Using GIS for Hydrologic Data-Processing and Modeling in Texas

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Abstract

Using GIS for Hydrologic Data-Processing and Modeling in Texas

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This report focuses on the use of grid-based computations to determine design discharge for flow conveyance structures on Texas highways. A 500m grid is laid over the State and the significant streams and rivers are mapped into cells on the grid. Using USGS data relating extreme peak discharge to drainage area, a 500m grid of extreme peak discharge was derived for Texas divided into 11 hydrologic regions. A set of hydrologic parameter estimation equations were developed in ArcView Avenue programs, and combined into a package called the TxDOT Hydrology Extension for application into ArcView. This extension can be used at any stream location on the 500m grid to estimate peak discharges for return periods of 2 to 100 years, and to calculate hydrologic parameters including drainage area, watershed slope, longest flow path and length, watershed shape factor, curve number, flow velocity, and travel time.
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1. Introduction

This report is a part of the work of the research project, “A System of GIS-Based Hydrologic and Hydraulic Applications for Highway Engineering”, which is being developed by the Center for Research in Water Resources (CRWR) of the University of Texas at Austin and sponsored by the Texas Department of Transportation (TxDOT). It is also an extension and improvement of the Hydrologic Data Development System (HDDS) developed by Smith (1995). This introduction presents the background and the significance of the work in this report.

1.1 Background and Significance

Hydrologic analysis is vital to the design of drainage facilities in highway engineering. The cost of drainage facilities, such as storm drains, highway culverts, bridges, and water quality and quantity control structures, accounts for twenty five to fifty percent of the total cost of highway projects. The importance of drainage structures covers the range from transportation facilities to security against natural disaster, life safety and economics. Hydrologic analysis has always been an important component in highway engineering design and directly affects the success of whole projects. Accurate hydrologic analysis is desired. But accurate analysis depends not only on advanced and reasonable hydrologic models, but also the availability and the processing of wide range of spatial data. Substantial efforts are required to manually establish and manipulate spatial data. The traditional approach usually balances accuracy with simplicity. In general,
simplicity limits the choice of hydrologic models and so limits the degree of accuracy. Due to the development of computer and hydrologic computation techniques, GIS-based hydrologic systems are improving the situation by both improving accuracy and reducing the effort of data establishment and manipulation.

The work in this report is a part of the work of the project of the System of GIS-Based Hydrologic and Hydraulic Applications for Highway Engineering which is being developed by the Center for Research in Water Resources (CRWR) of the University of Texas at Austin. The idea behind the system is combining a digital spatial description of the environment with GIS data processing and a graphic interface, and with hydrologic design procedures. The whole system includes a database for the entire state of Texas and a series of computer programs which employ relatively new hydrologic and hydraulic approaches based on the latest GIS technologies. The objective of work in this report is to make the system workable on PC machines with a CD-ROM storing all the required data.

1.2 Hydrologic Data Development System (HDDS)

The Hydrologic Data Development System (HDDS) is the achievement of the MS thesis of Smith(1995). The HDDS provides a package of spatial data and menu-driven programs that allow user-interactive determination of hydrologic parameters and estimation of flood frequency relationships for the design of highway drainage structures. The system was built within the environment of GIS Arc/Info through using the Arc Macro Language (AML).
The main purpose of HDDS was to establish and manipulate digital spatial data under a GIS environment to generate and provide fundamental hydrologic parameters as the input data for THYSYS, as well as creating drainage maps, tables and related documents. The HDDS focused on the design and programming by using Arc/Info Arc Marco Language and associate data. The hydrologic parameters generated by HDDS include drainage basin boundaries, areas and sub-areas, maximum flow path length, estimated travel time, average watershed slope, hydrologic soil group, design rainfall and weighted runoff coefficients. The system was applied on a study area of the North Sulphur River Basin in Northeast Texas above state highway 24. The results demonstrated that reasonable values of hydrologic parameters could be found by the automated system.

1.3 Work in This Report

The work in this report contains two main parts. The first part is focused on determining peak-flow discharge based on the relationship between the documented peak discharges and drainage area. The USGS potential extreme peak discharge equations for all the Texas hydrologic regions applied using a spatial database prepared for the state. The details of this part of work are discussed in Chapter 2.

The second part of the work is involved with developing the TxDOT Hydrology Extension, which is a further development and improvement of Hydrologic Data development System (HDDS). The TxDOT Extension is developed for hydrologic data processing and modeling analyzing, in the environment of ArcView on both PC machines and UNIX workstations. The
hydrologic parameters, which can be generated in HDDS using Arc/Info, can be generated in the TxDOT Extension through using ArcView. This change will make the work in HDDS available to more users, and with a less software cost, since ArcView is much cheaper than Arc/Info, and it is also easier for use, especially in a PC platform. The details of the TxDOT Hydrology Extension are discussed in the Chapter 3, 4, and 5.

As a part of the work of the research project of the System of GIS-Based Hydrologic and Hydraulic Applications for Highway Engineering, the hydrologic parameters generated in the TxDOT Hydrology Extension directly serve as input data for other parts of the system. One of the major functions of the TxDOT Hydrology Extension is to develop data processing and analysis programs which can be used to establish a linkage between the vast volume of spatial data and advanced hydrologic models in a GIS environment, through generating the hydrologic parameters mentioned above from the external spatial data. All the functions in the TxDOT Hydrology Extension are customized by using Avenue, an object-oriented language associated with ArcView. These functions for hydrologic modeling and analysis include delineating watershed and calculating its topographic parameters when the outlet is identified by a point clicked on the river basin map, determining peakflow at any selected location, calculating runoff curve number at any selected location, and calculating the average flow velocity and travel time. Grid modeling is used in the TxDOT Hydrology Extension.

