APPENDIX A1

HYDROLOGY

GENERAL INFORMATION

Watershed Description

The drainage area of the Trinity River, from its headwaters to the confluence of Five Mile Creek near IH 20 in south Dallas, was evaluated during the development of the Upper Trinity River Feasibility Study (UTRFS). This area, which is commonly referred to as the Upper Trinity River watershed, is approximately 6,275 square miles. It includes the majority of the Dallas-Fort Worth Metroplex. Terrain elevation of this watershed varies from approximately 1,200 feet National Geodetic Vertical Datum (NGVD) at the headwaters of the West Fork of the Trinity River northeast of Olney, Texas, to approximately 380 feet NGVD at the confluence with Five Mile Creek. A general watershed map is included as Plate A-1.

Five U.S. Army Corps of Engineers (USACE) flood control reservoirs are located in the study area. Benbrook Lake, Lewisville Lake, and Grapevine Lake were impounded in the early 1950's. Joe Pool Lake and Ray Roberts Lake were impounded in January 1986 and June 1987. Additional major USACE flood control projects in the study area include the Fort Worth Floodway and Dallas Floodway.

The two largest non-Federal lakes in the study area, Lake Bridgeport and Eagle Mountain Lake, are located on the West Fork of the Trinity River. Lake Bridgeport is located west of Bridgeport in Wise County. Eagle Mountain Lake is located in northwest Tarrant County, upstream from the much smaller Lake Worth, which is owned by the City of Fort Worth. Eagle Mountain Lake has two sets of outlet gates and an emergency spillway. Since it has no dedicated flood control storage, large releases are required during flooding periods. Smaller lakes within the Upper Trinity watershed include: Lake Amon Carter, located on Big Sandy Creek south of Bowie in southwestern Montague County; Lake Weatherford, located on the Clear Fork of the Trinity River northeast of Weatherford in Parker County; Lake Arlington, located on Village Creek in western Arlington in Tarrant County; and Mountain Creek Lake, located on Mountain Creek in Grand Prairie in western Dallas County.

Climatology

The climate in the Upper Trinity River watershed is humid subtropical with hot summers and mild winters. Snowfall and sub-freezing temperatures are experienced occasionally during the winter season. Generally, the winter temperatures are mild with occasional cold periods of short duration resulting from the rapid movement of cold pressure air masses from the northwest polar regions and the continental western highlands. Recorded temperatures at the Dallas-Fort Worth International Airport have ranged from a high of 113°F in June 1980 to a low of -1°F in December 1989. The average annual temperature over the watershed varies from 64°F at Bridgeport in the northwest extremity of the watershed to 66°F at DFW International Airport. The mean annual relative humidity for the DFW Metroplex is about 65 percent. The average annual precipitation over the watershed varies from about 30 inches at Jacksboro, in the northwest extremity of the watershed, to about 32 inches in the DFW Metroplex. The extreme annual precipitation amounts since 1887 include a maximum of 53.54 inches in 1991 at the Dallas-Fort Worth International Airport and a minimum of 17.91 inches in 1921 at Fort Worth. The maximum recorded precipitation in a 24-hour period was 9.57 inches at Fort Worth on September 4-5, 1932. A large part of the annual precipitation results from thunderstorm activity, with occasional very heavy rainfall over brief periods of time. Thunderstorms occur throughout the year, but are more frequent in the late spring and early summer. The average length of the warm season (freeze-free period) in the DFW Metroplex is about 249 days, extending from mid-March to mid-November.

MODEL DEVELOPMENT

Baseline/Existing Conditions Model

A watershed runoff model for the area was developed utilizing the USACE computer program HEC-1. The drainage area was divided into 110 sub-areas in order to be responsive to the timing of each major tributary's runoff contribution to the total flood hydrograph, and also to obtain detailed flow information (flood hydrographs) at all major points of interest on the Clear Fork, West Fork, Elm Fork, and the main stem of the Trinity River. Plate A-1 shows the sub-area arrangement. A one-hour computation time interval was used in the model. Each reservoir having flood control storage was assumed to be at conservation pool level at the start of the hypothetical, frequency related storms/floods and at a level corresponding at which one-third of the full flood control pool (except at Lewisville Lake, which was started at 89 percent full) would already be occupied at the start of the USACE Standard Project Flood (SPF). All reservoirs without flood control storage were assumed to be at normal (conservation pool) levels at the start of all storm/flood events. Lake Bridgeport, Eagle Mountain Lake, Lake Worth, and Lake Arlington were assumed to reside at a level corresponding to 2-feet, 3-feet, 2-feet, and 3-feet, respectively, above normal (conservation pool) level at the start of the SPF event.

Model Calibration

The Upper Trinity River Feasibility Study HEC-1 model was calibrated by reproducing the significant historical flood hydrographs of May-June 1989, April-May 1990, and December 1991. Initial abstractions, infiltration rates, and Snyder’s unit hydrograph parameters (lag time and peaking coefficient) were adjusted in order to generate computed hydrographs that would reasonably match the observed flood hydrographs at the streamflow gages and lakes (inflow) throughout the basin. Additionally the Muskingum parameters of travel time, attenuation and number of routing steps (in both the Muskingum and modified Puls routing methods) were adjusted during the calibration efforts. The results of the flood hydrograph reproductions for the May-June 1989, April-May 1990, and December 1991 events were tabulated and compared with the results of hydrograph reproductions for the October 1974, March 1977, October-November 1981, and May 1982 events, as published in the Upper Trinity River Reconnaissance Study May 1990. The results of these analyses for the seven storm/flood reproductions were used to assign each of the specific parameters noted above.

The model was further calibrated by adjusting infiltration rates, within reasonable limits, in order to match as closely as possible the peak values of eight different frequency related flood peaks, based on analyses of historical peaks at six streamflow gaging stations. These streamflow gaging sites include the Clear Fork of the Trinity River at Fort Worth, the West Fork of the Trinity River at Fort Worth, the West Fork of the Trinity River at Grand Prairie, the Elm Fork of the Trinity River near Carrollton, the Trinity River at Dallas, and the Trinity River below Dallas. The target values of the peak flows for hypothetical frequency related floods at any particular gage were determined by performing a flood flow frequency analysis from the record of flows at that gage. The time period covered by the gage record of flows was selected to extend from water year 1953 through water year 1992. Water year 1953 was used as the starting point since all of the major flood control reservoirs, except Joe Pool Lake and Ray Roberts Lake, were in place by 1952. Water year 1992 was used as the cut-off point for the statistical analyses since the last significant flood events on the major branches and the main stem of the Trinity River occurred in December 1991 (water year 1992). It should be noted that the degree of urbanization and conditions of available valley storage changed gradually, but significantly throughout this gaging period, therefore, a direct (perfect) calibration would not necessarily represent present day or projected baseline conditions. The flood flow frequency analysis was performed using the procedures described in "Guidelines for Determining Flood Flow Frequency, Bulletin No. 17B, Revised September 1981", and using USACE Southwestern Division's skew criteria. The USACE computer program HEC-FFA (May 1992) was used to statistically estimate the frequency versus discharge relationship at each of the investigated gaging sites. A graphical representation of these statistical frequency curves is presented on Plates A-2 through A-7.

Stream Gages

There are two USGS stream gages within the Central City study area (located within the Fort Worth Floodway). Pertinent data for these gages are as follows:

Gage	Clear Fork at Fort Worth 08047500	West Fork at Fort Worth 08048000
Location	On left bank at Fort Worth pumping station, 830 feet upstream of IH 30	On left bank 125 feet upstream of Nutt Dam, 980 feet downstream of North Main Street
Drainage area	518 sq. mi.	2615 sq. mi.
Period of record	March 1924 to current year	October 1920 to current year
Gage datum	532.91 feet	519.24 feet

Model Rainfall

The hypothetical precipitation for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year frequency storms was developed using data from the National Weather Service (NWS) "Technical Paper 40 (TP40)" and the National Oceanic and Atmospheric Administration (NOAA) Memorandum "NWS Hydro-35". Precipitation for the 500-year frequency storm was computed by extrapolation. Figure 15 of TP40, Depth-Area-Duration curves, was used to adjust the point rainfall to representative average values over the contributing watershed size at each point of interest. One-hour computation time intervals were used with 24-hour storm duration for each of the frequency related storm events. As an example, the point rainfall amounts for the 24-hour duration storms, with the storm center positioned approximately at the streamflow gage for the West Fork of the Trinity River at Grand Prairie, are as follows: 1-year, 3.20 inches; 2-year, 4.00 inches; 5-year, 5.38 inches; 10-year, 6.43 inches; 25-year, 7.54 inches; 50-year, 8.55 inches; 100-year, 9.55 inches; and 500-year, 13.10 inches. The area-adjusted 100-year frequency storm rainfall distribution is presented in Table A-1.

