CITY OF LEBANON
Storm Drainage Master Plan

CHAPTER 3

3.0 METHODOLOGY

This chapter describes the analytical techniques and outlines the conceptual methodology which this plan will use to analyze the existing and future drainage facility requirements. First, several basic assumptions are presented. Next, analytical techniques used for hydrologic and hydraulic analyses are described. Finally, this chapter briefly describes how the City's drainage facilities will be evaluated.

3.1 BASIC ASSUMPTIONS

The following basic assumptions for the hydrologic and hydraulic analyses were made:

- Land uses within the study area in the year 2005 will be assumed to be those designated in the Lebanon Comprehensive Land Use Plan.
- Percent impervious area for future development scenarios will be estimated based on an assumed percent impervious area which is typical for each of the various land uses.
- Full buildout within the current Urban Growth Boundary will be assumed to occur within the next 15 years.
- The National Oceanic and Atmospheric Administration's (NOAA) <u>Precipitation-Frequency Atlas of the Western United States, Volume X - Oregon, 1973</u> and local rain gauge data will be used as the basis to determine a design rainfall event. See Chapter 5, "Rainfall Analysis" for further details.
- Rainfall will be assumed to be constant throughout the watershed during a design storm event.
- Parameters, such as hydrologic soil types, will be estimated for drainage sub-basins using parameter values weighted by area within each sub-basin.
- Storm drain pipes will be assumed to have a 3 feet minimum cover when placed in a travelled right-of-way and will be assumed to be placed at a constant slope between points of known inverts. (Since many of the City's pipes will function in a surcharged condition during peak flows, estimated flows are not generally affected by this assumption.)

- Flow velocities in open channels or pipes, for the purpose of estimating times of concentration, were assumed to be constant.

- The 24-hour storm will be assumed to be the design storm. Recurrence intervals of 5, 10, 25, 50, and 100 years will be considered as appropriate. The relationship between recurrence interval or frequencies and annual probability of occurrence is as follows:

RECURRENCE INTERVAL (or) FREQUENCY	ANNUAL PROBABILITY OF OCCURRENCE
2	.50
5	.20
10	.10
25	.04
50	.02
100	.01

Larger storm events occur less frequently, i.e., at longer return intervals. If the potential for inconvenience or damage is large, it will be assumed that an relatively large recurrence interval (low probability) event will be an appropriate standard for that particular drainageway.

3.2 HYDROLOGIC ANALYSIS

Hydrologic analysis is used to estimate peak discharge rates in drainageways under existing and ultimate land use conditions. The Corps of Engineer's HEC-1 computer program (revised 1987 PC version) was utilized to estimate peak flows.

The HEC-1 model is designed to simulate the surface runoff response of a basin to precipitation. The rainfall hyetograph is translated into a runoff hydrograph and the hydrograph from each sub-basin is routed by the model to the point of confluence with other sub-basins. When combined with the hydrograph from another sub-basin, a composite hydrograph is computed by the model which accounts for any differences in time of concentration between the two hydrographs. The "Kinematic Wave" method was used for routing the runoff hydrographs through the sub-basins. The kinematic wave equation is a differential equation that models the behavior of the hydrograph as a function of channel cross-sectional area and flow.

The runoff hydrograph was determined by using the SCS unit hydrograph method. This method uses lag time as the single parameter in a set of empirical equations to determine the shape of the runoff hydrograph for each sub-basin.

The HEC-1 model requires five input parameters:

- **Sub-Basin Area (acres)**

  Sub-basin area is the surficial watershed within which runoff can be assumed to flow to a single discharge point.

- **Design Precipitation Hyetograph**

  The design hyetograph for the appropriate return interval is the bell-shaped relationship between precipitation intensity and time as the storm begins, then reaches peak intensity, then recedes.

- **Effective Impervious Area (EIA) (%)**

  The effective impervious area is computed for existing development conditions based on estimated mapped impervious area (MIA). EIA for future development conditions is based on typical percentages of impervious areas for the land use(s) planned for the sub-basin.

- **Composite Soil Conservation Service's (SCS) Soil Curve Number**

  The SCS soil curve number is estimated based on the composite hydrologic group of the soils within each sub-basin. The greater the soil curve number, the more impervious the soil is to infiltration and the greater the percentage runoff.

- **Lag Time (hours)**

  Lag time is a function of time of concentration and is the time difference between the peak precipitation intensity and the peak runoff rate from the sub-basin in question.