A CD-ROM was prepared to install the spatial database of peakflow and the TxDOT Hydrology Extension which includes the extension file and essential testing data.
2. Potential Extreme Peak Discharge in Texas

This part of the work is focused on using GIS to apply the latest USGS peak discharge equations to create a 500m grid that stores the potential peak discharge at all locations in Texas. Based on this grid, the potential peak discharge can be estimated for hydraulic structure design in highway engineering.

The document "Document and Potential Extreme Peak Discharges and Relation between Potential Extreme Peak Discharges and Probable Maximum Flood Peak Discharges in Texas" (Asquith and Slade, 1995) provides a study of extreme flood potential for Texas, in which documented stream peak discharge and associated data were aggregated from 832 sites in natural basins in Texas for over 100 years. A potential extreme peak discharge curve was developed for each of 11 hydrologic regions in Texas, based on the documented extreme peak discharges and associated contributing drainage areas.

Based on graphs of data on peak discharge versus drainage area in the document of extreme flood potential for Texas (Asquith and Slade, 1995), a series of mathematical equations were derived which relate potential peak discharge with drainage area for each hydrologic region. By using these equations, a grid of potential extreme peak discharge in Texas has been created in Arc/Info. The grid, with a resolution of 500m by 500m, stores the potential peak discharge over locations of the state of Texas.
2.1 Documented Extreme Peak Discharges for Natural Basins in Texas

Documented extreme peak discharges were aggregated from 832 sites distributed throughout Texas, of which 619 had gauging stations and 213 did not have gauging stations. For each site, the following information was provided by the USGS report: USGS station number and names, stream name and approximate location, hydrologic region number, latitude, longitude, drainage area, documented extreme peak discharge and date of occurrence. The data covers USGS monitoring records for over 100 years.

The peak discharges presented in this document result from natural basins, and they are not affected by reservoir regulations, diversions, urbanization, or other human-related activities. According to this methodology, potential peak discharges are calculated exclusively as a function of drainage area and hydrologic region. In their report, Asquith and Slade (1995) did not mention other physical characteristics of the watershed, such as land-use, soil type, or geology condition that might affect the routing of storm runoff through a terrain.

2.2 Create a Grid of Potential Extreme Peak Discharges

The methodology of creating the grid of potential extreme peak discharge consists of several steps. The first task is determining a mathematical relationship between the potential peak discharge and drainage area, which includes converting the paper documents to an electronic file and doing data processing. The second task is creating a drainage area grid and hydrologic region grid. Finally, a cell-
based calculation in Arc/Info Grid is used to create a grid of potential peak discharge by applying the regression equations, the drainage area grid, and the hydrological region grid.

2.2.1 Determine the Relationship of Peak Discharge and Drainage Area

The document of potential extreme peak discharge (Asquith and Slade, 1995) was used as a data source to determine the mathematical relationship of peak discharge and drainage area for each hydrological region. Since only the paper document was available, the first task was converting the paper document to an electronic file by scanning the data and checking, and doing some post-processing in a spreadsheet. Using the USGS station number and the corresponding latitude, longitude information from the document, a point coverage including 832 peak discharge sites in Texas was created by using Arc/Info and ArcView methods. Figure 2-1 shows the distribution of 11 hydrologic regions in Texas. Figure 2-2 shows the locations of all the documented sites.
Figure 2-1 Distribution of 11 Hydrologic Regions in Texas
To determine the relationship of peak discharge and drainage area for each hydrologic region, the following procedures were used.

(a) **Plotting charts of peak discharge vs. drainage area**

The peak discharge document in spreadsheet format was sorted by hydrologic regions, so that all monitoring records of peak discharge in each hydrologic region
were collected. Eleven charts of documented peak discharges vs. drainage area for
the stations of each of the 11 hydrologic regions were plotted.

(b) Drawing envelope curves on the charts of peak discharge vs. drainage
area
For each hydrologic region, a potential extreme peak discharge envelope curve
was formed by selecting the points at the upper edge of the data plot and fitting
them to a number of straight line segments in a contributing drainage area ~ peak
discharge plot. In developing this curve, it was assumed that potential peak
discharges were greater than the 100-year peak discharges, already available from
other USGS studies. One envelope curve was developed for each hydrologic
region which is displayed in Figures 2-3 to 2-13. Figure 2-14 shows the
comparison of potential extreme peak discharges over all 11 hydrologic regions in
Texas.

(c) Deriving mathematical equations of peak discharge vs. drainage area
The log scale plot of an envelope curve for each hydrologic region consists of
a number of segments which connect points at the upper edge of the plot of
drainage area vs. peak discharge. A series of equations in the form \( \log Q = k \log A + b \) were used to represent potential peak discharge envelop curves. Here \( k \) and
\( b \) are regression coefficients, \( A \) is the contributing drainage area, and \( Q \) is the
estimated extreme peak discharge. Table 2-1 shows the equation for 11
hydrological regions in Texas.
Figure 2-3: The Peak Discharge Envelope Curve for Hydrologic Region 1

Figure 2-4: The Peak Discharge Envelope Curve for Hydrologic Region 2
Figure 2-5: The Peak Discharge Envelope Curve for Hydrologic Region 3

Figure 2-6: The Peak Discharge Envelope Curve for Hydrologic Region 4
Figure 2-7: The Peak Discharge Envelope Curve for Hydrologic Region 5

Figure 2-8: The Peak Discharge Envelope Curve for Hydrologic Region 6
Figure 2-9: The Peak Discharge Envelope Curve for Hydrologic Region 7
Figure 2-10: The Peak Discharge Envelope Curve for Hydrologic Region 8

Figure 2-11: The Peak Discharge Envelope Curve for Hydrologic Region 9
Figure 2-12: The Peak Discharge Envelope Curve for Hydrologic Region 10

Figure 2-13: The Peak Discharge Envelope Curve for Hydrologic Region 11
Figure 2-14: Comparison of Potential Peak Discharges for 11 Hydrologic Regions in Texas.