The Standard Project Storm (SPS) was assumed to have a total rainfall amount equal to 50 percent of the Probable Maximum Storm (PMS) rainfall amount, as adjusted in accordance with USACE Hydrometeorological Report Number 52 (HMR 52). The PMS precipitation (commonly referred to as the PMP) was determined in accordance with the method described in HMR 51, dated June 1978, Subject: "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," and HMR 52", dated August 1982, Subject: "Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian." The computer program used to develop the SPS was the USACE HMR52. The SPS duration was 72 hours. Four separate elliptical storm positions were used to obtain critical centerings on the West Fork, Clear Fork, Elm Fork, and on the main stem of the Trinity River. One of these storm centers was critically centered for the Trinity River at Dallas streamflow gage, for which the dominant major storm axis orientation from HMR52 is 220 degrees bearing and the critical storm orientation angle is 246 degrees bearing. The average SPS precipitation over the 6,275 square miles of drainage area is 5.64 inches. This average precipitation is based on a critical centering of the hypothetical elliptical SPS at Hurst, in northeastern Tarrant County. As an example, the SPS rainfall amount for sub-area 50, located near the storm center, is 19.52 inches. The SPS rainfall distribution for that sub-area is presented in Table A-2.

Initial Abstractions and Infiltration Rates

The rainfall loss values were assumed to vary with the frequency of each storm event and the nature of the soil surface. The USACE Fort Worth District standard values are presented in Table A-3. Data on soils was obtained using generalized soils maps from the USDA Natural Resources Conservation Service, which had been linked electronically with the detailed sub-basin layout mapping in a Geographic Information System (GIS). The percent sand for each sub-area was determined by first assigning a value to each soil type and then weighting the value for each applicable soil type in proportion to the area of each soil type in a particular sub-area. Engineering judgment was used for some sub-areas to override the percent sand values obtained by the GIS. The initial abstraction and infiltration rate for each sub-area was weighted in accordance with the previously tabulated values for clayey (zero percent sand) and sandy (100 percent sand) soils.

Comparisons were made between the frequency versus discharge relationships determined based on the statistical analysis of historical data at the major streamflow gages and those based on results of the HEC-1 modeling. Adjustments were made to the rainfall losses at some sub-areas in order to produce a better correlation. The adjusted values were then used in this study. The loss rates for the SPF event varied regionally and were identical to those used in the Upper Trinity River Reconnaissance Study.

Development of Unit Hydrographs

Unit hydrographs for the sub-areas above Eagle Mountain Lake, Benbrook Lake, Grapevine Lake, and Lewisville Lake were based on the adopted Snyder's lag times and peaking coefficients obtained through the historical flood hydrograph reproductions of the May-June 1989, April-May 1990, and December 1991 events. Previously developed relationships between measurable sub-basin parameters and Snyder's unit hydrograph lag time, for both clayey and sandy soils, with consideration for the degree of urbanization, were used for the smaller, more urban sub-areas within the HEC-1 model, downstream of the lakes.

Land use data for year 2000 baseline conditions were obtained from the North Central Texas Council of Governments (NCTCOG). This data and a table correlating land use to percent urbanization and percent imperviousness was incorporated into the GIS. Net values of these parameters at each sub-area were derived from the GIS by weighting the land uses within each sub-area by the default values associated with each land use.

The Snyder's unit hydrograph lag time (time-to-peak) was developed for each small, urban sub-area using methodology described in "Synthetic Hydrograph Relationships, Trinity River Tributaries, Fort Worth-Dallas Urban Area" by T. L. Nelson, 1970. These mathematical relationships, which are referred to as Urbanization Curves, are available for both Cross Timbers sandy loam and Blackland Prairie clay dominated watersheds in the general vicinity of the DFW Metroplex. The geographical characteristics of each sub-area, including the length of the major stream (L), the distance from the sub-area outflow point to the location of the sub-area centroid (L_{ca}), the weighted slope (S_{st}) of the major stream, and the percent urbanization comprise the data used in the equations to determine the Snyder's lag time for the two general extremes of soil type. The Snyder's lag for each sub-area was then generated mathematically from the Cross Timbers Sandy Loam and Blackland Prairie Clay Urbanization Curves through direct interpolation, based on the percentage of each soil type within that sub-area. The sub-basin parameters (both measured and computed) for year 2000 baseline conditions are presented in Table A-4.

Routing Procedures

The modified Puls routing method was used along the reaches downstream of Lake Worth, Benbrook Lake, Grapevine Lake, and Lewisville Lake. The valley storage versus discharge relationships were based on the UTRFS calibrated backwater models, using 1991 2-foot contour interval topography along the Clear Fork, West Fork, Elm Fork, and the main stem of the Trinity River. The modified Puls routing method was also used along the reach of Denton Creek below Grapevine Lake, however, the valley storage versus discharge relationships were based on HEC-2 backwater analyses developed in the 1985 Denton County Flood Insurance Study.

The Muskingum routing method was generally used along the reaches upstream from Lake Worth, Benbrook Lake, and Lewisville Lake. The Muskingum routing method and number of routing steps (in both the Muskingum and modified Puls routing methods) were calibrated by reproducing the historical flood hydrographs of May-June 1989, April-May 1990, and December 1991.

Future Conditions Model

The hydrologic model used for Future Conditions for this study is the current Corridor Development Certificate (CDC) model for the West Fork of the Trinity River.

"The CDC Manual and Program affirm local government authority for local floodplain management while establishing a set of common permit criteria and procedures for development within the Trinity River Corridor." [1]

The Trinity River Steering Committee, consisting of local elected official from jurisdictions in the Trinity River Corridor, approved the first edition of the CDC manual 23 May 1991. Within the next two years, the participating communities (Arlington, Carrollton, Coppell, Dallas, Farmers Branch, Fort Worth, Grand Prairie, Irving, Lewisville) officially amended their floodplain ordinances to adopt the CDC common permitting criteria and process. In the CDC process, the CDC Model is considered the design model for proposed development projects in the Trinity River Corridor. The CDC Model was developed as part of the Upper Trinity River Feasibility Study. The CDC Model is the design model used for analysis of proposed floodplain development projects within the Upper Trinity River corridor.

The Existing Conditions calibration model was used as the base model in the development of the CDC Model. The major difference in the two models is the land use data of the drainage areas - the CDC Model uses 2050 land use. Land use data for year 2050 conditions were obtained from the North Central Texas Council of Governments (NCTCOG). This data and a table correlating land use to percent urbanization and percent imperviousness was incorporated into the GIS for the study area. Net values of these parameters at each sub-area were derived from the GIS by weighting the land uses within each sub-area by the default values associated with each land use. The sub-basin parameters (both measured and computed) for year 2050 conditions are presented in Table A-5. West Fork and Clear Fork frequency flood event discharges are shown on Table A-6 and Table A-7.

Revised Project Conditions Model

A revision to the CDC Model was developed to represent the recent modification to the Fort Worth Floodway (dredging and channel clearing maintenance operations, Beach Street Dam, Fourth Street Dam). Storage-discharge routing computed by the study HEC-RAS model data was input in the basin future conditions HEC-1 model. Revised peak discharges for the 100-year and SPF events were computed for use for this study to more accurately represent a current baseline condition for comparison to the proposed project conditions. The revised project discharges are listed in Tables A-6 and A-7).

