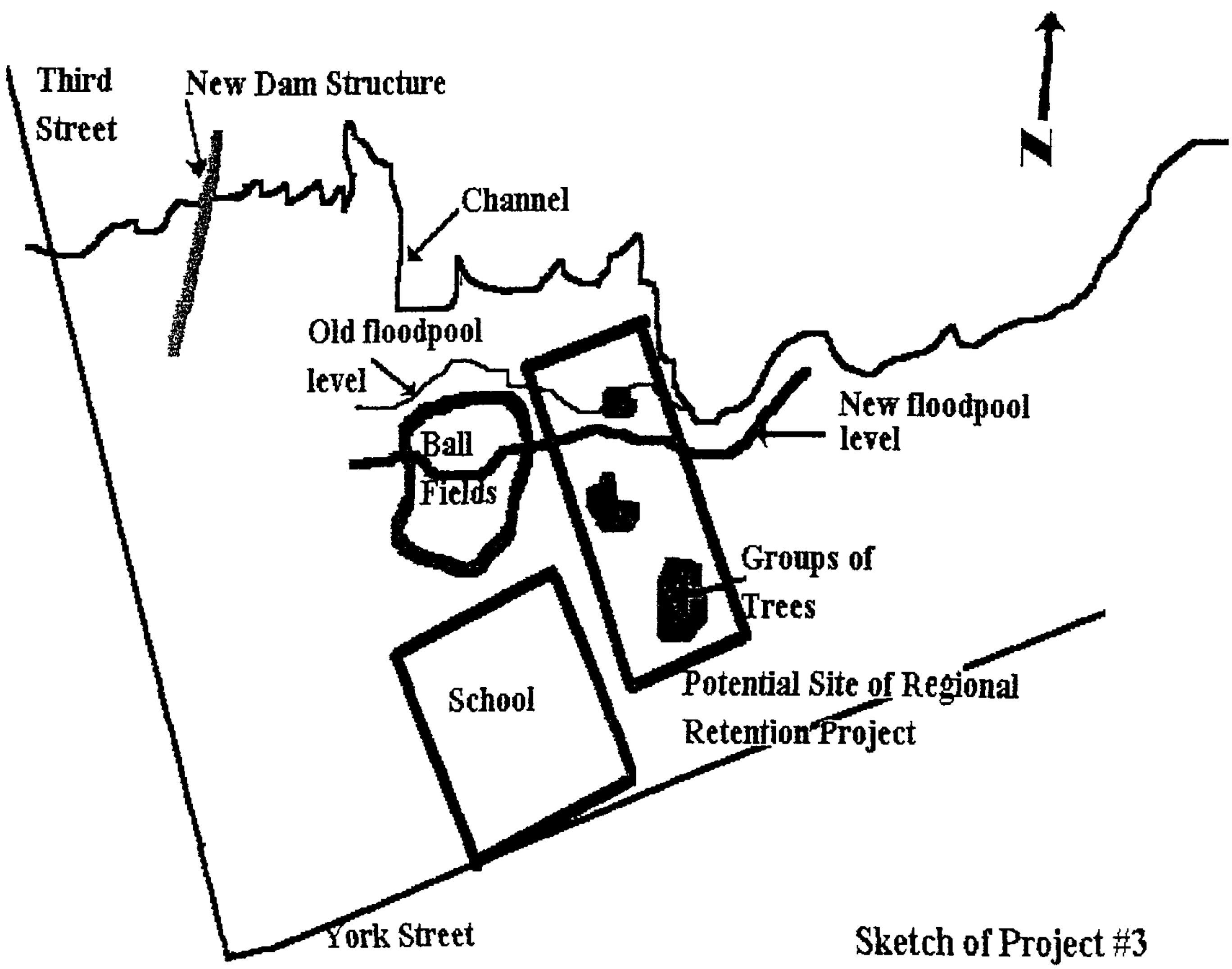
Main Stem of Hurricane Creek:

Specification of a major bypass channel directly west of the Main Stem below Kiwanis Park southward to the mall is an environmentally acceptable alternative. However, the channel would eliminate the newly installed Azalea Trail; consequently funding agencies may require the City of Lufkin to reconstruct it on the east side of the Creek at the City's expense. Secondly, it would eliminate parking behind some of the commercial businesses fronting old HWY 59. The City of Lufkin may <u>choose not to construct</u> the project.

Perhaps the bypass could be specified to be located **on the east side** of the Creek in the same manner with avoidance of existing homes where necessary. Channel excavation would provide considerable material for other berm construction projects nearby.

Proposed Project #3-Hurricane Creek Watershed

Typical excavation of Regional Retention Project capacity into adjacent vacant upland while avoiding currently flooding sensitive habitat.



Sketch of Project #3
Hurricane Creek
Watershed

not to scale

Project #5:

Similar to Project's #3 and #4 more fully described above, this project location appears to be suitable for regulatory purposes as well as storage potential. The berm site should be carefully selected, with appropriate mitigation proposed and constructed on-site.

Channelization proposed should be acceptable downstream to, <u>but not beyond</u> the Lowes Store with mitigation. Refer to detailed description recommendations made in the Lowe's Store area on page 22 of Wet Tech's previous Report dated 9/15/98.

Project #6:

The proposed low impact berm type retention specified for #6 is well suited to it's selected location with appropriate mitigation.

Channelization proposed from the Lowes Store downstream to the Project #6 floodpool, and downstream from Project #6 to the Loop most likely **would not be allowed** at some reasonable amount of mitigation. However, vacant upland directly adjacent to the south is suitable for installation of a small bypass channel (which would have a lower construction cost than the proposed channelization). Also, for that reason <u>either section would not pass 404 Alternative Analysis</u>.

Project #7:

<u>Channelization</u>- Improvements within neighborhoods upstream on Tributary #3 should be acceptable with a small amount of mitigation required. However, the channelization proposed downstream to the large bypass would be difficult to 404 Permit. If hydraulically feasible, the lower total cost to the City may be a small bypass channel excavated from the neighborhood outfall straight through the "S" of the natural stream to connect with the larger bypass downstream (which is appropriate as proposed).

<u>Additional Land for Storage</u>- Acquisition of un-developed land within the white area outlined in blue in order to prevent future development is suitable for this particular zone. However, as an existing floodpool small uplands would be required to be selected on-site for any excavation desired, and all other areas carefully avoided by construction equipment (see typical design on previous page).

On closer inspection, it might be determined that little or no additional capacity could be excavated into such a sensitive habitat. The adjacent area shown in blue fill has the same circumstances; in that lower elevations are <u>too high in quality</u> to excavate, and upper elevations may not be feasible for excavation.

Proposed Project #8, Project #9 and Project #10:

Each of these berm/dry bottom type designs should be acceptable to resource agencies if carefully sited for least impact and suitable mitigation is proposed.

Most channelization proposed south of the Loop will be acceptable east of HWY 59 (however, certain areas will not be); and most of that west of 59 will not be acceptable. As previously reported, the natural streambed outfalling from Crown Colony has been recently channelized behind the Church Retreat property as a part of current land development activity.

Projects proposed for Tributary Six:

Two large ponded areas are proposed to be expanded to increase storage volume. The transitional (flood up-flood down) wetland edges must be avoided by all construction activities. Excavation of uplands directly up to, but not into the wetland edge would be acceptable. Properly designed and constructed these upland work areas could qualify as mitigation for 404 impacts nearby.

Channelization southward from the Loop to the first existing pond may be acceptable; that specified south of the first pond to the Main Stem of Hurricane Creek would not.

Review of Proposed Mill Creek Project(s)

Project #1:

This major streambed will be difficult to 404 Permit impact due to the high quality habitat involved. Extreme care should be taken in exact site selection, and at least a ratio of 2:1 of mitigation should be offered resource agencies in the first approach to them.

Channelization in the large streambed directly upstream would not be allowed. Where the channel upstream to the west is a much smaller/lower quality habitat, channelization would be allowable with suitable mitigation offered.

Project #2:

Wet Tech is of the opinion that the large amount of flood storage resulting from this (one) project's impact is an excellent proposal for the watershed. However, the quality of habitat to be impacted by the dam/spillway structure is very high, slightly more so than described for Project #1 above. Under any "lesser benefit" set of circumstances this impact may not be Permitted. Specific project and mitigation design should consider all aspects of the proposed 404 Permit Application before proceding to agency contact.

Project #3:

This project is unique of all of the berm type projects proposed for both watersheds. It's special character is due to the large amount of flat open land proposed to be flooded that is now currently upland. We suggest that this particular elevation be left as-is for construction of a **regional mitigation project** rather than excavation to increase strorage capacity (of course, the edges rising above could be cut back to increase total project capacity). It also appears that the berm could be re-located a short distance downstream in order to flood a larger area of this elevation.

On closer inspection, it may be that the previously cleared land (site of overhead powerlines) is large enough to locate mitigation required for all four Mill Creek Projects. Savings in construction costs to the City would be extensive.

Channelization upstream of Project #3 will most likely be allowed with suitable habitat mitigation proposed.

Project #4:

This project is sited directly adjacent to/upstream of a good quality prairie wetland that would be difficult to impact. It is correctly located as drawn to temporarily flood a small wooded area behind the apartment complex.

Channelization proposed upstream behind the apartments would be acceptable up to, but not including the outfall area below Jones Lake (which should be protected from all proposed project impacts).

CALCULATION OF Tc USING VELOCITY METHOD
MILL CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Number								
			JONES	EBR1A	EBR1B	EBR1C1	EBR1C2	EBR1D	MYRAD	EBR2A	EBR2B
Drainage Area											
Area		ac	94	43	157	41	72	31	89	50	125
Area		sm	.147	.067	.245	.064	.113	.048	.139	.078	.195
Impervious Cover											
Land Use	I(%)										
Lakes	100%	ac	7.8	.0	.0	.0	.0	.0	14.5	.0	.0
Ind./Comm.	80%	ac	13.4	8.1	20.1	9.2	35.1	.0	5.6	7.0	1.4
Multi-Family	70%	ac	.0	7.5	.0	6.2	.0	.0	.0	.0	.0
Highway	60%	ac	.0	.0	.9	.0	.0	.0	.0	5.0	3.7
Community	40%	ac	.0	.0	.0	.0	.0	.0	3.4	.0	.0
S-F (Typical)	30%	ac	46.4	3.8	68.3	2.3	.0	.0	11.7	.0	6.7
S-F (Light)	15%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
Golf Course	5%	ac	.0	1.0	.0	.0	.0	24.2	47.8	6.1	39.1
Future Development		ac	26.2	22.8	67.4	23.3	36.9	6.5	6.3	32.1	74.4
Future Impervious		%	30%	30%	60%	80%	80%	80%	30%	80%	70
Total		ac	93.8	43.2	156.7	41.0	72.0	30.7	89.3	50.2	125.3
Imperv. Area		ac	40.3	19.8	77.6	31.0	57.6	6.4	28.1	34.6	59.4
Imperv. Cover		%	43.0	45.7	49.5	75.7	80.0	20.9	31.5	68.9	47.4
Overland		Curve:	C	C	C	C	C	C	C	C	C
Distance		ft	200	200	100	200	300	200	200	200	200
Slope		%	1.4	5.0	2.9	1.5	3.3	5.0	2.0	6.7	4.0
Velocity		ft/s	.8	1.6	1.2	.9	1.3	1.6	1.0	1.8	1.4
Travel Time		min	4.17	2.08	1.39	3.70	3.85	2.08	3.33	1.85	2.38
Shallow Concentrated		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	0	500	0	500	0	600	300	400	300
Slope		%	.0	6.0	.0	3.0	.0	5.0	2.0	5.0	4.0
Velocity		ft/s	.0	4.9	.0	3.5	.0	4.5	2.8	4.5	4.0
Travel Time		min	.00	1.70	.00	2.38	.00	2.22	1.79	1.48	1.25
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	1500	0	3600	400	1600	1100	1000	800	4500
Slope		%	1.4	.0	1.4	5.0	2.2	1.5	4.3	4.0	1.5
Velocity		ft/s	2.4	.0	2.4	4.5	3.0	2.4	4.1	4.0	2.5
Adjusted Velocity		ft/s	4.00	.00	4.00	7.50	5.00	4.00	6.83	6.67	4.17
Travel Time		min	6.25	.00	15.00	.89	5.33	4.58	2.44	2.00	18.00
Improved Drainage Channel											
Distance		ft	0	0	0	0	0	0	0	0	0
Velocity		ft/s	.0	.0	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel											
Distance		ft	0	1800	0	700	0	0	0	0	0
Velocity		ft/s	.0	3.0	.0	3.0	.0	.0	.0	.0	.0
Travel Time		min	.00	10.00	.00	3.89	.00	.00	.00	.00	.00
TC (minutes)			10.42	13.78	16.39	10.86	9.18	8.89	7.56	5.33	21.63
TC (hours)			.17	.23	.27	.18	.15	.15	.13	.09	.36
R = 2 x TC (hours)			.35	.46	.55	.36	.31	.30	.25	.18	.72

CALCULATION OF Tc USING VELOCITY METHOD
MILL CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Number								
			WFK1	WFK2A	WFK2B	EFK1	EFK2	EFK3A	EFK3B	CITY	DNSTM
Drainage Area											
Area		ac	356	282	62	109	171	46	21	164	273
Area		sm	.556	.441	.097	.170	.267	.072	.033	.256	.427
Impervious Cover											
Land Use	I(%)										
Lakes	100%	ac	.0	.0	.0	.0	.0	.0	.0	37.2	.0
Ind./Comm.	80%	ac	31.6	6.1	.0	4.6	3.2	.0	.0	6.1	28.7
Multi-Family	70%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
Highway	60%	ac	12.7	11.9	6.1	.0	.0	.0	.0	.0	6.5
Community	40%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	44.4	2.4	.0	20.0	61.4	.0	.0	4.7	2.4
S-F (Light)	15%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
Golf Course	5%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
Future Development		ac	267.2	261.6	55.9	84.8	106.1	46.0	21.0	116.1	235.3
Future Impervious		%	70%	80%	80%	60%	50%	80%	80%	80%	80%
Total		ac	355.9	282.0	62.0	109.4	170.7	46.0	21.0	164.1	272.9
Imperv. Area		ac	233.3	222.0	48.4	60.6	74.0	36.8	16.8	136.4	215.8
Imperv. Cover		%	65.5	78.7	78.0	55.4	43.4	80.0	80.0	83.1	79.1
Overland		Curve:	C	C	C	C	C	C	C	C	C
Distance		ft	200	300	300	300	300	200	200	300	300
Slope		%	4.0	4.0	2.5	2.5	2.0	6.7	5.0	2.0	2.0
Velocity		ft/s	1.4	1.4	1.2	1.2	1.0	1.8	1.7	1.0	1.0
Travel Time		min	2.38	3.57	4.17	4.17	5.00	1.85	1.96	5.00	5.00
Shallow Concentrated		Curve:	F	G	G	G	G	G	G	G	G
Distance		ft	200	300	0	300	300	1100	300	0	0
Slope		%	5.0	8.0	.0	4.0	2.0	8.0	10.0	.0	.0
Velocity		ft/s	3.4	5.7	.0	4.0	2.8	5.7	6.3	.0	.0
Travel Time		min	.98	.88	.00	1.25	1.79	3.22	.79	.00	.00
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	1200	2300	1800	1600	3400	0	700	2000	4000
Slope		%	2.0	4.0	3.3	1.9	1.6	.0	1.0	2.3	1.8
Velocity		ft/s	2.8	4.0	3.6	2.8	2.5	.0	2.0	3.0	2.7
Adjusted Velocity		ft/s	2.80	6.67	6.00	4.67	4.17	.00	3.33	5.00	4.50
Travel Time		min	7.14	5.75	5.00	5.71	13.60	.00	3.50	6.67	14.81
Improved Drainage Channel											
Distance		ft	2400	0	0	0	0	0	0	0	0
Velocity		ft/s	5.0	.0	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	8.00	.00	.00	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel											
Distance		ft	0	3100	800	1800	0	1100	500	0	1600
Velocity		ft/s	.0	3.0	3.0	3.0	.0	3.0	3.0	.0	3.0
Travel Time		min	.00	17.22	4.44	10.00	.00	6.11	2.78	.00	8.89
TC (minutes)			18.50	27.42	13.61	21.13	20.39	11.18	9.03	11.67	28.70
TC (hours)			.31	.46	.23	.35	.34	.19	.15	.19	.48
R = 2 x TC (hours)			.62	.91	.45	.70	.68	.37	.30	.39	.96

CALCULATION OF Tc USING VELOCITY METHOD
MILL CREEK WATERSHED
INTERIM WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	EBR1C1	EBR1C2	WFK2A	WFK2B	EFK3A	EFK3B
			Parameter Values for Given Sub-Area Num					
Drainage Area								
Area		ac	41	72	282	62	46	21
Area		sm	.064	.113	.441	.097	.072	.033
Impervious Cover								
Land Use	I(%)							
Lakes	100%	ac	.0	.0	.0	.0	.0	.0
Ind./Comm.	80%	ac	9.2	35.1	6.1	.0	.0	.0
Multi-Family	70%	ac	6.2	.0	.0	.0	.0	.0
Highway	60%	ac	.0	.0	11.9	6.1	.0	.0
Community	40%	ac	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	2.3	.0	2.4	.0	.0	.0
S-F (Light)	15%	ac	.0	.0	.0	.0	.0	.0
Golf Course	5%	ac	.0	.0	.0	.0	.0	.0
Future Development		ac	23.3	36.9	261.6	55.9	46.0	21.0
Future Impervious		%	0%	0%	0%	0%	0%	0%
Total		ac	41.0	72.0	282.0	62.0	46.0	21.0
Imperv. Area		ac	12.4	28.1	12.7	3.7	.0	.0
Imperv. Cover		%	30.2	39.0	4.5	5.9	.0	.0
Overland		Curve:	C	C	C	C	C	C
Distance		ft	200	300	300	300	200	200
Slope		%	1.5	3.3	4.0	2.5	6.7	5.0
Velocity		ft/s	.9	1.3	1.4	1.2	1.8	1.7
Travel Time		min	3.70	3.85	3.57	4.17	1.85	1.96
Shallow Concentrated		Curve:	F	F	F	F	F	F
Distance		ft	500	0	300	0	1100	300
Slope		%	3.0	.0	8.0	.0	8.0	10.0
Velocity		ft/s	2.7	.0	4.3	.0	4.3	4.9
Travel Time		min	3.09	.00	1.16	.00	4.26	1.02
Paved or Gully		Curve:	G	G	G	G	G	G
Distance		ft	400	1600	2300	1800	0	700
Slope		%	5.0	2.2	4.0	3.3	.0	1.0
Velocity		ft/s	4.5	3.0	4.0	3.6	.0	2.0
Adjusted Velocity		ft/s	4.50	3.00	4.00	3.60	.00	2.00
Travel Time		min	1.48	8.89	9.58	8.33	.00	5.83
Improved Drainage Channel								
Distance		ft	0	0	0	0	0	0
Velocity		ft/s	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel								
Distance		ft	700	0	3100	800	1100	500
Velocity		ft/s	3.0	.0	3.0	3.0	3.0	3.0
Travel Time		min	3.89	.00	17.22	4.44	6.11	2.78
TC (minutes)			12.16	12.74	31.54	16.94	12.23	11.59
TC (hours)			.20	.21	.53	.28	.20	.19
R = 2 x TC (hours)			.41	.42	1.05	.56	.41	.39

COST ESTIMATE FOR CHANNEL IMPROVEMENTS

WEST BRANCH, EAST FORK ABOVE BASIN #3				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	1,200	feet	-----	-----
Required Right-Of-Way Width	120	feet	-----	-----
Required Right-Of-Way Area	3.3	acres	-----	-----
Right-Of-Way Acquisition	3.3	acres	$10,000	$33,000.00
Clearing & Grubbing	3.3	acres	$1,000	$3,300.00
Excavation and Haul	1,750	cubic yards	$8.00	$14,000.00
Backslope Drains (600' Spacing)	4	each	$2,500	$10,000.00
Backslope Swales	2,400	linear feet	$1.00	$2,400.00
Vegetation Establishment	3.3	acres	$1,500	$4,950.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$67,650.00
Engineering Design & Permitting	10.00%			$6,765.00
Construction Oversight	5.00%			$3,382.50
Cost Sub-Total				$77,797.50
Contingency	15.00%			$11,669.63
TOTAL COST				$89,467.13

EAST BRANCH, EAST FORK ABOVE BASIN #4				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	1,300	feet	-----	-----
Required Right-Of-Way Width	120	feet	-----	-----
Required Right-Of-Way Area	3.6	acres	-----	-----
Right-Of-Way Acquisition	3.6	acres	$10,000	$36,000.00
Clearing & Grubbing	3.6	acres	$1,000	$3,600.00
Excavation and Haul	2,750	cubic yards	$8.00	$22,000.00
Backslope Drains (600' Spacing)	6	each	$2,500	$15,000.00
Backslope Swales	2,600	linear feet	$1.00	$2,600.00
Vegetation Establishment	3.6	acres	$1,500	$5,400.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$84,600.00
Engineering Design & Permitting	10.00%			$8,460.00
Construction Oversight	5.00%			$4,230.00
Cost Sub-Total				$97,290.00
Contingency	15.00%			$14,593.50
TOTAL COST				$111,883.50

COST ESTIMATE FOR REGIONAL DETENTION BASIN #2

QUANTITY TAKE-OFF WORK AREA

Item	Quantity	Units	Computation of Required Dam Fill Volume (cy)			
			Incr. Dist.	NG Elevation	Section Area	Incr. Volume
Maximum 100-Year WSEL =	293	feet				
Proposed Top of Dam Elevation =	296	feet	-----	296	0	0
Channel Invert Elevation at Proposed Dam Location =	278	feet	40	294	56	41
Natural Ground Surface Area at Top of Dam Elevation =	28.5	acres	70	290	264	415
100-Year Peak Discharge =	1029	cfs	30	288	416	378
Flow Area Required for Principal Outlet =	205.8	sq. ft.	40	286	600	753
Required Number & Size of Outlet Pipes =	4	9' x 6'	50	284	816	1311
Total Flow Area Provided in Principal Outlet =	216	sq. ft.	70	282	1064	2437
Maximum Height of Dam =	18	feet	140	280	1344	6243
Top Width of Dam =	20	feet	10	278	1656	556
Dam Side Slope Ratio =	4	(h/v)	20	280	1344	1111
Width of Dam at Toe =	164	feet	20	282	1064	892
Total Pipe Length for Principal Outlet =	656	feet	60	274	2376	3822
Spillway Crest Elevation =	290	feet	15	286	600	827
Spillway Crest Length =	80	feet	15	288	416	282
Required Number & Size of Riser Pipes =	4	9' x 6'	30	290	264	378
Total Pipe Length for Riser Pipes =	48	feet	50	296	0	244
Approximate Concrete Area =	200	sq. yd.	660	**Total Fill Volume =**		19690
Dam Excavation, Haul, & Compaction Volume =	19,690	cu. yd.				
Storage Excavation & Haul =	21	ac.-ft. =	33,880	cu. yd.		

COST ESTIMATE

Item	Quantity	Units	Unit Cost	Cost
Land Acquisition	42.75	acres	$10,000	$427,500
Excavation, Haul, & Compaction for Dam	19,690	cubic yards	$10.00	$196,896
Principal Discharge Culverts	656	linear feet	$425	$278,800
Riser Culverts	48	linear feet	$425	$20,400
Concrete Slope Paving	200	sq. yds.	$50.00	$10,000
Emergency Spillway	1	lump sum	$278,800	$278,800
Storage Excavation & Haul =	33,880	cubic yards	$5.00	$169,400
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$1,381,796
Engineering Design & Permitting	10.00%			$138,180
Construction Oversight	5.00%			$69,090
Cost Sub-Total				$1,589,066
Contingency	15.00%			$238,360
TOTAL COST				$1,827,426

COST ESTIMATE FOR REGIONAL DETENTION BASIN #3

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
			Incr. Dist.	*NG Elevation*	*Section Area*	*Incr. Volume*
Maximum 100-Year WSEL =	289	feet				
Proposed Top of Dam Elevation =	292	feet	-----	292	0	0
Channel Invert Elevation at Proposed Dam Location =	276	feet	15	290	56	16
Natural Ground Surface Area at Top of Dam Elevation =	20.4	acres	15	288	144	56
100-Year Peak Discharge =	405	cfs	20	286	264	151
Flow Area Required for Principal Outlet =	81.0	sq. ft.	30	284	416	378
Required Number & Size of Outlet Pipes =	2	7' x 6'	25	282	600	470
Total Flow Area Provided in Principal Outlet =	84	sq. ft.	90	280	816	2360
Maximum Height of Dam =	16	feet	170	278	1064	5919
Top Width of Dam =	20	feet	15	276	1344	669
Dam Side Slope Ratio =	4	(h/v)	20	278	1064	892
Width of Dam at Toe =	148	feet	15	280	816	522
Total Pipe Length for Principal Outlet =	296	feet	50	292	0	756
Spillway Crest Elevation =	287	feet	0	0	0	0
Spillway Crest Length =	30	feet	0	0	0	0
Required Number & Size of Riser Pipes =	2	7' x 6'	0	0	0	0
Total Pipe Length for Riser Pipes =	22	feet	0	0	0	0
Approximate Concrete Area =	100	sq. yd.	465	***Total Fill Volume =***		12187
Dam Excavation, Haul, & Compaction Volume =	12,187	cu. yd.				
Storage Excavation & Haul =	20	ac.-ft. =	32,267	cu. yd.		

COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	30.6	acres	$10,000	$306,000
Excavation, Haul, & Compaction for Dam	12,187	cubic yards	$10.00	$121,874
Principal Discharge Culverts	296	linear feet	$350	$103,600
Riser Culverts	22	linear feet	$350	$7,700
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$103,600	$103,600
Storage Excavation & Haul =	32,267	cubic yards	$5.00	$161,333
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$809,107
Engineering Design & Permitting	10.00%			$80,911
Construction Oversight	5.00%			$40,455
Cost Sub-Total				$930,474
Contingency	15.00%			$139,571
TOTAL COST				$1,070,045

COST ESTIMATE FOR REGIONAL DETENTION BASIN #4

QUANTITY TAKE-OFF WORK AREA

Item	Quantity	Units	Computation of Required Dam Fill Volume (cy)			
			Incr. Dist.	NG Elevation	Section Area	Incr. Volume
Maximum 100-Year WSEL =	292	feet				
Proposed Top of Dam Elevation =	295	feet	-----	295	0	0
Channel Invert Elevation at Proposed Dam Location =	276	feet	10	294	24	4
Natural Ground Surface Area at Top of Dam Elevation =	20.8	acres	90	292	96	200
100-Year Peak Discharge =	421	cfs	40	290	200	219
Flow Area Required for Principal Outlet =	84.2	sq. ft.	60	288	336	596
Required Number & Size of Outlet Pipes =	2	7' x 6'	50	286	504	778
Total Flow Area Provided in Principal Outlet =	84	sq. ft.	70	284	704	1566
Maximum Height of Dam =	19	feet	70	282	936	2126
Top Width of Dam =	20	feet	80	282	936	2773
Dam Side Slope Ratio =	4	(h/v)	30	284	704	911
Width of Dam at Toe =	172	feet	10	276	1824	468
Total Pipe Length for Principal Outlet =	344	feet	10	280	1200	560
Spillway Crest Elevation =	290	feet	30	282	936	1187
Spillway Crest Length =	30	feet	70	295	0	1213
Required Number & Size of Riser Pipes =	2	7' x 6'	0	0	0	0
Total Pipe Length for Riser Pipes =	28	feet	0	0	0	0
Approximate Concrete Area =	100	sq. yd.	620	Total Fill Volume =		12601
Dam Excavation, Haul, & Compaction Volume =	12,601	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

COST ESTIMATE

Item	Quantity	Units	Unit Cost	Cost
Land Acquisition	31.2	acres	$10,000	$312,000
Excavation, Haul, & Compaction for Dam	12,601	cubic yards	$10.00	$126,015
Principal Discharge Culverts	344	linear feet	$350	$120,400
Riser Culverts	28	linear feet	$350	$9,800
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$120,400	$120,400
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$693,615
Engineering Design & Permitting	10.00%			$69,361
Construction Oversight	5.00%			$34,681
Cost Sub-Total				$797,657
Contingency	15.00%			$119,649
TOTAL COST				$917,306

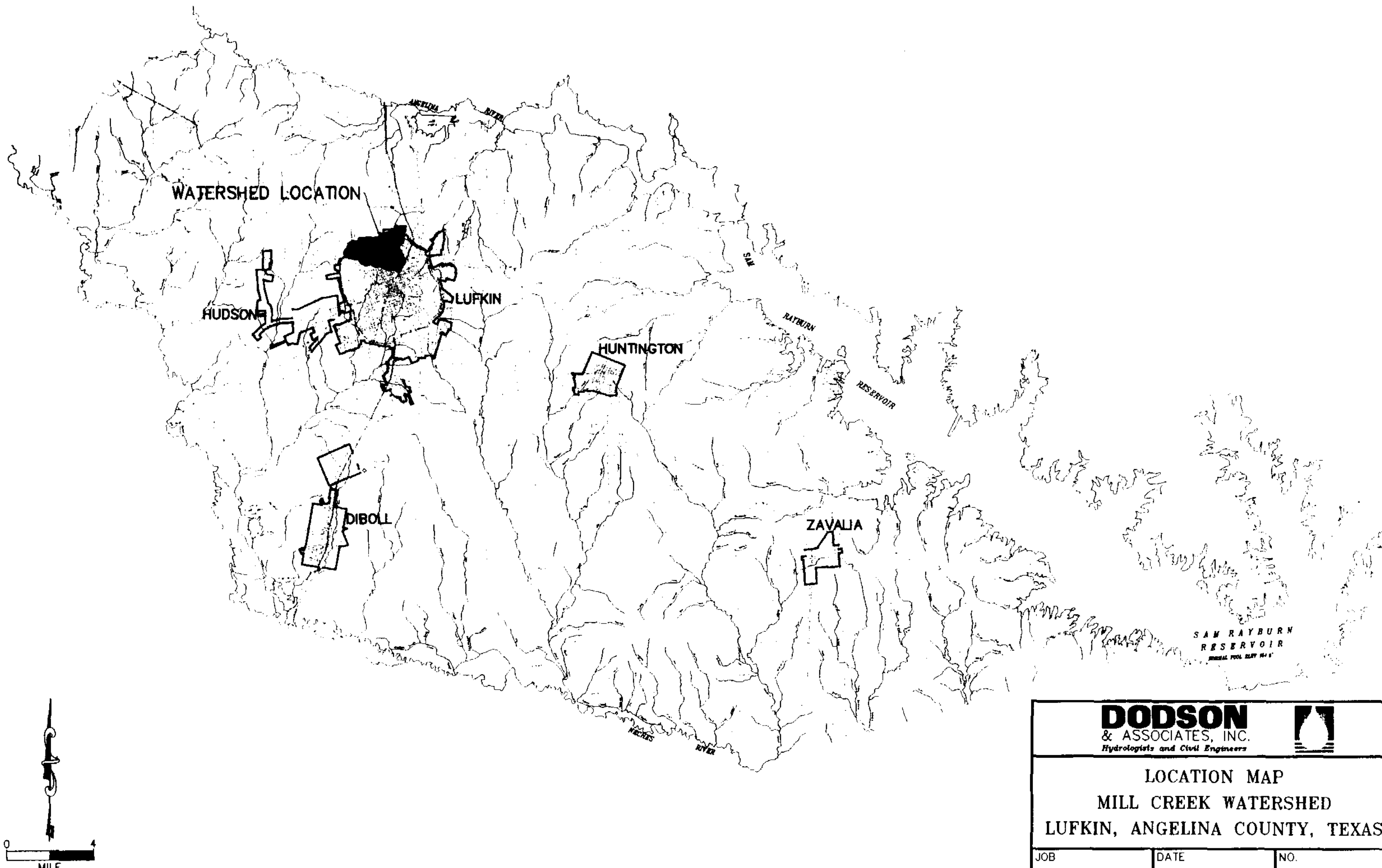
COST ESTIMATE FOR REGIONAL DETENTION BASIN #2

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
			Incr. Dist.	*NG Elevation*	*Section Area*	*Incr. Volume*
Maximum 100-Year WSEL =	293	feet	-----	296	0	0
Proposed Top of Dam Elevation =	296	feet	40	294	56	41
Channel Invert Elevation at Proposed Dam Location =	278	feet	70	290	264	415
Natural Ground Surface Area at Top of Dam Elevation =	28.5	acres	30	288	416	378
100-Year Peak Discharge =	1029	cfs	40	286	600	753
Flow Area Required for Principal Outlet =	205.8	sq. ft.	50	284	816	1311
Required Number & Size of Outlet Pipes =	4	9' x 6'	70	282	1064	2437
Total Flow Area Provided in Principal Outlet =	216	sq. ft.	140	280	1344	6243
Maximum Height of Dam =	18	feet	10	278	1656	556
Top Width of Dam =	20	feet	20	280	1344	1111
Dam Side Slope Ratio =	4	(h/v)	20	282	1064	892
Width of Dam at Toe =	164	feet	60	274	2376	3822
Total Pipe Length for Principal Outlet =	656	feet	15	286	600	827
Spillway Crest Elevation =	290	feet	15	288	416	282
Spillway Crest Length =	80	feet	30	290	264	378
Required Number & Size of Riser Pipes =	4	9' x 6'	50	296	0	244
Total Pipe Length for Riser Pipes =	48	feet	660	***Total Fill Volume =***		19690
Approximate Concrete Area =	200	sq. yd.				
Dam Excavation, Haul, & Compaction Volume =	19,690	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

COST ESTIMATE

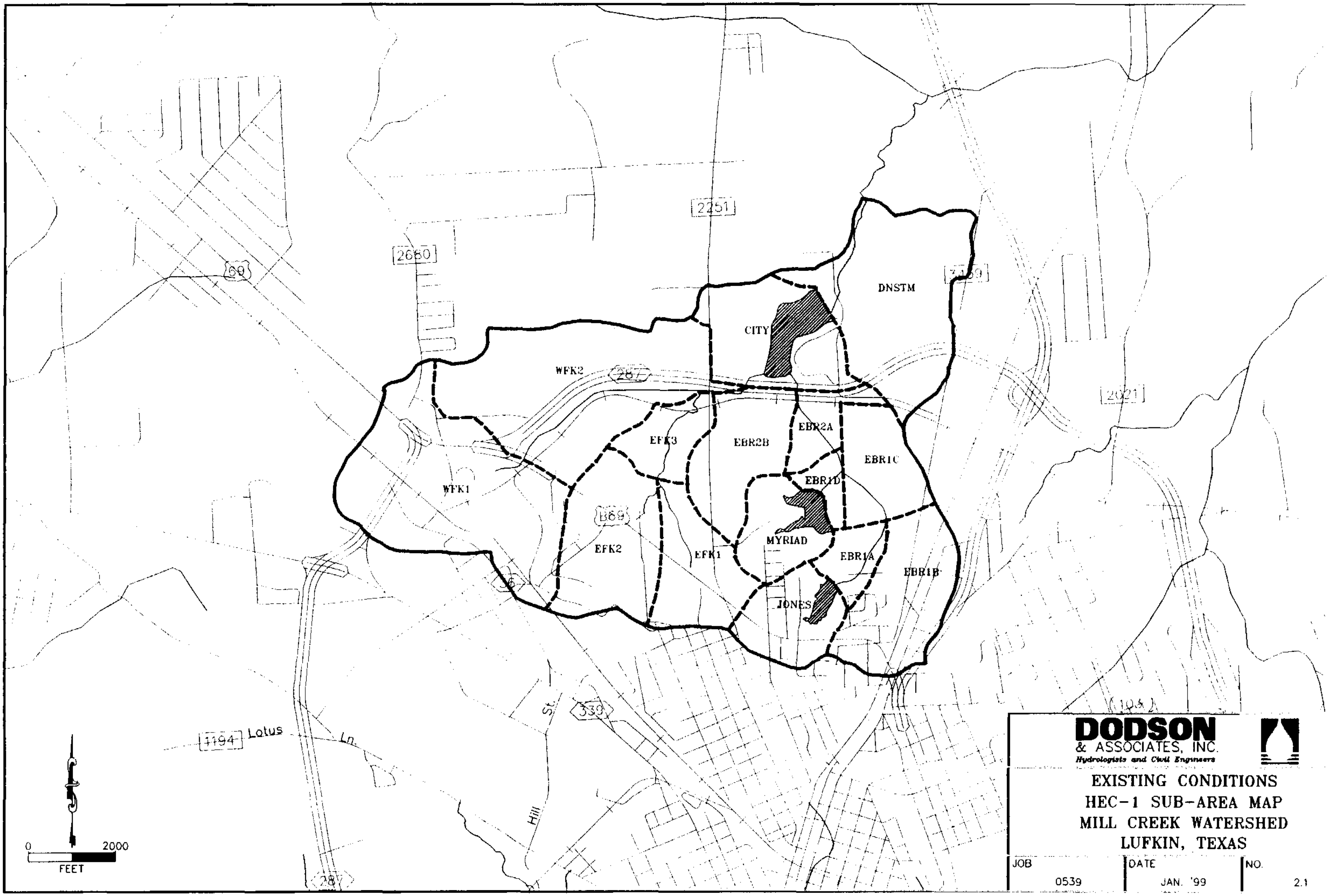
Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	42.75	acres	$10,000	$427,500
Excavation, Haul, & Compaction for Dam	19,690	cubic yards	$10.00	$196,896
Principal Discharge Culverts	656	linear feet	$425	$278,800
Riser Culverts	48	linear feet	$425	$20,400
Concrete Slope Paving	200	sq. yds.	$50.00	$10,000
Emergency Spillway	1	lump sum	$278,800	$278,800
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$1,212,396
Engineering Design & Permitting	10.00%			$121,240
Construction Oversight	5.00%			$60,620
Cost Sub-Total				$1,394,256
Contingency	15.00%			$209,138
TOTAL COST				$1,603,394



DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

LOCATION MAP
MILL CREEK WATERSHED
LUFKIN, ANGELINA COUNTY, TEXAS

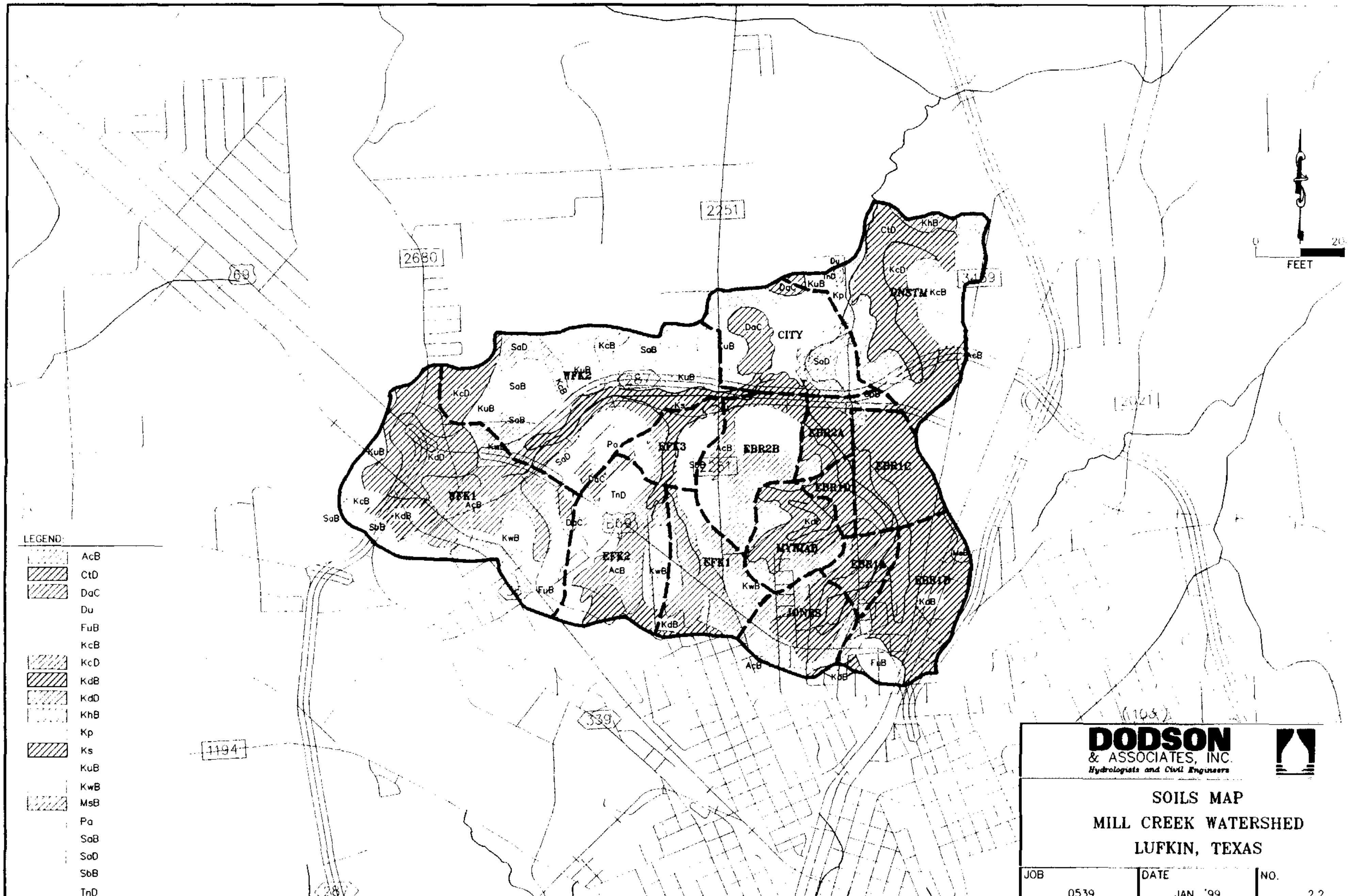
JOB	DATE	NO.
0539	JAN. '99	1.1

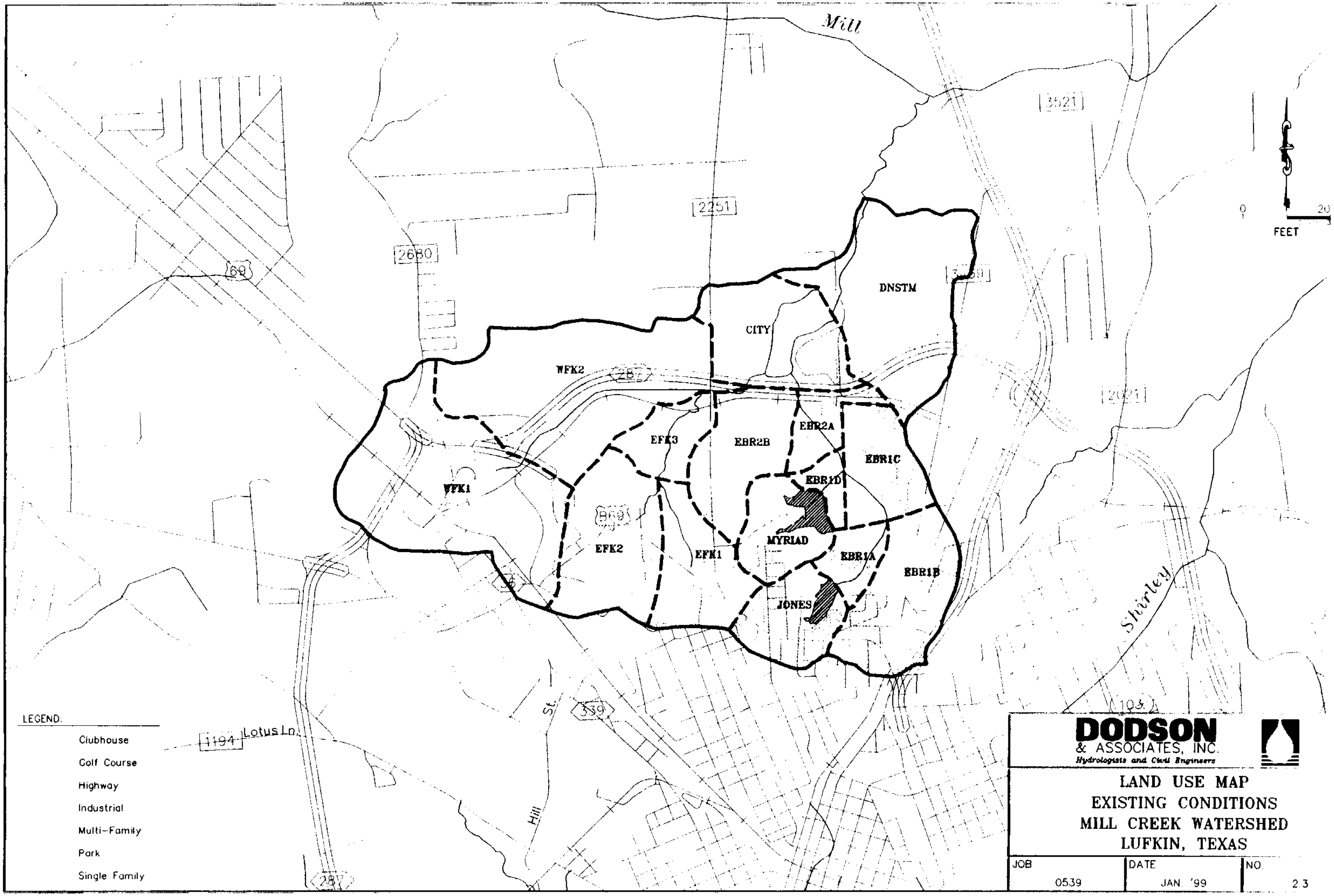


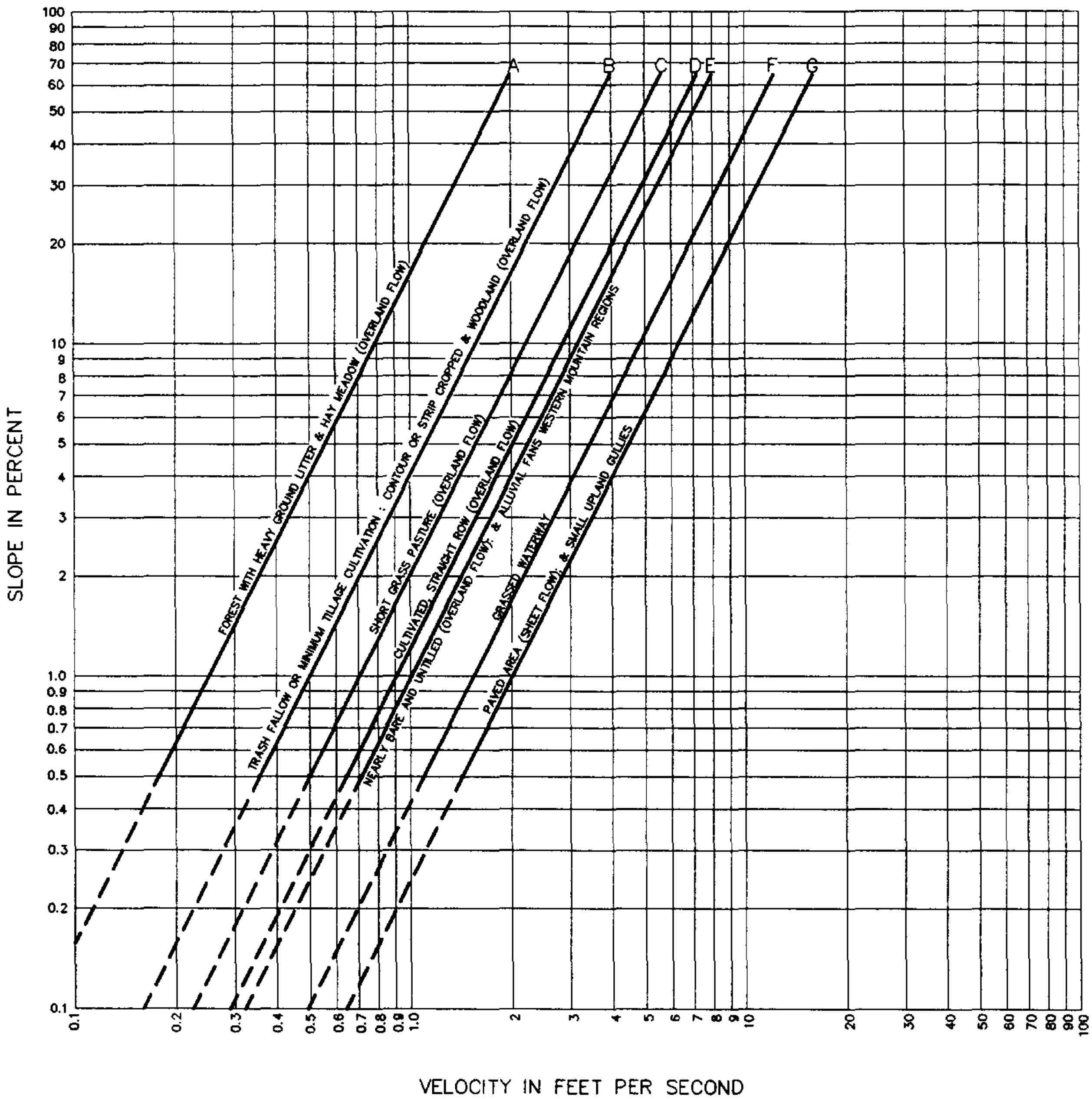
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

EXISTING CONDITIONS
HEC-1 SUB-AREA MAP
MILL CREEK WATERSHED
LUFKIN, TEXAS

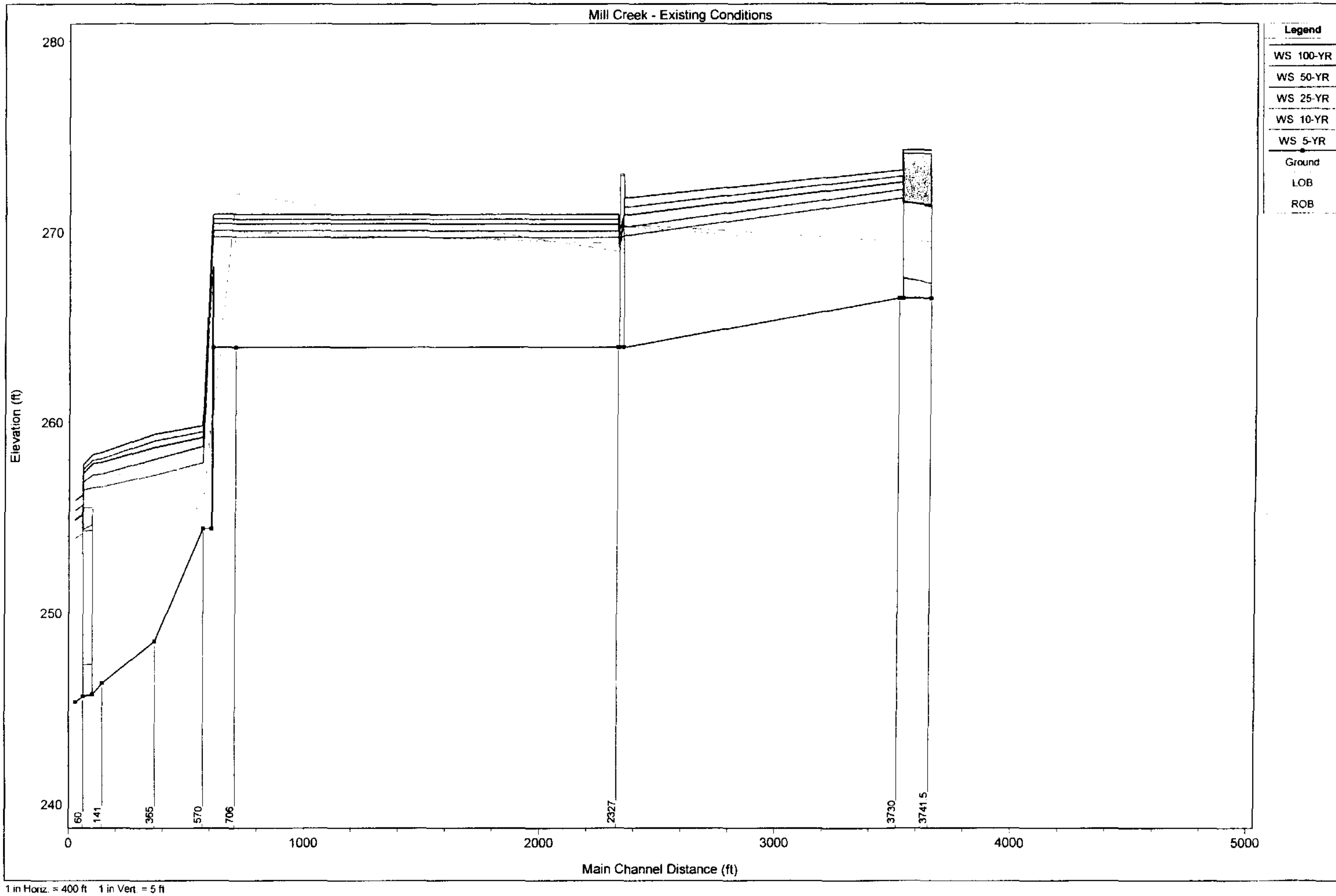
JOB	DATE	NO.
0539	JAN. '99	2.1


LEGEND:
AcB
CtD
DaC
Du
FuB
KcB
KcD
KdB
KdD
KhB
Kp
Ks
KuB
KwB
MsB
Pa
SaB
SaD
SbB
TnD
FEET
WFK1
WFK2
EFK1
EFK2
EFK3
EBR2B
EBR1C
CITY
MYRIAD
JONES
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers
SOILS MAP
MILL CREEK WATERSHED
LUFKIN, TEXAS
JOB
0539
DATE
JAN. '99
NO.
2.2


Mill
3521
2251
2680
69
DNSTM
CITY
WFK2
287
2021
EBR2A
EFK3
EBR2B
EBR1C
EBR1D
WFK1
B69
EFK2
EFK1
MYRIAD
EBR1A
EBR1B
JONES
Shirley
103
339
St.
1194
Lotus Ln.
Hill
287
0
20
FEET
LEGEND:
Clubhouse
Golf Course
Highway
Industrial
Multi-Family
Park
Single Family
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers
LAND USE MAP
EXISTING CONDITIONS
MILL CREEK WATERSHED
LUFKIN, TEXAS
JOB
0539
DATE
JAN. '99
NO.
2.3



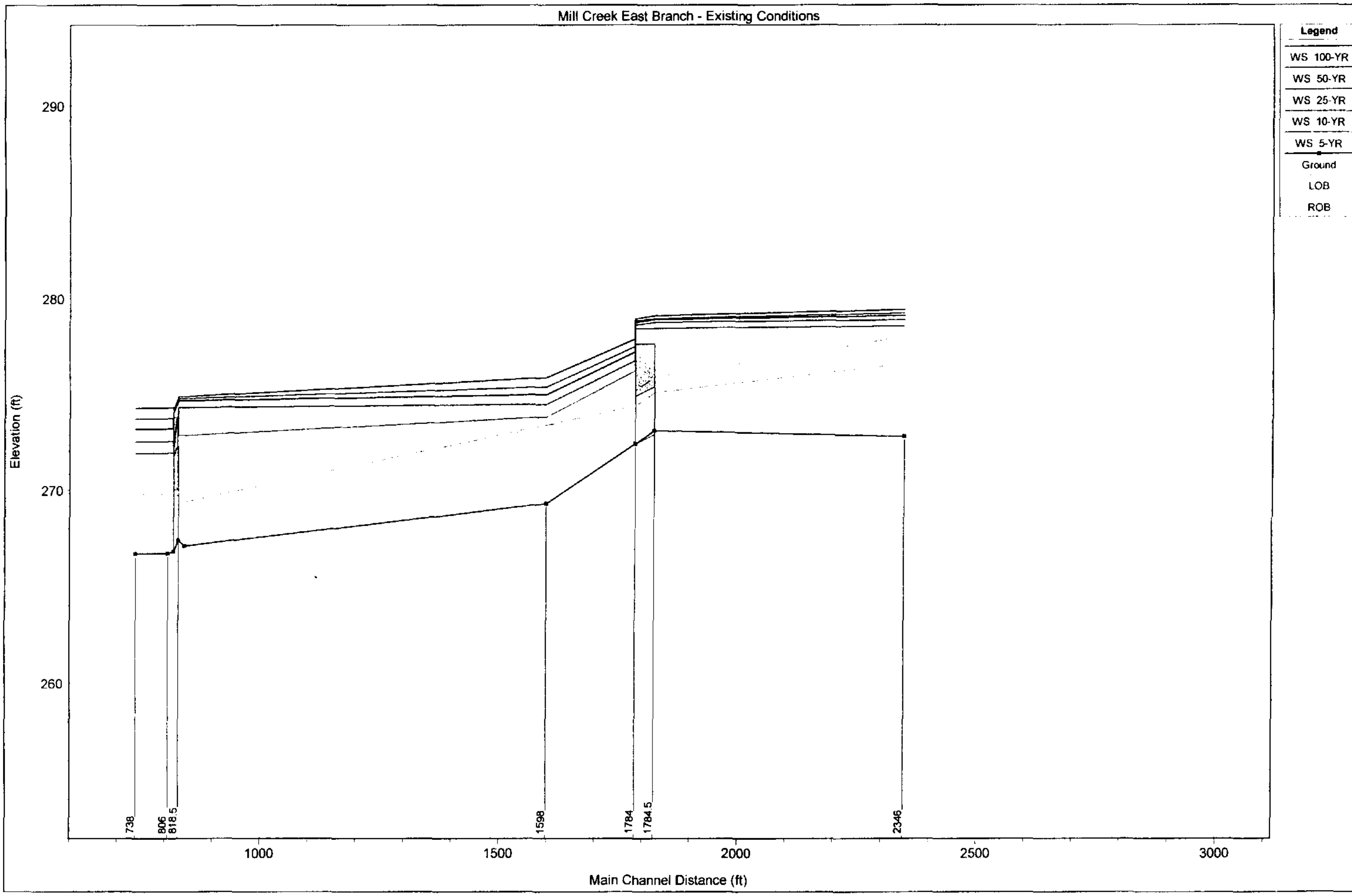
SCS UPLANDS METHOD VELOCITY vs. SLOPE GRAPHS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB 0539	DATE JAN. '99	NO. 2.4



COMPUTED STREAM PROFILES FOR MILL CREEK
EXISTING CONDITIONS

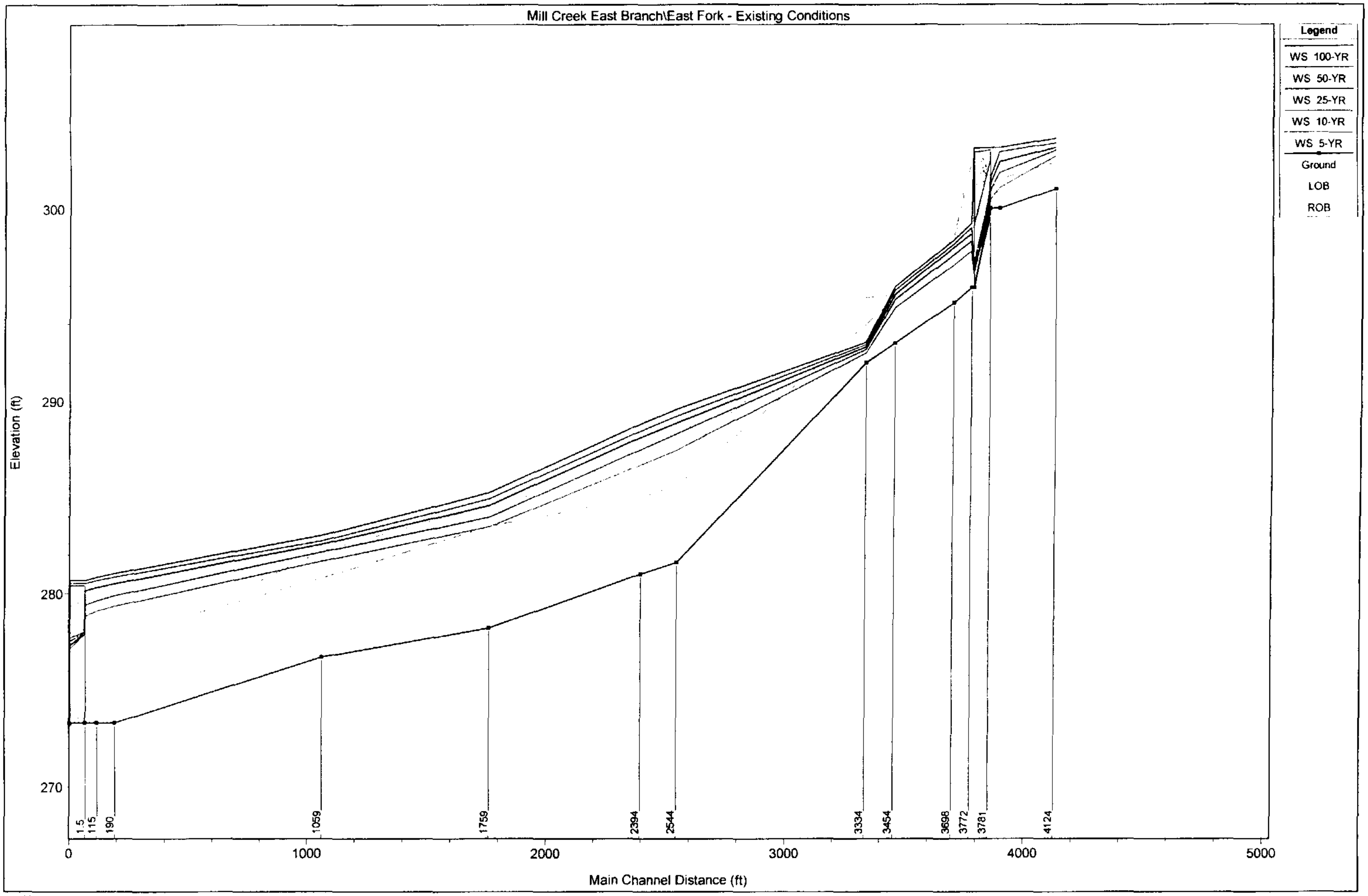
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0539	DATE: Dec. 1998	NO.: 3.1

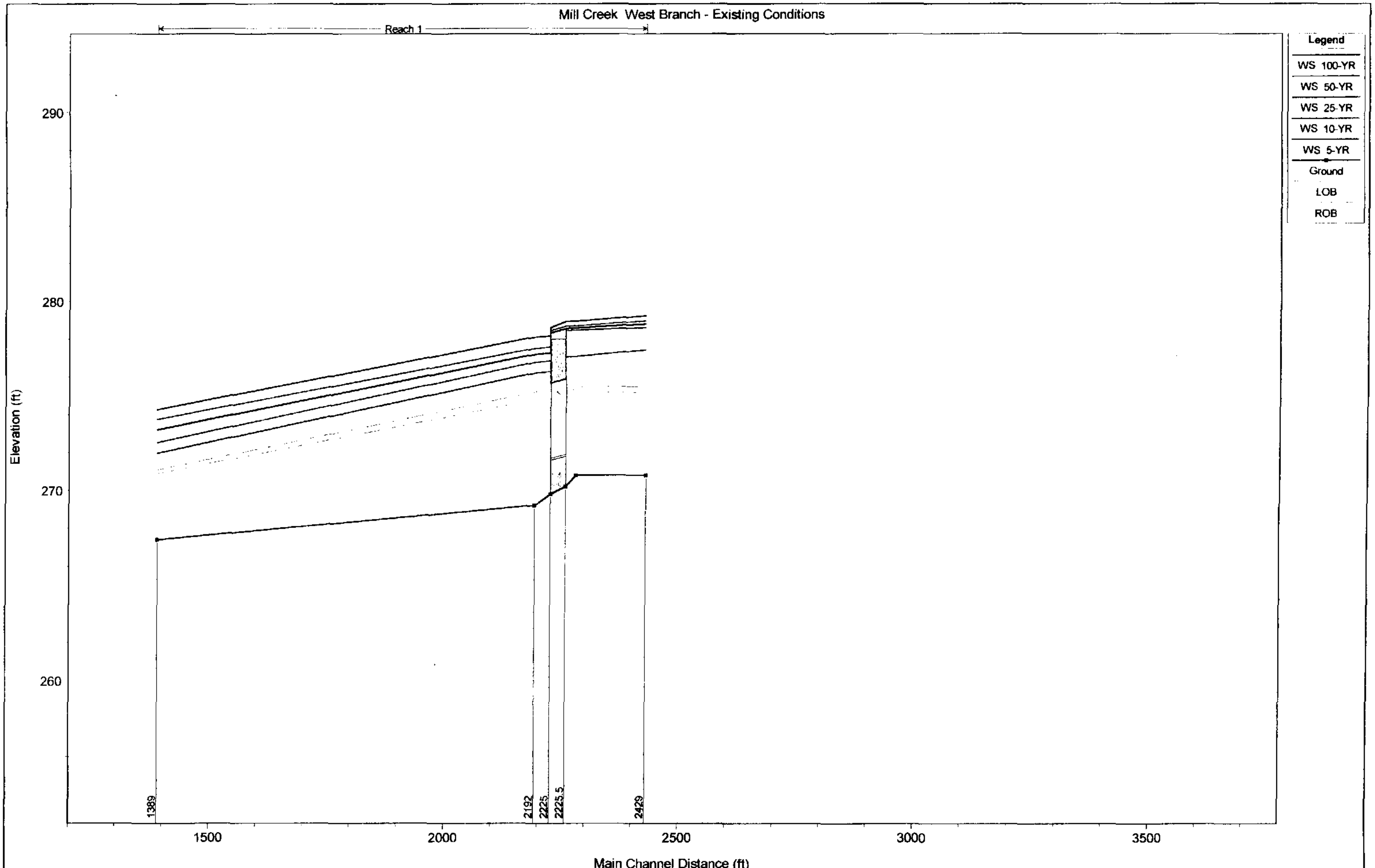


1 in Horiz. = 200 ft 1 in Vert. = 5 ft

COMPUTED STREAM PROFILES FOR MILL CREEK, EAST BRANCH EXISTING CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0539	DATE: Dec. 1998	NO.: 3.2

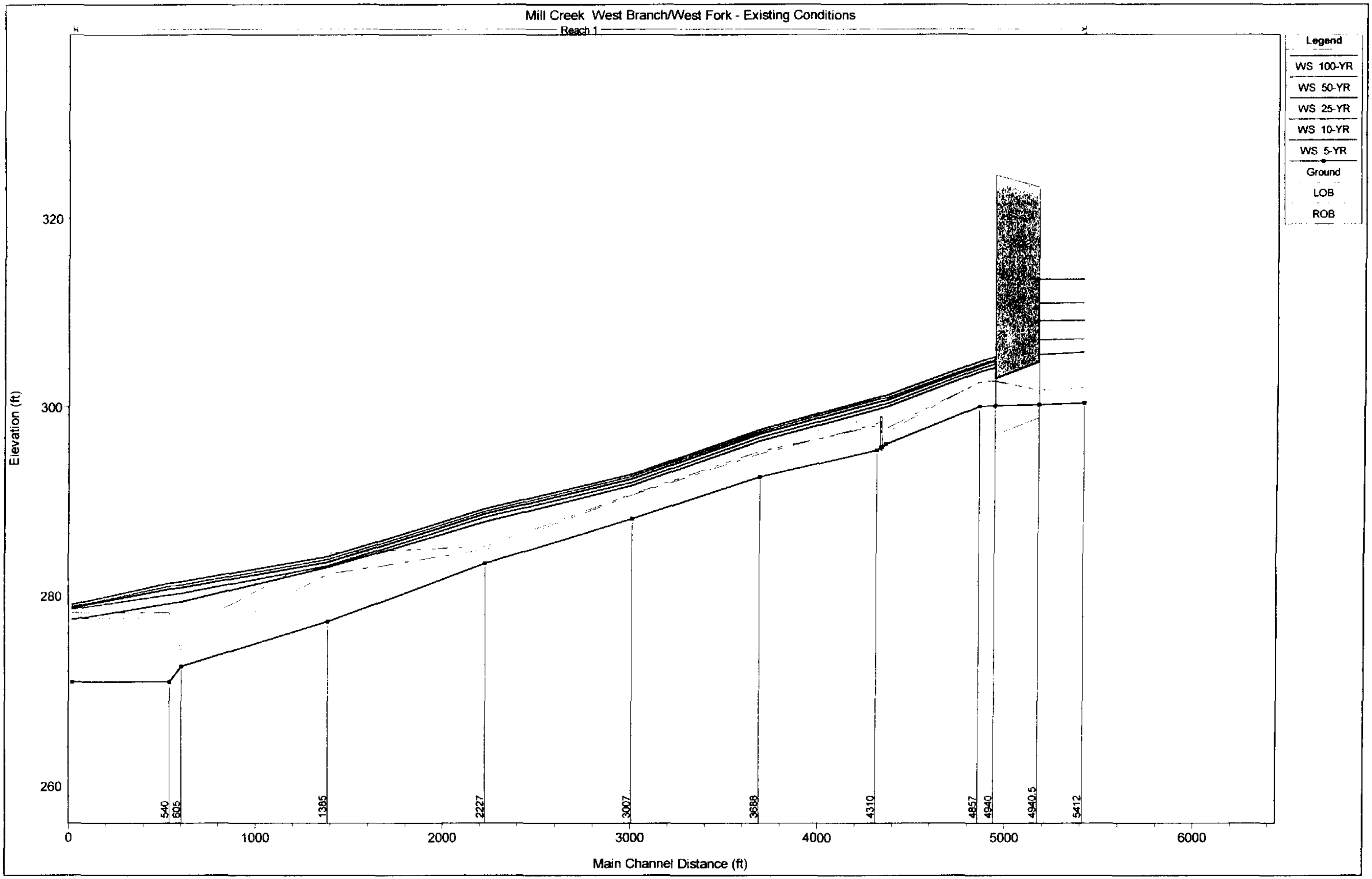


COMPUTED STREAM PROFILES FOR MILL CREEK, EAST BRANCH, EAST FORK EXISTING CONDITIONS	DODSON & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0539	DATE: Dec. 1998	NO.: 3.3



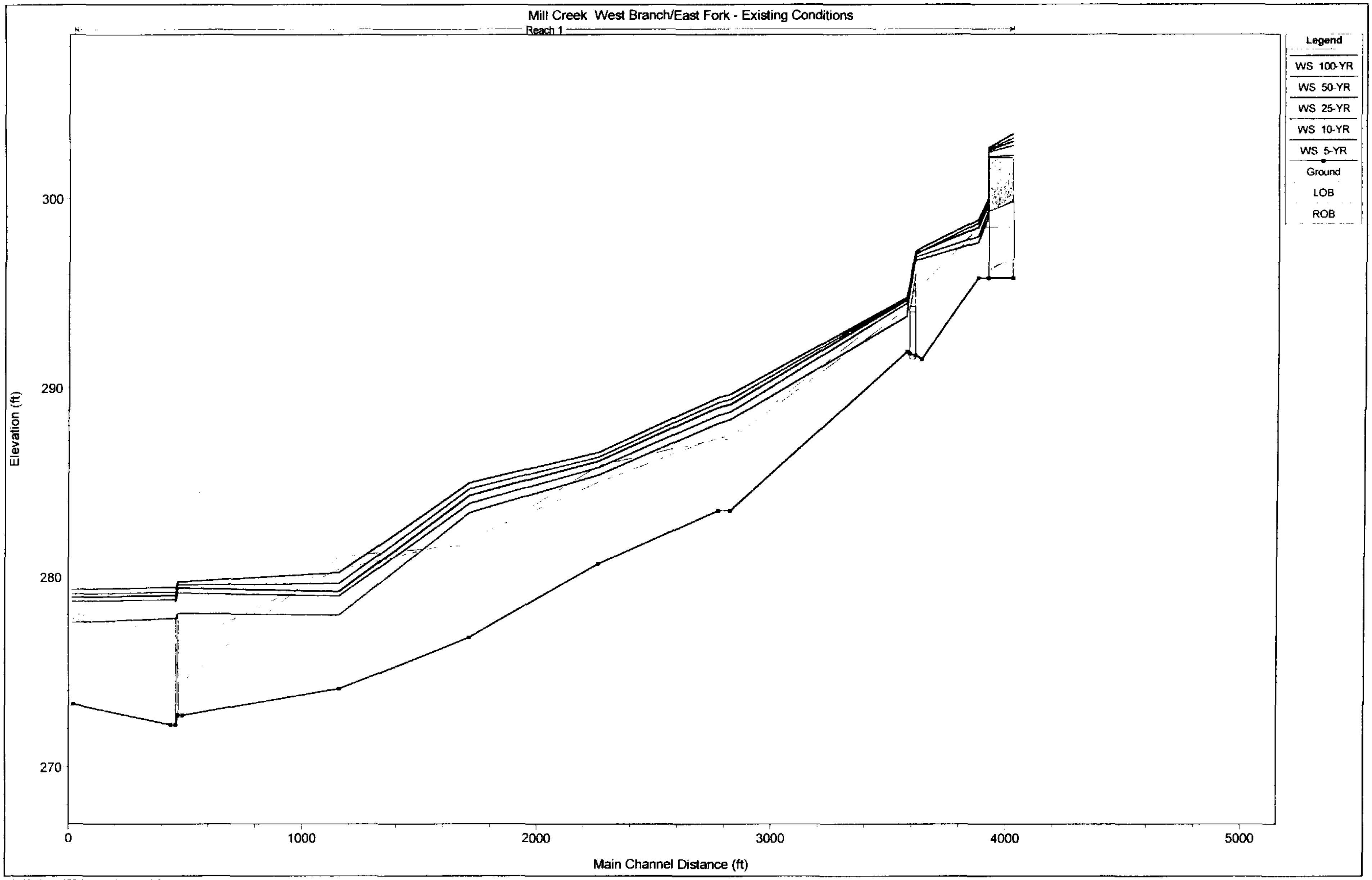
1 in Horiz. = 200 ft 1 in Vert. = 5 ft

COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH EXISTING CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0539	DATE: Dec. 1998	NO.: 3.4



1 in Horiz. = 500 ft   1 in Vert. = 10 ft

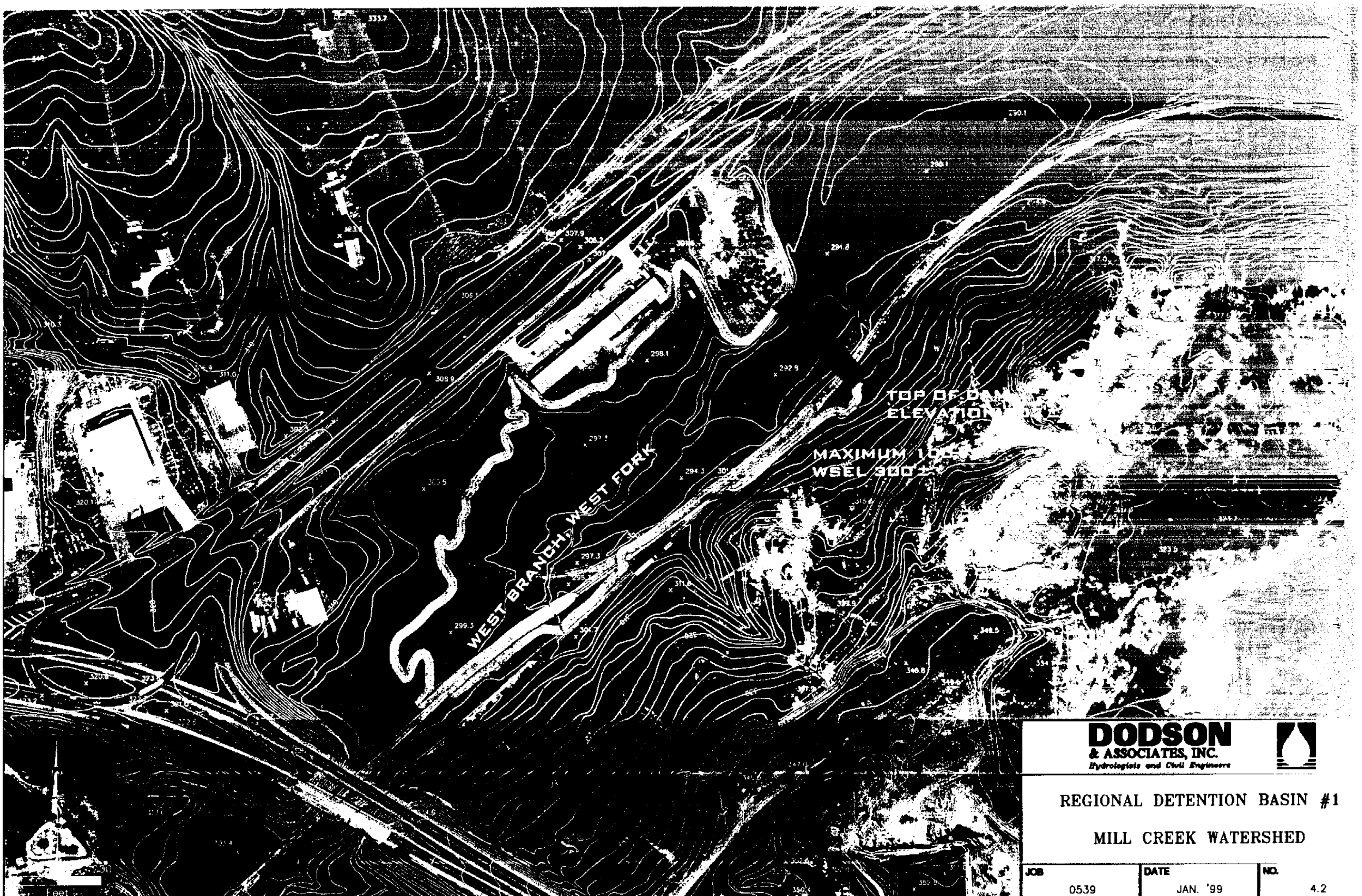
COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH, WEST FORK EXISTING CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0539	DATE: Dec. 1998	NO.: 3.5



COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH, EAST FORK
EXISTING CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0539	DATE: Dec. 1998	NO.: 3.6

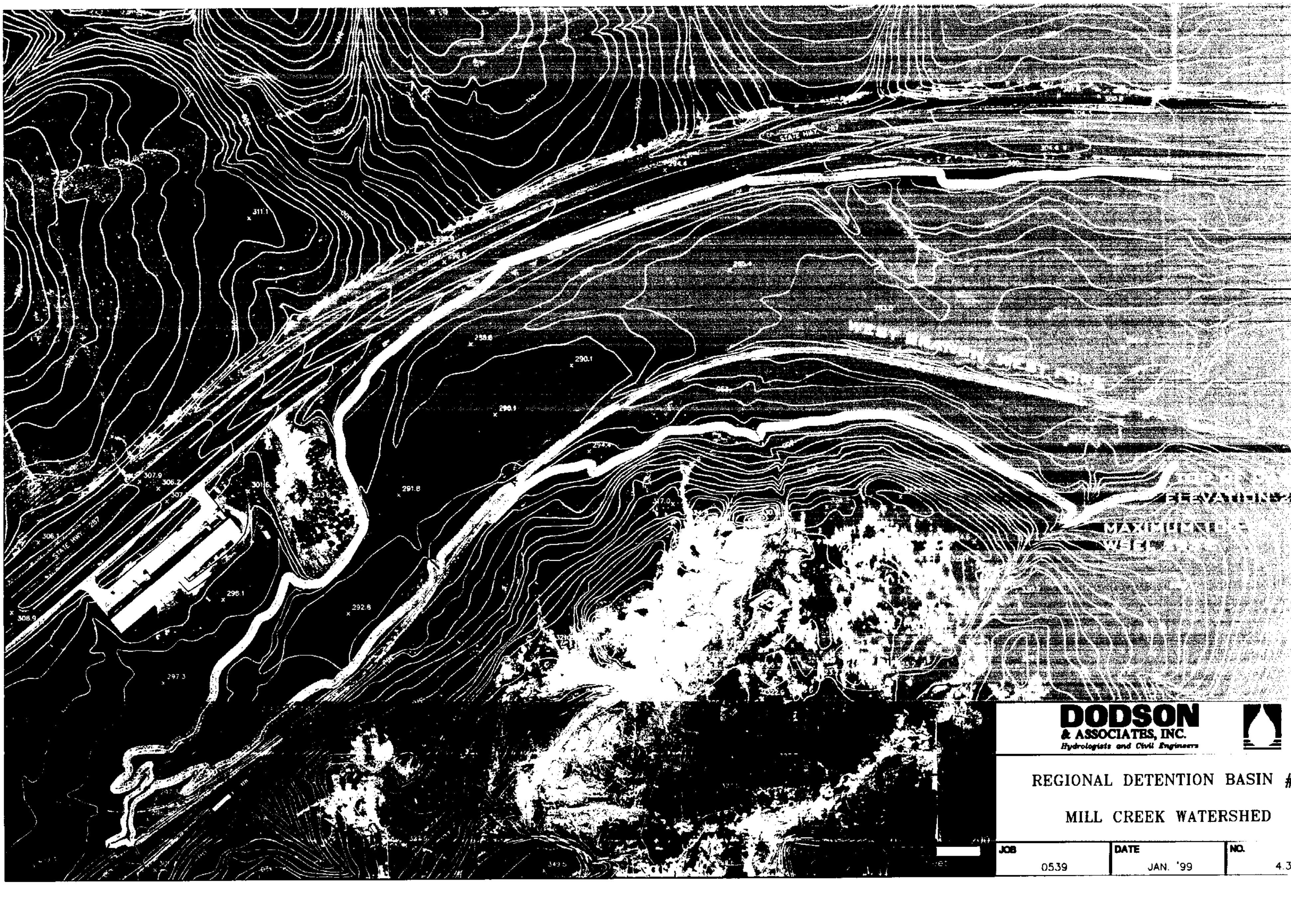


DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #1

MILL CREEK WATERSHED

JOB	DATE	NO.
0539	JAN. '99	4.2

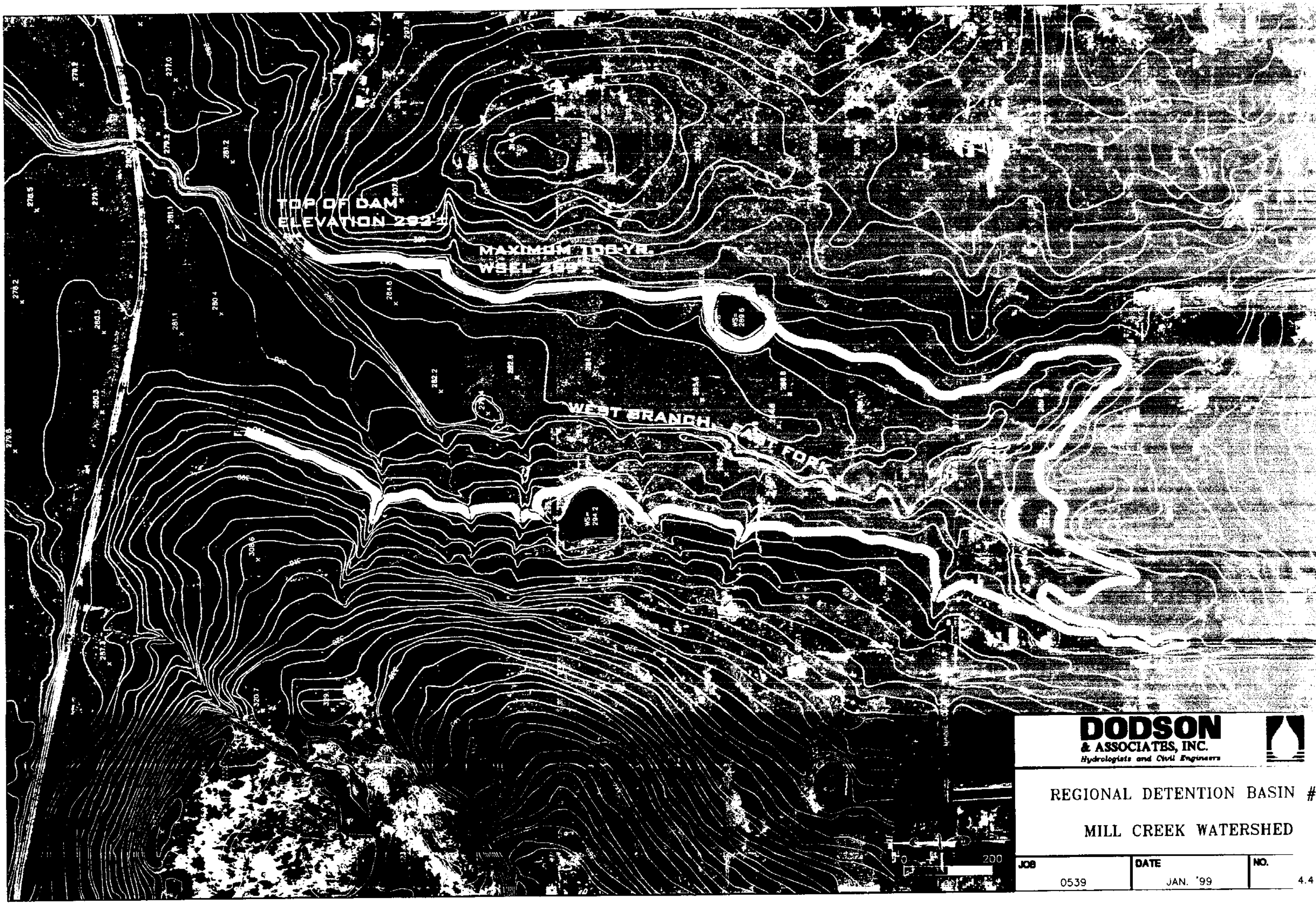


DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #2

MILL CREEK WATERSHED

JOB	DATE	NO.
0539	JAN. '99	4.3

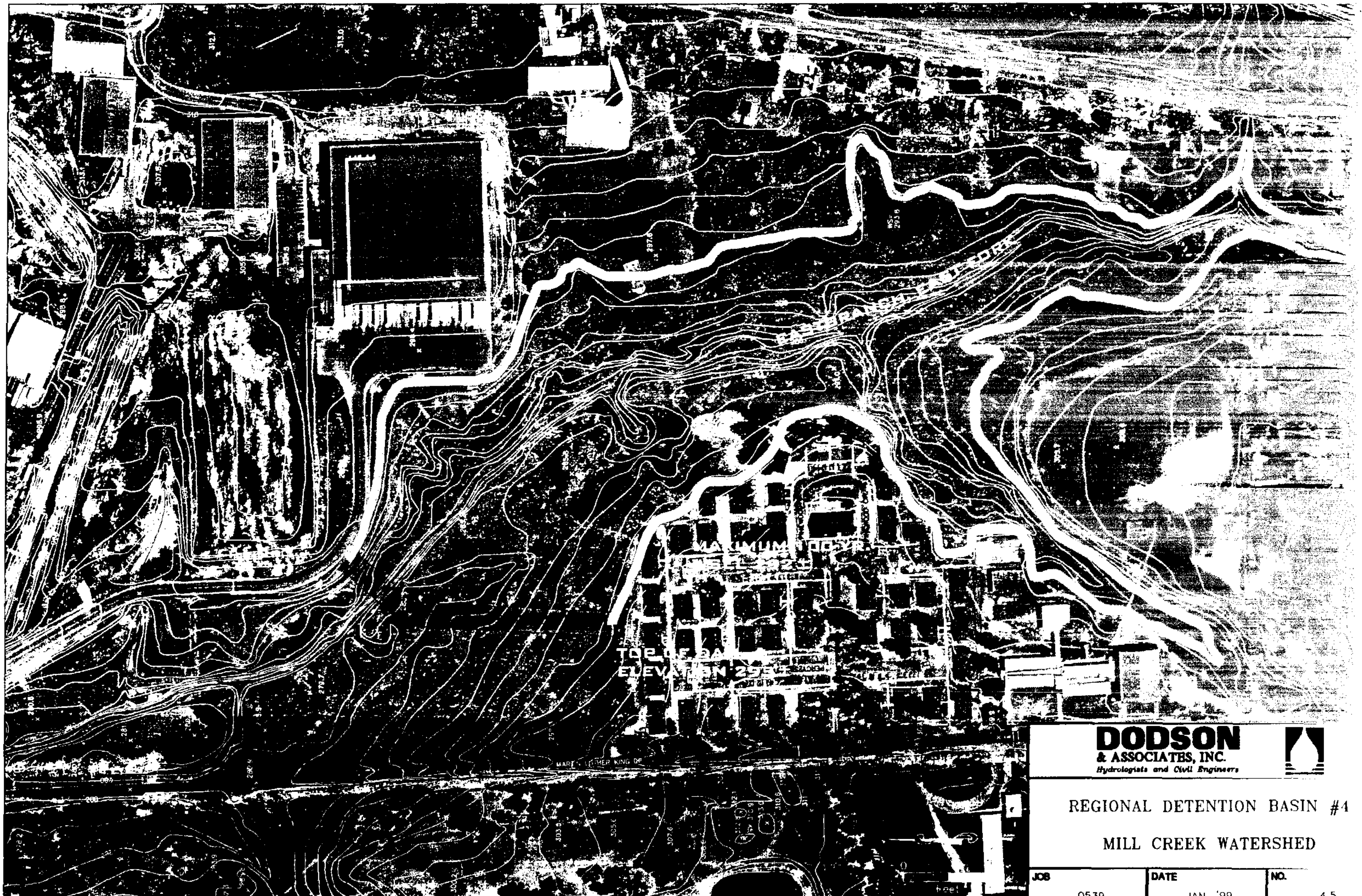


DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #3

MILL CREEK WATERSHED

JOB	DATE	NO.
0539	JAN. '99	4.4

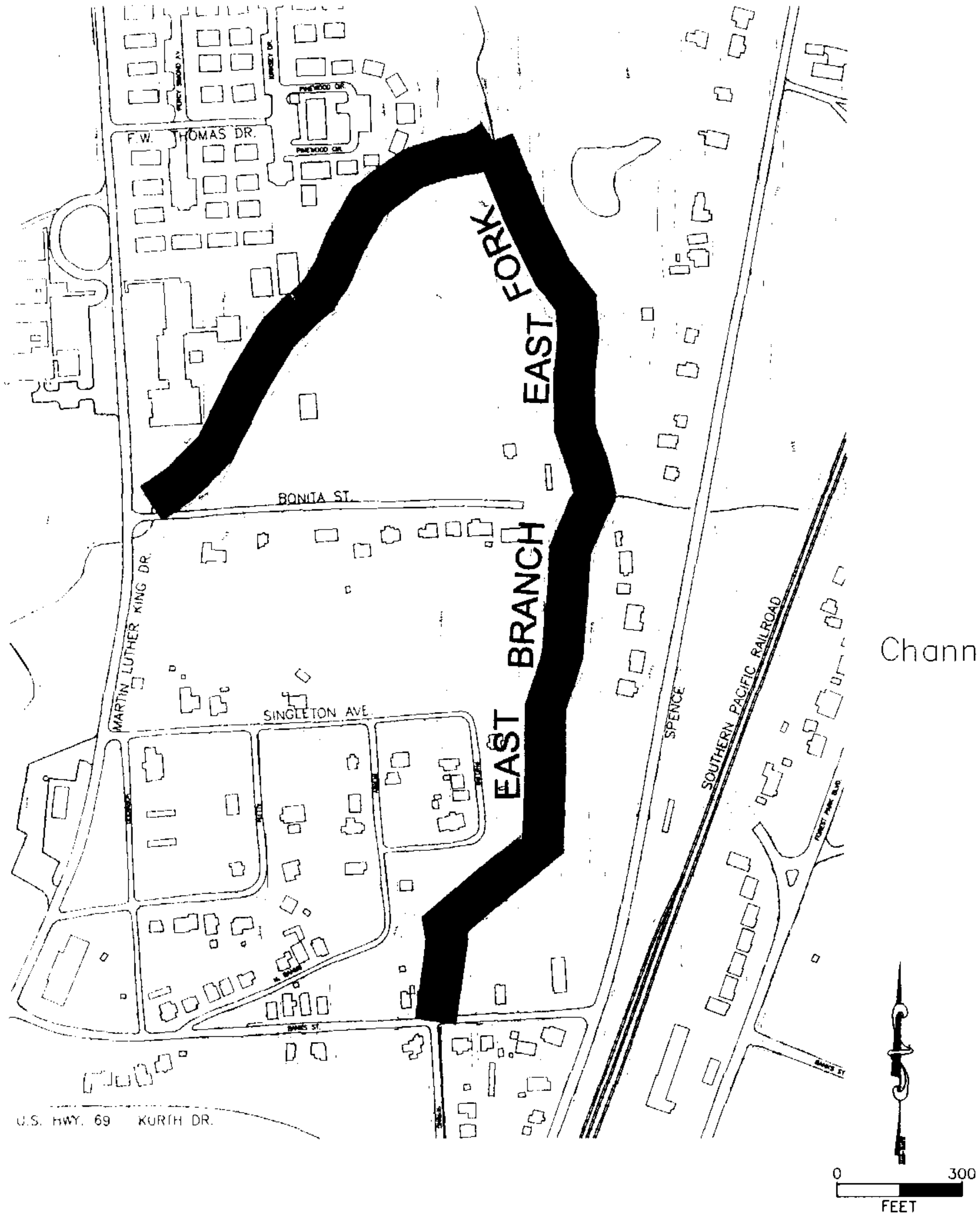


DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

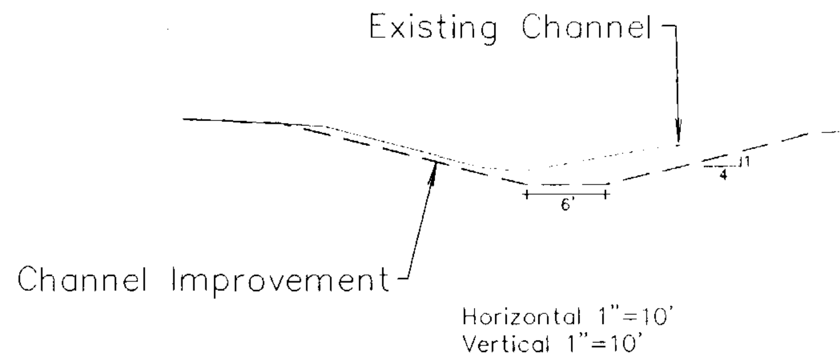
REGIONAL DETENTION BASIN #4

MILL CREEK WATERSHED

JOB	DATE	NO.
0539	JAN. '99	4.5



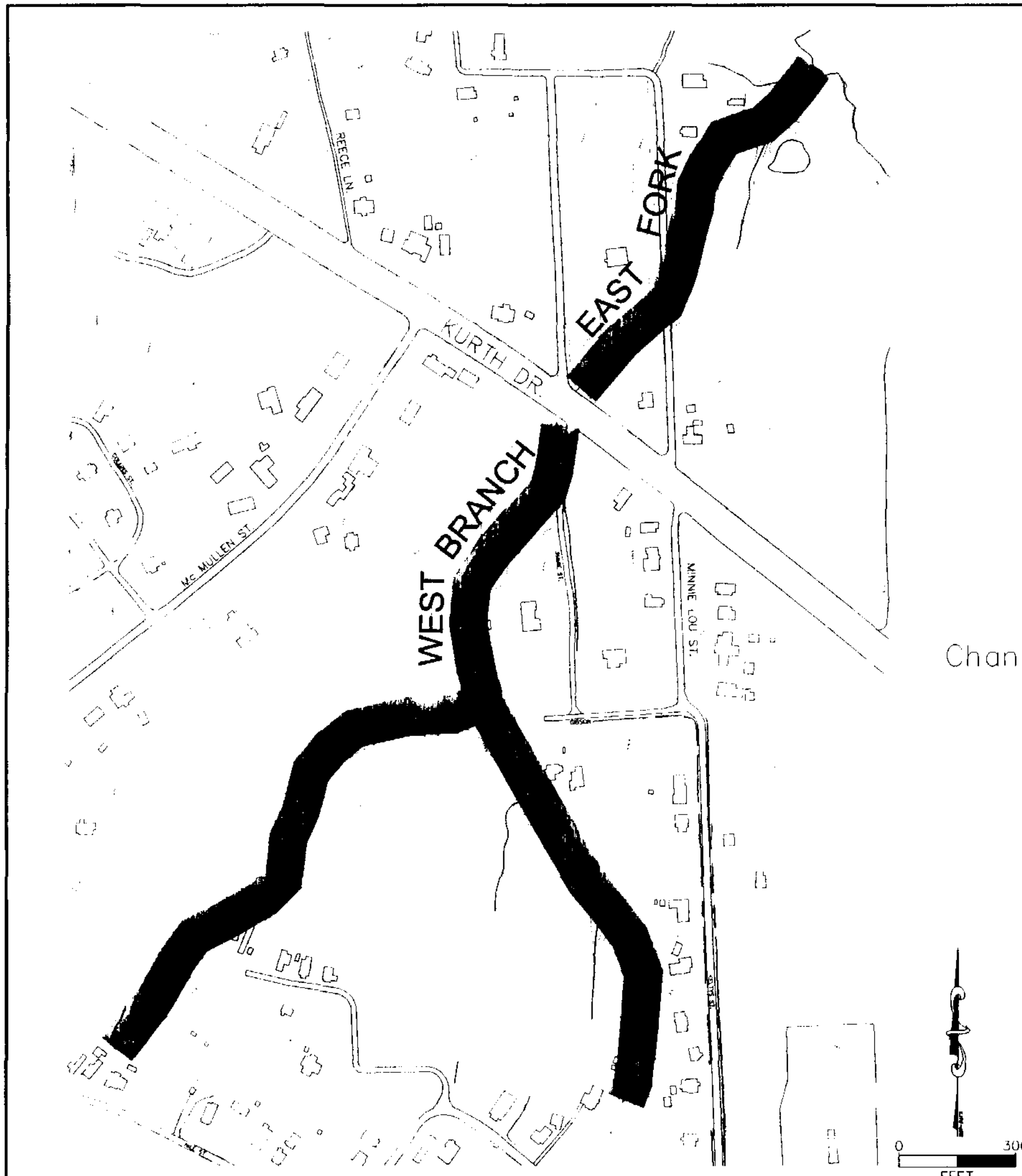
TYPICAL CROSS-SECTION



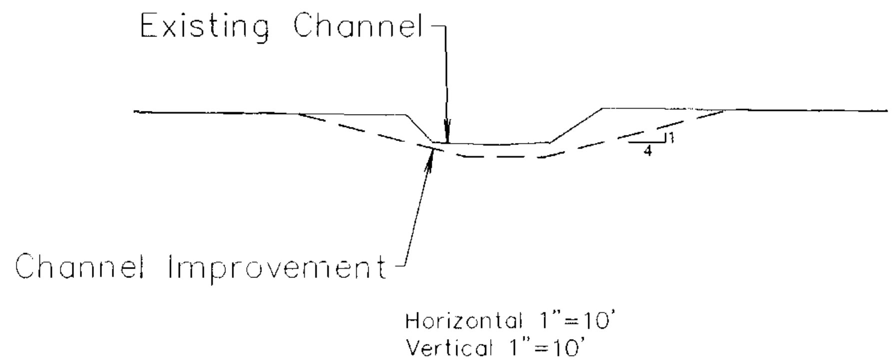
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