Table 2-1. Regression Equations for Eleven Hydrologic Region in Texas

<table>
<thead>
<tr>
<th>Region</th>
<th>Q: Estimated Peak Flow(cfs), A: Drainage Area(sq-mi)</th>
<th>Drainage Area Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$Q = 3950 \times A^{0.83}$</td>
<td>0 - - 5 mi</td>
</tr>
<tr>
<td>1</td>
<td>$Q = 5050 \times A^{0.65}$</td>
<td>5 - - 70 mi</td>
</tr>
<tr>
<td>1</td>
<td>$Q = 26871 \times A^{0.26}$</td>
<td>70 - - 1000 mi</td>
</tr>
<tr>
<td>1</td>
<td>$Q = 71072 \times A^{0.12}$</td>
<td>&gt; 1000 mi</td>
</tr>
<tr>
<td>2</td>
<td>$Q = 1824 \times A^{-0.32}$</td>
<td>0 - - 10 mi</td>
</tr>
<tr>
<td>2</td>
<td>$Q = 6017 \times A^{0.81}$</td>
<td>10 - - 75 mi</td>
</tr>
<tr>
<td>2</td>
<td>$Q = 34959 \times A^{-0.39}$</td>
<td>75 - - 750 mi</td>
</tr>
<tr>
<td>2</td>
<td>$Q = 121475 \times A^{0.21}$</td>
<td>&gt; 750 mi</td>
</tr>
<tr>
<td>3</td>
<td>$Q = 3437 \times A^{-1.14}$</td>
<td>0 - - 4 mi</td>
</tr>
<tr>
<td>3</td>
<td>$Q = 5108 \times A^{0.84}$</td>
<td>4 - - 40 mi</td>
</tr>
<tr>
<td>3</td>
<td>$Q = 20653 \times A^{0.36}$</td>
<td>40 - - 610 mi</td>
</tr>
<tr>
<td></td>
<td>Formula</td>
<td>Drainage Area Range</td>
</tr>
<tr>
<td>---</td>
<td>---------</td>
<td>---------------------</td>
</tr>
<tr>
<td>3</td>
<td>$Q = 252734 \times A^{0.37}$</td>
<td>&gt; 610 mfi</td>
</tr>
<tr>
<td>4</td>
<td>$Q = 3849 \times A^{-0.14}$</td>
<td>0 - - 1 mfi</td>
</tr>
<tr>
<td>4</td>
<td>$Q = 3656 \times A^{0.95}$</td>
<td>1 - - 15 mfi</td>
</tr>
<tr>
<td>4</td>
<td>$Q = 6939 \times A^{0.71}$</td>
<td>15 - - 60 mfi</td>
</tr>
<tr>
<td>4</td>
<td>$Q = 27455 \times A^{-0.37}$</td>
<td>60 - - 1850 mfi</td>
</tr>
<tr>
<td>4</td>
<td>$Q = 178803 \times A^{0.12}$</td>
<td>&gt; 1850 mfi</td>
</tr>
<tr>
<td>5</td>
<td>$Q = 6206 \times A^{0.89}$</td>
<td>0 - - 1.5 mfi</td>
</tr>
<tr>
<td>5</td>
<td>$Q = 6544 \times A^{0.76}$</td>
<td>1.5 - 400 mfi</td>
</tr>
<tr>
<td>5</td>
<td>$Q = 301606 \times A^{0.12}$</td>
<td>&gt; 400 mfi</td>
</tr>
<tr>
<td>6</td>
<td>$Q = 1146 \times A^{-0.35}$</td>
<td>0 - - 20 mfi</td>
</tr>
<tr>
<td>6</td>
<td>$Q = 2302 \times A^{-0.82}$</td>
<td>20 - - 100 mfi</td>
</tr>
<tr>
<td>6</td>
<td>$Q = 21555 \times A^{-0.34}$</td>
<td>&gt; 100 mfi</td>
</tr>
<tr>
<td>7</td>
<td>$Q = 3168 \times A^{-0.82}$</td>
<td>0 - - 16 mfi</td>
</tr>
<tr>
<td>7</td>
<td>$Q = 6790 \times A^{0.55}$</td>
<td>16 - - 1150 mfi</td>
</tr>
<tr>
<td>7</td>
<td>$Q = 101713 \times A^{0.16}$</td>
<td>&gt; 1150 mfi</td>
</tr>
<tr>
<td>8</td>
<td>$Q = 1318 \times A^{0.98}$</td>
<td>0 - - 150 mfi</td>
</tr>
<tr>
<td>8</td>
<td>$Q = 22895 \times A^{0.39}$</td>
<td>150 - - 7000 mfi</td>
</tr>
<tr>
<td>8</td>
<td>$Q = 181400 \times A^{0.15}$</td>
<td>&gt; 7000 mfi</td>
</tr>
<tr>
<td>9</td>
<td>$Q = 4345 \times A^{0.75}$</td>
<td>0 - - 100 mfi</td>
</tr>
<tr>
<td>9</td>
<td>$Q = 9300 \times A^{0.58}$</td>
<td>100 - - 500 mfi</td>
</tr>
<tr>
<td>9</td>
<td>$Q = 207940 \times A^{0.09}$</td>
<td>&gt; 500 mfi</td>
</tr>
<tr>
<td>10</td>
<td>$Q = 1577 \times A^{-0.92}$</td>
<td>0 - - 60 mfi</td>
</tr>
<tr>
<td>10</td>
<td>$Q = 3011 \times A^{0.66}$</td>
<td>60 - - 280 mfi</td>
</tr>
<tr>
<td>10</td>
<td>$Q = 34609 \times A^{0.23}$</td>
<td>&gt; 280 mfi</td>
</tr>
<tr>
<td>11</td>
<td>$Q = 1757 \times A^{0.94}$</td>
<td>0 - - 1.5 mfi</td>
</tr>
<tr>
<td>11</td>
<td>$Q = 1871 \times A^{0.75}$</td>
<td>1.5 - - 45 mfi</td>
</tr>
<tr>
<td>11</td>
<td>$Q = 5405 \times A^{0.50}$</td>
<td>45 - - 2800 mfi</td>
</tr>
<tr>
<td>11</td>
<td>$Q = 193327 \times A^{0.05}$</td>
<td>&gt; 2800 mfi</td>
</tr>
</tbody>
</table>
2.2.2 Create a Drainage Area Grid and a Hydrologic Region Grid