[1] Corridor Development Certificate Manual – 3rd Edition 2002

Table A-1
100-Year Frequency Storm Rainfall Distribution

Time (hour)	Rainfall (inch)
1	0.09
2	0.10
3	0.11
4	0.12
5	0.13
6	0.14
7	0.21
8	0.24
9	0.28
10	0.38
11	0.50
12	1.04
13	2.79
14	0.62
15	0.43
16	0.31
17	0.26
18	0.23
19	0.15
20	0.13
21	0.12
22	0.11
23	0.10
24	0.10
Total	8.69

Table A-2
Standard Project Storm (SPS) Rainfall Distribution for Sub-area 50

Time (hour)	Rainfall (inch)	Time (hour)	Rainfall (inch)	Time (hour)	Rainfall (inch)
1	0.05	5	0.07	49	0.89
2	0.05	26	0.07	50	1.42
3	0.05	27	0.07	51	2.00
4	0.05	28	0.07	52	3.64
5	0.05	29	0.07	53	1.78
6	0.05	30	0.07	54	1.26
7	0.05	31	0.10	55	0.29
8	0.05	32	0.10	56	0.26
9	0.05	33	0.10	57	0.23
10	0.05	34	0.10	57	0.22
11	0.05	35	0.10	59	0.20
12	0.05	36	0.10	60	0.19
13	0.06	37	0.14	61	0.12
14	0.06	38	0.14	62	0.12
15	0.06	39	0.15	63	0.12
16	0.06	40	0.16	64	0.12
17	0.06	41	0.17	65	0.12
18	0.06	42	0.18	66	0.12
19	0.06	43	0.32	67	0.08
20	0.06	44	0.35	68	0.08
21	0.06	45	0.39	69	0.08
22	0.06	46	0.45	70	0.08
23	0.06	47	0.52	71	0.08
24	0.06	48	0.60	72	0.08
				Total	**19.52**

Table A-3
Standard Rainfall Losses

Recurrence Interval (year)	Annual Exceedance Probability (%)	Clayey Soil		Sandy Soil	
		Initial Abstraction (inch)	Infiltration Rate (inch/hour)	Initial Abstraction (inch)	Infiltration Rate (inch/hour)
1	NA	1.35	0.18	1.89	0.23
2	50	1.20	0.16	1.68	0.21
5	20	1.30	0.16	1.80	0.21
10	10	1.12	0.14	1.50	0.18
25	4	0.95	0.12	1.30	0.15
50	2	0.84	0.10	1.10	0.13
100	1	0.75	0.07	0.90	0.10
500	0.2	0.50	0.05	0.60	0.08

Table A-4
Sub-basin Parameters for Baseline Conditions (Year 2000)

Sub-area Number	Drainage Area (sq. mi.)	C_t	t_{pR} (hour)	C_p	Q_{pR} (cfs)	Percent Sand (%)	Urban-ization (%)	Imperv-iousness (%)
1	683.00	2.3	18.00	.35	8785	100	<1	<1
2	149.25	1.7	9.00	.35	3805	100	2	1
3	97.78	1.4	8.00	.35	2785	100	7	4
4	160.97	1.3	6.00	.35	6047	100	4	2
5	20.00		**		12907			
6	71.17	1.6	7.00	.66	4370	100	8	4
7	97.46	1.6	6.00	.66	6927	100	5	3
8	2.34		**		1510			
9	69.90	2.0	10.00	.66	3045	100	2	1
10	90.10	1.8	9.00	.66	4346	100	5	3
11	73.20	1.8	7.00	.66	4495	100	2	<1
12	209.83	1.7	9.00	.66	10120	97	2	<1
13	55.65	1.5	5.00	.66	4734	75	3	2
14	47.52	1.2	3.00	.66	6567	20	8	6
15	127.45	1.6	8.00	.66	6885	100	7	5
16	14.38		**		9280			
17	13.60	***	0.82	.70	4170	30	22	15
18	74.84	***	4.82	.70	6970	50	9	7
19	5.56		**		3588			
20	20.99	***	3.55	.70	2609	60	57	36
21	107.11	1.6	8.00	.70	6155	100	1	1
22	1.89		**		1220			
23	142.38	1.8	13.00	.70	5056	100	3	2
24	62.47	1.3	6.00	.70	4719	89	2	1
25	33.61	1.2	5.00	.70	3023	80	2	<1
26	33.94	0.9	3.00	.70	4963	24	5	3
27	39.11	***	2.37	.70	7548	80	3	2
28	5.89		**		3801			
29	8.45	***	1.63	.70	2121	50	30	17
30	54.70	***	3.90	.60	5365	10	14	8
31	24.56	***	1.70	.70	5920	40	69	42
32	3.96	***	0.94	.70	1278	40	70	56
33	0.40	***	0.87	.70	129	40	70	54
34	8.91	***	1.16	.70	2875	5	10	6
35	0.38		**		245			
36	13.71	***	1.24	.70	4321	0	53	34
37	10.89	***	1.85	.70	2440	40	67	47
38	37.33	***	2.53	.70	6375	10	59	37
39	18.25	***	1.86	.70	4082	40	60	39
40	18.45	***	2.35	.70	3384	5	42	30

Sub-area Number	Drainage Area (sq. mi.)	C_t	t_{pR} (hour)	C_p	Q_{pR} (cfs)	Percent Sand (%)	Urban-ization (%)	Imperv-iousness (%)
41	54.70	***	3.97	.70	6111	1	24	15
42	11.30	***	3.39	.70	1484	30	29	20
43	114.76	***	6.73	.70	7715	50	16	10
44	14.42	***	1.36	.70	4197	60	62	40
45	10.38	***	1.64	.70	2589	100	73	42
46	3.44		**		2220			
47	48.63	***	5.51	.70	3981	90	48	29
49	1.79	***	1.53	.70	474	30	36	23
50	27.29	***	3.05	.70	3936	60	59	38
51	29.47	***	4.97	.70	2660	70	48	35
52	21.60	***	3.47	.70	2756	65	69	51
53	2.85	***	0.78	.70	920	10	60	39
54	4.12	***	1.40	.70	1172	5	46	31
55	83.16	***	9.10	.70	4200	90	37	20
56	9.64	***	3.44	.70	1243	80	37	27
57	8.85	***	2.33	.70	1636	5	30	23
58	33.00	***	3.08	.70	4745	0	9	7
59	68.00	***	6.51	.70	4742	85	11	7
60	77.08	***	2.72	.70	12257	7	9	6
61	42.25	***	1.62	.70	10663	8	9	6
62	11.67		**		7531			
63	30.58	***	2.49	.70	5301	5	34	20
64	17.84	***	1.39	.70	5104	5	57	40
65	10.35	***	1.13	.70	3340	5	24	14
66	4.23		**		2730			
67	9.00	***	1.32	.70	2697	5	36	26
68	9.23	***	2.38	.70	1663	75	75	47
69	110.00	1.5	7.00	.70	7157	100	1	<1
70	164.00	1.2	7.00	.70	10670	91	1	<1
71	58.00	1.0	4.00	.70	6453	54	2	2
72	68.00	.94	4.00	.70	7565	12	<1	<1
73	61.32	1.0	5.00	.70	5516	23	1	<1
74	36.86	1.4	5.00	.70	3316	5	6	4
75	102.44	1.6	7.00	.70	6665	0	4	3
76	83.01	1.4	4.00	.70	9235	80	14	9
77	11.37		**		7337			
78	23.63	***	4.02	.70	2625	25	24	15
79	295.00	1.9	16.00	.794	9717	74	2	2
80	55.34	1.9	9.50	.794	3032	24	4	3
81	275.10	1.9	14.28	.794	10105	50	3	3
82	92.80	1.9	*	.794	15714	25	2	1
83	145.60	1.9	8.04	.794	9373	86	2	2