The result of the HEC-1 modeling process is the computation of sub-basin runoff hydrographs (runoff from each individual sub-basin vs. time) and stream flow hydrographs (stream flow rates from all upstream sub-basins vs. time). The free flowing peak flows at desired locations in the drainageways were estimated for both existing and ultimate (full buildout) development conditions. Peak flows from individual sub-basins (Sub-Basin Flows) for existing development and future conditions are shown in Table 6.1 for the 2, 5, 10, 25, 50 and 100 year recurrence intervals. Composite peak flows (Peak Drainageway Flows) are shown in Table 6.2 for the same frequencies.

Estimated peak flows are used to input into the hydraulic models described below. The HEC-1 hydrologic model estimates "how much" flow is occurring and the hydraulic models estimate "how deep" the flow will get in the various types of conveyance structures.

3.3 HYDRAULIC ANALYSIS

Hydraulic analysis involves calculating the water surface profile under existing and ultimate land use conditions based on the estimated peak flows generated from the hydrologic analysis. Several different models were used depending on the application.

The Corps of Engineers' HEC-2 model was selected for modeling well-defined open channel flow in Cox Creek. The computer program "STORM Plus" by CivilSoft was selected for major piped systems with widely varying slopes and pipe sizes and for drainages which contain intermittent combinations of piped and open channel segments. The Federal Highway Administration's HY8 program was selected for complex or multiple culvert configurations, particularly for the major culverted crossings along Cox Creek. In addition, several in-house spreadsheets which solve Manning's Equation (for gravity flow in conduits) and the Hazen-Williams Equation (for head loss per length of pipe under surcharged conditions) were used for estimation purposes in minor drainageways and in the design of pressure conduits.

HEC-2

The HEC-2 model computes water surface profile using several input parameters: (1) peak flows from the hydrologic analysis, (2) cross-sectional areas at regular intervals along the channel, (3) Manning's "n" friction coefficient, and (3) starting downstream water surface elevations.

The HEC-2 model only models subcritical flow. Generally, subcritical flow is deep, slow flow, while super-critical flow is shallow, rapid flow. Starting at the water surface elevation at the outfall of the waterway, HEC-2 calculates water surface elevation at the next selected upstream point. The program then calculates the energy loss due to slope and friction between the points. Energy loss, or head loss, is expressed as loss in water surface elevation (relative to the stream bed). This procedure is repeated for the length of waterway, resulting in a water surface profile. Water surface profiles were developed for flows anticipated under existing and future development conditions for Cox Creek.

HY8

The Federal Highway Culvert Program HY8 model is a utility program which was used to supplement HEC-2's limited multiple culvert modeling capabilities. The HY8 program effectively models changes in the water surface profile due to multiple culverts and combination culvert/weir flow. The methodology of HY8 is identical to HEC-2, except that it requires the physical dimensions of the culvert/weir.

STORM Plus

While the HY8 program is ideal for modeling small sections of a reach, "STORM Plus", designed by CivilSoft, was used for modeling reaches conveyed predominantly by storm drain pipes. The methodology used in STORM Plus is similar to HEC-2, except that STORM Plus models both subcritical and super-critical flow. The analysis begins at the downstream end of the reach and calculates water surface elevations until it reaches the point where subcritical flow turns to super-critical flow. At that time, STORM Plus moves to the most upstream point and calculates water surface elevations towards the point of subcritical flow. The program also computes and plots water surface profiles based on pressure gradients in the pipes. STORM Plus also accounts for water storage capabilities of the system.

3.4 ANALYSIS APPROACH

The primary objective of the analysis was to evaluate the adequacy of existing drainage facilities to accommodate both existing and future flows and to develop a phased capital improvements plan to upgrade inadequate facilities. The approach involved problem identification, determination of improvement alternatives, and selection of the appropriate system improvements. This approach was used first to analyze the drainage system's response to existing peak flows, and then its response to future peak flows.

Major drainage basins were defined for the major drainageways. Drainage sub-basins were delineated by identifying areas which could be characterized as draining to one discharge point and which were relatively uniform as to slope, land use, and current level of development. Sub-basins were delineated into relatively small areas (30-60 acres) in densely developed or unique areas and were larger in predominantly undeveloped areas. For each sub-basin, HEC-1 input parameters were estimated. (See Chapter 4, "Basin Delineation and Model Parameters").

The design rainfall distribution for input into the HEC-1 model was determined using local rainfall data supplied by the Oregon State Climatologist. This annual maximum rainfall data was analyzed using a Pearson Type III statistical distribution (found to be most representative of western Oregon rainfall events) and rainfall depths for the 2, 5, 10, 25, 50, 100 year return periods determined. The total rainfall depths for each return period were transformed into a rainfall hyetograph using the SCS Type 1A storm distribution. (See Chapter 5, "Rainfall Analysis" for further details of this analysis.)

