APPENDIX A

Purpose and Methodology

Purpose

The Elm Fork Floodplain Management Study summarizes the results of the detailed master drainage studies completed for the City of Dallas within the Elm Fork project limits. The objective of the study is to define the limits for the ultimate development conditions of the 100-year floodplain. Additionally, the study will provide an overall management plan for the floodplains of the Elm Fork and the three tributaries. The study will provide the base information necessary to assist in the following:

1. Determination of flood hazard areas;
2. Planning for parks and recreational facilities within the floodplain area;
3. Design of future roads, bridges and utilities;
4. Determination of the improvements required for existing road/railroad crossings in flood hazard areas;
5. Establishment of minimum finish floor elevations for structures built in and adjacent to the floodplain areas; and
6. Creation of a tool for the evaluation and implementation of floodplain management alternatives.

Background

Freese and Nichols has been retained by the City of Dallas to provide engineering, surveying and environmental services for the Elm Fork Floodplain Management Study. The study deliverables include a local drainage master plan for Richards Branch, Wesco Channel and Daniels Creek and a report outlining overall watershed management concepts for the Elm Fork. The report also includes a recreational amenities plan for the study area.

The project limits are as follows:

1. Elm Fork - From the confluence of the Trinity River at SH 183 to Royal Lane (43,200 linear feet);
2. Richards Branch - From the confluence of the Elm Fork to the limits of the Elm Fork SPF (13,500 linear feet);
3. Wesco Channel - From the confluence of the Elm Fork to the limits of the Elm Fork SPF (15,000 linear feet); and
4. Daniels Creek - From the confluence of the Elm Fork to the limits of the Elm Fork SPF (14,900 linear feet).

This study encompasses a unique stretch of the Elm Fork. The river is relatively untouched by the industrial and recreational uses that occur just outside of its banks; however, the Elm Fork is not easily accessed from the City of Dallas side.

Elm Fork of the Trinity River

The U.S. Army Corps of Engineers updated the hydrology for the Elm Fork of the Trinity River for both the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) and the Trinity River Corridor Development Certificate (CDC) Base Model in 1995. The FIS hydrology provides peak flow values, in cubic feet per second (cfs) for the 10-, 50-, 100-, and 500-year storm events given current land use and river hydraulics. The CDC hydrology provides peak flow values, in cubic feet per second (cfs) for the 1-, 2-, 5-, 10-, 25-, 50-, 100-year, and Standard Project Flood (SPF) events given projected year 2050 land use and current river hydraulics. Due to this work by the Corps of Engineers, the Elm Fork hydrology was not updated as part of this study.

As part of its participation in the National Flood Insurance Program the City of Dallas has adopted the 100-year storm event as the basis for storm water design purposes. Moreover, its participation in the Trinity River CDC initiative requires both the 100-year and SPF events be used as design storms.

Tributaries to the Elm Fork

The three tributaries to the Elm Fork investigated by this study are Daniels Creek, Wesco Channel, and Richards Branch. A study of the tributaries requires information concerning rainfall, topography, soil type, land use, and proposed future developments. Unlike the hydrologic model of the Elm Fork available from the Corps of Engineers, hydrologic models were developed for the tributaries as part of this study.

The procedures for this study were based on industry-accepted methodologies and the resultant information was combined into hydrologic (HEC-1) and hydraulic (HEC-RAS) models of the tributaries to determine the peak flow values and peak stages for the 2- through 500-year and SPF frequency storm events for existing, ultimate, and proposed conditions. The following sections describe the methodologies and techniques used to develop the hydrologic and hydraulic models.

Hydrologic Methodology

Precipitation

The hypothetical storms rainfall data for this study were provided by HYDRO-35, TP-40, and TP-49. "NOAA Technical Memorandum NWS HYDRO-35, Five- To 60-Minute Precipitation Frequency For The Eastern And Central United States", from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Office of Hydrology, Silver Spring, MD, 1977, provided the 2- through 100-year, 5- through 60-minute rainfall data. "Technical Paper No. 40 (TP-40) Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years", from the U.S. Department of Commerce, Weather Bureau, Washington, D.C. 1961, provided the 2- through 100-year, 2- through 24-hour rainfall data. "Technical Paper No. 49 (TP-49) Two- To Ten-Day Precipitation For Return Periods Of 2 To 100 Years In The Contiguous United States", from the U.S. Department of Commerce, Weather Bureau, Washington, D.C. 1964, provided the 2- through 100-year, 2-day rainfall data.

The 1- and 500-year frequency rainfall data were derived through logarithmic extrapolation of the 2- through 100-year data while the Standard Project Flood rainfall data was determined by the U.S. Army Corps of Engineers (COE).

Topographic Information

Topographic information was used to delineate drainage basins and define hydrologic and hydraulic characteristics. The 1991 aerial contours produced for the U.S. Army Corps of Engineers Upper Trinity Study were provided by the North Central Texas Council of Governments and were supplemented by approximately 150 surveyed cross-sections of the three tributaries for use in this study.