Sub-area Number	Drainage Area (sq. mi.)	C_t	t_{pR} (hour)	C_p	Q_{pR} (cfs)	Percent Sand (%)	Urban-ization (%)	Imperv-iousness (%)
84	45.86		**		29595			
85	37.60	1.9	7.00	.794	2767	80	1	<1
86	221.61	1.9	*	.794	18397	50	11	8
87	75.50	1.4	9.00	.794	4371	21	2	1
88	236.71	1.9	*	.794	37998	50	5	3
89	46.24		**		29840			
90	19.95	***	3.33	.70	2639	15	24	16
91	15.93	***	2.43	.70	2826	0	19	12
92	24.98	***	5.24	.70	2155	80	26	16
93	19.51	***	1.76	.70	4567	0	45	29
94	12.81	***	1.37	.70	3707	0	52	37
95	15.22	***	2.27	.70	2885	5	42	28
96	13.70	***	1.21	.70	4403	0	68	51
97	24.12	***	1.88	.70	5346	0	48	30
98	21.62	***	1.09	.70	6976	0	67	48
99	12.59	***	1.01	.70	4062	0	87	49
100	5.12	***	0.74	.70	1652	40	55	42
101	2.95	***	1.12	.70	592	0	76	56
102	6.03	***	0.81	.70	1946	0	75	52
103	98.25	***	3.67	.70	11794	0	62	40
104	1.75		**		1129			
105	32.99	***	2.39	.70	5921	0	63	39
106	22.43	***	1.98	.70	4796	5	66	41
107	12.10	***	1.62	.70	3054	5	37	27
108	60.72	***	2.79	.70	9420	0	42	27
109	45.56	1.9	*	.794	18637	100	3	3
110	33.80	1.9	7.67	.794	2282	100	5	5
111	53.28	1.9	*	.794	24782	74	2	2

* A composite unit hydrograph was made from combining numerous sub-area unit hydrographs.

** A 1-hour instantaneous unit hydrograph was used for the lake surface area.

*** A C_t value was not required. Urbanization curve methodology was used.

Table A-5
Sub-basin Parameters for Future Conditions - CDC Model (Year 2050)

Sub-area Number	Drainage Area (sq. mi.)	C_t	t_{pR} (hour)	C_p	Q_{pR} (cfs)	Percent Sand (%)	Urban-ization (%)	Imperv-iousness (%)
1	683.00	2.3	18.00	.35	8785	100	<1	<1
2	149.25	1.7	9.00	.35	3805	100	2	1
3	97.78	1.4	8.00	.35	2785	100	7	4
4	160.97	1.3	6.00	.35	6047	100	4	2
5	20.00		**		12907			
6	71.17	1.6	7.00	.66	4370	100	8	4
7	97.46	1.6	6.00	.66	6927	100	5	3
8	2.34		**		1510			
9	69.90	2.0	10.00	.66	3045	100	2	1
10	90.10	1.8	9.00	.66	4346	100	5	3
11	73.20	1.8	7.00	.66	4495	100	2	<1
12	209.83	1.7	9.00	.66	10120	97	2	<1
13	55.65	1.5	5.00	.66	4734	75	3	2
14	47.52	1.2	3.00	.66	6567	20	23	16
15	127.45	1.6	8.00	.66	6885	100	21	15
16	14.38		**		9280			
17	13.60	***	0.77	.70	4388	30	32	22
18	74.84	***	4.43	.70	7561	50	23	16
19	5.56		**		3588			
20	20.99	***	3.47	.70	2678	60	60	39
21	107.11	1.6	8.00	.70	6155	100	1	1
22	1.89		**		1220			
23	142.38	1.8	13.00	.70	5056	100	19	13
24	62.47	1.3	6.00	.70	4719	89	19	13
25	33.61	1.2	5.00	.70	3023	80	18	13
26	33.94	0.9	3.00	.70	4963	24	20	13
27	39.11	***	2.14	.70	8291	80	20	13
28	5.89		**		3801			
29	8.45	***	1.52	.70	2248	50	42	25
30	54.70	***	3.60	.60	5751	10	28	18
31	24.56	***	1.61	.70	6234	40	78	48
32	3.96	***	0.93	.70	1278	40	72	58
33	0.40	***	0.87	.70	129	40	70	55
34	8.91	***	1.06	.70	2875	5	24	16
35	0.38		**		245			
36	13.71	***	1.19	.70	4424	0	60	39
37	10.89	***	1.80	.70	2497	40	71	50
38	37.33	***	2.44	.70	6595	10	65	41
39	18.25	***	1.76	.70	4272	40	68	45
40	18.45	***	2.21	.70	3549	5	52	37

Sub-area Number	Drainage Area (sq. mi.)	C_t	t_{pR} (hour)	C_p	Q_{pR} (cfs)	Percent Sand (%)	Urban-ization (%)	Imperv-iousness (%)
41	54.70	***	3.65	.70	6604	1	38	24
42	11.30	***	3.15	.70	1570	30	41	28
43	114.76	***	6.18	.70	8439	50	29	20
44	14.42	***	1.31	.70	4349	60	67	43
45	10.38	***	1.58	.70	2675	100	79	46
46	3.44		**		2220			
47	48.63	***	4.91	.70	4451	90	67	40
49	1.79	***	1.45	.70	496	30	45	29
50	27.29	***	2.81	.70	4205	60	73	47
51	29.47	***	4.40	.70	2999	70	67	50
52	21.60	***	3.29	.70	2882	65	77	58
53	2.85	***	0.76	.70	920	10	65	43
54	4.12	***	1.33	.70	1227	5	54	37
55	83.16	***	8.48	.70	4498	90	49	28
56	9.64	***	3.25	.70	1312	80	46	33
57	8.85	***	2.12	.70	1782	5	45	35
58	33.00	***	2.81	.70	5085	0	23	17
59	68.00	***	5.95	.70	5171	85	25	17
60	77.08	***	2.48	.70	13412	7	24	16
61	42.25	***	1.47	.70	11550	8	25	16
62	11.67		**		7531			
63	30.58	***	2.30	.70	5726	5	47	29
64	17.84	***	1.34	.70	5281	5	63	45
65	10.35	***	1.04	.70	3340	5	37	23
66	4.23		**		2730			
67	9.00	***	1.25	.70	2805	5	45	32
68	9.23	***	2.34	.70	1700	75	77	48
69	110.00	1.5	7.00	.70	7157	100	1	<1
70	164.00	1.2	7.00	.70	10670	91	1	<1
71	58.00	1.0	4.00	.70	6453	54	2	2
72	68.00	.94	4.00	.70	7565	12	18	13
73	61.32	1.0	5.00	.70	5516	23	18	13
74	36.86	1.4	5.00	.70	3316	5	22	15
75	102.44	1.6	7.00	.70	6665	0	21	15
76	83.01	1.45	4.00	.70	9235	80	28	19
77	11.37		**		7337			
78	23.63	***	3.27	.70	3185	25	57	35
79	295.00	1.95	16.00	.794	9717	74	2	2
80	55.34	1.95	9.50	.794	3032	24	21	14
81	275.10	1.95	14.28	.794	10105	50	3	3
82	92.80	1.95	*	.794	15714	25	2	1
83	145.60	1.95	8.04	.794	9373	86	2	2

Sub-area Number	Drainage Area (sq. mi.)	C_t	t_{pR} (hour)	C_p	Q_{pR} (cfs)	Percent Sand (%)	Urban-ization (%)	Imperv-iousness (%)
84	45.86		**		29595			
85	37.60	1.95	7.00	.794	2767	80	18	13
86	221.61	1.95	*	.794	18397	50	26	18
87	75.50	1.45	9.00	.794	4371	21	2	1
88	236.71	1.95	*	.794	37998	50	21	14
89	46.24		**		29840			
90	19.95	***	3.05	.70	2878	15	38	25
91	15.93	***	1.86	.70	3563	0	62	37
92	24.98	***	4.85	.70	2313	80	38	24
93	19.51	***	1.55	.70	5108	0	65	41
94	12.81	***	1.23	.70	4064	0	69	49
95	15.22	***	1.97	.70	3260	5	65	45
96	13.70	***	1.12	.70	4421	0	80	61
97	24.12	***	1.68	.70	5871	0	67	41
98	21.62	***	1.01	.70	6976	0	78	58
99	12.59	***	1.01	.70	4062	0	87	49
100	5.12	***	0.72	.70	1652	40	60	45
101	2.95	***	1.11	.70	952	0	77	57
102	6.03	***	0.76	.70	1946	0	84	60
103	98.25	***	3.39	.70	12899	0	74	49
104	1.75		**		1129			
105	32.99	***	2.30	.70	6177	0	69	44
106	22.43	***	1.92	.70	4878	5	71	45
107	12.10	***	1.54	.70	3185	5	46	33
108	60.72	***	2.63	.70	9906	0	51	33
109	45.56	1.95	*	.794	18637	100	3	3
110	3.80	1.95	7.67	.794	2282	100	5	5
111	53.28	1.95	*	.794	24782	74	2	2

* A composite unit hydrograph was made from combining numerous sub-area unit hydrographs.