The method of creating a drainage area grid includes (1) getting the DEM, (2) burning-in the stream network on the DEM, and (3) applying Arc/info-Grid functions, such as **fill**, **flowdirection** and **flowaccumulation**, to create a flow accumulation grid. The Grid function **flowaccumulation** stores in each cell the number of upstream cells whose drainage passes through the given cell. The cell size is 500m which equals 0.31068 miles, so the cell area = 500m*500m = 0.3168mile*0.3168mile=0.0965 mile$^2$. If the flowaccumulation is multiplied by this constant, the result is a grid in which each cell stores its upstream drainage area in units of square miles.

The hydrologic region grid was created by rasterizing the hydrologic-region polygon coverage shown in Figure 2-1 by using Arc/Info-Grid function **polygrid**. The same cell-size as that of the drainage area grid was applied for the hydrologic region grid.

2.2.3 Create the Grid of Potential Extreme Peak Discharges

A grid of potential extreme peak discharge was created by using a set of conditional statements in Arc/Info Grid. For each region the cell-based calculation was applied by using the corresponding mathematical equations from Table 2-1 to calculate the potential extreme peak discharge where the area $A$ was formed from the drainage area grid. The grids for each hydrologic region were then merged to
form a grid of Texas, using the command `merge` in Grid. The final result of the grid of potential extreme peak discharge can be viewed in Figure 2-15.

![Grid of Potential Extreme Peak Discharge in Texas](image)

**Figure 2-15: Grid of Potential Extreme Peak Discharge in Texas**

2.3 Assessment and Conclusion

The grid of potential extreme peak discharge in Texas stores the potential peak discharge over all locations of Texas. It can be used as an estimation of highest peak discharge for highway hydraulic structure design. This grid also can
be inserted in the TxDOT Hydrology Extension to provide peak flow information for return period over 100 years.

GIS is a powerful tool for displaying and analyzing the information related to the grid of the extreme peak discharge. By using GIS, the research document on potential discharges becomes a visualized tool supporting highway hydraulic-structure design.

The grid of potential extreme peak discharge is based on the mathematical equations showed in Table 2-1. These equations are suitable for drainage areas of 0.1~10000 sq-mi. For drainage area less than 0.1 sq-mi or bigger than 10000 sq-mi, these equations might be inaccurate. On the other hand, for drainage area less than 10 sq-mi, the Grid method of Arc/Info using 500m cell does not provide very accurate result for drainage area. Therefore, for using the grid created in this report, a drainage area of 10 ~ 10000 sq-mi is recommended.

This grid provides a very conservative estimate of flows since some watershed characteristics, such as land use, soil type, or geology, have been ignored and the worst-case values have been predicted. The effects of reservoirs and cities on the downstream water bodies have not been considered. So the peak flow in areas downstream of dams and urban areas may need to be corrected.
3. Hydrologic Modeling and Methods used TxDOT Hydrology Extension

The TxDOT Hydrology Extension is a GIS-based analysis system, specifically designed for TxDOT, and used for calculating peakflow and hydrologic parameters, including average slope, longest flow-path, curve number (CN), flow velocity, travel time etc., which can be used for highway engineering design.

For highway engineering facility design, the determination of design peak discharge and its frequency of occurrence is a key procedure of hydrologic analysis. Peak discharge can be determined through either of the following two approaches. One approach is based on the regression equations which are derived from statistical analysis of stream gauging records. The other is using a hydrologic system model. The TxDOT Hydrology Extension involves both of these approaches. For the regression approach, the system identifies peak flow based on the regression equations of peak discharge for six frequencies: 2 year, 5 year, 10 year, 25 year, 50 year, and 100 year. For the modeling approach, the system can be used to calculate the fundamental hydrologic parameters including travel time, average flow velocity and curve number, which are further used to calculate peak flow in rainfall-runoff models.

3.1 Peak Discharge Based on Historical Gauge Records

Chapter 2 discussed how to use gauging data to derive regression equations based on USGS research report (Asquith, and Slade, 1995), for which the
recurrence interval is greater than 100 years. Recently Asquith and Slade (1997) developed regression equations of peak-flow based on the records for various recurrence intervals: 2 years, 5 years, 10 years, 25 years, 50 years and 100 years, which are presented by U.S. geological survey (USGS, 1996). These new equations provide a more comprehensive description of the relation between peak discharge and its frequency than was previously available for Texas. The TxDOT Hydrology Extension uses these new regression equations, as listed in the Table 3-1.