PROPOSED CHANNEL IMPROVEMENT
MILL CREEK
EAST BRANCH, EAST FORK

JOB	DATE	NO.
0539	JAN '99	4.6



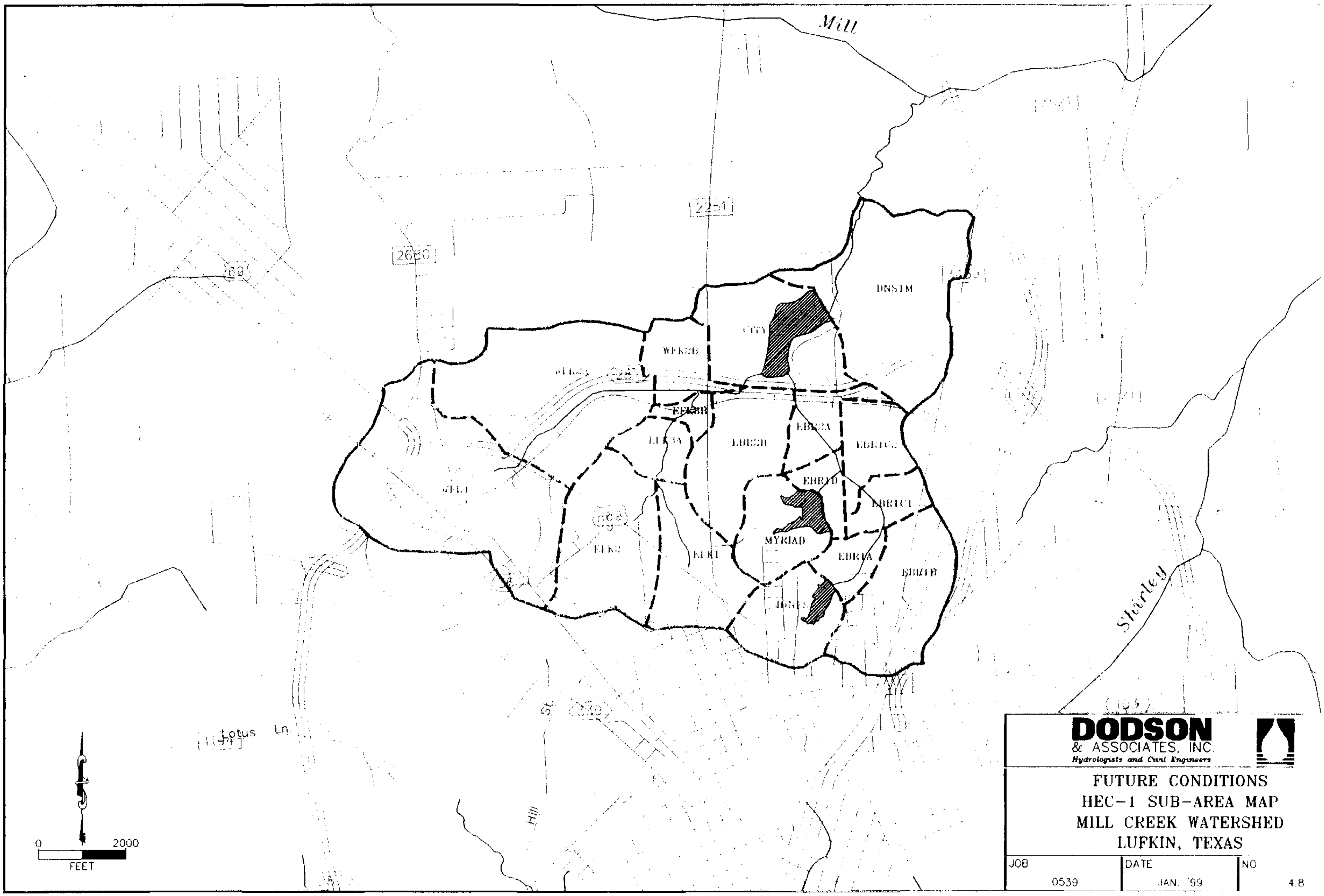
TYPICAL CROSS-SECTION

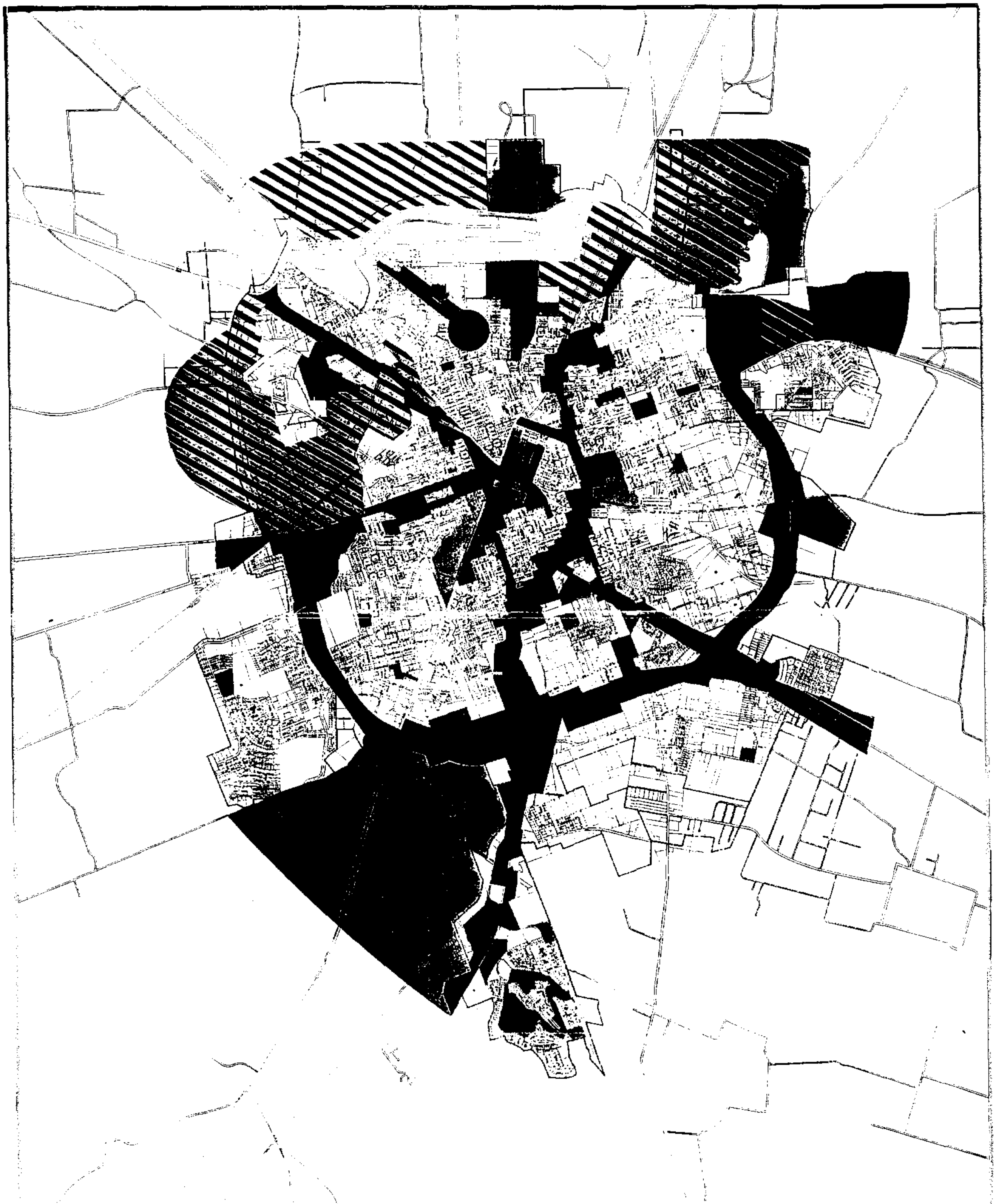


DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

PROPOSED CHANNEL IMPROVEMENT
MILL CREEK
WEST BRANCH, EAST FORK

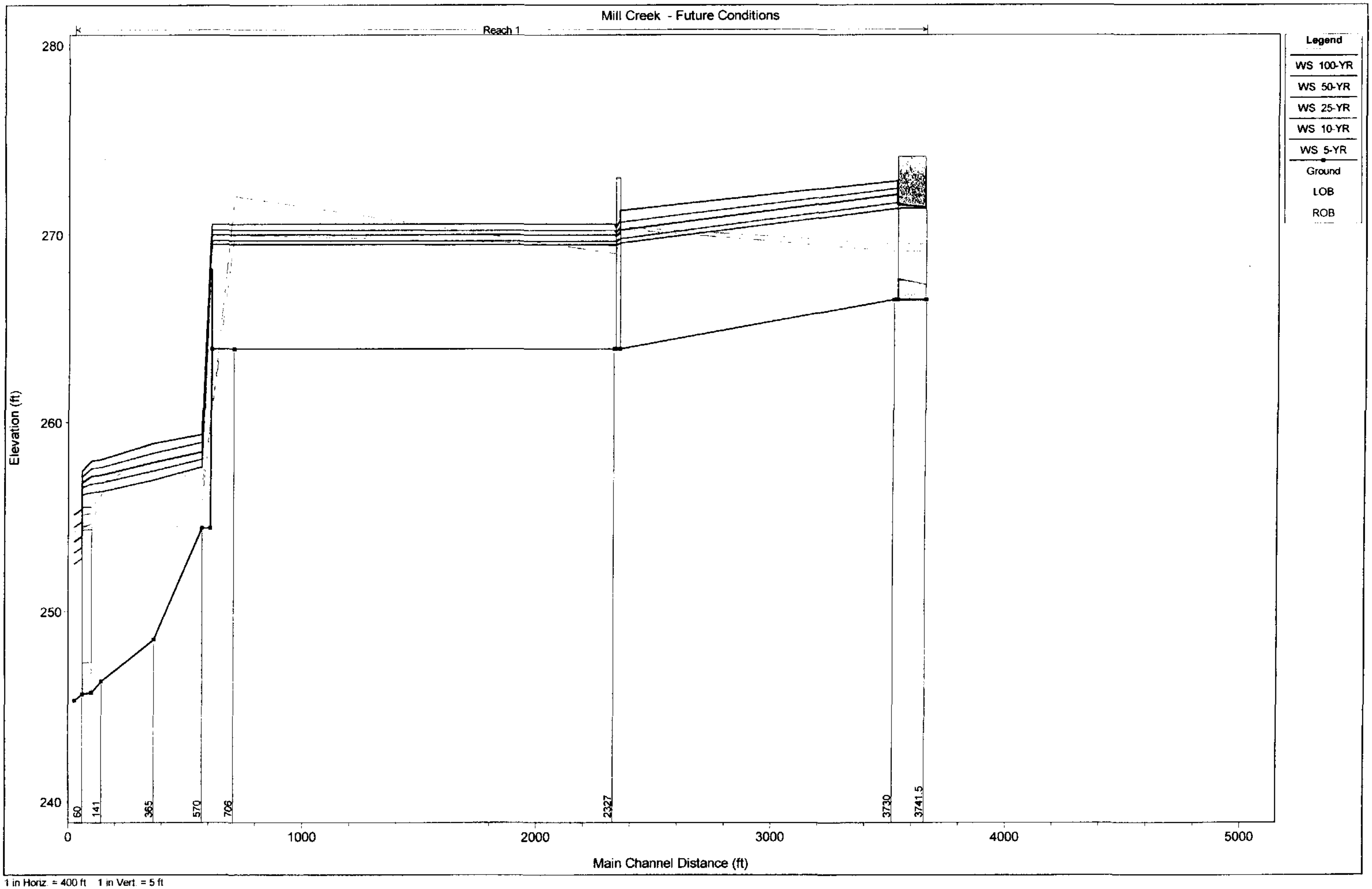
JOB	DATE	NO.
0539	JAN. '99	4.7


Mill
2251
2680
Shirley
Lotus Ln
DNSTM
CITY
WFK2B
MYRIAD
JONES
EBR1A
EBR1B
EBR1C1
EBR1D
0
2000
FEET
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers
FUTURE CONDITIONS
HEC-1 SUB-AREA MAP
MILL CREEK WATERSHED
LUFKIN, TEXAS
JOB
0539
DATE
JAN. '99
NO
4.8



LUFKIN, TEXAS

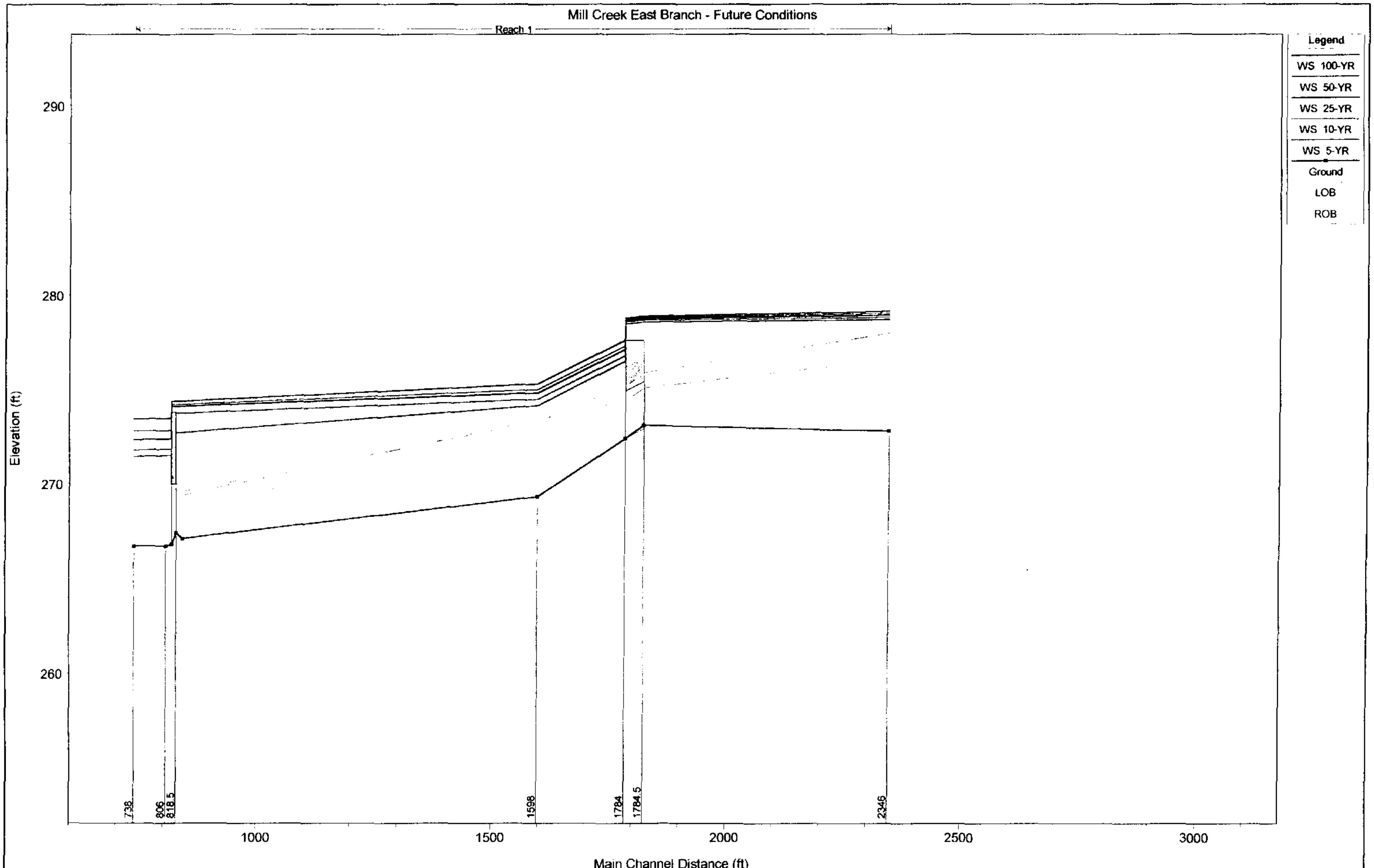
FUTURE LAND USE



COMPUTED STREAM PROFILES FOR MILL CREEK
FUTURE CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0539	DATE: Dec. 1998	NO.: 4.10

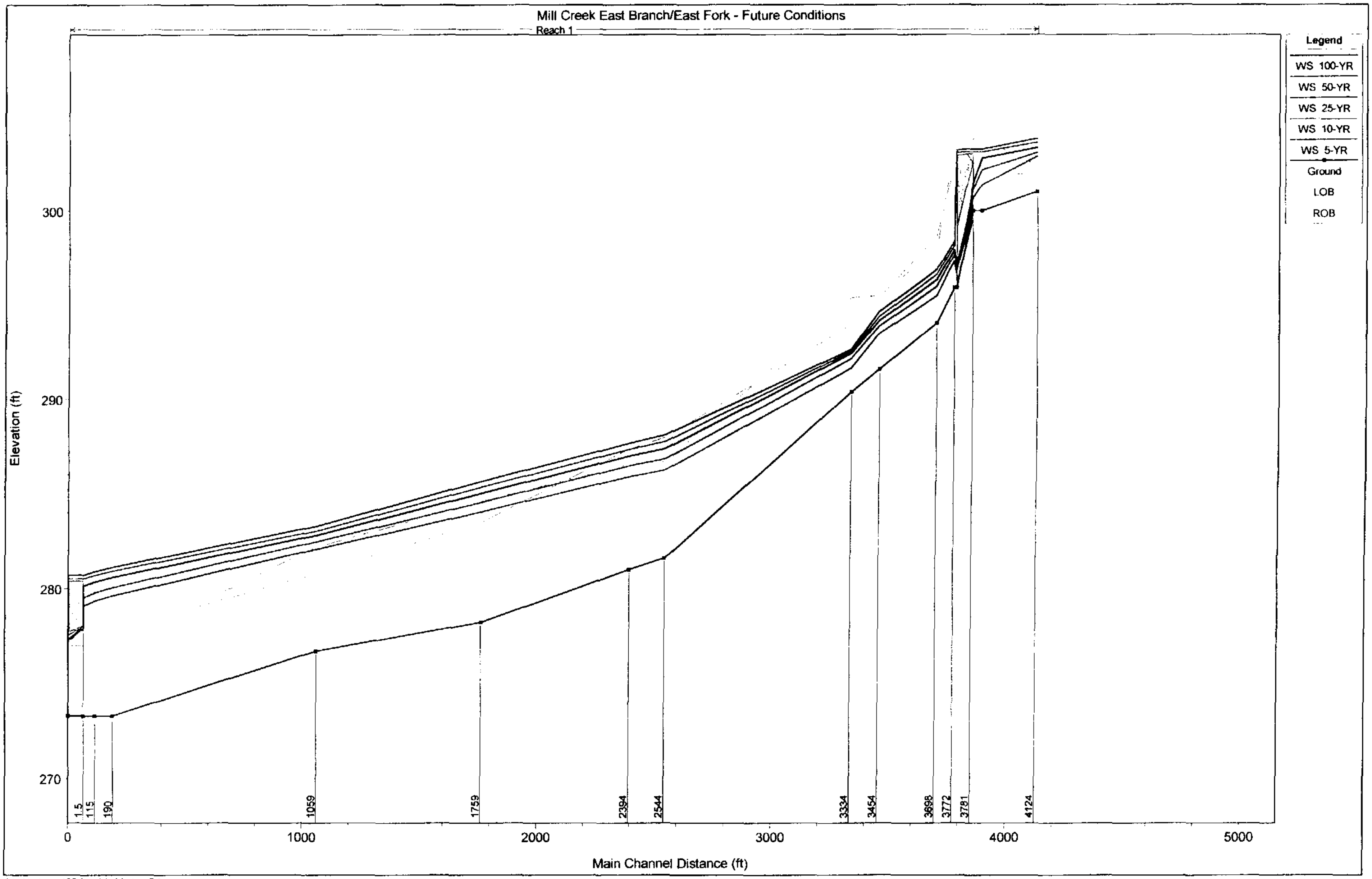


1 in Horiz. = 200 ft 1 in Vert. = 5 ft

COMPUTED STREAM PROFILES FOR MILL CREEK, EAST BRANCH
FUTURE CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

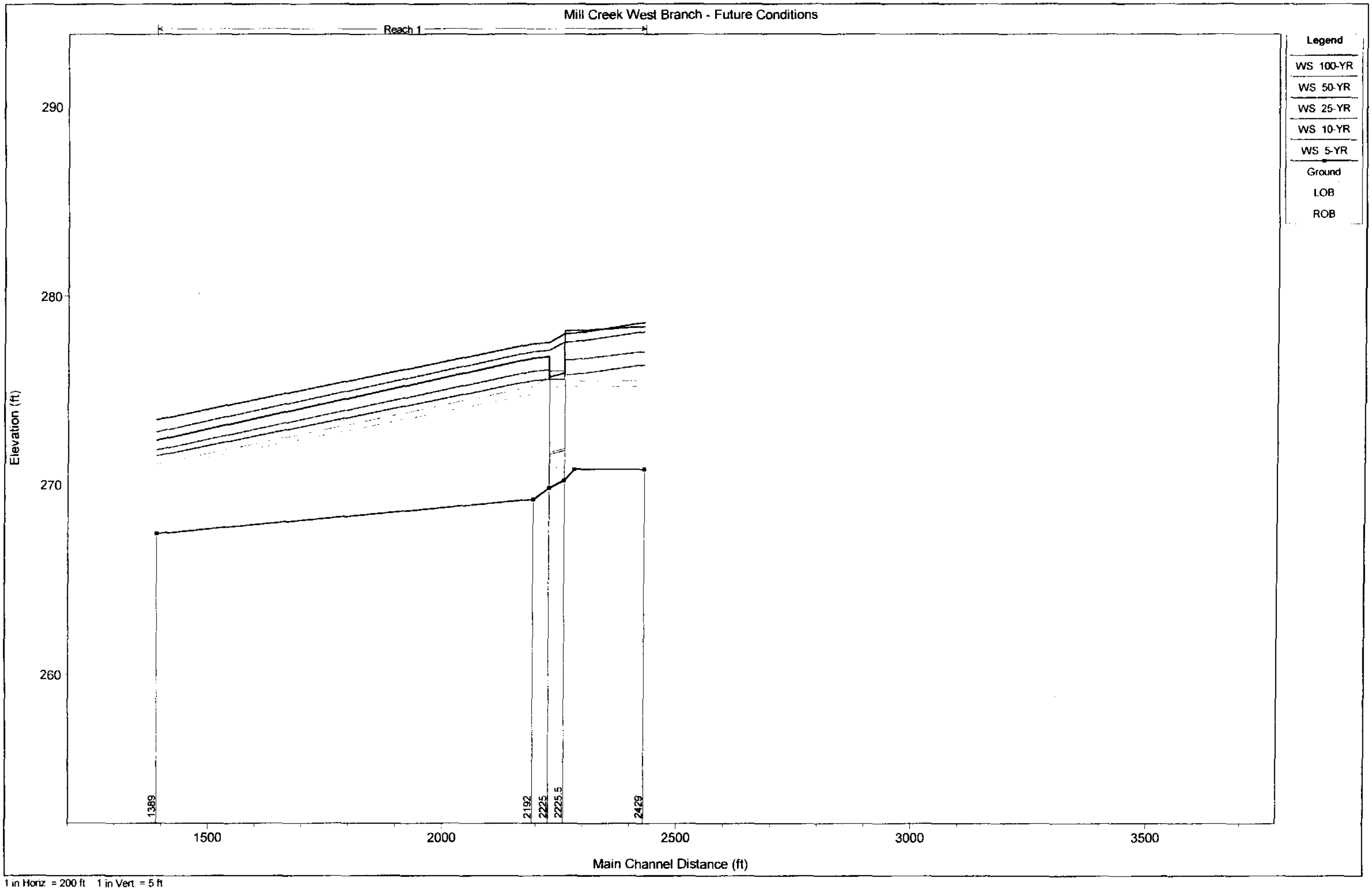
JOB: 0539	DATE: Dec 1998	NO.: 4.11



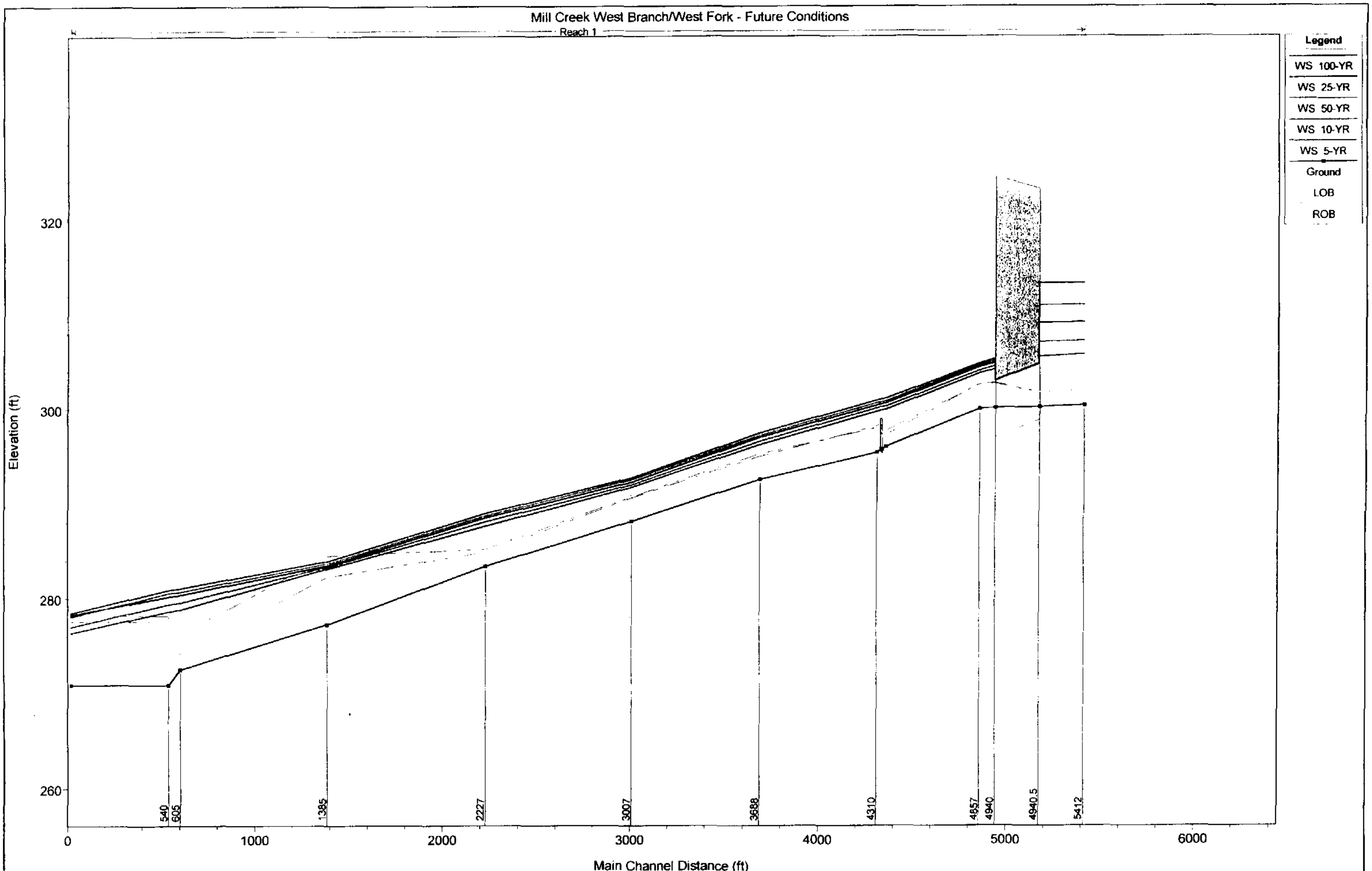
COMPUTED STREAM PROFILES FOR MILL CREEK, EAST BRANCH, EAST FORK
FUTURE CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0539	DATE: Dec. 1998	NO.: 4.12



COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH **FUTURE CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* **JOB:** 0539 **DATE:** Dec. 1998 **NO.:** 4.13



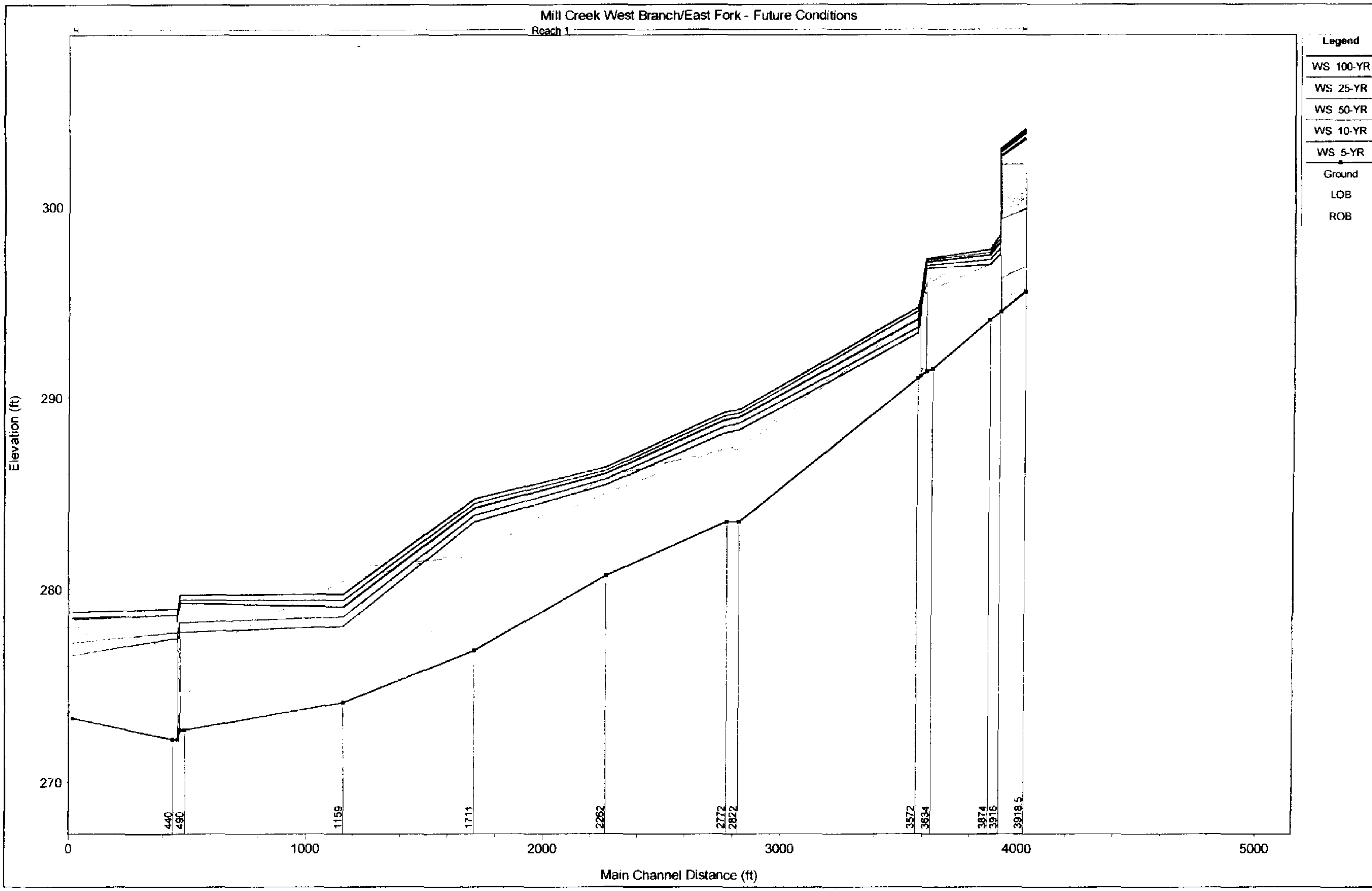
1 in Horiz. = 500 ft 1 in Vert. = 10 ft

COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH, WEST FORK

FUTURE CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

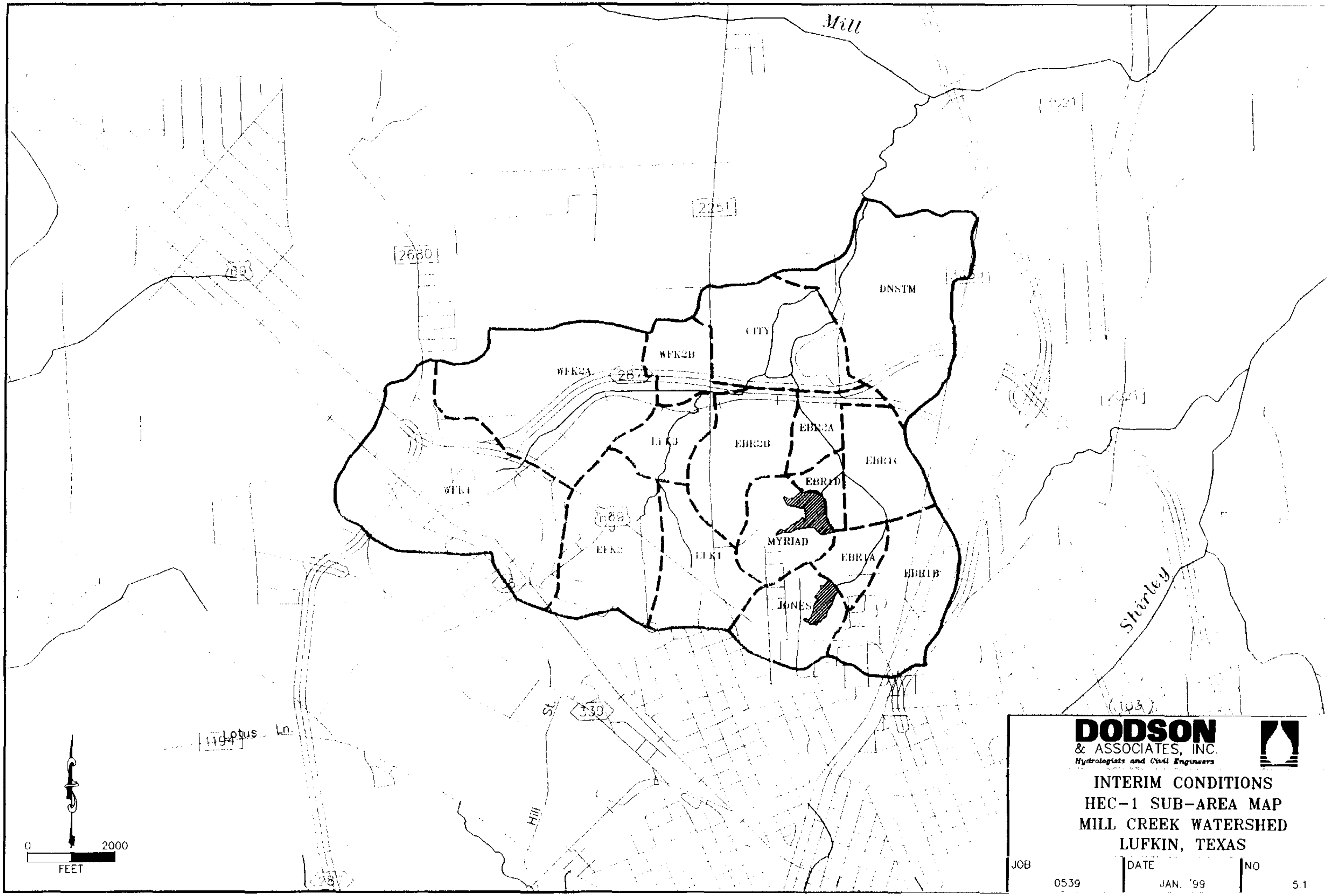
JOB: 0539	DATE: Dec. 1998	NO.: 4.14



COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH, EAST FORK
FUTURE CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

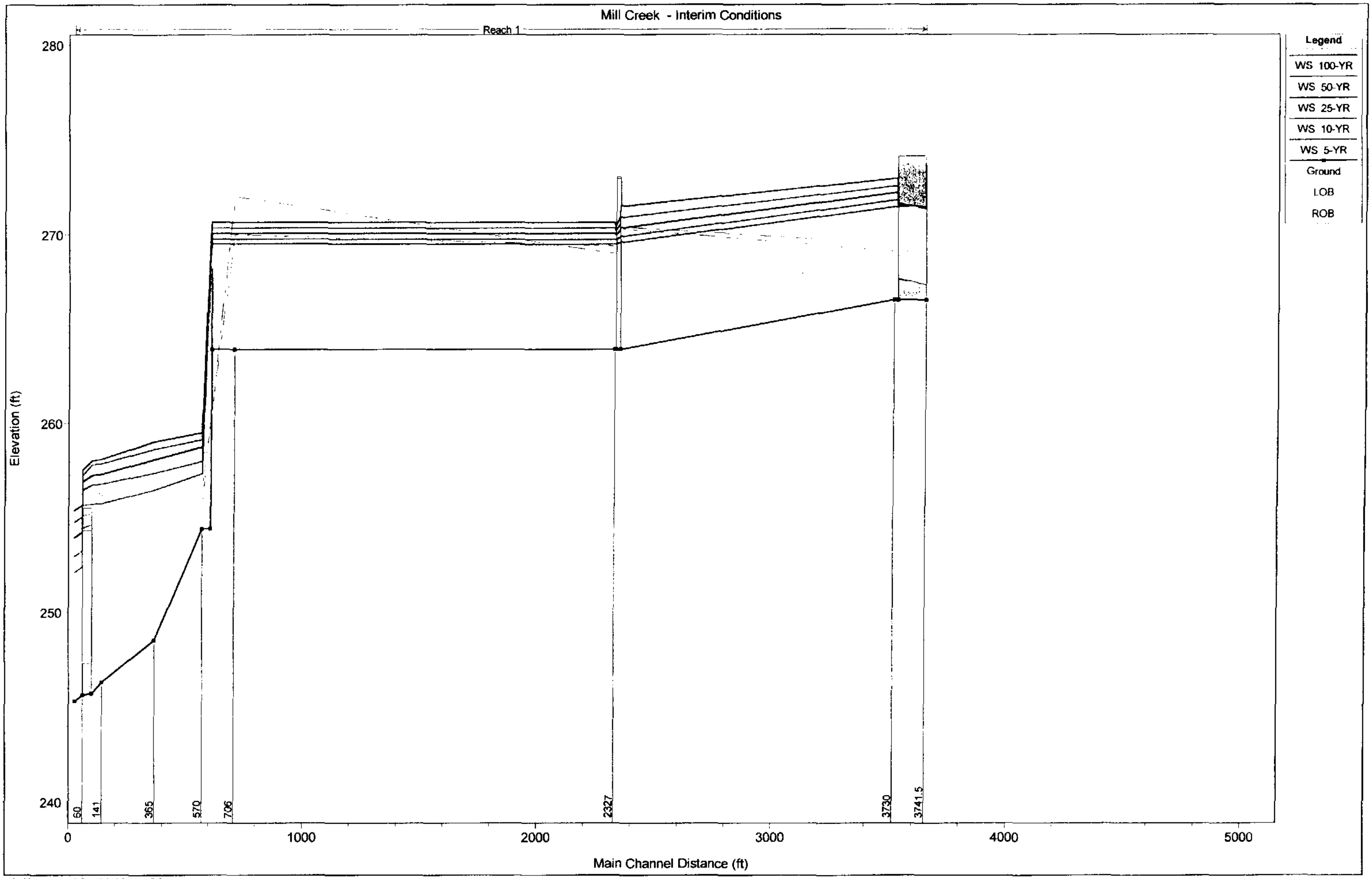
JOB: 0539	DATE: Dec. 1998	NO.: 4.15



DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

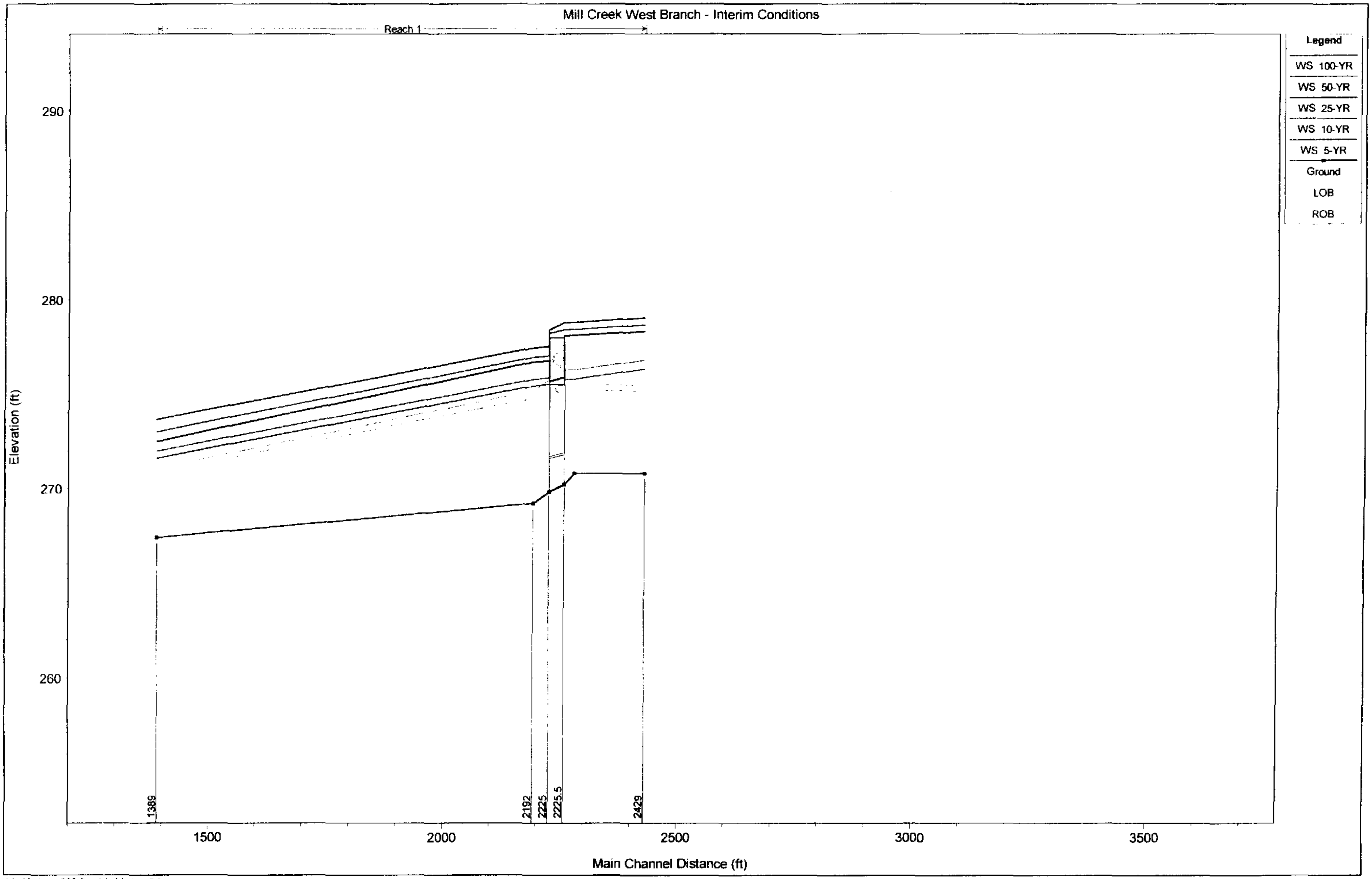
INTERIM CONDITIONS
HEC-1 SUB-AREA MAP
MILL CREEK WATERSHED
LUFKIN, TEXAS

JOB	DATE	NO
0539	JAN. '99	5.1



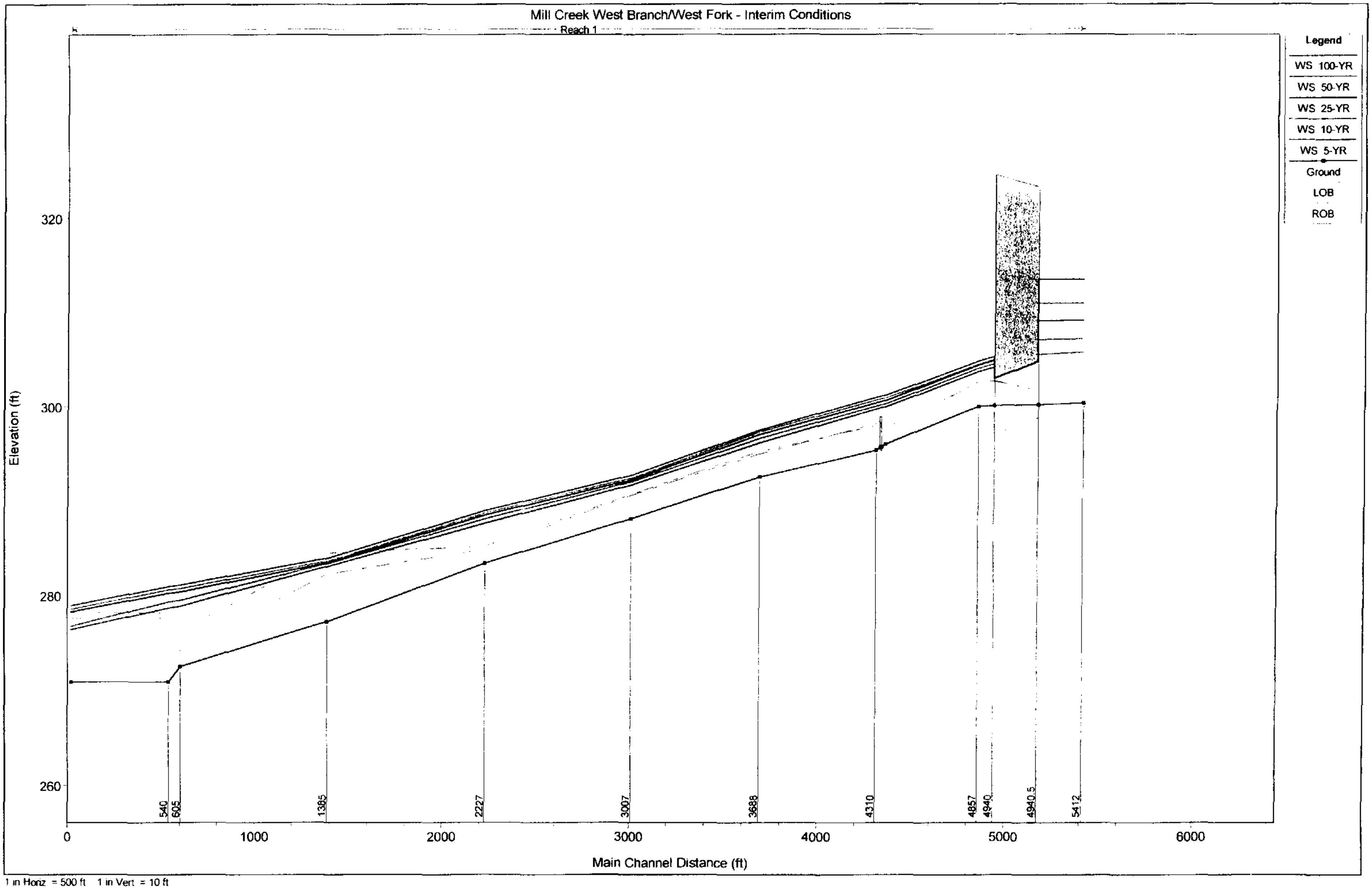
1 in Horiz. = 400 ft 1 in Vert. = 5 ft

COMPUTED STREAM PROFILES FOR MILL CREEK INTERIM CONDITIONS	DODSON & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0539	DATE: Dec. 1998	NO.: 5.2



1 in Horiz. = 200 ft 1 in Vert. = 5 ft

COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH **INTERIM CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* **JOB:** 0539 **DATE:** Dec. 1998 **NO.:** 5.3



COMPUTED STREAM PROFILES FOR MILL CREEK, WEST BRANCH, WEST FORK
INTERIM CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0539	DATE: Dec. 1998	NO.: 5.4

IDENTIFICATION OF EXISTING FLOOD HAZARDS AND DEVELOPMENT OF INTERIM AND FUTURE DRAINAGE IMPROVEMENT PLANS FOR THE MILL CREEK WATERSHED

City of Lukin/Angelina County,TX

DAI Job No. 0539 Part 1
Document No. 98/052 December 30, 1998

The following maps are not attached to this report. Due to their size, they could not be copied. They are located in the official file and may be copied upon request. Contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.

City of Lukin, Texas Angelina County Panel 5 of 10
Community-Panel Number 480009 0005 B
June 1, 1982

Dodson & Assoc. Drainage Improvement Planning Map Mill Creek Watershed Job 0539 Jan.99 No 4.1

Dodson & Assoc. Interim Conditions Flood Plain and Floodway Boundaries Mill Creek & Tributaries
Job #0539- Jan. 99 - No. 5.5

Contract # 98-483-238
Final Pt. 1 of 2

DAI Job No. 0565
Document No. 98/051

IDENTIFICATION OF EXISTING FLOOD HAZARDS AND DEVELOPMENT OF INTERIM AND FUTURE DRAINAGE IMPROVEMENT PLANS FOR THE HURRICANE CREEK WATERSHED

CITY OF LUFKIN
ANGELINA COUNTY, TEXAS

CITY OF LUFKIN
LUFKIN, TEXAS

TEXAS WATER DEVELOPMENT BOARD

Prepared by

Dodson & Associates, Inc.

for

The City of Lufkin, Texas

and the

Texas Water Development Board

STATE OF TEXAS
DUANE BARRETT
63703
REGISTERED
PROFESSIONAL ENGINEER
3/5/99

February 26, 1999

DAI Job No. 0565

Document No. 98/051

IDENTIFICATION OF EXISTING FLOOD HAZARDS AND DEVELOPMENT OF INTERIM AND FUTURE DRAINAGE IMPROVEMENT PLANS FOR THE HURRICANE CREEK WATERSHED

CITY OF LUFKIN
ANGELINA COUNTY, TEXAS

Prepared by

Dodson & Associates, Inc.

for

The City of Lufkin, Texas

February 26, 1998

TABLE OF CONTENTS

1. INTRODUCTION AND SUMMARY OF CONCLUSIONS

1.1 Purpose of This Report

This report describes the results of hydrologic and hydraulic analyses completed in an effort to identify existing flood hazards in the Hurricane Creek watershed in Lufkin, Texas and to develop a plan for mitigating those flood hazards.

1.2 Report Preview

Section 1 (this section) provides a brief overview of the report, including a description of the Hurricane Creek watershed and a summary of conclusions regarding the flood hazard analysis. Section 2 describes the methods and data used in hydrologic analyses of the Hurricane Creek watershed and provides a summary of the results obtained. Section 3 presents a summary of hydraulic analyses of Hurricane Creek and four tributary streams. Included in Section 3 are tabulations of computed water surface elevations for each of the studied streams. Section 4 describes the development of a plan for completing short-term drainage improvements and the results of an analysis of those improvements. Finally, Section 5 describes an analysis of the effects of long-term development and of the effectiveness of proposed future drainage improvements and policies.

1.3 Description of the Hurricane Creek Watershed

The watershed of Hurricane Creek covers a total area of approximately 12.17 square miles (7,790 acres). As indicated on Exhibit 1.1, the Hurricane Creek watershed covers much of the central portion of the City of Lufkin. The watershed is partially urbanized, especially in the upper portions. The study area is characterized by unimproved drainage channels and open ditch secondary drainage systems, although a few improved channels and underground storm sewer drainage systems do exist.

From its confluence with Hurricane Creek southwest of Lufkin, Hurricane Creek extends to the north and east, passing through the central portion of the city before reaching its upstream terminus upstream of Paul Avenue. Including Paul Avenue, a total of 16 roads and railroads cross the channel of Hurricane Creek. The existing channel of Hurricane Creek is for the most part unimproved. The channel side slopes are steep in many areas, and there is evidence of erosion in some reaches. The banks and bottom of the channel are vegetated with brush and small trees in many areas.

A total of seven major Hurricane Creek tributaries drain areas within the incorporated limits of the City of Lufkin. Five tributaries empty into Hurricane Creek from the east, while two approach from the west. Each of these tributaries drains incorporated areas of Lufkin. Beginning with the northernmost tributary, which will be referred to as Tributary #1 and proceeding southward, the approximate areas drained by the seven tributaries are 893 acres, 546 acres, 840 acres, 498 acres, 823 acres, 395 acres, and 1,523 acres. The seven Hurricane Creek tributaries are crossed by a total of 41 roads and railroads. The existing channels of the tributaries are for the most part unimproved. The channels are relatively small and are moderately to heavily vegetated with brush and small trees.

The City of Lufkin is a participant in the National Flood Insurance Program. The Flood Insurance Study for the City of Lufkin included Hurricane Creek and portions of Tributary #1, Tributary #3, Tributary #5, and Tributary #7. According to Flood Insurance Rate Maps for the City of Lufkin dated June 1, 1982 and June 3, 1988, Hurricane Creek flood plain widths are as great as 1,000 feet. Detailed studies on tributaries 1, 3, 5, and 7 indicate that significant overbank flooding will occur on all of these streams in a 100-year storm event. Exhibits 1.2

and 1.3 illustrate the flood plain boundaries from the effective Flood Insurance Rate Maps for the City of Lufkin.

1.4 Objectives of the Analyses Described in this Report

The major objectives of the analyses described in this report are as follows:

1. to develop a HEC-1 computer model of the Hurricane Creek watershed for the purpose of computing existing conditions runoff hydrographs and peak flow rates at strategic locations within the watershed;
2. to develop HEC-RAS models of Hurricane Creek and its seven main tributaries to reflect recent field-surveyed channel cross-section data;
3. to use the HEC-1 and HEC-RAS models to compute existing conditions peak flow rates and flood profiles for 5-year, 10-year, 25-year, 50-year, 100-year, and 500-year storm events;
4. to develop existing conditions flood plain boundary maps for the watershed;
5. to develop a long-range drainage plan that accommodates future development without exacerbating existing flooding problems and provides relief from existing drainage problems;
6. to develop a plan for implementing short-term drainage (interim) improvements to address the most critical existing flooding problems in the watershed;
7. to develop interim conditions floodway data for Hurricane Creek and tributaries;
8. to develop interim conditions flood plain and floodway maps for Hurricane Creek and tributaries.

1.5 Summary of Conclusions

The primary conclusions reached as a result of the Hurricane Creek study are as follows.

- Existing conditions flood plains are fairly extensive, covering low-lying areas along Hurricane Creek and its tributaries.
- Under current conditions, overbank flooding will occur in many areas for even a 5-year storm event.
- Existing wetlands and the lack of adequate rights-of-way along many of the streams in the Hurricane Creek watershed will make channelization projects difficult to permit and expensive to implement.
- Regional detention appears to be the best alternative to widespread channelization.
- On-site detention will be necessary in some portions of the watershed in which there are no appropriate regional detention sites.
- Future development in the Hurricane Creek can be accommodated through a combination of regional detention, on-site detention, and limited channelization.
- The proposed combination of detention and channelization will provide relief from existing flooding problems, but will not eliminate the potential for flooding during severe storm events.

2. EXISTING CONDITIONS HYDROLOGIC ANALYSIS

2.1 Method of Analysis

Hydrologic analyses of the Hurricane Creek watershed are completed using the HEC-1 computer program developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The HEC-1 program provides the means for computing, routing, and combining runoff hydrographs from multiple sub-areas within a watershed. For the purposes of applying the HEC-1 program to the Hurricane Creek study, the watershed has been subdivided into 33 sub-areas as indicated on Exhibit 2.1.

Rainfall data used for 10-year, 50-year, and 100-year storm events are developed using depth-duration-frequency data published by the National Weather Service. The HEC-1 program automatically distributes rainfall over a specified storm duration using a set of rainfall depths which correspond to a given storm frequency.

Infiltration losses for pervious areas are calculated using the SCS Curve Number method. This method relates the amount of infiltration to the soil structure and to the type and condition of vegetal cover. Infiltration for impervious areas is assumed by the HEC-1 program to be zero. The overall percent impervious cover for each sub-watershed is computed by estimating the total area covered by impervious materials (streets, parking lots, rooftops, etc.) and dividing by the drainage area.

Hydrographs are relationships between the rate of storm runoff (volume per unit of time, usually cubic feet per second) versus the elapsed time from the beginning of rainfall. In the HEC-1 program, a hydrograph is computed by first establishing a unit hydrograph, which is defined as the response of a watershed to a volume of runoff equivalent to 1 inch of depth over the watershed, then multiplying the ordinates of that unit hydrograph by the actual equivalent depth of storm water runoff. The Clark unit hydrograph method is used for computing runoff hydrographs. Clark unit hydrograph parameters are computed using a methodology developed specifically for this study.

The Modified Puls method is used to route hydrographs from point to point within the watershed. Storage-discharge data for the Modified Puls method are developed using HEC-RAS computer models of Hurricane Creek and its major tributaries.

2.2 Rainfall Data Development and Utilization

Table 2-1 presents rainfall depth-duration-frequency data developed through statistical analyses of recorded rainfall data and published in two publications: U.S. Weather Bureau Technical Paper No. 40 (*Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*) and National Weather Service Hydrometeorological Report No. 35 (*Five- to 60-Minute Precipitation Frequency for the Eastern and Central United States*). This information represents rainfall data which may be used to generate design storm events for drainage analyses and design studies. As indicated in the table, the 100-year, 24-hour rainfall depth for Lufkin is about 11.5 inches.

TABLE 2-1: HYDRO-35 & TP-40 RAINFALL DATA FOR LUFKIN, TEXAS								
Storm	Rainfall Depth in Inches for Given Storm Duration							
Event	5-Minute	15-Minute	60-Minute	2-Hour	3-Hour	6-Hour	12-Hour	24-Hour
2 year	0.54	1.16	2.18	2.67	2.94	3.48	4.15	4.75
5-year	0.61	1.33	2.65	3.45	3.82	4.54	5.50	6.43
10-year	0.66	1.46	2.99	3.98	4.41	5.39	6.55	7.73
25-year	0.75	1.65	3.48	4.55	5.12	6.33	7.69	9.07
50-year	0.81	1.81	3.87	5.09	5.67	7.05	8.70	10.20
100-year	0.88	1.96	4.25	5.67	6.34	8.00	9.77	11.48

In flood studies of the type completed for the Hurricane Creek watershed, hypothetical rainfall data are used in conjunction with the HEC-1 program. Rainfall depths are entered by the user to define the relationship between rainfall depth, storm duration, and frequency. The temporal distribution of the rainfall is developed internally by the HEC-1 program using built-in capabilities. The HEC-1 rainfall distribution is "balanced" in that it places the most intense rainfall at the center of the storm duration with decreasing rainfall amounts to either side of the period of maximum intensity. The depth of the rainfall occurring before and after the period of maximum intensity is approximately equal. A 24-hour storm duration is used for all analyses of the Hurricane Creek watershed.

2.3 Soils Data and Selection of SCS Curve Numbers

Information presented in the *Soil Survey of Angelina County, Texas* indicates that soils within the incorporated boundaries of Lufkin consist of fine sandy loams at slopes of 0 to 15 percent. The major soils present within the Hurricane Creek include those named in Table 2. Exhibit 2.2 illustrates the areal extents of the various soils.

The Curve Number method developed by the U.S. Soil Conservation Service for estimating infiltration losses us used for this study. The Curve Number method involves the classification of soils into one of four hydrologic soil groups. These groups, designated A, B, C, and D, provide a means of indexing soils in terms of infiltration capacity. Soils belonging to hydrologic soil group A have the highest infiltration capacity, while those belonging to group D have the lowest infiltration capacity. As indicated in Table 2-2, each of the four hydrologic soil groups are represented in Lufkin.

TABLE 2-2: SOILS FOUND IN THE HURRICANE CREEK WATERSHED			
Soil Symbol	Soil Name	Soil Description	HSG
AaB	Alazan	Alazan very fine sandy loam, 0-4 percent slopes	B
Ab	Alazan	Alazan-Besner complex, mounded	B
AcB	Alazan	Alazan-Urban land complex, 0-4 percent slopes	B
FfA	Fuller	Fuller fine sandy loam, 0 to 1 percent slopes	D
FfB	Fuller	Fuller fine sandy loam, 1-4 percent slopes	D
FuB	Fuller	Fuller-Urban land complex, 1-4 percent slopes	D
HeB	Herty	Herty very fine sandy loam, 1-5 percent slopes	D
HuB	Herty	Herty-Urban land complex, 1-5 percent slopes	D
KcB	Keltys	Keltys fine sandy loam, 1-5 percent slopes	B
KdB	Keltys	Keltys-Urban land complex, 1-5 percent slopes	B
Ks	Koury	Koury-Urban land complex, occasionally flooded	C
KuB	Kurth	Kurth fine sandy loam, 0-4 percent slopes	C
KwB	Kurth	Kurth-Urban land c omplex, 0-4 percent slopes	C
Mp	Mollville	Mollville-Besner complex, gently undulating	D
MsB	Moswell	Moswell loam, 1-5 percent slopes	D
MsD	Moswell	Moswell loam, 5-15 percent slopes	D
Mx	Moten	Moten-Multy complex, gently undulating	C/B
Po	Pophers	Pophers silty clay loam, frequently flooded	C
RoB	Rosenwall	Rosenwall fine sandy loam, 1-5 percent slopes	D
RoD	Rosenwall	Rosenwall fine sandy loam, 5-15 percent slopes	D
SbB	Sacul	Sacul-Urban land complex, 1-5 percent slopes	C

SCS curve numbers reflect the relative ability of water to infiltrate into soils. The maximum curve number is 100. A curve number of 100 indicates that no infiltration can take place. The lower the curve number, the greater the infiltration capacity. Curve numbers are related to the soil type and structure, which are accounted for by assigning soils to one of the four hydrologic soil groups just described, and to the type and condition of vegetal cover. The following table gives curve numbers for a few typical conditions.

TABLE 2-3: SCS CURVE NUMBERS FOR PERVIOUS AREAS				
	Hydrologic Soil Group			
Land Use Description	A	B	C	D
Pasture or Range Land: good condition	39	61	74	80
Wood or Forest Land: good cover	25	55	70	77
Lawns & Parks: good condition, grass on 75% or more of area	49	69	79	84
Meadow: good condition	30	58	71	78

Curve numbers for pasture or range land in good condition are averaged with those for wood or forest land with good cover to obtain values for use in the Hurricane Creek watershed. This is done to reflect the mixture of wooded and grassed areas found throughout the watershed. The curve numbers used for hydrologic soil groups A, B, C, and D are 32, 58, 72, and 79, respectively. Tables 2-4 and 2-5 present the weighted curve number tabulations for each of the major sub-watersheds in the Hurricane Creek watershed. These curve numbers are used in HEC-1 models of the Hurricane Creek watersheds for the major sub-watersheds listed in Table 4A and for any smaller subdivisions of those sub-watersheds. For example, sub-watershed HCT1 is divided into two smaller sub-areas, and a curve number of 73 is used for both of those sub-areas. Table 2-6 lists each of the sub-areas created for existing conditions HEC-1 modeling and the curve number used for each sub-area.

TABLE 2-4: SCS CURVE NUMBERS FOR MAJOR HURRICANE CREEK SUB-WATERSHEDS

		Area Belonging to Each Hydrologic Soil Group (acres)								
Hydrologic Soil Group	CN	HC1	HCT1	HC2	HCT2	HC3	HCT3	HC4	HCT4	HC5
A	32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	58	374.6	171.6	14.9	208.1	33.2	288.3	12.0	229.1	0.0
C	72	259.9	208.1	99.1	20.6	24.5	180.4	44.0	190.9	171.7
D	79	625.0	506.3	290.4	318.6	70.4	363.8	28.2	77.8	138.0
Weighted Curve Number		71	73	77	71	72	70	72	67	75

TABLE 2-5: SCS CURVE NUMBERS FOR MAJOR HURRICANE CREEK SUB-WATERSHEDS

		Area Belonging to Each Hydrologic Soil Group (acres)								
Hydrologic Soil Group	CN	HCT5	HC6	HCT6	HC7	HCT7	-----	-----	-----	-----
A	32	0.0	0.0	0.0	0.0	0.0	-----	-----	-----	-----
B	58	249.6	9.2	174.1	37.3	360.7	-----	-----	-----	-----
C	72	50.9	54.1	88.4	120.3	21.3	-----	-----	-----	-----
D	79	517.1	14.6	135.4	20.1	952.2	-----	-----	-----	-----
Weighted Curve Number		72	72	68	70	73	-----	-----	-----	-----

TABLE 2-6: SCS CURVE NUMBERS FOR HURRICANE CREEK HEC-1 SUB-AREAS		
Major Sub-Watershed	Sub-Area	SCS Curve Number
HC1	*HC1A*	71
	HC1B	71
HCT1	*HCT1A*	73
	HCT1B1	73
	HCT1B2	73
	HCT1B3	73
	HCT1B4	73
	HCT1B5	73
HC2	*HC2*	77
HCT2	*HCT2A*	71
	HCT2B	71
HC3	*CEDR3*	72
HCT3	*HCT3A*	70
	HCT3B	70
HC4	*HC4*	72
HCT4	*HCT4A*	67
	HCT4B	67
HC5	*HC5*	75
HCT5	*HCT5A*	72
	HCT5B	72
	HCT5C	72
	HCT5D	72
	HCT5E	72
HC6	*HC6*	72
HCT6	*HCT6A*	68
	HCT6B	68
HC7	*HC7*	70
HCT7	*HCT7A*	73
	HCT7B	73
	HCT7C	73
	HCT7D	73
	HCT7E	73
	HCT7F	73

2.4 Land Use Data & Impervious Cover Calculations

Existing land uses for the Hurricane Creek watershed have been divided into a number of categories. Recent aerial photographs have been used to determine the area of existing development which falls into each of those categories, each of which has a different average percentage of impervious cover. Exhibit 2.3 illustrates the distribution of existing development over the watershed. Tables of hydrologic parameters included in Appendix A to this report provide details regarding the breakdown of land uses within each sub-area and the computed impervious cover for each sub-area.

2.5 Times of Concentration & Storage Coefficients for the Clark Method

The Clark unit hydrograph method requires that the user specify a time of concentration and a storage coefficient for each sub-area in the HEC-1 model of the Hurricane Creek watershed. The time of concentration is set equal to the time required for storm runoff to travel from the most hydraulically remote point in the sub-area to the outlet point. The storage coefficient is a relative measure of the amount of storage in the sub-area. Typically, the flatter the slopes in a particular watershed, the greater the surface and depression storage, and the greater the value of the storage coefficient. As slopes increase, the storage coefficient typically decreases. Because this inverse relationship is similar to the relationship between time of concentration and slope, the storage coefficient is frequently computed as follows:

$$R = K \times TC$$

where R is the storage coefficient, TC is the time of concentration, and K is a multiplier. The value of K typically ranges from 2.0 for relatively steep slopes to 3.0 for flatter slopes. For all sub-areas in the Hurricane Creek watershed, K is set equal to 2.0.

The time of concentration for each sub-area in the Hurricane Creek watershed is computed by dividing the distance over which storm runoff must travel by the flow velocity. Because flow velocities vary with flow conditions, the longest watercourse in each sub-area is divided into four segments: overland flow, shallow concentrated flow, paved or gully flow, and channel flow. Overland flow represents sheet flow at very shallow depths, and is limited in this study to no more than 300 feet of distance at the upstream end of each watercourse. Shallow concentrated flow takes over as storm runoff collects in shallow rills and swales, and flow depths increase to a few inches. Paved or gully flow reflects flow in curb-and-gutter streets, concrete-lined swales, and small gullies. Finally, channel flow represents the flow of flood waters through relatively large gullies and creeks illustrated on U.S. Geologic Survey 7.5-minute quadrangle maps using blue lines.

Velocities for overland flow, shallow concentrated flow, and paved or gully flow are estimated using the SCS Uplands Method, which relates flow condition and slope to flow velocity. Exhibit 2.4 illustrates the relationships between flow velocity and slope developed for the Uplands Method. For channel flow, an average velocity of 3.0 feet per second is used for all sub-areas.

Detailed time of concentration calculations for each sub-area included in the Hurricane Creek HEC-1 model may be found in Appendix A to this report.

2.6 Summary of Hydrologic Parameters for Hurricane Creek Sub-Areas

Table 2-7 provides a summary of the hydrologic modeling data used to represent the thirty-three (33) sub-areas included in the Hurricane Creek HEC-1 computer model.

TABLE 2-7: SUMMARY OF HEC-1 PARAMETERS FOR HURRICANE CREEK SUB-AREAS					
Sub-Area	Drainage Area (acres)	SCS Curve Number	Impervious Cover (%)	Time of Concentration (hours)	Storage Coefficient (hours)
HC1A	302	71	40.5	0.83	1.65
HC1B	965	71	41.6	1.52	3.04
HCT1A	206	73	16.3	0.52	1.04
HCT1B1	78	73	31.0	0.31	0.62
HCT1B2	157	73	3.8	0.49	0.99
HCT1B3	44	73	17.5	0.29	0.59
HCT1B4	39	73	29.5	0.28	0.56
HCT1B5	369	73	32.2	0.92	1.85
HC2	403	77	23.6	1.10	2.20
HCT2A	234	71	28.7	0.49	0.99
HCT2B	312	71	21.7	0.76	1.52
HC3	131	72	47.9	0.54	1.07
HCT3A	321	70	49.7	1.49	2.99
HCT3B	519	70	22.6	1.02	2.04
HC4	86	72	12.3	0.31	0.62
HCT4A	126	67	16.1	0.33	0.66
HCT4B	372	67	11.6	0.81	1.61
HC5	308	75	11.2	0.82	1.63
HCT5A	139	72	2.4	0.39	0.78
HCT5B	172	72	5.0	0.61	1.21
HCT5C	155	72	3.4	0.65	1.31
HCT5D	223	72	6.2	0.77	1.55
HCT5E	134	72	22.3	0.58	1.16
HC6	78	72	1.3	0.40	0.80
HCT6A	110	68	29.1	0.32	0.64
HCT6B	285	68	4.4	1.07	2.14
HC7	180	70	3.5	0.77	1.54
HCT7A	118	73	10.2	0.45	0.89
HCT7B	335	73	24.4	0.82	1.65
HCT7C	203	73	17.7	0.38	0.75
HCT7D	114	73	27.4	0.28	0.56
HCT7E	415	73	20.2	0.92	1.84
HCT7F	158	73	5.3	0.60	1.20

2.7 Storage Routing Data for Hurricane Creek and Tributaries

Exhibit 2.1 illustrates the extents of the routing reaches for which storage-discharge are defined for this study. Tables 2-8 and 2-9 present a summary of the storage routing data developed for each routing reach. Routing volumes are computed using special multi-profile HEC-RAS models of Hurricane Creek and Tributaries 1 through 7. The number of routing steps used for each reach is determined by using HEC-RAS results to compute the average travel time through the reach and dividing the average travel time by the HEC-1 computation interval of 15 minutes (0.25 hour).

TABLE 2-8: STORAGE ROUTING DATA FOR HURRICANE CREEK										
Reach #1: Limit of Study to Tributary #1										# Steps
Flow Rate (cfs)	0	234	351	468	585	702				
Volume (ac-ft)	0	28	37	47	57	71				5
Reach #2: Tributary #1 to Tributary #2										# Steps
Flow Rate (cfs)	0	1260	1889	2519	3149	3779				
Volume (ac-ft)	0	102	163	225	294	359				5
Reach #3: Tributary #2 to Tributary #3										# Steps
Flow Rate (cfs)	0	1651	2476	3302	4127	4952				
Volume (ac-ft)	0	78	128	190	243	289				2
Reach #4: Tributary #3 to Tributary #4										# Steps
Flow Rate (cfs)	0	1994	2992	3989	4986	5983				
Volume (ac-ft)	0	59	90	114	136	157				1
Reach #5: Tributary #4 to Tributary #5										# Steps
Flow Rate (cfs)	0	2162	3244	4325	5406	6487				
Volume (ac-ft)	0	181	313	432	539	630				4
Reach #6: Tributary #5 to Tributary #6										# Steps
Flow Rate (cfs)	0	2320	3479	4639	5799	6959				
Volume (ac-ft)	0	36	51	64	77	90				1
Reach #7: Tributary #6 to Tributary #7										# Steps
Flow Rate (cfs)	0	2458	3686	4915	6144	7373				
Volume (ac-ft)	0	367	596	773	979	1165				8

TABLE 2-9: STORAGE ROUTING DATA FOR TRIBUTARIES

Tributary #1: Whippoorwill to North Branch										# Steps
Flow Rate (cfs)	0	202	303	404	505	606				
Volume (ac-ft)	0	6	9	13	16	20				1
Tributary #1: North Branch to Mouth										# Steps
Flow Rate (cfs)	0	505	757	1010	1262	1514				
Volume (ac-ft)	0	42	70	113	140	166				5
Tributary #2: Chestnut to Mouth										# Steps
Flow Rate (cfs)	0	240	360	480	600	720				
Volume (ac-ft)	0	16	25	35	46	56				3
Tributary #3: Park Lane to Mouth										# Steps
Flow Rate (cfs)	0	172	258	344	430	516				
Volume (ac-ft)	0	20	27	34	43	54				5
Tributary #4: Limit of Study to Mouth										# Steps
Flow Rate (cfs)	0	144	216	288	360	432				
Volume (ac-ft)	0	15	24	33	41	51				6
Tributary #5 (North Branch): Limit of Study to US 59										# Steps
Flow Rate (cfs)	0	148	222	296	370	444				
Volume (ac-ft)	0	7	10	15	22	27				2
Tributary #5 (South Branch): Limit of Study to US 59										# Steps
Flow Rate (cfs)	0	124	186	248	310	372				
Volume (ac-ft)	0	5	8	11	14	16				2
Tributary #5: US 59 to Mouth										# Steps
Flow Rate (cfs)	0	485	727	970	1212	1454				
Volume (ac-ft)	0	14	26	42	57	71				2
Tributary #6: Loop 287 to Mouth										# Steps
Flow Rate (cfs)	0	136	204	272	340	408				
Volume (ac-ft)	0	46	62	75	85	96				8
Tributary #7 (North Branch): Limit of Study to FM 324										# Steps
Flow Rate (cfs)	0	124	186	248	310	372	465			
Volume (ac-ft)	0	9	13	22	29	38	53			3
Tributary #7 (South Branch): Lake A to FM 324										# Steps
Flow Rate (cfs)	0	326	489	652	815	978	1223			
Volume (ac-ft)	0	40	58	80	102	127	171			6
Tributary #7: FM 324 to Mouth										# Steps
Flow Rate (cfs)	0	750	1125	1500	1875	2250	2813			
Volume (ac-ft)	0	81	114	144	171	195	229			8

2.8 Summary of HEC-1 Results

Table 2-10 provides a summary of computed 5-year, 10-year, 25-year, 50-year, and 100-year peak flow rates at a number of strategic points in the Hurricane Creek watershed. Exhibit 2.1 illustrates the locations of the computation points described in the table.

TABLE 2-10: COMPUTED PEAK FLOW RATES AT GIVEN LOCATIONS					
Location	5-Year	10-Year	25-Year	50-Year	100-Year
Hurricane Creek at Limit of Study	289	367	449	514	585
Hurricane Creek Above Tributary #1	804	1069	1320	1513	1736
Tributary #1 at Whippoorwill	239	309	384	444	507
Tributary #1 Above North Branch	300	389	474	541	618
Tributary #1 Below North Branch	582	756	943	1084	1233
Tributary #1 at Mouth	765	952	1145	1256	1397
Hurricane Creek Below Tributary #1	1559	2022	2464	2769	3127
Hurricane Creek Above Tributary #2	1666	2152	2642	2979	3372
Tributary #2 at Chestnut (SH 58)	289	368	455	523	596
Tributary #2 at Mouth	480	616	757	866	989
Hurricane Creek Below Tributary #2	1944	2504	3079	3481	3946
Hurricane Creek Above Tributary #3	1927	2475	3004	3415	3911
Tributary #3 at Park Lane	215	271	330	377	430
Tributary #3 at Mouth	451	612	774	891	1031
Hurricane Creek Below Tributary #3	2335	2995	3628	4126	4752
Hurricane Creek Above Tributary #4	2316	2980	3629	4131	4756
Tributary #4 at Limit of Study	160	211	269	314	361
Tributary #4 at Mouth	340	459	575	668	777
Hurricane Creek Below Tributary #4	2482	3198	3908	4452	5148
Hurricane Creek Above Tributary #5	2471	3180	3930	4493	5205
Tributary #5 North Branch at Limit of Study	163	217	273	318	367
Tributary #5 North Branch at US 59	284	386	488	556	630
Tributary #5 South Branch at Limit of Study	135	182	229	268	310
Tributary #5 South Branch at US 59	291	387	486	568	658
Tributary #5 at US 59	575	770	962	1114	1281
Tributary #5 at Mouth	641	837	1015	1163	1339
Hurricane Creek Below Tributary #5	2665	3434	4264	4891	5748
Hurricane Creek Above Tributary #6	2674	3444	4279	4913	5769
Tributary #6 at Loop 287	164	209	260	300	342
Tributary #6 at Mouth	165	230	297	352	415
Hurricane Creek Below Tributary #6	2815	3633	4523	5209	6124
Hurricane Creek Above Tributary #7	2782	3580	4498	5170	6032
Tributary #7 North Branch at Limit of Study	142	185	232	268	307
Tributary #7 North Branch at FM 324	391	512	634	722	812
Tributary #7 South Branch at Limit of Study	276	355	443	511	582
Tributary #7 South Branch at Lake A	479	611	755	868	985
Tributary #7 South Branch Below Lake A	340	479	616	712	627
Tributary #7 South Branch at FM 324	492	677	876	1001	1150
Tributary #7 at FM 324	812	1095	1404	1618	1857
Tributary #7 at Mouth	833	1140	1466	1707	1973
Hurricane Creek Below Tributary #7	3153	4028	5132	5882	6805

2.9 Comparison of FIS and Updated Peak Flow Rates

Table 2-11 provides a comparison of results from the Flood Insurance Study for Lufkin, Texas and the update study completed by Dodson & Associates, Inc. The comparison of computed

100-year peak flow rates indicates that updated peak flow rates are greater than Flood Insurance Study values at most locations, although updated flows are less than FIS values at a few locations.

TABLE 2-11: COMPARISON OF 100-YEAR FLOW RATES FROM FLOOD INSURANCE STUDY AND UPDATE STUDY				
	Flood Insurance Study		**Update Study**	
Location	Drainage Area (sq. mi.)	100-Year Peak Flow (cfs)	Drainage Area (sq. mi.)	100-Year Peak Flow (cfs)
Hurricane Creek Above Tributary #1	2.0	2350	1.98	1736
Hurricane Creek Above Tributary #2	4.0	3150	4.01	3372
Hurricane Creek Above Tributary #3	5.1	3270	5.07	3911
Hurricane Creek Above Tributary #5	7.7	4120	7.77	5205
Hurricane Creek Below Tributary #5	9.0	4440	9.06	5748
Tributary #1 At Mouth	1.5	1760	1.40	1397
Tributary #3 At Mouth	1.3	1360	1.31	1031
Tributary #5 At Mouth	1.3	1240	1.28	1339
Tributary #7 At Mouth	2.1	1690	2.10	1973

3. EXISTING CONDITIONS HYDRAULIC ANALYSES

3.1 Method of Analysis

The HEC-RAS computer program developed at the U.S. Army Corps of Engineers Hydrologic Engineering Center is used for all hydraulic analyses of Hurricane Creek and its tributaries. The HEC-RAS program uses Manning's Equation to compute water surface profiles given cross-section data, roughness coefficients, and flow rates. In addition, the program has a number of special capabilities related to the analysis of culverts and bridges at roadway crossings.

3.2 Hydraulic Conditions Along Hurricane Creek and Tributaries

3.2.1 Hurricane Creek

From its headwaters upstream of Paul Avenue, Hurricane Creek flows southward through the central and southern portions of Lufkin before reaching its confluence with Hurricane Creek. Between Paul Avenue and the Hurricane Creek confluence, there are sixteen (16) roadway crossings of Hurricane Creek. Table 3-1 provides brief descriptions of the existing roadway structures along the creek, beginning with the most downstream structure (FM 324) and ending with the most upstream (Groesbeck).

TABLE 3-1: EXISTING ROADWAY CROSSING STRUCTURES ALONG HURRICANE CREEK

Number	Name of Roadway	Description of Structure
HC-1	FM 324	Concrete Bridge
HC-2	Southern Pacific RR	Timber Trestle
HC-3	FM 819	Concrete Bridge
HC-4	Loop 287	Four 10' x 10' Box Culverts
HC-5	U.S. 59 (1st Street)	Concrete Bridge
HC-6	Tulane Street	Three 10' x 9' Box Culverts
HC-7	South 3rd Street	Three 10' x 9' Box Culverts
HC-8	Denman Ave. (US 69)	Two 15.5' x 9' Box Culverts
HC-9	Chestnut Village	Concrete Bridge
HC-10	Chestnut Village	Concrete Bridge
HC-11	Timberland Drive	Four 7' x 7' Box Culverts
HC-12	Lufkin Avenue	Two 12' x 6.5' Box Culverts
HC-13	Albertson's Driveway	Two 10' x 6' Box Culverts
HC-14	Railroad	Timber Trestle
HC-15	Groesbeck Avenue	Two 96" x 60" Corrugated Steel Pipe Arches

The channel of Hurricane Creek is for the most part unimproved, and is characterized by steep side slopes and brushy banks.