Basin Delineation

Utilizing the topographic information and City drainage plans the drainage basins and sub-basins for each of the three tributaries were delineated. A drainage basin is a defined area in which all runoff travels to a common point. A sub-basin is a drainage basin inside a larger basin. Several sub-basins are delineated for each stream to provide a more detailed model of the storm flows in the tributaries.

The aerial contours allowed rough delineation of each drainage basin and subsequent sub-basins. The City drainage plans indicated locations where storm flow would be diverted from its normal course because of inlets, culverts, or channels. The City drainage plans along with field visits allowed the drainage basins and sub-basins to be properly defined.

Land Use Conditions

Hydrologic Soil Group

The type of soil, whether sand, clay or a combination of the two, greatly affects the amount of rainfall that infiltrates the ground and how much results in runoff. A sandy soil will allow a greater amount of infiltration, while a clay soil will produce a greater amount of runoff. The "Soil Survey of Dallas County, Texas" from the U.S. Department of Agriculture, Soil Conservation Service, 1980, provided the hydrologic soil group information for the drainage basins, which contribute to the three tributaries.

Land Use

Like the soil type, land use also greatly affects the amount of runoff produced by rainfall. A parking lot will translate nearly all rainfall into runoff, while a park will retain the rainfall and allow it to soak or infiltrate into the ground. The North Central Texas Council of Governments provided a land use map of the drainage area of the basins for the existing conditions and the City of Dallas provided the ultimate development conditions.

This land use information was provided in a paper or a hardcopy format. The paper copy was scanned into digital format and the land use zones where delineated so the information could be used in a geographic information system (GIS) format.

SCS Curve Number

The SCS Curve Number (CN) is defined for hydrologic soil type and land use. A high CN indicates a high percentage of rainfall will be translated into runoff rather than infiltration. Conversely, a low CN indicates low runoff. The CN's are defined by "Urban Hydrology for Small Watersheds, TR-55," U.S. Department of Agriculture, Natural Resources Conservation Service, June 1986. Utilizing the sub-basin delineation, the CN matrix from TR-55, and both soil type and land use information in a GIS, a CN for each sub-basin was determined for both existing and proposed conditions.

Lag Time

The amount of time it takes for a drop of rain to travel from the hydraulically most remote portion of a drainage basin to the calculation point is the "time of concentration." The time of concentration (T_c) is calculated by the summation of the travel times of the storm flow over different segments of the basin. There are three types of flow conditions considered for time of concentration, 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow takes place in the most upper reaches of the basin. Sheet flow is the flow often seen in a parking lot where flow, as the name implies, travels across the surface but has not yet formed into a channel. This type of flow generally takes place for the first two- to three-hundred feet of a flow path before it forms concentrated flow. The sheet flow is generally less than an inch deep, and transverses the first two- to three-hundred feet within fifteen minutes.

After the sheet flow starts to concentrate it becomes shallow concentrated flow. The travel time for shallow concentrated flow is calculated from the velocity and distance of travel. The velocity is determined based on the slope and material over which the water travels. The steeper the slope the faster the flow and the less time it takes to transverse that segment of the hydraulic length.

Once the flow path reaches a point of surveyed cross sections or an area where a channel is discernable on aerial photos the flow becomes open channel flow. The travel time in an open channel portion of a flow path is calculated, as with shallow overland flow, from velocity and distance of travel. The velocity of open channel flow is determined by channel geometry, Manning's roughness coefficient, and channel slope.

Once the T_c for a sub-basin is determined, by the summation of the travel times, it is converted into lag time. Lag time has been determined to be $0.665*T_c$ by the Natural Resources Conservation Service.

Runoff Hydrographs and Flow Attenuation

The HEC-1 program uses the rainfall and hydrologic information to produce hydrographs for each sub-basin. The program also has the capability to combine and route the hydrographs to simulate storm events. As the hydrograph from a sub-basin travels through the next basin downstream the hydrograph peak value becomes lower and its base becomes longer because of valley storage.

Valley storage is the ability of the stream or river to attenuate or store a portion of the flood and lower the peak value. In this way the stream acts as a sponge or reservoir and though a large amount of water may enter it in a short period of time the water is released at a lower rate over a longer period of time. Each segment of stream has a valley storage rating curve determined from a hydraulic model.

Once the hydrograph of the most upstream sub-basin has been routed through the second sub-basin, the routed first hydrograph and un-routed second sub-basin are combined. The peak value of this combined hydrograph is the peak flow value of the segment through which the first hydrograph was routed. This process continues from the upper reach of the tributary to the confluence with the Elm Fork.

For this study the HEC-1 (hydrologic) and HEC-RAS (hydraulic) models were used to determine the valley storage rating curves for each segment of the tributaries. The HEC-1 model was run for the 500-year frequency storm with no routing. This produced a very high peak flow in the stream at each sub-basin.

The HEC-1 program has the capability to model valley storage with a rating curve with up to twenty values of flow and storage. The value of the 500-year un-routed model was therefore rounded up and linearly distributed from a value of 1/20th to 20/20ths to provide twenty evenly distributed values of flow at each stream segment. These twenty values were entered in the HEC-RAS model to determine valley storage and provided values below to above the range of values that would actually flow in the tributaries.