Note: in the table, $Q$(m$^3$/s) is peak discharge; $A$(km$^2$) is the area of watershed, the whole watershed area contributes the drainage to its pour point; $SL$(m/m) is the average slope of watershed which is defined as the slope between the 10% and 85% points along the longest flow path; $SH$(m$^2$/m$^2$) is the basin shape factor which is defined as the ratio of the square of the longest stream length to the watershed area.

Table 3-1: Regression Equations for Natural Basin in Texas.
($Q$: m$^3$/s, $A$: km$^2$, $SH$: m$^2$/m$^2$, $SL$: m/m)

<table>
<thead>
<tr>
<th>Hydrologic Region</th>
<th>Recurrence Interval</th>
<th>Regression Equations for Corresponding Recurrence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2yr</td>
<td>$Q_2 = 0.1694 * A^{0.304} * SH^{-0.537}$</td>
</tr>
<tr>
<td></td>
<td>5yr</td>
<td>$Q_5 = 0.6054 * A^{0.395} * SH^{-0.444}$</td>
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<tr>
<td></td>
<td>10yr</td>
<td>$Q_{10} = 1.1315 * A^{0.321} * SH^{-0.400}$</td>
</tr>
<tr>
<td></td>
<td>25yr</td>
<td>$Q_{25} = 2.1712 * A^{0.383} * SH^{-0.356}$</td>
</tr>
<tr>
<td></td>
<td>50yr</td>
<td>$Q_{50} = 3.2727 * A^{0.364} * SH^{-0.330}$</td>
</tr>
<tr>
<td></td>
<td>100yr</td>
<td>$Q_{100} = 4.6920 * A^{0.347} * SH^{-0.307}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2yr</td>
<td>$Q_2 = 0.0445 * A^{0.372} * SH^{0.669} * SL^{0.689}$</td>
</tr>
<tr>
<td></td>
<td>5yr</td>
<td>$Q_5 = 0.0435 * A^{0.372} * SH^{0.735} * SL^{-0.933}$</td>
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<tr>
<td></td>
<td>10yr</td>
<td>$Q_{10} = 0.0445 * A^{0.369} * SH^{0.734} * SL^{-1.050}$</td>
</tr>
<tr>
<td>Year</td>
<td>Q₂₅</td>
<td>Q₅₀</td>
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<td>------</td>
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<tr>
<td>25yr</td>
<td>$Q_{25} = 0.0411 \cdot A^{0.366} \cdot SH^{0.504} \cdot SL^{-1.190}$</td>
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<tr>
<td>50yr</td>
<td>$Q_{50} = 0.0405 \cdot A^{0.363} \cdot SH^{0.566} \cdot SL^{-1.27}$</td>
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<tr>
<td>100yr</td>
<td>$Q_{100} = 0.0411 \cdot A^{0.381} \cdot SH^{0.533} \cdot SL^{-1.346}$</td>
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<table>
<thead>
<tr>
<th>Age</th>
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<td>3yr</td>
<td>$Q_2 = 1.9183 \cdot A^{0.592}$</td>
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<td>5yr</td>
<td>$Q_5 = 3.9218 \cdot A^{0.629}$</td>
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<tr>
<td>10yr</td>
<td>$Q_{10} = 5.6791 \cdot A^{0.652}$</td>
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<tr>
<td>25yr</td>
<td>$Q_{25} = 8.3991 \cdot A^{0.679}$</td>
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<tr>
<td>50yr</td>
<td>$Q_{50} = 10.8281 \cdot A^{0.698}$</td>
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<tr>
<td>100yr</td>
<td>$Q_{100} = 13.5939 \cdot A^{0.715}$</td>
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<tr>
<th>Age</th>
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<tr>
<td>3yr</td>
<td>$Q_2 = 34.2746 \cdot A^{0.668} \cdot SH^{0.189} \cdot SL^{0.659}$</td>
<td>$A &lt; 83 \text{ km}^2$</td>
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<tr>
<td>5yr</td>
<td>$Q_5 = 89.8187 \cdot A^{0.629} \cdot SL^{0.574}$</td>
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<tr>
<td>10yr</td>
<td>$Q_{10} = 149.6630 \cdot A^{0.579} \cdot SL^{0.537}$</td>
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<tr>
<td>25yr</td>
<td>$Q_{25} = 237.2570 \cdot A^{0.523} \cdot SL^{0.476}$</td>
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<tr>
<td>50yr</td>
<td>$Q_{50} = 305.7774 \cdot A^{0.484} \cdot SL^{0.425}$</td>
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<tr>
<td>100yr</td>
<td>$Q_{100} = 374.8059 \cdot A^{0.447} \cdot SL^{0.372}$</td>
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<tr>
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<th>Q₂</th>
<th>Q₅</th>
<th>Q₁₀</th>
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<td>4yr</td>
<td>$Q_2 = 1.5154 \cdot A^{0.592}$</td>
<td>$A &lt; 83 \text{ km}^2$</td>
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<tr>
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<td>$Q_5 = 2.9899 \cdot A^{0.592} \cdot SH^{0.207}$</td>
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<td>$Q_{10} = 4.2741 \cdot A^{0.579} \cdot SH^{0.281}$</td>
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<td>25yr</td>
<td>$Q_{25} = 6.3650 \cdot A^{0.541} \cdot SH^{0.311}$</td>
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<td>$Q_{50} = 74.2031 \cdot A^{0.392} \cdot SH^{0.353} \cdot SL^{0.338}$</td>
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<tr>
<td>100yr</td>
<td>$Q_{100} = 124.0603 \cdot A^{0.386} \cdot SH^{0.353} \cdot SL^{0.327}$</td>
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<th>Age</th>
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<th>Q₅</th>
<th>Q₁₀</th>
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<tr>
<td>4yr</td>