3.2.2 Hurricane Creek Tributary #1

Hurricane Creek Tributary #1 flows westward from its headwaters near Loop 287, eventually emptying into Hurricane Creek just downstream (west) of Tulane Street and east of Business 59. Table 3-2 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #1.

TABLE 3-2: ROADWAY CROSSING STRUCTURES ALONG TRIBUTARY #1		
Number	Name of Roadway	Description of Structure
T1-1	Tulane Street	Two 10' x 9' Box Culverts
T1-2	South 3rd Street	Two 84-Inch Railroad Tank Cars
T1-3	Chestnut Drive	Four 5' x 5' Box Culverts
T1-4	Denman Ave. (US 69)	Three 6' x 4' Box Culverts
T1-5	Jones Street	Two 5' x 5' and One 7' x 4' Box Culvert
T1-6	Hunters Creek Drive	Timber Bridge
T1-7	Howard Avenue	Two 60-Inch Corrugated Steel Pipe Culverts
T1-8	Whippoorwill Drive	Two 36-Inch Corrugated Steel Pipe Culverts

Tributary #1 is a relatively small stream which, like Hurricane Creek, has brushy banks and steep side slopes.

3.2.3 Hurricane Creek Tributary #2

Tributary #2 rises near the intersection of Denman Avenue and Loop 287 in the eastern portion of the Hurricane Creek watershed. It flows westward, passing under Loop 287 and the Lufkin Mall before emptying into Hurricane Creek just to the east of Business 59. Table 3-3 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #2.

TABLE 3-3: ROADWAY CROSSING STRUCTURES ALONG TRIBUTARY #2		
Number	Name of Roadway	Description of Structure
T2-1	Loop 287	Two 8' x 7' Box Culverts
T2-2	Tulane Street	Two 8' x 7' Box Culverts
T2-3	Chestnut Drive	Two 6' x 4' Box Culverts

Tributary #2 is for the most part unimproved, although the lower portion of the channel has been enclosed in concrete box culverts which pass under Loop 287 and the Lufkin Mall.

3.2.4 Hurricane Creek Tributary #3

Tributary #3 empties into Hurricane Creek from the north at a point located a short distance north of Loop 287. From its confluence with Hurricane Creek, the tributary extends to the north toward its headwaters, which are located north of Frank Avenue and west of 1st Street. Table 3-4 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #3.

TABLE 3-4: ROADWAY CROSSING STRUCTURES ALONG TRIBUTARY #3		
Number	Name of Roadway	Description of Structure
T3-1	Mott Street	One 54-Inch and One 72-Inch Concrete Pipe Culvert
T3-2	Carroll Avenue	One 11' x 7.5' Corrugated Steel Pipe Arch
T3-3	Tom Temple Drive	Three 9' x 6' Box Culverts
T3-4	White Oak Drive	One 11' x 8' Corrugated Steel Pipe Arch
T3-5	Park Lane	One 9' x 6' Corrugated Steel Pipe Arch

Tributary #3 is an unimproved channel which passes through heavily urbanized areas in the central and southwestern portions of the City of Lufkin.

3.2.5 Hurricane Creek Tributary #4

Table 3-5 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #4, which empties into Hurricane Creek south of Loop 287 and west of Highway 59.

TABLE 3-5: ROADWAY CROSSING STRUCTURES ALONG TRIBUTARY #4		
Number	Name of Roadway	Description of Structure
T4-1	Scenic Acres	Concrete Bridge
T4-2	US 59	Three 6' x 4' Box Culverts
T4-3	Tulane Street	Two 54-Inch Concrete Pipe Culverts

3.2.6 Hurricane Tributary #5

Table 3-6 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #5, which empties into Hurricane Creek from the east at a point upstream of Highway 819, south of Loop 287, and west of Highway 59. Immediately upstream (east) of U.S. Highway 59, Tributary #5 splits into two branches, designated for the purposes of this study as the North Branch and the South Branch.

TABLE 3-6: ROADWAY CROSSING STRUCTURES ALONG TRIBUTARY #5		
Number	Name of Roadway	Description of Structure
North Branch		
T5N-1	Daniel McCall Dr.	Concrete Bridge
T5N-2	US 59	Two 7' x 7' Box Culverts
T5N-3	Driveway	Three 84-Inch Corrugated Steel Pipe Culverts
T5N-5	Brentwood Drive	One 7' x 5' Box Culvert
South Branch		
T5S-1	Brentwood Drive	One 7' x 5' Box Culvert

3.2.7 Hurricane Tributary #6

Table 3-7 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #6, which empties into Hurricane Creek south of Loop 287 and west of Highway 59.

TABLE 3-7: ROADWAY CROSSING STRUCTURES ALONG TRIBUTARY #6		
Number	Name of Roadway	Description of Structure
T6-1	Rail Spur	Two 84" x 54" Corrugated Steel Pipe Arches
T6-2	Southpark Drive	Two 48-Inch PVC Pipe Culverts
T6-3	Driveway	Steel Bridge
T6-4	FM 819	One 8' x 4' Box Culvert
T6-5	Dam	One 72-Inch Corrugated Steel Pipe Culvert
T6-6	Sandyland Drive	Two 36-Inch Corrugated Steel Pipe Culverts
T6-7	Loop 287	One 4' x 3' Box Culvert

3.2.8 Hurricane Tributary #7

Table 3-8 provides brief descriptions of the existing roadway structures along Hurricane Creek Tributary #7, which empties into Hurricane Creek south of Loop 287 and west of Highway 59. Tributary #7 splits into north and south branches just downstream (west) of Daniel McCall Drive.

watershed, base roughness coefficients of 0.08 and 0.17 were adopted for channels and overbank areas, respectively. These values were adjusted upward or downward depending upon conditions encountered in the field. The range of roughness coefficients established for each studied stream in the Hurricane Creek watershed is summarized in Table 3-9.

TABLE 3-9: MANNING ROUGHNESS COEFFICIENTS

Stream	Channel Coefficient	Overbank Coefficients
Hurricane Creek	0.06-0.08	0.10-0.18
Tributary #1	0.07-0.08	0.11-0.17
Tributary #2	0.03*-0.08	0.06*-0.17
Tributary #3	0.08	0.18
Tributary #4	0.08	0.18
Tributary #5	0.08	0.12*-0.18
Tributary #6	0.06*-0.07	0.06-0.16
Tributary #7	0.06*-0.09	0.10*-0.18

*Used at a limited number of cross-sections.

3.4.3 Flow Rates

Flow rates used in the HEC-RAS models of Hurricane Creek and tributaries 1 through 7 are determined using the results of HEC-1 analyses for 10-year, 50-year, and 100-year storm events. Flow rates for the 500-year storm are determined by plotting 10-year and 100-year values on log-probability paper and extrapolating.

3.4.4 Bridge and Culvert Modeling Data

Bridge and culvert modeling data are developed from the field survey data provided by Everett Griffith Jr. & Associates, Inc. and field observations made by representatives of Dodson & Associates, Inc. The Special Bridge and Special Culvert methods are used to represent most of the bridge and culvert structures. Roughness coefficients, minor loss coefficients, roadway elevation profiles, and other data are entered as necessary to provide a complete hydraulic definition for each structure.

3.5 Summary of HEC-RAS Modeling Results

3.5.1 Hurricane Creek

Table 3-10 provides a summary of computed water surface elevations for Hurricane Creek. Elevations are given at the upstream side of each of the roadways which cross Hurricane Creek. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that a flood of 10-year to 25-year magnitude causes flooding at a number of roadway crossings. Exhibit 3.1 illustrates computed flood profiles for existing conditions along Hurricane Creek.

TABLE 3-10: SUMMARY OF COMPUTED FLOOD LEVELS ALONG HURRICANE CREEK							
	HEC-RAS	Min. Top	Computed Water Surface Elevation				
Location	Cross-Section	of Road Elevation	5-Year	10-Year	25-Year	50-Year	100-Year
FM 324	4196.5	230.02	226.86	227.80	229.19	229.22	***230.77***
Southern Pacific RR	4311.5	227.88	227.52	***228.66***	***229.90***	***230.12***	***231.11***
FM 819	10346.5	235.50	233.58	234.80	***235.65***	***235.94***	***236.44***
Loop 287	17102.5	249.00	247.38	248.39	***249.17***	***249.58***	***249.93***
U.S. 59 (1st Street)	20690.5	258.00	253.65	255.00	256.16	257.13	257.32
Tulane Street	26932.5	266.70	265.31	266.24	***267.04***	***267.40***	***267.71***
South 3rd Street	28288.5	269.30	266.42	267.58	268.57	269.18	***269.52***
Denman Ave. (US 69)	30231.5	276.50	269.94	270.90	271.70	272.30	272.92
Chestnut Village	30933.5	276.38	273.97	275.04	276.11	***276.69***	***277.04***
Chestnut Village	31423.5	276.04	274.69	275.79	***276.76***	***277.19***	***277.47***
Timberland Drive	32043.5	282.20	276.61	277.61	278.51	279.06	279.62
Lufkin Avenue	33000.5	284.00	279.83	280.55	281.10	281.72	282.37
Albertson's Driveway	33383.5	284.20	281.92	282.55	283.18	283.75	***284.34***
Railroad	33545.5	286.70	282.58	283.24	283.87	284.40	285.06
Groesbeck Avenue	34193.5	287.37	286.66	***287.53***	***287.83***	***287.94***	***288.05***

3.5.2 Hurricane Creek Tributary #1

Table 3-11 provides a summary of computed water surface elevations for Hurricane Creek Tributary #1. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that even a 5-year storm event causes roadway overtopping at a number of locations. Exhibit 3.2 illustrates computed flood profiles for existing conditions along Tributary #1.

TABLE 3-11: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #1							
	HEC-RAS	Min. Top	Computed Water Surface Elevation				
Location	Cross-Section	of Road Elevation	5-Year	10-Year	25-Year	50-Year	100-Year
Tulane Street	99.5	264.09	260.52	261.68	262.94	263.65	***264.42***
South 3rd Street	1125.5	269.35	267.20	269.13	***269.80***	***269.93***	***270.01***
Chesnut Drive	5339.5	281.07	279.77	281.01	***281.46***	***281.64***	***281.77***
Denman Ave. (US 69)	6086.5	283.45	***283.84***	***284.21***	***284.45***	***284.56***	***284.65***
Jones Street	7379.5	285.97	***287.96***	***288.50***	***288.88***	***289.13***	***289.36***
Hunters Creek Drive	8471.5	291.14	***292.56***	***292.77***	***292.98***	***293.14***	***293.32***
Howard Avenue	9488.5	298.40	***298.75***	***299.19***	***299.38***	***299.47***	***299.53***
Whippoorwill Drive	10962.5	303.96	***304.72***	***304.87***	***304.98***	***305.04***	***305.12***

3.5.3 Hurricane Creek Tributary #2

Table 3-12 provides a summary of computed water surface elevations for Hurricane Creek Tributary #2. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that roadway overtopping occurs only during a 100-year storm event. Exhibit 3.3 illustrates computed flood profiles for existing conditions along Tributary #2.

TABLE 3-12: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #2							
	HEC-RAS	Min. Top	Computed Water Surface Elevation				
Location	Cross-Section	of Road Elevation	5-Year	10-Year	25-Year	50-Year	100-Year
Loop 287	500.5	260.17	254.10	255.73	257.43	258.83	***260.36***
Tulane Street	1525.5	261.98	258.97	259.89	260.71	261.53	***262.44***
Chestnut Drive	7700.5	294.03	288.15	289.73	291.09	292.21	293.49

3.5.4 Hurricane Creek Tributary #3

Table 3-13 provides a summary of computed water surface elevations for Hurricane Creek Tributary #3. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that roadway overtopping is limited in the upper reaches of the stream but will be relatively frequent in the lower portion of the Tributary #3 watershed. Exhibit 3.4 illustrates computed flood profiles for existing conditions along Tributary #3.

TABLE 3-13: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #3							
	HEC-RAS	Min. Top	Computed Water Surface Elevation				
Location	Cross-Section	of Road Elevation	5-Year	10-Year	25-Year	50-Year	100-Year
Mott Street	669.5	249.20	248.27	***250.36***	***250.85***	***251.21***	***251.55***
Carroll Avenue	5698.5	260.86	259.17	260.75	***261.53***	***261.68***	***261.82***
Tom Temple Drive	7333.5	266.52	263.84	264.72	265.41	265.86	266.31
White Oak Drive	9033.5	272.86	269.21	270.02	270.84	271.53	272.37
Park lane	9811.5	275.50	272.49	273.45	274.50	275.38	***275.73***

3.5.5 Hurricane Creek Tributary #4

Table 3-14 provides a summary of computed water surface elevations for Hurricane Creek Tributary #4. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that roadway overtopping will be especially frequent at Tulane Street. Exhibit 3.5 illustrates computed flood profiles for existing conditions along Tributary #4.

TABLE 3-14: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #4

Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation 5-Year	10-Year	25-Year	50-Year	100-Year
Scenic Acres	2296.5	252.00	250.17	250.88	251.30	251.58	251.87
US 59	3357.5	259.59	256.27	257.36	258.36	259.16	***259.98***
Tulane Street	4205.5	261.69	***262.24***	***262.46***	***262.78***	***263.07***	***263.31***

3.5.6 Hurricane Creek Tributary #5

Table 3-15 provides a summary of computed water surface elevations for Hurricane Creek Tributary #5. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that roadway overtopping will be limited under anything less severe than 25-year to 50-year storm conditions. Exhibit 3.6 illustrates computed flood profiles for existing conditions along Tributary #5.

TABLE 3-15: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #5

Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation 5-Year	10-Year	25-Year	50-Year	100-Year
North Branch							
Daniel McCall Drive	2420.5	245.24	242.63	243.41	244.34	244.46	244.48
US 59	3222.5	249.86	244.37	245.97	246.67	248.86	***250.12***
Driveway	3797.5	250.70	246.97	248.09	249.42	250.49	***251.18***
Brentwood Drive	4884.5	255.85	254.62	255.49	***255.99***	***256.08***	***256.19***
South Branch							
Brentwood Drive	1730.5	255.30	254.69	***255.71***	***256.02***	***256.16***	***256.27***

3.5.7 Hurricane Creek Tributary #6

Table 3-16 provides a summary of computed water surface elevations for Hurricane Creek Tributary #6. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that roadway overtopping will be common even under 5-year storm conditions. Exhibit 3.7 illustrates computed flood profiles for existing conditions along Tributary #6.

TABLE 3-16: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #6							
Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation				
			5-Year	10-Year	25-Year	50-Year	100-Year
Railroad Spur	808.5	235.40	230.73	231.21	231.66	232.08	232.62
Southpark Drive	1227.5	234.80	***234.96***	***235.37***	***235.59***	***235.69***	***235.85***
Driveway	2580.5	237.97	237.28	***238.12***	***238.71***	***239.08***	***239.41***
FM 819	5165.5	250.28	249.49	***250.34***	***250.66***	***250.78***	***251.72***
Dam	5442.5	254.30	***256.22***	***256.32***	***256.40***	***256.48***	***256.53***
Sandyland Drive	7213.5	255.72	***256.52***	***256.70***	***256.88***	***257.02***	***257.15***
Loop 287	8149.5	263.68	***263.93***	***264.10***	***264.23***	***264.31***	***264.38***

3.5.8 Hurricane Creek Tributary #7

Table 3-17 provides a summary of computed water surface elevations for Hurricane Creek Tributary #6. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. As shown in the table, the results of the existing conditions hydraulic analysis indicate that roadway overtopping will be fairly common for even a 5-year storm event. Exhibit 3.8 illustrates computed flood profiles for existing conditions along Tributary #7.

TABLE 3-17: SUMMARY OF COMPUTED FLOOD LEVELS ALONG TRIBUTARY #7							
Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation				
			5-Year	10-Year	25-Year	50-Year	100-Year
North Branch							
Daniel McCall Drive	239.5	238.56	234.95	235.76	236.32	236.65	236.95
Driveway	564.5	234.90	***235.33***	***236.12***	***236.71***	***237.08***	***237.43***
FM 819	2382.5	245.09	243.72	244.72	***245.58***	***245.77***	***245.92***
US 59	2735.5	253.99	246.26	246.95	247.24	248.26	249.34
South Branch							
Daniel McCall Drive	5262.5	239.73	236.06	236.75	237.39	237.75	238.34
US 59	8866.5	253.26	244.95	246.12	247.24	247.94	248.74
FM 819	10564.5	253.64	***254.03***	***254.41***	***254.66***	***254.80***	***254.92***
Champions Drive	10815.5	253.51	***254.70***	***254.94***	***255.13***	***255.26***	***255.40***
Crown Colony	11763.5	257.13	***258.25***	***258.56***	***258.81***	***258.96***	***259.09***

3.6 Comparison of FIS and Updated Flood Levels

Table 3-18 provides a comparision of FIS and updated 100-year flood levels for Hurricane Creek and Tributaries 1, 3, 5, and 7. As indicated in the table, updated flood levels are similar to or somewhat greater than FIS values at most locations. However, a few updated flood levels are lower than FIS values.

TABLE 3-18: COMPARISON OF 100-YEAR FLOOD LEVELS FROM FLOOD INSURANCE STUDY AND UPDATE STUDY

Location	FIS Flood Level (feet)	Updated Flood Level (feet)
HURRICANE CREEK		
Upstream of Loop 287	249.9	249.93
Upstream of US 59	253.2	257.32
Upstream of Tulane Street	266.5	267.71
Upstream of South 3rd Street	270.2	269.52
Upstream of Denman Avenue	274.0	272.92
Upstream of Timberland Drive	281.4	279.62
Upstream of Lufkin Avenue	285.2	282.37
TRIBUTARY #1 ("North Tributary")		
Upstream of Tulane Street	266.0	264.42
Upstream of South 3rd Street	267.3	270.01
Upstream of Chestnut Street	282.0	281.77
Upstream of Denman Avenue	285.2	284.65
Upstream of Jones Street	290.3	289.36
TRIBUTARY #3 ("Hurricane Creek West Branch")		
Upstream of Mott Road	251.0	251.55
Upstream of Carroll Drive	264.5	261.82
Upstream of Tom Temple Drive	265.5	266.31
TRIBUTARY #5 ("Hurricane Creek East Tributary (E)")		
Upstream of Daniel McCall Drive	244.2	244.48
Upstream of US 59	248.9	250.12
TRIBUTARY #7 North ("Hurricane Creek East Tributary (S)")		
Upstream of Daniel McCall Drive	236.6	236.95
Upstream of FM 819 (College Drive)	246.1	245.92
Upstream of US 59	254.5	249.34

4.

4. FUTURE CONDITIONS ANALYSIS

4.1 Purpose of the Ultimate Conditions Analysis

The purpose of the future conditions HEC-1 analysis described in this section of the report is to assess the effectiveness of regional detention facilities and other flood mitigation measures recommended for the Hurricane Creek watershed.

4.2 Goals of the Long-Term Drainage Improvement Plan

Major goals of the long-term drainage improvement plan for the Hurricane Creek watershed include the following.

- Prevent future increases in peak flow rates along Hurricane Creek and tributaries, thereby preventing future increases in the potential for flooding.
- Wherever possible, reduce the potential for flooding along Hurricane Creek and tributaries by reducing flow rates, replacing inadequate cross-drainage structures, or improving existing waterways.
- Make the plan as cost-effective as possible. Minimize capital improvement costs and long-term maintenance costs.
- Create parks and green spaces wherever possible and where the creation of such areas is consistent with the other goals of the plan.
- Make it possible for future development to occur without undue financial burdens on industrial, commercial, or residential developers.
- Develop a plan that can be implemented in manageable pieces or segments.
- Avoid impacts on environmentally and culturally sensitive areas whenever possible. When this is not possible, mitigate impacts to the greatest extent possible under constraints of cost and time.
- Reduce the frequency of flooding as well as the severity of flooding during major floods. Strive for a 5-year to 10-year level of protection with respect to significant overbank flooding.
- Eliminate structural flooding (homes and businesses) for a 25-year to 100-year storm event.
- To the greatest extent possible, limit the boundaries and base flood elevations (BFEs) of the interim and ultimate 100-year flood plains to the boundaries and BFE's shown on currently effective Flood Insurance Rate Maps (FIRMs) for the City of Lufkin.

4.3 Planning Constraints

A number of planning constraints have been identified in the process of developing a drainage plan for the Hurricane Creek watershed. These constraints include the following.

- Soils in the area are sandy, and channel side slopes do not hold up well. Erosion will likely be a problem.
- Maintenance of improved channels will likely be expensive due to soil conditions. Side slopes should be no steeper than 4:1 wherever possible.
- Existing development in the watershed is extensive. Large detention sites will be difficult to locate and acquire.

- Land values will likely be higher in this watershed than they are in the Cedar Creek watershed.
- A recreational amenity known as the Azalea Trail has been developed along Hurricane Creek between Grace Dunn Richardson Park and the Kiwanis Park. Improvements in this area may disturb the asphalt trail and electric lighting currently in place along the Azalea Trail.
- The upper portion of the watershed is almost entirely developed, making it difficult to obtain right-of-way along existing streams. In many areas along Hurricane Creek and its tributaries, existing buildings (including homes) and other structures are so close to the stream that obtaining sufficient right-of-way would involve the purchase of the buildings and structures.
- The City of Lufkin's wastewater treatment plant is located immediately north of Hurricane Creek and west of Highway 324, a short distance downstream of the Tributary #7 confluence. The plant could be affected by any residual increases in peak flow rates and flood levels in this area.
- Lufkin Mall and Angelina Mall are located immediately north of Loop 287 and south of Hurricane Creek. The creek channel was realigned to allow construction of the malls. Tributary 2 passes underneath Lufkin Mall via an enclosed system. Care must be taken to avoid increases in flood levels in this area, as both malls are affected by the existing flood plain of Hurricane Creek.
- Plans for the future Interstate Highway 69 may affect planning in the area if the route follows U.S. Highway 59 as anticipated.
- The Crown Colony development in the southeastern portion of the watershed is very extensive and has been substantially built out. Modifications to existing drainage systems within Crown Colony may be difficult if not impossible.
- The topography along Hurricane Creek itself does not lend itself to the development of detention facilities without major excavation. Topography along tributaries is better suited.
- Hurricane Creek and several tributaries cross either Loop 287 or U.S. Highway 59. Coordination with TxDOT will be necessary if improvements to existing crossing structures are required.
- Substantial areas in the lower portion of the Hurricane Creek watershed are outside the incorporated boundaries of the City of Lufkin. The City may not have complete control over developments, drainage improvements, etc. in these areas.
- Observations made during field visits indicate that there are significant wetlands along Hurricane Creek and its tributaries, especially in the areas where channel and overland slopes are relatively flat.

4.4 Cultural Resources and Wetlands Investigations

In order to identify significant natural and historical features in the Hurricane Creek watershed, cultural resources and wetlands investigations were completed. The cultural resources review was completed by Prewitt & Associates, Inc. of Austin, Texas. A copy of the report prepared by Prewitt & Associates, Inc. in connection with the Hurricane Creek flood planning study is attached as Appendix B to this report. The results of the cultural resources investigation indicate that the potential for damage to cultural sites in connection with the implementation of a drainage improvement plan in the Hurricane Creek watershed is minimal.

Wetlands investigations for the Hurricane Creek watershed were carried out by Wetland Technologies Corporation of Sugar Land, Texas. The results of the wetlands investigations indicate that there are significant wetlands along Hurricane Creek and its tributaries. Even in areas where wetlands may not be found, Hurricane Creek and its tributaries are considered to be "waters of the United States" and are subject to regulation by the U.S. Army Corps of Engineers. A copy of the report prepared by Wetland Technologies Corporation is attached as Appendix C to this report.

4.5 General Approach to Drainage Planning

Prior to the development of a drainage plan for the Hurricane Creek watershed, a number of general principles were developed to guide the planning effort. To the greatest possible extent, these principles have been adhered to in the development of the drainage improvement plan described in this section of the report. The planning principles are described in the following paragraphs.

- Avoid channelization on a large scale because of the difficulty and expense involved in obtaining right-of-way, the likelihood that channels would be difficult to maintain due to soil conditions in the area, the probable damage to existing wetlands, and the difficulty and expense associated with the procurement of the necessary permits.
- Focus on regional detention as the best overall solution for the Hurricane Creek watershed.
- To the greatest extent possible, create detention storage solely through the construction of dams across natural stream channels. Where necessary, supplement this natural storage through excavation within the boundaries of regional detention facilities.
- Include limited channelization in areas where flooding problems are especially significant and where there is sufficient room for an adequate right-of-way.
- To the greatest degree possible, minimize environmental impacts associated with channelization projects.
- Replace only those cross-drainage structures whose hydraulic capacity is substantially inconsistent with the capacities of upstream and downstream structures or whose physical condition is poor.
- Include on-site detention only in areas where regional detention sites are not available or where downstream flooding conditions cannot be relieved through channelization.
- Focus drainage planning activities on areas within the incorporated boundaries of the City of Lufkin and areas in which existing drainage problems are significant. Do not attempt to significantly reduce flood plain widths or flood elevations in undeveloped areas.
- To the greatest extent possible, make the plan hydraulically, economically, environmentally, and politically feasible.

4.6 Description of Proposed Long-Term Drainage Improvements

A total of ten (10) potential sites for regional detention facilities have been identified in the Hurricane Creek watershed. Exhibit 4.1 illustrates the location of each of these sites. Of these sites, nine (9) are recommended for inclusion in the regional drainage plan. Basin #2 is not included in the plan due to the existence of high-quality wetlands on the proposed detention site. Basin #7 (Grace Dunn Richardson Park) is included as a potential detention site because the property comprising the detention site is already owned by the City of Lufkin and because the site is strategically located at the confluence of Hurricane Creek and Tributary #3. However, no specific plans for Basin #7 have been developed in connection with this study due to the likelihood of extensive wetlands within the boundaries of the site. It is recommended that the City of Lufkin explore the possibility of acquiring additional land adjacent to the existing park for the purpose of preserving existing wetlands and mitigation wetlands impacts related to proposed drainage improvements. Exhibit 4.1 illustrates the boundaries of the area suggested for acquisition. Basin #6, proposed to be located on Tributary #2, may have to be reconfigured somewhat to take into account an existing detention facility at the Lowe's store on Loop 287 at Chestnut Drive. Alternatively, the Lowe's detention facility may be incorporated into the proposed regional basin. Exhibits 4.2 through 4.11 provide more detailed views of the ten potential detention sites identified in the Hurricane Creek watershed.

In addition to regional detention, limited channelization and the construction of two overflow relief channels are included in the future conditions drainage plan. Channelization called for along Hurricane Creek is divided into four segments: from Chestnut to Denman, from Denman to South Third Street, from Tulane to U.S. 59, and from U.S. 59 to Loop 287. Channelization is also called for on Tributary #4 from Regional Detention Basin #8 to U.S. Highway 59, on Tributary #5 (North) from Basin #9 to U.S. 59, and on Tributary #5 (South) from Basin #10 to U.S. 59. The two overflow relief channels are proposed: one for Hurricane Creek between Tulane Street and U.S. 59 and one for Tributary #3 between Carroll Avenue and Regional Detention Basin #7. The extents of each of these channel improvement projects are indicated on Exhibit 4.1. Exhibits 4.12 through 4.18 provide some details on each of the stream segments in which channelization has been recommended as a flood mitigation measure.

Additional channel excavation projects originally included in the Hurricane Creek drainage plan were eliminated due to concerns involving existing wetlands and to problems related to the acquisition of necessary rights-of-way. These projects included improvements to Tributary #1 downstream of Denman Avenue, Tributary #2 downstream of Chestnut Avenue, Tributary #3 downstream of Tom Temple Drive, Tributary #4 downstream of U.S. 59, Tributary #5 downstream of U.S. 59, Tributary #6 downstream of FM 819, and Tributary 7 downstream of U.S. 59. All channelization and regional detention projects included in the original draft drainage plan were reviewed by Wetland Technologies Corporation. A representative of WTC traveled to Lufkin and visited the locations that would be affected by the various channel improvement projects and detention facilities. Comments on most of the various improvement projects and detention facilities were summarized in a supplement to the original wetlands report prepared by WTC. A copy of the supplemental report is attached as Appendix D.

Roadway culvert replacements are recommended at the Whippoorwill and South Third Street crossings of Tributary #1 and at the Tulane Street crossing of Tributary #4. The suggested minimum culvert installations are two (2) 54-inch reinforced concrete pipes at Whippoorwill, two (2) 10' x 7' box culverts at South Third Street, and three (3) 5' x 4' box culverts or four (4) 54-inch reinforced concrete pipes at Tulane Street. The City of Lufkin has already made plans to replace the South Third Street and Tulane Street culverts.

The final component in the drainage plan is a recommendation that on-site detention be required for new development in Hurricane Creek sub-watersheds HC1A, HC1B, HCT1A, HCT1B1, HCT3A, HCT3B, HCT6A, HCT6B, HCT7A, and HCT7C. On-site detention is recommended because suitable regional detention sites are not available in these areas, there are significant flooding problems downstream of each of the areas, and existing wetlands make channelization difficult, if not unfeasible, in downstream areas.

4.7 Sub-Areas Used in the Ultimate Conditions HEC-1 Analysis

For the ultimate conditions HEC-1 analysis of the Hurricane Creek watershed, a separate sub-area has been established to represent the area draining to each of the ten potential regional detention sites. This is done to allow for an accurate accounting of storm runoff entering each of the regional detention facilities. A total of forty (40) sub-areas are included in the future conditions HEC-1 model of the Hurricane Creek watershed. Exhibit 4.19 illustrates the boundaries of each of the forty sub-areas included in the model.

4.8 SCS Curve Numbers

As indicated in Section 2 of this report, weighted SCS curve numbers have been determined for nine major sub-areas within the Hurricane Creek watershed. Where a major sub-area has been subdivided to create additional sub-watersheds, the curve number determined for the major sub-area is used for each of the smaller sub-areas. Future conditions curve numbers are identical to those used in the existing conditions analysis of the Hurricane Creek watershed.

4.9 Land Use Data & Impervious Cover Calculations

Existing land uses for the Hurricane Creek watershed have been divided into a number of categories. Recent aerial photographs have been used to determine the area of existing development which falls into those categories, each of which has a different average percentage of impervious cover. Assumptions regarding future development patterns have been established using information from the City of Lufkin Comprehensive Plan prepared in 1987 by Bucher Willis Ratliff. Exhibit 4.20 is a copy of the Future Conditions Land Use Map published in the City of Lufkin Comprehensive Plan. For each sub-area included in the future conditions HEC-1 analysis, the area of future development has been determined, and the expected average impervious cover associated with that development has been estimated. Land use breakdowns and impervious cover data for future conditions sub-areas are included in Appendix B to this report.

4.10 Future Conditions Times of Concentration & Storage Coefficients

The Clark unit hydrograph method requires that the user specify a time of concentration and a storage coefficient for each sub-area in the HEC-1 model of the Hurricane Creek watershed. The time of concentration is set equal to the time required for storm runoff to travel from the most hydraulically remote point in the sub-area to the outlet point. The storage coefficient is a relative measure of the amount of storage in the sub-area. Typically, the flatter the slopes in a particular watershed, the greater the surface and depression storage, and the greater the value of the storage coefficient. As slopes increase, the storage coefficient typically decreases. Because this inverse relationship is similar to the relationship between time of concentration and slope, the storage coefficient is frequently computed as follows:

$$R = K \times TC$$

where R is the storage coefficient, TC is the time of concentration, and K is a multiplier. The value of K typically ranges from 2.0 for relatively steep slopes to 3.0 for flatter slopes. For all sub-areas in the Hurricane Creek watershed, K is set equal to 2.0.

The time of concentration for each sub-area in the Hurricane Creek watershed is computed by dividing the distance over which storm runoff must travel by the flow velocity. Because flow velocities vary with flow conditions, the longest watercourse in each sub-area is divided into four segments: overland flow, shallow concentrated flow, paved or gully flow, and channel flow. Overland flow represents sheet flow at very shallow depths, and is limited in this study to no more than 300 feet of distance at the upstream end of each watercourse. Shallow concentrated flow takes over as storm runoff collects in shallow rills and swales, and flow depths increase to a few inches. Paved or gully flow reflects flow in curb-and-gutter streets, concrete-lined swales, and small gullies. Finally, channel flow represents the flow of flood waters through relatively large gullies and creeks illustrated on U.S. Geologic Survey 7.5-minute quadrangle maps using blue lines.

For existing conditions analyses of the Hurricane Creek watershed, velocities for overland flow, shallow concentrated flow, and paved or gully flow are estimated using the SCS Uplands Method, which relates flow condition and slope to flow velocity. For channel flow, an average flow velocity of 3.0 feet per second is used. For ultimate development conditions, the SCS Uplands Method is again used, but the condition assumed to apply to each segment in the watercourse is altered to reflect higher future flow velocities. The changes made are as follows.

1. For ultimate conditions overland flow, Uplands Method curves representing short grass pasture (or lawns) and paved areas are used for all sub-areas. For existing and interim

conditions, curves representing woodland areas and short grass pasture were used. The switch from woodland/pasture to pasture/paved represents assumed changes in the watershed associated with development.

2. For ultimate conditions shallow concentrated flow, the Uplands Method curve representing paved areas was used. For existing and interim conditions shallow concentrated flow, the curve representing a grassed waterway was used.
3. For existing and interim conditions conditions flow in gullies, the Uplands Method curve for paved areas and small gullies was used to estimate flow velocities. For ultimate conditions, the Uplands Method velocities are increased by 2/3 (66%) to reflect assumed improvements to or clean-outs of small gullies and ravines.

Most major channels are assumed to remain in their existing condition. For the unimproved channels, the average future conditions flow velocity is assumed to remain at 3.0 feet per second. For those channel segments where improvements are proposed, the channel velocity is assumed to increase from 3.0 feet per second to 4.0 or 5.0 feet per second, depending on the type and extent of the improvement. For sub-areas with on-site detention requirements, existing conditions times of concentrations and storage coefficients are used with some adjustments to account for channel improvements. The impervious cover of all sub-areas is adjusted to account for future development. Detailed time of concentration calculations for each sub-area included in the ultimate conditions Hurricane Creek HEC-1 model are provided in Appendix B to this report.

4.11 Summary of Future Conditions Hydrologic Parameters

Table 4-1 provides a summary of the hydrologic modeling data used to represent the forty (40) sub-areas included in the Hurricane Creek HEC-1 computer model for conditions of ultimate watershed development. Data shown in italicized print indicate sub-areas for which on-site detention is recommended.

TABLE 4-1: FUTURE CONDITIONS HEC-1 PARAMETERS FOR HURRICANE CREEK SUB-AREAS					
Sub-Area	Drainage Area (acres)	SCS Curve Number	Impervious Cover (%)	Time of Concentration (hours)	Storage Coefficient (hours)
HC1A	*302*	*71*	*40.5*	*0.83*	*1.65*
HC1B	*965*	*71*	*48.5*	*1.38*	*2.76*
HCT1A	*206*	*73*	*57.7*	*0.52*	*1.04*
HCT1B1	*78*	*73*	*41.9*	*0.31*	*0.62*
HCT1B2	157	73	30.6	0.31	0.61
HCT1B3	44	73	30.0	0.27	0.54
HCT1B4	39	73	30.0	0.26	0.51
HCT1B5	339	73	45.2	0.57	1.13
HCT1B6	30	73	76.4	0.27	0.54
HC2A	209	77	38.2	0.51	1.01
HC2B	194	77	52.4	0.39	0.79
HCT2A1	184	71	45.3	0.29	0.57
HCT2A2	50	71	52.4	0.20	0.39
HCT2B1	128	71	55.6	0.26	0.53
HCT2B2	184	71	57.1	0.44	0.88
HC3	131	72	71.3	0.36	0.72
HCT3A	*321*	*70*	*53.2*	*1.49*	*2.99*
HCT3B	*519*	*70*	*27.9*	*0.95*	*1.90*
HC4	86	72	70.1	0.30	0.60
HCT4A	126	67	21.1	0.22	0.43
HCT4B1	157	67	28.6	0.22	0.44
HCT4B2	215	67	49.7	0.58	1.16
HC5	308	75	70.1	0.64	1.28
HCT5A	139	72	27.9	0.31	0.63
HCT5B1	105	72	29.1	0.31	0.61
HCT5B2	68	72	30.4	0.24	0.49
HCT5C	155	72	26.6	0.47	0.93
HCT5D1	117	72	28.3	0.36	0.73
HCT5D2	107	72	35.0	0.31	0.62
HCT5E	134	72	67.1	0.45	0.91
HC6	78	72	79.8	0.27	0.54
HCT6A	*110*	*68*	*53.2*	*0.32*	*0.64*
HCT6B	*285*	*68*	*69.9*	*1.07*	*2.14*
HC7	180	70	77.3	0.57	1.14
HCT7A	*118*	*73*	*28.7*	*0.45*	*0.89*
HCT7B	335	73	36.8	0.74	1.48
HCT7C	*203*	*73*	*30.0*	*0.38*	*0.75*
HCT7D	114	73	30.0	0.21	0.43
HCT7E	415	73	43.3	0.75	1.50
HCT7F	158	73	62.1	0.53	1.05

4.12 Streamflow Routing Data

Because most of the major streams in the Hurricane Creek watershed are assumed to remain basically unchanged, the streamflow routing data used in the ultimate conditions analysis is in most cases identical to that used in the existing and interim conditions analyses. However, there are some reaches in which channelization is called for, or where an existing cross-drainage structure is proposed to be replaced. Tables 4-2 and 4-3 summarize the future conditions routing data used for Hurricane Creek and its tributaries.

TABLE 4-2: FUTURE CONDITIONS STORAGE ROUTING DATA FOR HURRICANE CREEK										
Reach #1: Limit of Study to Tributary #1										# Steps
Flow Rate (cfs)	0	234	351	468	585	702				
Volume (ac-ft)	0	28	37	47	57	71				5
Reach #2: Tributary #1 to Tributary #2										# Steps
Flow Rate (cfs)	0	1260	1889	2519	3149	3779				
Volume (ac-ft)	0	83	125	186	252	319				4

TABLE 4-3: FUTURE CONDITIONS STORAGE ROUTING DATA FOR TRIBUTARIES										
Tributary #1: Whippoorwill to North Branch										# Steps
Flow Rate (cfs)	0	202	303	404	505	606				
Volume (ac-ft)	0	6	9	13	16	20				1
Tributary #1: North Branch to Basin #3										# Steps
Flow Rate (cfs)	0	505	757	1010	1262	1514				
Volume (ac-ft)	0	17	32	46	58	69				2
Tributary #1: Basin #3 to Mouth										# Steps
Flow Rate (cfs)	0	505	757	1010	1262	1514				
Volume (ac-ft)	0	8	11	16	30	41				1
Tributary #2: Chestnut to Basin #6										# Steps
Flow Rate (cfs)	0	240	360	480	600	720				
Volume (ac-ft)	0	2.1	3.3	5.4	8.2	11.0				1
Tributary #2: Basin #6 to Mouth										# Steps
Flow Rate (cfs)	0	240	360	480	600	720				
Volume (ac-ft)	0	11	16	22	28	34				2
Tributary #3: Park Lane to Mouth										# Steps
Flow Rate (cfs)	0	172	258	344	430	516				
Volume (ac-ft)	0	20	28	35	44	54				5
Tributary #4: Basin #8 to Mouth										# Steps
Flow Rate (cfs)	0	144	216	288	360	432				
Volume (ac-ft)	0	7	10	13	16	20				2
Tributary #5 (North Branch): Basin #9 to US 59										# Steps
Flow Rate (cfs)	0	148	222	296	370	444				
Volume (ac-ft)	0	5	8	13	20	23				2
Tributary #5 (South Branch): Basin #10 to US 59										# Steps
Flow Rate (cfs)	0	124	186	248	310	372				
Volume (ac-ft)	0	3.7	5.1	6.7	9.0	11.7				1
Tributary #5: US 59 to Mouth										# Steps
Flow Rate (cfs)	0	485	727	970	1212	1454				
Volume (ac-ft)	0	14	26	42	57	71				2

4.13 HEC-1 Analysis of Regional Detention Facilities

Each of the detention facilities included in the Hurricane Creek drainage plan is represented using a modified Puls storage routing step. Elevation vs. storage volume data for each basin are entered on SE and SV records. Low-level and weir outlet data are entered on SL and SS records, respectively. The low-level outlet option of the HEC-1 program computes discharges using the standard orifice equation:

$$Q = CA(2gH)^{0.5}$$

where: Q = low-level outlet discharge rate (cfs)

C = an orifice flow coefficient

A = the cross-sectional area of the orifice opening (square feet)

g = the acceleration of gravity (32.2 ft/sec^2)

H = the difference between the basin water surface elevation and the elevation at the centroid of the orifice (feet).

The weir option of the program computes discharges using the standard weir equation:

$$Q = CLH^{1.5}$$

where: Q = weir discharge rate (cfs)

L = weir crest length (feet)

H = the difference between the basin water surface elevation and the weir crest elevation (feet).

Tables 4-4 through 4-7 provide a summary of the HEC-1 routing data used to simulate each of the regional detention facilities.

TABLE 4-4: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #1 (With 11 Acre-Feet of Excavation)		***Basin #3 (With 100 Acre-Feet of Excavation)***	
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
300	0.0	264	0.0
302	0.1	266	0.4
304	0.5	268	11
306	1.7	270	46
308	6	272	91
310	19	274	138
312	41	276	183
314	70	-----	-----
316	107	-----	-----
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	4.9	Orifice Area (ft^2)	15.9
Centroid Elevation (ft)	301.25	Centroid Elevation (ft)	266.0
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	312.0	Crest Elevation (feet)	271.0
Crest Length (feet)	15	Crest Length (feet)	80
Weir Coefficient	2.6	Weir Coefficient	2.6

TABLE 4-5: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #4 (With 44 Acre-Feet of Excavation)		***Basin #5 (No Storage Excavation)***	
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
262	0.0	290	0.0
264	2.2	292	2.8
266	10	294	8.9
268	30	296	18.6
270	86	298	32.0
272	122	300	51.0
-----	-----	302	78.3
-----	-----	304	114.8
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	7.1	Orifice Area (ft^2)	7.1
Centroid Elevation (ft)	262.0	Centroid Elevation (ft)	291.5
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	268.0	Crest Elevation (feet)	300.0
Crest Length (feet)	40	Crest Length (feet)	30
Weir Coefficient	2.6	Weir Coefficient	2.6

TABLE 4-6: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #6 (With 48 Acre-Feet of Excavation)		***Basin #8 (No Storage Excavation)***	
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
266	0.0	272	0.0
268	0.2	274	1.2
270	1.1	276	4.4
272	3.1	278	11.0
274	14	280	21.6
276	38	282	36.4
278	62	284	57.1
280	87	286	86.5
282	111	288	129.4
-----	-----	290	186.9
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	7.1	Orifice Area (ft^2)	12.6
Centroid Elevation (ft)	267.5	Centroid Elevation (ft)	274.0
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	277.0	Crest Elevation (feet)	284.0
Crest Length (feet)	50	Crest Length (feet)	50
Weir Coefficient	2.6	Weir Coefficient	2.6

TABLE 4-7: HEC-1 ROUTING DATA FOR REGIONAL DETENTION FACILITIES			
Basin #9 (No Storage Excavation)		***Basin #10 (No Storage Excavation)***	
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
254	0.0	260	0.0
256	0.2	262	0.4
258	0.9	264	2.0
260	2.2	266	5.9
262	4.9	268	12.7
264	9.8	270	23.5
266	17.8	272	39.6
268	30.0	274	62.5
270	46.5	276	93.0
272	67.3	278	131.7
274	92.8	280	178.8
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	9.6	Orifice Area (ft^2)	7.1
Centroid Elevation (ft)	255.75	Centroid Elevation (ft)	261.5
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	270.0	Crest Elevation (feet)	273.0
Crest Length (feet)	50	Crest Length (feet)	20
Weir Coefficient	2.6	Weir Coefficient	2.6

4.14 Regional Detention Routing Results

Table 4-8 provides a summary of computed routing results for each of the detention facilities included in the ultimate conditions HEC-1 model.

TABLE 4-8: SUMMARY OF COMPUTED DETENTION ROUTING RESULTS								
Parameter	Basin #1	Basin #3	Basin #4	Basin #5	Basin #6	Basin #8	Basin #9	Basin #10
10-Year Storm Event								
Peak Inflow (cfs)	337	1074	370	427	524	632	506	463
Peak Discharge (cfs)	73	776	109	91	127	175	163	114
Maximum Elevation (feet)	310.75	272.96	268.36	298.67	277.28	282.30	268.28	272.67
100-Year Storm Event								
Peak Inflow (cfs)	531	1587	572	661	773	1031	803	743
Peak Discharge (cfs)	106	1362	222	176	354	336	332	271
Maximum Elevation (feet)	312.76	274.11	269.15	300.94	278.50	285.02	271.10	274.98

4.15 Comparison of Existing and Future Conditions HEC-1 Results

Tables 4-9 and 4-10 provide a summary of computed 10-year and 100-year peak flow rates at a number of strategic points in the Hurricane Creek watershed. Exhibit 4.19 illustrates the locations of the computation points described in the table. As indicated in the tables, the recommended regional detention facilities and on-site detention policy keep future conditions peak flow rates at or below existing conditions levels at nearly all locations along Hurricane Creek and its tributaries. Increases in peak flow rates above existing conditions values occur at only a few isolated locations. Of the increases in peak flow rates, the only ones of real concern are those occurring on Tributary #6 and Tributary #7. These increases occur in spite of the recommendation for on-site detention in sub-areas HCT6A, HCT6B, HCT7A, and HCT7C. These results indicate that careful regulation of future development in the watersheds of Tributary #6 and Tributary #7 will be necessary.

It is important to note that the implementation of the recommended regional detention plan will not eliminate flooding in Lufkin. It will, however, achieve the following goals.

- It will allow for full development of the Hurricane Creek watershed without worsening flooding problems.
- It will provide some reductions in existing flood levels along Hurricane Creek and its tributaries.
- It will allow future development without an on-site detention requirement for much of the watershed.
- Impacts on existing wetlands are minimized to the greatest extent possible.
- It will provide additional park space and recreational areas for the City of Lufkin.

TABLE 4-9: COMPARISON OF COMPUTED 10-YEAR PEAK FLOW RATES		
Location	Existing 10-Year	Future 10-Year
Hurricane Creek at Limit of Study	367	367
Hurricane Creek Above Tributary #1	1069	1144
Tributary #1 at Whippoorwill	309	368
Tributary #1 Above North Branch	389	445
Tributary #1 Below North Branch	756	672
Tributary #1 at Mouth	952	777
Hurricane Creek Below Tributary #1	2022	1891
Hurricane Creek Above Tributary #2	2152	2000
Tributary #2 at Chestnut (SH 58)	368	212
Tributary #2 at Mouth	616	430
Hurricane Creek Below Tributary #2	2504	2200
Hurricane Creek Above Tributary #3	2475	2187
Tributary #3 at Park Lane	271	276
Tributary #3 at Mouth	612	618
Hurricane Creek Below Tributary #3	2995	2742
Hurricane Creek Above Tributary #4	2980	2721
Tributary #4 at Limit of Study	211	276
Tributary #4 at Mouth	459	448
Hurricane Creek Below Tributary #4	3198	2980
Hurricane Creek Above Tributary #5	3180	2966
Tributary #5 North Branch at Limit of Study	217	285
Tributary #5 North Branch at US 59	386	270
Tributary #5 South Branch at Limit of Study	182	253
Tributary #5 South Branch at US 59	387	301
Tributary #5 at US 59	770	571
Tributary #5 at Mouth	837	748
Hurricane Creek Below Tributary #5	3434	3299
Hurricane Creek Above Tributary #6	3444	3312
Tributary #6 at Loop 287	***209***	***239***
Tributary #6 at Mouth	***230***	***348***
Hurricane Creek Below Tributary #6	3633	3546
Hurricane Creek Above Tributary #7	3580	3503
Tributary #7 North Branch at Limit of Study	***185***	***201***
Tributary #7 North Branch at FM 324	***512***	***568***
Tributary #7 South Branch at Limit of Study	***355***	***376***
Tributary #7 South Branch at Lake A	***611***	***666***
Tributary #7 South Branch Below Lake A	***479***	***515***
Tributary #7 South Branch at FM 324	***677***	***733***
Tributary #7 at FM 324	***1095***	***1229***
Tributary #7 at Mouth	***1140***	***1288***
Hurricane Creek Below Tributary #7	4028	4042

TABLE 4-10: COMPARISON OF COMPUTED 100-YEAR PEAK FLOW RATES		
Location	Existing 100-Year	Future 100-Year
Hurricane Creek at Limit of Study	585	585
Hurricane Creek Above Tributary #1	1736	1851
Tributary #1 at Whippoorwill	507	561
Tributary #1 Above North Branch	618	678
Tributary #1 Below North Branch	1233	994
Tributary #1 at Mouth	1397	1280
Hurricane Creek Below Tributary #1	3127	3072
Hurricane Creek Above Tributary #2	3372	3271
Tributary #2 at Chestnut (SH 58)	596	299
Tributary #2 at Mouth	989	624
Hurricane Creek Below Tributary #2	3946	3741
Hurricane Creek Above Tributary #3	3911	3752
Tributary #3 at Park Lane	430	435
Tributary #3 at Mouth	1031	1048
Hurricane Creek Below Tributary #3	4752	4666
Hurricane Creek Above Tributary #4	4756	4666
Tributary #4 at Limit of Study	361	455
Tributary #4 at Mouth	777	667
Hurricane Creek Below Tributary #4	5148	5066
Hurricane Creek Above Tributary #5	5205	5090
Tributary #5 North Branch at Limit of Study	367	456
Tributary #5 North Branch at US 59	630	387
Tributary #5 South Branch at Limit of Study	310	408
Tributary #5 South Branch at US 59	658	450
Tributary #5 at US 59	1281	837
Tributary #5 at Mouth	1339	1051
Hurricane Creek Below Tributary #5	5748	5680
Hurricane Creek Above Tributary #6	5769	5696
Tributary #6 at Loop 287	***342***	***369***
Tributary #6 at Mouth	***415***	***535***
Hurricane Creek Below Tributary #6	6124	6100
Hurricane Creek Above Tributary #7	6032	5969
Tributary #7 North Branch at Limit of Study	***307***	***321***
Tributary #7 North Branch at FM 324	***812***	***881***
Tributary #7 South Branch at Limit of Study	***582***	***601***
Tributary #7 South Branch at Lake A	***985***	***1053***
Tributary #7 South Branch Below Lake A	***815***	***849***
Tributary #7 South Branch at FM 324	***1150***	***1206***
Tributary #7 at FM 324	***1857***	***1977***
Tributary #7 at Mouth	***1973***	***2135***
Hurricane Creek Below Tributary #7	6805	6712

4.16 Comparison of Existing and Future Conditions Flood Levels

4.16.1 Discussion of Future Conditions HEC-RAS Analysis

For future conditions analyses, existing conditions HEC-RAS models are revised to reflect channelization, structure replacements, relief channels, regional detention facilities, and future conditions flow rates. The resulting HEC-RAS models are used to compute future conditions flood levels along Hurricane Creek and all tributaries. The following sections describe the results of a comparison of existing and future conditions HEC-RAS analyses.

4.16.2 Future Conditions HEC-RAS Results for Hurricane Creek

Table 4-11 provides a comparison between 10-year and 100-year flood levels computed for existing and future conditions. As indicated, 10-year flood levels along Hurricane Creek are reduced by as much as 2.27 feet with the proposed drainage plan in place. The maximum reduction in 100-year flood levels is 1.84 foot. Exhibit 4.22 illustrates computed interim conditions stream profiles for Hurricane Creek.

TABLE 4-11: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG HURRICANE CREEK

Location	HEC-RAS Cross-Section	Computed Water Surface Elevations					
		Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
FM 324	4196.5	227.80	227.81	***+0.01***	230.77	230.50	-0.27
Southern Pacific RR	4311.5	228.66	228.66	0.00	231.11	230.91	-0.20
FM 819	10346.5	234.80	234.60	-0.20	236.44	236.39	-0.05
Loop 287	17102.5	248.39	247.96	-0.43	249.93	249.86	-0.07
U.S. 59 (1st Street)	20690.5	255.00	252.73	-2.27	257.32	255.48	-1.84
Tulane Street	26932.5	266.24	264.54	-1.70	267.71	266.85	-0.86
South 3rd Street	28288.5	267.58	266.96	-0.62	269.52	269.45	-0.07
Denman Ave. (US 69)	30231.5	270.90	269.54	-1.36	272.92	271.72	-1.20
Chestnut Village	30933.5	275.04	273.65	-1.39	277.04	275.54	-1.50
Chestnut Village	31423.5	275.79	274.61	-1.18	277.47	276.65	-0.82
Timberland Drive	32043.5	277.61	276.00	-1.61	279.62	278.05	-1.57
Lufkin Avenue	33000.5	280.55	280.62	***+0.07***	282.37	282.29	-0.08
Albertson's Driveway	33383.5	282.55	282.62	***+0.07***	284.34	284.37	***+0.03***
Railroad	33545.5	283.24	283.30	***+0.06***	285.06	285.11	***+0.05***
Groesbeck Avenue	34193.5	287.53	287.54	***+0.01***	288.05	288.05	0.00

4.16.3 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #1

Table 4-12 provides a comparison between Hurricane Creek Tributary #1 existing and future conditions 10-year and 100-year flood levels. As indicated, 10-year flood levels along Tributary #1 are reduced by as much as 3.59 feet with the proposed drainage improvements in place. The maximum reduction in 100-year flood levels is 0.81 feet. A few small increases in flood levels are noted in areas where future flow rates are slightly higher than existing conditions values. Exhibit 4.23 illustrates computed future conditions stream profiles for Tributary #1.

TABLE 4-12: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #1							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
Tulane Street	99.5	261.68	260.59	-1.09	264.42	263.81	-0.61
South 3rd Street	1125.5	269.13	265.54	-3.59	270.01	269.20	-0.81
Chestnut Drive	5339.5	281.01	281.13	***+0.12***	281.77	281.76	-0.01
Denman Ave. (US 69)	6086.5	284.21	284.17	-0.04	284.65	284.59	-0.06
Jones Street	7379.5	288.50	288.35	-0.15	289.36	289.07	-0.29
Hunters Creek Drive	8471.5	292.77	292.88	***+0.11***	293.32	293.38	***+0.06***
Howard Avenue	9488.5	299.19	299.34	***+0.15***	299.53	299.54	***+0.01***
Whippoorwill Drive	10962.5	304.87	304.67	-0.20	305.12	305.34	***+0.22***

4.16.4 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #2

Table 4-13 provides a comparison between Hurricane Creek Tributary #2 existing and future conditions 10-year and 100-year flood levels. As indicated, 10-year flood levels along Tributary #2 downstream of Basin #6 are reduced by as much as 2.28 feet with the proposed regional detention facilities in place. The maximum reduction in 100-year flood levels is 4.73 feet. Exhibit 4.24 illustrates computed future conditions stream profiles for Tributary #2.

TABLE 4-13: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #2							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
Loop 287	500.5	255.73	253.45	-2.28	260.36	255.63	-4.73
Tulane Street	1525.5	259.89	257.93	-1.96	262.44	259.71	-2.73
Chestnut Drive	7700.5	289.73	288.32	-1.41	293.49	289.50	-3.99

4.16.5 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #3

Table 4-14 provides a comparison between Hurricane Creek Tributary #3 existing and future conditions 10-year and 100-year flood levels. As indicated, 10-year flood levels along Tributary #3 are increased by as much as 0.09 foot with the proposed bypass channel in place. The maximum reduction in 100-year flood levels is 0.08 foot. These increases occur upstream of the proposed relief channel and are caused by slight increases in future conditions peak flow rates over corresponding existing conditions values. These increases in peak flow rates are caused by future increases in impervious cover. In the future conditions HEC-1 models of the Hurricane Creek watershed, these increases in peak flow rates occur even though existing conditions TC and R values are used to reflect the recommended on-site detention policy for this watershed. Exhibit 4.25 illustrates computed future conditions stream profiles for Tributary #3.

TABLE 4-14: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #3							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
Mott Street	669.5	250.36	250.40	***+0.04***	251.55	251.58	***+0.03***
Carroll Avenue	5698.5	260.75	260.62	-0.13	261.82	261.82	***+0.00***
Tom Temple Drive	7333.5	264.72	264.77	***+0.05***	266.31	266.35	***+0.04***
White Oak Drive	9033.5	270.02	270.08	***+0.06***	272.37	272.45	***+0.08***
Park Lane	9811.5	273.45	273.54	***+0.09***	275.73	275.75	***+0.02***

4.16.6 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #4

Table 4-15 provides a comparison between 10-year and 100-year flood levels computed for existing and future conditions on Tributary #4. As indicated, 10-year flood levels along Tributary #4 downstream of the proposed detention basin are reduced by as much as 2.91 feet. The maximum reduction in 100-year flood levels is 2.30 feet. Exhibit 4.26 illustrates computed future conditions stream profiles for Tributary #4.

TABLE 4-15: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #4							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
Scenic Acres	2296.5	250.88	250.64	-0.24	251.87	251.46	-0.41
US 59	3357.5	257.36	256.60	-0.76	259.98	258.60	-1.38
Tulane Street	4205.5	262.46	259.55	-2.91	263.31	261.01	-2.30

4.16.7 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #5

Table 4-16 provides a comparison between 10-year and 100-year flood levels computed for existing and future conditions on the north and south branches of Tributary #5. As indicated, 10-year flood levels along Tributary #5 downstream of the proposed detention basins are reduced by as much as 2.35 feet. The maximum reduction in 100-year flood levels is 3.26 feet. Both of these reductions occur on the north branch of Tributary #5. Exhibits 4.27a and 4.27b illustrate computed future conditions stream profiles for Tributary #5.

TABLE 4-16: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #5							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
North Branch							
Daniel McCall Drive	2420.5	243.41	242.79	-0.62	244.48	244.27	-0.21
US 59	3222.5	245.97	244.48	-1.49	250.12	246.86	-3.26
Driveway	3797.5	248.09	245.74	-2.35	251.18	247.94	-3.24
Brentwood Drive	4884.5	255.49	254.06	-1.43	256.19	255.95	-0.24
South Branch							
Brentwood Drive	1730.5	255.71	253.90	-1.81	256.27	256.11	-0.18

4.16.8 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #6

Table 4-17 provides a comparison between 10-year and 100-year flood levels for existing and future conditions along Tributary #6. As indicated, 10-year flood levels along Tributary #6 are unchanged. This result is based on the recommendation that a strict on-site detention policy be adopted for the watershed of Tributary #6 and that peak flow rates will remain unchanged. Exhibit 4.28 illustrates computed future conditions stream profiles for Tributary #6.

TABLE 4-17: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #6							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
Railroad Spur	808.5	231.21	231.21	0.00	232.62	232.62	0.00
Southpark Drive	1227.5	235.37	235.37	0.00	235.85	235.85	0.00
Driveway	2580.5	238.12	238.12	0.00	239.41	239.41	0.00
FM 819	5165.5	250.34	250.34	0.00	251.72	251.72	0.00
Dam	5442.5	256.32	256.32	0.00	256.53	256.53	0.00
Sandyland Drive	7213.5	256.70	256.70	0.00	257.15	257.15	0.00
Loop 287	8149.5	264.10	264.10	0.00	264.38	264.38	0.00

4.16.9 Future Conditions HEC-RAS Results for Hurricane Creek Tributary #7

Table 4-18 provides a comparison between 10-year and 100-year flood levels computed for existing and future conditions on the north and south branches of Tributary #7. As indicated, 10-year flood levels along Tributary #7 are increased by as much as 0.66 foot. The maximum increase in 100-year flood levels is 0.76 foot. These results are based on the recommendation that an on-site detention policy be implemented for new development in sub-areas HCT7A and HCT7C. Other areas, mainly within or adjacent to the boundaries of the Crown Colony development, are assumed to develop without detention. On-site detention may be necessary for additional areas in the Tributary #7 watershed if these increases in flood levels will cause flooding of existing structures. Exhibit 4.29a and 4.29b illustrate computed future conditions stream profiles for the north and south branches of Tributary #7.

TABLE 4-18: COMPARISON OF EXISTING & FUTURE FLOOD LEVELS ALONG TRIBUTARY #7							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Future 10-Year	Change	Existing 100-Year	Future 100-Year	Change
North Branch							
Daniel McCall Drive	239.5	235.76	236.04	***+0.28***	236.95	237.16	***+0.21***
Driveway	564.5	236.12	236.40	***+0.28***	237.43	237.68	***+0.25***
FM 819	2382.5	244.72	245.38	***+0.66***	245.92	246.01	***+0.09***
US 59	2735.5	247.21	246.82	***-0.39****	249.65	250.38	***+0.73***
South Branch							
Daniel McCall Drive	5262.5	236.75	236.99	***+0.24***	238.34	238.52	***+0.18***
US 59	8866.5	246.12	246.43	***+0.31***	248.74	249.02	***+0.28***
FM 819	10564.5	254.41	254.49	***+0.08***	254.92	254.96	***+0.04***
Champions Drive	10815.5	254.94	255.00	***+0.06***	255.40	255.46	***+0.06***
Crown Colony	11763.5	258.56	258.63	***+0.07***	259.09	259.14	***+0.05***

** This computed reduction in 10-year flood level is due to differences in the culvert flow solution criteria used by HEC-RAS for existing and future conditions. In reality, the future conditions flood level upstream of US 59 will be somewhat higher than the existing conditions value.*

4.17 Preliminary Cost Estimates for Drainage Improvements

Preliminary estimates of construction costs for regional detention facilities and channelization projects are included in Appendix G to this report. Cost estimates for detention basins include the following cost items:

- land acquisition;
- excavation, haul and compaction for dam construction;
- principal discharge structure;
- emergency spillway;
- storage excavation and haul;
- engineering and surveying;
- 15% contingency.

Cost estimates for channelization projects include the following items:

- right-of-way acquisition;
- excavation and haul for channel excavation;
- slope stabilization;
- engineering and surveying;
- 15% contingency.

Culvert replacement costs are estimated separately. Potential costs associated with wetlands mitigation requirements are not included in the cost estimates due to uncertainties regarding the actual extent and quality of wetlands that may be impacted by individual improvement projects. Table 4-11 provides a summary of the estimated construction costs associated with each of the major components of the recommended drainage plan for the Hurricane Creek watershed.

TABLE 4-11: ESTIMATED CONSTRUCTION COSTS FOR RECOMMENDED DRAINAGE PLAN

Drainage Plan Component	***Estimated Construction Cost***
Regional Detention Basin #1	$887,600
Regional Detention Basin #3	$2,609,000
Regional Detention Basin #4	$1,184,100
Regional Detention Basin #5	$845,700
Regional Detention Basin #6	$1,181,400
Regional Detention Basin #8	$1,051,300
Regional Detention Basin #9	$812,100
Regional Detention Basin #10	$821,300
Hurricane Creek Improvements, Loop 287 to U.S 59	$716,000
Hurricane Creek Improvements, U.S. 59 to Tulane	$834,300
Hurricane Creek Improvements, South Third to Denman	$311,900
Hurricane Creek Improvements, Denman to Chestnut	$170,000
Tributary #3 Relief Channel	$342,300
Tributary #4 Channel Improvements	$327,600
Tributary #5 (North) Channel Improvements	$344,500
Tributary #5 (South) Channel Improvements	$363,200
Tributary #1 Culverts at Whippoorwill	$24,000
Tributary #1 Culverts at South Third Street	$63,000
Tributary #4 Culverts at Tulane Street	$40,000

5. INTERIM CONDITIONS ANALYSIS

5.1 Purpose of Interim Conditions Analysis

The purpose of the interim conditions analysis described in this section of the report is to assess the effectiveness of near-term drainage improvements recommended for the Hurricane Creek watershed.

5.2 Description of Proposed Near-Term Drainage Improvements

The near-term drainage improvements recommended for the Hurricane Creek watershed consist of three (3) regional detention facilities. These three facilities have been selected from a total of 10 potential regional detention sites identified in the Hurricane Creek watershed. As indicated on Exhibit 5.1, one of these facilities (Basin #1) is located on the north branch of Tributary #1 immediately upstream of the Englewood Subdivision, an area that has suffered significant flooding problems in the past. The second facility (Basin #4) is located on a small tributary that empties into Hurricane Creek a short distance upstream of the Lufkin and Angelina Malls. The third detention facility included in the interim drainage improvement plan (Basin #8) is located on Hurricane Creek Tributary #4 upstream of Tulane Street. The location, size, and shape of each of these basins are illustrated on Exhibits 4.2, 4.5, and 4.9, respectively.

For interim conditions, detention storage in all three of the detention facilities included in the interim drainage plan is assumed to be created solely through the construction of a dam. Only natural storage is included. No excavation is called for in either facility for interim conditions, with the exception of the earth required to construct the dam.

In addition to the construction of the three regional detention facilities, it is recommended that the existing cross-drainage structures at the Whippoorwill Drive and South Third Street crossings of Tributary #1 and the Tulane Street crossing of Tributary #4 be replaced. The minimum recommended culvert installation at Whippoorwill is two (2) 54-inch reinforced concrete pipes. The minimum culvert installation at South Third Street is two (2) 10' x 7' box culverts. The minimum culvert installation at Tulane Street is three (3) 5' x 4' box culverts or four (4) 54-inch reinforced concrete pipes.

5.3 Preliminary Construction Cost Estimates for Interim Detention

Preliminary estimates of construction costs for Basin #1, Basin #4, and Basin #8 and for the recommended culvert replacements are included in Appendix H to this report. These estimates include the following cost items:

- land acquisition;
- excavation, haul and compaction for dam construction;
- principal discharge structure;
- emergency spillway;
- surveying and engineering;
- 15% contingency.

Culvert replacement costs are estimated separately. Potential costs associated with wetlands mitigation requirements are not included in the cost estimates due to uncertainties regarding the actual extent and quality of wetlands that may be impacted by individual improvement projects.

The estimated cost for Basin #1 is $887,600. For Basin #4, the estimated cost is $714,700. For Basin #8, the estimated cost is $1,051,300. The estimated costs of the Whippoorwill, South Third Street, and Tulane Street culvert replacements are $24,000, $63,000, and $40,000, respectively.

5.4 HEC-1 Analysis of Near-Term Drainage Improvements

The existing conditions HEC-1 model of the Hurricane Creek watershed described in Section 2 of this report is used as the basis for the interim conditions analysis. For the purposes of the interim conditions analysis, the existing conditions models are modified through the introduction of storage routing data for each of the two proposed detention basins, the creation of additional sub-areas as needed to accurately reflect the area draining into each detention facility, and adjustments to streamflow routing data to account for structure replacements and detention facility construction. No other changes are made to the existing conditions HEC-1 model.

Each detention facility is represented using a modified Puls storage routing step. Elevation vs. storage volume data based on natural ground contours within each basin are entered along with low-level and weir outlet data on SL and SS records, respectively. The low-level outlet option of the HEC-1 program computes discharges using the standard orifice equation:

$$Q = CA(2gH)^{0.5}$$

where: Q = low-level outlet discharge rate (cfs)

C = an orifice flow coefficient

A = the cross-sectional area of the orifice opening (square feet)

g = the acceleration of gravity (32.2 ft/sec^2)

H = the difference between the basin water surface elevation and the elevation at the centroid of the orifice (feet).

The weir option of the program computes discharges using the standard weir equation:

$$Q = CLH^{1.5}$$

where: Q = weir discharge rate (cfs)

L = weir crest length (feet)

H = the difference between the basin water surface elevation and the weir crest elevation (feet).

Table 5-1 provides a summary of the HEC-1 routing data used to simulate each of the detention facilities.

TABLE 5-1: HEC-1 ROUTING DATA FOR INTERIM DETENTION FACILITIES			
Basin on Tributary #1 (Basin #1)		***Basin on Small Tributary (Basin #4)***	
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
300	0.0	262	0.0
302	0.1	264	2.2
304	0.5	266	8.2
306	1.7	268	20.4
308	5.7	270	42.7
310	14.8	272	78.1
312	31.5	-----	-----
314	58.1	-----	-----
316	95.6	----	-----
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	4.9	Orifice Area (ft^2)	7.1
Centroid Elevation (ft)	301.25	Centroid Elevation (ft)	262.0
Orifice Coefficient	0.6	Orifice Coefficient	0.6
Weir Data		Weir Data	
Crest Elevation (feet)	312.0	Crest Elevation (feet)	268.0
Crest Length (feet)	15	Crest Length (feet)	40
Weir Coefficient	2.6	Weir Coefficient	2.6

TABLE 5-2: HEC-1 ROUTING DATA FOR INTERIM DETENTION FACILITIES			
Basin on Tributary #4 (Basin #8)			
Elevation vs. Storage Data		Elevation vs. Storage Data	
Elevation (feet)	Storage (acre-feet)	Elevation (feet)	Storage (acre-feet)
272	0.0	-----	-----
274	1.2	-----	-----
276	4.4	-----	-----
278	11.0	-----	-----
280	21.6	-----	-----
282	36.4	-----	-----
284	57.1	-----	-----
286	86.5	-----	-----
288	129.4	-----	-----
290	186.9	-----	-----
Low-Level Outlet Data		Low-Level Outlet Data	
Orifice Area (ft^2)	12.6	Orifice Area (ft^2)	-----
Centroid Elevation (ft)	274.0	Centroid Elevation (ft)	-----
Orifice Coefficient	0.6	Orifice Coefficient	-----
Weir Data		Weir Data	
Crest Elevation (feet)	284.0	Crest Elevation (feet)	-----
Crest Length (feet)	50	Crest Length (feet)	-----
Weir Coefficient	2.6	Weir Coefficient	-----

5.5 Summary of Interim Conditions HEC-1 Results

Tables 5-3 and 5-4 provide a comparison of computed existing and interim conditions 10-year and 100-year peak flow rates at a number of strategic points in the Hurricane Creek watershed. Exhibit 5.1 illustrates the locations of the computation points described in the tables.

TABLE 5-3: COMPARISON OF COMPUTED 10-YEAR PEAK FLOW RATES		
Location	Existing 10-Year	Interim 10-Year
Hurricane Creek at Limit of Study	367	367
Hurricane Creek Above Tributary #1	1069	1069
Tributary #1 at Whippoorwill	309	309
Tributary #1 Above North Branch	389	389
Tributary #1 Below North Branch	756	600
Tributary #1 at Mouth	952	875
Hurricane Creek Below Tributary #1	2022	1929
Hurricane Creek Above Tributary #2	2152	2020
Tributary #2 at Chestnut (SH 58)	368	368
Tributary #2 at Mouth	616	616
Hurricane Creek Below Tributary #2	2504	2380
Hurricane Creek Above Tributary #3	2475	2356
Tributary #3 at Park Lane	271	271
Tributary #3 at Mouth	612	612
Hurricane Creek Below Tributary #3	2995	2880
Hurricane Creek Above Tributary #4	2980	2866
Tributary #4 at Limit of Study	211	211
Tributary #4 at Mouth	459	343
Hurricane Creek Below Tributary #4	3198	3113
Hurricane Creek Above Tributary #5	3180	3094
Tributary #5 North Branch at Limit of Study	217	217
Tributary #5 North Branch at US 59	386	386
Tributary #5 South Branch at Limit of Study	182	182
Tributary #5 South Branch at US 59	387	387
Tributary #5 at US 59	770	770
Tributary #5 at Mouth	837	837
Hurricane Creek Below Tributary #5	3434	3343
Hurricane Creek Above Tributary #6	3444	3351
Tributary #6 at Loop 287	209	209
Tributary #6 at Mouth	230	230
Hurricane Creek Below Tributary #6	3633	3539
Hurricane Creek Above Tributary #7	3580	3492
Tributary #7 North Branch at Limit of Study	185	185
Tributary #7 North Branch at FM 324	512	512
Tributary #7 South Branch at Limit of Study	355	355
Tributary #7 South Branch at Lake A	611	611
Tributary #7 South Branch Below Lake A	479	479
Tributary #7 South Branch at FM 324	677	677
Tributary #7 at FM 324	1095	1095
Tributary #7 at Mouth	1140	1140
Hurricane Creek Below Tributary #7	4028	3951

TABLE 5-4: COMPARISON OF COMPUTED 100-YEAR PEAK FLOW RATES

Location	Existing 100-Year	Interim 100-Year
Hurricane Creek at Limit of Study	585	585
Hurricane Creek Above Tributary #1	1736	1736
Tributary #1 at Whippoorwill	507	507
Tributary #1 Above North Branch	618	618
Tributary #1 Below North Branch	1233	931
Tributary #1 at Mouth	1397	1310
Hurricane Creek Below Tributary #1	3127	3046
Hurricane Creek Above Tributary #2	3372	3239
Tributary #2 at Chestnut (SH 58)	596	596
Tributary #2 at Mouth	989	989
Hurricane Creek Below Tributary #2	3946	3838
Hurricane Creek Above Tributary #3	3911	3792
Tributary #3 at Park Lane	430	430
Tributary #3 at Mouth	1031	1031
Hurricane Creek Below Tributary #3	4752	4652
Hurricane Creek Above Tributary #4	4756	4655
Tributary #4 at Limit of Study	361	361
Tributary #4 at Mouth	777	523
Hurricane Creek Below Tributary #4	5148	5044
Hurricane Creek Above Tributary #5	5205	5080
Tributary #5 North Branch at Limit of Study	367	367
Tributary #5 North Branch at US 59	630	630
Tributary #5 South Branch at Limit of Study	310	310
Tributary #5 South Branch at US 59	658	658
Tributary #5 at US 59	1281	1281
Tributary #5 at Mouth	1339	1339
Hurricane Creek Below Tributary #5	5748	5586
Hurricane Creek Above Tributary #6	5769	5613
Tributary #6 at Loop 287	342	342
Tributary #6 at Mouth	415	415
Hurricane Creek Below Tributary #6	6124	5949
Hurricane Creek Above Tributary #7	6032	5860
Tributary #7 North Branch at Limit of Study	307	307
Tributary #7 North Branch at FM 324	812	812
Tributary #7 South Branch at Limit of Study	582	582
Tributary #7 South Branch at Lake A	985	985
Tributary #7 South Branch Below Lake A	815	815
Tributary #7 South Branch at FM 324	1150	1150
Tributary #7 at FM 324	1857	1857
Tributary #7 at Mouth	1973	1973
Hurricane Creek Below Tributary #7	6805	6618

Table 5-5 provides a summary of computed routing results for each of the three detention facilities included in the interim conditions HEC-1 model.

TABLE 5-5: SUMMARY OF COMPUTED DETENTION ROUTING RESULTS								
Parameter	Basin #1	Basin #3	Basin #4	Basin #5	Basin #6	Basin #8	Basin #9	Basin #10
10-Year Storm Event								
Peak Inflow (cfs)	228	-----	261	-----	-----	470	-----	-----
Peak Discharge (cfs)	72	-----	134	-----	-----	165	-----	-----
Maximum Elevation (feet)	310.63	-----	268.58	-----	-----	281.37	-----	-----
100-Year Storm Event								
Peak Inflow (cfs)	383	-----	422	-----	-----	818	-----	-----
Peak Discharge (cfs)	112	-----	288	-----	-----	266	-----	-----
Maximum Elevation (feet)	312.87	-----	269.51	-----	-----	284.64	-----	-----

5.6 Summary of Interim Conditions HEC-RAS Modeling Results

5.6.1 Discussion of Interim Conditions HEC-RAS Analysis

Because the proposed interim conditions drainage improvements will affect only Hurricane Creek, Tributary #1, and Tributary #4, only those streams are analyzed for interim conditions. HEC-RAS models used in the interim conditions analysis are identical to those used in the existing conditions analysis for these three streams, except that flow rates are modified to reflect the presence of the proposed regional drainage basins and proposed cross-drainage structure replacements are assumed to be in place.

5.6.2 Interim Conditions HEC-RAS Results for Hurricane Creek

Table 5-6 provides a summary of computed interim conditions water surface elevations for Hurricane Creek. Elevations are given at the upstream side of each of the roadways which cross Hurricane Creek. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. Exhibit 5.2 illustrates computed interim conditions stream profiles for Hurricane Creek.

TABLE 5-6: SUMMARY OF INTERIM FLOOD LEVELS ALONG HURRICANE CREEK							
	HEC-RAS	Min. Top	Computed Water Surface Elevation				
	Cross-	of Road					
Location	Section	Elevation	5-Year	10-Year	25-Year	50-Year	100-Year
FM 324	4196.5	230.02	226.83	227.72	228.77	229.04	***230.42***
Southern Pacific RR	4311.5	227.88	227.42	***228.57***	***229.58***	***229.94***	***230.84***
FM 819	10346.5	235.50	233.52	234.69	***235.53***	***235.83***	***236.36***
Loop 287	17102.5	249.00	247.22	248.20	***249.06***	***249.49***	***249.87***
U.S. 59 (1st Street)	20690.5	258.00	253.37	254.72	255.82	257.09	257.25
Tulane Street	26932.5	266.70	265.16	266.08	***266.87***	***267.31***	***267.66***
South 3rd Street	28288.5	269.30	266.32	267.48	268.48	269.13	***269.51***
Denman Ave. (US 69)	30231.5	276.50	269.94	270.89	271.69	272.29	272.92
Chestnut Village	30933.5	276.38	273.97	275.04	276.11	***276.69***	***277.04***
Chestnut Village	31423.5	276.04	274.69	275.79	***276.76***	***277.19***	***277.47***
Timberland Drive	32043.5	282.20	276.61	277.61	278.51	279.06	279.62
Lufkin Avenue	33000.5	284.00	279.83	280.55	281.10	281.72	282.37
Albertson's Driveway	33383.5	284.20	281.92	282.55	283.18	283.75	***284.34***
Railroad	33545.5	286.70	282.58	283.24	283.87	284.40	285.06
Groesbeck Avenue	34193.5	287.37	286.66	***287.53***	***287.83***	***287.94***	***288.05***

Table 5-7 provides a comparison between 10-year and 100-year flood levels computed for existing and interim conditions. As indicated, 10-year flood levels along Hurricane Creek are reduced by as much as 0.28 foot with the proposed regional detention facilities in place. The maximum reduction in 100-year flood levels is 0.27 foot.

TABLE 5-7: COMPARISON OF EXISTING & INTERIM FLOOD LEVELS ALONG HURRICANE CREEK							
	HEC-RAS	Computed Water Surface Elevations					
	Cross-	Existing	Interim		Existing	Interim	
Location	Section	10-Year	10-Year	Change	100-Year	100-Year	Change
FM 324	4196.5	227.80	227.72	-0.08	230.77	230.42	-0.25
Southern Pacific RR	4311.5	228.66	228.57	-0.09	231.11	230.84	-0.27
FM 819	10346.5	234.80	234.69	-0.11	236.44	236.36	-0.08
Loop 287	17102.5	248.39	248.20	-0.19	249.93	249.87	-0.06
U.S. 59 (1st Street)	20690.5	255.00	254.72	-0.28	257.32	257.25	-0.07
Tulane Street	26932.5	266.24	266.08	-0.16	267.71	267.66	-0.05
South 3rd Street	28288.5	267.58	267.48	-0.10	269.52	269.51	-0.01
Denman Ave. (US 69)	30231.5	270.90	270.89	-0.01	272.92	272.92	0.00
Chestnut Village	30933.5	275.04	275.04	0.00	277.04	277.04	0.00
Chestnut Village	31423.5	275.79	275.79	0.00	277.47	277.47	0.00
Timberland Drive	32043.5	277.61	277.61	0.00	279.62	279.62	0.00
Lufkin Avenue	33000.5	280.55	280.55	0.00	282.37	282.37	0.00
Albertson's Driveway	33383.5	282.55	282.55	0.00	284.34	284.34	0.00
Railroad	33545.5	283.24	283.24	0.00	285.06	285.06	0.00
Groesbeck Avenue	34193.5	287.53	287.53	0.00	288.05	288.05	0.00

5.6.3 Interim Conditions HEC-RAS Results for Hurricane Creek Tributary #1

Table 5-8 provides a summary of computed interim conditions water surface elevations for Hurricane Creek Tributary #1. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. Exhibit 5.3 illustrates computed interim conditions stream profiles for Tributary #1.

TABLE 5-8: SUMMARY OF INTERIM FLOOD LEVELS ALONG TRIBUTARY #1

Location	HEC-RAS Cross-Section	Min. Top of Road Elevation	Computed Water Surface Elevation 5-Year	10-Year	25-Year	50-Year	100-Year
Tulane Street	99.5	264.09	260.06	261.20	262.20	263.01	263.98
South 3rd Street	1125.5	269.35	264.86	265.97	267.03	267.93	268.99
Chestnut Drive	5339.5	281.07	279.17	280.06	281.05	***281.34***	***281.52***
Denman Ave. (US 69)	6086.5	283.45	283.45	***283.93***	***284.20***	***284.35***	***284.47***
Jones Street	7379.5	285.97	***287.50***	***288.10***	***288.45***	***288.67***	***288.89***
Hunters Creek Drive	8471.5	291.14	***292.57***	***292.75***	***292.95***	***293.11***	***293.28***
Howard Avenue	9488.5	298.40	***298.75***	***299.19***	***299.38***	***299.47***	***299.51***
Whippoorwill Drive	10962.5	303.96	***304.02***	***304.48***	***304.72***	***304.87***	***305.04***

Table 5-9 provides a comparison between 10-year and 100-year flood levels computed for existing and interim conditions. As indicated, 10-year flood levels along Tributary #1 are reduced by as much as 3.16 feet with the proposed regional detention facility in place upstream of Lotus Lane. The maximum reduction in 100-year flood levels is 1.02 feet.

TABLE 5-9: COMPARISON OF EXISTING & INTERIM FLOOD LEVELS ALONG TRIBUTARY #1

Location	HEC-RAS Cross-Section	Computed Water Surface Elevations Existing 10-Year	Interim 10-Year	Change	Existing 100-Year	Interim 100-Year	Change
Tulane Street	99.5	261.68	261.20	-0.48	264.42	263.98	-0.44
South 3rd Street	1125.5	269.13	265.97	-3.16	270.01	268.99	-1.02
Chesnut Drive	5339.5	281.01	280.06	-0.95	281.77	281.52	-0.25
Denman Ave. (US 69)	6086.5	284.21	283.93	-0.28	284.65	284.47	-0.18
Jones Street	7379.5	288.50	288.10	-0.40	289.36	288.89	-0.47
Hunters Creek Drive	8471.5	292.77	292.75	-0.02	293.32	293.28	-0.04
Howard Avenue	9488.5	299.19	299.19	0.00	299.53	299.51	-0.02
Whippoorwill Drive	10962.5	304.87	304.48	-0.39	305.12	305.04	-0.08

5.6.4 Interim Conditions HEC-RAS Results for Hurricane Creek Tributary #4

Table 5-10 provides a summary of computed interim conditions water surface elevations for Hurricane Creek Tributary #4. Elevations are given at the upstream side of each of the roadways which cross the tributary. Minimum top of road elevations are provided in the table for comparison. Computed water surface elevations shown in bold italicized print are those which exceed the minimum top of road elevation. Exhibit 5.4 illustrates computed interim conditions stream profiles for Tributary #4.

TABLE 5-10: SUMMARY OF INTERIM FLOOD LEVELS ALONG TRIBUTARY #4							
	HEC-RAS	Min. Top	Computed Water Surface Elevation				
Location	Cross-Section	of Road Elevation	5-Year	10-Year	25-Year	50-Year	100-Year
Scenic Acres	2296.5	252.00	249.44	250.00	250.49	250.73	251.02
US 59	3357.5	259.59	255.38	255.95	256.43	256.79	257.50
Tulane Street	4205.5	261.69	261.30	***261.79***	***262.05***	***262.16***	***262.41***

Table 5-11 provides a comparison between 10-year and 100-year flood levels computed for existing and interim conditions. As indicated, 10-year flood levels along Tributary #4 downstream of the proposed detention basin are reduced by as much as 1.41 feet. The maximum reduction in 100-year flood levels is 2.48 feet. Flood levels upstream of the basin remain unchanged for interim conditions.

TABLE 5-11: COMPARISON OF EXISTING & INTERIM FLOOD LEVELS ALONG TRIBUTARY #4							
	HEC-RAS	Computed Water Surface Elevations					
Location	Cross-Section	Existing 10-Year	Interim 10-Year	Change	Existing 100-Year	Interim 100-Year	Change
Scenic Acres	2296.5	250.88	250.00	-0.88	251.87	251.02	-0.85
US 59	3357.5	257.36	255.95	-1.41	259.98	257.50	-2.48
Tulane Street	4205.5	262.46	261.79	-0.67	263.31	262.41	-0.90

5.7 Interim Conditions Floodway Computations

Interim conditions floodway data have been computed for Hurricane Creek and all studied tributaries. Floodway method 4, which establishes floodway encroachments based on an equal loss of flow conveyance on each side of the stream channel, is used for preliminary floodway computations. Floodway Method 1, which relies on the modeler to input floodway encroachments, is used for final floodway computations on Hurricane Creek and all tributary streams. Method 1 floodway encroachments are based on Method 4 results, with adjustments made where appropriate to avoid oscillations in floodway widths, provide consistency in floodway data at roadway crossings, etc. Surcharge values are kept at or below 1.00 foot at all cross-sections.

5.8 Interim Conditions Flood Plain & Floodway Mapping

Flood plain and floodway boundaries for interim conditions are illustrated on Exhibit 5.5. Also illustrated on this exhibit are interim conditions base flood elevations, which are indicated with a "tick" mark across the channel and a number signifying the computed 100-year flood level. In the lower reaches of the tributary streams, the computed base flood levels are lower than the backwater from Hurricane Creek. In these areas, the backwater elevation from Hurricane Creek is used to establish flood plain boundaries.