** A 1-hour instantaneous unit hydrograph was used for the lake surface area.

*** A C_t value was not required. Urbanization curve methodology was used.

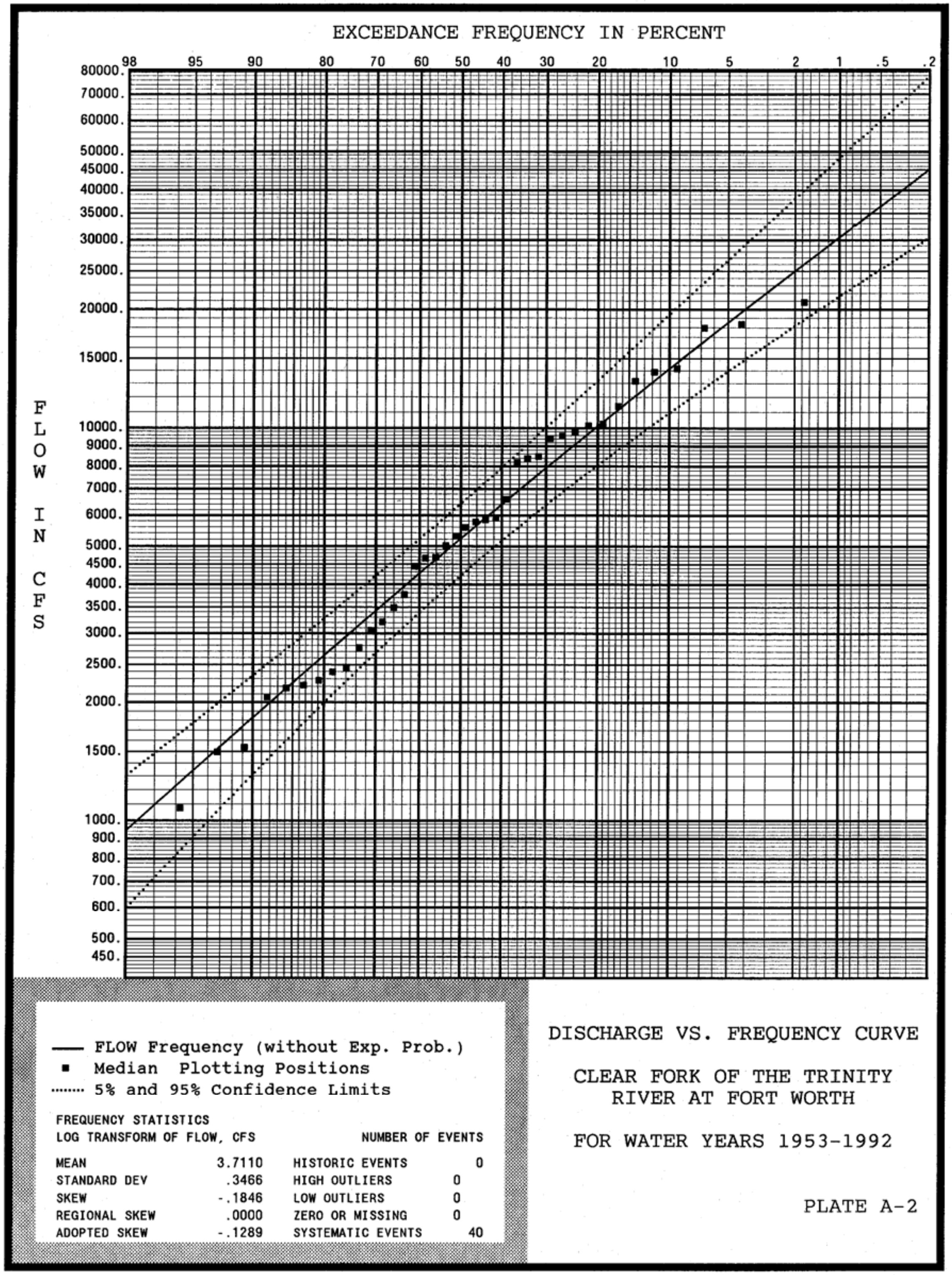
Table A-6
West Fork Trinity River
Existing Conditions/Future Conditions/<u>Revised Project Discharges</u>
Computed Probability Discharges in CFS

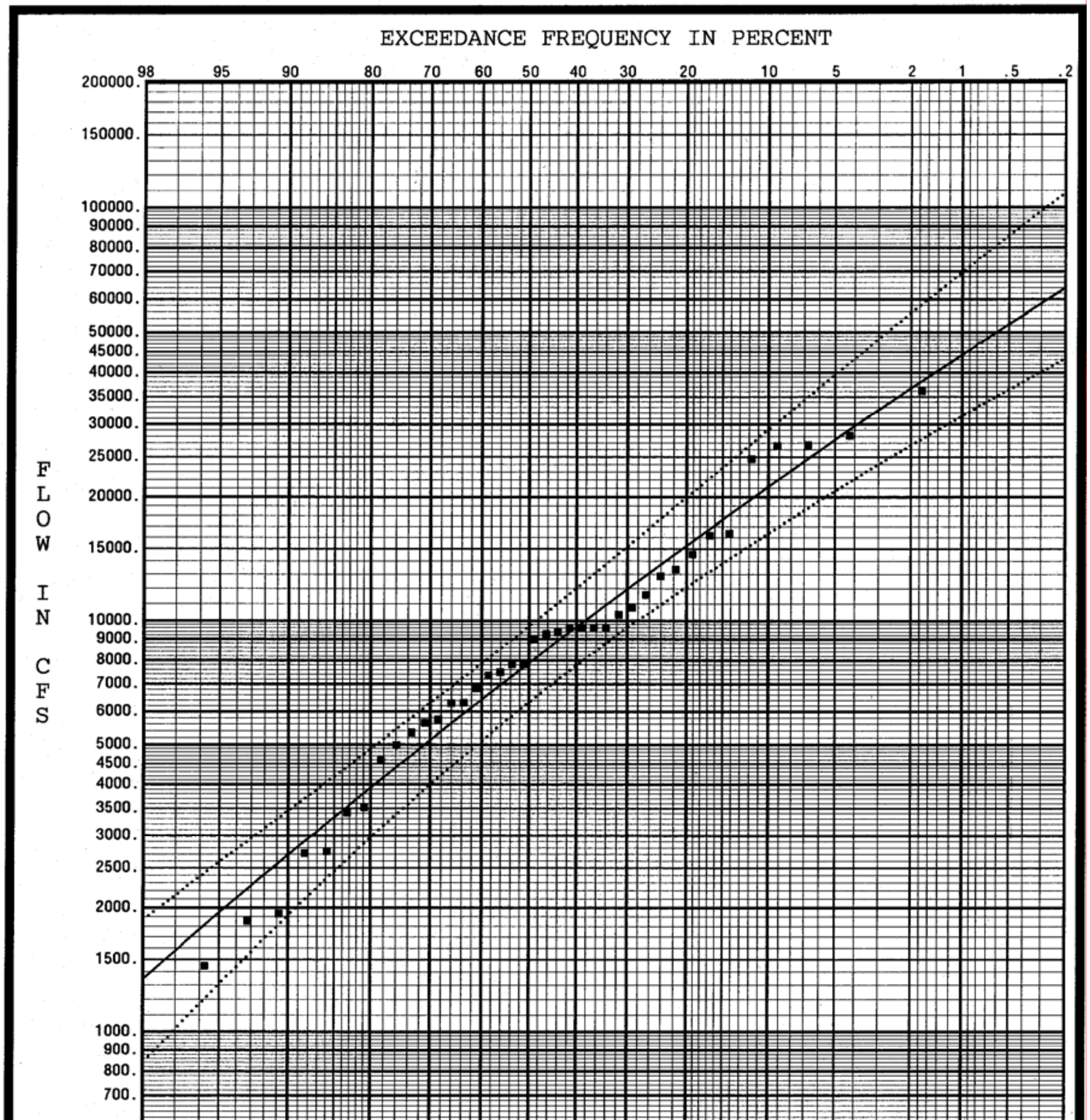
LOCATION	2 year	5 year	10 year	25 year	50 year	100 year	500 year	SPF
West Fork u/s of Big Fossil Creek	*11300* 13100	*20100* 21700	*25600* 27900	*35700* 38700	*47700* 52100	*60600* 64700 <u>63300</u>	*97500* 101900	*144300* 148500 <u>147800</u>
West Fork d/s of Sycamore Creek	*13200* 15000	*24800* 27000	*33800* 36300	*47400* 50700	*60500* 64200	*71700* 75300 <u>72800</u>	*110400* 114200	*155500* 158800 <u>156400</u>
West Fork u/s of Sycamore Creek	*9300* 10800	*16000* 17800	*21400* 24200	*30000* 33200	*39800* 43400	*47900* 51700 <u>50900</u>	*81100* 86600	*126500* 129600 <u>127300</u>
West Fork d/s of Marine Creek	*10800* 12100	*17000* 18800	*22300* 24400	*29600* 32400	*37700* 40900	*46000* 50500 <u>50300</u>	*80900* 85100	*118500* 122500 <u>122400</u>
West Fork u/s of Marine Creek	*9100* 10200	*13400* 15600	*18600* 21400	*26500* 30800	*35700* 39500	*44400* 48400 <u>48100</u>	*80900* 81500	*114000* 118600 <u>118900</u>
West Fork at Fort Worth Gage	*9400* 10400	*13800* 15800	*18900* 21500	*26900* 30800	*35700* 39900	*47000* 48700 <u>48400</u>	*77900* 82000	*113800* 118600 <u>119000</u>
West Fork u/s of Clear Fork	*7500* 7800	*13400* 13500	*14300* 14500	*23000* 23200	*28400* 28600	*35200* 35400 <u>35400</u>	*54600* 54700	*57200* 59700 <u>59800</u>
West Fork d/s of Lake Worth Dam	*7500* 7800	*13400* 13500	*14300* 14500	*23000* 23200	*28400* 28600	*35200* 35400 <u>35400</u>	*54600* 54700	*54300* 56400 <u>56400</u>