<td>$Q_2 = 3301.6992 \cdot A^{1.29} \cdot SL^{2.09}$</td>
<td>$A &gt; 83 \text{ km}^2$</td>
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<td>$Q_5 = 24056.4457 \cdot A^{1.24} \cdot SL^{2.18}$</td>
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<td>$Q_{10} = 55048.3692 \cdot A^{1.24} \cdot SL^{2.18}$</td>
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<tr>
<td>25yr</td>
<td>$Q_{25} = 124899.2199 \cdot A^{1.16} \cdot SL^{2.18}$</td>
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<td>50yr</td>
<td>$Q_{50} = 227873.0495 \cdot A^{1.13} \cdot SL^{2.19}$</td>
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<tr>
<td>100yr</td>
<td>$Q_{100} = 352574.9115 \cdot A^{1.11} \cdot SL^{2.19}$</td>
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<table>
<thead>
<tr>
<th>Age</th>
<th>Q₂</th>
<th>Q₅</th>
<th>Q₁₀</th>
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<tr>
<td>5yr</td>
<td>$Q_2 = 2.3572 \cdot A^{0.583}$</td>
<td>$A &lt; 83 \text{ km}^2$</td>
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<td>5yr</td>
<td>$Q_5 = 5.3735 \cdot A^{0.779}$</td>
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<td>10yr</td>
<td>$Q_{10} = 8.0970 \cdot A^{0.829}$</td>
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<tr>
<td>Year</td>
<td>Water Year</td>
<td>Equation</td>
<td>Area</td>
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<td>5</td>
<td>2yr</td>
<td>$Q_2 = 6.6461 \times A^{0.498}$</td>
<td>A &gt; 83 km²</td>
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<tr>
<td>5</td>
<td>5yr</td>
<td>$Q_5 = 21.6345 \times A^{0.534} \times SH^{0.145}$</td>
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<td>10yr</td>
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<td>$Q_{10} = 38.6826 \times A^{0.552} \times SH^{0.221}$</td>
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<td>25yr</td>
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<td>$Q_{25} = 71.2097 \times A^{0.571} \times SH^{0.307}$</td>
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<td>$Q_{50} = 104.8700 \times A^{0.583} \times SH^{0.366}$</td>
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<td>100yr</td>
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<td>$Q_{100} = 147.7025 \times A^{0.594} \times SH^{0.42}$</td>
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<td>6</td>
<td>2yr</td>
<td>$Q_2 = 1.0293 \times A^{0.504} \times SF^{0.523}$</td>
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<td>5</td>
<td>5yr</td>
<td>$Q_5 = 0.5242 \times A^{0.424} \times SL^{0.41}$</td>
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<td>10yr</td>
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<td>$Q_{10} = 0.9085 \times A^{0.419} \times SL^{0.419}$</td>
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<tr>
<td>25yr</td>
<td></td>
<td>$Q_{25} = 1.6273 \times A^{0.391} \times SL^{0.426}$</td>
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<tr>
<td>50yr</td>
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<td>$Q_{50} = 2.3506 \times A^{0.386} \times SL^{0.434}$</td>
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<td>100yr</td>
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<td>$Q_{100} = 33.1599 \times A^{0.44}$</td>
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<tr>
<td>7</td>
<td>2yr</td>
<td>$Q_2 = 1.1925 \times A^{0.308} \times SL^{0.286}$</td>
<td>A &lt; 83 km²</td>
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<tr>
<td>5</td>
<td>5yr</td>
<td>$Q_5 = 9.2543 \times A^{0.61}$</td>
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<td>10yr</td>
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<td>$Q_{10} = 13.3959 \times A^{0.592}$</td>
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<tr>
<td>25yr</td>
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<td>$Q_{25} = 19.5756 \times A^{0.576}$</td>
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</tr>
<tr>
<td>50yr</td>
<td></td>
<td>$Q_{50} = 24.8688 \times A^{0.566}$</td>
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</tr>
<tr>
<td>100yr</td>
<td></td>
<td>$Q_{100} = 30.6700 \times A^{0.538}$</td>
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<tr>
<td>7</td>
<td>2yr</td>
<td>$Q_2 = 47.7294 \times A^{0.376} \times SL^{0.664}$</td>
<td>A &gt; 83 km²</td>
</tr>
<tr>
<td>5</td>
<td>5yr</td>
<td>$Q_5 = 300.2844 \times A^{0.658} \times SL^{0.57}$</td>
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<td>10yr</td>
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<td>$Q_{10} = 1092.4994 \times A^{0.644} \times SH^{0.339} \times SL^{0.594}$</td>
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<td>$Q_{25} = 2583.4202 \times A^{0.651} \times SH^{0.267} \times SL^{0.76}$</td>
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<td>$Q_{50} = 4367.0970 \times A^{0.653} \times SH^{0.291} \times SL^{0.87}$</td>
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<td>$Q_{100} = 6883.4736 \times A^{0.654} \times SH^{0.318} \times SL^{0.649}$</td>
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<tr>
<td>8</td>
<td>2yr</td>
<td>$Q_2 = 122.6319 \times A^{0.627} \times SL^{0.652}$</td>