LIST OF EXHIBITS

LIST OF APPENDICES

A. Existing Conditions Hydrologic Parameters for Hurricane Creek Sub-Areas
B. Cultural Resources Report Prepared by Prewitt & Associates, Inc.
C. Wetlands Investigation Report Prepared by Wetland Technologies Corporation
D. Supplemental Report Prepared by Wetland Technologies Corporation
E. Ultimate Conditions Hydrologic Parameters for Hurricane Creek Sub-Areas
F. Interim Conditions Hydrologic Parameters for Hurricane Creek Sub-Areas
G. Preliminary Construction Cost Estimates, Future Conditions Drainage Improvements
H. Preliminary Construction Cost Estimates, Interim Conditions Drainage Improvements

LIST OF REFERENCES AND DATA SOURCES

1. Field Survey Data for Hurricane Creek and Tributaries, Provided by Everett Griffith Jr. & Associates, Inc. *Soil Survey of Angelina County, Texas*
2. U.S. Geological Survey "Lufkin," "Keltys," "Clawson," and "Redland" 7.5-Minute Quadrangle Maps
3. *Flood Insurance Study for the City of Lufkin, Texas.*
4. Aerial Topographic Maps Developed by United Aerial Mapping, Inc.
5. *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* (U.S. Weather Bureau Technical Paper No. 40)
6. *Five- to 60-Minute Precipitation Frequency for the Eastern and Central United States* (NOAA Technical Memorandum NWS HYDRO-35)
7. *SCS National Engineering Handbook*, Section 4.
8. *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (U.S. Geologic Survey Water-Supply Paper 2339)

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
LUFKIN, TEXAS

EXISTING WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	HC1A	HC1B	HCT1A	T1B1	T1B2	T1B3	T1B4	T1B5
			Parameter Values for Given Sub-Area Number							
Drainage Area										
Area		ac	302	965	206	78	157	44	39	369
Area		sm	.472	1.508	.322	.122	.245	.069	.061	.577
Impervious Cover										
Land Use	I(%)									
Ind./Comm.	80%	ac	98.5	345.7	21.5	18.5	.0	.0	.0	68.4
Multi-Family	70%	ac	.0	3.7	.0	.0	2.2	.0	.0	10.2
Highway	60%	ac	5.9	.0	13.1	.0	.0	.0	.0	.0
Community	40%	ac	.0	8.7	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	68.6	318.3	28.2	30.8	14.8	25.8	38.6	175.7
S-F (Light)	15%	ac	128.5	154.9	1.2	.0	.0	.0	.0	5.4
Vacant/Parks	0%	ac	.0	134.2	142.3	28.2	140.3	18.4	.6	98.4
Total		ac	301.5	965.5	206.3	0%	0%	0%	0%	0%
						77.5	157.3	44.2	39.2	358.1
Imperv. Area		ac	122.2	401.4	33.7					
Imperv. Cover		%	40.5	41.6	16.3	24.0	6.0	7.7	11.6	115.4
						31.0	3.8	17.5	29.5	32.2
Overland		Curve:	C	B	B					
Distance		ft	300	300	300	C	B	C	C	C
Slope		%	1.8	2.5	2.5	300	300	300	300	300
Velocity		ft/s	1.0	.8	.8	2.5	4.0	4.5	5.0	2.0
Travel Time		min	5.00	6.25	6.25	1.1	1.0	1.6	1.6	1.0
						4.55	5.00	3.13	3.13	5.00
Shallow Concentrated		Curve:	F	F	F					
Distance		ft	300	400	700	F	F	F	F	F
Slope		%	1.8	2.5	2.2	1000	300	700	0	0
Velocity		ft/s	2.0	2.4	2.3	4.0	2.9	1.8	.0	.0
Travel Time		min	2.50	2.78	5.07	3.1	2.6	2.1	.0	.0
						5.38	1.92	5.56	.00	.00
Paved or Gully		Curve:	G	G	G					
Distance		ft	4800	5700	2280	G	G	G	G	G
Slope		%	.9	1.2	.9	300	3000	0	800	2500
Velocity		ft/s	1.9	2.2	1.9	1.0	1.2	.0	3.3	2.0
Travel Time		min	42.11	43.18	20.00	2.0	2.2	.0	3.6	2.8
						2.0	2.2	.0	3.6	2.8
Storm Sewer						2.50	22.73	.00	3.70	14.88
Distance		ft	0	0	0					
Slope		%	.0	.0	.0					
Velocity		ft/s	.0	.0	.0	0	0	0	0	0
Travel Time		min	.00	.00	.00	.0	.0	.0	.0	.0
						.00	.00	.00	.00	.00
Drainage Channel										
Distance		ft	0	7000	0					
Velocity		ft/s	.0	3.0	.0	1100	0	1600	1800	6400
Travel Time		min	.00	38.89	.00	3.0	.0	3.0	3.0	3.0
						6.11	.00	8.89	10.00	35.56
TC (minutes)			49.61	91.10	31.32					
TC (hours)			.83	1.52	.52	18.53	29.65	17.57	16.83	55.44
R = 2 x TC (hours)			1.65	3.04	1.04	.31	.49	.29	.28	.92
R = 3 x TC (hours)			2.48	4.55	1.57	.62	.99	.59	.56	1.85

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
LUFKIN, TEXAS

EXISTING WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Number								
			HC2	HCT2A	HCT2B	HC3	HCT3A	HCT3B	HC4	HCT4A	HCT4B
Drainage Area											
Area		ac	403	234	312	131	321	519	86	126	372
Area		sm	.630	.366	.488	.205	.502	.811	.134	.197	.581
Impervious Cover											
Land Use	I(%)										
Ind./Comm.	80%	ac	73.5	37.5	66.4	65.6	141.5	17.6	7.9	3.1	32.3
Multi-Family	70%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
Highway	60%	ac	.0	12.0	21.7	13.0	.0	.0	3.8	.0	4.5
Community	40%	ac	.0	.0	.0	.0	13.4	4.3	.0	.0	.0
S-F (Typical)	30%	ac	114.2	99.7	4.2	.0	126.5	270.7	.0	16.9	9.1
S-F (Light)	15%	ac	18.9	.0	2.8	6.5	21.0	134.6	11.6	84.9	78.1
Vacant/Parks	0%	ac	199.3	84.9	216.8	42.9	18.9	91.5	60.9	21.2	247.9
Total		ac	405.9	234.1	311.9	128.0	321.3	518.7	84.2	126.1	371.9
Imperv. Area		ac	95.9	67.1	67.8	61.3	159.7	117.2	10.3	20.3	43.0
Imperv. Cover		%	23.6	28.7	21.7	47.9	49.7	22.6	12.3	16.1	11.6
Overland		Curve:	C	B	B	C	C	C	C	B	B
Distance		ft	300	300	200	300	300	300	300	300	300
Slope		%	3.6	1.3	2.5	1.8	.7	1.3	1.3	5.0	3.0
Velocity		ft/s	1.3	.6	.8	1.0	.6	.8	.8	1.1	.9
Travel Time		min	3.85	8.33	4.17	5.00	8.33	6.25	6.25	4.55	5.56
Shallow Concentrated		Curve:	F	F	F	F	F	F	F	F	F
Distance		ft	600	200	200	300	0	300	400	200	300
Slope		%	1.8	5.6	2.5	1.8	.0	1.3	5.3	5.0	6.7
Velocity		ft/s	2.0	3.5	2.4	2.0	.0	1.7	3.4	3.3	3.9
Travel Time		min	5.00	.95	1.39	2.50	.00	2.94	1.96	1.01	1.28
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	5470	2270	2200	1120	7800	2100	0	1900	1200
Slope		%	1.1	2.2	2.3	.6	.6	1.4	.0	1.6	2.0
Velocity		ft/s	2.1	3.0	3.0	1.6	1.6	2.4	.0	2.5	2.8
Travel Time		min	43.41	12.61	12.22	11.67	81.25	14.58	.00	12.67	7.14
Storm Sewer											
Distance		ft	0	0	0	0	0	0	0	0	0
Slope		%	.0	.0	.0	.0	.0	.0	.0	.0	.0
Velocity		ft/s	.0	.0	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00	.00	.00	.00
Drainage Channel											
Distance		ft	2500	1400	5000	2350	0	6710	1850	300	6200
Velocity		ft/s	3.0	3.0	3.0	3.0	.0	3.0	3.0	3.0	3.0
Travel Time		min	13.89	7.78	27.78	13.06	.00	37.28	10.28	1.67	34.44
TC (minutes)			66.15	29.67	45.56	32.22	89.58	61.05	18.49	19.89	48.42
TC (hours)			1.10	.49	.76	.54	1.49	1.02	.31	.33	.81
R = 2 x TC (hours)			2.20	.99	1.52	1.07	2.99	2.04	.62	.66	1.61
R = 3 x TC (hours)			3.31	1.48	2.28	1.61	4.48	3.05	.92	.99	2.42

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
LUFKIN, TEXAS

EXISTING WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Number								
			HC5	HCT5A	HCT5B	HCT5C	HCT5D	HCT5E	HC6	HCT6A	HCT6B
Drainage Area											
Area		ac	308	139	172	155	223	134	78	110	285
Area		sm	.481	.217	.269	.242	.348	.209	.122	.172	.445
Impervious Cover											
Land Use	I(%)										
Ind./Comm.	80%	ac	30.0	.0	1.2	.0	3.5	10.2	.0	24.3	7.3
Multi-Family	70%	ac	.0	.0	5.6	.0	7.2	19.4	1.5	.0	.0
Highway	60%	ac	6.1	.0	.1	.0	.1	11.3	.0	12.2	.1
Community	40%	ac	.0	.0	.0	.0	6.6	1.0	.0	.0	.0
S-F (Typical)	30%	ac	.4	1.2	.8	.0	4.6	.0	.0	5.9	.0
S-F (Light)	15%	ac	45.1	19.6	23.2	35.0	13.2	6.4	.0	23.5	44.3
Vacant/Parks	0%	ac	227.5	117.8	141.5	119.9	188.1	85.5	76.5	44.1	233.3
Total		ac	309.1	138.6	172.4	154.9	223.3	133.8	78.0	110.0	285.0
Imperv. Area		ac	34.5	3.3	8.7	5.3	13.9	29.9	1.1	32.1	12.5
Imperv. Cover		%	11.2	2.4	5.0	3.4	6.2	22.3	1.3	29.1	4.4
Overland		Curve:	B	B	B	B	B	B	B	B	C
Distance		ft	300	300	300	300	300	300	300	300	300
Slope		%	4.0	3.3	4.0	.5	2.5	4.5	5.0	2.0	1.3
Velocity		ft/s	1.0	.9	1.0	.4	.8	1.1	1.1	.7	.8
Travel Time		min	5.00	5.56	5.00	12.50	6.25	4.55	4.55	7.14	6.25
Shallow Concentrated		Curve:	F	F	F	F	F	F	F	F	F
Distance		ft	400	400	200	500	1100	600	200	400	1800
Slope		%	5.0	4.0	5.0	.5	2.7	3.3	5.0	2.0	1.6
Velocity		ft/s	3.3	3.0	3.4	1.1	2.5	2.7	3.3	2.1	1.9
Travel Time		min	2.02	2.22	.98	7.58	7.33	3.70	1.01	3.17	15.79
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	3320	1100	1900	2740	2300	2000	1990	1420	0
Slope		%	1.8	2.7	2.5	1.8	1.3	1.5	1.2	1.8	.0
Velocity		ft/s	2.7	3.3	3.2	2.7	2.3	2.5	2.2	2.7	.0
Travel Time		min	20.49	5.56	9.90	16.91	16.67	13.33	15.08	8.77	.00
Storm Sewer											
Distance		ft	0	0	0	0	0	0	0	0	0
Slope		%	.0	.0	.0	.0	.0	.0	.0	.0	.0
Velocity		ft/s	.0	.0	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00	.00	.00	.00
Drainage Channel											
Distance		ft	3850	1800	3700	400	2900	2400	630	0	7600
Velocity		ft/s	3.0	3.0	3.0	3.0	3.0	3.0	3.0	.0	3.0
Travel Time		min	21.39	10.00	20.56	2.22	16.11	13.33	3.50	.00	42.22
TC (minutes)			48.90	23.33	36.43	39.21	46.36	34.92	24.13	19.08	64.26
TC (hours)			.82	.39	.61	.65	.77	.58	.40	.32	1.07
R = 2 x TC (hours)			1.63	.78	1.21	1.31	1.55	1.16	.80	.64	2.14
R = 3 x TC (hours)			2.45	1.17	1.82	1.96	2.32	1.75	1.21	.95	3.21

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
LUFKIN, TEXAS

EXISTING WATERSHED CONDITIONS
December 30, 1998

Parameter	I(%)	Units	Parameter Values for Given Sub-Area Number						
			HC7	HCT7A	HCT7B	HCT7C	HCT7D	HCT7E	HCT7F
Drainage Area									
Area		ac	180	118	335	203	114	415	158
Area		sm	.281	.184	.523	.317	.178	.648	.247
Impervious Cover									
Land Use	I(%)								
Ind./Comm.	80%	ac	3.3	.0	12.0	.0	.0	38.2	.1
Multi-Family	70%	ac	.8	.0	6.4	.0	.0	.0	.0
Highway	60%	ac	.0	.0	6.9	.0	.0	5.4	.2
Community	40%	ac	6.1	.0	23.3	.0	.0	.0	5.5
S-F (Typical)	30%	ac	.0	34.9	158.1	120.3	103.8	154.0	.0
S-F (Light)	15%	ac	3.4	10.4	45.0	.0	.0	25.9	40.2
Vacant/Parks	0%	ac	164.2	72.9	83.6	83.1	9.8	191.6	112.4
Total		ac	177.8	118.2	335.3	203.4	113.6	415.1	158.4
Imperv. Area		ac	6.2	12.0	81.7	36.1	31.1	83.9	8.4
Imperv. Cover		%	3.5	10.2	24.4	17.7	27.4	20.2	5.3
Overland		Curve:	B	B	B	B	C	C	C
Distance		ft	300	200	300	300	300	200	300
Slope		%	3.3	2.5	3.0	2.5	2.5	3.0	2.9
Velocity		ft/s	.9	.8	.9	.8	1.1	1.2	1.2
Travel Time		min	5.56	4.17	5.56	6.25	4.55	2.78	4.17
Shallow Concentrated		Curve:	F	F	F	F	F	F	F
Distance		ft	200	200	500	200	900	200	1000
Slope		%	3.3	2.5	4.0	4.0	2.5	3.0	2.2
Velocity		ft/s	2.7	2.4	3.0	3.0	2.4	2.6	2.2
Travel Time		min	1.23	1.39	2.78	1.11	6.25	1.28	7.58
Paved or Gully		Curve:	G	G	G	G	G	G	G
Distance		ft	3410	1500	1300	1900	1000	3800	1000
Slope		%	1.3	1.6	2.3	1.9	2.0	1.6	2.0
Velocity		ft/s	2.3	2.6	3.0	2.8	2.8	2.6	2.8
Travel Time		min	24.71	9.62	7.22	11.31	5.95	24.36	5.95
Storm Sewer									
Distance		ft	0	0	0	0	0	0	0
Slope		%	.0	.0	.0	.0	.0	.0	.0
Velocity		ft/s	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00	.00
Drainage Channel									
Distance		ft	2640	2100	6100	700	0	4800	3300
Velocity		ft/s	3.0	3.0	3.0	3.0	.0	3.0	3.0
Travel Time		min	14.67	11.67	33.89	3.89	.00	26.67	18.33
TC (minutes)			46.17	26.84	49.44	22.56	16.75	55.09	36.03
TC (hours)			.77	.45	.82	.38	.28	.92	.60
R = 2 x TC (hours)			1.54	.89	1.65	.75	.56	1.84	1.20
R = 3 x TC (hours)			2.31	1.34	2.47	1.13	.84	2.75	1.80

ASSESSMENT OF THE POTENTIAL FOR CULTURAL RESOURCES IN THE HURRICANE AND MILL CREEK WATERSHEDS, ANGELINA COUNTY, TEXAS

by

Ross C. Fields

Principal Investigator: Ross C. Fields

Letter Report No. 421

Submitted to

Dodson and Associates, Inc.
Houston, Texas

by

Prewitt and Associates, Inc.
Consulting Archeologists
Austin, Texas

April 1998

Texas Antiquities Committee Archeology Permit No. 1971

Introduction: This project consists of a files search and reconnaissance field survey to identify known cultural resources within the Hurricane and Mill Creek watersheds and to assess the potential for as-yet-unrecorded resources. These two watersheds are within and adjacent to the City of Lufkin in Angelina County, Texas. The larger of the two, Hurricane Creek, arises within the central and eastern parts of the city and flows southward to join Cedar Creek south-southwest of town. Cedar Creek is a tributary to Jack Creek, which flows into the Neches River. The part of the Mill Creek watershed under consideration here encompasses several generally north-flowing tributaries in the north-central part of the city, with Mill Creek itself being an eastward- and northeastward-flowing tributary of the Angelina River.

This work was done in March–April 1998 by Prewitt and Associates, Inc., for Dodson and Associates, Inc., of Houston, Texas, as part of a planning study concerning future drainage improvements along these streams. The study was done for the City of Lufkin, with partial funding by the Texas Water Development Board. Because of the funding sources, the cultural resources work was done under Texas Antiquities Committee Archeology Permit No. 1971 from the Texas Historical Commission. The overall goal of the cultural resources effort was to provide information on known and potential sites so that areas sensitive in terms of cultural resources can be identified. This will serve as baseline data for the future development of plans for specific drainage improvement projects.

Setting: The mainstem of Hurricane Creek heads in the middle of town near the intersection of Chestnut and Dozier Streets (Figure 1). From there, it flows south along the east side of U.S. Highway 59 to Lufkin Mall where it crosses U.S. Highway 59 and flows southwestward behind Angelina Mall to Loop 287. Three tributaries join the mainstem along this stretch. Tributaries 1 and 2 are westward-flowing streams that join at Kiwanis Park and Lufkin Mall, respectively. Tributary 3 flows to the south and joins just north of Loop 287. Much of this part of the watershed is urbanized, with substantial commercial development along U.S. Highway 59 and Loop 287 and residential development mostly along the upper parts of Tributaries 1 and 3. Relatively undeveloped are the mainstem between Denman Avenue and Lufkin Mall and between Angelina Mall and Grace-Dunn Richardson Park (although this stretch flows through Kiwanis Park and is the route of the Azalea Trail connecting the two parks), Tributary 1 between Chestnut Street and Kiwanis Park, Tributary 2 between Chestnut Street and Tulane Road south of Loop 287, and Tributary 3 in and just north of Grace-Dunn Richardson Park.

Below Loop 287, the mainstem runs south and west through largely undeveloped land before joining Cedar Creek west of FM 324 (Figure 2). Tributaries 4, 5, and 7 are west-flowing streams that join from the east (not far south of Loop 287, southwest of the intersection of U.S. Highway 59 and Daniel McCall Road, and just east of FM 324, respectively), while Tributary 6 flows south and joins the west bank between FM 324 and Daniel McCall Road. Like the mainstem, Tributary 6 and the lower reaches of the three east-bank tributaries have seen limited development. Parts of the middle and upper reaches of the eastern tributaries are more urbanized, with commercial development along U.S. Highway 59 and residential development along the upper reaches of Tributary 4 and both branches of Tributary 7.

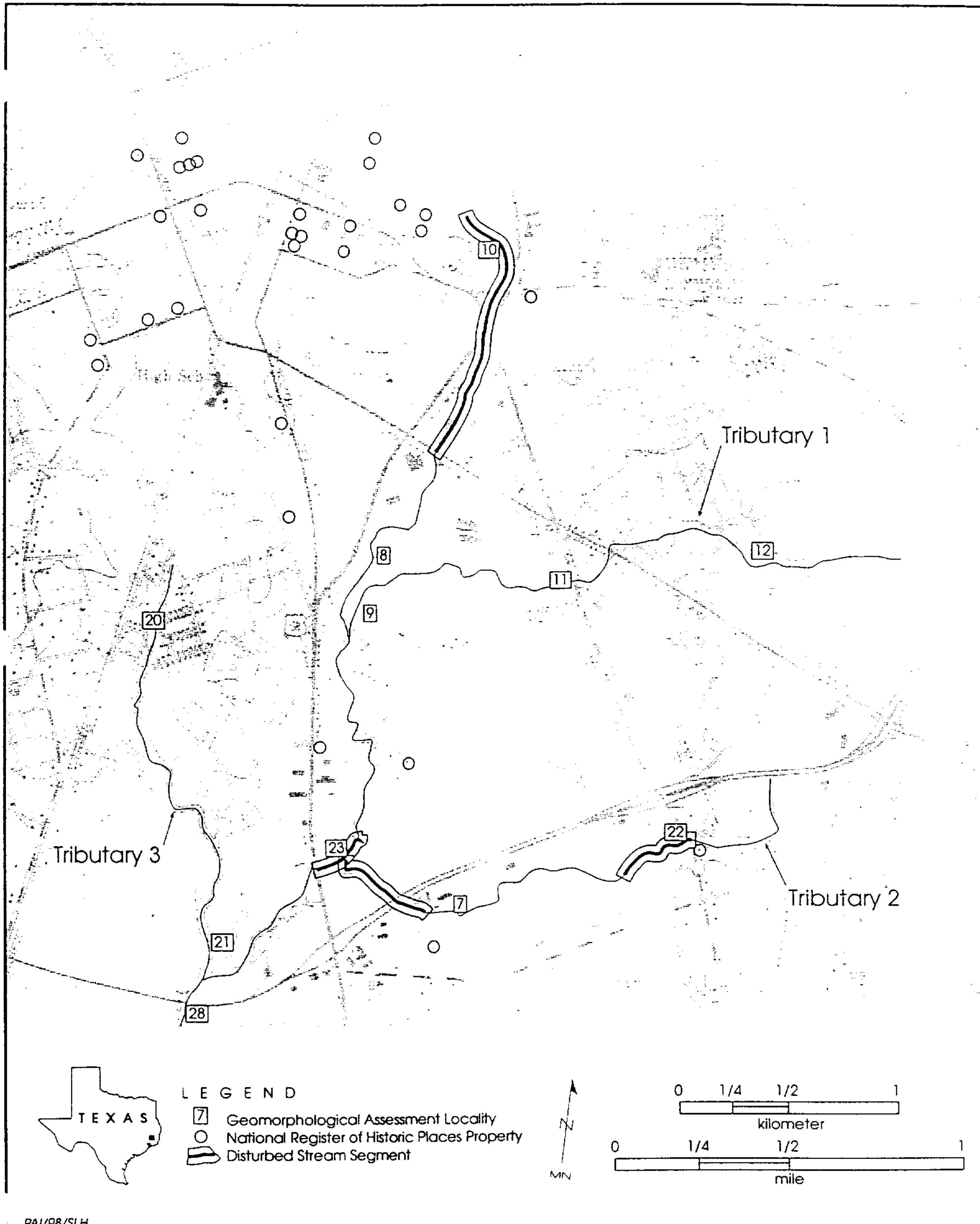


Figure 1. USGS map section (Lufkin quadrangle) showing upper Hurricane Creek watershed.

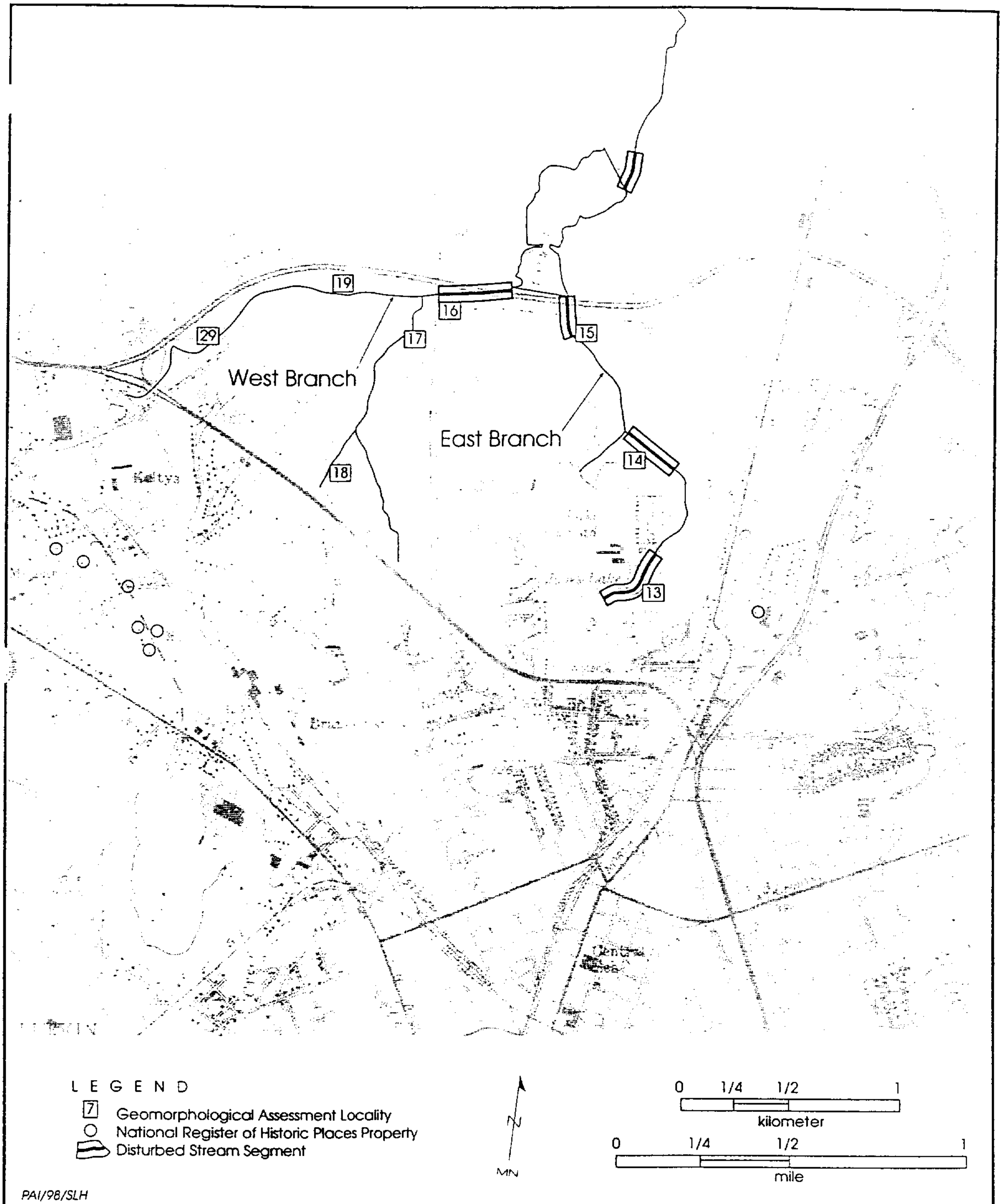
Two branches of Mill Creek are within the project area (Figure 3). The east branch heads just north of Kurth Drive near Martin Luther King Road. Its upper reaches have been affected by recreational development (i.e., Jones Park and the Lufkin Country Club), as well as construction and use of Lufkin Intermediate School and nearby residential development. The stretch north of the country club and south of Loop 287 is less developed. The two forks of the west branch head not far south of Kurth Drive between Sayers Drive and the intersection of Kurth Drive and Loop 287. These streams have not been extensively developed, although the west fork is sandwiched between Loop 287 and the tracks of the Angelina and Neches River Railroad. The east and west branches join just north of Loop 287 where they have been dammed to create Ellen Trout Memorial Lake. This part of the project area has been affected by recreational development around the lake and the construction of a water plant just to the north. The segment of Mill Creek north of the water plant appears to be largely undeveloped.

The project area is on the West Gulf Coastal Plain, where the bedrock geology consists of a series of stacked and tilted units that dip and become progressively younger toward the Gulf. The Eocene Yegua Formation, consisting of fluvial-deltaic sands and clays, crops out in the Lufkin area (Bureau of Economic Geology 1992). The topography generally is gently rolling, with elevations ranging from ca. 210 ft above mean sea level at the confluence of Hurricane and Cedar Creeks to 380 ft on a high hill in the western part of the Mill Creek watershed. The lower and middle reaches of Hurricane Creek have a well-developed floodplain that reaches widths of 1,000–2,000 ft. The upper part of this creek, its tributaries, and Mill Creek have floodplains that are less substantial.

Mapped soils in the uplands belong primarily to the loamy Fuller-Keltys and Keltys-Kurth groups (Dolezel 1988:5–7). They typically consist of fine sandy loam A and E horizons to a depth of 26–39 inches, with sandy clay, sandy clay loam, silty clay loam, loam, or fine sandy loam B or E horizons to 47–56 inches. The Fuller and Keltys soils are underlain by siltstone, while sandstone underlies Kurth soils. Koury floodplain soils are mapped along the lower to middle reaches of Hurricane Creek and consist of a loam and very fine sandy loam A horizon to 17 inches, a silt loam B horizon to 50 inches, and a silt loam C horizon to at least 70 inches. As discussed below, observations made during this project suggest that these alluvial deposits may be quite thick (up to 4–5 m, or 13–16 ft).

Methods: This project consisted of two primary tasks, a files search and a reconnaissance field survey. The following sources were consulted in the files search: (1) the map, county, and site files at the Texas Archeological Research Laboratory at The University of Texas at Austin (for known archeological sites); (2) the county report files at the Texas Historical Commission (for previous archeological surveys); and (3) the National Register and neighborhood surveys files at the Texas Historical Commission (for recorded historic properties).

The reconnaissance field survey was carried out over two days. It consisted of two subtasks. The first involved inspection of 29 locales along Hurricane and Mill Creeks to assess the thickness of the Holocene deposits, and thus the potential for buried archeological sites (see Figures 1–3). The locales were chosen to sample the full lengths of the streams in the study area, with the primary restriction being that most locales had to be accessible via public roads.



igure 3. USGS map section (Lufkin, Kelty and Redlands quadrangles) showing Mill Creek watershed.

Twenty–one locales were in the Hurricane Creek watershed: six on the mainstem, three on Tributary 1, two each on Tributaries 2–4, one each on Tributaries 5 and 6, and four on Tributary 7. Eight locales on Mill Creek were examined, five on the west branch and three on the east branch. Observations made at each locale included approximate cutbank height (estimated, not measured) and visibility, thickness of the Holocene sediments, presence/ absence of bedrock, and extent and kind of disturbance. Formal descriptions of cleaned profiles were not done, and no shovel tests were dug to try to locate archeological sites.

The second subtask involved combining observations made at the 29 locales above with those made during a windshield survey of both watersheds to identify stream segments that obviously are too disturbed to be considered sensitive in terms of cultural resources. This entailed driving all public roads that cross Hurricane and Mill Creeks and their tributaries and noting the extent of development and disturbance. Because not all stream segments were accessible, however, this assessment should not be considered comprehensive.

Files Search: The files search at the Texas Archeological Research Laboratory revealed that there are no recorded archeological sites within the study area. The closest known sites are 41AG12 and 41AG21. Site 41AG12 was recorded by G. E. Arnold, probably in 1939. Local collectors apparently had recovered lithic and ceramic artifacts, and Arnold reported the site as a Native American village covering about 12 acres near the southern limit of the community of Redland. Its plotted location is on the north side of Mill Creek not far west of U.S. Highway 59, ca. 0.5 mile north of the part of the Mill Creek watershed that is within this study area. Site 41AG21 also was recorded by Arnold in 1939 based on stone and ceramic artifacts recovered by a local collector. He reported it as a Native American village covering about 1 acre. It is plotted as being just east of Cedar Creek ca. 0.3 mile north of its confluence with Hurricane Creek. A subsequent survey of the area by personnel from the Texas Water Development Board (see below) was unable to re–locate the site, however, and it is likely that this plotting is in error.

The county report files at the Texas Historical Commission contain information on eight archeological surveys conducted within the study area, none of which found any cultural resources. One, done by D. E. Fox and C. J. Jurgens of the Texas Water Development Board in 1983, consisted of examination of parts of a proposed wastewater line route extending from the wastewater treatment plant on FM 324 just north of Hurricane Creek northward across the Hurricane Creek floodplain and then over the uplands bordering the Cedar Creek valley almost to Loop 287 (Fox and Jurgens 1983). In 1992, J. E. Corbin of Stephen F. Austin State University conducted a survey of the proposed Azalea Trail that follows the mainstem of Hurricane Creek from Kiwanis Park to Grace-Dunn Richardson Park; he also surveyed the latter park, which includes the lower part of Tributary 3 (Corbin 1992). Two years later, Corbin (1994) conducted a survey of a proposed waterline route from the city water plant northward to FM 2021 at the community of Redland; the southern end of this route is just north of Ellen Trout Memorial Lake and runs along Mill Creek and across the adjacent uplands.

The other five surveys were done by personnel from the Texas Department of Transportation. A 1984 survey covered ca. 0.7 mile along Paul Avenue from U.S. Highway 59 to Lubbock

Street; this is in the upper part of the Hurricane Creek watershed, northeast of the head of the mainstem. A 1987 survey covered the ca. 1.7-mile proposed extension of FM [illegible] northward from U.S. Highway 59 to Loop 287; this route crosses the mainstem of Hurricane Creek in an area with a well-developed floodplain, as well as Tributaries 6 and 7 and adjacent uplands. A 1989 survey covered ca. 0.7 mile along Brentwood Drive from U.S. Highway 59 south and eastward to Chestnut Street; this route crosses Tributary 5 to Hurricane Creek and the uplands north and south of the tributary. A 1993 survey involved coverage of ca. 6 [illegible] around the intersection of Loop 287 and Kurth Drive; this area flanks the head of the western fork of the west branch of Mill Creek. Finally, a 1996 survey covered ca. 2.0 miles along FM 819 from U.S. Highway 59 south to FM 2108; this route crosses Tributary 7 to Hurricane Creek and adjacent uplands, as well as the next drainage to the south (Moccasin Creek).

The National Register files at the Texas Historical Commission contain information on 37 properties within Lufkin that are listed in the National Register of Historic Places. All but one of these are within or very near the Hurricane (n = 29) and Mill Creek (n = 7) watersheds (Table 1; see Figures 1–3). Twenty-five of those within or near the Hurricane Creek watershed are commercial or public buildings (Pines Theater, Fenley Commercial Building, McClendon-Abney Hardware, Corstone Sales Co., and the Old Federal Building) located downtown or residences located just to the north, east, west, and south on Howe, Lufkin, Kerr, and Jefferson Avenues and Paul, Groesbeck, Raguet, Grove, Mantooth, Moore, Bynum and Menefee Streets. The other four are residences located farther south from the center of town on South First Street, Tulane Road (the house at this property has been removed recently, although the barn included in the listing still stands), Harmony Hill Drive, and Chestnut Street.

Six of the seven listed properties in or near the Mill Creek watershed are located on or just off of Old Mill Road. All six are residences associated with the community that was established at the Angelina County Lumber Company sawmill at Keltys, which began operation in the 1880s. The seventh property is the Texas Department of Transportation complex, which is bounded on the west by Forest Park Street and on the east by U.S. Highway 59.

These 36 buildings were listed in the National Register as a result of a Multiple Resource Nomination done in 1986–1988 by Victor and Victor Consultants for the Angelina County Historical Commission. This was part of a larger project to assess the standing architecture across Angelina County as a whole. Over 1,000 buildings and structures were documented (ca. 800 in Lufkin), and 41 were considered to be of sufficient significance to warrant listing in the National Register (including the 36 listed above). These 41 properties date between 1880 and 1940 and were considered significant architecturally or for their association with New Deal programs or the development of transportation networks.

Geomorphological Assessment: Observations made during the geomorphological assessment are summarized in Table 2. While no estimate could be made for the thickness of alluvium at six locations due to the lack of a cutbank or very poor visibility (Localities 10, 11, 13, 19, 24, and 29), all of the other localities yielded some information. Especially useful data came from Localities 1, 7–9, 23, and 28 where the streams are sufficiently incised to expose the underlying bedrock. These localities are on the mainstem of Hurricane Creek (lower,

Table 1. **Properties Listed in the National Register of Historic Places**

Name	Address	Watershed
C. W. Perry/Hallmark Residence	302 Bynum St., South	Hurricane Creek
A. F. Perry/Pitmann Residence	402 Bynum St., South	Hurricane Creek
G. E. Lawrence Residence	2005 Chestnut St., South	Hurricane Creek
Pines Theater	113 First St., South	Hurricane Creek
Rastus Reed Residence	1509 First St., South	Hurricane Creek
Kennedy/Lowrey Residence	519 Groesbeck St., East	Hurricane Creek
Banks/Ogg Residence	602 Groesbeck St., East	Hurricane Creek
A. C. Kennedy/Runnels Residence	603 Groesbeck St., East	Hurricane Creek
Humason/Pinkerton Residence	602 Grove St.	Hurricane Creek (adjacent)
Howard Walker Residence	503 Harmony Hill Dr.	Hurricane Creek
Brookshire/Theatres Residence	304 Howe Ave., East	Hurricane Creek
Walter C. Trout/White Residence	444 Jefferson Ave.	Hurricane Creek
Percy/Abney Residence	466 Jefferson Ave.	Hurricane Creek
Boynton/Kent Residence	107 Kerr St., West	Hurricane Creek
Fenley Commercial Building	112 Lufkin Ave., East	Hurricane Creek
McClendon-Abney Hardware Co.	119 Lufkin Ave., East	Hurricane Creek
Lufkin Land/Log Bell/Buck Residence	1218 Lufkin Ave., East	Hurricane Creek
Binion/Casper Residence	404 Mantooth St.,	Hurricane Creek
Byus/Kirkland Residence	411 Mantooth, St.	Hurricane Creek
Newsom/Moss Residence	420 Mantooth, St.	Hurricane Creek
Russell/Arnold Residence	121 Menefee St., West	Hurricane Creek
Everitt/Cox Residence	418 Moore St.	Hurricane Creek
Abercrombie/Cavanaugh Residence	304 Paul St.	Hurricane Creek
Parker/Bradshaw Residence	213 Raguet St., North	Hurricane Creek
Marsh/Smith Residence	503 Raguet St., North	Hurricane Creek (adjacent)
Corstone Sales Co.	109/111 Shepherd St., East	Hurricane Creek
Behannon/Kenley Residence	317 Shepherd St., East	Hurricane Creek
Old Federal Building	104 Third St., North	Hurricane Creek
Standley Residence	1607 Tulane Rd.	Hurricane Creek
Texas Department of Transportation Complex	110 Forest Park St.	Mill Creek
S. W. Henderson/Bridges Residence	202 Henderson Rd.	Mill Creek (adjacent)
Keltys Worker Housing	109 Medford St.	Mill Creek (adjacent)
Kurth/Glover Residence	1847 Old Mill Rd.	Mill Creek (adjacent)
J. H. Kurth Residence	1860 Old Mill Rd.	Mill Creek
Clark/Whitton Residence	1865 Old Mill Rd.	Mill Creek (adjacent)
McGilbert Residence	1902 Old Mill Rd.	Mill Creek

middle, and upper reaches) and the lower parts of Tributaries 1 and 2. The alluvial deposits at these locations are 3–5 m thick. Elsewhere, only estimates of minimum thickness could be made since bedrock was not exposed. Relatively thick deposits, 4+ m, were documented on lower Hurricane Creek and lower Tributary 7 (Localities 3, 25, and 26), while alluvium of at least moderate thickness, 2–3+ m, was observed in the following areas: upper and lower Tributary 3 (Localities 20 and 21); the middle reaches of Tributaries 4, 5, and 7 (Localities 2, 4, and 6); and lower Mill Creek (Localities 15 and 16). Alluvial deposits at least 0.5–1.5 m thick were noted on the upper parts of Tributaries 1, 2, 4, and 6 (Localities 5, 12, 22, and 27) and the middle and upper parts of Mill Creek (Localities 14, 17, and 18).

Table 2. Localities Examined for Geomorphological Assessment

No.	Location	Cutbank Height/ Visibility	Thickness of Alluvium
1	Hurricane Creek mainstem (lower) at FM 324	4–5 m; fair	3–4 m above bedrock
2	Hurricane Creek Tributary 7 (middle south branch) east of U.S. Highway 59	2–3 m; good	2–3+ m; bedrock not observed
3	Hurricane Creek Tributary 7 (lower south branch) west of U.S. Highway 59	3–4 m; fair	3–4+ m; bedrock not observed
4	Hurricane Creek Tributary 5 (middle) east of U.S. Highway 59	2 m; fair	2+ m; bedrock not observed
5	Hurricane Creek Tributary 4 (upper) off of Hickory Hill Dr.	0.5 m; poor	0.5+ m; bedrock not observed
6	Hurricane Creek Tributary 4 (middle) at Tulane Rd.	2 m; poor	2+ m; bedrock not observed
7	Hurricane Creek Tributary 2 (lower) east of Tulane Rd.	3 m; poor	3 m above bedrock
8	Hurricane Creek mainstem (upper) in Kiwanis Park	3 m; good	3 m above possible bedrock; some introduced fill
9	Hurricane Creek Tributary 1 (lower) in Kiwanis Park	4 m; good	3 m above bedrock; some introduced fill
10	Hurricane Creek mainstem (upper) north of Dozier St.	1 m; very poor	Unknown
11	Hurricane Creek Tributary 1 (middle) west of Chestnut St.	2–3 m; very poor	Unknown
12	Hurricane Creek Tributary 1 (upper) south of Howard Ave.	1 m; poor	1+ m; bedrock not observed
13	Mill Creek east branch (upper east fork) east of Martin Luther King Rd.	No cutbank	Unknown
14	Mill Creek east branch (lower east fork) east of Martin Luther King Rd.	1 m; poor	1+ m; bedrock not observed
15	Mill Creek east branch (lower) south of Loop 287	2.5 m; poor	2.5+ m; bedrock not observed
16	Mill Creek west branch (lower) east of Sayers Dr.	2 m; fair	2+ m; bedrock not observed
17	Mill Creek west branch (lower east fork) west of Sayers Dr.	1.5 m; fair	1.5+ m; bedrock not observed
18	Mill Creek west branch (upper east fork) north of Kurth Dr.	1 m; poor	1+ m; bedrock not observed
19	Mill Creek west branch (middle west fork) south of Loop 287	No cutbank	Unknown
20	Hurricane Creek Tributary 3 (upper) at Morrow St.	3 m; fair	3+ m; bedrock not observed
21	Hurricane Creek Tributary 3 (lower) at Grace-Dunne Richardson Park	3 m; good	3+ m; bedrock not observed
22	Hurricane Creek Tributary 2 (upper) east of Chestnut St.	1 m; poor	1+ m; bedrock not observed
23	Hurricane Creek mainstem (middle) north of Lufkin Mall	4–5 m; good	4–5 m above possible bedrock
24	Hurricane Creek Tributary 7 (upper north branch) at Champions Dr.	0.5 m; very poor	Unknown

date covered small areas and involved little or no shovel testing or other subsurface inspection, however, the lack of known sites is not surprising. Based on the topography and the locations of the few recorded sites nearby, the part of the project area that is considered most likely to contain prehistoric archeological sites is the Hurricane Creek watershed downstream from U.S. Highway 59 to the confluence with Cedar Creek, i.e., the lower part of the valley with a well-developed floodplain. Within this area, sites are most likely on elevated landforms within or adjacent to the floodplains of the mainstem of the creek and the lower parts of Tributaries 3–7; such landforms would include isolated rises probably representing remnants of levees and terraces, as well as terrace and upland margins bordering the floodplains. Sites also could lie buried in the thick (at least 3–5 m) Holocene alluvium in this area, although too little geomorphological work has been done in the Lufkin area and east Texas in general to fully assess this possibility. It is less likely, though certainly not impossible, that prehistoric sites could be present along the smaller stream segments, i.e., the upper parts of Hurricane Creek and its tributaries and along Mill Creek. If so, they probably will occur on elevated landforms near the creeks.

Thirty-six buildings listed in the National Register of Historic Places are within or adjacent to the Hurricane and Mill Creek watersheds. Most are residences, with a small number of commercial and public buildings included as well. Most are privately owned and hence are afforded little protection from disturbance by their National Register listing. Only two—the Rastus Reed Residence at 1509 South First Street (U.S. Highway 59) and the G. E. Lawrence Residence at 2005 South Chestnut Street—are located sufficiently close to creek channels that they are likely to be threatened by drainage improvement projects. Given that the National Register survey was done ca. 10 years ago and did not record all buildings and structures that were 50 years old or older at that time, it is possible that additional historic buildings and structures are located in the study area.

At this point, it is difficult to assess whether significant historic archeological sites might be present. None have been documented, but the National Register survey done in the late 1980s was concerned with architectural rather than archeological resources, and, as noted above, the few archeological surveys have covered only small areas. Lufkin was not founded until 1882, but an earlier settlement called Denman Springs was present before that time (Bowman 1996). Given that the upper part of the Hurricane Creek watershed is within the older part of town, it is possible that archeological remains pertaining to early settlement are present.

As plans for specific drainage improvement projects are developed in the future, the U.S. Army Corps of Engineers, Texas Historical Commission, and Texas Water Development Board may require cultural resources investigations based on the location and nature of the project and extent of prior disturbance. As described above, parts of the study area clearly are too disturbed to be sensitive in terms of cultural resources, and it is recommended that surveys not be required in these areas. Otherwise, some level of survey may be appropriate. Where modifications to existing channels are proposed, this may involve only inspection of cutbanks to ensure that buried prehistoric or historic sites are not present. Where more-extensive impacts are planned (e.g., large detention ponds), three kinds of activities may be needed: (1) historic archival research using old maps and legal records to identify potential early historic sites; (2) archeological survey involving pedestrian coverage, shovel testing, and perhaps

Preliminary Wetlands Survey

for the:

City of Lufkin Watershed Study

prepared by:

Wetland Technologies Corp.

in association with:

Dodson & Associates, Inc.

Date:

September 15, 1998

Preliminary Wetland Study of Hurricane Creek and Mill Creek

located within and near:

The City of Lufkin, Angelina County, Texas

Introduction:

Wetland Technologies Corporation (Wet Tech) was engaged to perform this preliminary wetland study according to the current requirements of the U.S. Army Corps of Engineers (Corps) by Dodson & Associates, Inc. (Dodson) on behalf of the City of Lufkin (City) in order to assess potential environmental impacts from future flood control projects that may be planned for the Hurricane Creek and Mill Creek watersheds.

A preliminary cultural history study has been concurrently prepared by Prewitt & Associates, Inc. (Prewitt). These two reports meet the requirements of the Texas Water Development Board for preliminary project planning.

The report(s) serve the purpose of describing areas of potential impacts to wetlands, endangered species and cultural resources should they be selected for future project planning and development. Those areas chosen as potential development project locations will require more definitive environmental and archeological study at that time. We have provided some general suggestions for potential development as the results of this study.

Methods:

Pre-mapping- A U.S.G.S. Quad Survey was used as the primary mapping unit to locate proposed project area(s) and the attached map enclosures are prepared from the same materials. The primary quad map utilized consisted of the northwest section of the Lufkin Quadrangle, 7.5 minute series; along with a small part of the Keltys and Redland Quadrangles.

A copy of the *Soil Survey of Angelina County, Texas* soils map and it's associated hydric soil list was obtained from the Natural Resources Conservation Service (NRCS) Lufkin office and compared to the quad map in order to determine potential hydric soil conditions before site inspections were performed.

As a part of pre-mapping studies, we examined a series of aerial photos flown on 3/2/96, scale ratio of 1:9996, which were provided by Dodson. Wet Tech was also provided a streambank and watershed location map by Dodson; along with a set of detailed 2 foot topological drawings of the Hurricane Creek study area.

Site inspections- After noting areas of potential concern during the pre-mapping; the Mill Creek streambank was examined for one full day, and three full days were expended inspecting Hurricane Creek streambank(s).

About 30% of the study area(s) consisted of fully developed urban land, about 30% of partially developed urban land, and about 40% of rural land impacted by certain agricultural practices (timber management and clearing for cattle pastures).

Conditions during site investigations were influenced by a major thunderstorm that traversed study area(s) at the beginning of our trip. Violent high winds downed many large trees and sudden (but short duration) heavy rainfall produced a visible high-water mark for the entire inspection period. Several homes reported as flood-prone on the upper Hurricane Creek experienced stormwater rising in their yards, and most large downstream channels overflowed their banks.

Agency Comments:

Prior to preparation of this report we obtained a copy of *Guidelines for the Preparation of Environmental Assessments* (ed-1, 10/10/97) from the Texas Water Development Board (Water Board). We subsequently contacted the Corps' Dallas Division office regarding persons responsible for the Lufkin area at the Corps' Ft. Worth District. We then contacted the Chief of Enforcement (regarding 404 Determinations) and the Chief of Evaluation (regarding 404 Permitting) of the Corps' Ft. Worth District. The Chief of Evaluation is currently involved in developing recommendations for alternatives to streambank modifications with other interested agencies similar to those in this report, and is planning a series of workshops to present these criteria to concerned parties.

The biologist responsible for East Texas for the U.S. Fish & Wildlife Service (USF&WS) was contacted regarding endangered species, as well as the Texas Parks & Wildlife Department (TP&WD) Tyler office.

Background Information:

Our primary focus in this study is to assess overall environmental liability according to directives of the Water Board in order to aid in potential site selection for detention facilities and other flood control measures, as well as potential sites for 404 mitigation of those projects. Although other environmental concerns are addressed herein, the primary regulatory area that will be involved is Corps 404 jurisdictional authority.

A part of that jurisdiction is determined by the Corps according to the current definition of wetlands (whether associated with a stream or not); whereas another part is determined by them according to whether projects are located in "waters of the U.S." (in association with a wetland or not).

These two major parts of a 404 jurisdictional determination are (separately) then considered in several sub-parts before a combined decision is rendered by the Corps Enforcement biologists. Once 404 jurisdiction is determined, they will notify the Corps Permit Evaluation project managers (and the proposing entity) that an application for a 404 permit to impact them is required.

Section 404 of the Clean Water Act: Each of the many Sections of the Clean Water Act (the Act, as passed by Congress [and in various revisions] in the early and mid 1970's) addressed some individual public concern by establishing regulations over pollutants contaminating the public water supply. The water quality concern referenced within Section 404 was primarily related to dredge spoils from channelization, and fill materials from upland construction being deposited into "waters of the U.S".

Congress had determined that functions desirable to the public interest currently being performed by waters of the U.S. were seriously degraded by deposition of these materials; therefore, public waters were to be protected from such pollutants in order to achieve clean water goals along with "end of pipe" regulations established in other Sections of the Act. As soil-based materials dissolve into sediments, they pollute public waters, and fill materials greatly restrict the amount of public water. Consequently in both cases, the filling entity was "taking " that "non-productive" public water area for it's own use.

Therefore, Section 404 was promulgated primarily to protect exsisting water quality (for both drinking water and recreational uses) to be improved by other Sections of the Act, and to reserve available water capacity for future public use(s).

Although the Sections regulating end of pipe discharges were assigned to the States and (a federal authority that became) the Environmental Protection Agency (EPA); Section 404 was assigned to the Corps of Engineers as it had an existing regulatory permit program in place. The Corps had previously maintained a long term permit authority over placement of obstructions into or excavations from "navigable waters of the United States" per Section 10 of the Rivers and Harbors Act of 1899.

However, project proponents have desired that 404 wetlands be classified as "good, better, and best" in quality in order to negotiate mitigation requirements with resource agencies somewhat predictably. The development groups have agreed that they will accept the Act's supporters' desire for recognition of wetlands according to function in order to achieve a "good, better, best" classification. Accordingly, the Corps has committed to scientific classification of wetlands (both existing and mitigation to be built) with adoption of a method titled the *Hydrogeomorphic Assessment Method* known as HGM with a focus on wetland functional values.

1.) data points (DP's)- Are selected by the inspecting biologist as being typical of the site and their locations are mapped on his report. Each DP should be located entirely within one (1) occurrence of either a typical upland or wetland, not on a dividing line between them. If a typical delineation line is to be established as a part of the work, it should be selected between the wetland DP and the upland DP, and flagged a reasonable distance in each direction.

2.) hydric plants- National Plant List- The *National List of Plant Species That Occur in Wetlands: yr. pub. National Summary* is compiled and published by the U.S.F.&W.S. with the year published denoting a particular edition (revision). For example the '88 edition is noted as *Biological Report 88(24), September 1988.* The hydric status of individual plant species is negotiated and agreed on before publishing between the National and Regional Interagency Review Panels. The list divides known U.S. plant species into five (5) categories in descending order from upland to wetland with three (3) intermediate categories designated as "facultative". The four (4) categories that are known to grow in wetlands are provided (there are very few upland only species listed within this publication).

The four ratings are:

a.) facultative upland (FACU) species- mostly upland, occasionally found in a wetland, and
b.) facultative (FAC) species- found either in upland or wetland, and
c.) facultative wetland (FACW) species- mostly wetland, occasionally found in an upland, and
d.) obligate (OBL) species- found only in wetlands.

The three facultative designations are further modified with either a (+) or a (-) for some species that "weight" the numerical score somewhat.

Species within the designated DP inspection area are identified and those that are dominant noted first; with individuals of occasional species noted last onto the accepted Corps Determination form for the '87 Method. If a delineation line (the Line) is to be marked, a species known locally by the biologist to dominate at the edge (such as FACW + species *Andropogon glomeratus* [bushy bluestem] within open-sun prairie areas) is selected for closer examination. The soils are shovel tested for wetness on either side of the proposed Line in order to confirm the species selection. The Line is then marked in both directions along the plant species/soils gradient until a change is noted.

3.) hydric soils- National\County Soils List- The list titled *Hydric Soils of the United States* is prepared and published by the NRCS (previously the SCS) in cooperation with the National Technical Committee for Hydric Soils. The local county soils map of the NRCS (such as the *Soil Survey of Angelina County, Texas*) is provided with a list of hydric soils found in that county, including a breakdown of hydric soil type inclusions found in upland soils.

Soil types are described and their locations mapped within the NRCS county handbook to the extent that field identification (of a soil type) is possible by a properly trained individual. Such detailed NRCS soil descriptions also include landform, position on the landscape and frequency of flooding; which should (also) be observed at each DP, and noted as to whether they conform to hydrological indicators found at the same DP (more fully described below).

The hydric list(s) were prepared for agricultural uses only; consequently many wet soils that will qualify as 404 hydric soils are not listed as such by the NRCS. It is important to note that NRCS determination of a soil type as hydric is only one of a number of hydric soil indicators listed (as qualified) by the '87 Method. Therefore, if the soil type identified during site inspection is not NRCS listed (as hydric) ; but other indicators are present sufficient to meet '87 Method requirements, the soil type is then classified as hydric for 404 purposes.

Some biologists extensively trained in the '87 Method are able to identify various soil types sufficient to report on the '87 DP form. However, the additional expertise of soil scientists or technicians may be required to make the soil determination when soil classification is the deciding factor, or a soil type not described in the NRCS county soil survey is present.

On agricultural lands, NRCS soil scientists trained in the '87 Method will make a determination according to Swampbuster Act rules. At the limits of rural communities where agricultural lands encroach into 404 jurisdictions, there is a necessary cooperation between the Corps and the NRCS, as the '87 Manual is the basis for the Method to be utilized by all parties.

4.) hydrology- hydrologic indicators- There are no national or county lists of true hydrologic indicators provided to practioners of 404 determinations. Certain "wetness" indicators are described in the '87 Method which may or may not be present on-site. These are more visual, less technical in nature, such as "blackened leaves" accumulated in deposits up to the high water mark. Each is ranked as either a primary or a secondary indicator in order to "weight" the numerical finding. These indicators are noted on the DP form where required and are calculated into the finding which determines whether available water source(s) are sufficient (or not).

As most trained 404 practioners have biology backgrounds, and a few have soils backgrounds, these visual "clues" allow a 404 determination to be made without an opinion of a wetland hydrologist. However, a proper observation of the depressional nature of the landform, size of the upslope watershed, and the probable frequency and duration of flooding is a superior indicator of sufficient hydrology.

In urban areas, hydrological expertise is available from practioners who make such observations in order to design construction of mitigation wetlands into previously upland sites. In rural areas, NRCS personnel are skilled in hydrology calculations as a consequence of determining the hydric nature of soils, and calculation of upslope watershed(s) for farm pond designs.

The driving force for adoption of the HGM Method described previously is it's rating of functional values for use by all entities participating in 404 rulemaking. However, HGM is based on a true technical observation of a site's actual hydrologic characteristics. If the HGM Method does replace the '87 Method, the '87 Manual's visual clue indicators will not be sufficient to determine a site's hydrology (or lack of) for 404 purposes.

5.) 404 determinations- All three hydric indicators (plants, soils and hydrology) must be present and determined to be sufficiently wet in order to qualify a DP as a wetland site. If any one of the three indicators is judged to be lacking by the '87 Method, then the DP is not a qualified 404 wetland.

A typical example would be documenting by the on-site observer of a previously ditched and drained (before the end of 1985) wetland site; whose wet soils continued to germinate wet plants from normal rainfall (only), but the necessary hydrology is no longer present according to the '87 Method. Over a long period of time the soil would lose it's hydric nature, and FACU plant species would eventually dominate such a habitat (FAC species such as *Pinus taeda* [loblloly pine] are classified as wetland species for 404 qualification purposes).

Conversely, a non-hydric soil can be provided more hydrology than historically available by development activities wherein the soil would develop wet characteristics and thereby begin to germinate seeds of wet species within it's local area. This happens when a flat or concave surface is cut into a previously sloped surface over a slowly permeable soil type; or upstream development begins to flood an area not historically a floodplain.

As any determination by the observer of a lack of one type of hydric indicator will remove a DP (and all similar habitat on-site) from Corps Jurisdiction, then all other considerations required by the '87 Method are rigorously enforced (hence the Corps designation Enforcement Section). There is considerable lattitude for use of "best professional judgement" by all parties practicing in the 404 field which can lead to disagreement as to the meaning of a particular indicator.

Therefore, Corps Enforcement Section confirmation of a private practioner's 404 determination (and delineation lines if a part of the work) is required in order to be accepted by all parties. That is, an incorrect determination of a qualified 404 wetland area as technically too dry according to the '87 Method by a wetland consultant will not protect a project developer from Act penalties if the Corps does not agree.

U.S. Army Corps of Engineers 404 Enforcement Program: Any public complaint that construction work is impacting a 404 wetland must be investigated by qualified Corps biologists within 24 hours of the call. Concurrence by the inspecting biologist that 404 impacts are in progress will bring an immediate on-the-spot "cease work" order. An investigation ensues that lasts about one year which concludes with a finding of the monetary fine to be paid, and a requirement to re-construct the impacted wetland on it's original site and to it's original state.

Considerable effort is expended in order to determine whether a development impact was intentional (or not). If "intent" is discovered, the case may be referred by the Corps to the EPA for prosecution under penalties of the current revision of the Clean Water Act.

At the time of the initial finding, a project developer may negotiate a settlement agreeable to all parties by proposing suitable mitigation (more fully described below) to offset existing project impacts, and mitigation for future impacts of the site's development plan. If the Corps agrees (and the EPA, if involved), the Enforcement Action will be put on hold while an after-the-fact permit is negotiated with the Evaluation Section. If an after-the-fact permit is negotiated between the parties (which also takes about one year), the project is allowed to proceed along with simultaneous construction of the mitigation agreed to.

However, on a daily basis the Corps Enforcement Section's work consists mainly of inspection of proposed wetland impacts by qualified biologists in order to determine their 404 wetland status. If the Corps' biologist agrees with the findings presented by the developer's consultant regarding the number of acres and location of jurisdictional impacts planned, the proposed project is forwarded to the Corps Evaluation Section to process the developer's request.

U. S. Army Corps of Engineers' 404 Permit Evaluation Program: The 404 program consists of a separate review of 404 permit requirements by Corps Evaluation Section permit specialists; who may be, but are not necessarily biologists themselves.

Corps evaluation of an application to permit proposed 404 Wetland impacts will include consideration of qualification for various components of the Nationwide Permit program for small impacts or the Individual Permit program for larger impacts. The Nationwide Permit program will be modified (the Nationwide #26 Permit will be dropped altogether) before any actual projects are constructed in the Hurricane Creek or Mill Creek watersheds, or elsewhere within the City of Lufkin. Individual Permits include all 404 impacts in a single project permit and require public notice.

All Corps rulemaking must meet the requirements of the *National Environmental Policy Act* (NEPA) and include co-ordination with the USF&WS for Endangered Species review, and co-ordination with the State Historic Preservation Officer (SHPO) for cultural resources review.

1.) mitigation of wetland impacts- An application to the Corps for a 404 permit to impact wetlands must contain an offer to mitigate (offset) such impacts by creation or restoration of new wetland areas. Certain poor quality wetlands may be replaced at the rate of 1:1; however, most mitigation ratios will be 2:1 (2 new acres constructed for every acre impacted) or higher.

Due to the cost of land acquisition, design, construction and maintenance of mitigation wetlands, avoidance of wetland impacts whenever possible is the lowest project cost alternative.

2.) mitigation sequencing- To be granted mitigation, a project applicant must first actively practice a series of sequential actions during preliminary planning wherein the first is avoidance of all 404 impacts, then minimization of as many 404 impacts as is possible; and finally, if any 404 impacts are determined to be not avoidable, then mitigation may be offered by applicant. Avoidance of the best quality wetlands also will result in lowering the mitigation ratio, thereby lowering hard costs of mitigation to applicant.

Wetland Types: Two primary wetland habitat types occur within the watersheds described in the Results section of this report; as follows:

1.) braided channel- Typical floodway configuration where storm surges regularly overflow the main channel. Such overflow cuts many smaller channels into the floodplain above the main channel's normal bank level. This type of habitat is more complex than a backwater floodplain wetland due to a considerable amount of edge effect, whether open-sun or forested.

2.) flooded forest- Typical forested wetland whether lying in the active floodway or on the backwater floodplain above. All of the effects of shade dominance that occur in upland forests are also a factor in forested wetlands, along with selection for tree and shrub species tolerant of wet soil conditions. Where standing pool levels prevents wet tree and shrub species from invading (except for bald cypress [*Taxodium distichum*], black gum [*Nyssa sylvatica*], and buttonbush [*Cephalanthus occidentalis*]), an open-sun prairie wetland may exist within a forested area. However, at the edge of standing water, a water oak (*Quercus nigra*) -willow oak (*Quercus phellos*) forest will invade the floodpool unless managed by fire or mowing.

U.S. Fish & Wildlife Service's Endangered Species Program: The USF&WS maintains a permanent program for Threatened and Endangered Species (T & E Species) that includes identification and listing of species at risk of extinction, development of recovery plans for those species, and implementation of such plans to attempt recovery and de-listing of T & E Species. The TP&WD also operates a similar program for species identification and state listing, which may include other species not listed by USF&WS.

State Historic Preservation Officer's Cultural Resources Program: The Corps co-ordinates with the SHPO's office in Austin, Texas to determine whether any potential project areas may have cultural significance. If so, an intensive cultural resources survey may be required. Such a survey would entail pedestrian coverage accompanied by shovel testing and trenching/augering, perhaps followed by test excavations, to identify and evaluate archeological sites, while historic buildings and structures would be recorded and evaluated through an architectural survey. Adverse effects to significant resources can be mitigated, usually through data recovery excavations at archeological sites and Historic American Buildings Survey (HABS) or Historic American Engineering Record (HAER) documentation of buildings and structures, or the project can be designed to avoid the resources. The Corps' Fort Worth District maintains on staff an archeologist for preliminary determinations and co-ordination with the SHPO's office.

Discussion of Study Area 404 Considerations:

Corps' 404 Jurisdictional Program: Several factors are a part of current 404 rules in effect that are directly related to whether the Corps' Ft. Worth District exercises jurisdictional authority over the City's proposed watershed projects within areas appearing to be non-jurisdictional; as follows:

1.) **NRCS Soils List-** A critical part of the definition of a wetland is a sub-part determination of whether a site's soil type can be considered hydric (wet) in any particular area being examined. As is more fully described above, consideration is given in the '87 Method to the soil type's listing on the NRCS county hydric soil list. However, as a practical matter, a listed soil can be drained sufficiently to prevent it's being hydric; conversely a non-listed soil can have sufficient hydrology to cause it to develop definite hydric characteristics.

We note that the NCRS has not listed as hydric soil types within the Mill Creek streambanks, and also Hurricane Creek streambanks until about a mile south of Loop 287. Though soil types described within Mill Creek and upper Hurricane Creek are not listed as such, the soils are very wet as described, consequently any area flooded sufficiently enough to meet the 404 hydrology criterion will also meet the Corps hydric soil requirements.

2.) **Small Urbanized Channels-** When considering determination of "waters of the US" that are jurisdictional, wetland vegetation is not necessary, as the high-water mark is the primary determining factor. Consequently, on-site observation of this high-water mark invokes Corps authority in small streams where there may be no plants existing.

This is important to the City of Lufkin as all of the urban tributaries share this regulatory qualification.

Jurisdictional Corps authority ceases above the high-water mark, provided no associated wetland exists (above the high-water mark). Exemption from jurisdiction of "above the headwaters" (5cfs streamflow) only applies to Nationwide Permit #26, which will not be available shortly.

Corps 404 Mitigation Program: Where the Corps requires mitigation to offset impacts to regulated wetland habitats, certain rules are in effect that control criteria of the proposed design.

The specified mitigation-

a.) must be located nearby (preferably directly adjacent to the impacted area), and
b.) must be "like kind" (same type of habitat as is destroyed by development project), and
c.) must be at least a mitigation ratio of one new acre created to one existing acre destroyed (but may be a higher ratio agreed to by applicant in order to proceed).

Potential Mitigation Projects: We have identified a number of areas in the following report where detention ponds could be installed along with (or rather than) channelization in order to reduce flood hazard. These could be detention areas with a permanently wet bottom that may also be designed to serve as mitigation sites for un-avoidable 404 impacts, thereby reducing costs of mitigation by as much as 50%. We have denoted these areas as potential detention/mitigation sites in the following material and as **Sites** on the attached maps.

As permanently wet bottom projects, these combined project designs would require natural pond type sedimentation traps to prevent mitigated wetlands from becoming uplands due to accretion of sediments. Accordingly, State and Federal requirements for control of in-stream sediments to be enacted in the future would also be provided for.

Typical Mitigation Design: These wetland design details are typical (only) such that most of the following proposed project sites would be constructed in a similar manner. They do not represent the level of detail required in order to successfully construct a mitigation quality wetland.

Within a typical detention/wetland project, the site's fertile topsoils would be stripped and set aside for subsequent construction of wetland planting shelves, and topsoiling sideslopes. The major excavation contractor would cut away sterile subsoil down to slightly below the Creek's bottom elevation and haul it away from the project. A berm about 5' wide and 2' high of natural ground would be left along the Creek bank to prevent small flows from entering until completion.

The detail contractor would shape bottom configurations according to the agreed on design, and then lay saved topsoils onto wetland planting areas up to final elevation. Naturally shaped large capacity (deep) sedimentation pools would be excavated at the designated infall area. Plants would be taken from storm ditches nearby and installed within on prepared planting shelves at the correct elevation for their particular species. Plants would be watered by pump from the Creek every day it does not rain until final flooding. On completion the inlet channel and outlet channel would be dug through the separation berm to connect with the streambed.

Discussion of Other Considerations:

T & E Species Program: The national and state regulations governing T & E Species primarily address identification of unique habitat with potential for utilization by such species. Biologists trained in T & E Species inspections must prepare their reports identifying potential habitats as described in specific laws passed at the national and state level (as well as whether any animals or plants are actually observed by them). However, agencies involved which will review the inspecting biologist's report have determined the actual location (or lack thereof) of most of these species. Consequently, the appropriate method of determining future comments of resource agencies is to submit areas under consideration for potential project locations to them prior to beginning any definitive environmental studies.

If either agency replies that it has mapped one or more listed species in a potential project area a qualified biologist must be engaged to determine whether any individual listed animal or plant actually inhabits the area.

USF&WS and TP&WD biologists have stated to us that no T & E Species are a concern within urbanized areas of the City. Where lower Hurricane Creek becomes a major stream about one mile south of Loop 287, there may begin to be a concern regarding some of the fishes as well as the alligator snapping turtle (*Macreclemys temminchii*). At the extreme remote end of Hurricane Creek west of Hwy. 324, the timber rattlesnake (*Croatalus horridus horridus*) may or may not be a concern until they consider a particular proposed project site. We recommend that early in planning a specific project (that) a proposed site be submitted to them for their comments; which comments would then (if negative) be provided the Corps and Water Board, and if positive, necessary avoidance or mitigation agreements negotiated with them in advance of any 404 Permit or Water Board application.

It must be noted that such a T & E Species restriction may prevent developing a specific project site completely. Mitigation for T & E Species is much more complex than 404 wetland mitigation and in some cases impossible to construct. An example would be an attempt to re-create a particular flowing stream habitat for fishes in lower Hurricane Creek which would not be possible without access to a similar floodflow pattern.

Cultural Resources Program: All preliminary comments regarding Cultural Resources has been provided in a report by Prewitt. Such report completes our combined requirements (scope of work) for this contract.

Results: Hurricane Creek

We have organized this report on the streambanks of Hurricane Creek into our findings regarding 1.) urban areas, 2.) semi-urban areas, and 3.) remote areas downstream of the City proper.

Section One- fullv urbanized- Upper Hurricane Creek:

We define this Section to consist of the Main Stem and Tributary One above Denman Avenue, Tributary Two above the Lowe's store, Tributary Three within developed neighborhoods, Tributary Four adjacent to the apartment complex east of Hwy. 59, and Tributary Five within Crown Colony. The area is identified as shown on the map marked as **Exhibit 1**. As is more fully described in item 2.) Small Urbanized Channels- on page thirteen (13), the Corps will exercise jurisdiction within stream bottoms in residential areas up to the small channel's high water mark, but the yards are maintained by homeowners such that it is unlikely that wetlands will be associated.

Nationwide Permits for stream crossings and other small impacts may still be available in future years, and may or may not require mitigation for them. Full channelization or replacement with submerged concrete sewer would require 404 permitting and mitigation.

Main Stem: The headwaters flow through residential backyards until passing under the intersection of Hwy. 59 and Hwy. 69 where inflow from major storm sewers substantially increase it's stormflow rate. The underlying soil type is the Koury-Urban land complex (Ks) which is not listed among the NRCS hydric soils. However, it is described as a wet loam located within floodplains with slopes of less than one percent; and includes small areas (inclusions) of Pophers soil which is a listed hydric soil. It's description is summarized with the statement "Koury soil is poorly suited to urban and recreational uses because of wetness and flooding". Therefore any Koury soil provided sufficient hydrology will meet the tests of a 404 hydric soil.

We have identified a potential detention/mitigation site shown as a **Site** on the enclosed **Exhibit 1** on commercial land directly adjacent to the stream on it's east bank and bound by Baskin's, Lufkin Rx and the Cook Tire store. We estimate the potential area to be from one to two acres in size depending on setback required from established buildings. Some upstream peak storm surge may be attenuated within it.

Tributary One: Above the intersection of Denman Avenue and Hwy. 69 this small channel runs through residential yards maintained as is described above, and is also of the Koury soil type. Consequently, 404 permitting would be simplified as is more fully described above.

We noted a potential project site at the north end of Hunter's Creek street that is also identified as a **Site** on the attached map. It is about three acres of vacant residential land directly adjacent to a pink house that is shown as a repetitive flood loss property, located on the northeast corner of the deadend of Hunter's Creek street. Water had risen in the yard of the pink house during the recent storm event, and also in the lower corner of the prospective project site. Excavation of additional flood capacity into that lower corner may hydrologically benefit the pink house and several nearby repetitive flood loss properties.

Tributary Two: The short length of channel located in a residential neighborhood above the Lowe's store is sited on Fuller fine sandy loam (FfB) and Fuller-Urban land complex (FuB) soils. Fullers' description of saturation in winter and frequent high water table, location in interstream divides, and poor suitability for urban development indicate the potential to be hydric where regularly flooded (though not listed as hydric).

We observed that the new Lowe's has installed behind the store a small detention pond for collection of their runoff directly adjacent to (but not within) the streambed. A potential project **Site** shown is (recommended to be) expansion of Lowe's existing small pond into the vacant land surrounding it, in order to capture upstream runoff within the enlarged detention volume.

Tributary Three: Most of the upper section runs through residential yards as is described above. It's soil type is the Koury soil also more fully described above. Immediately on falling out of the last neighborhood, it enters a large, remote, un-developed area described in Section Two below. We did not observe any potential project sites directly adjacent to the small channel within the developed Section; however, flood capacity could be excavated at the outfall from the neighborhood into un-developed land as is shown on the enclosed map.

Tributary Four: Only a very small section is urbanized as the stream is semi-urbanized above and below Hwy. 59 as is described in Section Two below. It is developed into an apartment complex directly east of Hwy. 59 that does not offer opportunities for flood detention projects. The soil type is Alazan very fine sandy loam (AaB) of 0 to 4 percent slopes. It is another loamy soil limited from most uses due to wetness, but is not listed on the NRCS hydric soils list.

Tributary Five: The upper section flowing through the Crown Colony subdivision is residential and does not appear to contain a potential project site within it. The soil type is Alazan described in Tributary Four above.

We observed that where the stream outfalls from the tankcar culvert under Edmund Grey Road that the streambed has recently been channelized behind the Church Retreat property. We have not noted the area on our map, but perhaps the vacant land adjacent to the east of the new channel would serve as a project site.

Summary of Section One Report:

1.) Most of Upper Hurricane Creek that is significantly developed occurs in the upper parts of the Main Stem and Tributaries One, Two, Three and Five. The soil types identified for the Main Stem and all of the Tributaries are not listed on the Angelina County- NRCS hydric soil list; however, each type is sufficiently wet in composition to qualify as a 404 hydric soil where frequently flooded or depressional.

This factor is of little consequence in Section One (but becomes a major factor in Section Two reported below) as very few wetlands are associated with small channels located within residential backyards.

2.) Such small channels are regulated up to the historical high water mark on their streambank, and small impacts (such as stream crossings) may be allowed by various Nationwide Permits.

Channelization of the small streams will require complete 404 Individual Permits that include public notice and comment, and mitigation of those impacts. All of the tributaries within the City share this regulatory concern.

3.) Care has been taken during field work to identify and characterize sites within floodprone areas that have potential to provide flood capacity through temporary detention, and to mitigate small 404 impacts on-site.

Section Two- semi urbanized- Middle Hurricane Creek:

This Section is comprised of the Main Stem and Tributary One below Denman Avenue to the Main Stem junction with Tributary Four, Tributary Two below the Lowe's store, Tributary Three below the residential neighborhood, most of Tributary Four except within the apartment complex, and Tributary Five below Crown Colony to (but not including) it's junction with the Main Stem. This Section is also shown on **Exhibit 1**, except for that area south of Loop 287.

All of these are described as semi-urban stream segments whether large or small in size within this Section. The Main Stem's junction with Tributary Four about one mile downstream of Loop 287 marks Section Three where the area becomes very remote and rural in nature.

Generally the difference(s) between these areas and Section One reported on previous pages relates to their lower position on the landscape which must contain larger flows and have developed larger channels, some of which overflow their banks during heavy rainfall events. These floodplains adjacent to and above the main channels consist of complex, high quality wetlands that would be difficult to 404 permit complete development of as would be a part of in-stream channelization projects. Due to established high water marks, lack of NRCS hydric listing of soil types would have no effect on qualification as a Corps regulated area.

A second difference with Section One is the existing un-developed land above the high water mark directly adjacent to some parts of these channels. Such non-regulated uplands offer the opportunity for location of diversion channels and/or detention areas provided some remaining floodflow was allowed to continue to provide hydrology to existing Creek channels and adjacent floodpools.

Upper Main Stem and Tributary One: The upper Main Stem and Tributary One fall downslope toward each other below Denman Avenue, turn parallel for a short distance below the high school, and then run together within the Kiwanis City Park. A braided channel, flooded forest type of high quality wetland habitat begins within the area behind the high school and continues completely to the end of Hurricane Creek. All of the area consists of the Koury soil type more fully described in Section One above, which is flooded sufficiently throughout to qualify as hydric, and would be regulated up to the high water mark in any case. Consequently, the interstream divide and most of the streambank to either side will qualify as high quality 404 wetland.

1.) Denman Avenue South- A short distance south of Denman Avenue both the Main Stem and Tributary One begin to exhibit adjacent floodplains from frequent overflows. These are small pocket wetlands that could allow a channel to be excavated between them to intersect with the existing channel for diversion with very little wetland impact from construction activities. The existing main channels and small wetlands would require full Corps permitting to impact.

Small areas of uplands directly adjacent could site flood control projects accessed by diversion channels from and to either of the main channels.

2.) East of High School- In the area behind the high school, the Main Stem and Tributary One turn almost parallel to each other and run southward toward the Kiwanis City Park. Where the interstream divide eventually falls below the established high water mark for both channels, a good quality forested wetland is reletively intact. This quality of forested wetland would be difficult to permit 404 impacts to; and if allowed, would be a mitigation ratio in excess of one-to-one. Channelization and/or detention on adjacent upland outside wetland floodpools would be prefered, provided sufficient hydrology was available to both segments downstream.

3.) High School to Kiwanis City Park- From directly below the high school downstream to the park lies the least impacted high quality wetland along the Main Stem within the City of Lufkin. Within the interstream divide, large loblolly pines stand on mounded areas less frequently flooded, and floodplain hardwoods from saplings to mature large trees inhabit lower areas. Between large trees a typical scrub/shrub habitat provides very dense cover for wildlife. Evidently the loblolly pine timber has been thinned, but not clearcut in perhaps 50 or 60 years, and the floodplain hardwoods may be somewhat older than the pines.

Most likely, impacts from flood control projects would not be allowed, including reduction of upstream floodflow by bypassing the area within an uplands with a channelization project. Excessive ponding more than is currently existing may or may not be allowed.

4.) Kiwanis City Park- Most of the park lies within an established floodplain between the Main Stem and Tributary One flowing to their junction at the lower park boundary, except for a small amount of high ground along the eastern edge. This naturally formed floodpool acts as a small volume detention basin when the two channels overflow their banks and pond against the roadbed along the southern edge of the park. However, during smaller rainfall events that do not cause overflow, water drains quickly off into both bordering channels, which enables the interstream divide to dry faster than nearby poorly drained areas. Large pines and hardwoods provide extensive shade cover for the park, but all small shruby species that would normally live between them are prevented by park maintenance.

As the park is currently impacted by development, additional development for flood control may be more acceptable to wildlife agencies than the area directly upstream. However, the City may not desire loss of any park area to flood control. Mitigation would be required for any type of development actvity that is more intrusive than existing park facilities.

5.) Summary of Upper Main Stem/Tributary One- There appear to be opportunities for small flood control projects within uplands directly adjacent to both stream segment(s) described in item **1.)**. Some projects may be allowed within Corps regulated wetlands in both stream segments identified as items **1.)**, **2.)** and **4.)** above. Such impacts would require suitable mitigation nearby and to be like-kind habitat replacement.

Most likely, development impacts would not be allowed to either stream segment and/or their interstream divide within item **3.)**, including negatively affecting their flooding regime.

Lower Main Stem: The Main Stem flows through an active floodplain along the Azalea Trail to Richardson Park where it is joined by Tributary Three. Their combined flow continues as the lower Main Stem of Hurricane Creek to it's junction with Tributary Four. All of the Main Stem below Tributary Four is reported on in the following Section Three due to it's considerable change in character from that point. That part inside Loop 287 is shown on **Exhibit 1**, and that part below the Loop is shown on **Exhibit 2**.

The area from the City Park to Tributary Four consists of frequently flooded Koury soil that qualifies as a 404 wetland. The high quality flooded forest type of habitat described previously continues throughout the area and is not described in detail here.

1.) Azalea Trail Segment- Hurricane Creek flowing from the City Park along the Azalea Trail flooded it's streamside zone from the storm event occurring during our field work. The small amount of rainfall during the event indicates that the zone is frequently flooded. The available hydrology causes the Koury soil type to be considered hydric, except where new deposits of sand changes it's nature. At the end of the Azalea Trail, the stream is joined with Tributary Three in Richardson Park and turns southward under Loop 287.

The narrow floodway is constrained by development all it's length to the park junction limiting potential for projects outside the floodway. The floodway zone would be Corps regulated and difficult to permit development projects within that are more intrusive than the Azalea Trail.

2.) Segment below Loop 287- As the Creek emerges from under the Loop, it's channel widens considerably in order to allow larger flows from the addition of Tributary Three. It begins to curve sinuously in a manner that continues on an increasingly larger scale through Section Three described below to it's junction with Cedar Creek. The soil type is the Koury soil which is sufficiently flooded to be hydric below the stream's regulated high water mark. A short distance downstream at the junction with Tributary Four, the soil type changes to Pophers (Po) silty clay loam, which is a NRCS listed hydric soil.

Due to the soil type change, additional floodflows of Tributary Four, and remote nature of the landscape, we have selected the boundary between Section Two and Section Three to be at that junction. Accordingly, this small segment noted as item **2.)** is shown on the map identified as **Exhibit 2**, rather than with the balance of Section Two on **Exhibit 1**.

a.) potential flood control project(s)- This segment is unique due to it's potential for location of flood control projects for the City, provided that it is not too far downstream from problem areas in the center of the city to be effective. This is the last segment of Koury soil such that any area not frequently flooded will not qualify as a wetland. Those areas under the high water marks are limited by high banks and small flood zones across the inside of curves in the streambed. This presents a much narrower regulated zone to Corps permit than the broad floodways prevalent both upstream and downstream. Channels could be cut from an outside bank curve through uplands to the next outside bank, bypassing the lower regulated riparian wetland on the inside curve with only minor 404 permitting.

b.) <u>other considerations</u>- Small amounts of mitigation would be required for areas where cuts were made into the bank. However, the inner loop wetland will be required to have as much access to floodwater as before project construction for this strategy to be easily approved. The abandoned inner loop will provide some additional flood capacity, but may cause undesirable turbulence. Also, future siltation may cause the Creek to leave the new channel and return to the old sinuous configuration.

c.) <u>potential detention/mitigation project(s)</u>- This area appears to be the first un-developed land along the Main Stem of Hurricane Creek where acreage may be available for large scale detention projects (there are some large raw land tracts upstream along Tributaries Two and Three described below). Within such a large detention project, there are opportunites for landscape scale 404 mitigation.

Large wetland projects may be operated as mitigation banks where other City project 404 impacts could be mitigated, and/or space may be sold to a private developer. Along the gulf coast, the Texas Department of Transportation has participated in a number of mitigation banks operated by other entities.

Tributary Two: The semi-urban area starts directly below the Lowes' store and flows westward outside of and parallel to Loop 287 until it falls beneath the Loop and mall parking lot. At about the Lowes' store the soil type changes from Fuller fine sandy loam (Ffb) to Alazan very fine sandy loam (Aab) of 0 to 4 percent slopes. It is another loamy soil limited from most uses due to wetness, but is not listed on the NRCS hydric soil list. The stream segment is shown on the map attached as **Exhibit 1**.

A short distance downslope from Lowes' the channel splits into a braided multi-channel flooded forest configuration. The high quality of forested wetland active flood zone would be difficult to 404 permit. The narrow landform between the floodway and the Loop does not seem suitable for flood control projects. As described more fully in Section One above, a large upland area is located directly adjacent to the south of Lowes' small detention pond that may have potential for expansion into a large detention project.

Alternatively, a channel could be cut into the upland running parallel, but bypassing entirely around the floodway zone downslope to the main culvert under the Loop, provided that sufficient flow continued to be available to the avoided wetland area.

Tributary Three: This segment falls out of the developed neighborhoods and flows through a large un-developed area in a large curving stream southward to Grace Dunn Richardson Park where it joins the Main Stem. It is located on Koury soil it's entire length and is shown on the map attached as **Exhibit 1**.

At the upper end it is a small channel with raw land tracts on both sides that has the potential for 404 permitting for flood control. This short reach of low quality mostly in-channel streamflow has the potential to be one of very few in the City that may be allowed in-stream channelization with appropriate mitigation proposed for it's 404 impacts.

A short distance downstream several large flows are introduced that widen the channel into a major stream with frequent overflows similar to other streams within Loop 287. This larger channel would be difficult to 404 permit impacts to as is previously described several places.

We noted that the City owns and is actively developing land on the western shoreline above the park. This tract happens to lie within the inside curve of the stream that maintains a large floodway across the lower elevations when flowing above the inner bank. Due to previous landclearing activities, the floodzone is changing into an open-sun wet prairie habitat rarely observed within the City.

There may be potential for location of a channel within the upland lying above wetland level. It could cut across the inner loop directly southward to the next outer loop segment within Richardson Park, but allow the inner zone to continue to flood.

Tributary Four: A different profile begins with Tributary Four in that it's located entirely outside of the central City of Lufkin (outside the Loop). East of the apartment project at HWY 59 the channel is reletively small and rarely overflows into 404 wetlands. Below HWY 59, the channel widens from larger inflows and many adjacent forested wetlands are associated with the channel. It is shown on the map titled **Exhibit 2**.

The soil type is the Alazan (Aab) loam type described previously on page 22, except for a small area prior to infall into the Main Stem of Moten-Multey complex (Mx), gently undulating, nearly level stream terraces. Although Moten-Multey is not listed on the hydric soils list, it's description is wet enough that where sufficient hydrology was available, it would be considered a 404 hydric soil. The lower floodpool at the junction of Tributary Four begins the Pophers soil type which is a listed hydric soil type.

East of HWY 59 the small channel exhibits vacant land on either or both sides for most of it's length, although there is a considerable amount of development upslope on the higher ridgelines. It falls out of a large lake flowing westward, and mostly remains within the small channel. This may be another of those segments that would be able to permit in-stream channelization with an appropriate amount of mitigation offered for it's un-avoidable impacts. West of HWY 59 the larger stream would be difficult to permit in-stream projects. However, adjacent vacant uplands on both sides of the segment offer project opportunities.

Tributary Five: The northernmost reach falls out of Crown Colony through a recently channelized area behind the Church Retreat development and joins it's southern arm in a very good quality forested floodpool between their junction and HWY 59. It's soil type is the Alazan (Aab) loam described above east of HWY 59, west of 59 the Pophers hydric soil begins as a part of the Main Stems' upper floodpool down to it's junction with the Main Stem.

The southern segment above the junction is a very small channel that would have a minor amount of 404 permitting requirement as is more fully described in Section One above, including the rare possibility of in-stream channelization. The floodpool east of HWY 59 and all of the main channel west of 59 would be difficult to permit impacts to.

Summary of Section Two Report:

1.) The segment defined as Middle Hurricane Creek lies within a highly developed floodplain that constricts floodflow between well drained commercial land directly adjacent. Most of the Main Stem is currently utilized as public park area and stormwater is allowed to overflow the main channel(s) through the minimally developed floodplain.

2.) The Main Stem and it's floodplain wetlands consist of high quality forested wetland habitat, such that major development projects would be difficult to permit with wildlife agencies that are more intrusive than existing park facilities.

3.) The Main Stem south/outside of Loop 287 does have potential for 404 permitting of large scale flood control projects provided adequate mitigation is proposed to offset wetland/stream impacts. If the project were a detention basin excavated from uplands, it would have flooded land available sufficient to mitigate it's own 404 impacts, and additional area to mitigate impacts from other City projects nearby.

4.) Tributaries Two, Three, Four and Five are adjacent to large tracts of land which have potential for flood control projects to be 404 permitted for construction within their upland areas outside of existing floodways.

5.) The eastern upstream channels of Tributaries Four and Five, and a short segment below developed neighboods of Tributary Three are small in size and rarely overflow into adjacent wetlands. They may be allowed in-stream channelization by wildlife agencies with appropriate mitigation proposed.

Section Three- semi rural- Lower Hurricane Creek:

This Section is described as that part of the Main Stem of Hurricane Creek below it's juncture with Tributary Four throughout it's length to Cedar Creek, and all of the streambanks of Tributaries Six and Seven. The difference(s) between these areas and Section(s) One and Two reported on previous pages relates to their considerably larger stormflows. The Main Stem has developed a large riverine channel that overflows its' banks during heavy rainfall conditions. Similar to Section Two within the City, these floodplains consist of complex, high quality wetlands that would be difficult to 404 permit complete development of.

In addition, the streambank(s) and associated floodplain of the Main Stem at and downstream from Tributary Four is located on soils that are listed as hydric by the NRCS. From the City Treatment Plant at FM 324 downstream to Cedar Creek there may be (or may not be) endangered species associated with either the streambed or the streambanks. All of Section Three is shown on the map attached as **Exhibit 2**, with suggested project locations described below marked as a **Site**.

Main Stem: The hydric soil Pophers (Po) is mapped in a floodpool configuration around the the junction with Tributary Four along with a less hydric soil Moten-Multey complex (Mx) upstream within Tributary Four. The Pophers soil type is mapped by the NRCS along the Main Stem completely to Cedar Creek, and is mapped to extend up the floodpools of junctions with Tributaries Five, Six and Seven. It is mapped upstream on both banks of Tributary Five eastward to HWY 59.

Pophers is described as "deep, slowly permeable, somewhat poorly drained soils on bottomlands. These soils formed in loamy and silty alluvium. They are subject to flooding mainly in winter and spring. Slopes are generally less than 1 percent" according to the NRCS.

This mapping of broad areas of Pophers hydric soil along both streambanks of the Main Stem, and even wider flood zones at tributary junctions, is important to consideration of potential for 404 permitting of flood control projects on adjacent lands. Upstream the non-hydric listing of soils allowed classification of most areas outside the high water mark technically as uplands, consequently such uplands have been suggested as having potential for development of City projects. This downstream segment and associated wider floodpools have no uplands directly adjacent to propose projects within (that may be easily permitted by wildlife agencies).

From it's junction with Tributary Four downstream to Cedar Creek there may be a T & E Species consideration of small fishes. Downstream of FM 324 there may be a concern for timber rattlesnakes along streambanks on either side of the channel.

Directly south of Loop 287, Tributary Six runs parallel to and west of the Main Stem almost to their junction before flowing westward under FM 324. Above their junction floodpool, there is an upland ridgeline area suitable for 404 permitting between the tributary and main channel that may (or may not) have potential as a flood control project area shown as a **Site** on the attached map.

West of FM 324 the large floodway resulting from joining of the Main Stem and Tributary Six continues downstream to Cedar Creek. This habitat is a large scale flooded forest similar to a major river floodplain. The highest flood elevation is somewhat lower than the base of the adjacent City Treatment Plant. Except for that small area around the plant that is regularly mowed, tracts of land on both sides of the Creek consist of floodplain hardwood tree species. It would be difficult to 404 permit any type of development project adjacent to the Creek west of FM 324 any more intrusive than the timber harvesting currently practiced by private landowners.

Tributary Six: The headwaters of Tributary Six begin at the edge of Loop 287 and flow southward a short distance to the Main Stem. The soil type is Fuller fine sandy loam (FfB), 1 to 4 percent slopes. Fuller is a soil that is not wet enough to be classified as hydric above any channel high water marks. For a short distance below Loop 287 it flows within it's banks to the extent that this segment may be allowed in-stream channelization. Large tracts of uplands to either side may have potential for detention projects, also shown as a **Site** on **Exhibit 2**.

Several thousand feet south of Loop 287 the channel widens into a major stream, and floodflows above the bankside have established a floodway wetland on both sides. Although the Fuller soil type continues downstream, it is flooded suficiently to be hydric, and is regulated as being below the streams' high water mark.

Tributary Seven: The north and south branches of Tributary Seven are located on Alazan (AaB) and Fuller (FfA) soils more fully described above, as well as a short reach of Herty very fine sandy loam (HeB), 1 to 5 percent slopes along the north branch between HWY 59 and Daniel McCall Road. All three soil types are not wet enough to be listed as hydric by the NRCS.

Both branches east of HWY 59 are small enough that in-stream channelization may be permitted, except where they pond against the highway. From the floodpool formed at the junction of the north and south branches west to the Main Stem, the flooded forest habitat is such that permitting direct impacts to the habitat by wildlife agencies would be difficult.

Results: Mill Creek

We have organized our report on the watersheds of Mill Creek into details regarding it's east and west branches, which larger streams are further divided into east and west forks upstream. A number of technical descriptions are similar to those described at length in the previous report on Hurricane Creek and are not re-described in great detail here. The nature of Mill Creek is considerably different from Hurricane Creek, due to it's character consisting of at least 50% of prairie wetlands.

All of the area within Mill Creek watersheds are as is shown on the enclosed **Exhibit 3**, and suggested project locations are marked as a **Site**. The area is reported on as follows:

East Branch: The East Fork begins to flow northward from the outfall of Jones Lake within Jones Park under Martin Luther King. It's upper segment is located on Keltys-Urban land complex (KdD), 5 to 15 percent slopes that is a well drained upland fine sandy loam. The only hydric soils are those located directly under constant streamflow and associated wetland floodpools. The floodway below the outfall of Jones Lake is a good quality prairie (open-sun) wetland varying in width from 20' to 50'.

East of Martin Luther King the stream mostly remains in the small channel as it curves northward around the apartment complex. It enters an area of small trees at the edge of the apartments where the soil changes to the Koury type reported on previously. An in-stream channelization project may be allowed in this segment. As the channel emerges from under the trees, it widens out into an established floodpool that supports a very good quality prairie wetland.

A small area directly adjacent, parallel to Martin Luther King (located under powerlines) may have potential for a small detention/mitigation project as is marked as a **Site** on the attached map. We suggest that it would be <u>an excellent area for location of a small 404 mitigation project</u> if it were not suitable for flood control.

At this point, the East Fork flows northwestward under Martin Luther King again. The West Fork joins it immediately after flowing from Lake Myriad. The combined flow of the East Branch runs alternatively through flooded forest and back into the open sun to and under the railroad tracks and Loop 287 to the City Lake. Wetlands associated with the floodway (both forested and prairie) are 50' to 200' wide, establishing a large regulated area that will be difficult to permit impacts to. A separate floodpool between the railroad tracks and the Loop has established a large prairie wetland that is mowed regularly during dry weather periods.