The HEC-1 model was constructed using the branching configurations of the sub-basins and the HEC-1 input parameters. The model was run to determine the "free-flowing" peak flows for both individual sub-basin flow and for cumulative drainageway flows. These flows were estimated for a variety of return intervals and for both existing and future levels of development. (See Chapter 6, "Runoff Analysis")

The peak drainageway flows estimated in Chapter 6 were input into the hydraulic models constructed for each major drainageway. The HEC-2 model was used for the open channel portions of Cox Creek. Return frequencies from 25 to 100 years were considered for the major culverted crossings in Cox Creek.

Each major drainage reach was modelled using a either STORM Plus or in-house spreadsheets. In-house spreadsheets are suitable for analyzing reaches in which each segment is surcharged. A STORM Plus model was developed for each major drainageway when wide variations in slopes, conduit size, conduit shape or flow regime were such that in-house spreadsheets did not adequately represent the hydraulics of the system. The drainageways modelled with STORM Plus included the main tributary to Cox Creek near the Lebanon High School, the Main Street trunk line outfalling to Mark's Slough, and the trunk line outfalling into Oak Creek at South Hill Road. For each major drainageway modelled with either STORM-Plus or in-house spreadsheets, a hydraulic profile was calculated and was compared to the conduit invert profile and to the ground surface (or top-of-bank). Storm drainage reaches were modelled for the 2, 5, and 10 year storm events.

The capacity of a pipe was considered to be exceeded when the hydraulic grade line (free water surface) rose above the ground surface or forced the hydraulic grade line of tributary systems to break the ground surface. The capacity of an open channel system was considered to be exceeded when it over-topped its banks or forced flooding in tributary systems.

Each major drainageway in the watershed was evaluated to determine its adequacy in terms of frequency capacity under both existing and future development conditions. The frequency of deficiency was compared to the approximate risk to adjacent development. For example, if a local street or parking lot were inundated every 5 years it would probably be considered tolerable. If an industrial or commercial development were flooded even at a 25 year frequency, it would probably be considered intolerable. The severity of each identified problem area was evaluated based on the extent of flooding hazards, such as inconvenience or property damage. The timing of improvements to correct an identified problem was dependant on the severity of risk associated with system deficiencies and the rate of upstream growth that could further aggravate the situation.

After the hydraulic grade lines of the major drainageways were determined and corrected, minor drainageways discharging into those major drainageways were checked for capacities using the in-house hydraulic spreadsheets. A graph relating partial sub-basin area to peak flow was developed and used in conjunction with the total sub-basin flow to determine the peak flow in a pipe reach draining only a portion of the whole sub-basin. Once the flow for a given reach was determined, known information about the pipe diameter and length of reach was used to determine the head loss in the pipe. The water surface elevation at the upstream end of the pipe reach was computed by adding this head loss to the elevation of the hydraulic grade line in the major drainage system at the confluence point. A potential problem existed when the resulting upstream water surface elevation exceeded the ground surface elevation. Each minor pipe reach was analyzed for 2, 5 and 10 year flows.

After the problem areas were identified, improvement alternatives for alleviating flooding were developed. The following alternatives were considered in this approximate order:

(1) **Surcharge** - Consider allowing pipes to be surcharged if the hydraulic grade line does not rise above the ground surface.

(2) **Design Storm** - Consider allowing a lesser design storm standard such as a 25 year standard in the floodplain area or a 5 year capacity in a smaller drainageway where the risk of damage is minimal or low.

(3) **Bypass** - Re-route the flow around or away from the problem area in order to alleviate the problem and avoid replacement of system components.

(4) **Detention** - Consider the construction of detention facilities upstream of the problem area to hold back peak flows upstream in order to moderate downstream flows.

(5) **Replacement** - Replace the conduit with a larger diameter pipe and/or increase the slope of the pipe or replace culvert crossings with small open bridge structures.

The effects of these alternatives were evaluated by an iterative process using the previously constructed HEC-2, HY8, STORM Plus and in-house spread sheet computer programs. The alternative that minimized costs without unacceptable risk was the alternative recommended. (See Chapter 7, "Hydraulic Analysis and Recommended Drainage Improvements".)

When analyzing future system improvements, it was assumed that improvements required for the existing development conditions were in place. Costs were estimated for the recommended improvements and the costs, scope of improvement, and suggested phasing are summarized in Chapter 8, "Phased Capital Improvement Plan".