Table A-7
Clear Fork Trinity River
Existing Conditions/ **Future Conditions/<u>Revised Project Conditions</u>**
Computed Probability Discharges in CFS

LOCATION	2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR	500 YEAR	SPF
Clear Fork u/s of West Fork	*7500* 8400	*11100* 12900	*15100* 17100	*20000* 22500	*25000* 27700	*30000* 32600 <u>32100</u>	*46000** 47700	*76300* 78100 <u>78300</u>
Clear Fork at IH 30	*7100* 8100	*10600* 11900	*13800* 16200	*19100* 21700	*24600* 27100	*29800* 32700 <u>32300</u>	*46000** 48700	*78500* 79600 <u>81200</u>
Clear Fork d/s of Marys Creek	*4900* 6300	*8100* 9900	*11700* 13700	*16500* 18600	*20700* 22800	25400 27600 <u>27600</u>	*46000** 46000*	*71800** 71800* <u>71800</u>*
Clear Fork u/s of Marys Creek	*2300* 2700	*3700* 4100	*6000** 6000*	*3800* 7300	*8400* 9000	13000* 13000* <u>13000</u>*	*46000** 46000*	*71800** 71800* <u>71800</u>*

* Discharge-frequency releases from Benbrook Lake are considered critical discharges where they exceed local discharges.


EXCEEDANCE FREQUENCY IN PERCENT
98 95 90 80 70 60 50 40 30 20 10 5 2 1 .5 .2
FLOW IN CFS
80000. 70000. 60000. 50000. 45000. 40000. 35000. 30000. 25000. 20000. 15000. 10000. 9000. 8000. 7000. 6000. 5000. 4500. 4000. 3500. 3000. 2500. 2000. 1500. 1000. 900. 800. 700. 600. 500. 450.
—— FLOW Frequency (without Exp. Prob.)
▪ Median Plotting Positions
······· 5% and 95% Confidence Limits
FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS
MEAN 3.7110
STANDARD DEV .3466
SKEW -.1846
REGIONAL SKEW .0000
ADOPTED SKEW -.1289
NUMBER OF EVENTS
HISTORIC EVENTS 0
HIGH OUTLIERS 0
LOW OUTLIERS 0
ZERO OR MISSING 0
SYSTEMATIC EVENTS 40
DISCHARGE VS. FREQUENCY CURVE
CLEAR FORK OF THE TRINITY RIVER AT FORT WORTH
FOR WATER YEARS 1953-1992
PLATE A-2



—— FLOW Frequency (without Exp. Prob.)
■ Median Plotting Positions
.... 5% and 95% Confidence Limits

FREQUENCY STATISTICS

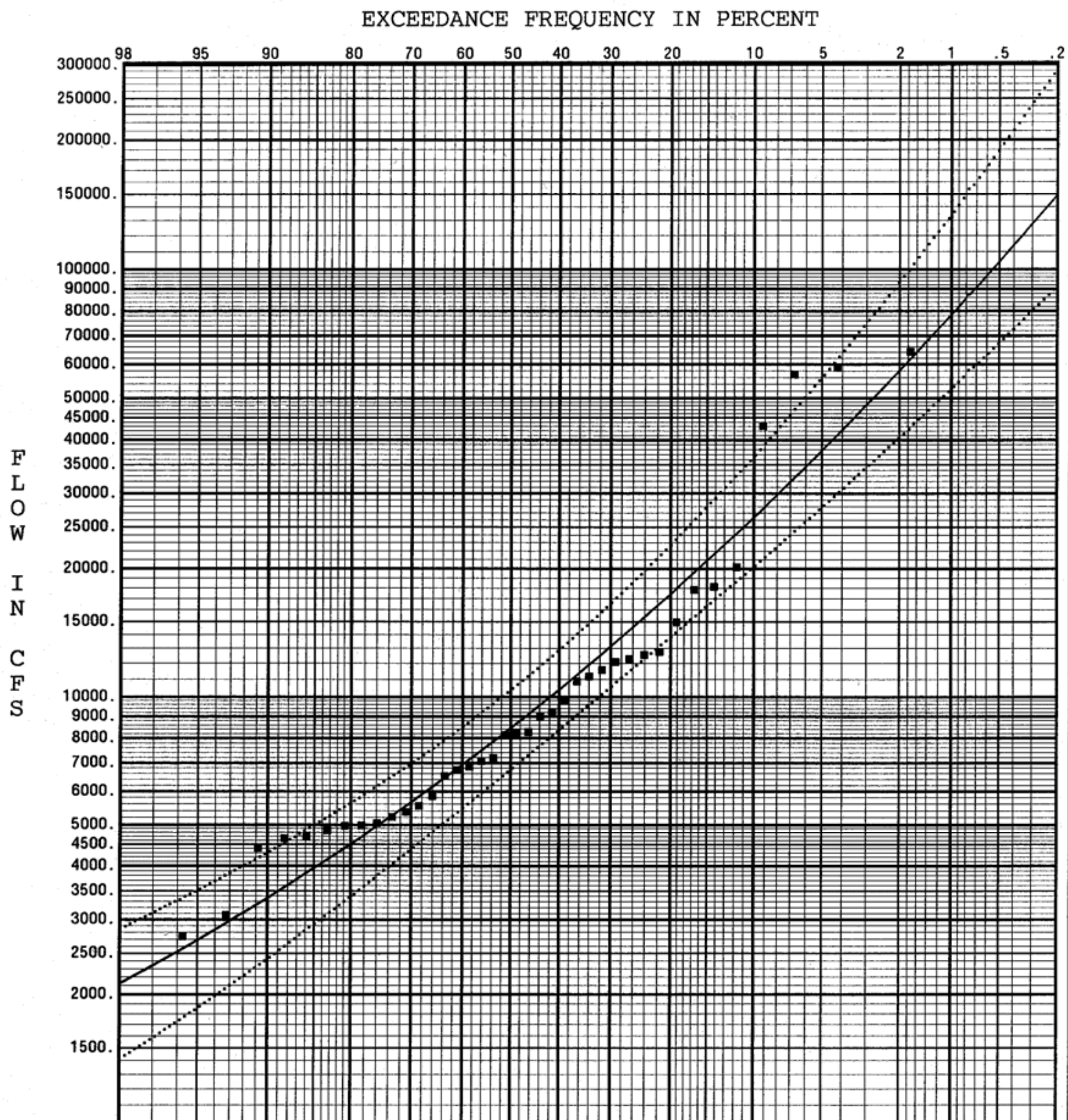
LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.8852	HISTORIC EVENTS	0
STANDARD DEV	.3498	HIGH OUTLIERS	0
SKEW	-.2964	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	-.2031	SYSTEMATIC EVENTS	40