West Branch: The East Fork consists of two small arms falling steeply downslope from HWY 103 northward, parallel and west of FM 2251 to it's junction with the West Fork. The upper channels are located on soils of Alazan-Urban land complex (AcB), 0 to 4 percent slopes and the lower elevations cross the Koury soil type. The channels of the East Fork and their associated wetlands are small at this time, which may have potential for in-stream channelization or detention/mitigation projects. Where it joins the West Fork, a large floodpool is formed that would be difficult to permit impacts to.

The West Fork has established a major floodway that runs parallel to and between the Loop and railroad tracks, eastward towards City Lake. It is also located on the Koury soil type. The floodplain alternates between forested and prairie depending on which different ownerships mow their land regularly. All of the West Fork and it's floodplain wetlands are large and of very good quality. They would be difficult to permit (any type of development activity to) with wildlife agencies.

Main Stem: We observed the large floodpool between the railroad tracks and Loop 287 during flood conditions, in which the flood storage capacity (of) was impressive. It receives all of the combined flows from the East Branch and West Branch, and outfalls below the Loop northward into City Lake (Ellen Trout Memorial Lake).

Directly northward of the Loop culvert is a forested floodpool at the head of the Lake. This particular wetland area resembles the description of habitat typical of that utilized by the alligator snapping turtle. However, the USF&WS and the TP&WD did not express a concern about the area for T & E Species. Whether or not any snapping turtles may inhabit the area, as potential habitat it may be very difficult to construct any type of projects within.

Downstream of the Lake, Mill Creek flows northward within a large channel through a large pasture area towards HWY 59. It is also located on the Koury (Ko) soil type described previously. Within the short reach inside the City of Lufkin, it mainly stays within the large channel. Where it is not associated with a wetland floodpool, flood control projects may be allowed within or at least adjacent to the stream. Whether or not it is suitable for flood control projects, the large area of cleared pasture would be suitable for constructing a large wetland mitigation project, which is shown as a **Site** on **Exhibit 3**.

City of Lufkin Map Exhibits

Three (3) map exhibits are presented on following pages in support of Wet Tech's Preliminary Wetlands Survey as a part of the City of Lufkin Watershed Study.

Exhibit 1- **illustrates material from the report on Upper and Middle Hurricane Creek.**

Exhibit 2- **maps the areas described within Lower Hurricane Creek; and**

Exhibit 3- **maps areas identified within Mill Creek watersheds.**

Legend:

1.) Tributary Number---------------------------------- **5**

Identifying Tributary number as assigned by Dodson & Associates on the map of Stream Names of Lufkin, Texas.

2.) Potential Flood Control Project Site---------------- Site

A partial mapping of suggested project sites described in report text, proposed to be located in uplands adjacent to stream.

3.) Upper Tributary Flow------------------------------ DRAINAGE

Direction of flow of tributary toward Main Stem of Hurricane Creek or Mill Creek.

4.) Major Stream Overflow Areas (at Junctions)------ PONDING LOWLANDS

Typical areas of long term ponding during floodflow at junctions between tributaries or with main stem.

5.) Typical Wetland Areas in vicinity------------------ WETLANDS

Location of wetlands typical (of wetlands) nearby as is described in report.

6.) Typical Wetland Type in vicinity------------------- FOREST FLOOD PLAIN

Type of wetlands typical of those indicated in area as is described in report.

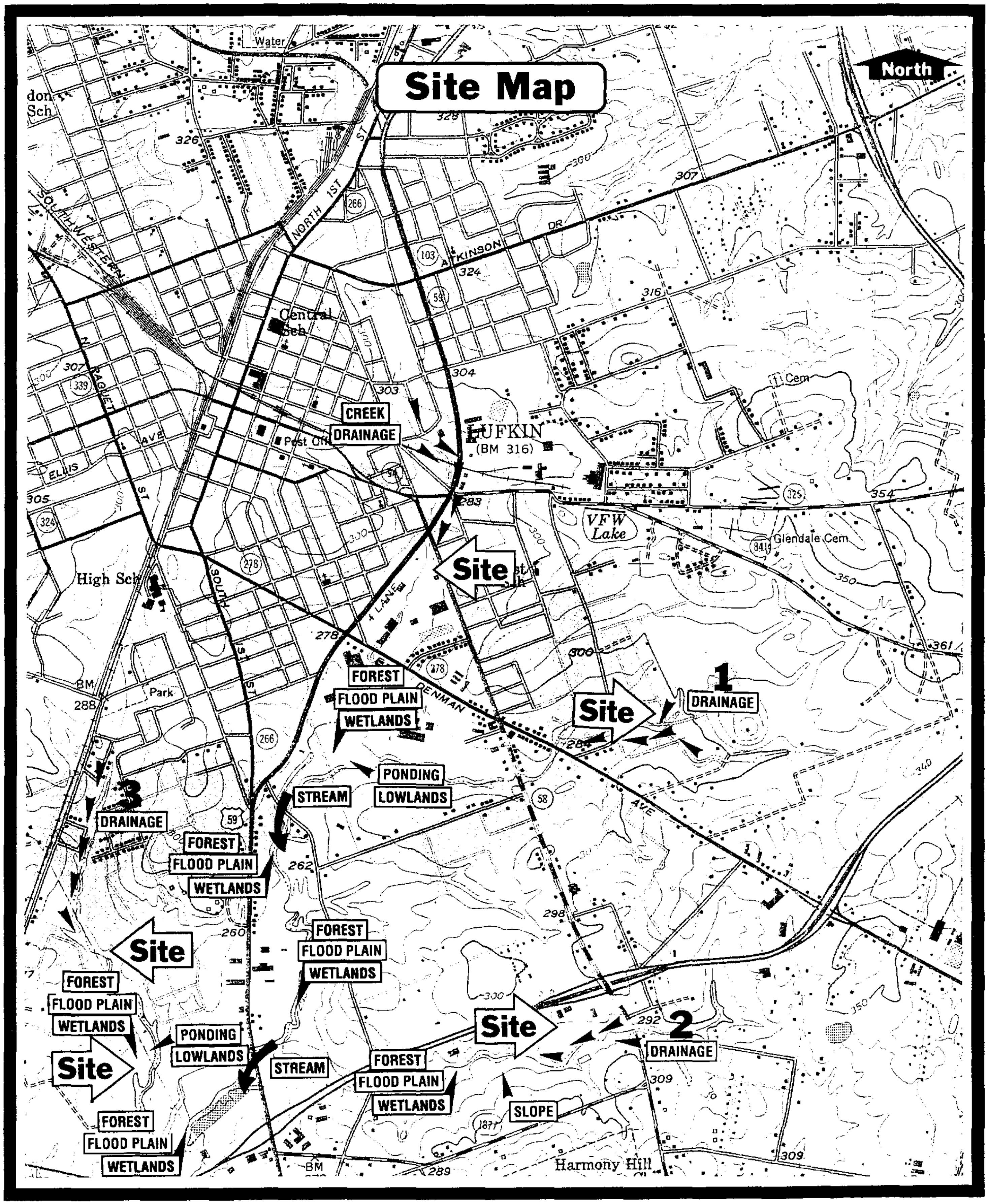

Site Map
North
Site
Site
Site
Site
Site
CREEK
DRAINAGE
1
DRAINAGE
2
DRAINAGE
3
DRAINAGE
FOREST
FLOOD PLAIN
WETLANDS
PONDING
LOWLANDS
STREAM
SLOPE
LUFKIN
(BM 316)
VFW Lake
Glendale Cem
Central Sch
High Sch
Park
Post Off
Harmony Hill
ATKINSON DR
DENMAN AVE
NORTH 1ST ST
SOUTH 1ST ST
SOUTHWESTERN
ELLIS
4 LANE
Water

Exhibit 1

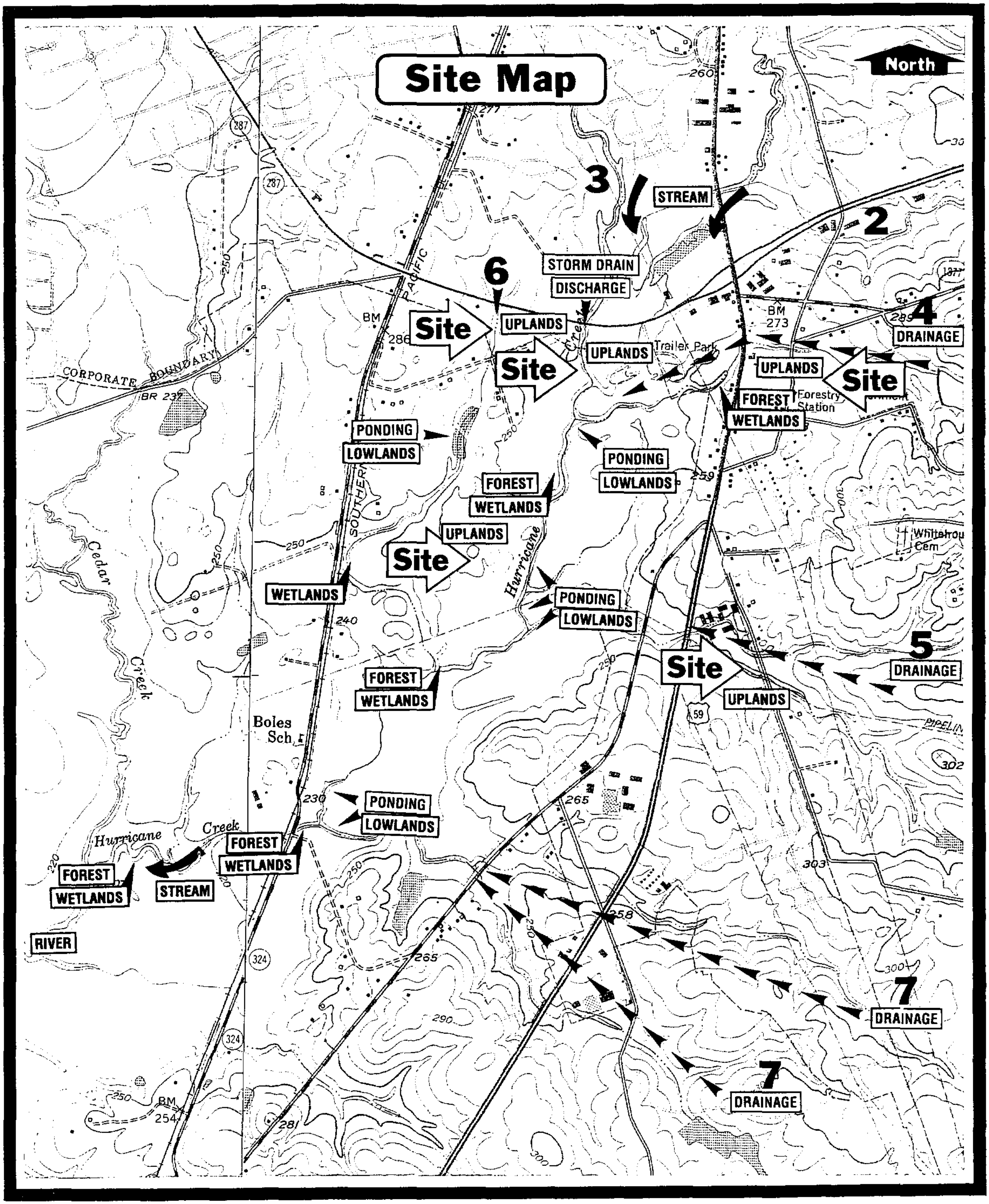

Site Map
North
STREAM
STORM DRAIN
DISCHARGE
UPLANDS
Site
DRAINAGE
FOREST
WETLANDS
PONDING
LOWLANDS
Trailer Park
Forestry Station
SOUTHERN PACIFIC
CORPORATE BOUNDARY
Hurricane Creek
Cedar Creek
Boles Sch
RIVER
PIPELINE
Whitehouse Cem
2
3
4
5
6
7
7

Exhibit 2

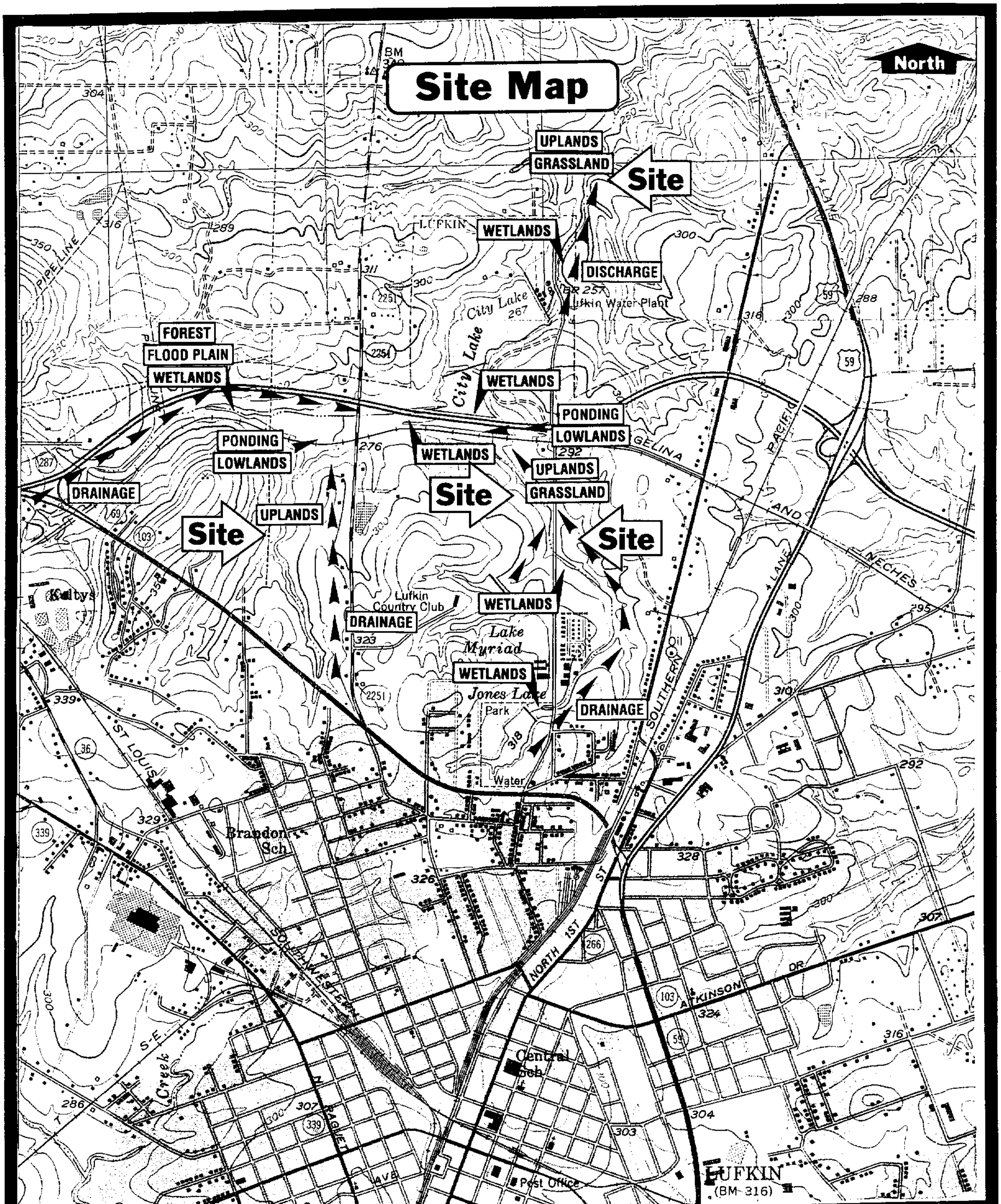

Site Map
North
UPLANDS
GRASSLAND
Site
WETLANDS
DISCHARGE
Lufkin Water Plant
City Lake
FOREST
FLOOD PLAIN
WETLANDS
WETLANDS
PONDING
LOWLANDS
PONDING
LOWLANDS
WETLANDS
UPLANDS
GRASSLAND
DRAINAGE
Site
Site
UPLANDS
Site
Lufkin Country Club
DRAINAGE
WETLANDS
Lake Myriad
WETLANDS
Jones Lake
Park
DRAINAGE
Brandon Sch
Central Sch
Post Office
LUFKIN
(BM 316)
NORTH 1ST ST
ATKINSON DR
SOUTHERN
PACIFIC
ANGELINA AND NECHES
ST LOUIS
SOUTHWESTERN

Exhibit 3

Wet Tech
Wetland Technologies Corporation

... providing watershed assessment, design, and construction supervision services.

November 16, 1998

Mr. Duane Barrett, P.E.
Dodson & Associates, Inc.
5629 FM 1960 West, Suite 314
Houston, Tx. 77069-4216

Re: Interim Project Review- Proposed City of Lufkin Stormwater Project(s)

Subject: Hurricane Creek and Mill Creek Watershed(s)

Dear Mr. Barrett;

Please find following our Report detailing findings regarding the proposed project sites. This material was developed during an inspection the afternoon of November 4, 1998, all day of the 5th, and the early morning of the 6th. A recent storm had flooded some of the lower areas several days before.

We noted that certain placement guidelines had been developed from our previous Report and employed to greatly reduce potential conflicts with regulatory agencies; however, where these are not appropriate for a particular site is described herein.

Please let us know if there are any questions regarding the enclosed material.

Sincerely;

WETLAND TECHNOLOGIES CORPORATION

Glenn Jarrett,
General Manager

1831 Pinewood Ct. • Sugar Land, TX 77478 • off: ~~713~~ 281-242-8734 • fax: ~~713~~ 281-491-0825

Additional Comments regarding:

Project Site Selection & Design Criteria

Location of Flood Control Structure(s):

Most proposed projects consist primarily of a berm type dam/spillway sited across a small channel that would detain stormwater a required period of time, and then drain slowly to a "dry-bottom" configuration. As these berms have a small footprint of impact across a regulated streambed, and no permanent impoundment is created, then resource agency objections will be minor to the extent mitigation should be allowed by them (in most cases). This criteria would not constitute a "small impact" within major channels, and we note that none are proposed to do so (Project's #1 and #2 on Mill Creek are close).

However, several proposals specify excavate-and-haul-away which impacts an entire site permanently. Those that would be minimal impact and those that would not are differentiated to the extent possible below without extensive on-site work.

Where an improvement in re-locating a site a short distance is appropriate, we have so described in the following material.

Design Criteria:

Where the **purpose of a project** would not incorporate construction of mitigation within, the berm's "footprint impact" will be required to be the smallest possible to achieve the desired storage capacity. Where mitigation is planned within, mitigation requirements will be required to be **primary** over capacity considerations.

Mitigation Criteria:

Certain proposed project sites that appear to be more suitable for mitigation meet a specific criteria that generally floods a large area (that) currently qualifies as upland. In some cases we recommend re-locating a structure in order to flood a flatter area now currently proposed to be avoided. An example would be our comments regarding Mill Creek Watershed's Project #3 wherein a part of the avoided area may be suitable to be incorporated within. Where upland sites are excavated for retention, opportunities exist for mitigation projects to be specified. **It is important to note that all of the projects proposed will require some amount of mitigation offset.**

Review of Proposed Hurricane Creek Project(s)

Introduction:

Inspection of major projects proposed inside Loop 287 and Project's #5 & #6 outside the Loop revealed no major impediment to regulatory approval for sturctures or excavation (except for #2 more fully described below). Where upstream channelization may be allowed varies with each stream and is described to the extent possible in this work.

Project #1:

This project appears from Cunningham and Ford Chapel Rd. to be a large, well drained site. There is an undeveloped area to the south that does not have an approach (is not easily viewed). It appears to flood a large volume with the proposed berm location such that excavation would not be needed for additional capacity. Such criteria may indicte a potential for location of a suitable mitigation site. If so, Wet Tech is of the opinion that **necessary mitigation required** for this project and others nearby be incorporated within.

Mitigation would specify little or no landclearing; rather the shallow excavations should be specified to be constructed between groups of trees with inter-connecting swales. The fertile topsoils would be cut out and set aside for re-installation and planting after shallow excavation work is complete. If the underlying subsoils are suitable, they would be used for berm construction; thereby saving the cost of hauling them away, and the cost of materials importation (for berm construction).

Most likely the improvements proposed for the small channel would be allowed (with suitable mitigation) downstream to Denman Avenue.

Project #2

This project may not be feasible as proposed. It is specified to be over-excavation of an existing depressional site for additional stormwater capacity (it currently holds and slowly releases a large volume of run-off). The existing forested over-bank depressions surrounding the confluence of several small channels is of very high habitat quality.

The site's **only potential** would be in delineating existing wetlands and excavating outer edges of available un-developed land up to, but not within the specified "avoid area". Final outfall elevation must remain as currently exists, only capacity would be increased.

Project #3:

The channelization proposed above and under Chestnut St. would most likely be allowed, while that proposed south of Chestnut would not.

The area designated behind Kurth Elementary school currently floods, consequently increasing the floodpool footprint would be acceptable provided little or no impact occurred from berm construction. Care must be taken to select an upland area for the specific berm location; otherwise, the site is excellent as proposed.

Additionally, there is a vacant land tract directly adjacent east of the school ballfields that (if available) would be suitable for excavation of a regional retention project with mitigation incorporated within (see drawing on next page). It may be appropriate to install paths and decks across the permanent wet bottom areas as a neighborhood park in the same manner as Kiwanis Park/Azalea Trail nearby (warning signs of danger during major floods would be required for the school's ballfields and the public use area).

Project #4:

This project is proposed to be specified in a similar manner as Project #3 in the southeast corner of Tulane and York Streets. Again, provided the specific berm location is carefully selected for least habitat impact, this is an excellent project location. Additionally, an un-developed area above the intended floodpool directly to the southeast would be suitable for mitigation. Upon closer on-site inspection it may prove acceptable for significant excavation also. As a large volume of material will be required to construct the berm, a cost off-set from balance of cut-and-fill may be possible.

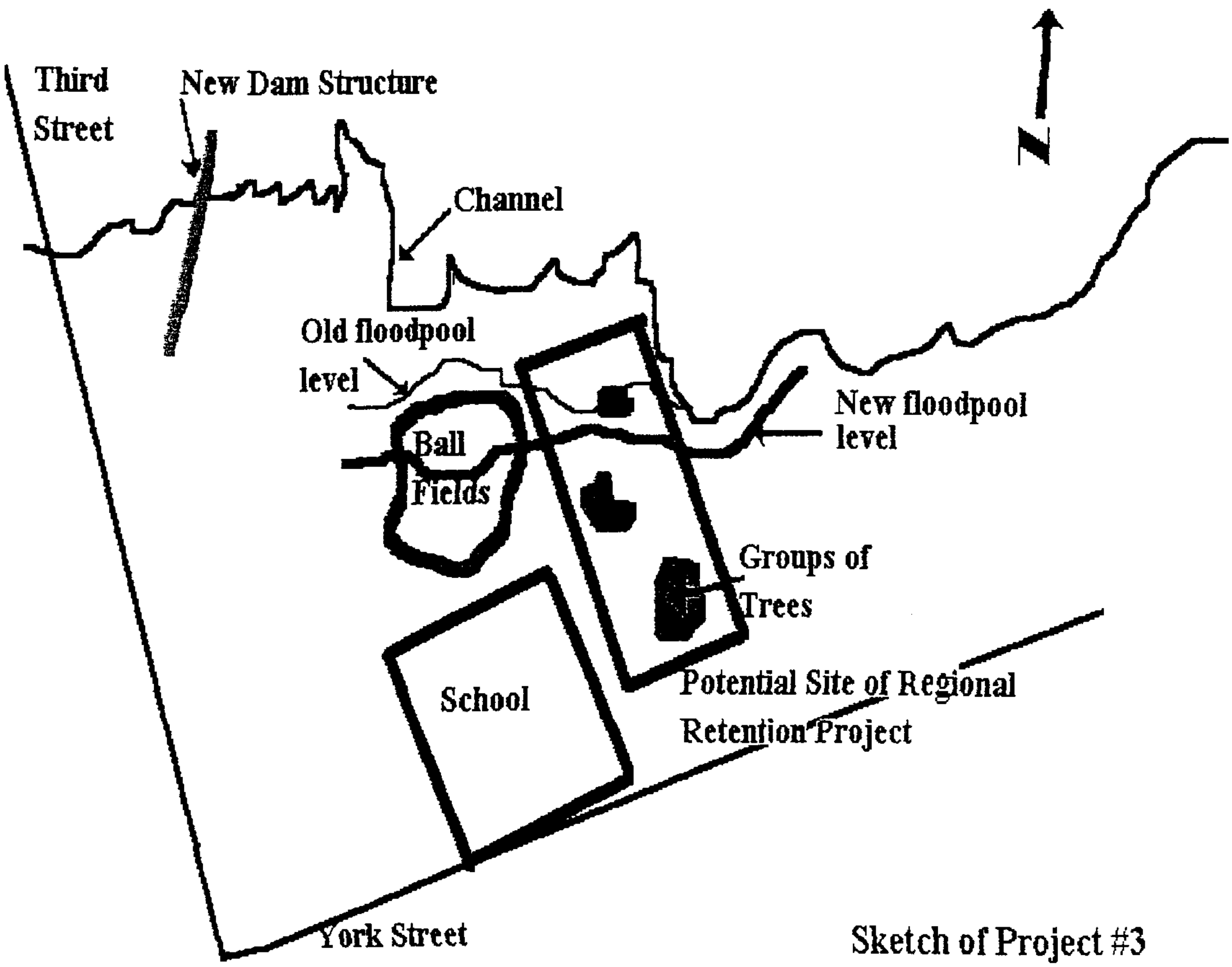
Main Stem of Hurricane Creek:

Specification of a major bypass channel directly west of the Main Stem below Kiwanis Park southward to the mall is an environmentally acceptable alternative. However, the channel would eliminate the newly installed Azalea Trail; consequently funding agencies may require the City of Lufkin to reconstruct it on the east side of the Creek at the City's expense. Secondly, it would eliminate parking behind some of the commercial businesses fronting old HWY 59. The City of Lufkin may <u>choose not to construct</u> the project.

Perhaps the bypass could be specified to be located **on the east side** of the Creek in the same manner with avoidance of existing homes where necessary. Channel excavation would provide considerable material for other berm construction projects nearby.

Proposed Project #3-Hurricane Creek Watershed

Typical excavation of Regional Retention Project capacity into adjacent vacant upland while avoiding currently flooding sensitive habitat.



Sketch of Project #3
Hurricane Creek
Watershed

not to scale

Project #5:

Similar to Project's #3 and #4 more fully described above, this project location appears to be suitable for regulatory purposes as well as storage potential. The berm site should be carefully selected, with appropriate mitigation proposed and constructed on-site.

Channelization proposed should be acceptable downstream to, <u>but not beyond</u> the Lowes Store with mitigation. Refer to detailed description recommendations made in the Lowe's Store area on page 22 of Wet Tech's previous Report dated 9/15/98.

Project #6:

The proposed low impact berm type retention specified for #6 is well suited to it's selected location with appropriate mitigation.

Channelization proposed from the Lowes Store downstream to the Project #6 floodpool, and downstream from Project #6 to the Loop most likely **would not be allowed** at some reasonable amount of mitigation. However, vacant upland directly adjacent to the south is suitable for installation of a small bypass channel (which would have a lower construction cost than the proposed channelization). Also, for that reason <u>either section would not pass 404 Alternative Analysis</u>.

Project #7:

<u>Channelization</u>- Improvements within neighborhoods upstream on Tributary #3 should be acceptable with a small amount of mitigation required. However, the channelization proposed downstream to the large bypass would be difficult to 404 Permit. If hydraulically feasible, the lower total cost to the City may be a small bypass channel excavated from the neighborhood outfall straight through the "S" of the natural stream to connect with the larger bypass downstream (which is appropriate as proposed).

<u>Additional Land for Storage</u>- Acquisition of un-developed land within the white area outlined in blue in order to prevent future development is suitable for this particular zone. However, as an existing floodpool small uplands would be required to be selected on-site for any excavation desired, and all other areas carefully avoided by construction equipment (see typical design on previous page).

On closer inspection, it might be determined that little or no additional capacity could be excavated into such a sensitive habitat. The adjacent area shown in blue fill has the same circumstances; in that lower elevations are <u>too high in quality</u> to excavate, and upper elevations may not be feasible for excavation.

Proposed Project #8, Project #9 and Project #10:

Each of these berm/dry bottom type designs should be acceptable to resource agencies if carefully sited for least impact and suitable mitigation is proposed.

Most channelization proposed south of the Loop will be acceptable east of HWY 59 (however, certain areas will not be); and most of that west of 59 will not be acceptable. As previously reported, the natural streambed outfalling from Crown Colony has been recently channelized behind the Church Retreat property as a part of current land development activity.

Projects proposed for Tributary Six:

Two large ponded areas are proposed to be expanded to increase storage volume. The transitional (flood up-flood down) wetland edges must be avoided by all construction activities. Excavation of uplands directly up to, but not into the wetland edge would be acceptable. Properly designed and constructed these upland work areas could qualify as mitigation for 404 impacts nearby.

Channelization southward from the Loop to the first existing pond may be acceptable; that specified south of the first pond to the Main Stem of Hurricane Creek would not.

Review of Proposed Mill Creek Project(s)

Project #1:

This major streambed will be difficult to 404 Permit impact due to the high quality habitat involved. Extreme care should be taken in exact site selection, and at least a ratio of 2:1 of mitigation should be offered resource agencies in the first approach to them.

Channelization in the large streambed directly upstream would not be allowed. Where the channel upstream to the west is a much smaller/lower quality habitat, channelization would be allowable with suitable mitigation offered.

Project #2:

Wet Tech is of the opinion that the large amount of flood storage resulting from this (one) project's impact is an excellent proposal for the watershed. However, the quality of habitat to be impacted by the dam/spillway structure is very high, slightly more so than described for Project #1 above. Under any "lesser benefit" set of circumstances this impact may not be Permitted. Specific project and mitigation design should consider all aspects of the proposed 404 Permit Application before proceding to agency contact.

Project #3:

This project is unique of all of the berm type projects proposed for both watersheds. It's special character is due to the large amount of flat open land proposed to be flooded that is now currently upland. We suggest that this particular elevation be left as-is for construction of a **regional mitigation project** rather than excavation to increase strorage capacity (of course, the edges rising above could be cut back to increase total project capacity). It also appears that the berm could be re-located a short distance downstream in order to flood a larger area of this elevation.

On closer inspection, it may be that the previously cleared land (site of overhead powerlines) is large enough to locate mitigation required for all four Mill Creek Projects. Savings in construction costs to the City would be extensive.

Channelization upstream of Project #3 will most likely be allowed with suitable habitat mitigation proposed.

Project #4:

This project is sited directly adjacent to/upstream of a good quality prairie wetland that would be difficult to impact. It is correctly located as drawn to temporarily flood a small wooded area behind the apartment complex.

Channelization proposed upstream behind the apartments would be acceptable up to, but not including the outfall area below Jones Lake (which should be protected from all proposed project impacts).

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	*HC1A*	*HC1B*	*HCT1A*	*T1B1*	T1B2	T1B3	T1B4	T1B5	T1B6
			Parameter Values for Given Sub-Area Number								
Drainage Area											
Area		ac	302	965	206	78	157	44	39	339	30
Area		sm	.472	1.508	.322	.122	.245	.069	.061	.530	.047
Impervious Cover											
Land Use	I(%)										
Ind./Comm.	80%	ac	98.5	345.7	21.5	18.5	.0	.0	.0	63.0	5.4
Multi-Family	70%	ac	.0	3.7	.0	.0	2.2	.0	.0	10.2	.0
Highway	60%	ac	5.9	.0	13.1	.0	.0	.0	.0	.0	.0
Community	40%	ac	.0	8.7	.0	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	68.6	318.3	28.2	30.8	14.8	25.8	38.6	173.5	2.2
S-F (Light)	15%	ac	128.5	154.9	1.2	.0	.0	.0	.0	5.4	.0
Future Development		ac	.0	134.2	142.3	28.2	140.3	18.4	.6	75.8	22.6
Future Impervious		%	60%	50%	60%	30%	30%	30%	30%	50%	80%
Total		ac	301.5	965.5	206.3	77.5	157.3	44.2	39.2	327.9	30.2
Imperv. Area		ac	122.2	468.5	119.1	32.5	48.1	13.3	11.8	148.3	23.1
Imperv. Cover		%	40.5	48.5	57.7	41.9	30.6	30.0	30.0	45.2	76.4
Overland		Curve:	C	B	B	C	C	C	C	C	C
Distance		ft	300	300	300	300	300	300	300	300	300
Slope		%	1.8	2.5	2.5	2.5	4.0	4.5	5.0	2.0	2.8
Velocity		ft/s	1.0	.8	.8	1.1	1.5	1.6	1.6	1.0	1.2
Travel Time		min	5.00	6.25	6.25	4.55	3.33	3.13	3.13	5.00	4.17
Shallow Concentrated		Curve:	F	F	F	F	G	G	G	G	G
Distance		ft	300	400	700	1000	300	700	0	0	500
Slope		%	1.8	2.5	2.2	4.0	2.9	1.8	.0	.0	2.8
Velocity		ft/s	2.0	2.4	2.3	3.1	3.4	2.7	.0	.0	3.3
Travel Time		min	2.50	2.78	5.07	5.38	1.47	4.32	.00	.00	2.53
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	4800	5700	2280	300	3000	0	800	2500	0
Slope		%	.9	1.2	.9	1.0	1.2	.0	3.3	2.0	.0
Velocity		ft/s	1.9	2.2	1.9	2.0	2.2	.0	3.6	2.8	.0
Adjusted Velocity		ft/s	1.90	2.20	1.90	2.00	3.67	.00	6.00	4.67	.00
Travel Time		min	42.11	43.18	20.00	2.50	13.64	.00	2.22	8.93	.00
Improved Drainage Channel											
Distance		ft	0	3800	0	0	0	0	0	2000	0
Velocity		ft/s	.0	5.0	.0	.0	.0	.0	.0	5.0	.0
Travel Time		min	.00	12.67	.00	.00	.00	.00	.00	6.67	.00
Unimproved Drainage Channel											
Distance		ft	0	3200	0	1100	0	1600	1800	2400	1700
Velocity		ft/s	.0	3.0	.0	3.0	.0	3.0	3.0	3.0	3.0
Travel Time		min	.00	17.78	.00	6.11	.00	8.89	10.00	13.33	9.44
TC (minutes)			49.61	82.65	31.32	18.53	18.44	16.33	15.35	33.93	16.14
TC (hours)			.83	1.38	.52	.31	.31	.27	.26	.57	.27
R = 2 x TC (hours)			1.65	2.76	1.04	.62	.61	.54	.51	1.13	.54

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Nu							
			HC2A	HC2B	T2A1	T2A2	T2B1	T2B2	HC3	***HCT3A***
Drainage Area										
Area		ac	211	195	184	50	128	184	131	321
Area		sm	.330	.305	.288	.078	.200	.288	.205	.502
Impervious Cover										
Land Use	I(%)									
Ind./Comm.	80%	ac	9.2	64.3	25.6	11.8	24.3	42.1	65.6	141.5
Multi-Family	70%	ac	.0	.0	.0	.0	.0	.0	.0	.0
Highway	60%	ac	.0	.0	6.4	5.7	6.1	15.6	13.0	.0
Community	40%	ac	.0	.0	.0	.0	.0	.0	.0	13.4
S-F (Typical)	30%	ac	74.0	40.2	84.9	14.6	3.7	.5	.0	126.5
S-F (Light)	15%	ac	.0	18.9	.0	.0	.0	2.8	6.5	21.0
Future Development		ac	127.5	71.8	67.5	18.2	94.2	122.6	42.9	18.9
Future Impervious		%	40%	50%	50%	50%	50%	50%	70%	60%
Total		ac	210.7	195.2	184.4	50.3	128.3	183.6	128.0	321.3
Imperv. Area		ac	80.6	102.2	83.5	26.3	71.3	104.9	91.3	171.0
Imperv. Cover		%	38.2	52.4	45.3	52.4	55.6	57.1	71.3	53.2
Overland		Curve:	C	C	C	C	C	C	C	C
Distance		ft	300	300	300	300	200	300	300	300
Slope		%	3.6	3.4	1.3	4.0	2.5	6.7	1.8	.7
Velocity		ft/s	1.3	1.3	1.0	1.5	1.1	1.8	1.0	.6
Travel Time		min	3.85	3.85	5.00	3.33	3.03	2.78	5.00	8.33
Shallow Concentrated		Curve:	G	G	G	G	G	G	G	F
Distance		ft	600	400	200	600	200	1300	300	0
Slope		%	1.8	3.0	5.6	4.0	2.5	3.3	1.8	.0
Velocity		ft/s	2.7	3.5	4.7	4.0	3.2	3.7	2.7	.0
Travel Time		min	3.70	1.90	.71	2.50	1.04	5.86	1.85	.00
Paved or Gully		Curve:	G	G	G	G	G	G	G	G
Distance		ft	4800	900	2270	1200	2200	0	1120	7800
Slope		%	1.1	2.5	2.2	1.0	2.3	.0	.6	.6
Velocity		ft/s	2.1	3.2	3.0	2.0	3.0	.0	1.6	1.6
Adjusted Velocity		ft/s	3.50	5.33	5.00	3.33	5.00	.00	2.67	1.60
Travel Time		min	22.86	2.81	7.57	6.00	7.33	.00	7.00	81.25
Improved Drainage Channel										
Distance		ft	0	3600	0	0	0	0	2350	0
Velocity		ft/s	.0	4.0	.0	.0	.0	.0	5.0	.0
Travel Time		min	.00	15.00	.00	.00	.00	.00	7.83	.00
Unimproved Drainage Channel										
Distance		ft	0	0	700	0	800	3200	0	0
Velocity		ft/s	3.0	.0	3.0	3.0	3.0	3.0	.0	.0
Travel Time		min	.00	.00	3.89	.00	4.44	17.78	.00	.00
TC (minutes)			30.41	23.56	17.16	11.83	15.85	26.41	21.69	89.58
TC (hours)			.51	.39	.29	.20	.26	.44	.36	1.49
R = 2 x TC (hours)			1.01	.79	.57	.39	.53	.88	.72	2.99

However, project proponents have desired that 404 wetlands be classified as "good, better, and best" in quality in order to negotiate mitigation requirements with resource agencies somewhat predictably. The development groups have agreed that they will accept the Act's supporters' desire for recognition of wetlands according to function in order to achieve a "good, better, best" classification. Accordingly, the Corps has committed to scientific classification of wetlands (both existing and mitigation to be built) with adoption of a method titled the *Hydrogeomorphic Assessment Method* known as HGM with a focus on wetland functional values.

1.) data points (DP's)- Are selected by the inspecting biologist as being typical of the site and their locations are mapped on his report. Each DP should be located entirely within one (1) occurrence of either a typical upland or wetland, not on a dividing line between them. If a typical delineation line is to be established as a part of the work, it should be selected between the wetland DP and the upland DP, and flagged a reasonable distance in each direction.

2.) hydric plants- National Plant List- The *National List of Plant Species That Occur in Wetlands: yr. pub. National Summary* is compiled and published by the U.S.F.&W.S. with the year published denoting a particular edition (revision). For example the '88 edition is noted as *Biological Report 88(24), September 1988.* The hydric status of individual plant species is negotiated and agreed on before publishing between the National and Regional Interagency Review Panels. The list divides known U.S. plant species into five (5) categories in descending order from upland to wetland with three (3) intermediate categories designated as "facultative". The four (4) categories that are known to grow in wetlands are provided (there are very few upland only species listed within this publication).

The four ratings are:

a.) facultative upland (FACU) species- mostly upland, occasionally found in a wetland, and
b.) facultative (FAC) species- found either in upland or wetland, and
c.) facultative wetland (FACW) species- mostly wetland, occasionally found in an upland, and
d.) obligate (OBL) species- found only in wetlands.

The three facultative designations are further modified with either a (+) or a (-) for some species that "weight" the numerical score somewhat.

Species within the designated DP inspection area are identified and those that are dominant noted first; with individuals of occasional species noted last onto the accepted Corps Determination form for the '87 Method. If a delineation line (the Line) is to be marked, a species known locally by the biologist to dominate at the edge (such as FACW + species *Andropogon glomeratus* [bushy bluestem] within open-sun prairie areas) is selected for closer examination. The soils are shovel tested for wetness on either side of the proposed Line in order to confirm the species selection. The Line is then marked in both directions along the plant species/soils gradient until a change is noted.

3.) hydric soils- National\County Soils List- The list titled *Hydric Soils of the United States* is prepared and published by the NRCS (previously the SCS) in cooperation with the National Technical Committee for Hydric Soils. The local county soils map of the NRCS (such as the *Soil Survey of Angelina County, Texas*) is provided with a list of hydric soils found in that county, including a breakdown of hydric soil type inclusions found in upland soils.

Soil types are described and their locations mapped within the NRCS county handbook to the extent that field identification (of a soil type) is possible by a properly trained individual. Such detailed NRCS soil descriptions also include landform, position on the landscape and frequency of flooding; which should (also) be observed at each DP, and noted as to whether they conform to hydrological indicators found at the same DP (more fully described below).

The hydric list(s) were prepared for agricultural uses only; consequently many wet soils that will qualify as 404 hydric soils are not listed as such by the NRCS. It is important to note that NRCS determination of a soil type as hydric is only one of a number of hydric soil indicators listed (as qualified) by the '87 Method. Therefore, if the soil type identified during site inspection is not NRCS listed (as hydric) ; but other indicators are present sufficient to meet '87 Method requirements, the soil type is then classified as hydric for 404 purposes.

Some biologists extensively trained in the '87 Method are able to identify various soil types sufficient to report on the '87 DP form. However, the additional expertise of soil scientists or technicians may be required to make the soil determination when soil classification is the deciding factor, or a soil type not described in the NRCS county soil survey is present.

On agricultural lands, NRCS soil scientists trained in the '87 Method will make a determination according to Swampbuster Act rules. At the limits of rural communities where agricultural lands encroach into 404 jurisdictions, there is a necessary cooperation between the Corps and the NRCS, as the '87 Manual is the basis for the Method to be utilized by all parties.

4.) hydrology- hydrologic indicators- There are no national or county lists of true hydrologic indicators provided to practioners of 404 determinations. Certain "wetness" indicators are described in the '87 Method which may or may not be present on-site. These are more visual, less technical in nature, such as "blackened leaves" accumulated in deposits up to the high water mark. Each is ranked as either a primary or a secondary indicator in order to "weight" the numerical finding. These indicators are noted on the DP form where required and are calculated into the finding which determines whether available water source(s) are sufficient (or not).

As most trained 404 practioners have biology backgrounds, and a few have soils backgrounds, these visual "clues" allow a 404 determination to be made without an opinion of a wetland hydrologist. However, a proper observation of the depressional nature of the landform, size of the upslope watershed, and the probable frequency and duration of flooding is a superior indicator of sufficient hydrology.

In urban areas, hydrological expertise is available from practioners who make such observations in order to design construction of mitigation wetlands into previously upland sites. In rural areas, NRCS personnel are skilled in hydrology calculations as a consequence of determining the hydric nature of soils, and calculation of upslope watershed(s) for farm pond designs.

The driving force for adoption of the HGM Method described previously is it's rating of functional values for use by all entities participating in 404 rulemaking. However, HGM is based on a true technical observation of a site's actual hydrologic characteristics. If the HGM Method does replace the '87 Method, the '87 Manual's visual clue indicators will not be sufficient to determine a site's hydrology (or lack of) for 404 purposes.

5.) 404 determinations- All three hydric indicators (plants, soils and hydrology) must be present and determined to be sufficiently wet in order to qualify a DP as a wetland site. If any one of the three indicators is judged to be lacking by the '87 Method, then the DP is not a qualified 404 wetland.

A typical example would be documenting by the on-site observer of a previously ditched and drained (before the end of 1985) wetland site; whose wet soils continued to germinate wet plants from normal rainfall (only), but the necessary hydrology is no longer present according to the '87 Method. Over a long period of time the soil would lose it's hydric nature, and FACU plant species would eventually dominate such a habitat (FAC species such as *Pinus taeda* [loblloly pine] are classified as wetland species for 404 qualification purposes).

Conversely, a non-hydric soil can be provided more hydrology than historically available by development activities wherein the soil would develop wet characteristics and thereby begin to germinate seeds of wet species within it's local area. This happens when a flat or concave surface is cut into a previously sloped surface over a slowly permeable soil type; or upstream development begins to flood an area not historically a floodplain.

As any determination by the observer of a lack of one type of hydric indicator will remove a DP (and all similar habitat on-site) from Corps Jurisdiction, then all other considerations required by the '87 Method are rigorously enforced (hence the Corps designation Enforcement Section). There is considerable lattitude for use of "best professional judgement" by all parties practicing in the 404 field which can lead to disagreement as to the meaning of a particular indicator.

Therefore, Corps Enforcement Section confirmation of a private practioner's 404 determination (and delineation lines if a part of the work) is required in order to be accepted by all parties. That is, an incorrect determination of a qualified 404 wetland area as technically too dry according to the '87 Method by a wetland consultant will not protect a project developer from Act penalties if the Corps does not agree.

U.S. Army Corps of Engineers 404 Enforcement Program: Any public complaint that construction work is impacting a 404 wetland must be investigated by qualified Corps biologists within 24 hours of the call. Concurrence by the inspecting biologist that 404 impacts are in progress will bring an immediate on-the-spot "cease work" order. An investigation ensues that lasts about one year which concludes with a finding of the monetary fine to be paid, and a requirement to re-construct the impacted wetland on it's original site and to it's original state.

Considerable effort is expended in order to determine whether a development impact was intentional (or not). If "intent" is discovered, the case may be referred by the Corps to the EPA for prosecution under penalties of the current revision of the Clean Water Act.

At the time of the initial finding, a project developer may negotiate a settlement agreeable to all parties by proposing suitable mitigation (more fully described below) to offset existing project impacts, and mitigation for future impacts of the site's development plan. If the Corps agrees (and the EPA, if involved), the Enforcement Action will be put on hold while an after-the-fact permit is negotiated with the Evaluation Section. If an after-the-fact permit is negotiated between the parties (which also takes about one year), the project is allowed to proceed along with simultaneous construction of the mitigation agreed to.

However, on a daily basis the Corps Enforcement Section's work consists mainly of inspection of proposed wetland impacts by qualified biologists in order to determine their 404 wetland status. If the Corps' biologist agrees with the findings presented by the developer's consultant regarding the number of acres and location of jurisdictional impacts planned, the proposed project is forwarded to the Corps Evaluation Section to process the developer's request.

U. S. Army Corps of Engineers' 404 Permit Evaluation Program: The 404 program consists of a separate review of 404 permit requirements by Corps Evaluation Section permit specialists; who may be, but are not necessarily biologists themselves.

Corps evaluation of an application to permit proposed 404 Wetland impacts will include consideration of qualification for various components of the Nationwide Permit program for small impacts or the Individual Permit program for larger impacts. The Nationwide Permit program will be modified (the Nationwide #26 Permit will be dropped altogether) before any actual projects are constructed in the Hurricane Creek or Mill Creek watersheds, or elsewhere within the City of Lufkin. Individual Permits include all 404 impacts in a single project permit and require public notice.

All Corps rulemaking must meet the requirements of the *National Environmental Policy Act* (NEPA) and include co-ordination with the USF&WS for Endangered Species review, and co-ordination with the State Historic Preservation Officer (SHPO) for cultural resources review.

1.) mitigation of wetland impacts- An application to the Corps for a 404 permit to impact wetlands must contain an offer to mitigate (offset) such impacts by creation or restoration of new wetland areas. Certain poor quality wetlands may be replaced at the rate of 1:1; however, most mitigation ratios will be 2:1 (2 new acres constructed for every acre impacted) or higher.

Due to the cost of land acquisition, design, construction and maintenance of mitigation wetlands, avoidance of wetland impacts whenever possible is the lowest project cost alternative.

2.) mitigation sequencing- To be granted mitigation, a project applicant must first actively practice a series of sequential actions during preliminary planning wherein the first is avoidance of all 404 impacts, then minimization of as many 404 impacts as is possible; and finally, if any 404 impacts are determined to be not avoidable, then mitigation may be offered by applicant. Avoidance of the best quality wetlands also will result in lowering the mitigation ratio, thereby lowering hard costs of mitigation to applicant.

Wetland Types: Two primary wetland habitat types occur within the watersheds described in the <u>Results</u> section of this report; as follows:

1.) braided channel- Typical floodway configuration where storm surges regularly overflow the main channel. Such overflow cuts many smaller channels into the floodplain above the main channel's normal bank level. This type of habitat is more complex than a backwater floodplain wetland due to a considerable amount of edge effect, whether open-sun or forested.

2.) flooded forest- Typical forested wetland whether lying in the active floodway or on the backwater floodplain above. All of the effects of shade dominance that occur in upland forests are also a factor in forested wetlands, along with selection for tree and shrub species tolerant of wet soil conditions. Where standing pool levels prevents wet tree and shrub species from invading (except for bald cypress [*Taxodium distichum*], black gum [*Nyssa sylvatica*], and buttonbush [*Cephalanthus occidentalis*]), an open-sun prairie wetland may exist within a forested area. However, at the edge of standing water, a water oak (*Quercus nigra*) -willow oak (*Quercus phellos*) forest will invade the floodpool unless managed by fire or mowing.

U.S. Fish & Wildlife Service's Endangered Species Program: The USF&WS maintains a permanent program for Threatened and Endangered Species (T & E Species) that includes identification and listing of species at risk of extinction, development of recovery plans for those species, and implementation of such plans to attempt recovery and de-listing of T & E Species. The TP&WD also operates a similar program for species identification and state listing, which may include other species not listed by USF&WS.

State Historic Preservation Officer's Cultural Resources Program: The Corps co-ordinates with the SHPO's office in Austin, Texas to determine whether any potential project areas may have cultural significance. If so, an intensive cultural resources survey may be required. Such a survey would entail pedestrian coverage accompanied by shovel testing and trenching/augering, perhaps followed by test excavations, to identify and evaluate archeological sites, while historic buildings and structures would be recorded and evaluated through an architectural survey. Adverse effects to significant resources can be mitigated, usually through data recovery excavations at archeological sites and Historic American Buildings Survey (HABS) or Historic American Engineering Record (HAER) documentation of buildings and structures, or the project can be designed to avoid the resources. The Corps' Fort Worth District maintains on staff an archeologist for preliminary determinations and co-ordination with the SHPO's office.

Discussion of Study Area 404 Considerations:

Corps' 404 Jurisdictional Program: Several factors are a part of current 404 rules in effect that are directly related to whether the Corps' Ft. Worth District exercises jurisdictional authority over the City's proposed watershed projects within areas appearing to be non-jurisdictional; as follows:

1.) NRCS Soils List- A critical part of the definition of a wetland is a sub-part determination of whether a site's soil type can be considered hydric (wet) in any particular area being examined. As is more fully described above, consideration is given in the '87 Method to the soil type's listing on the NRCS county hydric soil list. However, as a practical matter, a listed soil can be drained sufficiently to prevent it's being hydric; conversely a non-listed soil can have sufficient hydrology to cause it to develop definite hydric characteristics.

We note that the NCRS has not listed as hydric soil types within the Mill Creek streambanks, and also Hurricane Creek streambanks until about a mile south of Loop 287. Though soil types described within Mill Creek and upper Hurricane Creek are not listed as such, the soils are very wet as described, consequently any area flooded sufficiently enough to meet the 404 hydrology criterion will also meet the Corps hydric soil requirements.

2.) Small Urbanized Channels- When considering determination of "waters of the US" that are jurisdictional, wetland vegetation is not necessary, as the high-water mark is the primary determining factor. Consequently, on-site observation of this high-water mark invokes Corps authority in small streams where there may be no plants existing.

This is important to the City of Lufkin as all of the urban tributaries share this regulatory qualification.

Jurisdictional Corps authority ceases above the high-water mark, provided no associated wetland exists (above the high-water mark). Exemption from jurisdiction of "above the headwaters" (5cfs streamflow) only applies to Nationwide Permit #26, which will not be available shortly.

Corps 404 Mitigation Program: Where the Corps requires mitigation to offset impacts to regulated wetland habitats, certain rules are in effect that control criteria of the proposed design.

The specified mitigation-

a.) must be located nearby (preferably directly adjacent to the impacted area), and
b.) must be "like kind" (same type of habitat as is destroyed by development project), and
c.) must be at least a mitigation ratio of one new acre created to one existing acre destroyed (but may be a higher ratio agreed to by applicant in order to proceed).

Potential Mitigation Projects: We have identified a number of areas in the following report where detention ponds could be installed along with (or rather than) channelization in order to reduce flood hazard. These could be detention areas with a permanently wet bottom that may also be designed to serve as mitigation sites for un-avoidable 404 impacts, thereby reducing costs of mitigation by as much as 50%. We have denoted these areas as potential detention/mitigation sites in the following material and as **Sites** on the attached maps.

As permanently wet bottom projects, these combined project designs would require natural pond type sedimentation traps to prevent mitigated wetlands from becoming uplands due to accretion of sediments. Accordingly, State and Federal requirements for control of in-stream sediments to be enacted in the future would also be provided for.

Typical Mitigation Design: These wetland design details are typical (only) such that most of the following proposed project sites would be constructed in a similar manner. They do not represent the level of detail required in order to successfully construct a mitigation quality wetland.

Within a typical detention/wetland project, the site's fertile topsoils would be stripped and set aside for subsequent construction of wetland planting shelves, and topsoiling sideslopes. The major excavation contractor would cut away sterile subsoil down to slightly below the Creek's bottom elevation and haul it away from the project. A berm about 5' wide and 2' high of natural ground would be left along the Creek bank to prevent small flows from entering until completion.

The detail contractor would shape bottom configurations according to the agreed on design, and then lay saved topsoils onto wetland planting areas up to final elevation. Naturally shaped large capacity (deep) sedimentation pools would be excavated at the designated infall area. Plants would be taken from storm ditches nearby and installed within on prepared planting shelves at the correct elevation for their particular species. Plants would be watered by pump from the Creek every day it does not rain until final flooding. On completion the inlet channel and outlet channel would be dug through the separation berm to connect with the streambed.

Discussion of Other Considerations:

T & E Species Program: The national and state regulations governing T & E Species primarily address identification of unique habitat with potential for utilization by such species. Biologists trained in T & E Species inspections must prepare their reports identifying potential habitats as described in specific laws passed at the national and state level (as well as whether any animals or plants are actually observed by them). However, agencies involved which will review the inspecting biologist's report have determined the actual location (or lack thereof) of most of these species. Consequently, the appropriate method of determining future comments of resource agencies is to submit areas under consideration for potential project locations to them prior to beginning any definitive environmental studies.

If either agency replies that it has mapped one or more listed species in a potential project area a qualified biologist must be engaged to determine whether any individual listed animal or plant actually inhabits the area.

USF&WS and TP&WD biologists have stated to us that no T & E Species are a concern within urbanized areas of the City. Where lower Hurricane Creek becomes a major stream about one mile south of Loop 287, there may begin to be a concern regarding some of the fishes as well as the alligator snapping turtle (*Macreclemys temminchii*). At the extreme remote end of Hurricane Creek west of Hwy. 324, the timber rattlesnake (*Croatalus horridus horridus*) may or may not be a concern until they consider a particular proposed project site. We recommend that early in planning a specific project (that) a proposed site be submitted to them for their comments; which comments would then (if negative) be provided the Corps and Water Board, and if positive, necessary avoidance or mitigation agreements negotiated with them in advance of any 404 Permit or Water Board application.

It must be noted that such a T & E Species restriction may prevent developing a specific project site completely. Mitigation for T & E Species is much more complex than 404 wetland mitigation and in some cases impossible to construct. An example would be an attempt to re-create a particular flowing stream habitat for fishes in lower Hurricane Creek which would not be possible without access to a similar floodflow pattern.

Cultural Resources Program: All preliminary comments regarding Cultural Resources has been provided in a report by Prewitt. Such report completes our combined requirements (scope of work) for this contract.

Results: Hurricane Creek

We have organized this report on the streambanks of Hurricane Creek into our findings regarding 1.) urban areas, 2.) semi-urban areas, and 3.) remote areas downstream of the City proper.

Section One- fully urbanized- Upper Hurricane Creek:

We define this Section to consist of the Main Stem and Tributary One above Denman Avenue, Tributary Two above the Lowe's store, Tributary Three within developed neighborhoods, Tributary Four adjacent to the apartment complex east of Hwy. 59, and Tributary Five within Crown Colony. The area is identified as shown on the map marked as **Exhibit 1**. As is more fully described in item 2.) Small Urbanized Channels- on page thirteen (13), the Corps will exercise jurisdiction within stream bottoms in residential areas up to the small channel's high water mark, but the yards are maintained by homeowners such that it is unlikely that wetlands will be associated.

Nationwide Permits for stream crossings and other small impacts may still be available in future years, and may or may not require mitigation for them. Full channelization or replacement with submerged concrete sewer would require 404 permitting and mitigation.

Main Stem: The headwaters flow through residential backyards until passing under the intersection of Hwy. 59 and Hwy. 69 where inflow from major storm sewers substantially increase it's stormflow rate. The underlying soil type is the Koury-Urban land complex (Ks) which is not listed among the NRCS hydric soils. However, it is described as a wet loam located within floodplains with slopes of less than one percent; and includes small areas (inclusions) of Pophers soil which is a listed hydric soil. It's description is summarized with the statement "Koury soil is poorly suited to urban and recreational uses because of wetness and flooding". Therefore any Koury soil provided sufficient hydrology will meet the tests of a 404 hydric soil.

We have identified a potential detention/mitigation site shown as a **Site** on the enclosed **Exhibit 1** on commercial land directly adjacent to the stream on it's east bank and bound by Baskin's, Lufkin Rx and the Cook Tire store. We estimate the potential area to be from one to two acres in size depending on setback required from established buildings. Some upstream peak storm surge may be attenuated within it.

Tributary One: Above the intersection of Denman Avenue and Hwy. 69 this small channel runs through residential yards maintained as is described above, and is also of the Koury soil type. Consequently, 404 permitting would be simplified as is more fully described above.

We noted a potential project site at the north end of Hunter's Creek street that is also identified as a **Site** on the attached map. It is about three acres of vacant residential land directly adjacent to a pink house that is shown as a repetitive flood loss property, located on the northeast corner of the deadend of Hunter's Creek street. Water had risen in the yard of the pink house during the recent storm event, and also in the lower corner of the prospective project site. Excavation of additional flood capacity into that lower corner may hydrologically benefit the pink house and several nearby repetitive flood loss properties.

Tributary Two: The short length of channel located in a residential neighborhood above the Lowe's store is sited on Fuller fine sandy loam (FfB) and Fuller-Urban land complex (FuB) soils. Fullers' description of saturation in winter and frequent high water table, location in interstream divides, and poor suitability for urban development indicate the potential to be hydric where regularly flooded (though not listed as hydric).

We observed that the new Lowe's has installed behind the store a small detention pond for collection of their runoff directly adjacent to (but not within) the streambed. A potential project **Site** shown is (recommended to be) expansion of Lowe's existing small pond into the vacant land surrounding it, in order to capture upstream runoff within the enlarged detention volume.

Tributary Three: Most of the upper section runs through residential yards as is described above. It's soil type is the Koury soil also more fully described above. Immediately on falling out of the last neighborhood, it enters a large, remote, un-developed area described in Section Two below. We did not observe any potential project sites directly adjacent to the small channel within the developed Section; however, flood capacity could be excavated at the outfall from the neighborhood into un-developed land as is shown on the enclosed map.

Tributary Four: Only a very small section is urbanized as the stream is semi-urbanized above and below Hwy. 59 as is described in Section Two below. It is developed into an apartment complex directly east of Hwy. 59 that does not offer opportunities for flood detention projects. The soil type is Alazan very fine sandy loam (AaB) of 0 to 4 percent slopes. It is another loamy soil limited from most uses due to wetness, but is not listed on the NRCS hydric soils list.

Tributary Five: The upper section flowing through the Crown Colony subdivision is residential and does not appear to contain a potential project site within it. The soil type is Alazan described in Tributary Four above.

We observed that where the stream outfalls from the tankcar culvert under Edmund Grey Road that the streambed has recently been channelized behind the Church Retreat property. We have not noted the area on our map, but perhaps the vacant land adjacent to the east of the new channel would serve as a project site.

Summary of Section One Report:

1.) Most of Upper Hurricane Creek that is significantly developed occurs in the upper parts of the Main Stem and Tributaries One, Two, Three and Five. The soil types identified for the Main Stem and all of the Tributaries are not listed on the Angelina County- NRCS hydric soil list; however, each type is sufficiently wet in composition to qualify as a 404 hydric soil where frequently flooded or depressional.

This factor is of little consequence in Section One (but becomes a major factor in Section Two reported below) as very few wetlands are associated with small channels located within residential backyards.

2.) Such small channels are regulated up to the historical high water mark on their streambank, and small impacts (such as stream crossings) may be allowed by various Nationwide Permits.

Channelization of the small streams will require complete 404 Individual Permits that include public notice and comment, and mitigation of those impacts. All of the tributaries within the City share this regulatory concern.

3.) Care has been taken during field work to identify and characterize sites within floodprone areas that have potential to provide flood capacity through temporary detention, and to mitigate small 404 impacts on-site.

Section Two- semi urbanized- Middle Hurricane Creek:

This Section is comprised of the Main Stem and Tributary One below Denman Avenue to the Main Stem junction with Tributary Four, Tributary Two below the Lowe's store, Tributary Three below the residential neighborhood, most of Tributary Four except within the apartment complex, and Tributary Five below Crown Colony to (but not including) it's junction with the Main Stem. This Section is also shown on **Exhibit 1**, except for that area south of Loop 287.

All of these are described as semi-urban stream segments whether large or small in size within this Section. The Main Stem's junction with Tributary Four about one mile downstream of Loop 287 marks Section Three where the area becomes very remote and rural in nature.

Generally the difference(s) between these areas and Section One reported on previous pages relates to their lower position on the landscape which must contain larger flows and have developed larger channels, some of which overflow their banks during heavy rainfall events. These floodplains adjacent to and above the main channels consist of complex, high quality wetlands that would be difficult to 404 permit complete development of as would be a part of in-stream channelization projects. Due to established high water marks, lack of NRCS hydric listing of soil types would have no effect on qualification as a Corps regulated area.

A second difference with Section One is the existing un-developed land above the high water mark directly adjacent to some parts of these channels. Such non-regulated uplands offer the opportunity for location of diversion channels and/or detention areas provided some remaining floodflow was allowed to continue to provide hydrology to existing Creek channels and adjacent floodpools.

Upper Main Stem and Tributary One: The upper Main Stem and Tributary One fall downslope toward each other below Denman Avenue, turn parallel for a short distance below the high school, and then run together within the Kiwanis City Park. A braided channel, flooded forest type of high quality wetland habitat begins within the area behind the high school and continues completely to the end of Hurricane Creek. All of the area consists of the Koury soil type more fully described in Section One above, which is flooded sufficiently throughout to qualify as hydric, and would be regulated up to the high water mark in any case. Consequently, the interstream divide and most of the streambank to either side will qualify as high quality 404 wetland.

1.) **Denman Avenue South-** A short distance south of Denman Avenue both the Main Stem and Tributary One begin to exhibit adjacent floodplains from frequent overflows. These are small pocket wetlands that could allow a channel to be excavated between them to intersect with the existing channel for diversion with very little wetland impact from construction activities. The existing main channels and small wetlands would require full Corps permitting to impact.

Small areas of uplands directly adjacent could site flood control projects accessed by diversion channels from and to either of the main channels.

2.) East of High School- In the area behind the high school, the Main Stem and Tributary One turn almost parallel to each other and run southward toward the Kiwanis City Park. Where the interstream divide eventually falls below the established high water mark for both channels, a good quality forested wetland is reletively intact. This quality of forested wetland would be difficult to permit 404 impacts to; and if allowed, would be a mitigation ratio in excess of one-to-one. Channelization and/or detention on adjacent upland outside wetland floodpools would be prefered, provided sufficient hydrology was available to both segments downstream.

3.) High School to Kiwanis City Park- From directly below the high school downstream to the park lies the least impacted high quality wetland along the Main Stem within the City of Lufkin. Within the interstream divide, large loblolly pines stand on mounded areas less frequently flooded, and floodplain hardwoods from saplings to mature large trees inhabit lower areas. Between large trees a typical scrub/shrub habitat provides very dense cover for wildlife. Evidently the loblolly pine timber has been thinned, but not clearcut in perhaps 50 or 60 years, and the floodplain hardwoods may be somewhat older than the pines.

Most likely, impacts from flood control projects would not be allowed, including reduction of upstream floodflow by bypassing the area within an uplands with a channelization project. Excessive ponding more than is currently existing may or may not be allowed.

4.) Kiwanis City Park- Most of the park lies within an established floodplain between the Main Stem and Tributary One flowing to their junction at the lower park boundary, except for a small amount of high ground along the eastern edge. This naturally formed floodpool acts as a small volume detention basin when the two channels overflow their banks and pond against the roadbed along the southern edge of the park. However, during smaller rainfall events that do not cause overflow, water drains quickly off into both bordering channels, which enables the interstream divide to dry faster than nearby poorly drained areas. Large pines and hardwoods provide extensive shade cover for the park, but all small shruby species that would normally live between them are prevented by park maintenance.

As the park is currently impacted by development, additional development for flood control may be more acceptable to wildlife agencies than the area directly upstream. However, the City may not desire loss of any park area to flood control. Mitigation would be required for any type of development actvity that is more intrusive than existing park facilities.

5.) Summary of Upper Main Stem/Tributary One- There appear to be opportunities for small flood control projects within uplands directly adjacent to both stream segment(s) described in item **1.)**. Some projects may be allowed within Corps regulated wetlands in both stream segments identified as items **1.)**, **2.)** and **4.)** above. Such impacts would require suitable mitigation nearby and to be like-kind habitat replacement.

Most likely, development impacts would not be allowed to either stream segment and/or their interstream divide within item **3.)**, including negatively affecting their flooding regime.

Lower Main Stem: The Main Stem flows through an active floodplain along the Azalea Trail to Richardson Park where it is joined by Tributary Three. Their combined flow continues as the lower Main Stem of Hurricane Creek to it's junction with Tributary Four. All of the Main Stem below Tributary Four is reported on in the following Section Three due to it's considerable change in character ~~from~~ that point. That part inside Loop 287 is shown on **Exhibit 1**, and that part below the Loop is shown on **Exhibit 2**.

The area from the City Park to Tributary Four consists of frequently flooded Koury soil that qualifies as a 404 wetland. The high quality flooded forest type of habitat described previously continues throughout the area and is not described in detail here.

1.) Azalea Trail Segment- Hurricane Creek flowing from the City Park along the Azalea Trail flooded it's streamside zone from the storm event occurring during our field work. The small amount of rainfall during the event indicates that the zone is frequently flooded. The available hydrology causes the Koury soil type to be considered hydric, except where new deposits of sand changes it's nature. At the end of the Azalea Trail, the stream is joined with Tributary Three in Richardson Park and turns southward under Loop 287.

The narrow floodway is constrained by development all it's length to the park junction limiting potential for projects outside the floodway. The floodway zone would be Corps regulated and difficult to permit development projects within that are more intrusive than the Azalea Trail.

2.) Segment below Loop 287- As the Creek emerges from under the Loop, it's channel widens considerably in order to allow larger flows from the addition of Tributary Three. It begins to curve sinuously in a manner that continues on an increasingly larger scale through Section Three described below to it's junction with Cedar Creek. The soil type is the Koury soil which is sufficiently flooded to be hydric below the stream's regulated high water mark. A short distance downstream at the junction with Tributary Four, the soil type changes to Pophers (Po) silty clay loam, which is a NRCS listed hydric soil.

Due to the soil type change, additional floodflows of Tributary Four, and remote nature of the landscape, we have selected the boundary between Section Two and Section Three to be at that junction. Accordingly, this small segment noted as item **2.)** is shown on the map identified as **Exhibit 2**, rather than with the balance of Section Two on **Exhibit 1**.

a.) potential flood control project(s)- This segment is unique due to it's potential for location of flood control projects for the City, provided that it is not too far downstream from problem areas in the center of the city to be effective. This is the last segment of Koury soil such that any area not frequently flooded will not qualify as a wetland. Those areas under the high water marks are limited by high banks and small flood zones across the inside of curves in the streambed. This presents a much narrower regulated zone to Corps permit than the broad floodways prevalent both upstream and downstream. Channels could be cut from an outside bank curve through uplands to the next outside bank, bypassing the lower regulated riparian wetland on the inside curve with only minor 404 permitting.

b.) other considerations- Small amounts of mitigation would be required for areas where cuts were made into the bank. However, the inner loop wetland will be required to have as much access to floodwater as before project construction for this strategy to be easily approved. The abandoned inner loop will provide some additional flood capacity, but may cause undesirable turbulence. Also, future siltation may cause the Creek to leave the new channel and return to the old sinuous configuration.

c.) potential detention/mitigation project(s)- This area appears to be the first un-developed land along the Main Stem of Hurricane Creek where acreage may be available for large scale detention projects (there are some large raw land tracts upstream along Tributaries Two and Three described below). Within such a large detention project, there are opportunites for landscape scale 404 mitigation.

Large wetland projects may be operated as mitigation banks where other City project 404 impacts could be mitigated, and/or space may be sold to a private developer. Along the gulf coast, the Texas Department of Transportation has participated in a number of mitigation banks operated by other entities.

Tributary Two: The semi-urban area starts directly below the Lowes' store and flows westward outside of and parallel to Loop 287 until it falls beneath the Loop and mall parking lot. At about the Lowes' store the soil type changes from Fuller fine sandy loam (Ffb) to Alazan very fine sandy loam (Aab) of 0 to 4 percent slopes. It is another loamy soil limited from most uses due to wetness, but is not listed on the NRCS hydric soil list. The stream segment is shown on the map attached as **Exhibit 1**.

A short distance downslope from Lowes' the channel splits into a braided multi-channel flooded forest configuration. The high quality of forested wetland active flood zone would be difficult to 404 permit. The narrow landform between the floodway and the Loop does not seem suitable for flood control projects. As described more fully in Section One above, a large upland area is located directly adjacent to the south of Lowes' small detention pond that may have potential for expansion into a large detention project.

Alternatively, a channel could be cut into the upland running parallel, but bypassing entirely around the floodway zone downslope to the main culvert under the Loop, provided that sufficient flow continued to be available to the avoided wetland area.

Tributary Three: This segment falls out of the developed neighborhoods and flows through a large un-developed area in a large curving stream southward to Grace Dunn Richardson Park where it joins the Main Stem. It is located on Koury soil it's entire length and is shown on the map attached as **Exhibit 1**.

At the upper end it is a small channel with raw land tracts on both sides that has the potential for 404 permitting for flood control. This short reach of low quality mostly in-channel streamflow has the potential to be one of very few in the City that may be allowed in-stream channelization with appropriate mitigation proposed for it's 404 impacts.

A short distance downstream several large flows are introduced that widen the channel into a major stream with frequent overflows similar to other streams within Loop 287. This larger channel would be difficult to 404 permit impacts to as is previously described several places.

We noted that the City owns and is actively developing land on the western shoreline above the park. This tract happens to lie within the inside curve of the stream that maintains a large floodway across the lower elevations when flowing above the inner bank. Due to previous landclearing activities, the floodzone is changing into an open-sun wet prairie habitat rarely observed within the City.

There may be potential for location of a channel within the upland lying above wetland level. It could cut across the inner loop directly southward to the next outer loop segment within Richardson Park, but allow the inner zone to continue to flood.

Tributary Four: A different profile begins with Tributary Four in that it's located entirely outside of the central City of Lufkin (outside the Loop). East of the apartment project at HWY 59 the channel is reletively small and rarely overflows into 404 wetlands. Below HWY 59, the channel widens from larger inflows and many adjacent forested wetlands are associated with the channel. It is shown on the map titled **Exhibit 2**.

The soil type is the Alazan (Aab) loam type described previously on page 22, except for a small area prior to infall into the ~~Main~~ Stem of Moten-Multey complex (Mx), gently undulating, nearly level stream terraces. Although Moten-Multey is not listed on the hydric soils list, it's description is wet enough that where sufficient hydrology was available, it would be considered a 404 hydric soil. The lower floodpool at the junction of Tributary Four begins the Pophers soil type which is a listed hydric soil type.

East of HWY 59 the small channel exhibits vacant land on either or both sides for most of it's length, although there is a considerable amount of development upslope on the higher ridgelines. It falls out of a large lake flowing westward, and mostly remains within the small channel. This may be another of those segments that would be able to permit in-stream channelization with an appropriate amount of mitigation offered for it's un-avoidable impacts. West of HWY 59 the larger stream would be difficult to permit in-stream projects. However, adjacent vacant uplands on both sides of the segment offer project opportunities.

Tributary Five: The northernmost reach falls out of Crown Colony through a recently channelized area behind the Church Retreat development and joins it's southern arm in a very good quality forested floodpool between their junction and HWY 59. It's soil type is the Alazan (Aab) loam described above east of HWY 59, west of 59 the Pophers hydric soil begins as a part of the Main Stems' upper floodpool down to it's junction with the Main Stem.

The southern segment above the junction is a very small channel that would have a minor amount of 404 permitting requirement as is more fully described in Section One above, including the rare possibility of in-stream channelization. The floodpool east of HWY 59 and all of the main channel west of 59 would be difficult to permit impacts to.

Summary of Section Two Report:

1.) The segment defined as Middle Hurricane Creek lies within a highly developed floodplain that constricts floodflow between well drained commercial land directly adjacent. Most of the Main Stem is currently utilized as public park area and stormwater is allowed to overflow the main channel(s) through the minimally developed floodplain.

2.) The Main Stem and it's floodplain wetlands consist of high quality forested wetland habitat, such that major development projects would be difficult to permit with wildlife agencies that are more intrusive than existing park facilities.

3.) The Main Stem south/outside of Loop 287 does have potential for 404 permitting of large scale flood control projects provided adequate mitigation is proposed to offset wetland/stream impacts. If the project were a detention basin excavated from uplands, it would have flooded land available sufficient to mitigate it's own 404 impacts, and additional area to mitigate impacts from other City projects nearby.

4.) Tributaries Two, Three, Four and Five are adjacent to large tracts of land which have potential for flood control projects to be 404 permitted for construction within their upland areas outside of existing floodways.

5.) The eastern upstream channels of Tributaries Four and Five, and a short segment below developed neighboods of Tributary Three are small in size and rarely overflow into adjacent wetlands. They may be allowed in-stream channelization by wildlife agencies with appropriate mitigation proposed.

Section Three- semi rural- Lower Hurricane Creek:

This Section is described as that part of the Main Stem of Hurricane Creek below it's juncture with Tributary Four throughout it's length to Cedar Creek, and all of the streambanks of Tributaries Six and Seven. The difference(s) between these areas and Section(s) One and Two reported on previous pages relates to their considerably larger stormflows. The Main Stem has developed a large riverine channel that overflows its' banks during heavy rainfall conditions. Similar to Section Two within the City, these floodplains consist of complex, high quality wetlands that would be difficult to 404 permit complete development of.

In addition, the streambank(s) and associated floodplain of the Main Stem at and downstream from Tributary Four is located on soils that are listed as hydric by the NRCS. From the City Treatment Plant at FM 324 downstream to Cedar Creek there may be (or may not be) endangered species associated with either the streambed or the streambanks. All of Section Three is shown on the map attached as **Exhibit 2**, with suggested project locations described below marked as a **Site**.

Main Stem: The hydric soil Pophers (Po) is mapped in a floodpool configuration around the the junction with Tributary Four along with a less hydric soil Moten-Multey complex (Mx) upstream within Tributary Four. The Pophers soil type is mapped by the NRCS along the Main Stem completely to Cedar Creek, and is mapped to extend up the floodpools of junctions with Tributaries Five, Six and Seven. It is mapped upstream on both banks of Tributary Five eastward to HWY 59.

Pophers is described as "deep, slowly permeable, somewhat poorly drained soils on bottomlands. These soils formed in loamy and silty alluvium. They are subject to flooding mainly in winter and spring. Slopes are generally less than 1 percent" according to the NRCS.

This mapping of broad areas of Pophers hydric soil along both streambanks of the Main Stem, and even wider flood zones at tributary junctions, is important to consideration of potential for 404 permitting of flood control projects on adjacent lands. Upstream the non-hydric listing of soils allowed classification of most areas outside the high water mark technically as uplands, consequently such uplands have been suggested as having potential for development of City projects. This downstream segment and associated wider floodpools have no uplands directly adjacent to propose projects within (that may be easily permitted by wildlife agencies).

From it's junction with Tributary Four downstream to Cedar Creek there may be a T & E Species consideration of small fishes. Downstream of FM 324 there may be a concern for timber rattlesnakes along streambanks on either side of the channel.

Directly south of Loop 287, Tributary Six runs parallel to and west of the Main Stem almost to their junction before flowing westward under FM 324. Above their junction floodpool, there is an upland ridgeline area suitable for 404 permitting between the tributary and main channel that may (or may not) have potential as a flood control project area shown as a **Site** on the attached map.

West of FM 324 the large floodway resulting from joining of the Main Stem and Tributary Six continues downstream to Cedar Creek. This habitat is a large scale flooded forest similar to a major river floodplain. The highest flood elevation is somewhat lower than the base of the adjacent City Treatment Plant. Except for that small area around the plant that is regularly mowed, tracts of land on both sides of the Creek consist of floodplain hardwood tree species. It would be difficult to 404 permit any type of development project adjacent to the Creek west of FM 324 any more intrusive than the timber harvesting currently practiced by private landowners.

Tributary Six: The headwaters of Tributary Six begin at the edge of Loop 287 and flow southward a short distance to the Main Stem. The soil type is Fuller fine sandy loam (FfB), 1 to 4 percent slopes. Fuller is a soil that is not wet enough to be classified as hydric above any channel high water marks. For a short distance below Loop 287 it flows within it's banks to the extent that this segment may be allowed in-stream channelization. Large tracts of uplands to either side may have potential for detention projects, also shown as a **Site** on **Exhibit 2**.

Several thousand feet south of Loop 287 the channel widens into a major stream, and floodflows above the bankside have established a floodway wetland on both sides. Although the Fuller soil type continues downstream, it is flooded suficiently to be hydric, and is regulated as being below the streams' high water mark.

Tributary Seven: The north and south branches of Tributary Seven are located on Alazan (AaB) and Fuller (FfA) soils more fully described above, as well as a short reach of Herty very fine sandy loam (HeB), 1 to 5 percent slopes along the north branch between HWY 59 and Daniel McCall Road. All three soil types are not wet enough to be listed as hydric by the NRCS.

Both branches east of HWY 59 are small enough that in-stream channelization may be permitted, except where they pond against the highway. From the floodpool formed at the junction of the north and south branches west to the Main Stem, the flooded forest habitat is such that permitting direct impacts to the habitat by wildlife agencies would be difficult.

<u>Results: Mill Creek</u>

We have organized our report on the watersheds of Mill Creek into details regarding it's east and west branches, which larger streams are further divided into east and west forks upstream. A number of technical descriptions are similar to those described at length in the previous report on Hurricane Creek and are not re-described in great detail here. The nature of Mill Creek is considerably different from Hurricane Creek, due to it's character consisting of at least 50% of prairie wetlands.

All of the area within Mill Creek watersheds are as is shown on the enclosed **Exhibit 3**, and suggested project locations are marked as a **Site**. The area is reported on as follows:

East Branch: The East Fork begins to flow northward from the outfall of Jones Lake within Jones Park under Martin Luther King. It's upper segment is located on Keltys-Urban land complex (KdD), 5 to 15 percent slopes that is a well drained upland fine sandy loam. The only hydric soils are those located directly under constant streamflow and associated wetland floodpools. The floodway below the outfall of Jones Lake is a good quality prairie (open-sun) wetland varying in width from 20' to 50'.

East of Martin Luther King the stream mostly remains in the small channel as it curves northward around the apartment complex. It enters an area of small trees at the edge of the apartments where the soil changes to the Koury type reported on previously. An in-stream channelization project may be allowed in this segment. As the channel emerges from under the trees, it widens out into an established floodpool that supports a very good quality prairie wetland.

A small area directly adjacent, parallel to Martin Luther King (located under powerlines) may have potential for a small detention/mitigation project as is marked as a **Site** on the attached map. We suggest that it would be <u>an excellent area for location of a small 404 mitigation project</u> if it were not suitable for flood control.

At this point, the East Fork flows northwestward under Martin Luther King again. The West Fork joins it immediately after flowing from Lake Myriad. The combined flow of the East Branch runs alternatively through flooded forest and back into the open sun to and under the railroad tracks and Loop 287 to the City Lake. Wetlands associated with the floodway (both forested and prairie) are 50' to 200' wide, establishing a large regulated area that will be difficult to permit impacts to. A separate floodpool between the railroad tracks and the Loop has established a large prairie wetland that is mowed regularly during dry weather periods.

West Branch: The East Fork consists of two small arms falling steeply downslope from HWY 103 northward, parallel and west of FM 2251 to it's junction with the West Fork. The upper channels are located on soils of Alazan-Urban land complex (AcB), 0 to 4 percent slopes and the lower elevations cross the Koury soil type. The channels of the East Fork and their associated wetlands are small at this time, which may have potential for in-stream channelization or detention/mitigation projects. Where it joins the West Fork, a large floodpool is formed that would be difficult to permit impacts to.

The West Fork has established a major floodway that runs parallel to and between the Loop and railroad tracks, eastward towards City Lake. It is also located on the Koury soil type. The floodplain alternates between forested and prairie depending on which different ownerships mow their land regularly. All of the West Fork and it's floodplain wetlands are large and of very good quality. They would be difficult to permit (any type of development activity to) with wildlife agencies.

Main Stem: We observed the large floodpool between the railroad tracks and Loop 287 during flood conditions, in which the flood storage capacity (of) was impressive. It receives all of the combined flows from the East Branch and West Branch, and outfalls below the Loop northward into City Lake (Ellen Trout Memorial Lake).

Directly northward of the Loop culvert is a forested floodpool at the head of the Lake. This particular wetland area resembles the description of habitat typical of that utilized by the alligator snapping turtle. However, the USF&WS and the TP&WD did not express a concern about the area for T & E Species. Whether or not any snapping turtles may inhabit the area, as potential habitat it may be very difficult to construct any type of projects within.

Downstream of the Lake, Mill Creek flows northward within a large channel through a large pasture area towards HWY 59. It is also located on the Koury (Ko) soil type described previously. Within the short reach inside the City of Lufkin, it mainly stays within the large channel. Where it is not associated with a wetland floodpool, flood control projects may be allowed within or at least adjacent to the stream. Whether or not it is suitable for flood control projects, the large area of cleared pasture would be suitable for constructing a large wetland mitigation project, which is shown as a **Site** on **Exhibit 3**.

City of Lufkin Map Exhibits

Three (3) map exhibits are presented on following pages in support of Wet Tech's Preliminary Wetlands Survey as a part of the City of Lufkin Watershed Study.

Exhibit 1- **illustrates material from the report on Upper and Middle Hurricane Creek.**

Exhibit 2- **maps the areas described within Lower Hurricane Creek; and**

Exhibit 3- **maps areas identified within Mill Creek watersheds.**

Legend:

1.) **Tributary Number**---------------------------------- **5**

Identifying Tributary number as assigned by Dodson & Associates on the map of Stream Names of Lufkin, Texas.

2.) **Potential Flood Control Project Site**---------------- **Site**

A partial mapping of suggested project sites described in report text, proposed to be located in uplands adjacent to stream.

3.) **Upper Tributary Flow**------------------------------ DRAINAGE

Direction of flow of tributary toward Main Stem of Hurricane Creek or Mill Creek.

4.) **Major Stream Overflow Areas (at Junctions)**------ PONDING LOWLANDS

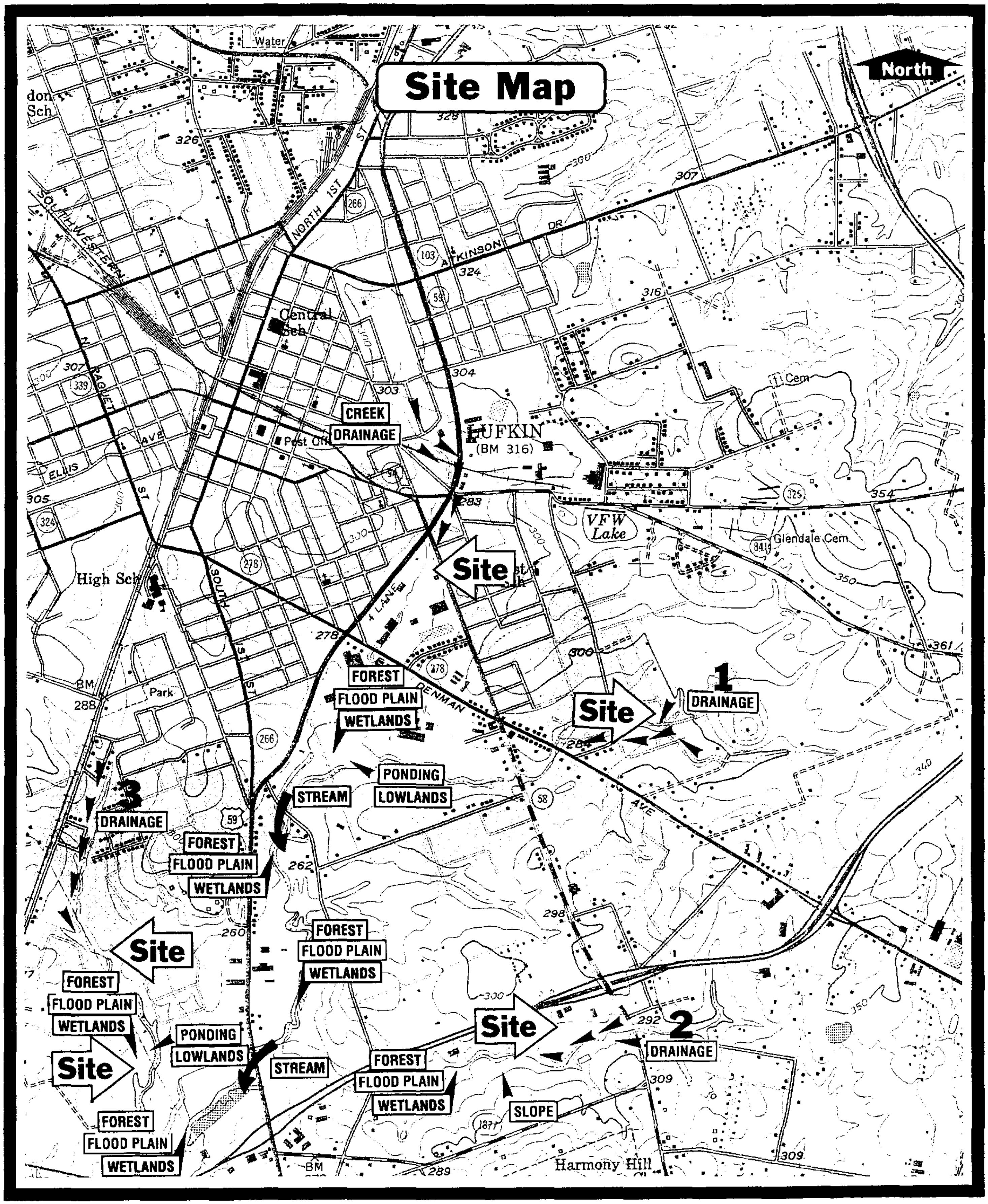
Typical areas of long term ponding during floodflow at junctions between tributaries or with main stem.

5.) **Typical Wetland Areas in vicinity**------------------ WETLANDS

Location of wetlands typical (of wetlands) nearby as is described in report.

6.) **Typical Wetland Type in vicinity**------------------- FOREST FLOOD PLAIN

Type of wetlands typical of those indicated in area as is described in report.