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<tr>
<td>5</td>
<td>5yr</td>
<td>$Q_5 = 113.3012 \times A^{0.688} \times SL^{0.52}$</td>
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<td>10yr</td>
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<td>$Q_{10} = 117.0641 \times A^{0.675} \times SL^{0.475}$</td>
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<td>25yr</td>
<td>50yr</td>
<td>100yr</td>
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<tr>
<td>Q&lt;sub&gt;25&lt;/sub&gt;</td>
<td>126.1105 * A&lt;sup&gt;0.895&lt;/sup&gt; * SL&lt;sup&gt;0.444&lt;/sup&gt;</td>
<td>135.9037 * A&lt;sup&gt;0.793&lt;/sup&gt; * SL&lt;sup&gt;0.333&lt;/sup&gt;</td>
<td>147.5524 * A&lt;sup&gt;0.718&lt;/sup&gt; * SL&lt;sup&gt;0.429&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;50&lt;/sub&gt;</td>
<td>33.2386 * A&lt;sup&gt;0.695&lt;/sup&gt; * SH&lt;sup&gt;-0.245&lt;/sup&gt; * SL&lt;sup&gt;0.22&lt;/sup&gt;</td>
<td>97.1374 * A&lt;sup&gt;0.691&lt;/sup&gt; * SH&lt;sup&gt;-0.321&lt;/sup&gt; * SL&lt;sup&gt;0.343&lt;/sup&gt;</td>
<td>289.5838 * A&lt;sup&gt;0.743&lt;/sup&gt; * SH&lt;sup&gt;-0.413&lt;/sup&gt; * SL&lt;sup&gt;0.466&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;100&lt;/sub&gt;</td>
<td>147.5524 * A&lt;sup&gt;0.718&lt;/sup&gt; * SL&lt;sup&gt;0.429&lt;/sup&gt;</td>
<td>570.3826 * A&lt;sup&gt;0.776&lt;/sup&gt; * SH&lt;sup&gt;-0.477&lt;/sup&gt; * SL&lt;sup&gt;0.541&lt;/sup&gt;</td>
<td>1042.2502 * A&lt;sup&gt;0.811&lt;/sup&gt; * SH&lt;sup&gt;-0.538&lt;/sup&gt; * SL&lt;sup&gt;0.607&lt;/sup&gt;</td>
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<th>2yr</th>
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<tbody>
<tr>
<td>Q&lt;sub&gt;2&lt;/sub&gt;</td>
<td>4.7719 * A&lt;sup&gt;0.326&lt;/sup&gt;</td>
<td>33.2386 * A&lt;sup&gt;0.695&lt;/sup&gt; * SH&lt;sup&gt;-0.445&lt;/sup&gt; * SL&lt;sup&gt;0.22&lt;/sup&gt;</td>
<td>97.1374 * A&lt;sup&gt;0.691&lt;/sup&gt; * SH&lt;sup&gt;-0.321&lt;/sup&gt; * SL&lt;sup&gt;0.343&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;5&lt;/sub&gt;</td>
<td>33.2386 * A&lt;sup&gt;0.695&lt;/sup&gt; * SH&lt;sup&gt;-0.445&lt;/sup&gt; * SL&lt;sup&gt;0.22&lt;/sup&gt;</td>
<td>289.5838 * A&lt;sup&gt;0.743&lt;/sup&gt; * SH&lt;sup&gt;-0.413&lt;/sup&gt; * SL&lt;sup&gt;0.466&lt;/sup&gt;</td>
<td>570.3826 * A&lt;sup&gt;0.776&lt;/sup&gt; * SH&lt;sup&gt;-0.477&lt;/sup&gt; * SL&lt;sup&gt;0.541&lt;/sup&gt;</td>
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<td>Q&lt;sub&gt;10&lt;/sub&gt;</td>
<td>97.1374 * A&lt;sup&gt;0.691&lt;/sup&gt; * SH&lt;sup&gt;-0.321&lt;/sup&gt; * SL&lt;sup&gt;0.343&lt;/sup&gt;</td>
<td>1042.2502 * A&lt;sup&gt;0.811&lt;/sup&gt; * SH&lt;sup&gt;-0.538&lt;/sup&gt; * SL&lt;sup&gt;0.607&lt;/sup&gt;</td>
<td>1042.2502 * A&lt;sup&gt;0.811&lt;/sup&gt; * SH&lt;sup&gt;-0.538&lt;/sup&gt; * SL&lt;sup&gt;0.607&lt;/sup&gt;</td>
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<tbody>
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<td>Q&lt;sub&gt;2&lt;/sub&gt;</td>
<td>8.0270 * A&lt;sup&gt;0.789&lt;/sup&gt; * SL&lt;sup&gt;0.279&lt;/sup&gt;</td>
<td>17.4696 * A&lt;sup&gt;0.808&lt;/sup&gt; * SL&lt;sup&gt;0.33&lt;/sup&gt;</td>
<td>26.6161 * A&lt;sup&gt;0.884&lt;/sup&gt; * SL&lt;sup&gt;0.339&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;5&lt;/sub&gt;</td>
<td>17.4696 * A&lt;sup&gt;0.808&lt;/sup&gt; * SL&lt;sup&gt;0.33&lt;/sup&gt;</td>
<td>42.0347 * A&lt;sup&gt;0.867&lt;/sup&gt; * SL&lt;sup&gt;0.39&lt;/sup&gt;</td>
<td>55.7797 * A&lt;sup&gt;0.904&lt;/sup&gt; * SL&lt;sup&gt;0.408&lt;/sup&gt;</td>
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<td>Q&lt;sub&gt;10&lt;/sub&gt;</td>
<td>26.6161 * A&lt;sup&gt;0.884&lt;/sup&gt; * SL&lt;sup&gt;0.339&lt;/sup&gt;</td>
<td>72.2851 * A&lt;sup&gt;1.064&lt;/sup&gt; * SL&lt;sup&gt;0.426&lt;/sup&gt;</td>
<td>72.2851 * A&lt;sup&gt;1.064&lt;/sup&gt; * SL&lt;sup&gt;0.426&lt;/sup&gt;</td>
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<th>5yr</th>
<th>10yr</th>
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<tbody>
<tr>
<td>Q&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2.3820 * A&lt;sup&gt;0.889&lt;/sup&gt; * SH&lt;sup&gt;-0.262&lt;/sup&gt;</td>
<td>8.4989 * A&lt;sup&gt;0.796&lt;/sup&gt; * SH&lt;sup&gt;-0.186&lt;/sup&gt; * SL&lt;sup&gt;0.13&lt;/sup&gt;</td>
<td>18.9170 * A&lt;sup&gt;0.796&lt;/sup&gt; * SH&lt;sup&gt;-0.186&lt;/sup&gt; * SL&lt;sup&gt;0.13&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;5&lt;/sub&gt;</td>
<td>8.4989 * A&lt;sup&gt;0.796&lt;/sup&gt; * SH&lt;sup&gt;-0.186&lt;/sup&gt; * SL&lt;sup&gt;0.13&lt;/sup&gt;</td>
<td>42.2418 * A&lt;sup&gt;0.713&lt;/sup&gt; * SL&lt;sup&gt;0.313&lt;/sup&gt;</td>
<td>75.6556 * A&lt;sup&gt;0.713&lt;/sup&gt; * SL&lt;sup&gt;0.336&lt;/sup&gt;</td>
</tr>
<tr>
<td>Q&lt;sub&gt;10&lt;/sub&gt;</td>
<td>18.9170 * A&lt;sup&gt;0.796&lt;/sup&gt; * SH&lt;sup&gt;-0.186&lt;/sup&gt; * SL&lt;sup&gt;0.13&lt;/sup&gt;</td>
<td>129.9534 * A&lt;sup&gt;0.735&lt;/sup&gt; * SL&lt;sup&gt;0.442&lt;/sup&gt;</td>
<td>129.9534 * A&lt;sup&gt;0.735&lt;/sup&gt; * SL&lt;sup&gt;0.442&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