DISCHARGE VS. FREQUENCY CURVE

WEST FORK OF THE TRINITY RIVER AT FORT WORTH

FOR WATER YEARS 1953-1992

PLATE A-3



—— FLOW Frequency (without Exp. Prob.)
■ Median Plotting Positions
········ 5% and 95% Confidence Limits

FREQUENCY STATISTICS

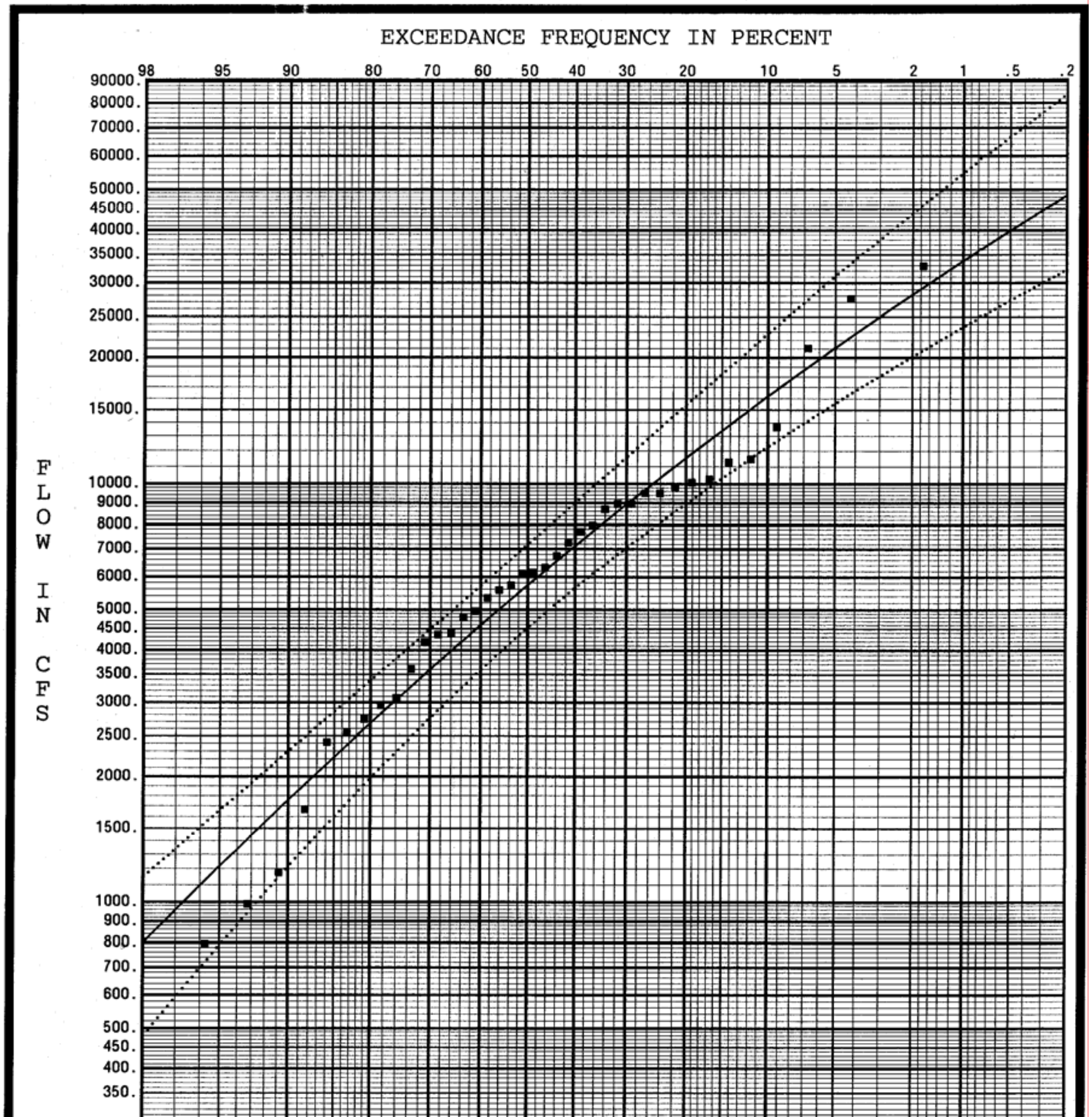
LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.9551	HISTORIC EVENTS	0
STANDARD DEV	.3514	HIGH OUTLIERS	0
SKEW	.7718	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	.4838	SYSTEMATIC EVENTS	40

DISCHARGE VS. FREQUENCY CURVE

WEST FORK OF THE TRINITY RIVER AT GRAND PRAIRIE

FOR WATER YEARS 1953-1992

PLATE A-4



—— FLOW Frequency (without Exp. Prob.)
▪ Median Plotting Positions
······· 5% and 95% Confidence Limits

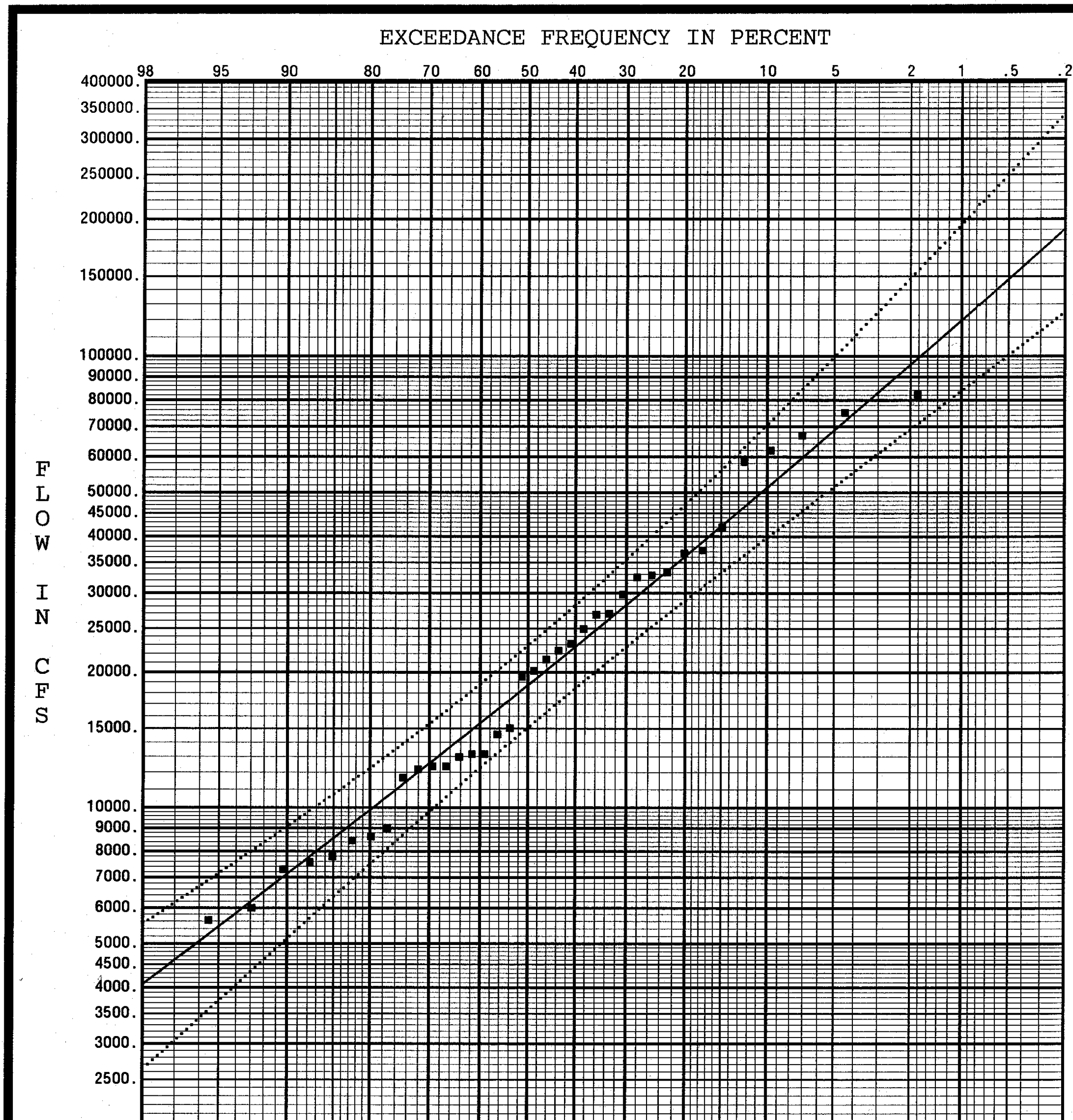
FREQUENCY STATISTICS LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.7390	HISTORIC EVENTS	0
STANDARD DEV	.3775	HIGH OUTLIERS	0
SKEW	-.4652	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	-.3094	SYSTEMATIC EVENTS	40