Site Map
North
Site
Site
Site
Site
Site
1
DRAINAGE
2
DRAINAGE
3
DRAINAGE
CREEK
DRAINAGE
FOREST
FLOOD PLAIN
WETLANDS
PONDING
LOWLANDS
STREAM
SLOPE
LUFKIN
(BM 316)
VFW Lake
Central Sch
High Sch
Park
Harmony Hill
Glendale Cem
Cem
ATKINSON DR
DENMAN AVE
NORTH 1ST ST
SOUTH 1ST ST
ELLIS
SOUTHWESTERN
4 LANE

Exhibit 1

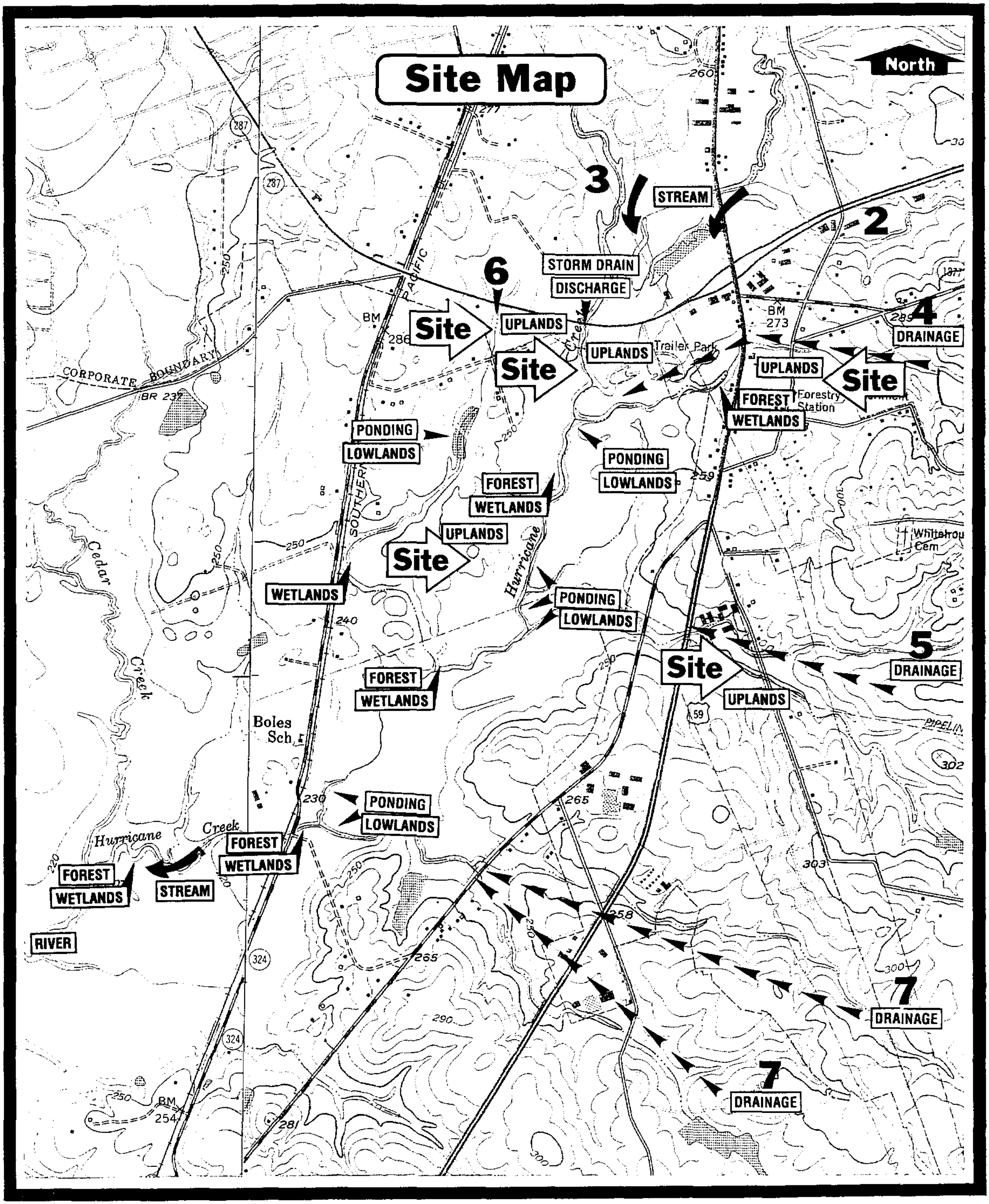
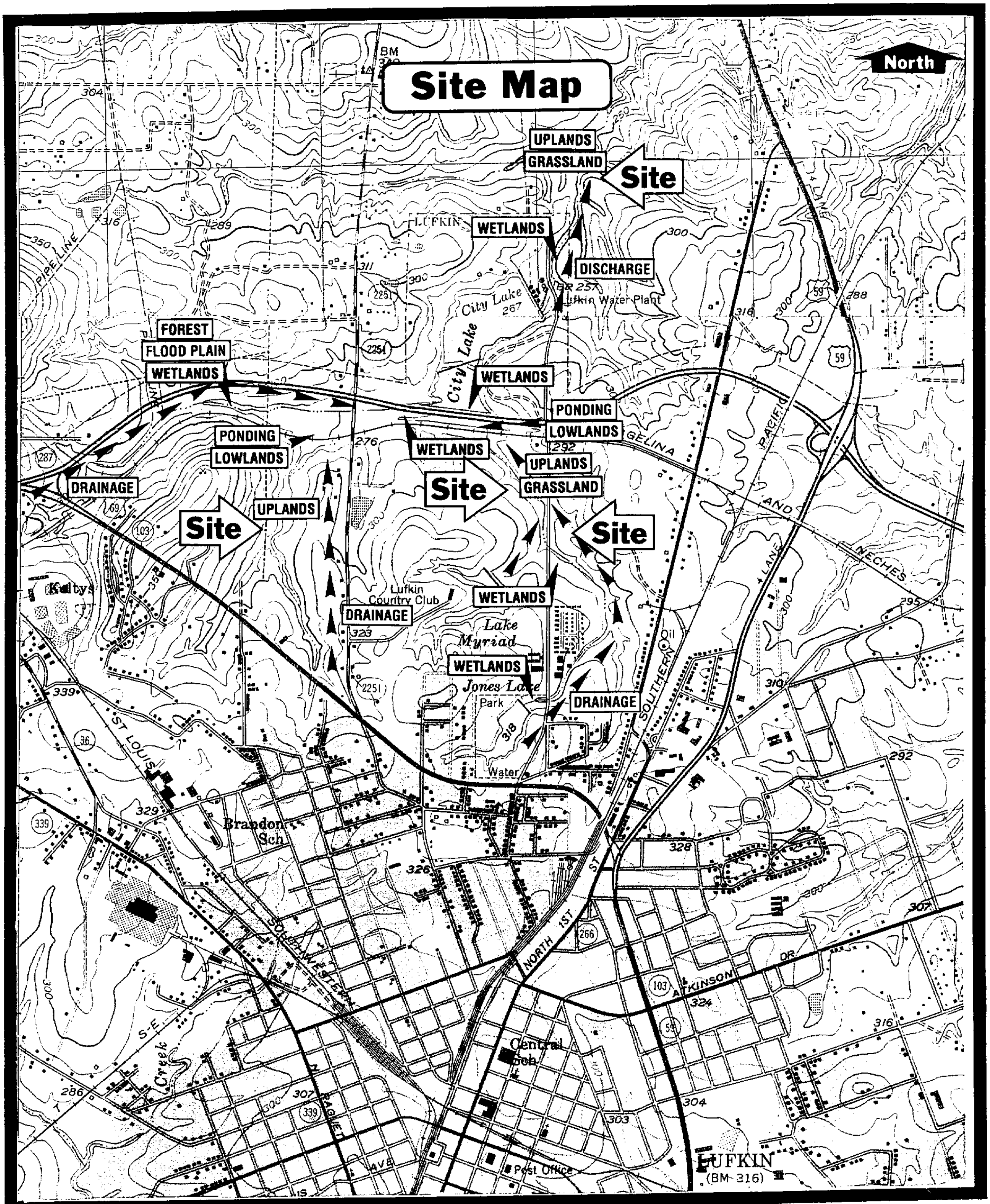

Site Map
North
STREAM
STORM DRAIN
DISCHARGE
UPLANDS
Site
DRAINAGE
Trailer Park
Forestry Station
FOREST
WETLANDS
PONDING
LOWLANDS
CORPORATE BOUNDARY
SOUTHERN PACIFIC
Hurricane Creek
Cedar Creek
Boles Sch
RIVER
PIPELINE
2
3
4
5
6
7

Exhibit 2



Site Map
North
UPLANDS
GRASSLAND
Site
WETLANDS
DISCHARGE
Lufkin Water Plant
City Lake
FOREST
FLOOD PLAIN
WETLANDS
WETLANDS
PONDING
LOWLANDS
PONDING
LOWLANDS
WETLANDS
UPLANDS
GRASSLAND
DRAINAGE
Site
UPLANDS
Site
Site
Lufkin Country Club
DRAINAGE
WETLANDS
Lake Myriad
WETLANDS
Jones Lake
Park
DRAINAGE
Brandon Sch
Central Sch
Post Office
LUFKIN
(BM 316)

Exhibit 3

Wet Tech
Wetland Technologies Corporation

... providing watershed assessment, design, and construction supervision services.

November 16, 1998

Mr. Duane Barrett, P.E.
Dodson & Associates, Inc.
5629 FM 1960 West, Suite 314
Houston, Tx. 77069-4216

Re: Interim Project Review- Proposed City of Lufkin Stormwater Project(s)

Subject: Hurricane Creek and Mill Creek Watershed(s)

Dear Mr. Barrett;

Please find following our Report detailing findings regarding the proposed project sites. This material was developed during an inspection the afternoon of November 4, 1998, all day of the 5th, and the early morning of the 6th. A recent storm had flooded some of the lower areas several days before.

We noted that certain placement guidelines had been developed from our previous Report and employed to greatly reduce potential conflicts with regulatory agencies; however, where these are not appropriate for a particular site is described herein.

Please let us know if there are any questions regarding the enclosed material.

Sincerely;

WETLAND TECHNOLOGIES CORPORATION

Glenn Jarrett,
General Manager

1831 Pinewood Ct. • Sugar Land, TX 77478 • off: ~~713~~ 281-242-8734 • fax: ~~713~~ 281-491-0825

Additional Comments regarding:

Project Site Selection & Design Criteria

Location of Flood Control Structure(s):

Most proposed projects consist primarily of a berm type dam/spillway sited across a small channel that would detain stormwater a required period of time, and then drain slowly to a "dry-bottom" configuration. As these berms have a small footprint of impact across a regulated streambed, and no permanent impoundment is created, then resource agency objections will be minor to the extent mitigation should be allowed by them (in most cases). This criteria would not constitute a "small impact" within major channels, and we note that none are proposed to do so (Project's #1 and #2 on Mill Creek are close).

However, several proposals specify excavate-and-haul-away which impacts an entire site permanently. Those that would be minimal impact and those that would not are differentiated to the extent possible below without extensive on-site work.

Where an improvement in re-locating a site a short distance is appropriate, we have so described in the following material.

Design Criteria:

Where the **purpose of a project** would not incorporate construction of mitigation within, the berm's "footprint impact" will be required to be the smallest possible to achieve the desired storage capacity. Where mitigation is planned within, mitigation requirements will be required to be **primary** over capacity considerations.

Mitigation Criteria:

Certain proposed project sites that appear to be more suitable for mitigation meet a specific criteria that generally floods a large area (that) currently qualifies as upland. In some cases we recommend re-locating a structure in order to flood a flatter area now currently proposed to be avoided. An example would be our comments regarding Mill Creek Watershed's Project #3 wherein a part of the avoided area may be suitable to be incorporated within. Where upland sites are excavated for retention, opportunities exist for mitigation projects to be specified. **It is important to note that all of the projects proposed will require some amount of mitigation offset.**

Review of Proposed Hurricane Creek Project(s)

Introduction:

Inspection of major projects proposed inside Loop 287 and Project's #5 & #6 outside the Loop revealed no major impediment to regulatory approval for sturctures or excavation (except for #2 more fully described below). Where upstream channelization may be allowed varies with each stream and is described to the extent possible in this work.

Project #1:

This project appears from Cunningham and Ford Chapel Rd. to be a large, well drained site. There is an undeveloped area to the south that does not have an approach (is not easily viewed). It appears to flood a large volume with the proposed berm location such that excavation would not be needed for additional capacity. Such criteria may indicte a potential for location of a suitable mitigation site. If so, Wet Tech is of the opinion that **necessary mitigation required** for this project and others nearby be incorporated within.

Mitigation would specify little or no landclearing; rather the shallow excavations should be specified to be constructed between groups of trees with inter-connecting swales. The fertile topsoils would be cut out and set aside for re-installation and planting after shallow excavation work is complete. If the underlying subsoils are suitable, they would be used for berm construction; thereby saving the cost of hauling them away, and the cost of materials importation (for berm construction).

Most likely the improvements proposed for the small channel would be allowed (with suitable mitigation) downstream to Denman Avenue.

Project #2

This project may not be feasible as proposed. It is specified to be over-excavation of an existing depressional site for additional stormwater capacity (it currently holds and slowly releases a large volume of run-off). The existing forested over-bank depressions surrounding the confluence of several small channels is of <u>very high</u> habitat quality.

The site's **only potential** would be in delineating existing wetlands and excavating outer edges of available un-developed land up to, but not within the specified "avoid area". Final outfall <u>elevation must remain</u> as currently exists, <u>only capacity</u> would be increased.

Project #3:

The channelization proposed above and under Chestnut St. would most likely be allowed, while that proposed south of Chestnut would not.

The area designated behind Kurth Elementary school currently floods, consequently increasing the floodpool footprint would be acceptable provided little or no impact occurred from berm construction. Care must be taken to select an upland area for the specific berm location; otherwise, the site is excellent as proposed.

Additionally, there is a vacant land tract directly adjacent east of the school ballfields that (if available) would be suitable for excavation of a regional retention project with mitigation incorporated within (see drawing on next page). It may be appropriate to install paths and decks across the permanent wet bottom areas as a neighborhood park in the same manner as Kiwanis Park/Azalea Trail nearby (warning signs of danger during major floods would be required for the school's ballfields and the public use area).

Project #4:

This project is proposed to be specified in a similar manner as Project #3 in the southeast corner of Tulane and York Streets. Again, provided the specific berm location is carefully selected for least habitat impact, this is an excellent project location. Additionally, an un-developed area above the intended floodpool directly to the southeast would be suitable for mitigation. Upon closer on-site inspection it may prove acceptable for significant excavation also. As a large volume of material will be required to construct the berm, a cost off-set from balance of cut-and-fill may be possible.

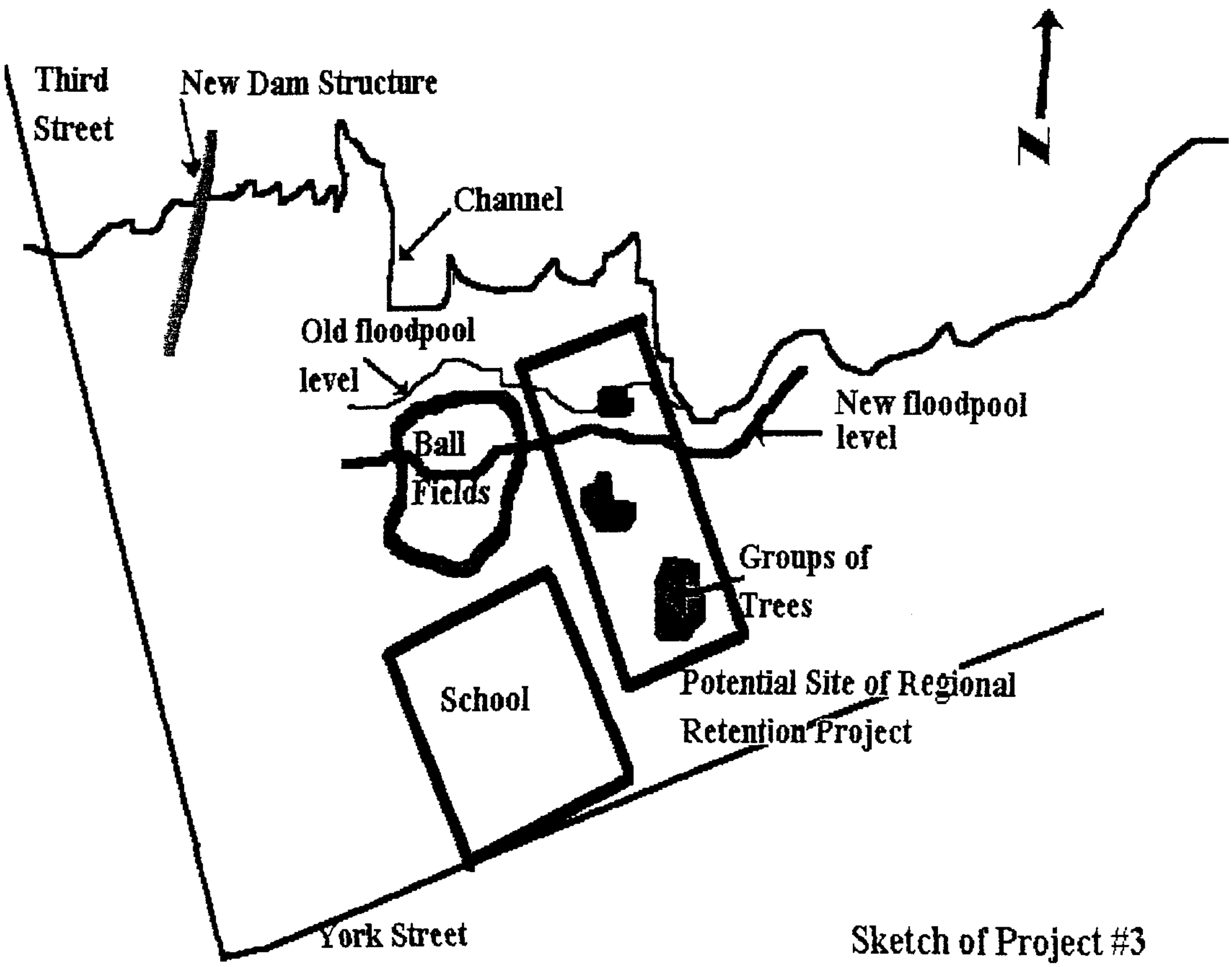
Main Stem of Hurricane Creek:

Specification of a major bypass channel directly west of the Main Stem below Kiwanis Park southward to the mall is an environmentally acceptable alternative. However, the channel would eliminate the newly installed Azalea Trail; consequently funding agencies may require the City of Lufkin to reconstruct it on the east side of the Creek at the City's expense. Secondly, it would eliminate parking behind some of the commercial businesses fronting old HWY 59. The City of Lufkin may <u>choose not to construct</u> the project.

Perhaps the bypass could be specified to be located **on the east side** of the Creek in the same manner with avoidance of existing homes where necessary. Channel excavation would provide considerable material for other berm construction projects nearby.

Proposed Project #3-Hurricane Creek Watershed

Typical excavation of Regional Retention Project capacity into adjacent vacant upland while avoiding currently flooding sensitive habitat.



Sketch of Project #3
Hurricane Creek
Watershed

not to scale

Project #5:

Similar to Project's #3 and #4 more fully described above, this project location appears to be suitable for regulatory purposes as well as storage potential. The berm site should be carefully selected, with appropriate mitigation proposed and constructed on-site.

Channelization proposed should be acceptable downstream to, but not beyond the Lowes Store with mitigation. Refer to detailed description recommendations made in the Lowe's Store area on page 22 of Wet Tech's previous Report dated 9/15/98.

Project #6:

The proposed low impact berm type retention specified for #6 is well suited to it's selected location with appropriate mitigation.

Channelization proposed from the Lowes Store downstream to the Project #6 floodpool, and downstream from Project #6 to the Loop most likely **would not be allowed** at some reasonable amount of mitigation. However, vacant upland directly adjacent to the south is suitable for installation of a small bypass channel (which would have a lower construction cost than the proposed channelization). Also, for that reason either section would not pass 404 Alternative Analysis.

Project #7:

Channelization- Improvements within neighborhoods upstream on Tributary #3 should be acceptable with a small amount of mitigation required. However, the channelization proposed downstream to the large bypass would be difficult to 404 Permit. If hydraulically feasible, the lower total cost to the City may be a small bypass channel excavated from the neighborhood outfall straight through the "S" of the natural stream to connect with the larger bypass downstream (which is appropriate as proposed).

Additional Land for Storage- Acquisition of un-developed land within the white area outlined in blue in order to prevent future development is suitable for this particular zone. However, as an existing floodpool small uplands would be required to be selected on-site for any excavation desired, and all other areas carefully avoided by construction equipment (see typical design on previous page).

On closer inspection, it might be determined that little or no additional capacity could be excavated into such a sensitive habitat. The adjacent area shown in blue fill has the same circumstances; in that lower elevations are too high in quality to excavate, and upper elevations may not be feasible for excavation.

Proposed Project #8, Project #9 and Project #10:

Each of these berm/dry bottom type designs should be acceptable to resource agencies if carefully sited for least impact and suitable mitigation is proposed.

Most channelization proposed south of the Loop will be acceptable east of HWY 59 (however, certain areas will not be); and most of that west of 59 will not be acceptable. As previously reported, the natural streambed outfalling from Crown Colony has been recently channelized behind the Church Retreat property as a part of current land development activity.

Projects proposed for Tributary Six:

Two large ponded areas are proposed to be expanded to increase storage volume. The transitional (flood up-flood down) wetland edges must be avoided by all construction activities. Excavation of uplands directly up to, but not into the wetland edge would be acceptable. Properly designed and constructed these upland work areas could qualify as mitigation for 404 impacts nearby.

Channelization southward from the Loop to the first existing pond may be acceptable; that specified south of the first pond to the Main Stem of Hurricane Creek would not.

Review of Proposed Mill Creek Project(s)

Project #1:

This major streambed will be difficult to 404 Permit impact due to the high quality habitat involved. Extreme care should be taken in exact site selection, and at least a ratio of 2:1 of mitigation should be offered resource agencies in the first approach to them.

Channelization in the large streambed directly upstream would not be allowed. Where the channel upstream to the west is a much smaller/lower quality habitat, channelization would be allowable with suitable mitigation offered.

Project #2:

Wet Tech is of the opinion that the large amount of flood storage resulting from this (one) project's impact is an excellent proposal for the watershed. However, the quality of habitat to be impacted by the dam/spillway structure is very high, slightly more so than described for Project #1 above. Under any "lesser benefit" set of circumstances this impact may not be Permitted. Specific project and mitigation design should consider all aspects of the proposed 404 Permit Application before proceding to agency contact.

Project #3:

This project is unique of all of the berm type projects proposed for both watersheds. It's special character is due to the large amount of flat open land proposed to be flooded that is now currently upland. We suggest that this particular elevation be left as-is for construction of a **regional mitigation project** rather than excavation to increase strorage capacity (of course, the edges rising above could be cut back to increase total project capacity). It also appears that the berm could be re-located a short distance downstream in order to flood a larger area of this elevation.

On closer inspection, it may be that the previously cleared land (site of overhead powerlines) is large enough to locate mitigation required for all four Mill Creek Projects. Savings in construction costs to the City would be extensive.

Channelization upstream of Project #3 will most likely be allowed with suitable habitat mitigation proposed.

Project #4:

This project is sited directly adjacent to/upstream of a good quality prairie wetland that would be difficult to impact. It is correctly located as drawn to temporarily flood a small wooded area behind the apartment complex.

Channelization proposed upstream behind the apartments would be acceptable up to, but not including the outfall area below Jones Lake (which should be protected from all proposed project impacts).

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Number								
			HC1A	***HC1B***	***HCT1A***	***T1B1***	T1B2	T1B3	T1B4	T1B5	T1B6
Drainage Area											
Area		ac	302	965	206	78	157	44	39	339	30
Area		sm	.472	1.508	.322	.122	.245	.069	.061	.530	.047
Impervious Cover											
Land Use	I(%)										
Ind./Comm.	80%	ac	98.5	345.7	21.5	18.5	.0	.0	.0	63.0	5.4
Multi-Family	70%	ac	.0	3.7	.0	.0	2.2	.0	.0	10.2	.0
Highway	60%	ac	5.9	.0	13.1	.0	.0	.0	.0	.0	.0
Community	40%	ac	.0	8.7	.0	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	68.6	318.3	28.2	30.8	14.8	25.8	38.6	173.5	2.2
S-F (Light)	15%	ac	128.5	154.9	1.2	.0	.0	.0	.0	5.4	.0
Future Development		ac	.0	134.2	142.3	28.2	140.3	18.4	.6	75.8	22.6
Future Impervious		%	60%	50%	60%	30%	30%	30%	30%	50%	80%
Total		ac	301.5	965.5	206.3	77.5	157.3	44.2	39.2	327.9	30.2
Imperv. Area		ac	122.2	468.5	119.1	32.5	48.1	13.3	11.8	148.3	23.1
Imperv. Cover		%	40.5	48.5	57.7	41.9	30.6	30.0	30.0	45.2	76.4
Overland		Curve:	C	B	B	C	C	C	C	C	C
Distance		ft	300	300	300	300	300	300	300	300	300
Slope		%	1.8	2.5	2.5	2.5	4.0	4.5	5.0	2.0	2.8
Velocity		ft/s	1.0	.8	.8	1.1	1.5	1.6	1.6	1.0	1.2
Travel Time		min	5.00	6.25	6.25	4.55	3.33	3.13	3.13	5.00	4.17
Shallow Concentrated		Curve:	F	F	F	F	G	G	G	G	G
Distance		ft	300	400	700	1000	300	700	0	0	500
Slope		%	1.8	2.5	2.2	4.0	2.9	1.8	.0	.0	2.8
Velocity		ft/s	2.0	2.4	2.3	3.1	3.4	2.7	.0	.0	3.3
Travel Time		min	2.50	2.78	5.07	5.38	1.47	4.32	.00	.00	2.53
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	4800	5700	2280	300	3000	0	800	2500	0
Slope		%	.9	1.2	.9	1.0	1.2	.0	3.3	2.0	.0
Velocity		ft/s	1.9	2.2	1.9	2.0	2.2	.0	3.6	2.8	.0
Adjusted Velocity		ft/s	1.90	2.20	1.90	2.00	3.67	.00	6.00	4.67	.00
Travel Time		min	42.11	43.18	20.00	2.50	13.64	.00	2.22	8.93	.00
Improved Drainage Channel											
Distance		ft	0	3800	0	0	0	0	0	2000	0
Velocity		ft/s	.0	5.0	.0	.0	.0	.0	.0	5.0	.0
Travel Time		min	.00	12.67	.00	.00	.00	.00	.00	6.67	.00
Unimproved Drainage Channel											
Distance		ft	0	3200	0	1100	0	1600	1800	2400	1700
Velocity		ft/s	.0	3.0	.0	3.0	.0	3.0	3.0	3.0	3.0
Travel Time		min	.00	17.78	.00	6.11	.00	8.89	10.00	13.33	9.44
TC (minutes)			49.61	82.65	31.32	18.53	18.44	16.33	15.35	33.93	16.14
TC (hours)			.83	1.38	.52	.31	.31	.27	.26	.57	.27
R = 2 x TC (hours)			1.65	2.76	1.04	.62	.61	.54	.51	1.13	.54

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Nu							
			HC2A	HC2B	T2A1	T2A2	T2B1	T2B2	HC3	***HCT3A***
Drainage Area										
Area		ac	211	195	184	50	128	184	131	321
Area		sm	.330	.305	.288	.078	.200	.288	.205	.502
Impervious Cover										
Land Use	I(%)									
Ind./Comm.	80%	ac	9.2	64.3	25.6	11.8	24.3	42.1	65.6	141.5
Multi-Family	70%	ac	.0	.0	.0	.0	.0	.0	.0	.0
Highway	60%	ac	.0	.0	6.4	5.7	6.1	15.6	13.0	.0
Community	40%	ac	.0	.0	.0	.0	.0	.0	.0	13.4
S-F (Typical)	30%	ac	74.0	40.2	84.9	14.6	3.7	.5	.0	126.5
S-F (Light)	15%	ac	.0	18.9	.0	.0	.0	2.8	6.5	21.0
Future Development		ac	127.5	71.8	67.5	18.2	94.2	122.6	42.9	18.9
Future Impervious		%	40%	50%	50%	50%	50%	50%	70%	60%
Total		ac	210.7	195.2	184.4	50.3	128.3	183.6	128.0	321.3
Imperv. Area		ac	80.6	102.2	83.5	26.3	71.3	104.9	91.3	171.0
Imperv. Cover		%	38.2	52.4	45.3	52.4	55.6	57.1	71.3	53.2
Overland		Curve:	C	C	C	C	C	C	C	C
Distance		ft	300	300	300	300	200	300	300	300
Slope		%	3.6	3.4	1.3	4.0	2.5	6.7	1.8	.7
Velocity		ft/s	1.3	1.3	1.0	1.5	1.1	1.8	1.0	.6
Travel Time		min	3.85	3.85	5.00	3.33	3.03	2.78	5.00	8.33
Shallow Concentrated		Curve:	G	G	G	G	G	G	G	F
Distance		ft	600	400	200	600	200	1300	300	0
Slope		%	1.8	3.0	5.6	4.0	2.5	3.3	1.8	.0
Velocity		ft/s	2.7	3.5	4.7	4.0	3.2	3.7	2.7	.0
Travel Time		min	3.70	1.90	.71	2.50	1.04	5.86	1.85	.00
Paved or Gully		Curve:	G	G	G	G	G	G	G	G
Distance		ft	4800	900	2270	1200	2200	0	1120	7800
Slope		%	1.1	2.5	2.2	1.0	2.3	.0	.6	.6
Velocity		ft/s	2.1	3.2	3.0	2.0	3.0	.0	1.6	1.6
Adjusted Velocity		ft/s	3.50	5.33	5.00	3.33	5.00	.00	2.67	1.60
Travel Time		min	22.86	2.81	7.57	6.00	7.33	.00	7.00	81.25
Improved Drainage Channel										
Distance		ft	0	3600	0	0	0	0	2350	0
Velocity		ft/s	.0	4.0	.0	.0	.0	.0	5.0	.0
Travel Time		min	.00	15.00	.00	.00	.00	.00	7.83	.00
Unimproved Drainage Channel										
Distance		ft	0	0	700	0	800	3200	0	0
Velocity		ft/s	3.0	.0	3.0	3.0	3.0	3.0	.0	.0
Travel Time		min	.00	.00	3.89	.00	4.44	17.78	.00	.00
TC (minutes)			30.41	23.56	17.16	11.83	15.85	26.41	21.69	89.58
TC (hours)			.51	.39	.29	.20	.26	.44	.36	1.49
R = 2 x TC (hours)			1.01	.79	.57	.39	.53	.88	.72	2.99

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	Parameter Values for Given Sub-Area Number								
			HCT5C	T5D1	T5D2	HCT5E	HC6	***HCT6A***	***HCT6B***	HC7	***HCT7A***
Drainage Area											
Area		ac	155	117	107	134	78	110	285	180	118
Area		sm	.242	.183	.167	.209	.122	.172	.445	.281	.184
Impervious Cover											
Land Use	I(%)										
Ind./Comm.	80%	ac	.0	.0	3.5	10.2	.0	24.3	7.3	3.3	.0
Multi-Family	70%	ac	.0	.0	7.2	19.4	1.5	.0	.0	.8	.0
Highway	60%	ac	.0	.0	.1	11.3	.0	12.2	.1	.0	.0
Community	40%	ac	.0	.0	6.6	1.0	.0	.0	.0	6.1	.0
S-F (Typical)	30%	ac	.0	.0	4.6	.0	.0	5.9	.0	.0	34.9
S-F (Light)	15%	ac	35.0	13.2	.0	6.4	.0	23.5	44.3	3.4	10.4
Future Development		ac	119.9	103.6	84.5	85.5	76.5	44.1	233.3	164.2	72.9
Future Impervious		%	30%	30%	30%	70%	80%	60%	80%	80%	30%
Total		ac	154.9	116.8	106.5	133.8	78.0	110.0	285.0	177.8	118.2
Imperv. Area		ac	41.2	33.1	37.3	89.7	62.3	58.5	199.2	137.5	33.9
Imperv. Cover		%	26.6	28.3	35.0	67.1	79.8	53.2	69.9	77.3	28.7
Overland		Curve:	C	C	C	C	C	B	C	C	B
Distance		ft	300	300	300	300	300	300	300	300	200
Slope		%	.5	2.5	4.0	4.5	5.0	2.0	1.3	3.3	2.5
Velocity		ft/s	.5	1.1	1.5	1.6	1.7	.7	.8	1.3	.8
Travel Time		min	10.00	4.55	3.33	3.13	2.94	7.14	6.25	3.85	4.17
Shallow Concentrated		Curve:	G	G	G	G	G	F	F	G	F
Distance		ft	500	1100	200	600	200	400	1800	200	200
Slope		%	.5	2.7	4.0	3.3	5.0	2.0	1.6	3.3	2.5
Velocity		ft/s	1.5	3.3	4.0	3.7	4.5	2.1	1.9	3.7	2.4
Travel Time		min	5.56	5.56	.83	2.70	.74	3.17	15.79	.90	1.39
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	2740	2300	2600	2000	1990	1420	0	3410	1500
Slope		%	1.8	1.3	1.5	1.5	1.2	1.8	.0	1.3	1.6
Velocity		ft/s	2.7	2.3	2.4	2.5	2.2	2.7	.0	2.3	2.6
Adjusted Velocity		ft/s	4.50	3.83	4.00	4.17	3.67	2.70	.00	3.83	2.60
Travel Time		min	10.15	10.00	10.83	8.00	9.05	8.77	.00	14.83	9.62
Improved Drainage Channel											
Distance		ft	0	0	1100	0	0	0	0	0	0
Velocity		ft/s	.0	.0	5.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	3.67	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel											
Distance		ft	400	300	0	2400	630	0	7600	2640	2100
Velocity		ft/s	3.0	3.0	.0	3.0	3.0	.0	3.0	3.0	3.0
Travel Time		min	2.22	1.67	.00	13.33	3.50	.00	42.22	14.67	11.67
TC (minutes)			27.93	21.77	18.67	27.16	16.23	19.08	64.26	34.24	26.84
TC (hours)			.47	.36	.31	.45	.27	.32	1.07	.57	.45
R = 2 x TC (hours)			.93	.73	.62	.91	.54	.64	2.14	1.14	.89

CALCULATION OF Tc USING VELOCITY METHOD
HURRICANE CREEK WATERSHED
ULTIMATE WATERSHED CONDITIONS
December 30, 1998

Parameter		Units	HCT7B	*HCT7C*	HCT7D	HCT7E	HCT7F
			Parameter Values for Given Sub-Area Number				
Drainage Area							
Area		ac	335	203	114	415	158
Area		sm	.523	.317	.178	.648	.247
Impervious Cover							
Land Use	I(%)						
Ind./Comm.	80%	ac	12.0	.0	.0	38.2	.1
Multi-Family	70%	ac	6.4	.0	.0	.0	.0
Highway	60%	ac	6.9	.0	.0	5.4	.2
Community	40%	ac	23.3	.0	.0	.0	5.5
S-F (Typical)	30%	ac	158.1	120.3	103.8	154.0	.0
S-F (Light)	15%	ac	45.0	.0	.0	25.9	40.2
Future Development		ac	83.6	83.1	9.8	191.6	112.4
Future Impervious		%	50%	30%	30%	50%	80%
Total		ac	335.3	203.4	113.6	415.1	158.4
Imperv. Area		ac	123.5	61.0	34.1	179.7	98.4
Imperv. Cover		%	36.8	30.0	30.0	43.3	62.1
Overland		Curve:	C	B	C	C	C
Distance		ft	300	300	300	200	300
Slope		%	3.0	2.5	2.5	3.0	2.9
Velocity		ft/s	1.2	.8	1.1	1.2	1.2
Travel Time		min	4.17	6.25	4.55	2.78	4.17
Shallow Concentrated		Curve:	G	F	G	G	G
Distance		ft	500	200	900	200	1000
Slope		%	4.0	4.0	2.5	3.0	2.2
Velocity		ft/s	4.0	3.0	3.2	3.5	3.0
Travel Time		min	2.08	1.11	4.69	.95	5.56
Paved or Gully		Curve:	G	G	G	G	G
Distance		ft	1300	1900	1000	3800	1000
Slope		%	2.3	1.9	2.0	1.6	2.0
Velocity		ft/s	3.0	2.8	2.8	2.6	2.8
Adjusted Velocity		ft/s	5.00	2.80	4.67	4.33	4.67
Travel Time		min	4.33	11.31	3.57	14.62	3.57
Improved Drainage Channel							
Distance		ft	0	0	0	0	0
Velocity		ft/s	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00
Unimproved Drainage Channel							
Distance		ft	6100	700	0	4800	3300
Velocity		ft/s	3.0	3.0	.0	3.0	3.0
Travel Time		min	33.89	3.89	.00	26.67	18.33
TC (minutes)			44.47	22.56	12.80	45.01	31.63
TC (hours)			.74	.38	.21	.75	.53
R = 2 x TC (hours)			1.48	.75	.43	1.50	1.05

INTERIM CONDITIONS TC & R VALUES
HURRICANE CREEK WATERSHED
December 30, 1998

Parameter		Units	T1B1	T1B2	T1B3	T1B4	T1B5	HC2A	HC2B	T4B1	T4B2
Drainage Area											
Area		ac	78	157	44	39	369	211	195	157	215
Area		sm	.122	.245	.069	.061	.577	.330	.305	.245	.336
Impervious Cover											
Land Use	I(%)										
Ind./Comm.	80%	ac	18.5	.0	.0	.0	68.4	9.2	64.3	.0	32.3
Multi-Family	70%	ac	.0	2.2	.0	.0	10.2	.0	.0	.0	.0
Highway	60%	ac	.0	.0	.0	.0	.0	.0	.0	.0	4.5
Community	40%	ac	.0	.0	.0	.0	.0	.0	.0	.0	.0
S-F (Typical)	30%	ac	30.8	14.8	25.8	38.6	175.7	74.0	40.2	9.1	.0
S-F (Light)	15%	ac	.0	.0	.0	.0	5.4	.0	18.9	14.6	63.5
Future Development		ac	28.2	140.3	18.4	.6	98.4	127.5	71.8	133.4	114.5
Future Impervious		%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total		ac	77.5	157.3	44.2	39.2	358.1	210.7	195.2	157.1	214.8
Imperv. Area		ac	24.0	6.0	7.7	11.6	115.4	29.6	66.3	4.9	38.1
Imperv. Cover		%	31.0	3.8	17.5	29.5	32.2	14.0	34.0	3.1	17.7
Overland		Curve:	C	B	C	C	C	C	C	B	B
Distance		ft	300	300	300	300	300	300	300	300	300
Slope		%	2.5	4.0	4.5	5.0	2.0	3.6	3.4	3.0	5.0
Velocity		ft/s	1.1	1.0	1.6	1.6	1.0	1.3	1.3	.9	1.1
Travel Time		min	4.55	5.00	3.13	3.13	5.00	3.85	3.85	5.56	4.55
Shallow Concentrated		Curve:	F	F	F	F	F	F	F	F	F
Distance		ft	1000	300	700	0	0	600	400	300	0
Slope		%	4.0	2.9	1.8	.0	.0	1.8	3.0	6.7	.0
Velocity		ft/s	3.1	2.6	2.1	.0	.0	2.1	2.7	4.0	.0
Travel Time		min	5.38	1.92	5.56	.00	.00	4.76	2.47	1.25	.00
Paved or Gully		Curve:	G	G	G	G	G	G	G	G	G
Distance		ft	300	3000	0	800	2500	4800	900	1200	3000
Slope		%	1.0	1.2	.0	3.3	2.0	1.1	2.5	2.0	1.5
Velocity		ft/s	2.0	2.2	.0	3.6	2.8	2.1	3.2	2.8	2.4
Adjusted Velocity		ft/s	2.0	2.2	.0	3.6	2.8	2.1	3.2	2.8	2.4
Travel Time		min	2.50	22.73	.00	3.70	14.88	38.10	4.69	7.14	20.83
Improved Drainage Channel											
Distance		ft	0	0	0	0	0	0	0	0	0
Velocity		ft/s	.0	.0	.0	.0	.0	.0	.0	.0	.0
Travel Time		min	.00	.00	.00	.00	.00	.00	.00	.00	.00
Unimproved Drainage Channel											
Distance		ft	1100	0	1600	1800	6400	0	3600	700	3800
Velocity		ft/s	3.0	.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Travel Time		min	6.11	.00	8.89	10.00	35.56	.00	20.00	3.89	21.11
TC (minutes)			18.53	29.65	17.57	16.83	55.44	46.70	31.00	17.84	46.49
TC (hours)			.31	.49	.29	.28	.92	.78	.52	.30	.77
R = 2 x TC (hours)			.62	.99	.59	.56	1.85	1.56	1.03	.59	1.55

COST ESTIMATE FOR CHANNEL IMPROVEMENTS

HURRICANE CREEK FROM LOOP 287 TO U.S. 59				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	3,400	feet	-----	-----
Required Right-Of-Way Width	200	feet	-----	-----
Required Right-Of-Way Area	15.6	acres	-----	-----
Right-Of-Way Acquisition	15.6	acres	$10,000	$156,000.00
Clearing & Grubbing	15.6	acres	$1,000	$15,600.00
Excavation and Haul	41,000	cubic yards	$8.00	$328,000.00
Backslope Drains (600' Spacing)	6	each	$2,500	$15,000.00
Backslope Swales	3,400	linear feet	$1.00	$3,400.00
Vegetation Establishment	15.6	acres	$1,500	$23,400.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$541,400.00
Engineering Design & Permitting	10.00%			$54,140.00
Construction Oversight	5.00%			$27,070.00
Cost Sub-Total				$622,610.00
Contingency	15.00%			$93,391.50
TOTAL COST				$716,001.50

HURRICANE CREEK FROM U.S. 59 TO TULANE				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	4,500	feet	-----	-----
Required Right-Of-Way Width	150	feet	-----	-----
Required Right-Of-Way Area	15.5	acres	-----	-----
Right-Of-Way Acquisition	23.4	acres	$10,000	$234,000.00
Clearing & Grubbing	15.5	acres	$1,000	$15,500.00
Excavation and Haul	39,500	cubic yards	$8.00	$316,000.00
Backslope Drains (600' Spacing)	14	each	$2,500	$35,000.00
Backslope Swales	7,100	linear feet	$1.00	$7,100.00
Vegetation Establishment	15.5	acres	$1,500	$23,250.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$630,850.00
Engineering Design & Permitting	10.00%			$63,085.00
Construction Oversight	5.00%			$31,542.50
Cost Sub-Total				$725,477.50
Contingency	15.00%			$108,821.63
TOTAL COST				$834,299.13

COST ESTIMATE FOR CHANNEL IMPROVEMENTS

HURRICANE CREEK FROM SOUTH THIRD TO DENMAN				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	1,850	feet	-----	-----
Required Right-Of-Way Width	150	feet	-----	-----
Required Right-Of-Way Area	6.4	acres	-----	-----
Right-Of-Way Acquisition	6.4	acres	$10,000	$64,000.00
Clearing & Grubbing	6.4	acres	$1,000	$6,400.00
Excavation and Haul	18,000	cubic yards	$8.00	$144,000.00
Backslope Drains (600' Spacing)	4	each	$2,500	$10,000.00
Backslope Swales	1,850	linear feet	$1.00	$1,850.00
Vegetation Establishment	6.4	acres	$1,500	$9,600.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$235,850.00
Engineering Design & Permitting	10.00%			$23,585.00
Construction Oversight	5.00%			$11,792.50
Cost Sub-Total				$271,227.50
Contingency	15.00%			$40,684.13
TOTAL COST				$311,911.63

HURRICANE CREEK FROM DENMAN TO CHESTNUT				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	1,650	feet	-----	-----
Required Right-Of-Way Width	140	feet	-----	-----
Required Right-Of-Way Area	5.3	acres	-----	-----
Right-Of-Way Acquisition	5.3	acres	$10,000	$53,000.00
Clearing & Grubbing	5.3	acres	$1,000	$5,300.00
Excavation and Haul	5,500	cubic yards	$8.00	$44,000.00
Backslope Drains (600' Spacing)	6	each	$2,500	$15,000.00
Backslope Swales	3,300	linear feet	$1.00	$3,300.00
Vegetation Establishment	5.3	acres	$1,500	$7,950.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$128,550.00
Engineering Design & Permitting	10.00%			$12,855.00
Construction Oversight	5.00%			$6,427.50
Cost Sub-Total				$147,832.50
Contingency	15.00%			$22,174.88
TOTAL COST				$170,007.38

COST ESTIMATE FOR CHANNEL IMPROVEMENTS

TRIBUTARY #3 BYPASS CHANNEL				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	1,400	feet	-----	-----
Required Right-Of-Way Width	160	feet	-----	-----
Required Right-Of-Way Area	5.2	acres	-----	-----
Right-Of-Way Acquisition	5.2	acres	$10,000	$52,000.00
Clearing & Grubbing	5.2	acres	$1,000	$5,200.00
Excavation and Haul	22,000	cubic yards	$8.00	$176,000.00
Backslope Drains (600' Spacing)	6	each	$2,500	$15,000.00
Backslope Swales	2,800	linear feet	$1.00	$2,800.00
Vegetation Establishment	5.2	acres	$1,500	$7,800.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$258,800.00
Engineering Design & Permitting	10.00%			$25,880.00
Construction Oversight	5.00%			$12,940.00
Cost Sub-Total				$297,620.00
Contingency	15.00%			$44,643.00
TOTAL COST				$342,263.00

TRIBUTARY #4				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	3,000	feet	-----	-----
Required Right-Of-Way Width	120	feet	-----	-----
Required Right-Of-Way Area	8.3	acres	-----	-----
Right-Of-Way Acquisition	8.3	acres	$10,000	$83,000.00
Clearing & Grubbing	8.3	acres	$1,000	$8,300.00
Excavation and Haul	13,500	cubic yards	$8.00	$108,000.00
Backslope Drains (600' Spacing)	12	each	$2,500	$30,000.00
Backslope Swales	6,000	linear feet	$1.00	$6,000.00
Vegetation Establishment	8.3	acres	$1,500	$12,450.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$247,750.00
Engineering Design & Permitting	10.00%			$24,775.00
Construction Oversight	5.00%			$12,387.50
Cost Sub-Total				$284,912.50
Contingency	15.00%			$42,736.88
TOTAL COST				$327,649.38

COST ESTIMATE FOR CHANNEL IMPROVEMENTS

TRIBUTARY #5 (NORTH)				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	3,000	feet	-----	-----
Required Right-Of-Way Width	130	feet	-----	-----
Required Right-Of-Way Area	9.0	acres	-----	-----
Right-Of-Way Acquisition	9.0	acres	$10,000	$90,000.00
Clearing & Grubbing	9.0	acres	$1,000	$9,000.00
Excavation and Haul	14,000	cubic yards	$8.00	$112,000.00
Backslope Drains (600' Spacing)	12	each	$2,500	$30,000.00
Backslope Swales	6,000	linear feet	$1.00	$6,000.00
Vegetation Establishment	9.0	acres	$1,500	$13,500.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$260,500.00
Engineering Design & Permitting	10.00%			$26,050.00
Construction Oversight	5.00%			$13,025.00
Cost Sub-Total				$299,575.00
Contingency	15.00%			$44,936.25
TOTAL COST				$344,511.25

TRIBUTARY #5 (SOUTH)				
Item	***Quantity***	***Unit***	***Unit Cost***	***Cost***
Channel Length	4,800	feet	-----	-----
Required Right-Of-Way Width	120	feet	-----	-----
Required Right-Of-Way Area	13.2	acres	-----	-----
Right-Of-Way Acquisition	13.2	acres	$10,000	$132,000.00
Clearing & Grubbing	13.2	acres	$1,000	$13,200.00
Excavation and Haul	7,500	cubic yards	$8.00	$60,000.00
Backslope Drains (600' Spacing)	16	each	$2,500	$40,000.00
Backslope Swales	9,600	linear feet	$1.00	$9,600.00
Vegetation Establishment	13.2	acres	$1,500	$19,800.00
Land for Wetlands Mitigation	0.0	acres	$2,500	$0.00
Wetlands Grading & Planting	0.0	acres	$15,000	$0.00
Cost Sub-Total				$274,600.00
Engineering Design & Permitting	10.00%			$27,460.00
Construction Oversight	5.00%			$13,730.00
Cost Sub-Total				$315,790.00
Contingency	15.00%			$47,368.50
TOTAL COST				$363,158.50

COST ESTIMATE FOR REGIONAL DETENTION BASIN #1

QUANTITY TAKE-OFF WORK AREA

Item	***Quantity***	***Units***	***Computation of Required Dam Fill Volume (cy)***			
			Incr. Dist.	***NG Elevation***	***Section Area***	***Incr. Volume***
Maximum 100-Year WSEL =	313	feet	-----	316	0	0
Proposed Top of Dam Elevation =	316	feet	25	314	56	26
Channel Invert Elevation at Proposed Dam Location =	300	feet	35	312	144	130
Natural Ground Surface Area at Top of Dam Elevation =	21.9	acres	20	310	264	151
100-Year Peak Discharge =	106	cfs	40	308	416	504
Flow Area Required for Principal Outlet =	21.2	sq. ft.	205	306	600	3857
Required Number & Size of Outlet Pipes =	1	66" RCP	200	306	600	4444
Total Flow Area Provided in Principal Outlet =	23.8	sq. ft.	10	300	1344	360
Maximum Height of Dam =	16	feet	15	300	1344	747
Top Width of Dam =	20	feet	5	306	600	180
Dam Side Slope Ratio =	4	(h/v)	80	306	600	1778
Width of Dam at Toe =	148	feet	100	308	416	1881
Total Pipe Length for Principal Outlet =	148	feet	100	310	264	1259
Spillway Crest Elevation =	312	feet	100	312	144	756
Spillway Crest Length =	15	feet	55	314	56	204
Required Number & Size of Riser Pipes =	1	78" RCP	45	316	0	47
Total Pipe Length for Riser Pipes =	12	feet				
Approximate Concrete Area =	100	sq. yd.	1035	***Total Fill Volume =***		16323
Dam Excavation, Haul, & Compaction Volume =	16,323	cu. yd.				
Storage Excavation & Haul =	12	ac.-ft. =	19,360	cu. yd.		

COST ESTIMATE

Item	***Quantity***	***Units***	***Unit Cost***	***Cost***
Land Acquisition	32.85	acres	$10,000	$328,500
Excavation, Haul, & Compaction for Dam	16,323	cubic yards	$10.00	$163,230
Principal Discharge Culverts	148	linear feet	$250	$37,000
Riser Culverts	12	linear feet	$300	$3,600
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$37,000	$37,000
Storage Excavation & Haul =	19,360	cubic yards	$5.00	$96,800
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$671,130
Engineering Design & Permitting	10.00%			$67,113
Construction Oversight	5.00%			$33,556
Cost Sub-Total				$771,799
Contingency	15.00%			$115,770
TOTAL COST				$887,569

COST ESTIMATE FOR REGIONAL DETENTION BASIN #3

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
Maximum 100-Year WSEL =	274	feet	*Incr. Dist.*	*NG Elevation*	*Section Area*	*Incr. Volume*
Proposed Top of Dam Elevation =	276	feet	-----	276	0	0
Channel Invert Elevation at Proposed Dam Location =	260	feet	50	274	56	52
Natural Ground Surface Area at Top of Dam Elevation =	28.3	acres	110	272	144	407
100-Year Peak Discharge =	1362	cfs	95	270	264	718
Flow Area Required for Principal Outlet =	272.4	sq. ft.	25	268	416	315
Required Number & Size of Outlet Pipes =	5	9' x 6'	30	266	600	564
Total Flow Area Provided in Principal Outlet =	270	sq. ft.	40	268	416	753
Maximum Height of Dam =	16	feet	45	268	416	693
Top Width of Dam =	20	feet	35	266	600	659
Dam Side Slope Ratio =	4	(h/v)	55	264	816	1442
Width of Dam at Toe =	148	feet	30	260	1344	1200
Total Pipe Length for Principal Outlet =	740	feet	5	264	816	200
Spillway Crest Elevation =	271	feet	10	268	416	228
Spillway Crest Length =	80	feet	10	270	264	126
Required Number & Size of Riser Pipes =	5	9' x 6'	70	272	144	529
Total Pipe Length for Riser Pipes =	55	feet	10	274	56	37
Approximate Concrete Area =	200	sq. yd.	620	***Total Fill Volume =***		7923
Dam Excavation, Haul, & Compaction Volume =	7,923	cu. yd.				
Storage Excavation & Haul =	100	ac.-ft. =	161,333	cu. yd.		

COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	42.45	acres	$10,000	$424,500
Excavation, Haul, & Compaction for Dam	7,923	cubic yards	$10.00	$79,230
Principal Discharge Culverts	740	linear feet	$425	$314,500
Riser Culverts	55	linear feet	$425	$23,375
Concrete Slope Paving	200	sq. yds.	$50.00	$10,000
Emergency Spillway	1	lump sum	$314,500	$314,500
Storage Excavation & Haul =	161,333	cubic yards	$5.00	$806,667
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$1,972,771
Engineering Design & Permitting	10.00%			$197,277
Construction Oversight	5.00%			$98,639
Cost Sub-Total				$2,268,687
Contingency	15.00%			$340,303
TOTAL COST				$2,608,990

COST ESTIMATE FOR REGIONAL DETENTION BASIN #4

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
Maximum 100-Year WSEL =	269	feet	***Incr. Dist.***	***NG Elevation***	***Section Area***	***Incr. Volume***
Proposed Top of Dam Elevation =	272	feet	-----	272	0	0
Channel Invert Elevation at Proposed Dam Location =	260	feet	100	270	56	104
Natural Ground Surface Area at Top of Dam Elevation =	21.0	acres	30	268	144	111
100-Year Peak Discharge =	222	cfs	100	266	264	756
Flow Area Required for Principal Outlet =	44.4	sq. ft.	110	264	416	1385
Required Number & Size of Outlet Pipes =	1	9' x 5'	80	266	264	1007
Total Flow Area Provided in Principal Outlet =	45	sq. ft.	70	266	264	684
Maximum Height of Dam =	12	feet	40	264	416	504
Top Width of Dam =	20	feet	90	262	600	1693
Dam Side Slope Ratio =	4	(h/v)	55	260	816	1442
Width of Dam at Toe =	116	feet	5	262	600	131
Total Pipe Length for Principal Outlet =	116	feet	140	264	416	2634
Spillway Crest Elevation =	268	feet	140	266	264	1763
Spillway Crest Length =	40	feet	35	268	144	264
Required Number & Size of Riser Pipes =	1	10' x 10'	45	270	56	167
Total Pipe Length for Riser Pipes =	8	feet	130	272	0	135
Approximate Concrete Area =	100	sq. yd.	1170	***Total Fill Volume =***		12781
Dam Excavation, Haul, & Compaction Volume =	12,781	cu. yd.				
Storage Excavation & Haul =	44	ac.-ft. =	70,987	cu. yd.		

COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	31.5	acres	$10,000	$315,000
Excavation, Haul, & Compaction for Dam	12,781	cubic yards	$10.00	$127,807
Principal Discharge Culverts	116	linear feet	$375	$43,500
Riser Culverts	8	linear feet	$700	$5,600
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$43,500	$43,500
Storage Excavation & Haul =	70,987	cubic yards	$5.00	$354,933
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$895,341
Engineering Design & Permitting	10.00%			$89,534
Construction Oversight	5.00%			$44,767
Cost Sub-Total				$1,029,642
Contingency	15.00%			$154,446
TOTAL COST				$1,184,088

COST ESTIMATE FOR REGIONAL DETENTION BASIN #6

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
Maximum 100-Year WSEL =	279	feet	***Incr. Dist.***	***NG Elevation***	***Section Area***	***Incr. Volume***
Proposed Top of Dam Elevation =	282	feet	-----	282	0	0
Channel Invert Elevation at Proposed Dam Location =	264	feet	60	280	56	62
Natural Ground Surface Area at Top of Dam Elevation =	14.4	acres	40	278	144	148
100-Year Peak Discharge =	354	cfs	70	276	264	529
Flow Area Required for Principal Outlet =	70.8	sq. ft.	90	274	416	1133
Required Number & Size of Outlet Pipes =	2	7' x 5'	15	272	600	282
Total Flow Area Provided in Principal Outlet =	70	sq. ft.	10	270	816	262
Maximum Height of Dam =	18	feet	30	264	1656	1373
Top Width of Dam =	20	feet	20	270	816	916
Dam Side Slope Ratio =	4	(h/v)	15	272	600	393
Width of Dam at Toe =	164	feet	10	274	416	188
Total Pipe Length for Principal Outlet =	328	feet	75	276	264	944
Spillway Crest Elevation =	277	feet	155	278	144	1171
Spillway Crest Length =	50	feet	40	280	56	148
Required Number & Size of Riser Pipes =	2	8' x 6'	230	282	0	239
Total Pipe Length for Riser Pipes =	26	feet	0	0	0	0
Approximate Concrete Area =	100	sq. yd.	860	***Total Fill Volume =***		7790
Dam Excavation, Haul, & Compaction Volume =	7,790	cu. yd.				
Storage Excavation & Haul =	48	ac.-ft. =	77,440	cu. yd.		

COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	21.6	acres	$10,000	$216,000
Excavation, Haul, & Compaction for Dam	7,790	cubic yards	$10.00	$77,896
Principal Discharge Culverts	328	linear feet	$300	$98,400
Riser Culverts	26	linear feet	$400	$10,400
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$98,400	$98,400
Storage Excavation & Haul =	77,440	cubic yards	$5.00	$387,200
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$893,296
Engineering Design & Permitting	10.00%			$89,330
Construction Oversight	5.00%			$44,665
Cost Sub-Total				$1,027,291
Contingency	15.00%			$154,094
TOTAL COST				$1,181,384

COST ESTIMATE FOR REGIONAL DETENTION BASIN #8

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
			Incr. Dist.	*NG Elevation*	*Section Area*	*Incr. Volume*
Maximum 100-Year WSEL =	285	feet				
Proposed Top of Dam Elevation =	288	feet	-----	286	56	0
Channel Invert Elevation at Proposed Dam Location =	270	feet	80	284	144	296
Natural Ground Surface Area at Top of Dam Elevation =	25.7	acres	100	282	264	756
100-Year Peak Discharge =	336	cfs	45	280	416	567
Flow Area Required for Principal Outlet =	67.2	sq. ft.	140	278	600	2634
Required Number & Size of Outlet Pipes =	2	7' x 5'	55	276	816	1442
Total Flow Area Provided in Principal Outlet =	70	sq. ft.	60	274	1064	2089
Maximum Height of Dam =	18	feet	40	270	1656	2015
Top Width of Dam =	20	feet	40	274	1064	2015
Dam Side Slope Ratio =	4	(h/v)	40	270	1656	2015
Width of Dam at Toe =	164	feet	30	274	1064	1511
Total Pipe Length for Principal Outlet =	328	feet	80	278	600	2465
Spillway Crest Elevation =	284	feet	70	282	264	1120
Spillway Crest Length =	50	feet	65	284	144	491
Required Number & Size of Riser Pipes =	2	8' x 6'	55	286	56	204
Total Pipe Length for Riser Pipes =	28	feet	20	288	0	21
Approximate Concrete Area =	100	sq. yd.	920	***Total Fill Volume =***		19640
Dam Excavation, Haul, & Compaction Volume =	19,640	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	38.55	acres	$10,000	$385,500
Excavation, Haul, & Compaction for Dam	19,640	cubic yards	$10.00	$196,400
Principal Discharge Culverts	328	linear feet	$300	$98,400
Riser Culverts	28	linear feet	$400	$11,200
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$98,400	$98,400
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$794,900
Engineering Design & Permitting	10.00%			$79,490
Construction Oversight	5.00%			$39,745
Cost Sub-Total				$914,135
Contingency	15.00%			$137,120
TOTAL COST				$1,051,255

COST ESTIMATE FOR REGIONAL DETENTION BASIN #9

QUANTITY TAKE-OFF WORK AREA

Item	***Quantity***	***Units***	***Computation of Required Dam Fill Volume (cy)***			
Maximum 100-Year WSEL =	271	feet	***Incr. Dist.***	***NG Elevation***	***Section Area***	***Incr. Volume***
Proposed Top of Dam Elevation =	274	feet	-----	274	0	0
Channel Invert Elevation at Proposed Dam Location =	252	feet	35	272	56	36
Natural Ground Surface Area at Top of Dam Elevation =	13.9	acres	80	270	144	296
100-Year Peak Discharge =	332	cfs	180	270	144	960
Flow Area Required for Principal Outlet =	66.4	sq. ft.	25	268	264	189
Required Number & Size of Outlet Pipes =	2	7' x 5'	50	266	416	630
Total Flow Area Provided in Principal Outlet =	70	sq. ft.	50	264	600	941
Maximum Height of Dam =	22	feet	70	260	1064	2157
Top Width of Dam =	20	feet	30	252	2376	1911
Dam Side Slope Ratio =	4	(h/v)	20	260	1064	1274
Width of Dam at Toe =	196	feet	120	262	816	4178
Total Pipe Length for Principal Outlet =	392	feet	45	264	600	1180
Spillway Crest Elevation =	270	feet	35	266	416	659
Spillway Crest Length =	50	feet	50	270	144	519
Required Number & Size of Riser Pipes =	2	8' x 6'	15	272	56	56
Total Pipe Length for Riser Pipes =	36	feet	105	274	0	109
Approximate Concrete Area =	100	sq. yd.	910	***Total Fill Volume =***		15093
Dam Excavation, Haul, & Compaction Volume =	15,093	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

COST ESTIMATE

Item	***Quantity***	***Units***	***Unit Cost***	***Cost***
Land Acquisition	20.85	acres	$10,000	$208,500
Excavation, Haul, & Compaction for Dam	15,093	cubic yards	$10.00	$150,933
Principal Discharge Culverts	392	linear feet	$300	$117,600
Riser Culverts	36	linear feet	$400	$14,400
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$117,600	$117,600
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$614,033
Engineering Design & Permitting	10.00%			$61,403
Construction Oversight	5.00%			$30,702
Cost Sub-Total				$706,138
Contingency	15.00%			$105,921
TOTAL COST				$812,059

COST ESTIMATE FOR REGIONAL DETENTION BASIN #10

QUANTITY TAKE-OFF WORK AREA

Item	***Quantity***	***Units***	***Computation of Required Dam Fill Volume (cy)***			
Maximum 100-Year WSEL =	275	feet	***Incr. Dist.***	***NG Elevation***	***Section Area***	***Incr. Volume***
Proposed Top of Dam Elevation =	278	feet	-----	278	0	0
Channel Invert Elevation at Proposed Dam Location =	258	feet	40	268	600	444
Natural Ground Surface Area at Top of Dam Elevation =	21.5	acres	10	266	816	262
100-Year Peak Discharge =	271	cfs	15	264	1064	522
Flow Area Required for Principal Outlet =	54.2	sq. ft.	20	258	2000	1135
Required Number & Size of Outlet Pipes =	1	10' x 6'	20	264	1064	1135
Total Flow Area Provided in Principal Outlet =	60	sq. ft.	55	264	1064	2167
Maximum Height of Dam =	20	feet	90	266	816	3133
Top Width of Dam =	20	feet	70	268	600	1836
Dam Side Slope Ratio =	4	(h/v)	40	270	416	753
Width of Dam at Toe =	180	feet	40	272	264	504
Total Pipe Length for Principal Outlet =	180	feet	55	274	144	416
Spillway Crest Elevation =	273	feet	35	276	56	130
Spillway Crest Length =	20	feet	40	278	0	41
Required Number & Size of Riser Pipes =	1	10' x 6'	0	0	0	0
Total Pipe Length for Riser Pipes =	15	feet	0	0	0	0
Approximate Concrete Area =	100	sq. yd.	530	***Total Fill Volume =***		12478
Dam Excavation, Haul, & Compaction Volume =	12,478	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

COST ESTIMATE

Item	***Quantity***	***Units***	***Unit Cost***	***Cost***
Land Acquisition	32.25	acres	$10,000	$322,500
Excavation, Haul, & Compaction for Dam	12,478	cubic yards	$10.00	$124,778
Principal Discharge Culverts	180	linear feet	$450	$81,000
Riser Culverts	15	linear feet	$450	$6,750
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$81,000	$81,000
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$621,028
Engineering Design & Permitting	10.00%			$62,103
Construction Oversight	5.00%			$31,051
Cost Sub-Total				$714,182
Contingency	15.00%			$107,127
TOTAL COST				$821,309

COST ESTIMATE FOR REGIONAL DETENTION BASIN #1

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
			Incr. Dist.	*NG Elevation*	*Section Area*	*Incr. Volume*
Maximum 100-Year WSEL =	313	feet				
Proposed Top of Dam Elevation =	316	feet	-----	316	0	0
Channel Invert Elevation at Proposed Dam Location =	300	feet	25	314	56	26
Natural Ground Surface Area at Top of Dam Elevation =	21.9	acres	35	312	144	130
100-Year Peak Discharge =	106	cfs	20	310	264	151
Flow Area Required for Principal Outlet =	21.2	sq. ft.	40	308	416	504
Required Number & Size of Outlet Pipes =	1	66" RCP	205	306	600	3857
Total Flow Area Provided in Principal Outlet =	23.8	sq. ft.	200	306	600	4444
Maximum Height of Dam =	16	feet	10	300	1344	360
Top Width of Dam =	20	feet	15	300	1344	747
Dam Side Slope Ratio =	4	(h/v)	5	306	600	180
Width of Dam at Toe =	148	feet	80	306	600	1778
Total Pipe Length for Principal Outlet =	148	feet	100	308	416	1881
Spillway Crest Elevation =	312	feet	100	310	264	1259
Spillway Crest Length =	15	feet	100	312	144	756
Required Number & Size of Riser Pipes =	1	78" RCP	55	314	56	204
Total Pipe Length for Riser Pipes =	12	feet	45	316	0	47
Approximate Concrete Area =	100	sq. yd.	1035	***Total Fill Volume =***		16323
Dam Excavation, Haul, & Compaction Volume =	16,323	cu. yd.				
Storage Excavation & Haul =	12	ac.-ft. =	19,360	cu. yd.		

COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	32.85	acres	$10,000	$328,500
Excavation, Haul, & Compaction for Dam	16,323	cubic yards	$10.00	$163,230
Principal Discharge Culverts	148	linear feet	$250	$37,000
Riser Culverts	12	linear feet	$300	$3,600
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$37,000	$37,000
Storage Excavation & Haul =	19,360	cubic yards	$5.00	$96,800
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$671,130
Engineering Design & Permitting	10.00%			$67,113
Construction Oversight	5.00%			$33,556
Cost Sub-Total				$771,799
Contingency	15.00%			$115,770
TOTAL COST				$887,569

COST ESTIMATE FOR REGIONAL DETENTION BASIN #4

QUANTITY TAKE-OFF WORK AREA

Item	Quantity	Units	Computation of Required Dam Fill Volume (cy)			
Maximum 100-Year WSEL =	269	feet	Incr. Dist.	NG Elevation	Section Area	Incr. Volume
Proposed Top of Dam Elevation =	272	feet	-----	272	0	0
Channel Invert Elevation at Proposed Dam Location =	260	feet	100	270	56	104
Natural Ground Surface Area at Top of Dam Elevation =	21.0	acres	30	268	144	111
100-Year Peak Discharge =	222	cfs	100	266	264	756
Flow Area Required for Principal Outlet =	44.4	sq. ft.	110	264	416	1385
Required Number & Size of Outlet Pipes =	1	9' x 5'	80	266	264	1007
Total Flow Area Provided in Principal Outlet =	45	sq. ft.	70	266	264	684
Maximum Height of Dam =	12	feet	40	264	416	504
Top Width of Dam =	20	feet	90	262	600	1693
Dam Side Slope Ratio =	4	(h/v)	55	260	816	1442
Width of Dam at Toe =	116	feet	5	262	600	131
Total Pipe Length for Principal Outlet =	116	feet	140	264	416	2634
Spillway Crest Elevation =	268	feet	140	266	264	1763
Spillway Crest Length =	40	feet	35	268	144	264
Required Number & Size of Riser Pipes =	1	10' x 10'	45	270	56	167
Total Pipe Length for Riser Pipes =	8	feet	130	272	0	135
Approximate Concrete Area =	100	sq. yd.	1170	Total Fill Volume =		12781
Dam Excavation, Haul, & Compaction Volume =	12,781	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

COST ESTIMATE

Item	Quantity	Units	Unit Cost	Cost
Land Acquisition	31.5	acres	$10,000	$315,000
Excavation, Haul, & Compaction for Dam	12,781	cubic yards	$10.00	$127,807
Principal Discharge Culverts	116	linear feet	$375	$43,500
Riser Culverts	8	linear feet	$700	$5,600
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$43,500	$43,500
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$540,407
Engineering Design & Permitting	10.00%			$54,041
Construction Oversight	5.00%			$27,020
Cost Sub-Total				$621,469
Contingency	15.00%			$93,220
TOTAL COST				$714,689

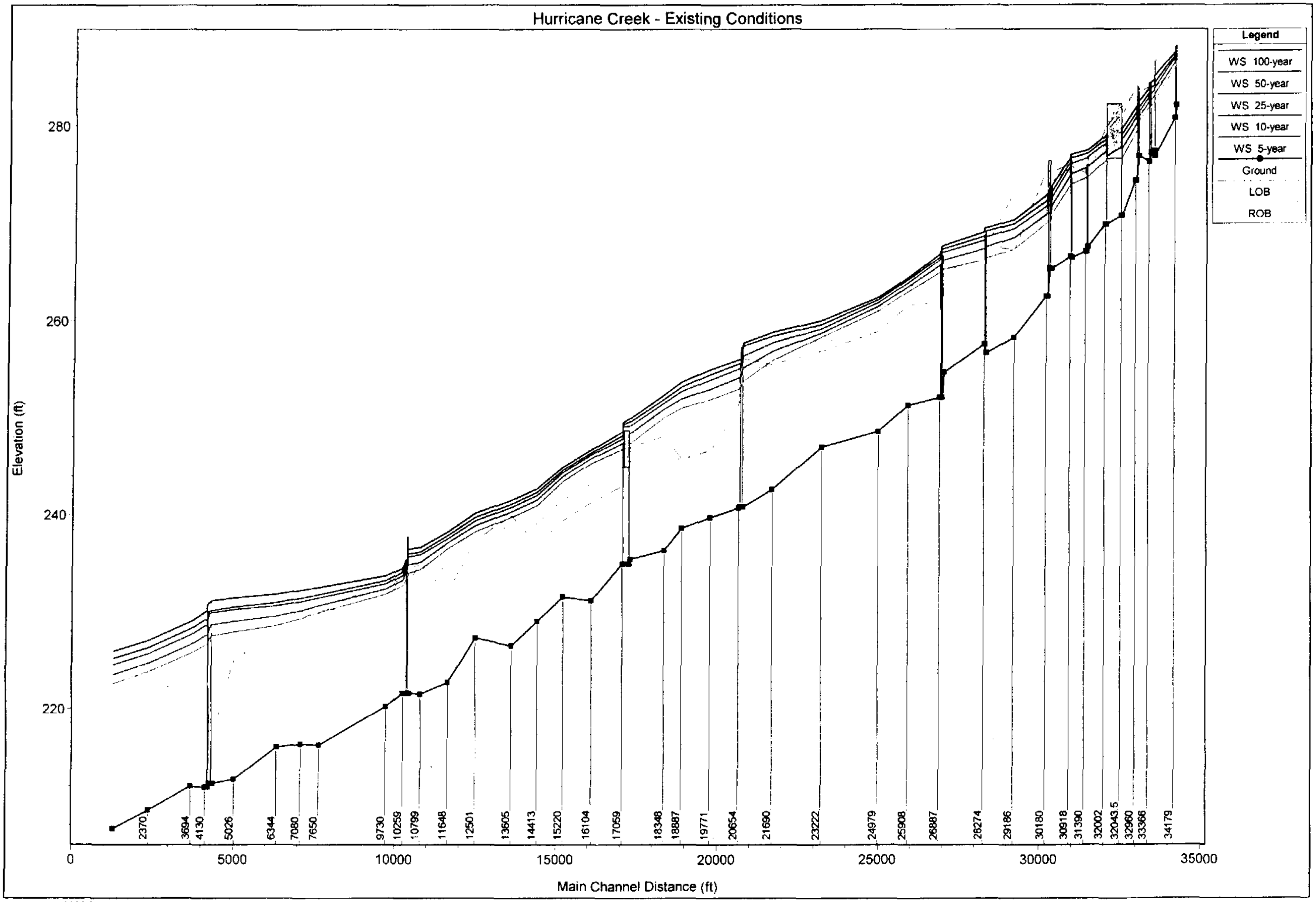
COST ESTIMATE FOR REGIONAL DETENTION BASIN #8

QUANTITY TAKE-OFF WORK AREA

Item	*Quantity*	*Units*	*Computation of Required Dam Fill Volume (cy)*			
			Incr. Dist.	***NG Elevation***	***Section Area***	***Incr. Volume***
Maximum 100-Year WSEL =	285	feet	-----	286	56	0
Proposed Top of Dam Elevation =	288	feet	80	284	144	296
Channel Invert Elevation at Proposed Dam Location =	270	feet	100	282	264	756
Natural Ground Surface Area at Top of Dam Elevation =	25.7	acres	45	280	416	567
100-Year Peak Discharge =	336	cfs	140	278	600	2634
Flow Area Required for Principal Outlet =	67.2	sq. ft.	55	276	816	1442
Required Number & Size of Outlet Pipes =	2	7' x 5'	60	274	1064	2089
Total Flow Area Provided in Principal Outlet =	70	sq. ft.	40	270	1656	2015
Maximum Height of Dam =	18	feet	40	274	1064	2015
Top Width of Dam =	20	feet	40	270	1656	2015
Dam Side Slope Ratio =	4	(h/v)	30	274	1064	1511
Width of Dam at Toe =	164	feet	80	278	600	2465
Total Pipe Length for Principal Outlet =	328	feet	70	282	264	1120
Spillway Crest Elevation =	284	feet	65	284	144	491
Spillway Crest Length =	50	feet	55	286	56	204
Required Number & Size of Riser Pipes =	2	8' x 6'	20	288	0	21
Total Pipe Length for Riser Pipes =	28	feet	920	***Total Fill Volume =***		19640
Approximate Concrete Area =	100	sq. yd.				
Dam Excavation, Haul, & Compaction Volume =	19,640	cu. yd.				
Storage Excavation & Haul =	0	ac.-ft. =	0	cu. yd.		

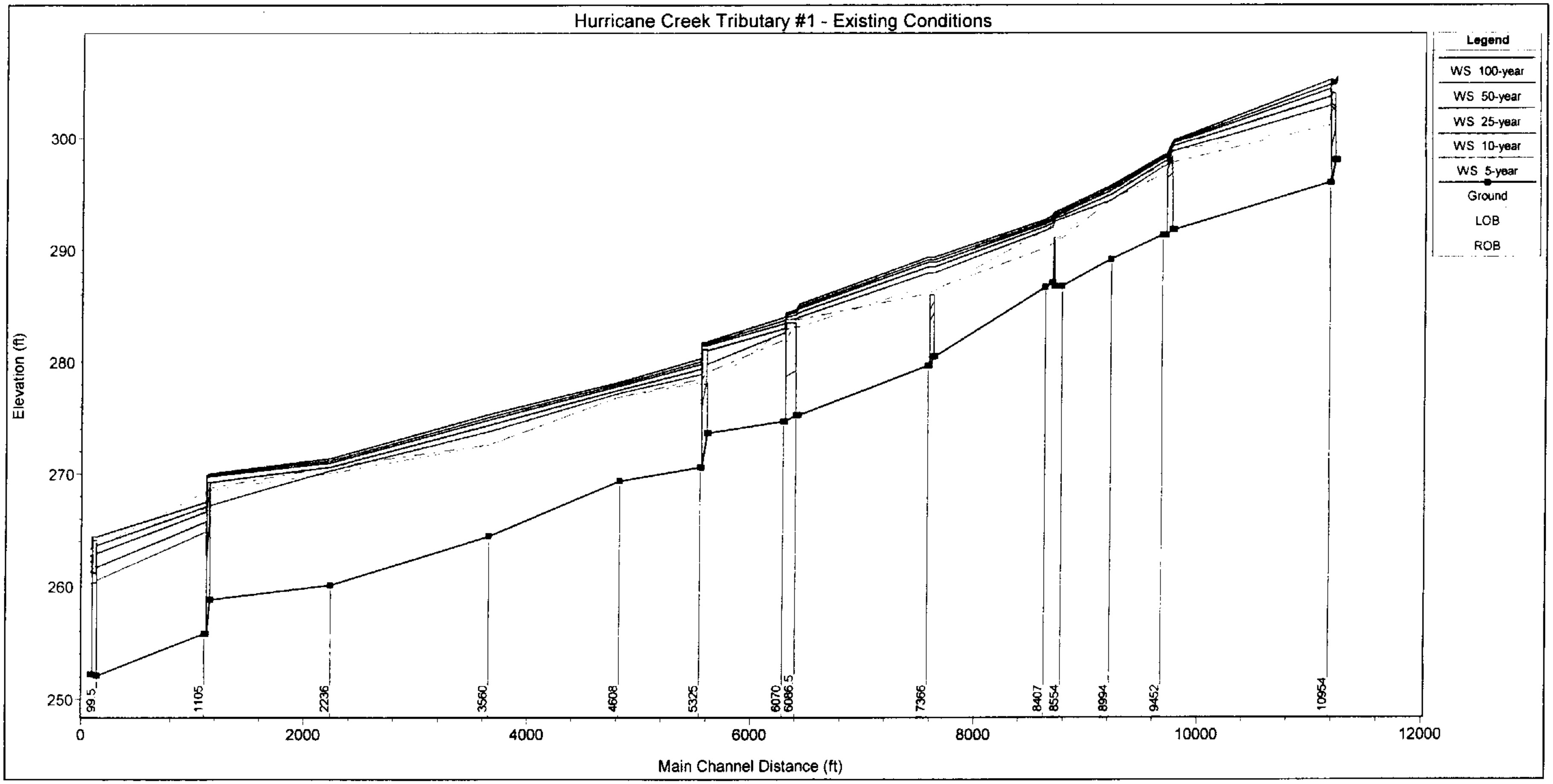
COST ESTIMATE

Item	*Quantity*	*Units*	*Unit Cost*	*Cost*
Land Acquisition	38.55	acres	$10,000	$385,500
Excavation, Haul, & Compaction for Dam	19,640	cubic yards	$10.00	$196,400
Principal Discharge Culverts	328	linear feet	$300	$98,400
Riser Culverts	28	linear feet	$400	$11,200
Concrete Slope Paving	100	sq. yds.	$50.00	$5,000
Emergency Spillway	1	lump sum	$98,400	$98,400
Storage Excavation & Haul =	0	cubic yards	$5.00	$0
Vegetation Establishment	0.00	acres	$1,500	$0.00
Land for Wetlands Mitigation	0.00	acres	$2,500	$0.00
Wetlands Grading & Planting	0.00	acres	$15,000	$0.00
Cost Sub-Total				$794,900
Engineering Design & Permitting	10.00%			$79,490
Construction Oversight	5.00%			$39,745
Cost Sub-Total				$914,135
Contingency	15.00%			$137,120
TOTAL COST				$1,051,255



1 in Horiz = 3000 ft 1 in Vert = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK EXISTING CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0565	DATE: Dec. 1998	NO.: 3.1

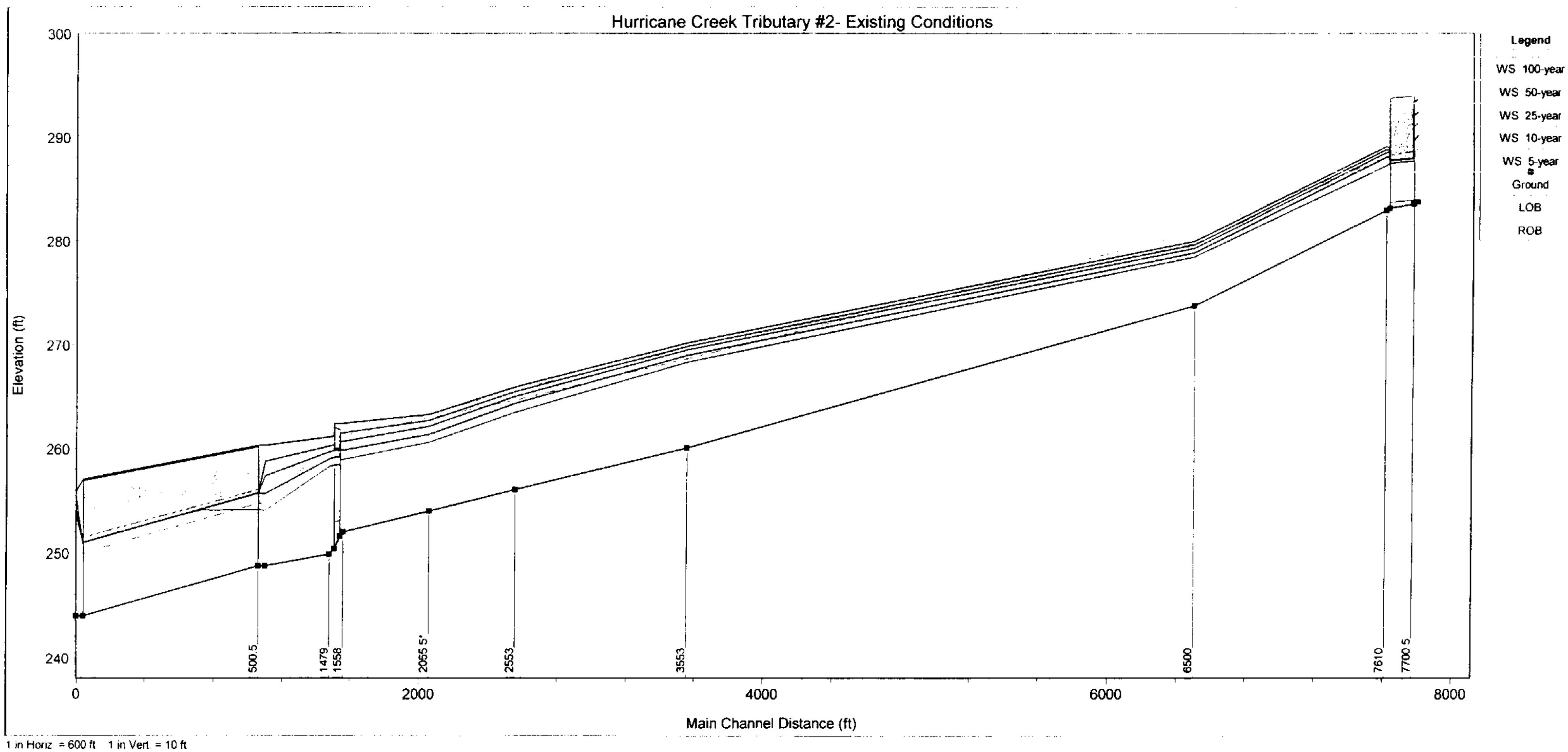


1 in Horiz. = 1000 ft 1 in Vert = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #1
EXISTING CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

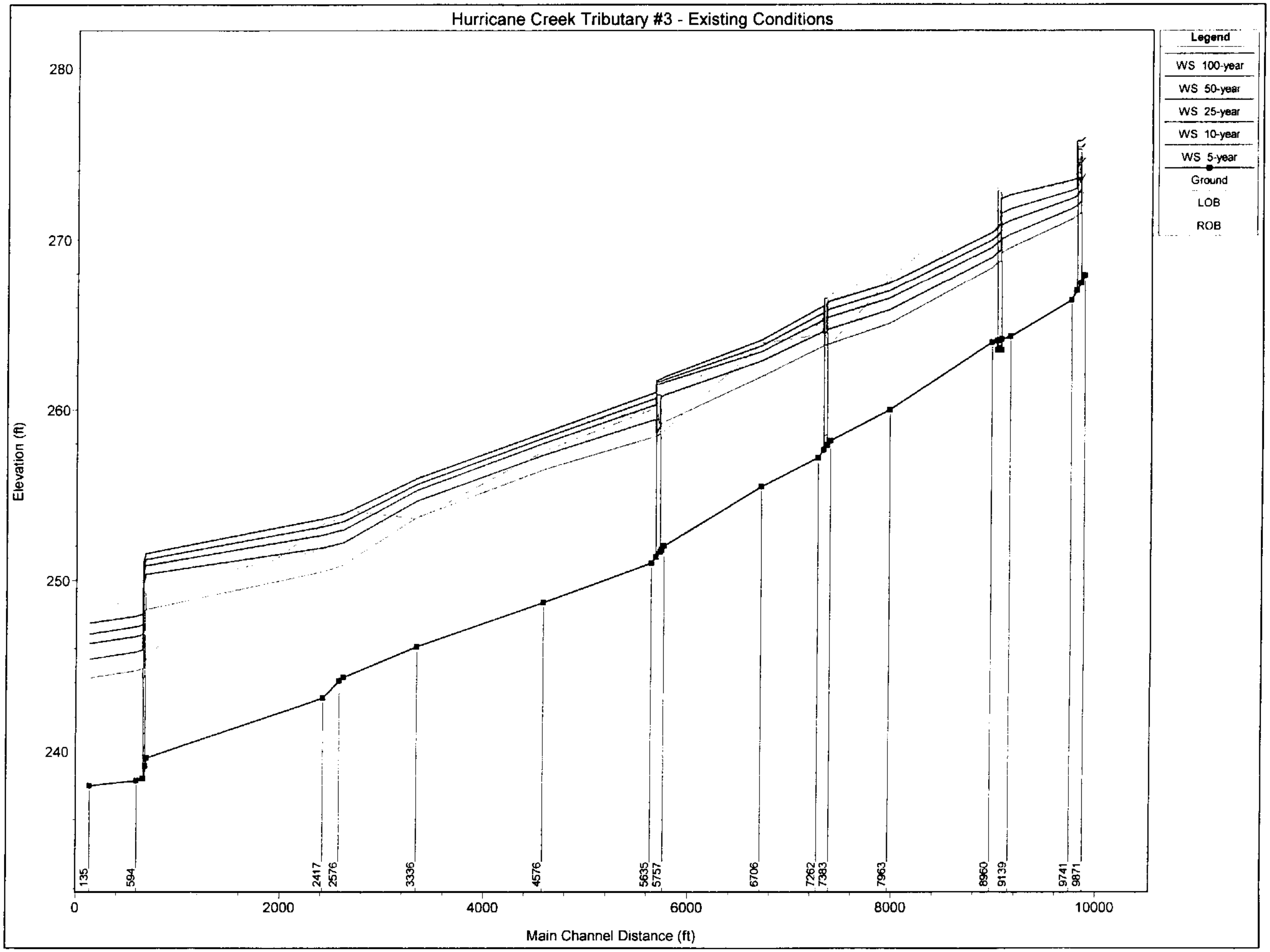
JOB: 0565	DATE: Dec. 1998	NO.: 3.2



COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #2
EXISTING CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

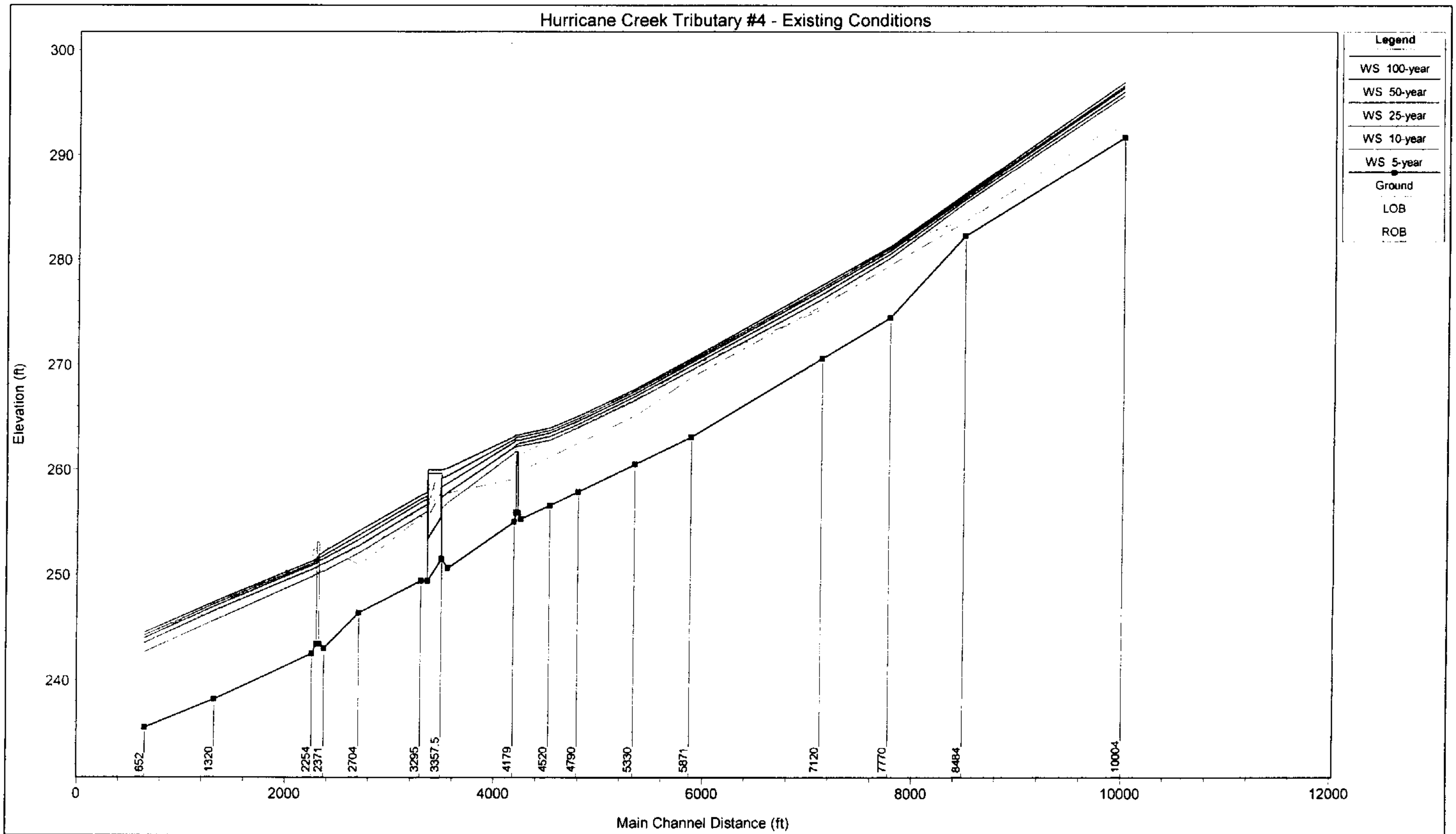
JOB: 0565 | DATE: Dec. 1998 | NO.: 3.3



COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #3
EXISTING CONDITIONS

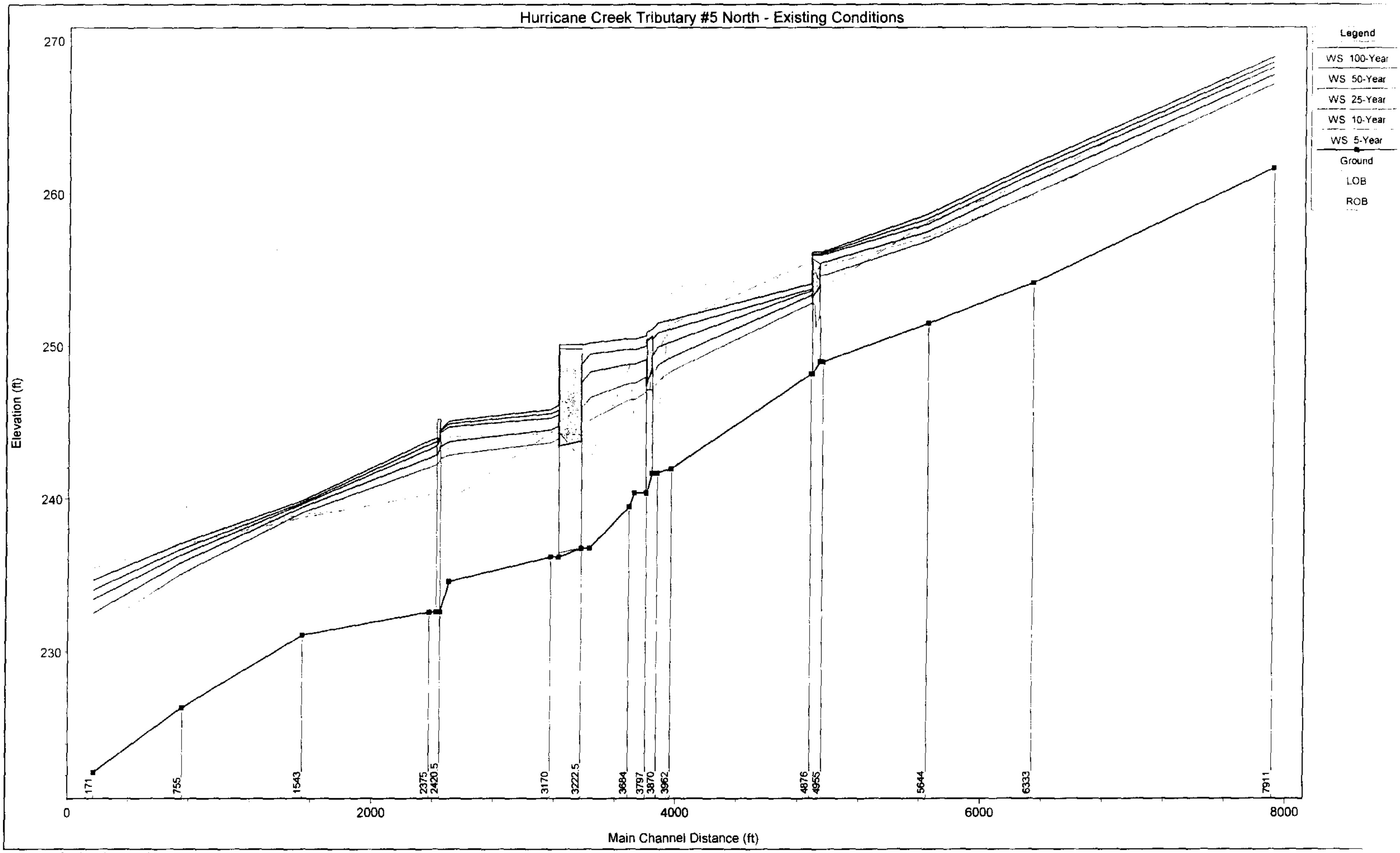
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec. 1998	NO.: 3.4