Each of the twenty series of flow values entered into the HEC-RAS model is considered a profile. The value of each series decreases in each stream segment from downstream to upstream. This allows a true relationship throughout the tributary for that profile.

Valley storage rating curves were determined through this method for existing and proposed hydraulic conditions. Refer to the *Valley Storage* section of this appendix for additional information regarding valley storage calculations.

Other Information

In addition to what has been mentioned above, other information was also gathered concerning existing and future conditions. City drainage plans for the existing drainage systems and stream crossings were gathered to delineate drainage basins and identify existing hydraulic parameters. TxDOT, City of Dallas, and DART plans for future projects were obtained to minimize alternative conflicts with those plans.

Also, several drainage reports analyzing this area of Dallas in the past were obtained to compare potential solutions to existing drainage problems. These reports include the revised 1989 Halff and Associates "Feasibility Study for Luna Road Improvements Northwest Highway to Royal Lane", the August 1983 Owen Ayres & Associates "Stemmons North Industrial District Interior Drainage Study", the June 2000 U.S. Army Corps of Engineers, Fort Worth District "Programmatic Environmental Impact Statement, Upper Trinity River Basin, Trinity River, Texas" and the April 1989 Nathan D. Maier Consulting Engineers, Inc. "Information and Management Joe's Creek" study.

Hydraulics Methodology

Stream Cross Section Data

The existing CDC and FEMA FIS HEC-RAS models, completed by the U.S. Army Corps of Engineers for the Upper Trinity Study, were used for the analysis of the Elm Fork and the effects the proposed conditions would have on the floodplain.

Hydraulic models of each of the tributaries were developed using the surveyed cross-sections that were obtained for this study and the 1991 aerial contours. The surveyed cross-sections defined the channel and bank adjacent to the tributary as well as bridges and culverts. The surveyed cross-sections were extended with the aerial contours to provide cross-sections for the hydraulic model that extended beyond the floodplain.

The hydraulic characteristics of each stream were determined from the aerial contours, surveyed cross-sections, photographs of the cross-sections and field visits. More specifically, the geometric data for the models was derived from the 1991 aerial contours and surveyed cross-sections while the Manning's roughness coefficients were determined from the photographs of the cross-sections and field visits.

Split Flow

Further revisions were made to the model(s) regarding the split flow reaches. Since even slight alterations to geometry can have a significant impact on split flow regimes, the amount of flow in each of the two split flow reaches within the study area was recalculated. Using an iterative approach the appropriate distribution of discharges between the two reaches was determined by balancing the energy grade line elevation at the cross-section immediately upstream of the split flow region (i.e., cross-section 499+16). The energy grade line elevations were matched to 0.00 feet, but the exact discharges were then rounded to the nearest 100 cfs per the Effective Model(s). This technique was applied to recalculate the split flow distribution for all of the scenarios including the Modified Alternative 2 and the proposed conditions model(s).

Flood Profiles

The starting water surface of a hydraulic model directly affects the level of inundation experienced in the downstream portion of a stream. The higher the starting water surface the less of an influence the local channel has on flooding and the greater the influence the receiving stream has. Because of the size and location of the tributaries with respect to the Elm Fork drainage basin, the 100-year CDC elevation, as determined by the U.S. Army Corps of Engineers Upper Trinity Study, is the water surface used for all frequency profiles in the tributaries. The two exceptions to this occur in the Daniels Creek analysis. The existing conditions model uses the 10-year Elm Fork elevation and the proposed conditions model uses an elevation of 415.0 feet. As part of the proposed improvements (refer to *Flood Management Projects* section of the report for details regarding proposed improvements) Daniels Creek will no longer be susceptible to Elm Fork backwater. Rather, Daniels Creek will outfall to a pond at water surface elevation 415.0 feet.

Valley Storage

In addition to water surface elevation this study considered the effects various scenarios may have on the region's ability to accommodate flood waters. Per the discussion above the hydrologic and hydraulic models use a method of calculating the volume of flood water within a channel reach (i.e., valley storage) for the purposes of routing hydrographs. This approach was used for modeling the tributaries and is able to capture the watershed characteristics in enough detail to provide sufficient accuracy. However, in order to determine the valley storage of the entire region (i.e., the Elm Fork floodplain) a more advanced technique was necessary.

The cross-sections in the hydraulic model represent the landscape sufficiently but are spaced too far apart to account for all of the varied topography in the region. For this reason an electronic surface in a geographic information system (GIS) of the project area was created which much more accurately depicts the actual physical landscape. Using the electronic landscape surface and overlaying another surface representing the flood water (based on the elevations from the hydraulic model output) on top of the first produces a third feature whose volume is equivalent to the valley storage of the region. This technique was performed to compare several watershed conditions ranging from existing to proposed scenarios. Refer to *Appendix D Flood Management Projects* for the results of these analyses.