DISCHARGE VS. FREQUENCY CURVE

ELM FORK OF THE TRINITY
RIVER NEAR CARROLLTON

FOR WATER YEARS 1953-1992

PLATE A-5



—— FLOW Frequency (without Exp. Prob.)
■ Median Plotting Positions
········ 5% and 95% Confidence Limits

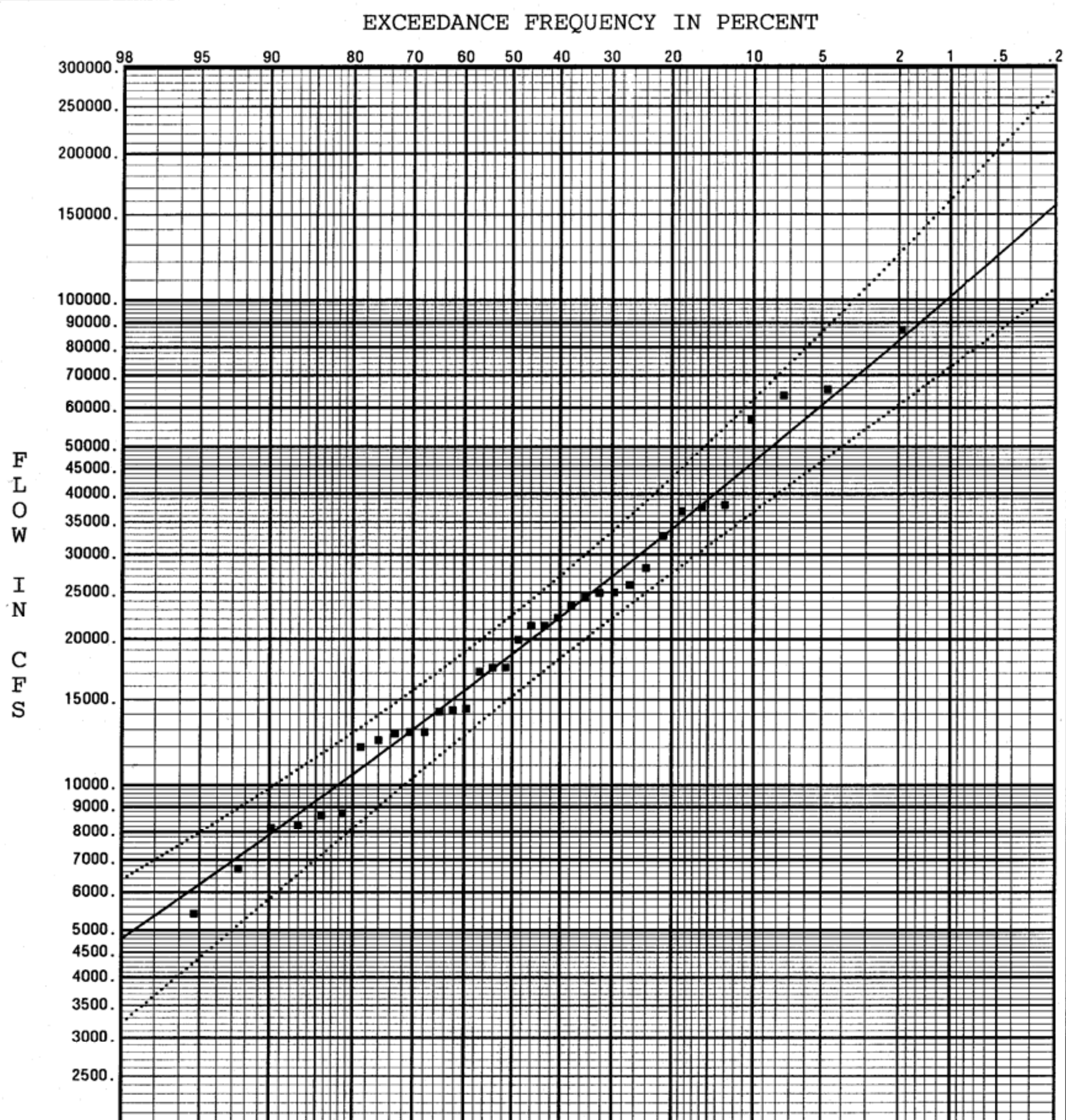
FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

		NUMBER OF EVENTS	
MEAN	4.2779	HISTORIC EVENTS	0
STANDARD DEV	.3341	HIGH OUTLIERS	0
SKEW	.1416	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	.0982	SYSTEMATIC EVENTS	38

DISCHARGE VS. FREQUENCY CURVE

TRINITY RIVER AT DALLAS
FOR WATER YEARS 1953-1992

PLATE A-6



—— FLOW Frequency (without Exp. Prob.)
■ Median Plotting Positions
······· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	4.2770	HISTORIC EVENTS	0
STANDARD DEV	.3010	HIGH OUTLIERS	0
SKEW	.2070	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	.1398	SYSTEMATIC EVENTS	36

DISCHARGE VS. FREQUENCY CURVE

TRINITY RIVER BELOW DALLAS
FOR WATER YEARS 1953-1992

PLATE A-7

INTERIOR DRAINAGE ANALYSIS

The existing Fort Worth Floodway interior drainage sump areas and located within the Central City study areas are listed below by each of the levees they are located behind:

West Fork Levee Loop	28, 29, 20, 31
North Main Levee Loop	26
Clear Fork Levee Loop	14W, 15W, 16W, 22C, 23C, 24C, 25C
Water Works Levee	19C, 20C, 21C
Crestwood Levee	11W, 13W
Brookside Levee	10W, 12W
Riverbend Levee	9W
WFR1	7W, 8W

Each of the sump areas is gravity-drained through the levee to the river by a sluice structure. Detailed hydrologic analyses were performed on Sump 14W/Sump. AN interior drainage model originally developed by a private engineering firm for computation of the 100-year flood sump elevation was used as the base model. The model was updated and modified to produce the flood events.

Table A-8 shows the 50-year and 100-year flood elevations for the sumps in the study area. The data is a compilation of interior drainage analysis developed from previous USACE studies and private engineering firms.

Table A-8
100-Year Sump Elevations

Sump	Drainage Area (acre)	50-year Flood Elevation	100-year Flood Elevation
7W	1284	546.6	548.3
8W			
9W	455	539.5	540.9
10W	194	540.8	540.9
12W	849	540.5	540.9
11W	83	540.8	541.0
13W	103	530.2	530.7
14W 15W	510	536.7	537.5
19C	121	542.8	543.2
20C			
21C			
22C	211	539.5	539.7
23C	276	539.5	539.7
24C	65	539.5	539.7
25C	21	534.6	534.9
26	448	532.7	533.1
16W	69	533.8	534.6
28	448	523.4	523.5
29	287	517.3	520.9
30	126	520.3	520.8
31	254	516.1	516.7