1 in Horiz. = 1000 ft   1 in Vert. = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #4 **EXISTING CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*	
	JOB: 0565	DATE: Dec. 1998 — NO.: 3.5

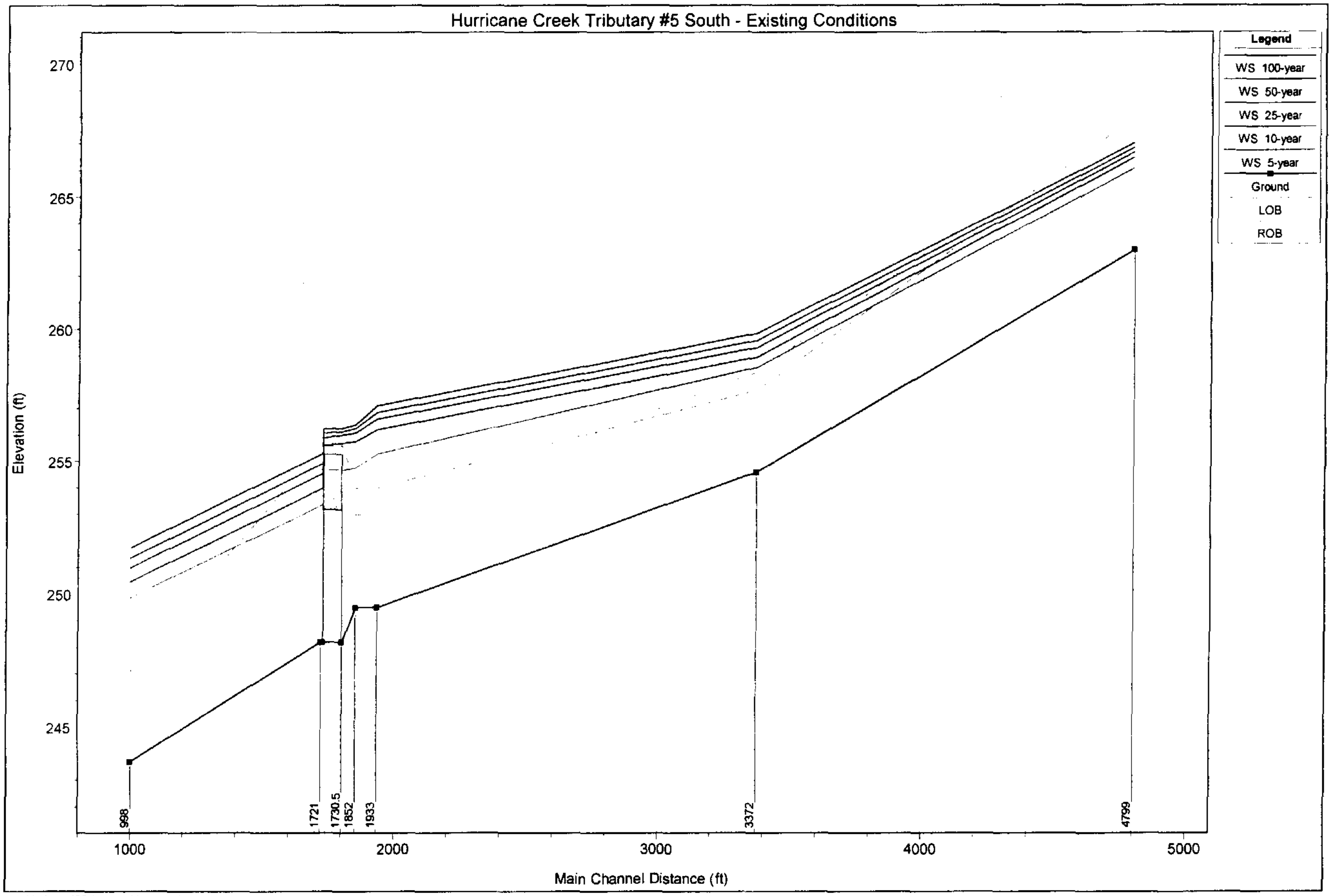


1 in Horiz = 600 ft 1 in Vert = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #5 (NORTH)
EXISTING CONDITIONS

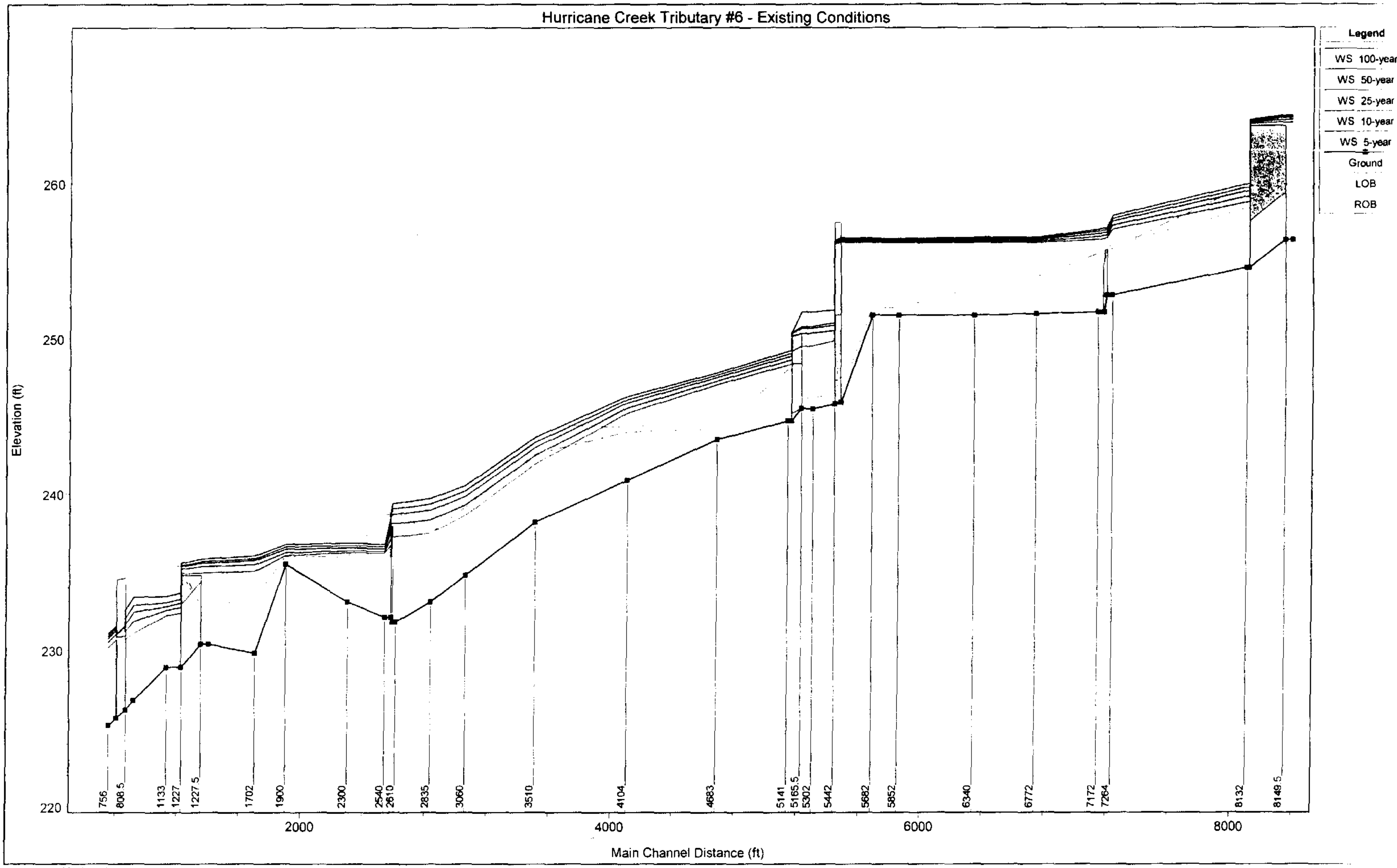
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec. 1998	NO.: 3.6a

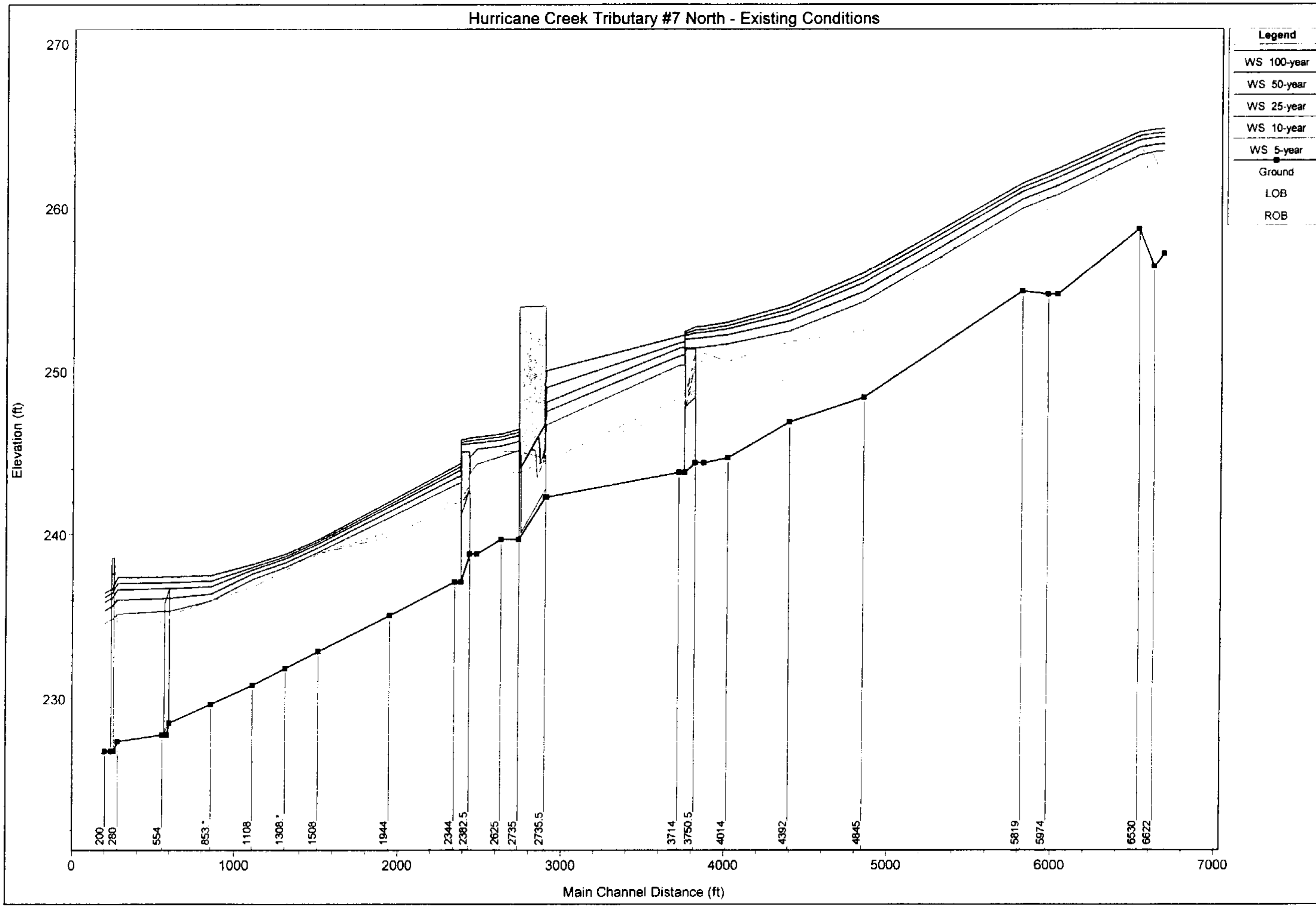


1 in Horiz. = 400 ft 1 in Vert. = 4 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #5 (SOUTH) **EXISTING CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* JOB: 0565 DATE: Dec. 1998 NO.: 3.6b

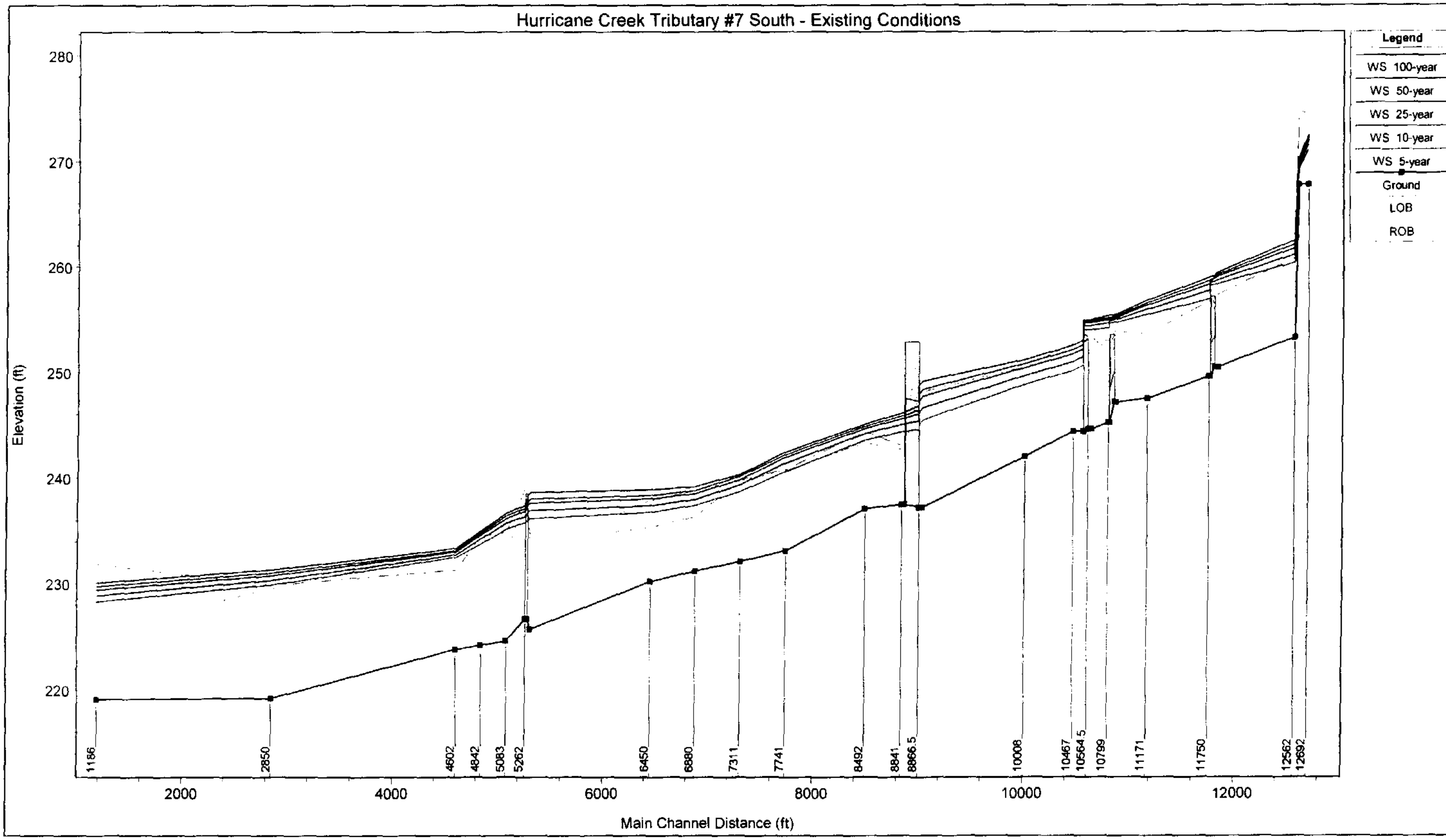


COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #6 **EXISTING CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* **JOB:** 0565 **DATE:** Dec 1998 **NO.:** 3.7



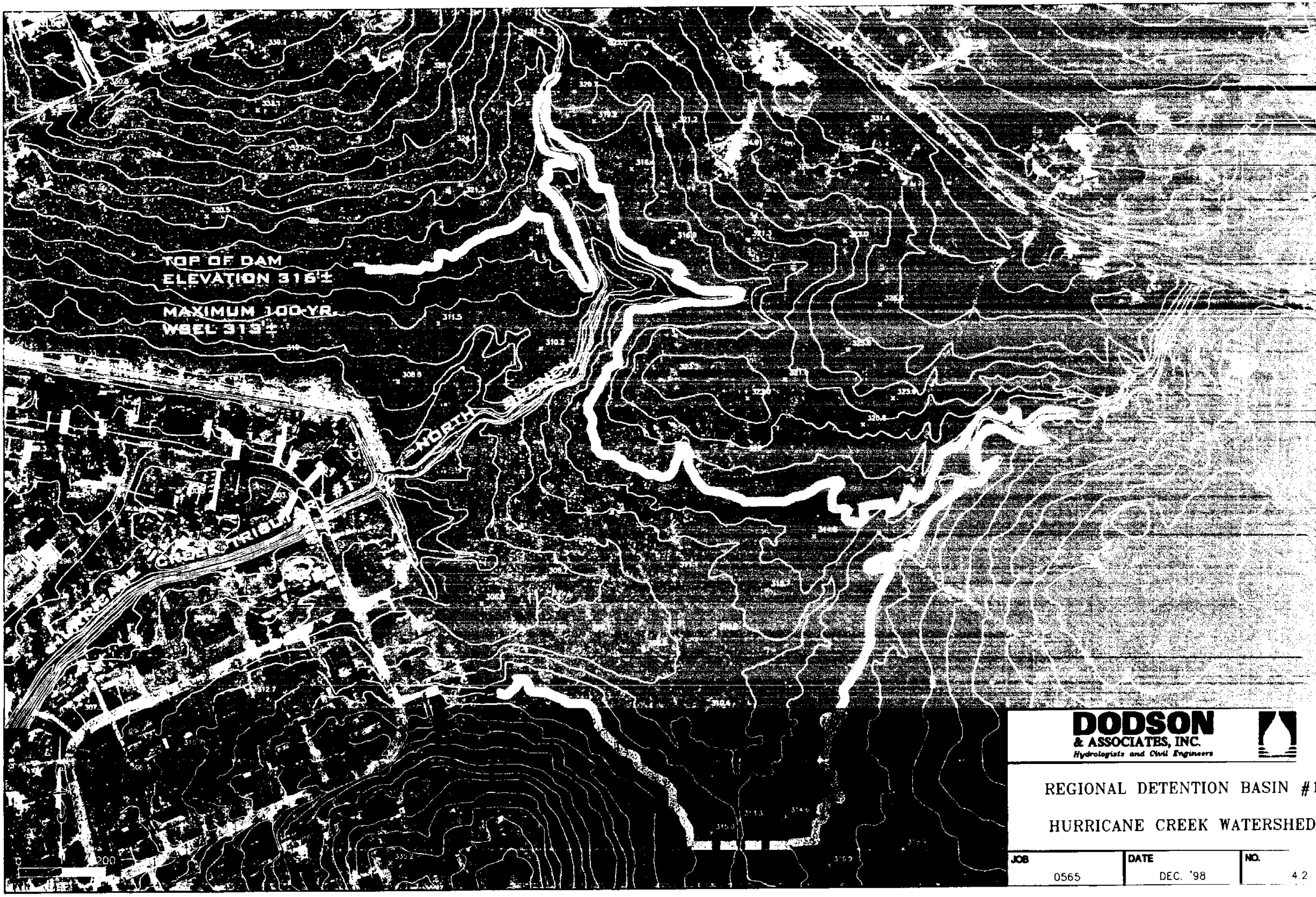
1 in Horiz. = 600 ft 1 in Vert. = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #7 (NORTH) EXISTING CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* JOB: 0565 | DATE: Dec. 1998 | NO.: 3.8a



1 in Horiz. = 1000 ft 1 in Vert. = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #7 (SOUTH) EXISTING CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0565	DATE: Dec. 1998	NO.: 3.8b

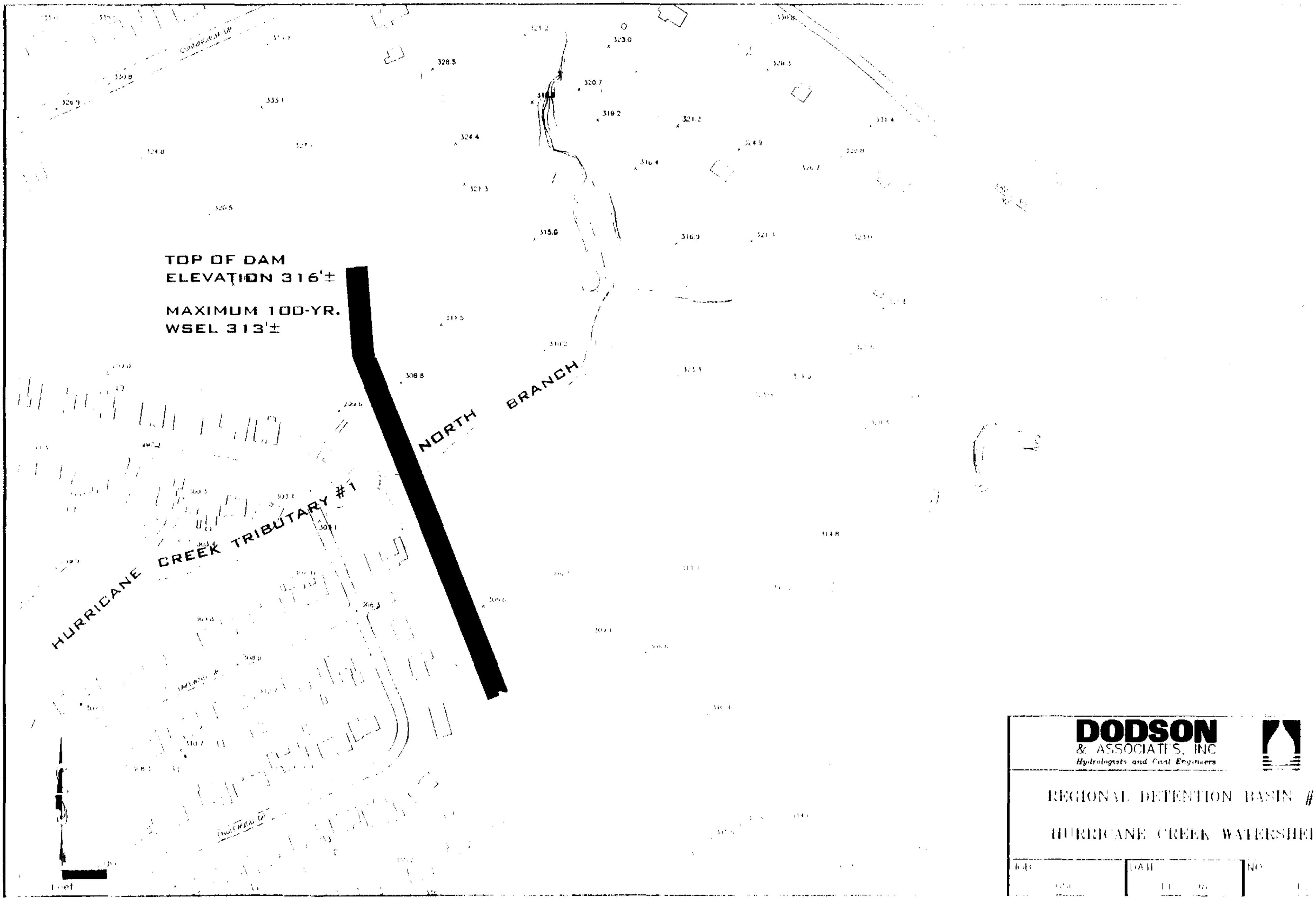


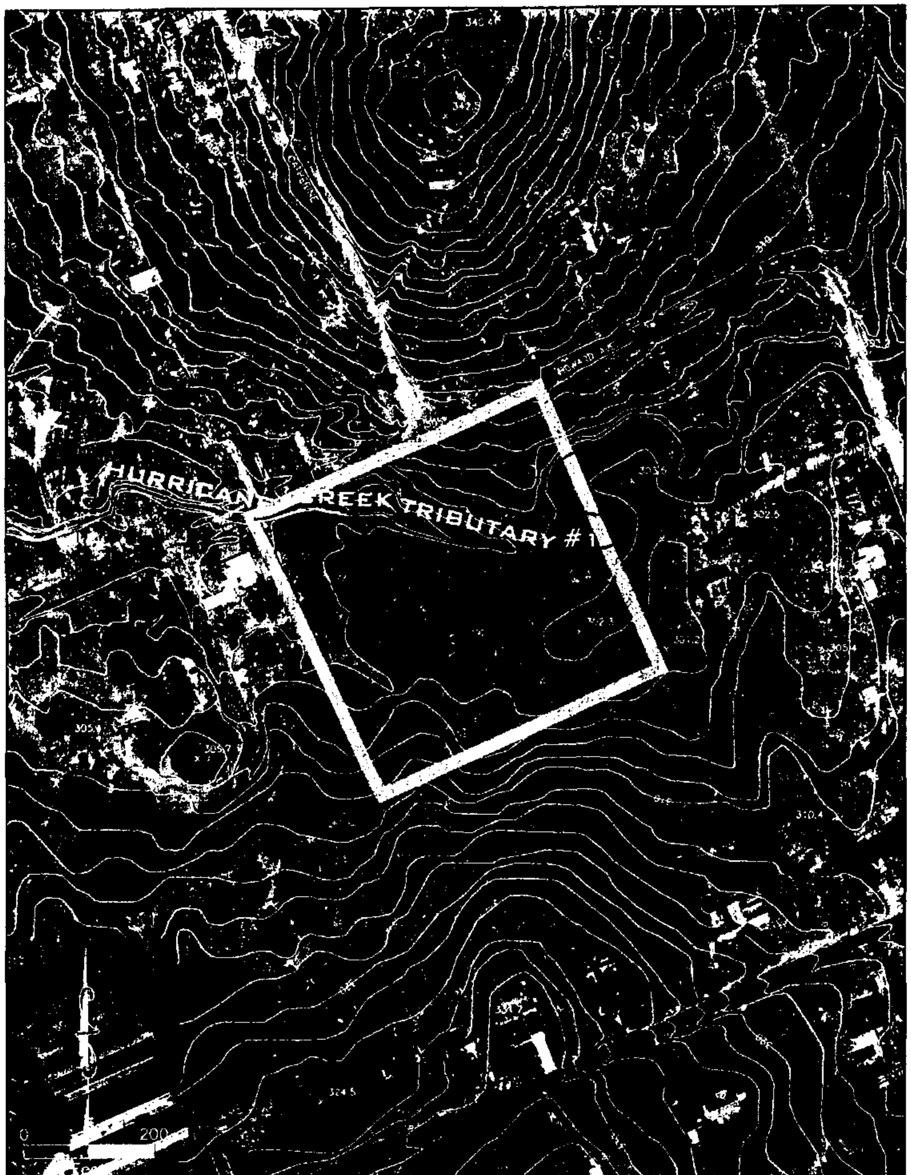
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #1

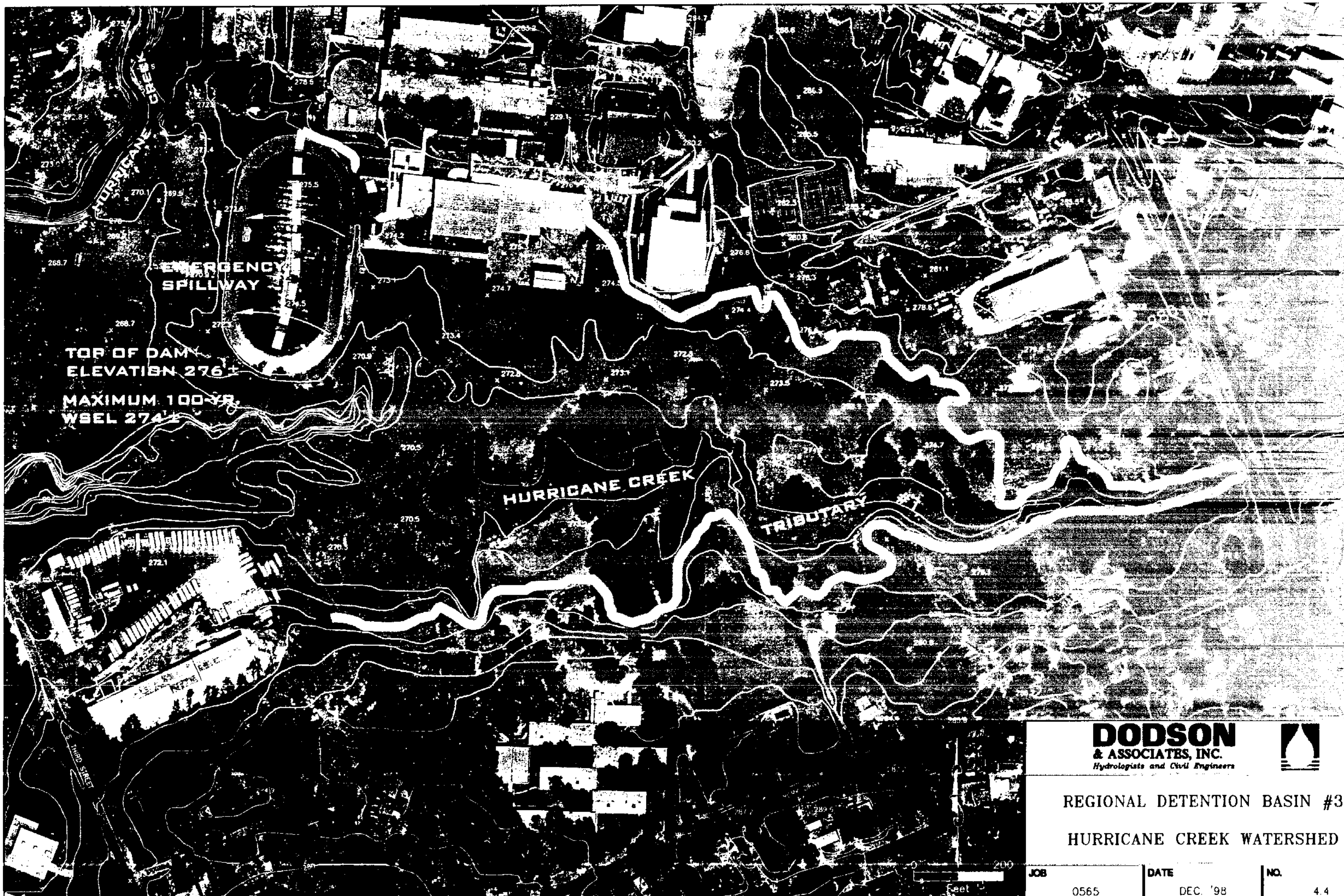
HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.2


TOP OF DAM
ELEVATION 316'±
MAXIMUM 100-YR.
WSEL 313'±
NORTH BRANCH
HURRICANE CREEK TRIBUTARY #1
Feet
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN #
HURRICANE CREEK WATERSHED
DATE
NO.



REGIONAL DETENTION BASIN #2 HURRICANE CREEK WATERSHED	DODSON & ASSOCIATES, INC. Hydrologists and Civil Engineers		
	JOB 0565	DATE DEC. '98	NO. 4.3

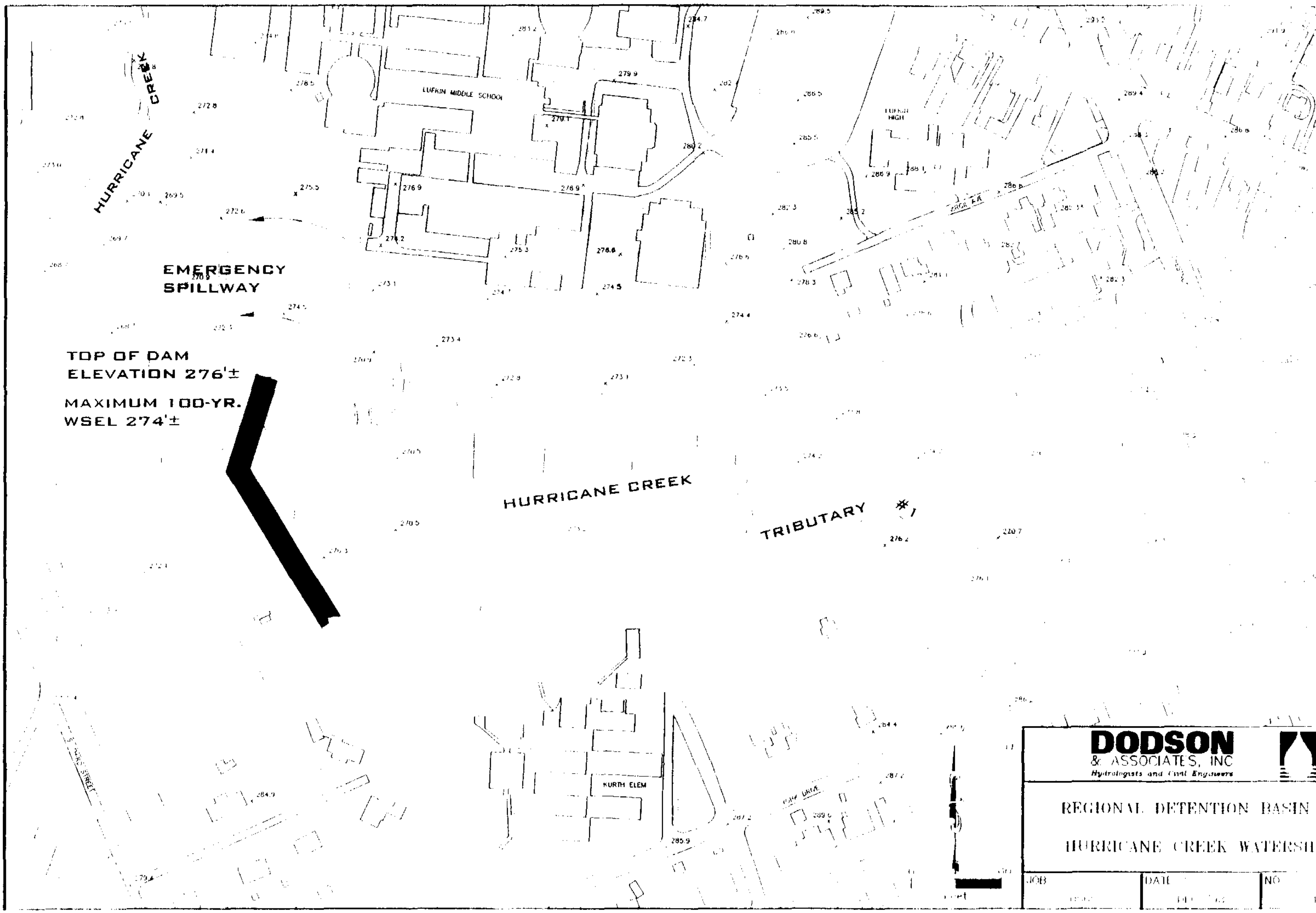


DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #3

HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.4

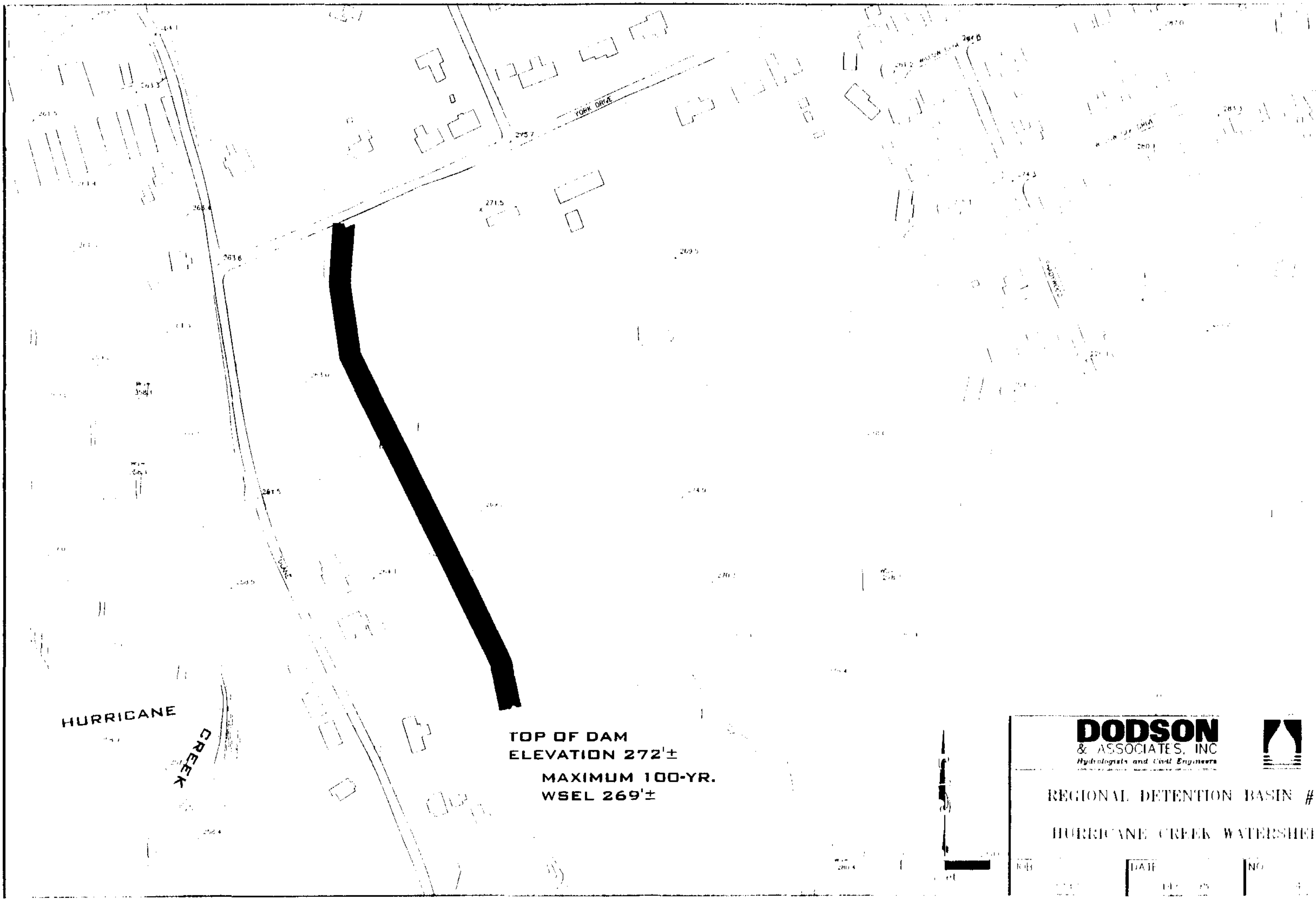

HURRICANE CREEK
LUFKIN MIDDLE SCHOOL
EMERGENCY SPILLWAY
TOP OF DAM ELEVATION 276'±
MAXIMUM 100-YR. WSEL 274'±
HURRICANE CREEK
TRIBUTARY #1
KURTH ELEM
DODSON & ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN #
HURRICANE CREEK WATERSHED
JOB
DATE
NO

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #4

HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.5

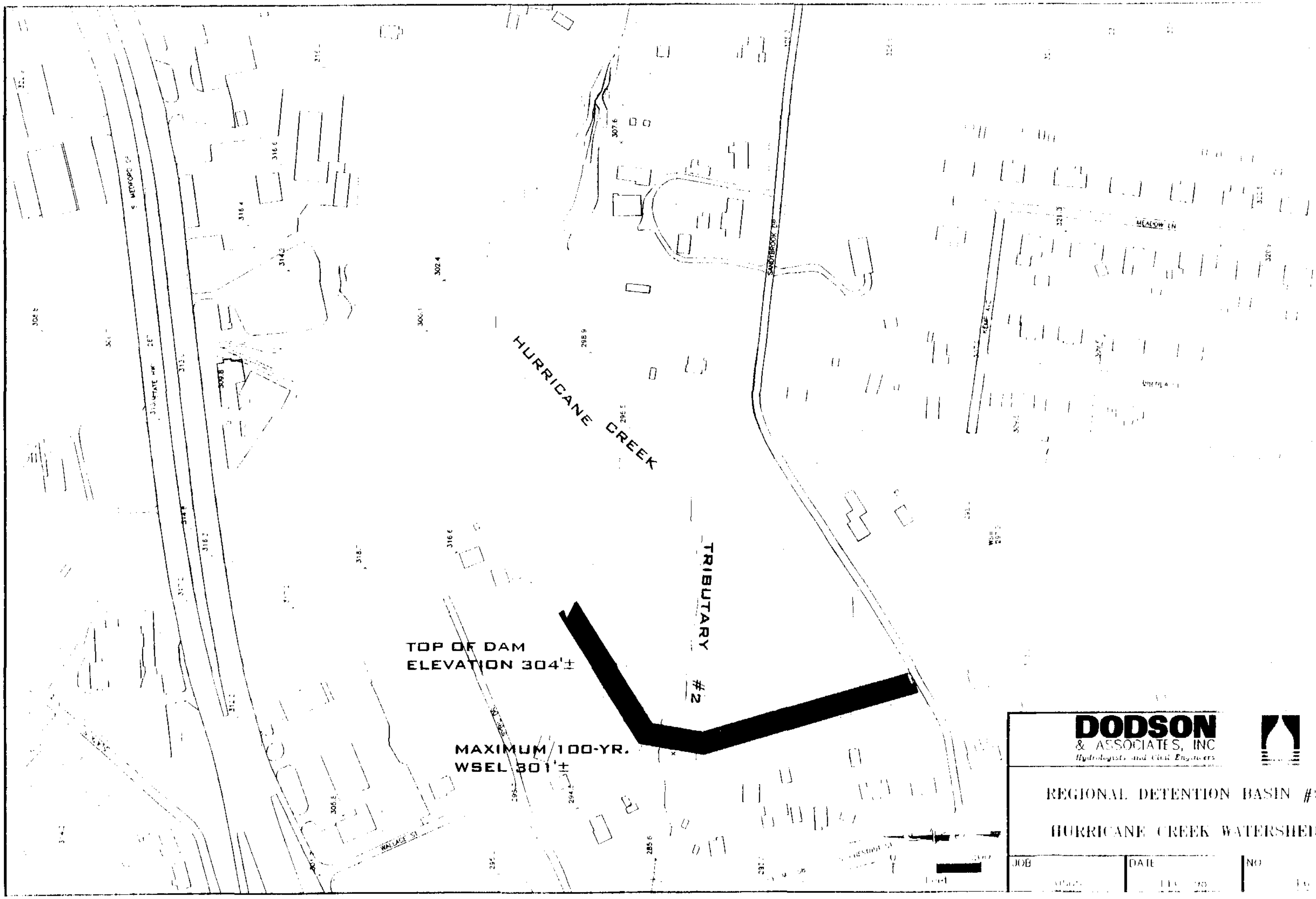

YORK DRIVE
HURRICANE
CREEK
TOP OF DAM
ELEVATION 272'±
MAXIMUM 100-YR.
WSEL 269'±
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN #
HURRICANE CREEK WATERSHED
JOB
DATE
NO

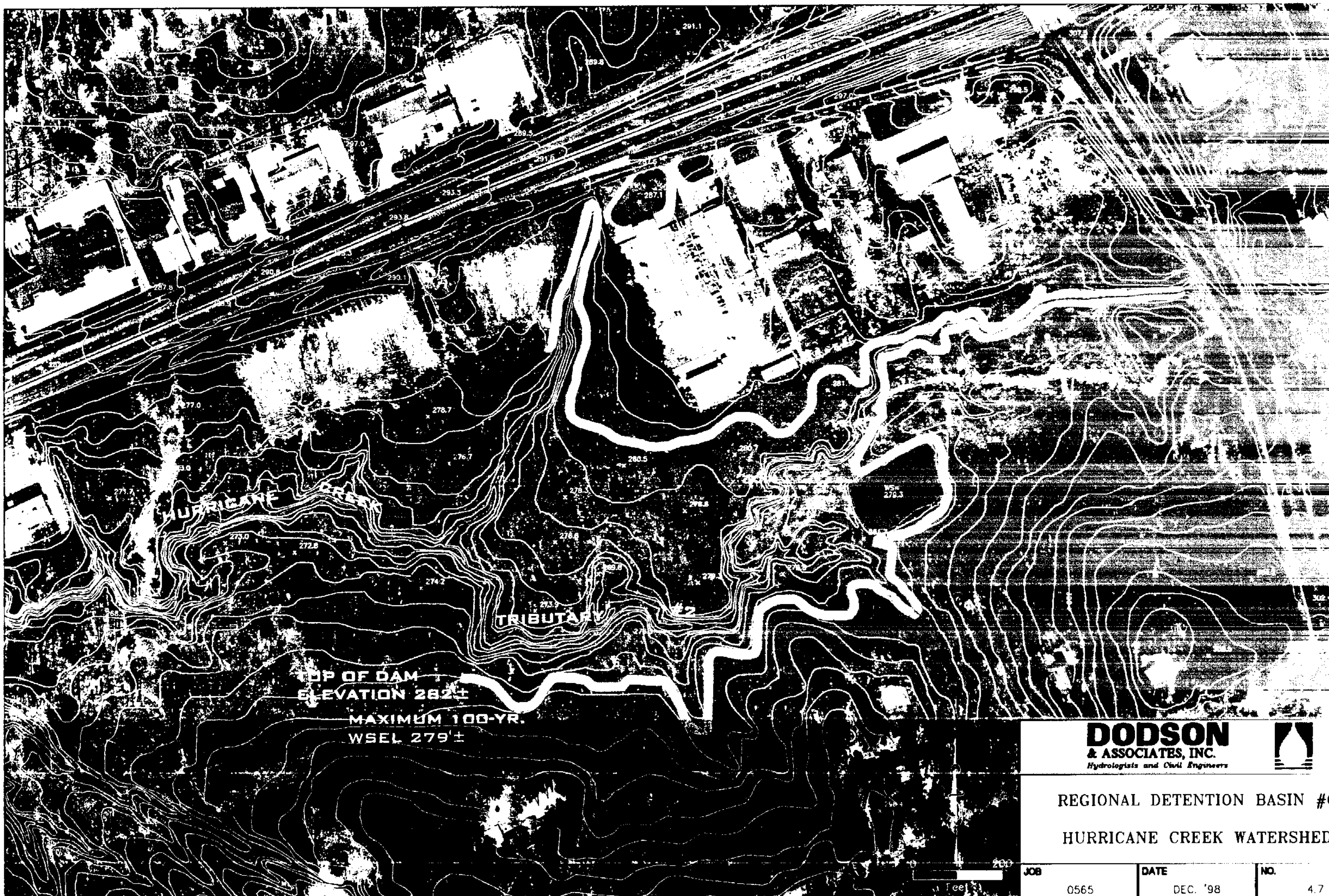
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #5

HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.6


HURRICANE CREEK
TRIBUTARY #2
TOP OF DAM
ELEVATION 304'±
MAXIMUM 100-YR.
WSEL 301'±
SANDBROOK DR
MEADOW LN
WALLACE ST
S. MEDFORD DR
INTERSTATE HW 28
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN #
HURRICANE CREEK WATERSHED
JOB
DATE
NO

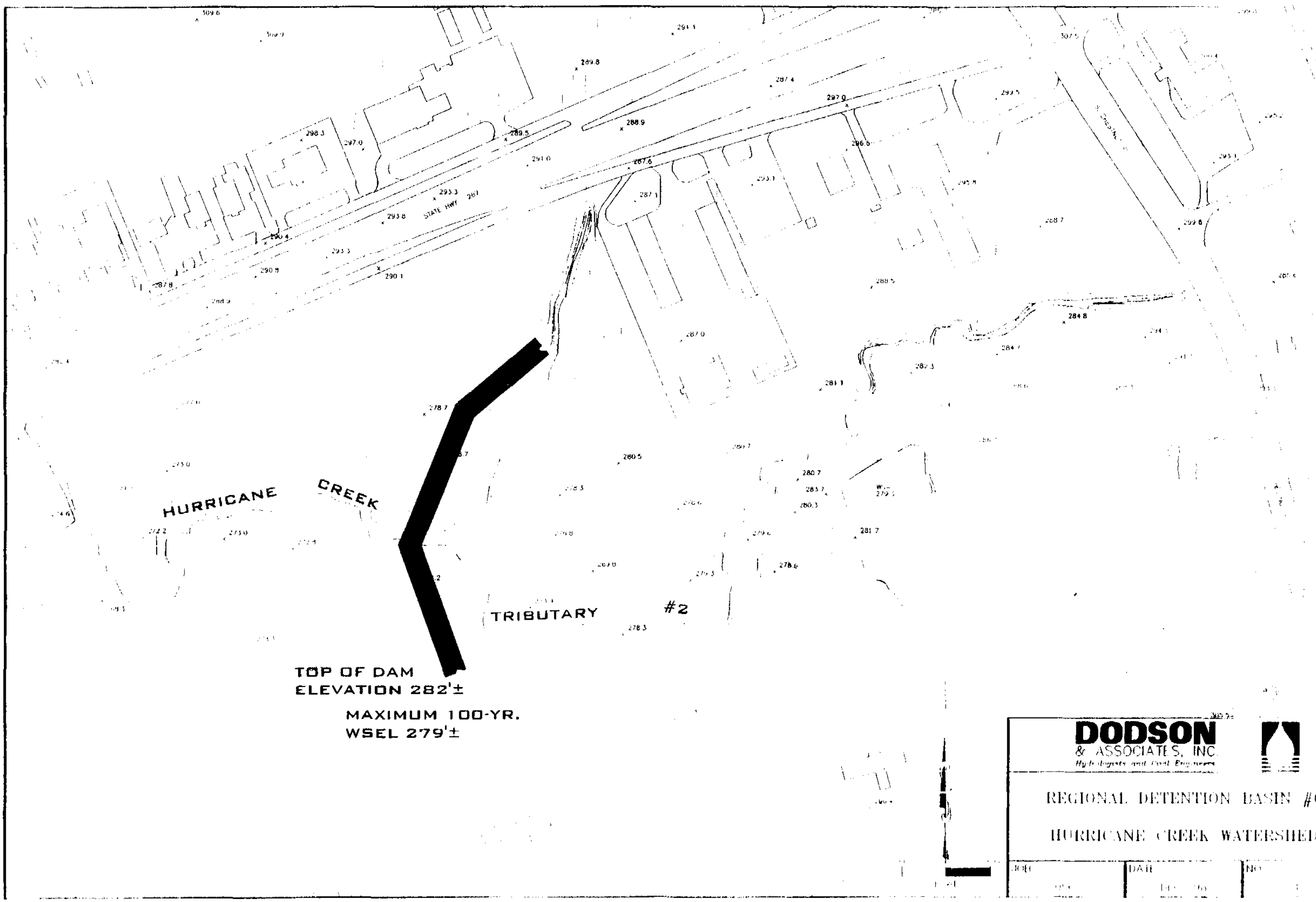


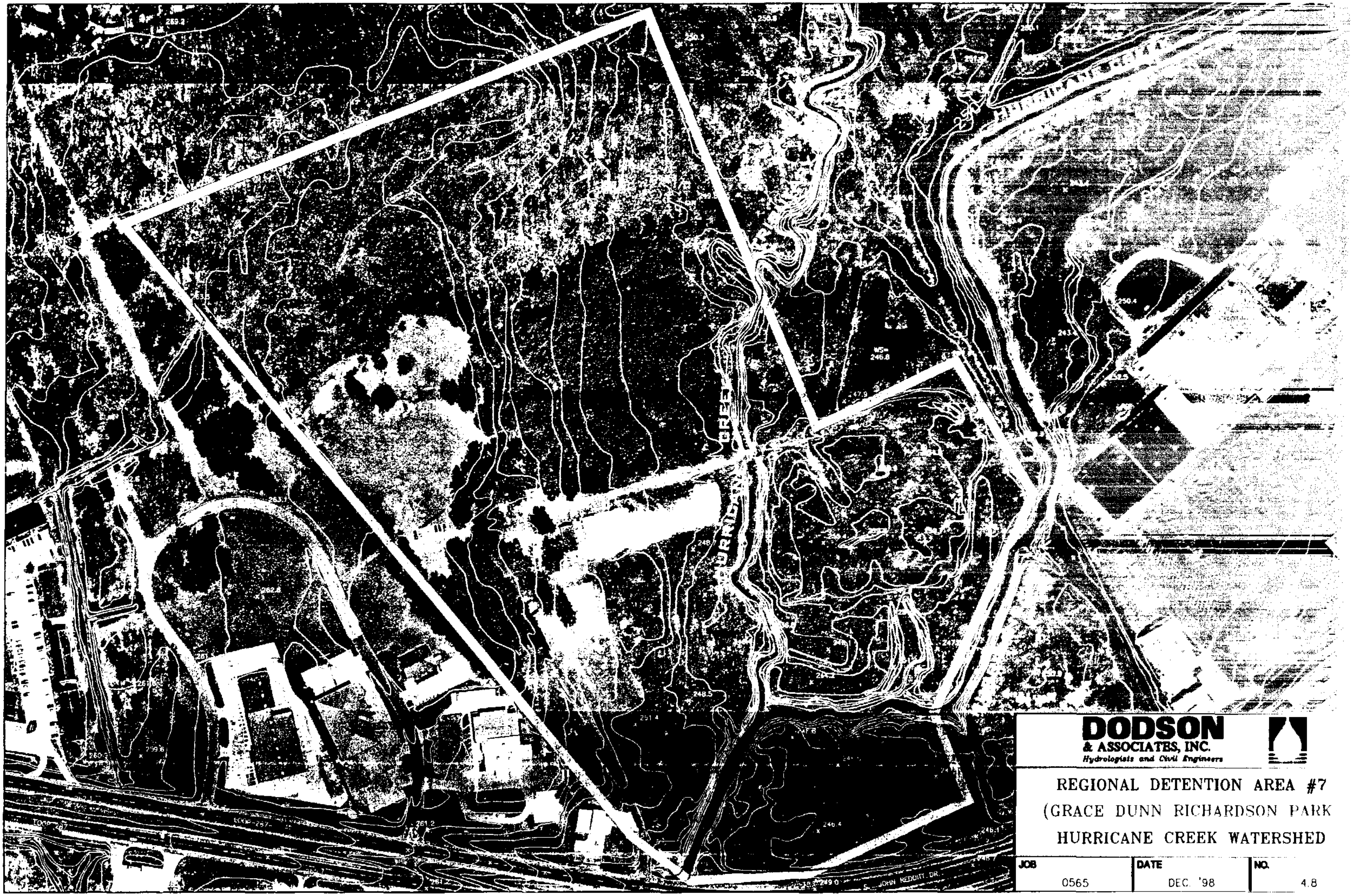
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #6

HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.7


HURRICANE CREEK
TRIBUTARY #2
TOP OF DAM
ELEVATION 282'±
MAXIMUM 100-YR.
WSEL 279'±
STATE HWY
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN #6
HURRICANE CREEK WATERSHED
JOB
DATE
NO.



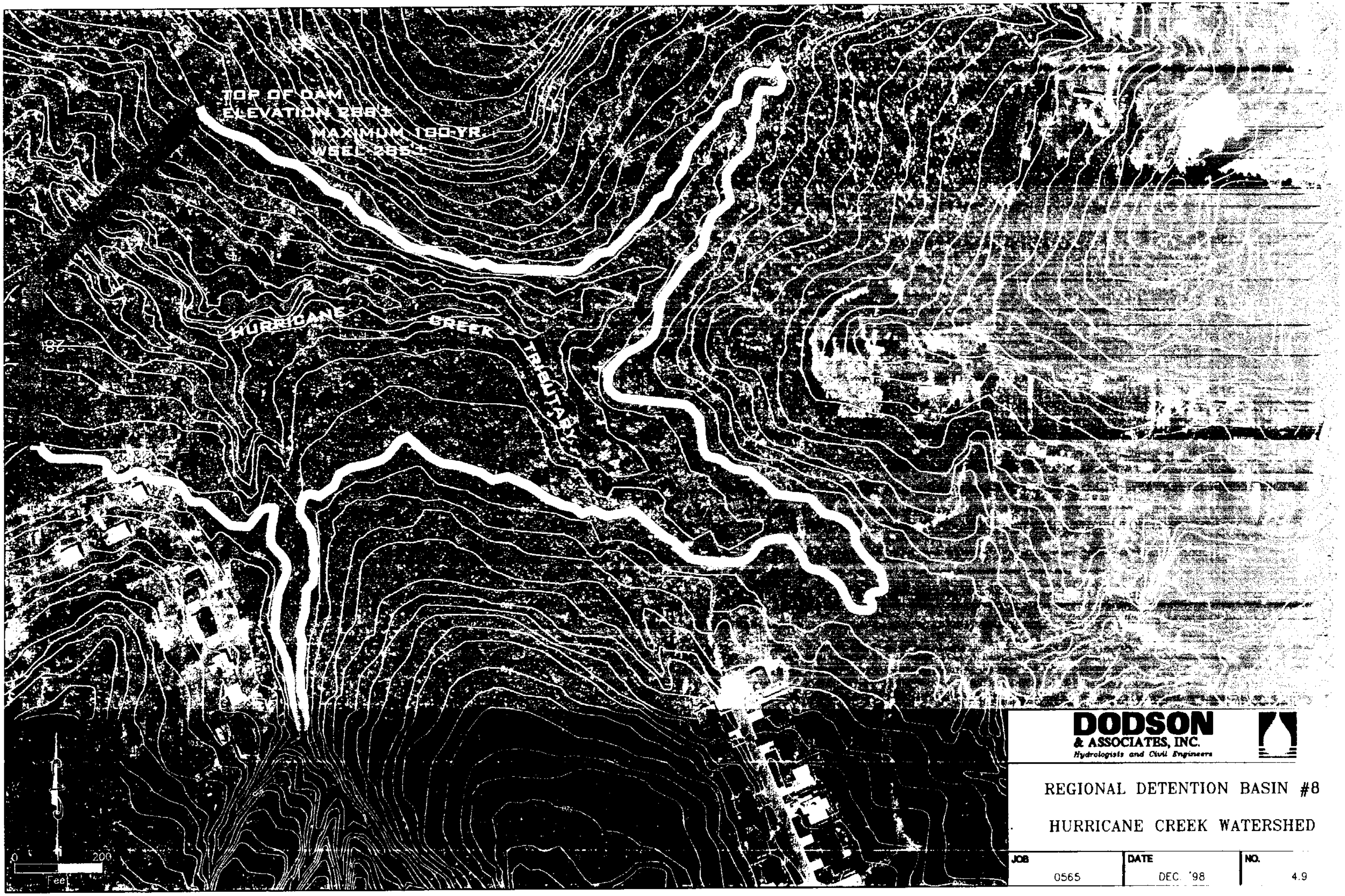
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION AREA #7
(GRACE DUNN RICHARDSON PARK
HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.8

DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

REGIONAL DETENTION AREA #7
(GRACE DUSH RICHARDSON, ...)
HURRICANE CREEK WATERSHED

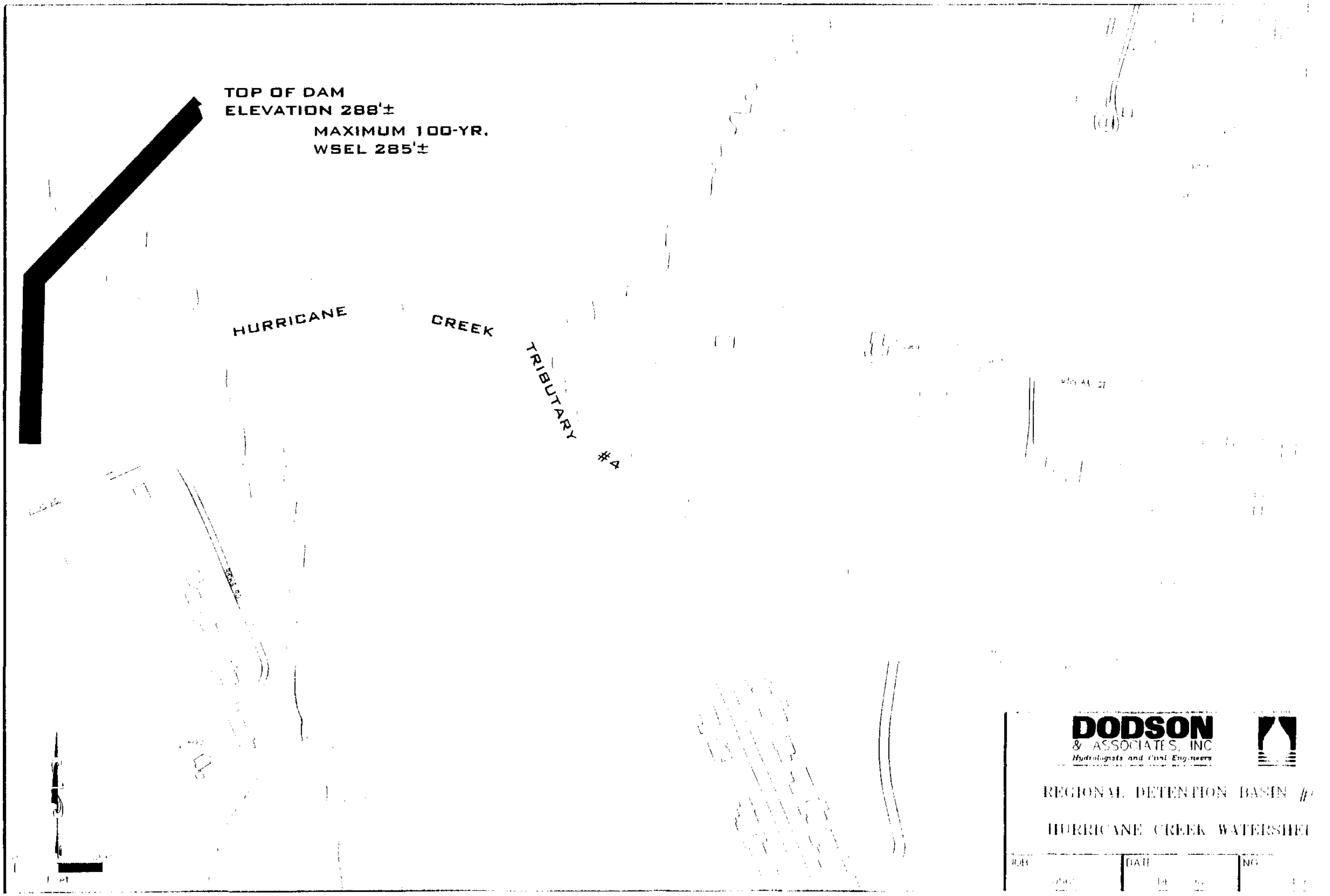


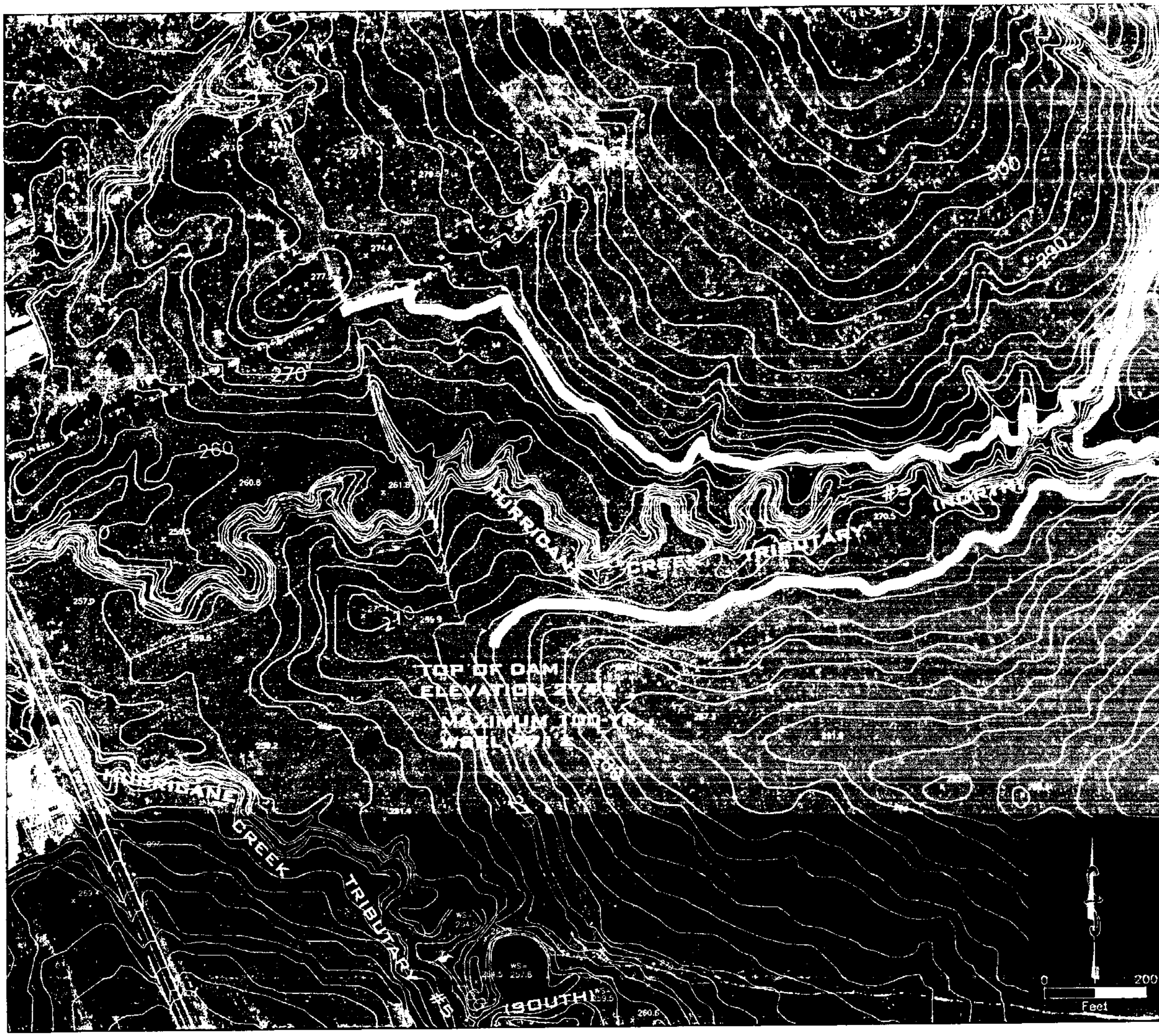
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #8

HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.9


TOP OF DAM
ELEVATION 288'±
MAXIMUM 100-YR.
WSEL 285'±
HURRICANE CREEK
TRIBUTARY #4
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN
HURRICANE CREEK
JOB
DATE
NO

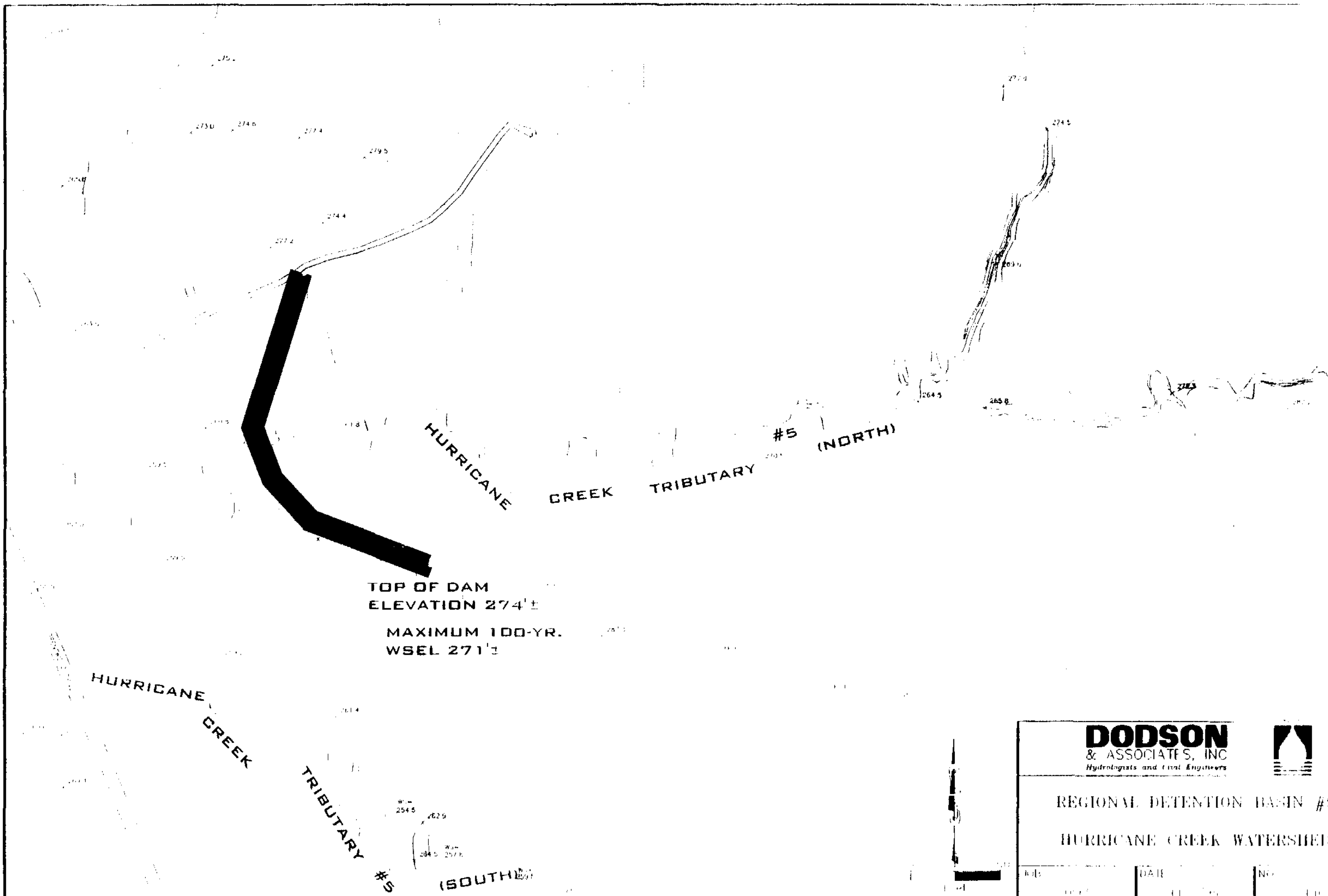


DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #9

HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.10

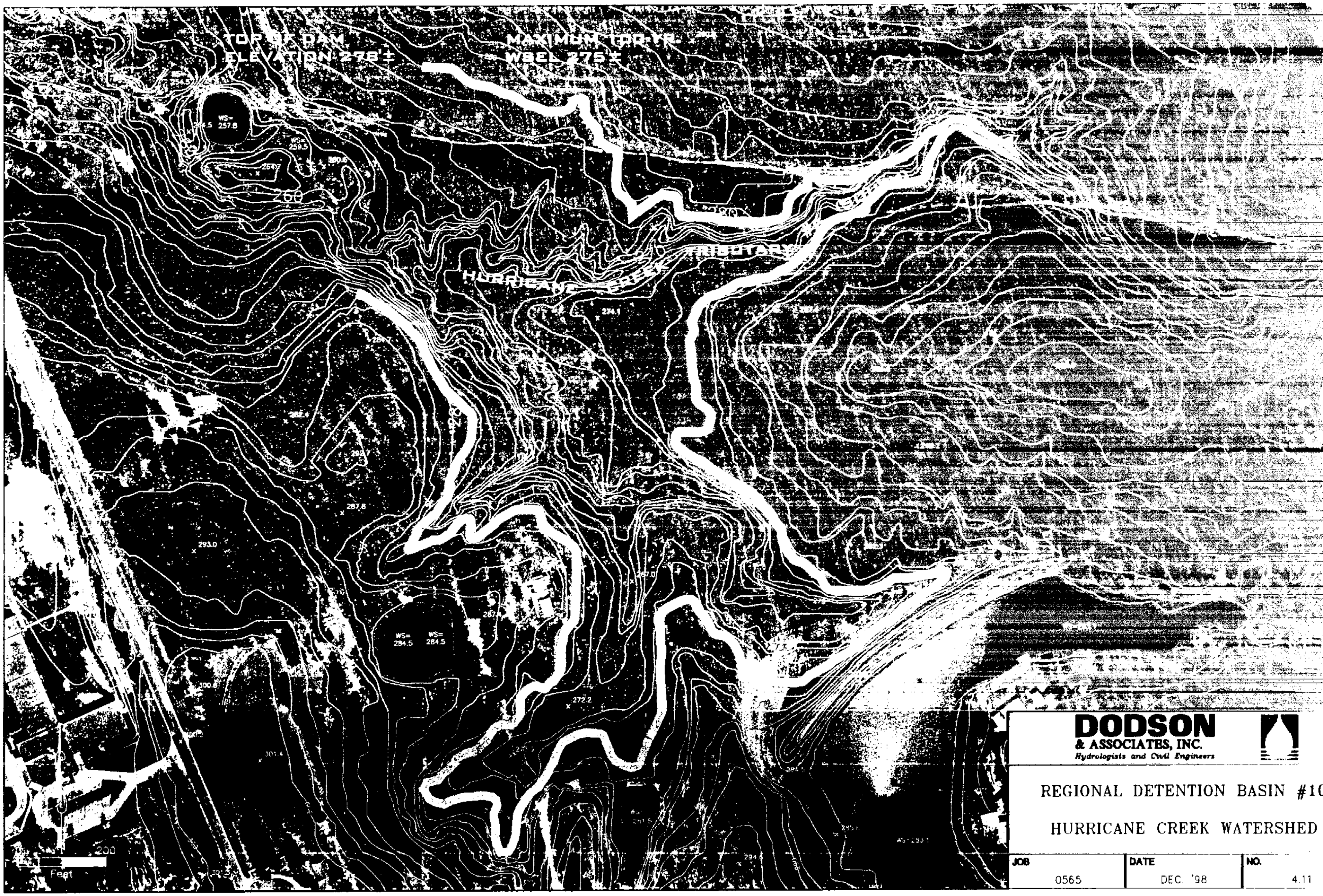


DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #9

HURRICANE CREEK WATERSHED

JOB	DATE	NO.

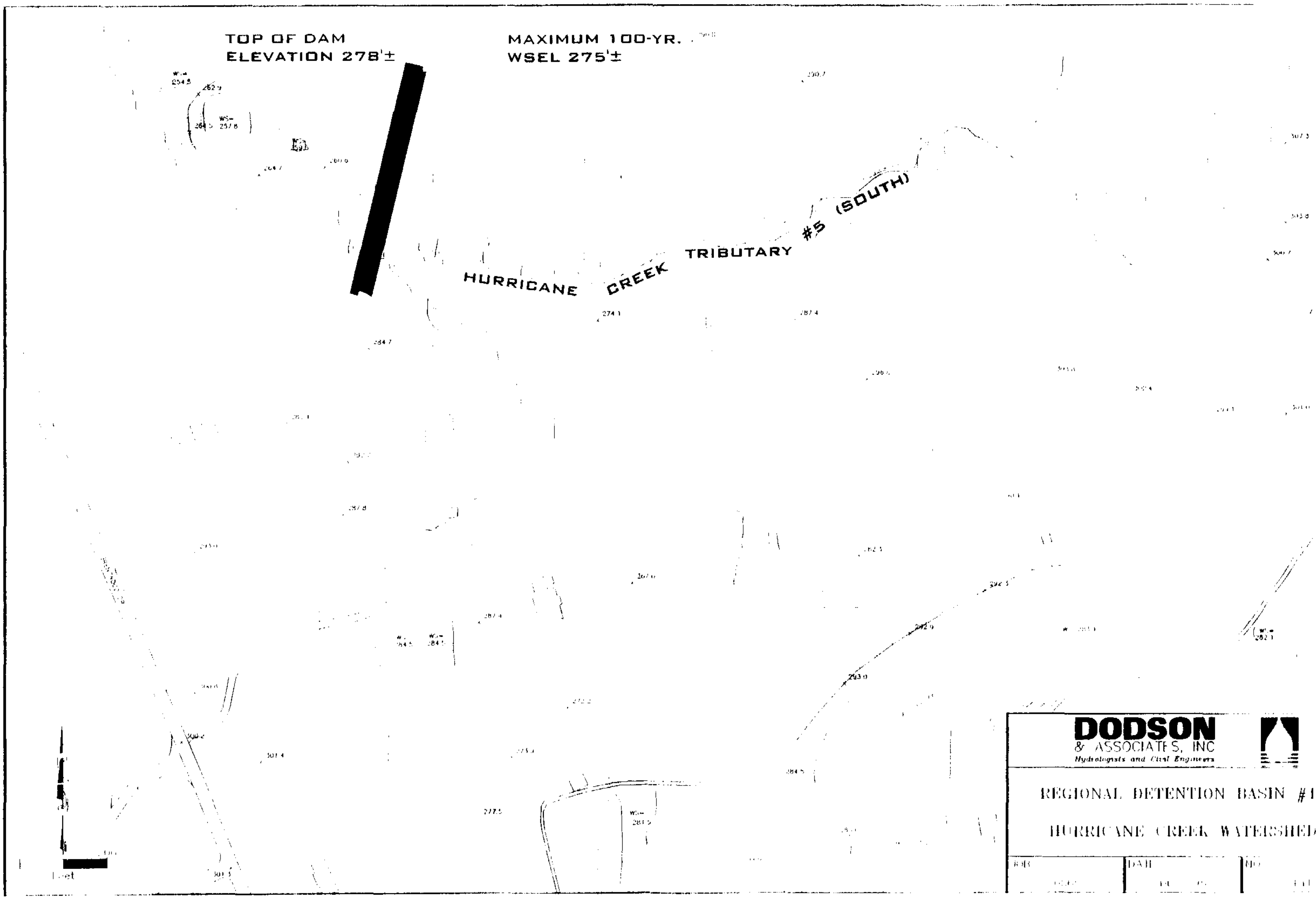


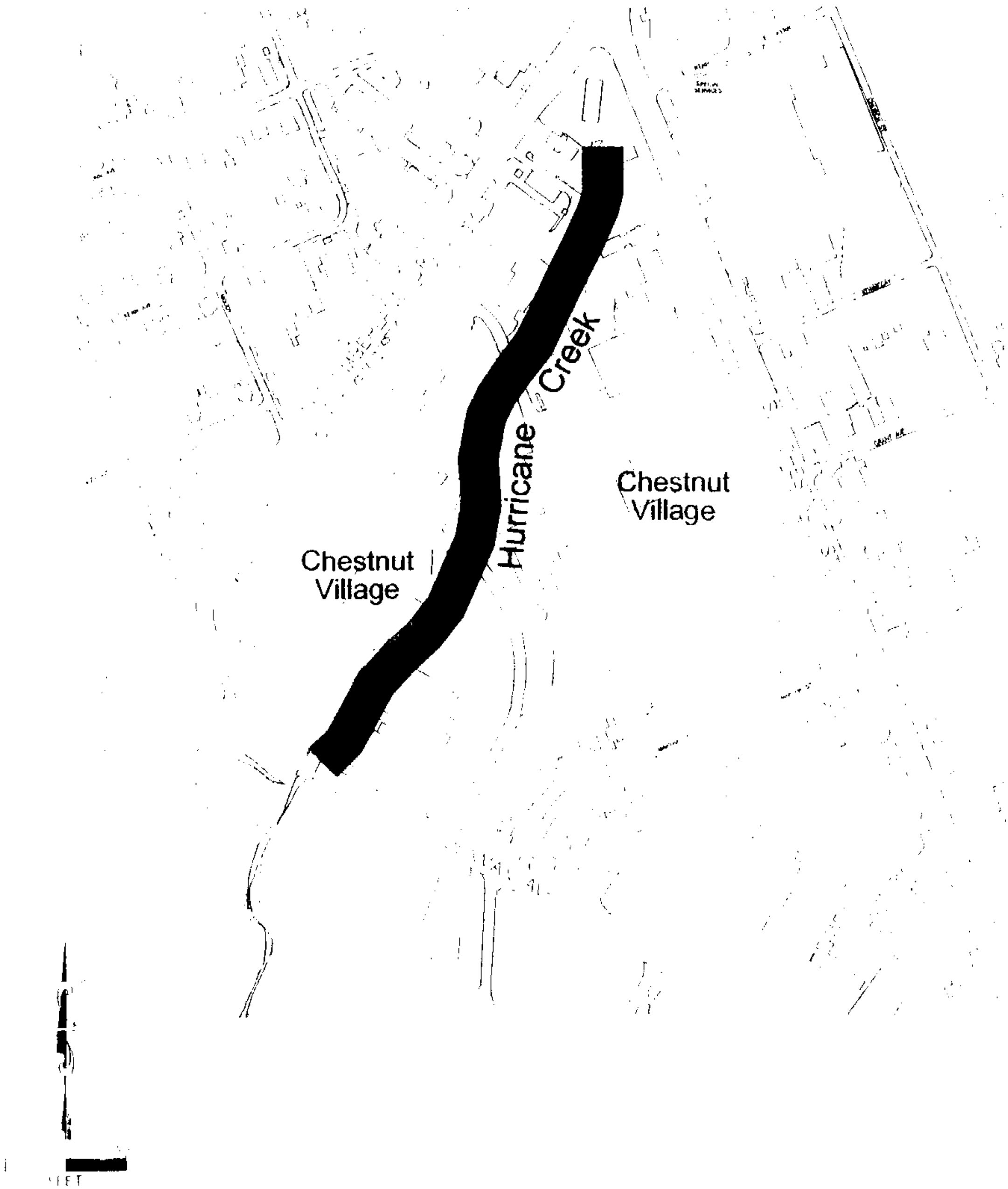
DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

REGIONAL DETENTION BASIN #10

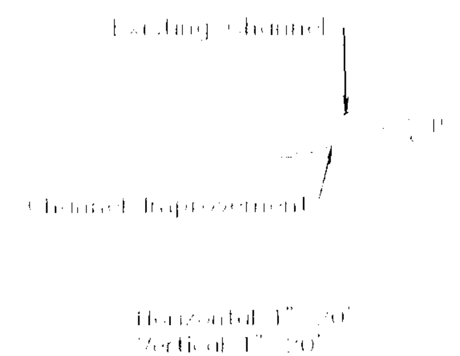
HURRICANE CREEK WATERSHED

JOB	DATE	NO.
0565	DEC. '98	4.11


TOP OF DAM
ELEVATION 278'±
MAXIMUM 100-YR.
WSEL 275'±
HURRICANE CREEK TRIBUTARY #5 (SOUTH)
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers
REGIONAL DETENTION BASIN #1
HURRICANE CREEK WATERSHED

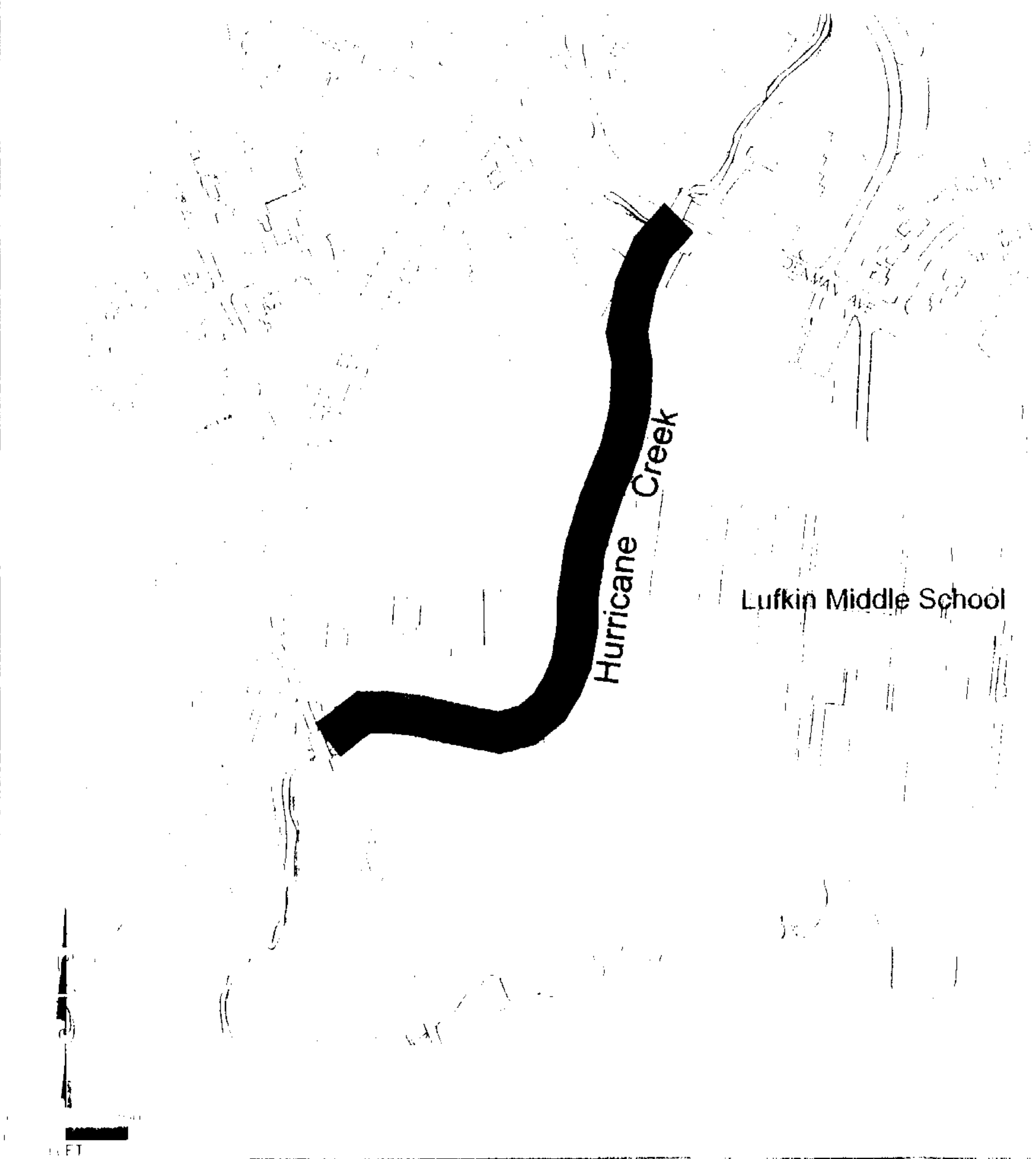


TYPICAL CROSS-SECTION



DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

PROPOSED CHANNEL IMPROVEMEN
HURRICANE CREEK
CHESTNUT TO DENMAN



TYPICAL CROSS-SECTION

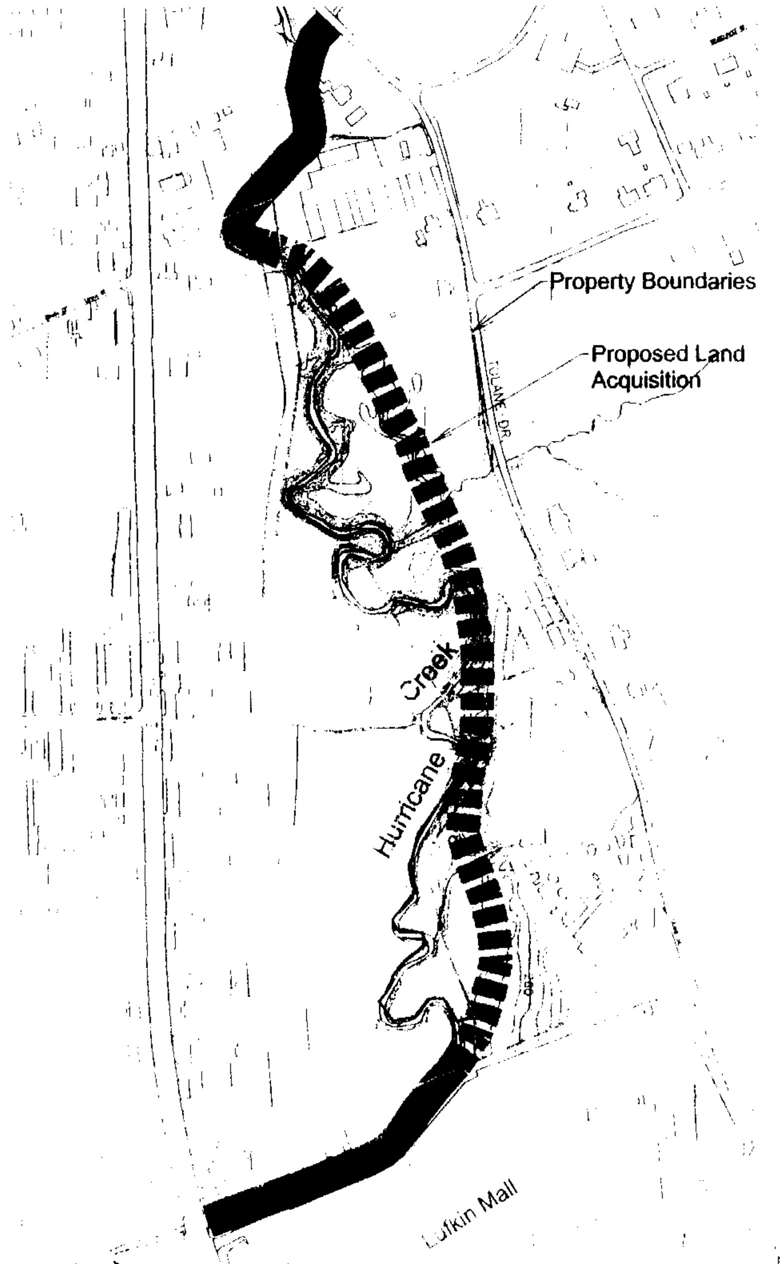
Existing Channel

Channel Improvement

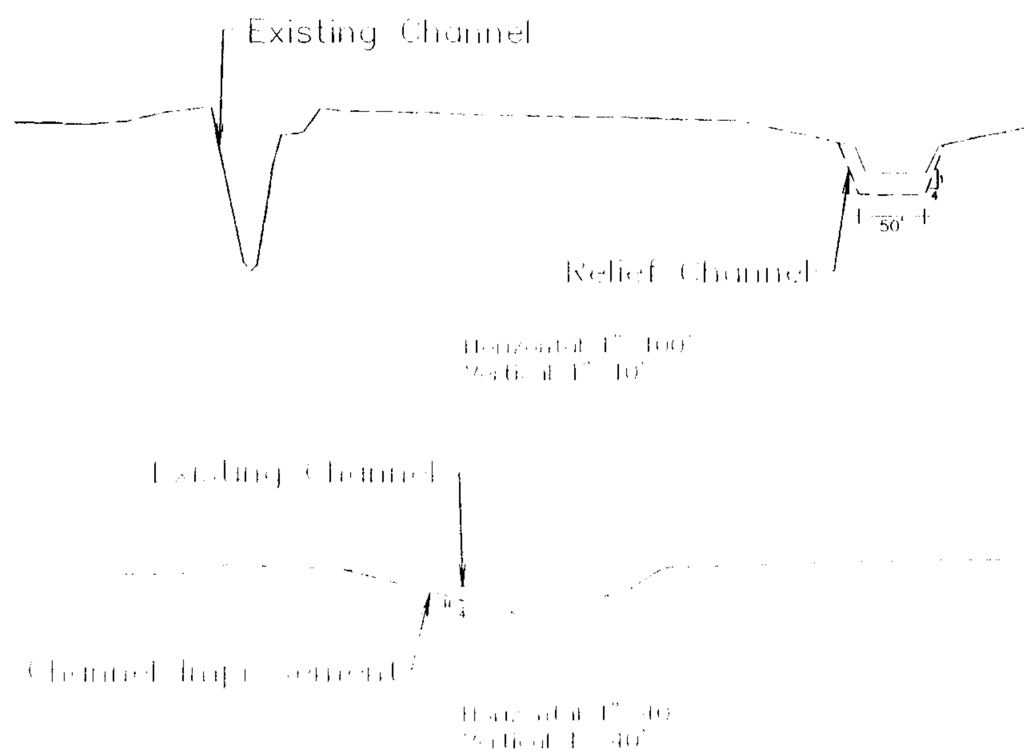
Horizontal 1" = 60'
Vertical 1" = 60'

DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

PROPOSED CHANNEL IMPROVEMENT
HURRICANE CREEK
DENMAN TO SOUTH 3RD STREET

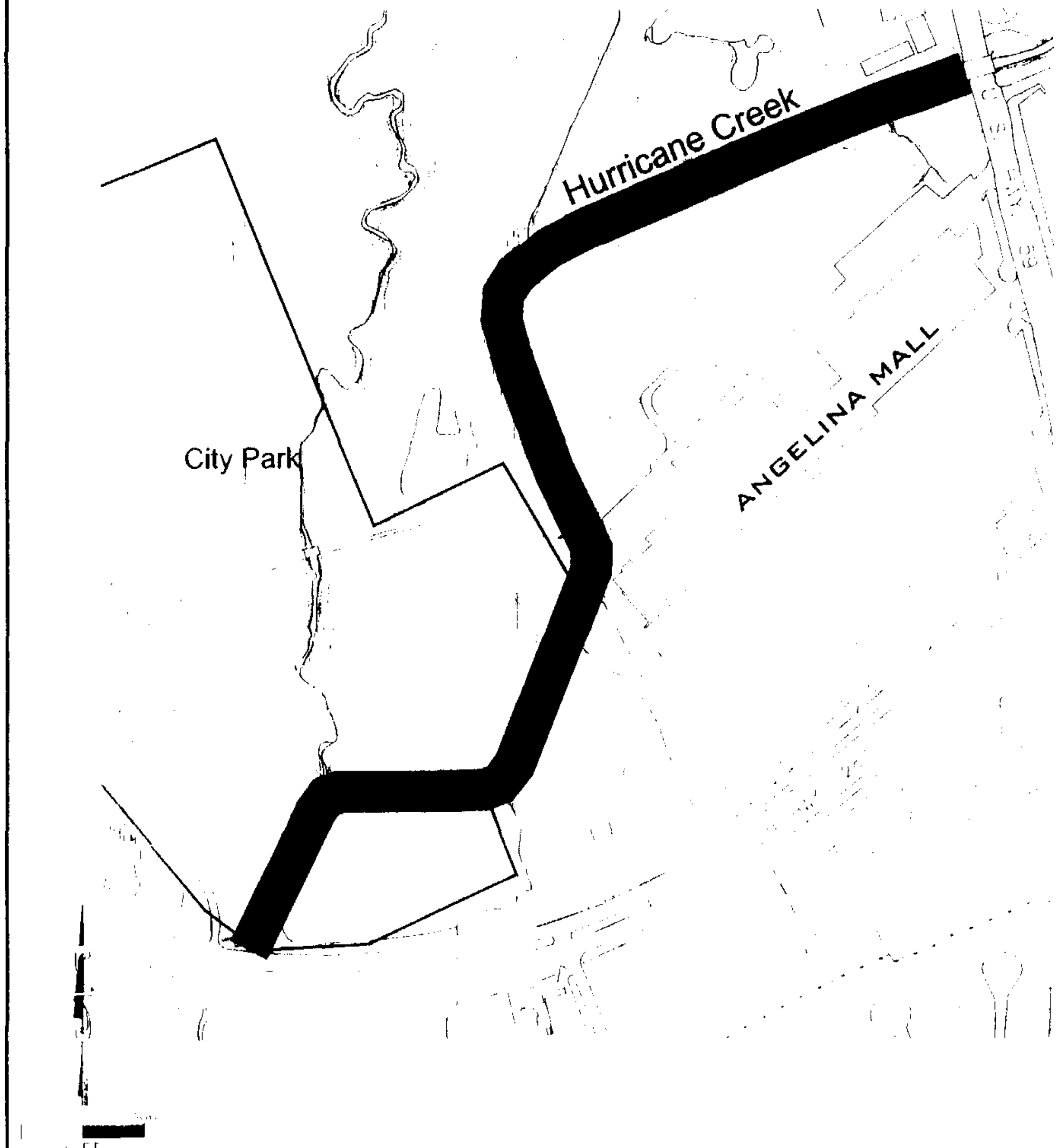


TYPICAL CROSS-SECTIONS

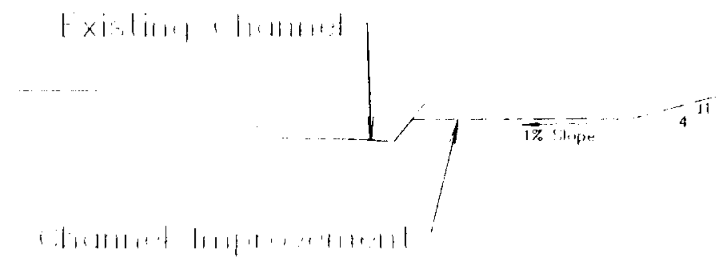


DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

PROPOSED CHANNEL IMPROVEMEN
& RELIEF CHANNEL
HURRICANE CREEK
TULANE TO U.S. 59

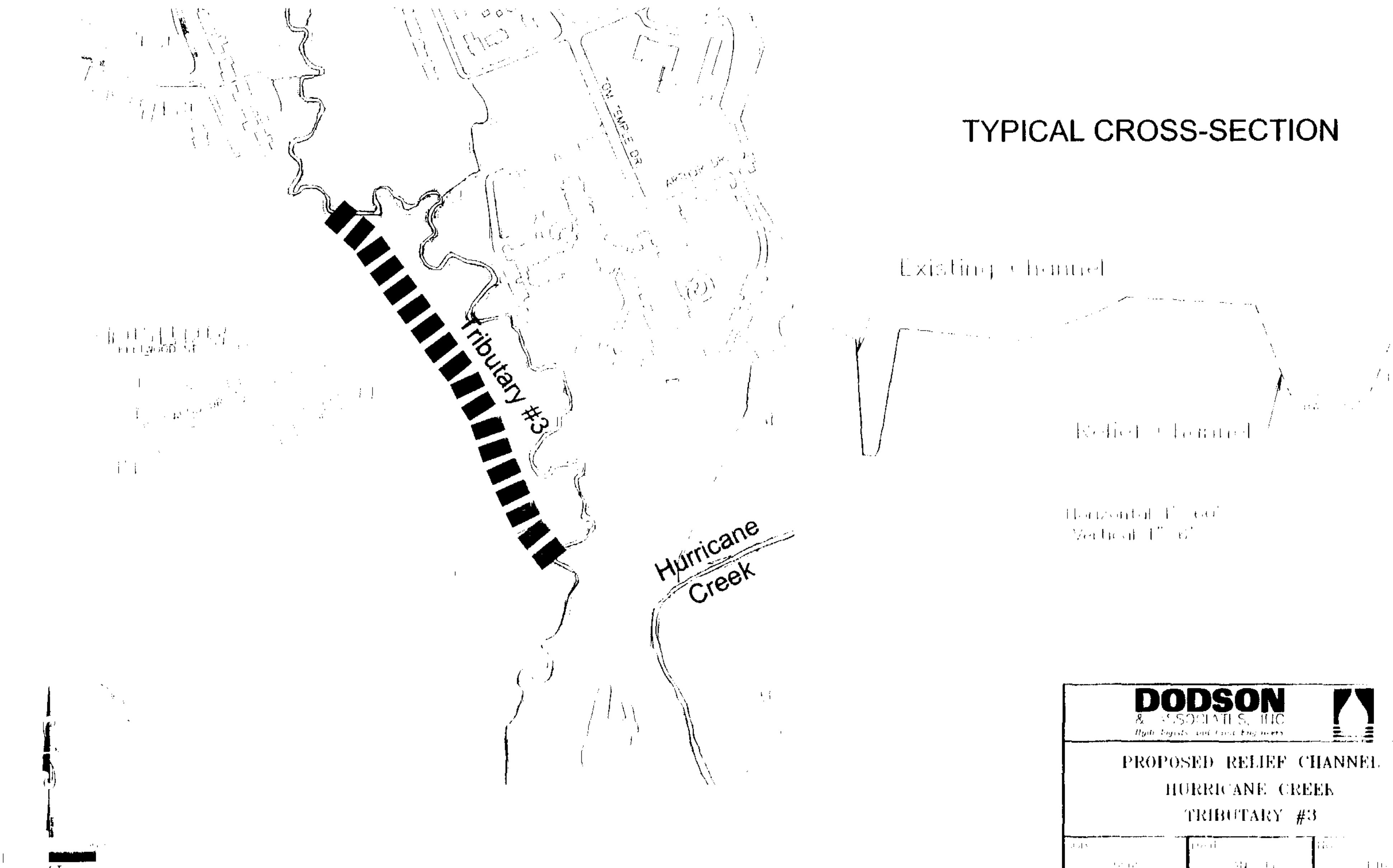


TYPICAL CROSS-SECTION



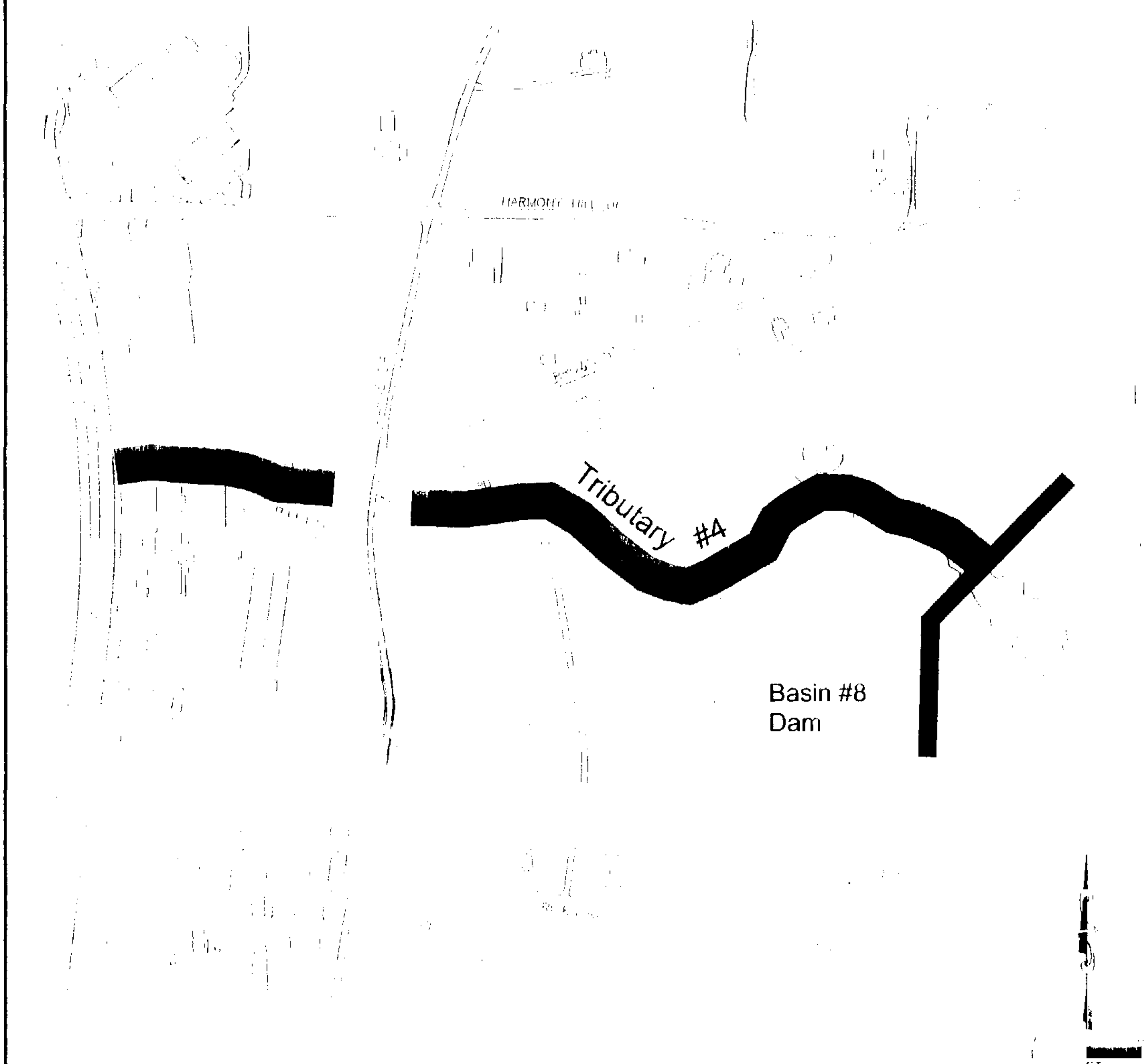
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

PROPOSED CHANNEL IMPROVEMEN
HURRICANE CREEK
U.S. 59 TO LOOP 287



DODSON
& ASSOCIATES, INC.

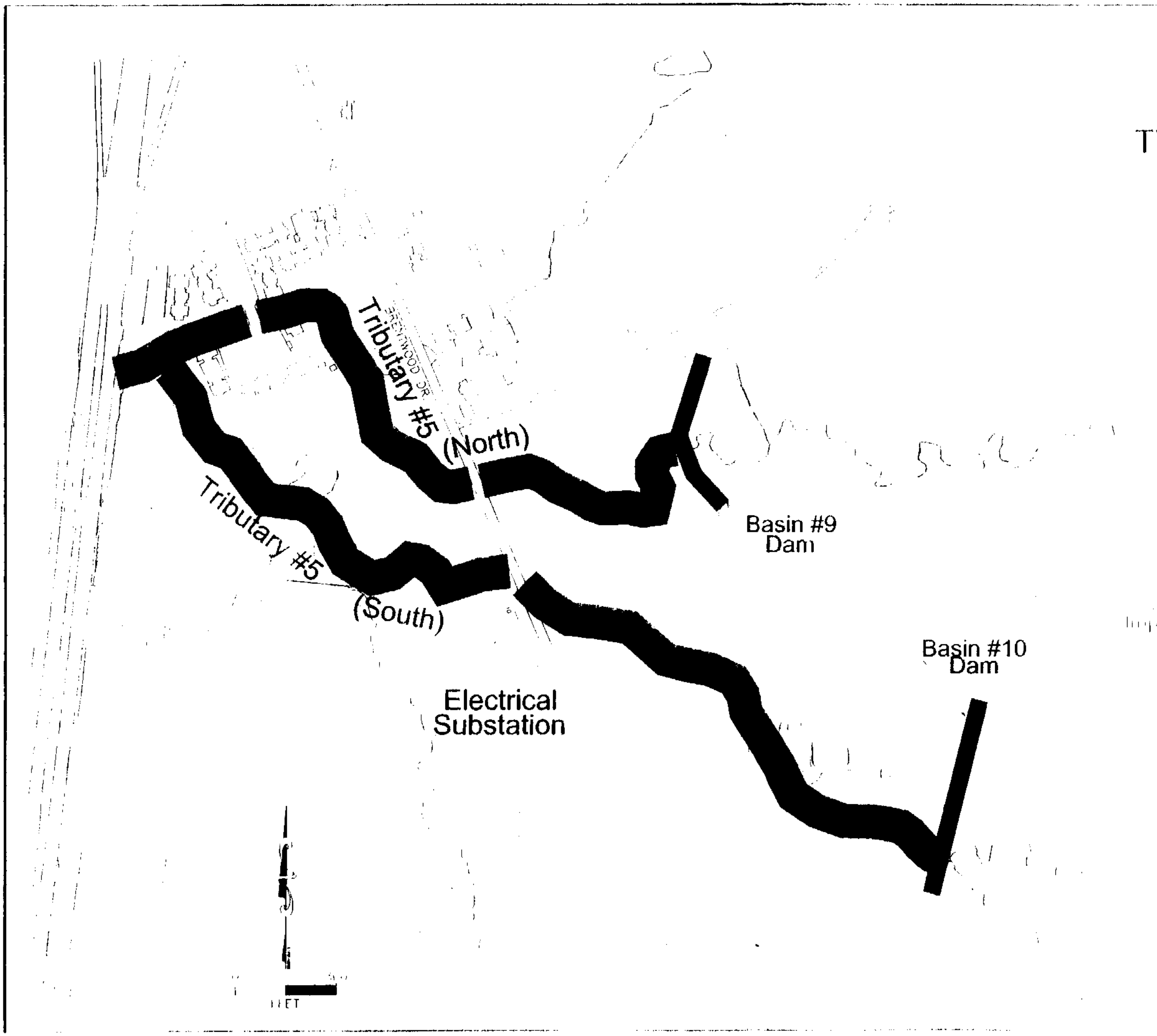
PROPOSED RELIEF CHANNEL
HURRICANE CREEK
TRIBUTARY #3



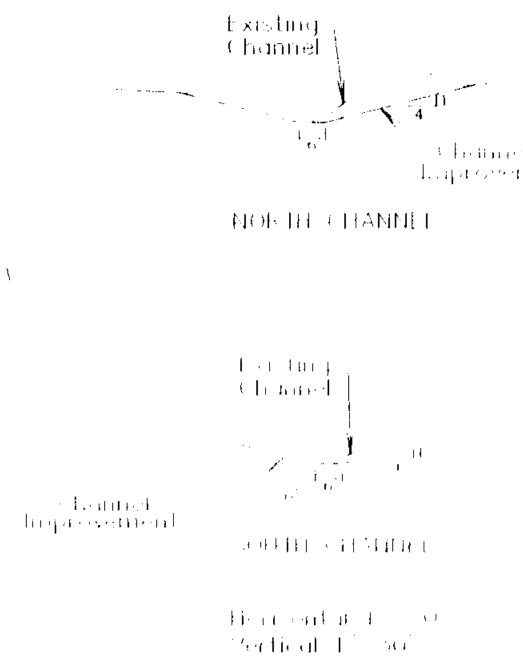
TYPICAL CROSS-SECTION

DODSON
& ASSOCIATES, INC.

PROPOSED CHANNEL IMPROVEMEN
HURRICANE CREEK
TRIBUTARY #4



TYPICAL CROSS-SECTIO

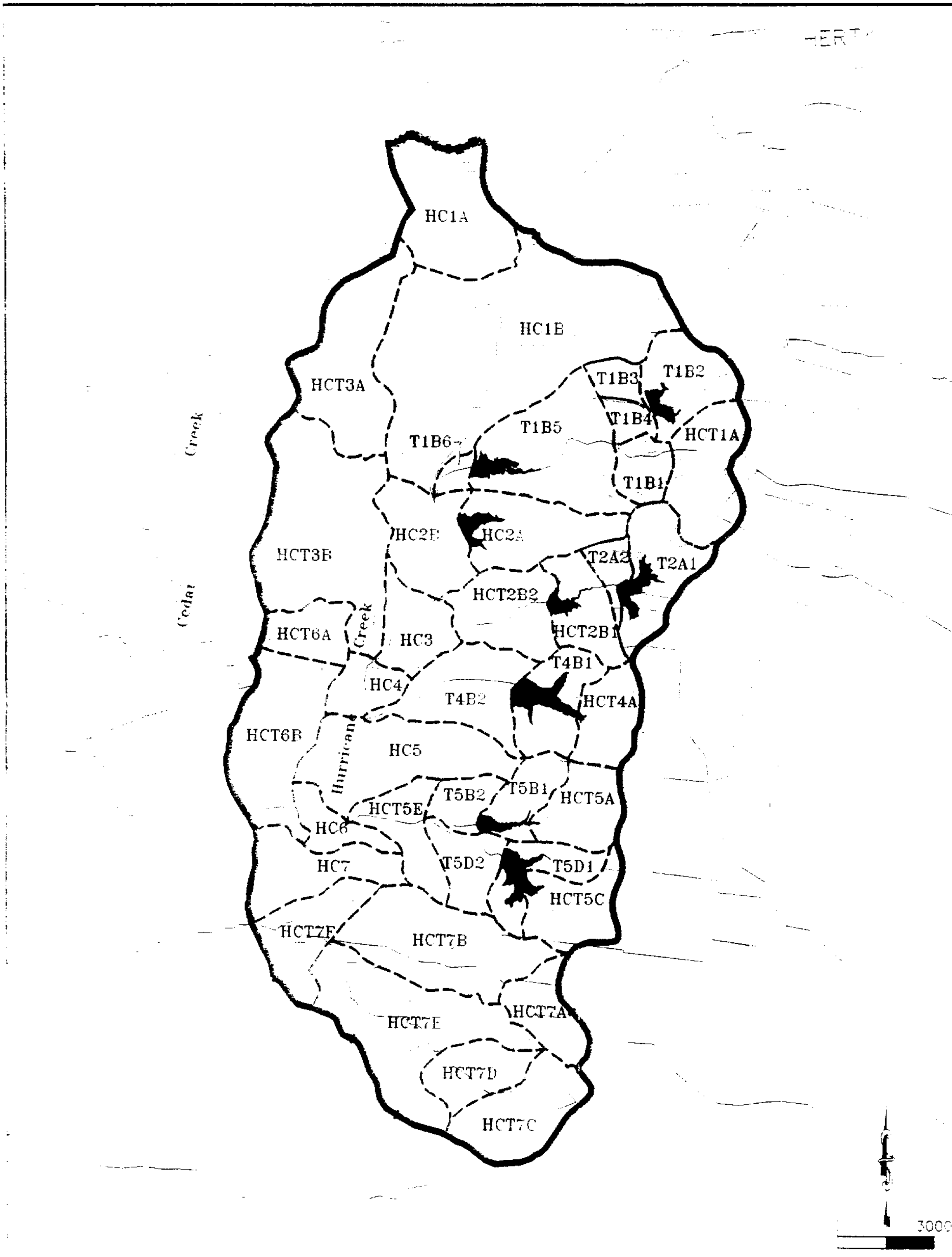


DODSON & ASSOCIATES, INC

PROPOSED CHANNEL IMPROVEMEN

HURRICANE CREEK

TRIBUTARY #5 (NORTH



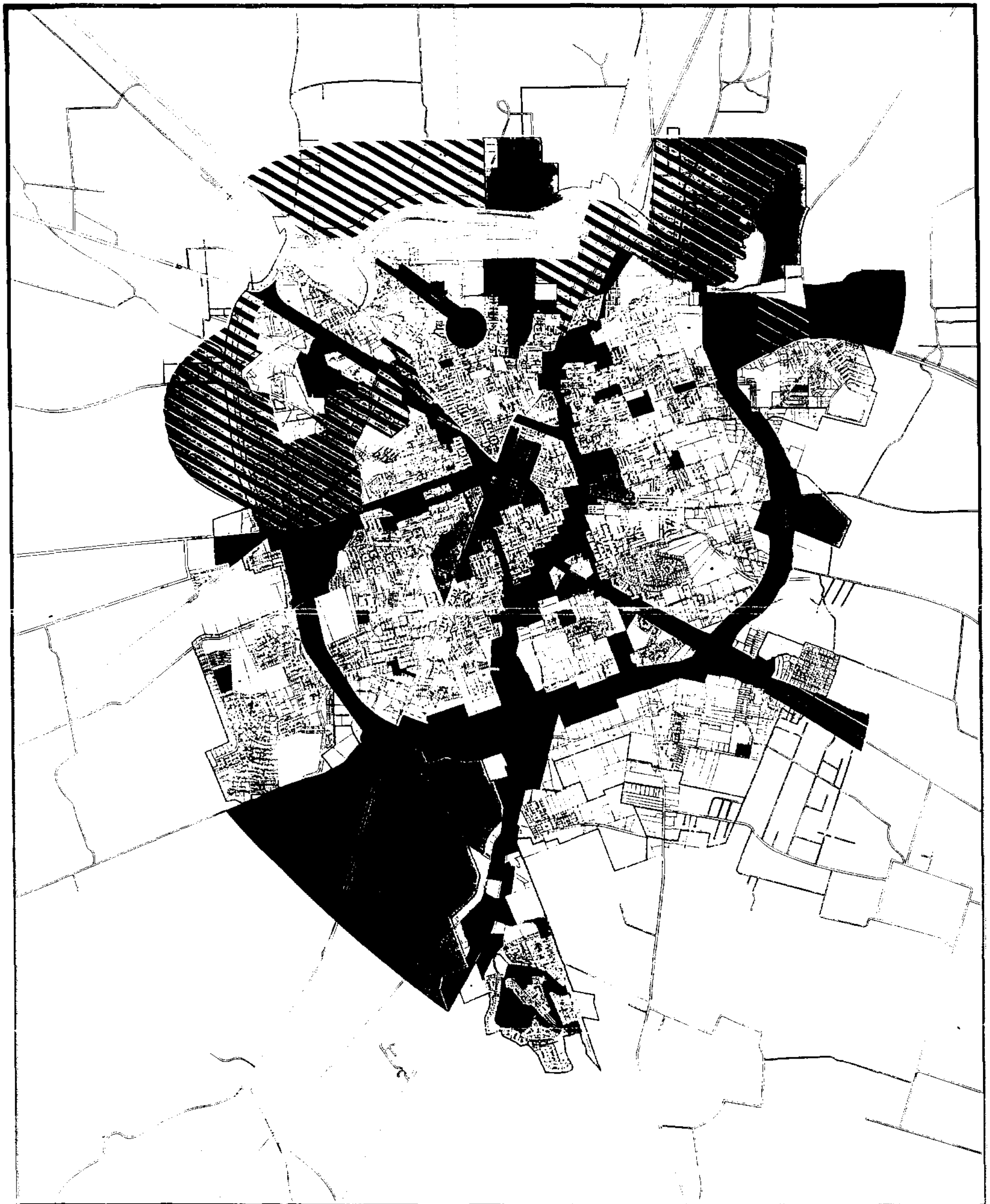
LEGEND

Regional Detention

Watershed Boundaries

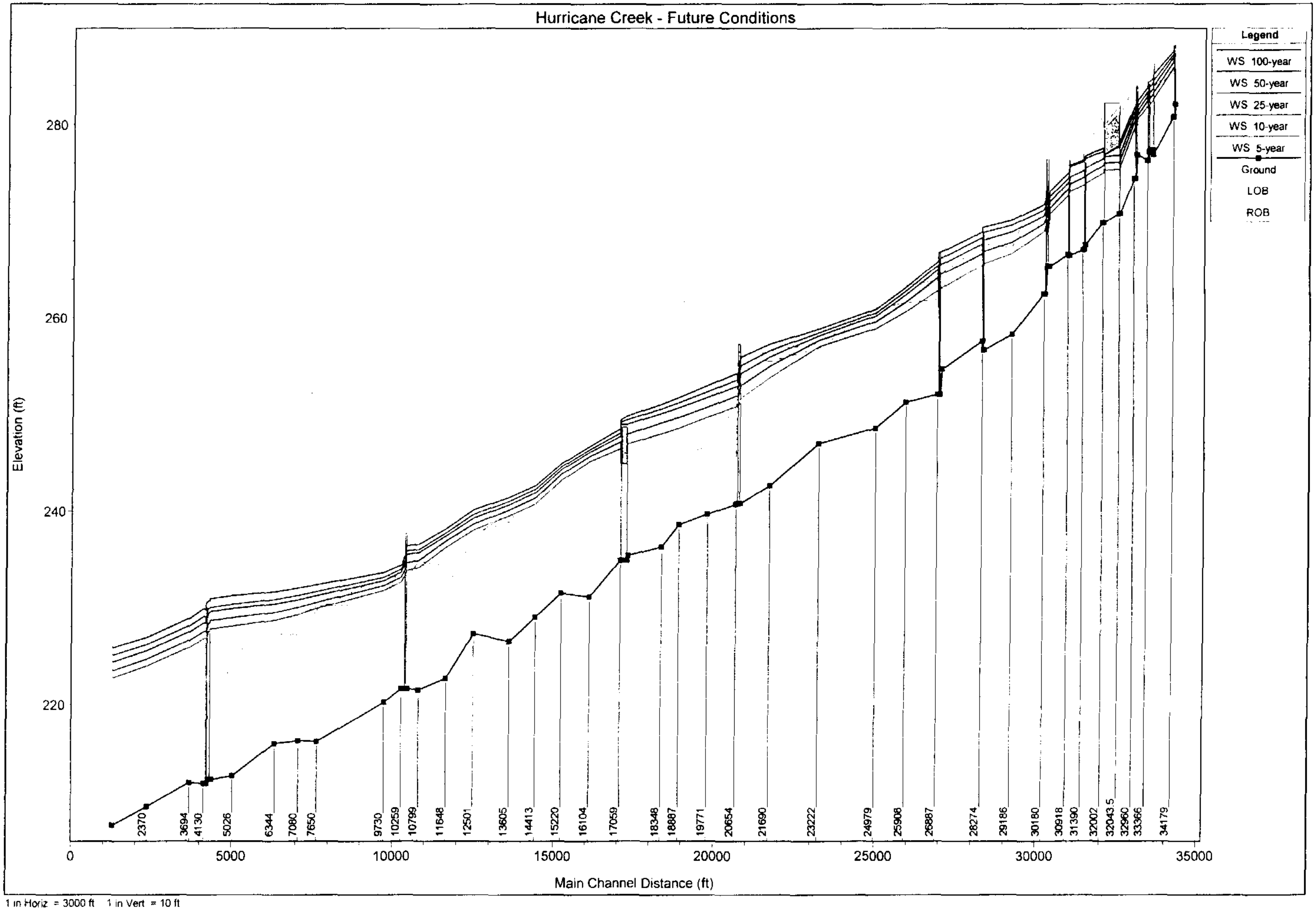
DODSON
& ASSOCIATES, INC
Hydrologists and Civil Engineers

HEC-1 SUB-AREA MAP
FUTURE CONDITIONS
HURRICANE CREEK



LUFKIN, TEXAS

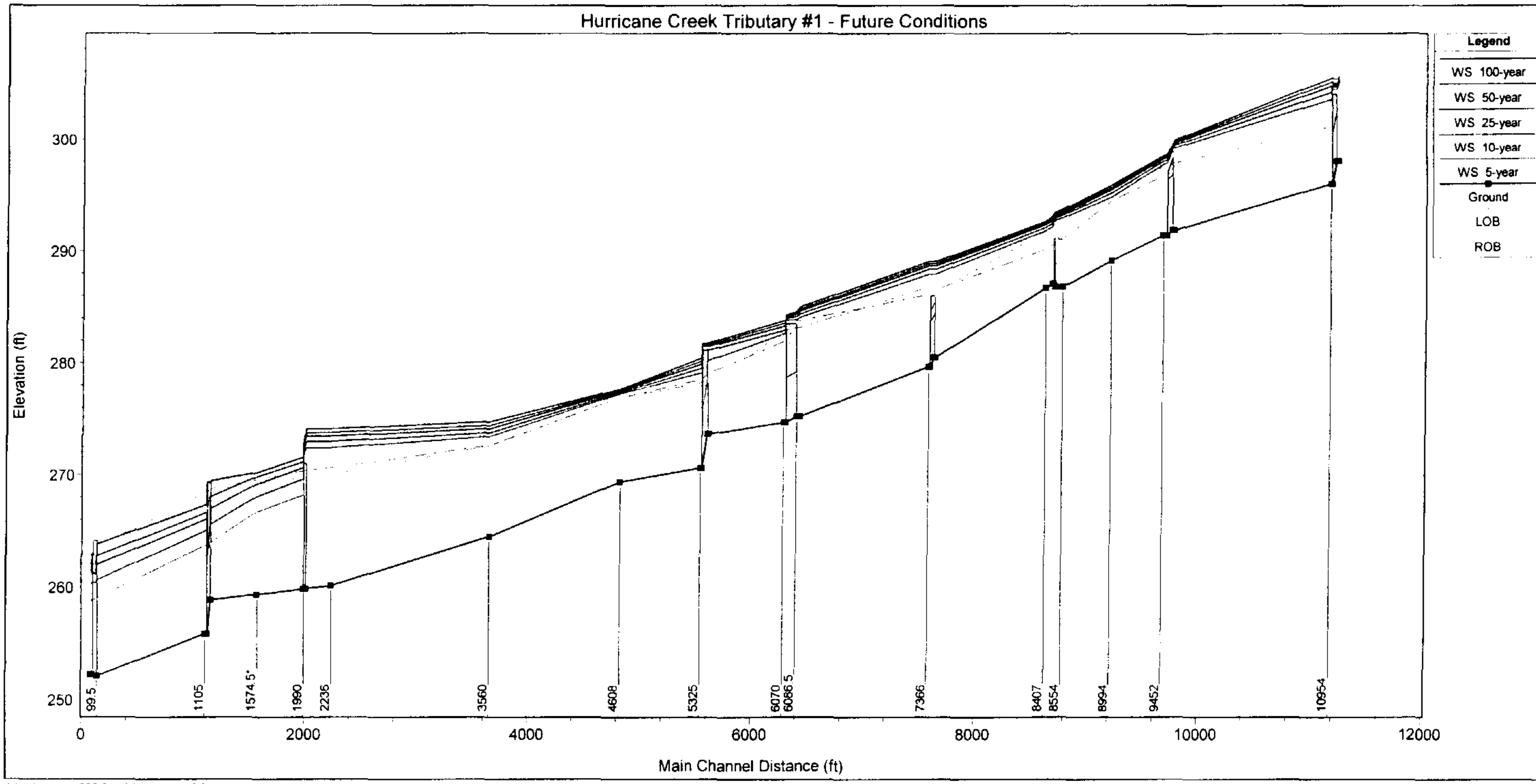
FUTURE LAND USE



COMPUTED STREAM PROFILES FOR HURRICANE CREEK
FUTURE CONDITIONS

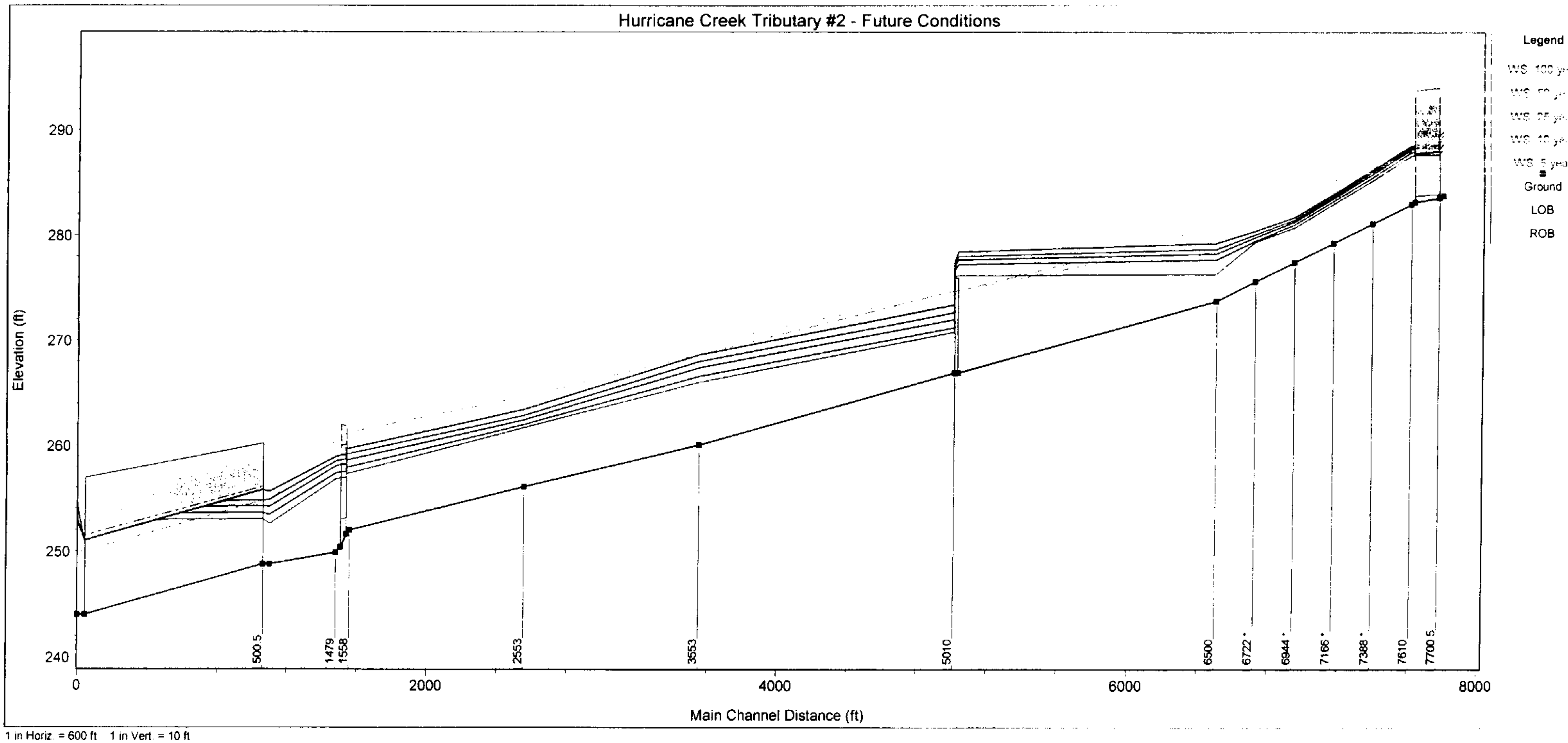
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec. 1998	NO.: 4.21

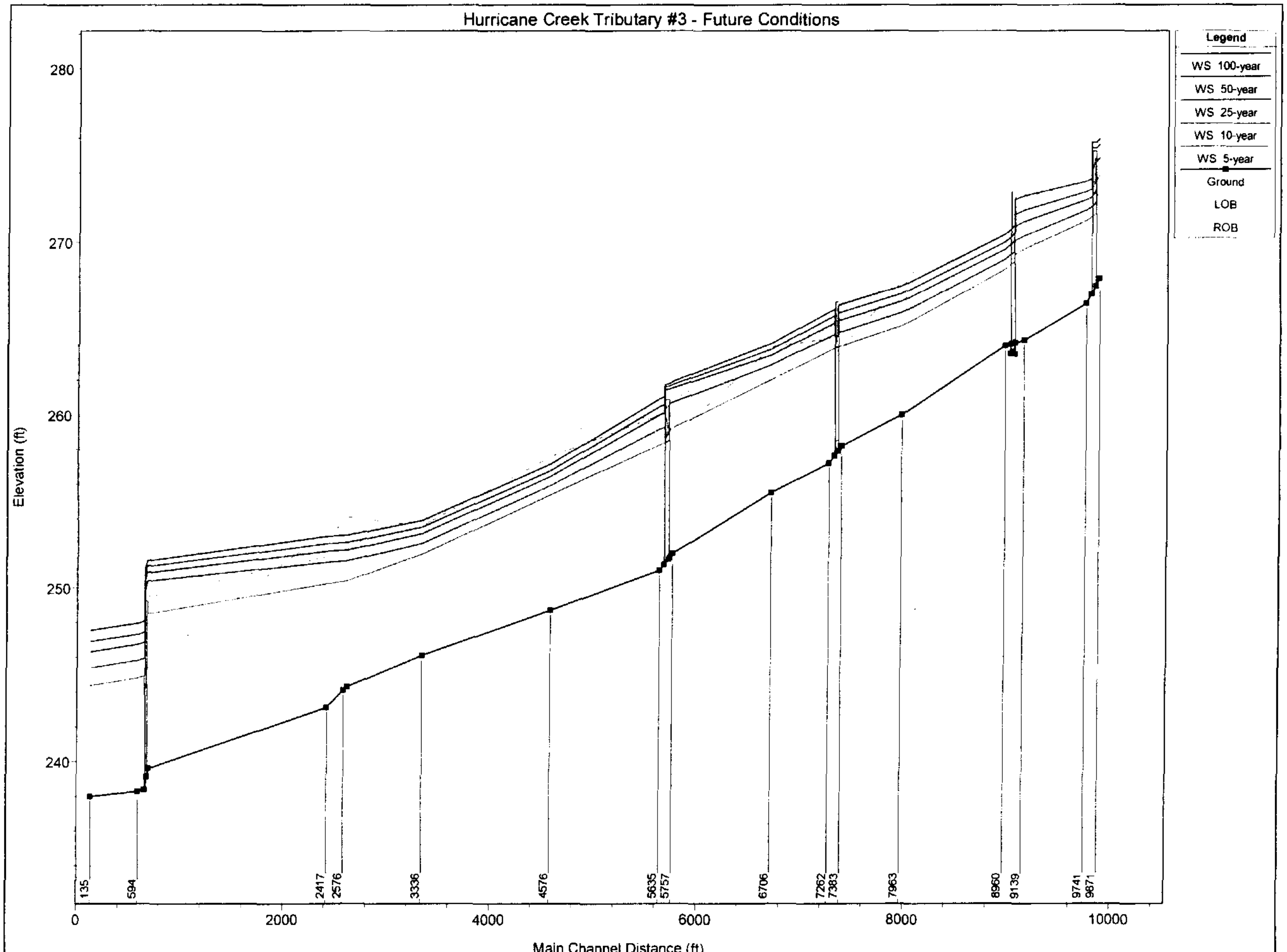


1 in Horiz. = 1000 ft   1 in Vert = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #1 **FUTURE CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* **JOB:** 0565 **DATE:** Dec. 1998 **NO.:** 4.22

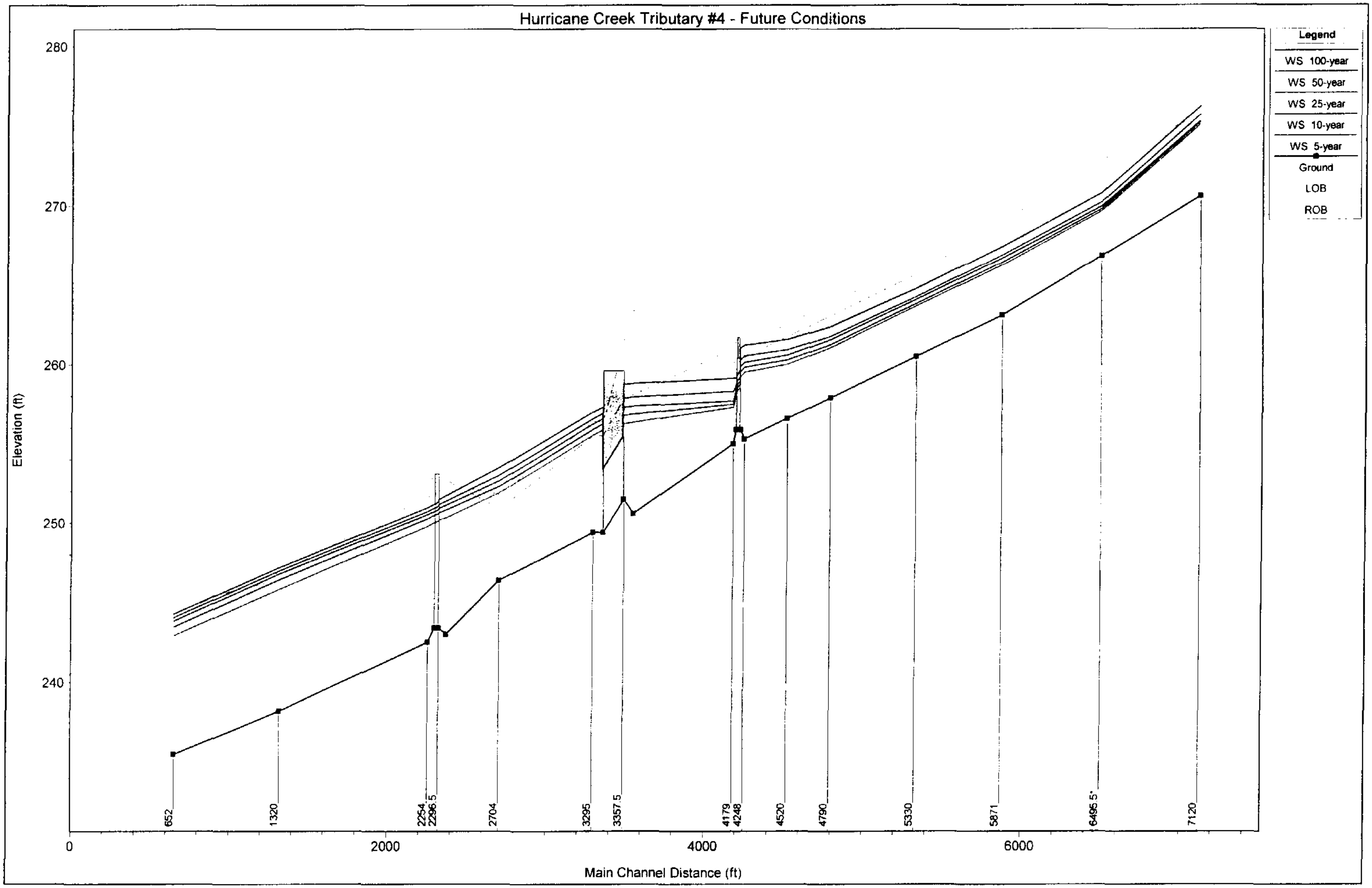


COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #2 **FUTURE CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* JOB: 0565 | DATE: Dec. 1998 | NO.: 4.23



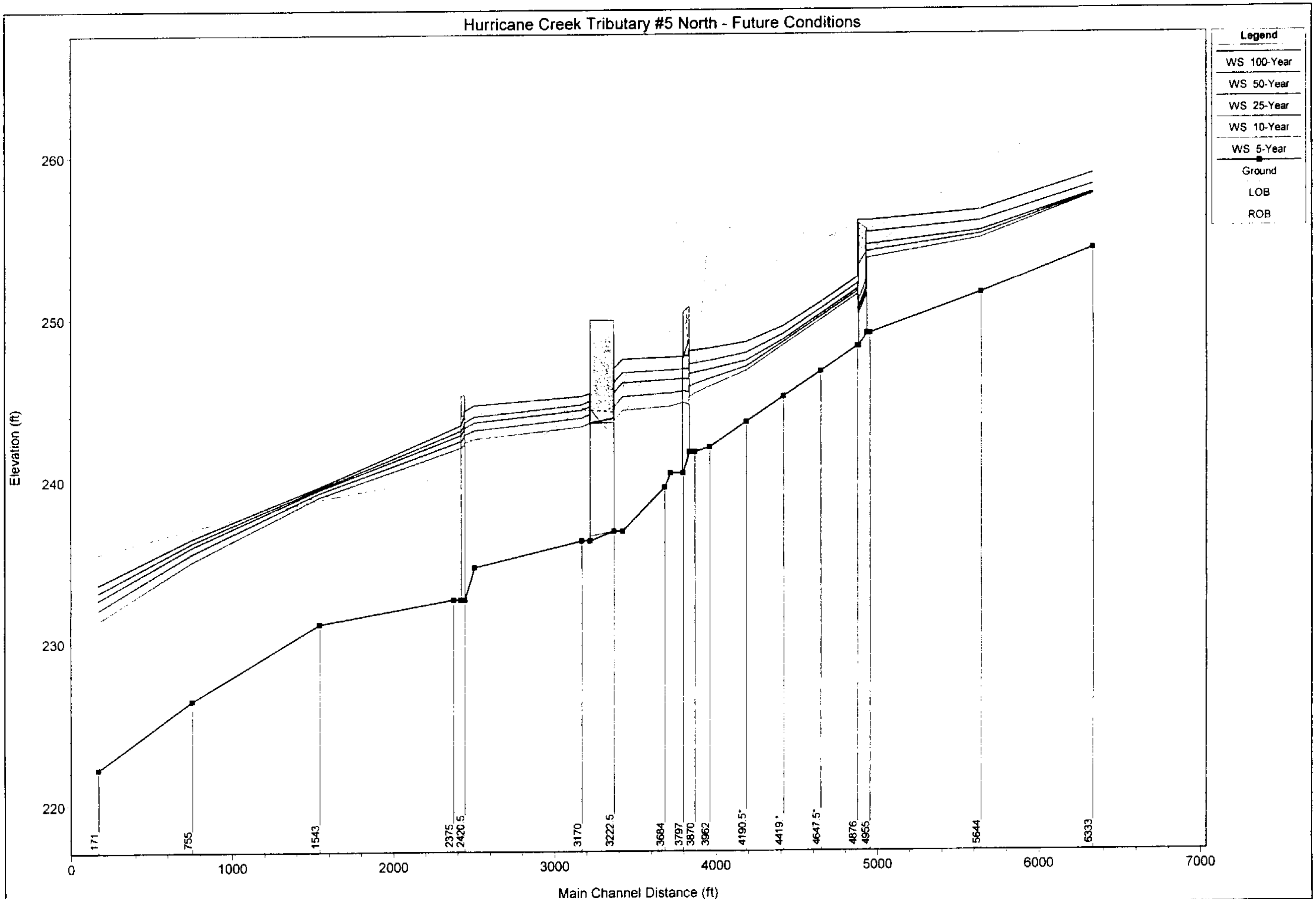
1 in Horiz. = 1000 ft   1 in Vert = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #3 **FUTURE CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* **JOB:** 0565 **DATE:** Dec. 1998 **NO.:** 4.24



1 in Horiz = 600 ft   1 in Vert = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #4 FUTURE CONDITIONS	DODSON & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB: 0565	DATE: Dec. 1998	NO.: 4.25

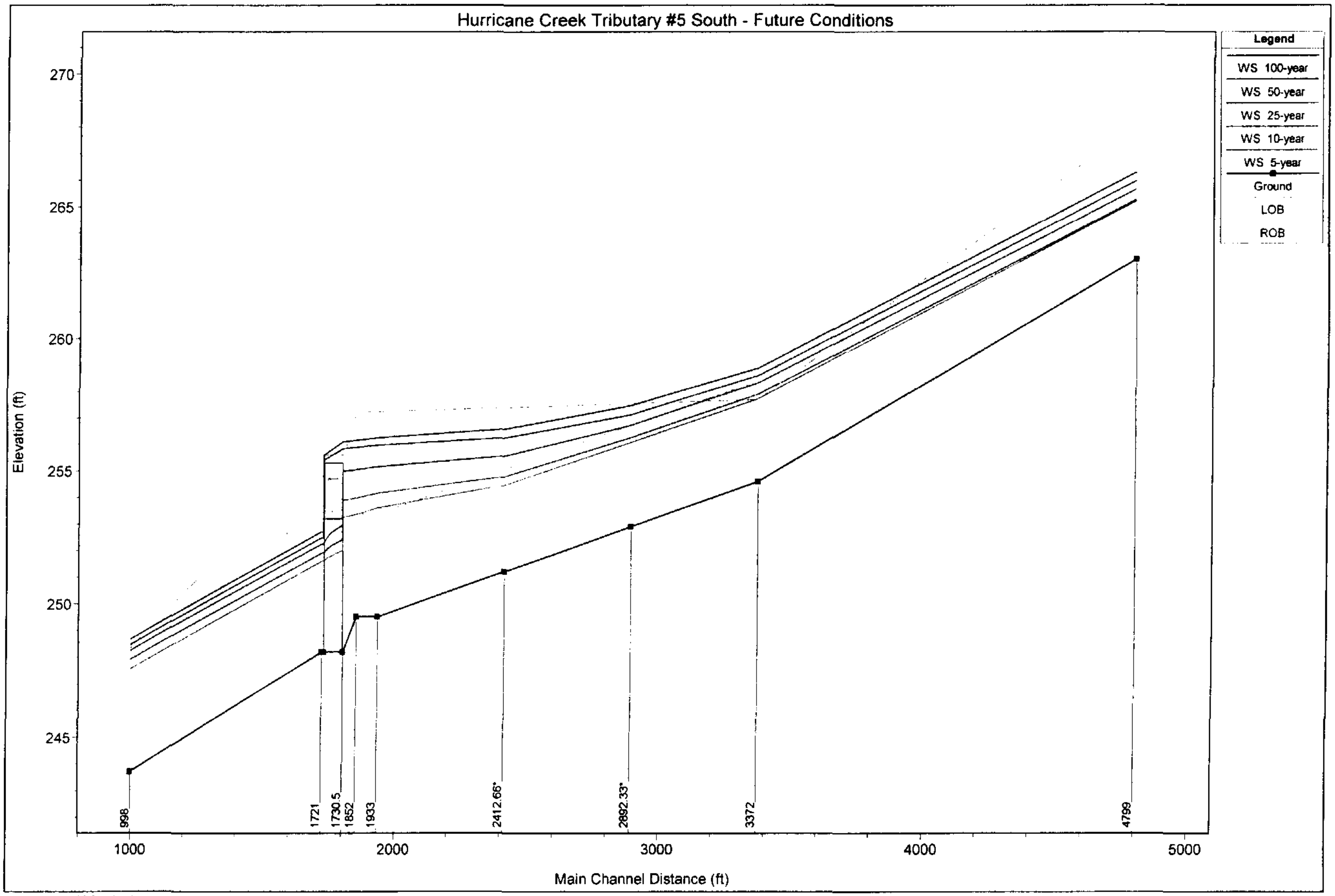


1 in Horiz. = 600 ft 1 in Vert. = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #5 (NORTH)
FUTURE CONDITIONS

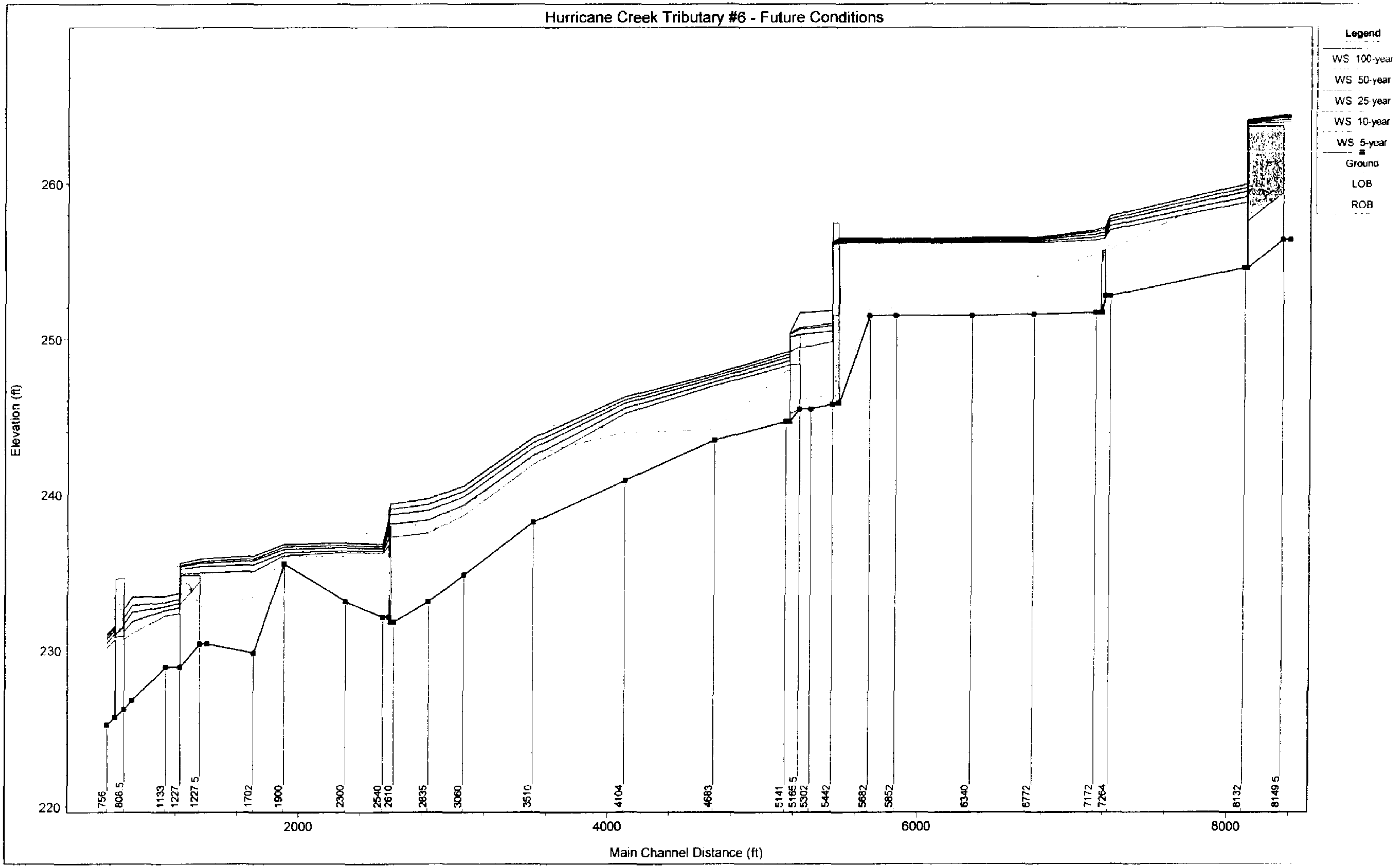
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec 1998	NO.: 4.26a



1 in Horiz. = 400 ft 1 in Vert. = 4 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #5 (SOUTH) FUTURE CONDITIONS	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* JOB: 0565 DATE: Dec. 1998 NO.: 4.26b

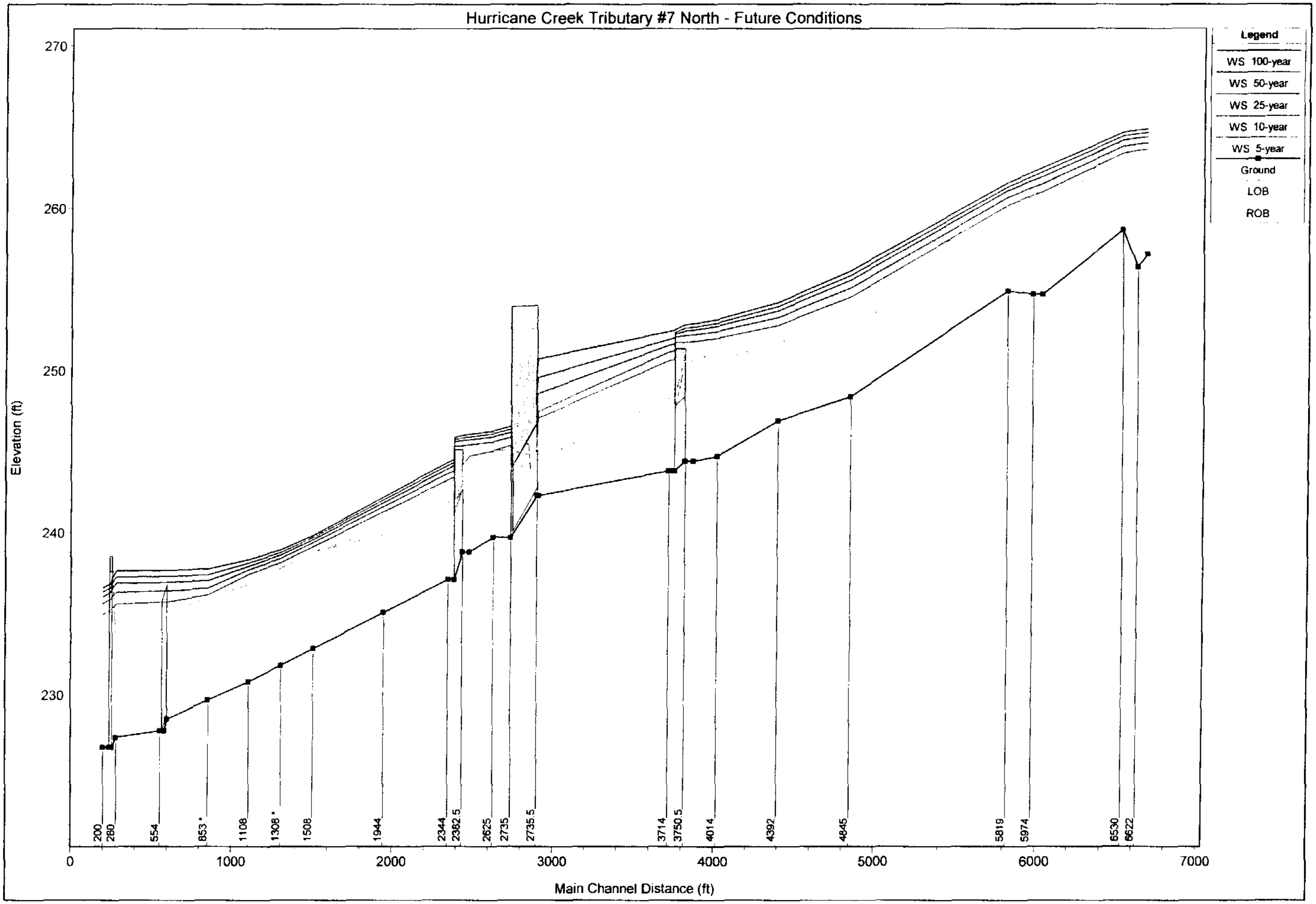


1 in Horiz. = 600 ft 1 in Vert. = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #6
FUTURE CONDITIONS

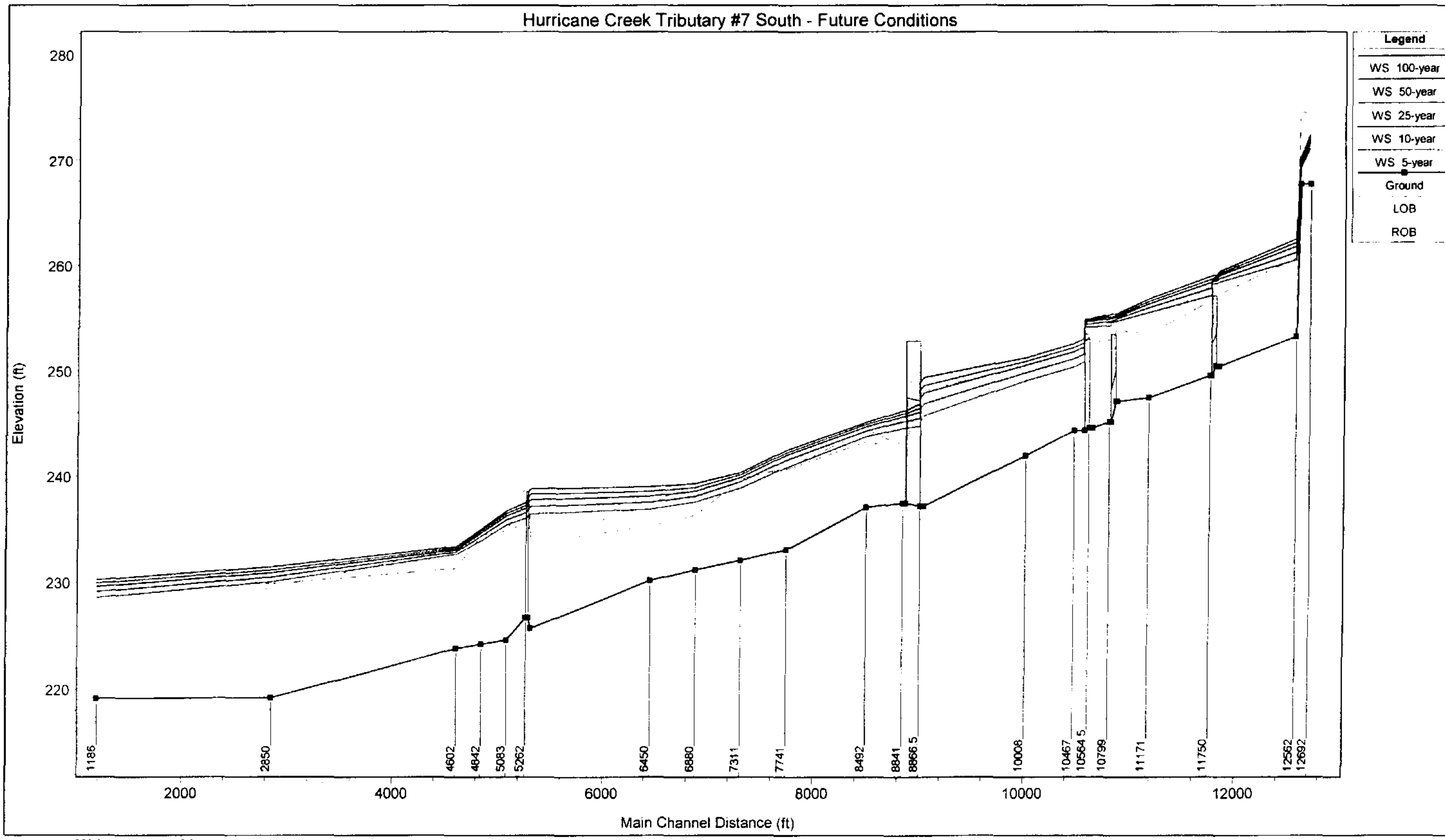
DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec. 1998	NO.: 4.27



1 in Horiz. = 600 ft 1 in Vert. = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #7 (NORTH) **FUTURE CONDITIONS**	**DODSON** & ASSOCIATES, INC. *Hydrologists and Civil Engineers* JOB: 0565 DATE: Dec. 1998 NO.: 4.28a

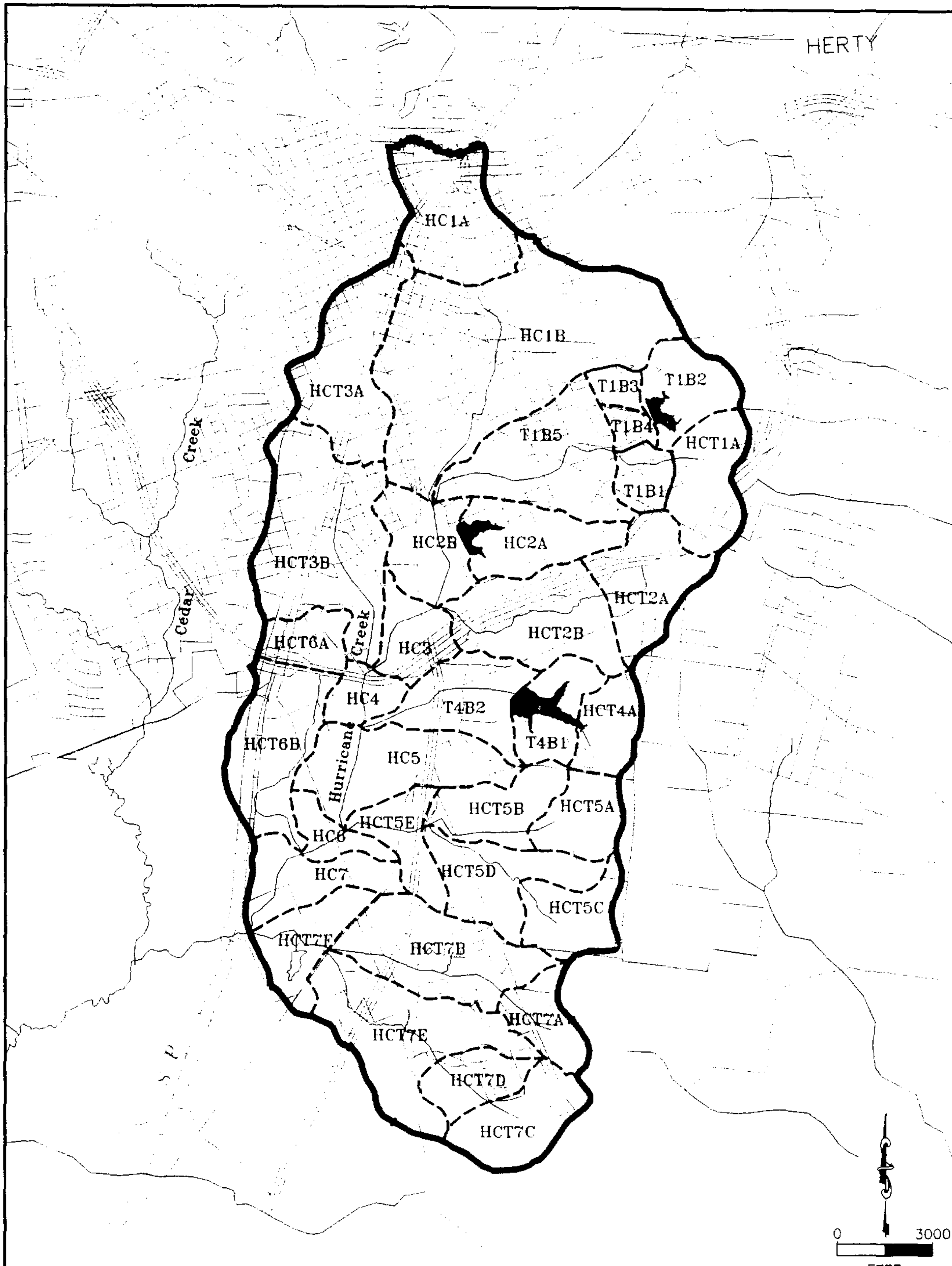


1 in Horiz = 1000 ft   1 in Vert = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #7 (SOUTH)
FUTURE CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec 1998	NO.: 4.28b



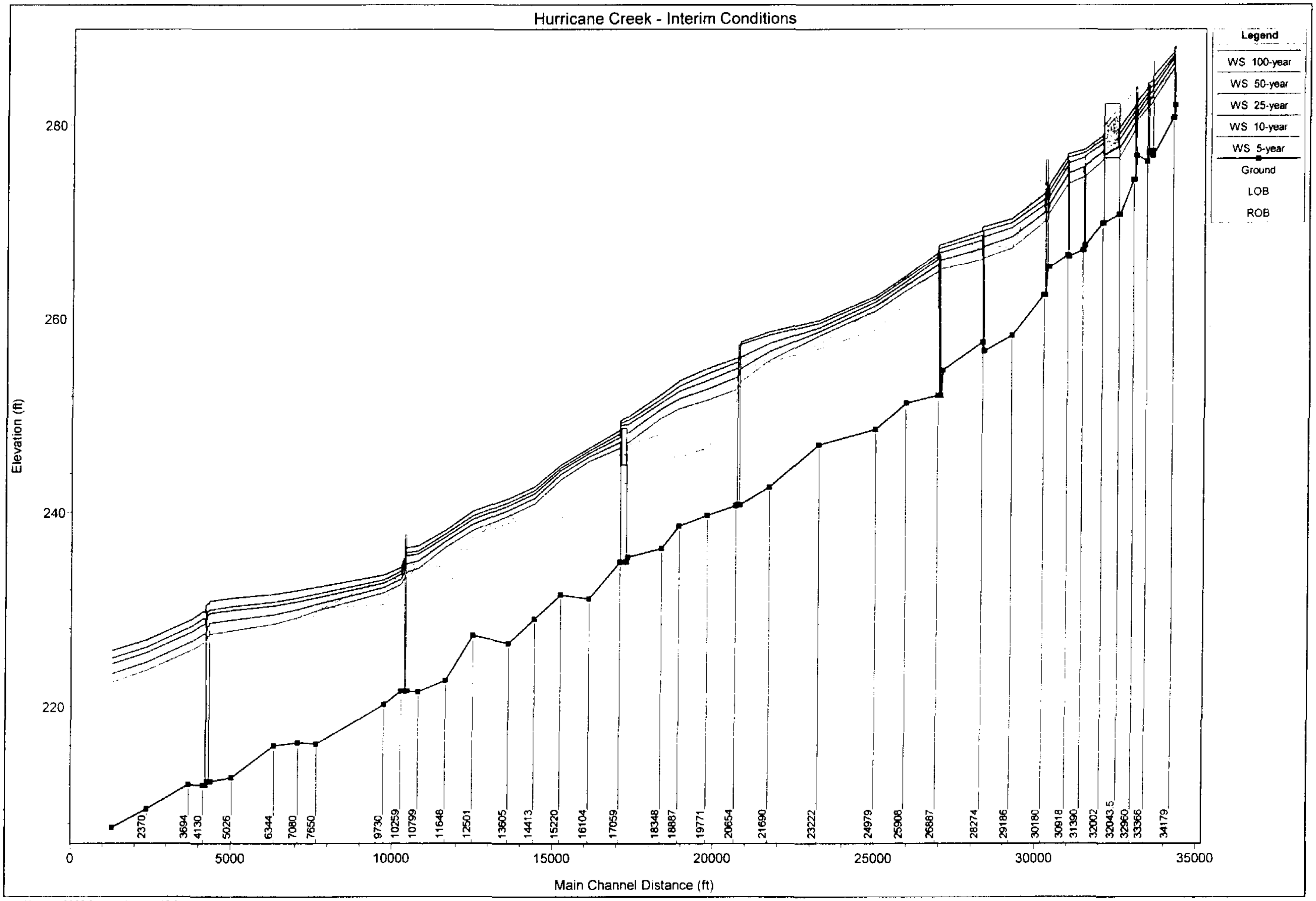
LEGEND:

Regional Detention
Watershed Boundaries
Sub-area Boundaries
City Boundary

DODSON
& ASSOCIATES, INC.
Hydrologists and Civil Engineers

HEC-1 SUB-AREA MAP
INTERIM CONDITIONS
HURRICANE CREEK

JOB	DATE	NO.
0565	JAN. '99	5.1

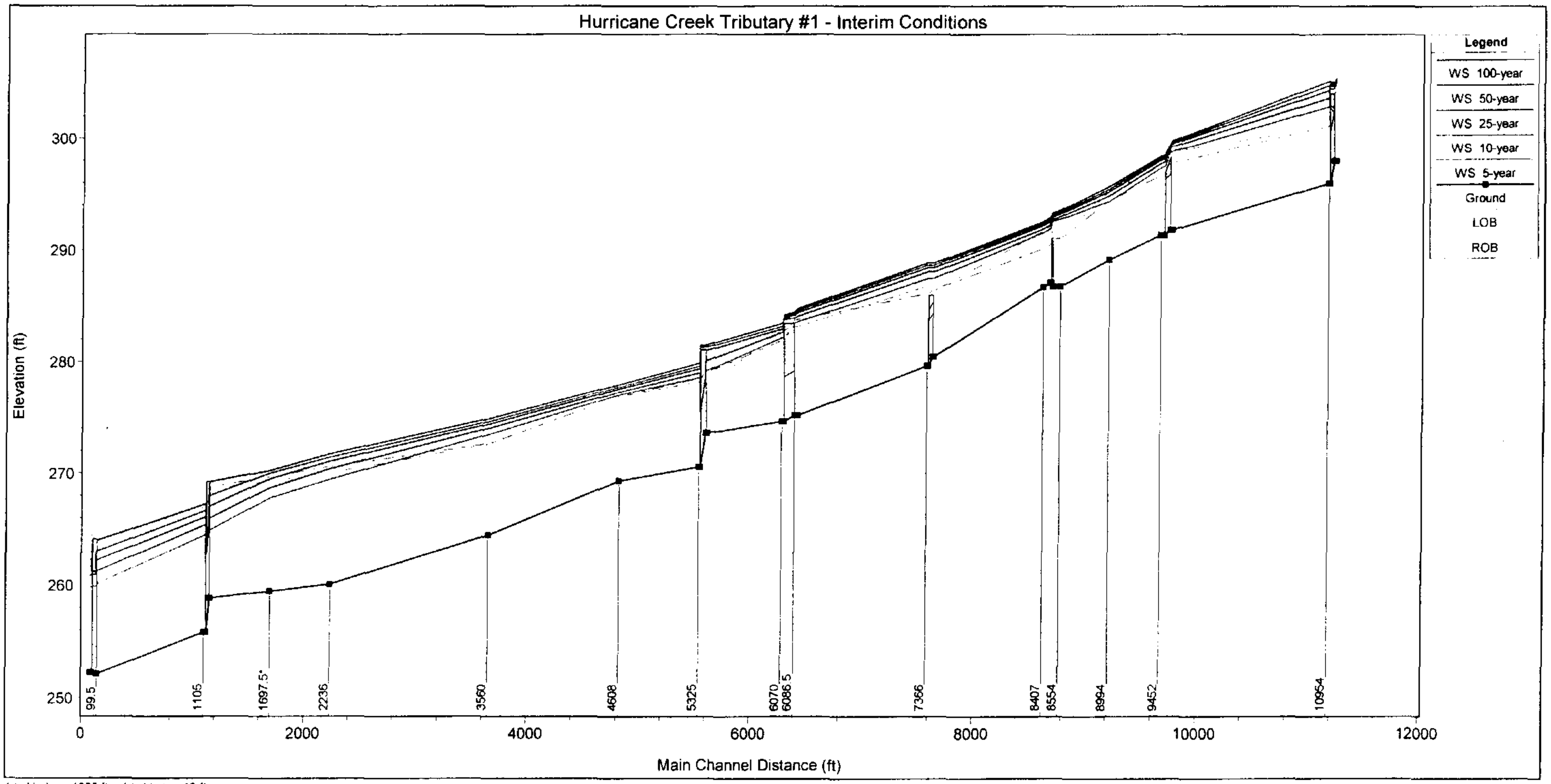


1 in Horiz. = 3000 ft 1 in Vert. = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK
INTERIM CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

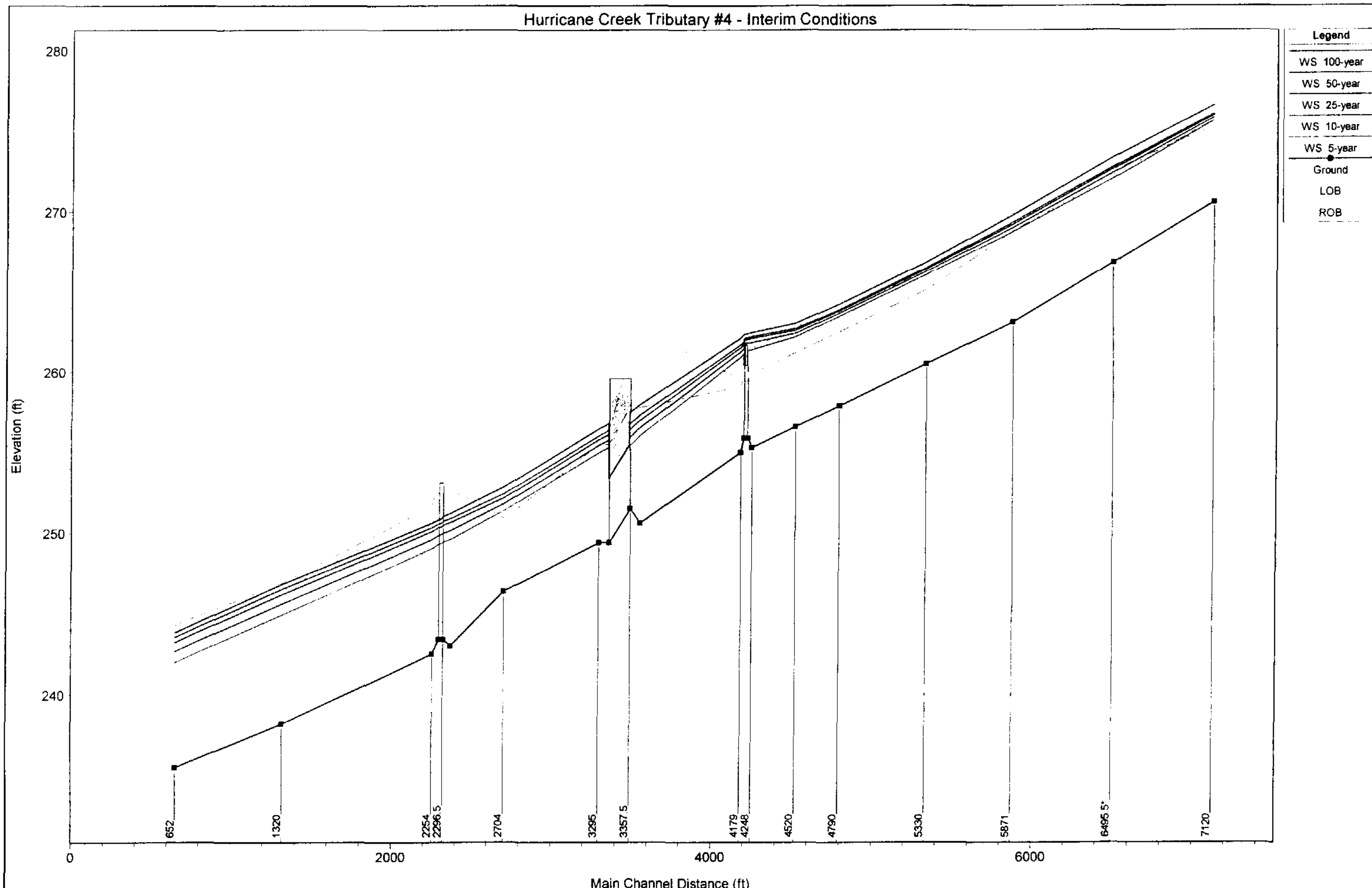
JOB: 0565	DATE: Dec. 1998	NO.: 5.2



1 in Horiz. = 1000 ft 1 in Vert = 10 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #1
INTERIM CONDITIONS

DODSON & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
JOB: 0565	DATE: Dec. 1998	NO.: 5.3

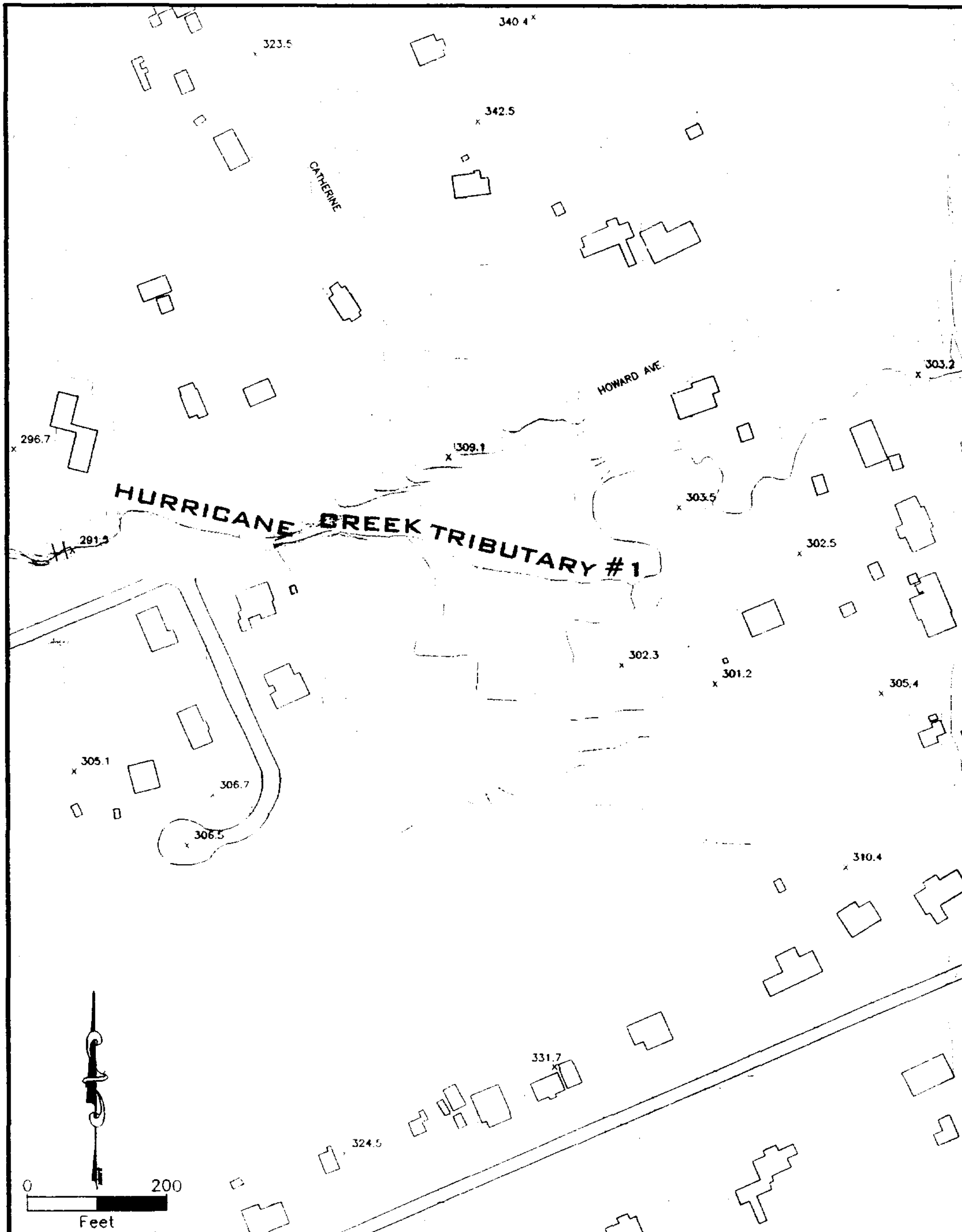


1 in Horiz. = 600 ft 1 in Vert. = 6 ft

COMPUTED STREAM PROFILES FOR HURRICANE CREEK TRIBUTARY #4
INTERIM CONDITIONS

DODSON & ASSOCIATES, INC.
Hydrologists and Civil Engineers

JOB: 0565	DATE: Dec. 1998	NO.: 5.4



REGIONAL DETENTION BASIN #2 HURRICANE CREEK WATERSHED	DODSON & ASSOCIATES, INC. *Hydrologists and Civil Engineers*		
	JOB 0565	DATE DEC. '98	NO. 4.3

IDENTIFICATION OF EXISTING FLOOD HAZARDS AND DEVELOPMENT OF INTERIM AND FUTURE DRAINAGE IMPROVEMENT PLANS FOR THE HURRICANE CREEK WATERSHED
CITY OF LUFKIN
ANGELINA COUNTY, TEXAS

DAI Job No. 0565- Document No. 98/051 Feb. 26, 1999

The following maps are not attached to this report. Due to their size, they could not be copied. They are located in the official file and may be copied upon request.

Dodson & Associates, Inc.
Drainage Improvement Planning Map
Hurricane Creek Watershed Job 0565 - Jan 99 No. 4.1

Interim Conditions Flood Plain and Floodway Boundaries
Hurricane Creek and Tributaries Job 0565 -Jan. 99 No 5.5

City of Lufkin, Texas Angelina County - Panel 5 of 10
Community-Panel Number 480009 0005 B June 1, 1982

City of Lufkin, Texas Angelina County- Panel 10 of 10
Community-Panel Number 480009 0010 C Map Revised: June 3, 1988