To determine peak discharge using the equations in the Table 3-1, watershed area, average watershed slope and watershed shape factor are needed. The
following is an example showing the calculation of peak discharge by using the regression equations.

**Example:**

*Determine the peak discharge for a 100 year flood in region 2 of Texas for a watershed of 135 km\(^2\) drainage area whose shaper factor is 4.5, and whose channel slope is 0.0015 m/m.*

**Solution:**

*From Table 3-1, the estimating equation is given by:*

\[
Q_{100} = 0.0411 \times A^{0.361} \times SH^{0.531} \times SL^{-1.340}
\]

*Where  \( A = 135 \text{ km}^2 \)*

\[
SH = 4.5 \text{ (km}^2\text{/km}^2\text{)}
\]

\[
SL = 0.0015 \text{ m/m}
\]

*so:  \( Q_{100} = 0.0411 \times 135^{0.361} \times 4.5^{0.531} \times 0.0015^{-1.340} = 3264 \text{ m}^3/\text{s} \)*

3.2 Fundamental Hydrologic Parameters for Hydrologic Analysis

Due to the complexity of hydrologic variables including random space-related and time-dependent properties, the unit hydrograph method is widely used in practical design. Superposition based on the linearity of this method efficiently simplifies the procedure and reduces the amount of hydrologic calculation. Both the inherent assumptions of this method and the results have been shown to be acceptable for engineering practice. The hydrologic parameters required for the unit hydrograph method, include drainage basin boundary and area, longest flow path length, flow velocity, flow travel time, watershed average slope, and runoff.
curve number. All these parameters can be analyzed and determined in the TxDOT Hydrology Extension.

Geomorphologic parameters include land elevation, land slope, stream direction, flow accumulation, upstream length, downstream length, watershed boundary, and watershed area. These parameters are determined by topography of the studied area. Among these parameters, terrain elevation is fundamental and the others can be derived from terrain elevation by topographical analysis methods, which are implemented in the TxDOT Hydrology Extension.

• **Terrain Elevation**

Land elevation is defined as the height above the mean sea level of a point on the earth surface. The proportionality between gravity potential and land surface elevation determines the direction of flow movement.
Figure 3-1: Processing the DEM Grid

- **Land Slope and Flow Direction**

  Surface runoff occurs when rainfall intensity exceeds the infiltration capacity. For a point on the land surface, land slope varies with the direction around the point. The gravity potential gradient decides the direction of flow movement. The direction with the steepest downward slope is defined as the flow direction. In this definition, it is inherently assumed that all runoff from a point flows in only one direction. The terrain is defined by a grid. All cells except boundary cells in a grid have eight adjacent cells. So the runoff direction has to be one of the eight directions between a given cell and its neighbors on the
horizontal and vertical axes and on the diagonals as shown in Figure 3-1(b) and (c). A binary geometric series is used to define the directions: 1 = East, 2 = Southeast, 4 = South, 8 = Southwest, 16 = West, 32 = Northwest, 64 = North, and 128 = Northeast.

• **Flow Accumulation**

When runoff occurs, it takes the form of a sheet flow whose depth might be measured in fractions of an inch. Due to the flow being in only one direction, all runoff of up-slope cells goes through each of down-slope cells, and we define this process as flow accumulation. The depth of the overland sheet flow increases along the flow direction because of the flow accumulation. Flow accumulation covers both the overland sheet flow and stream flow, which are discussed below. The flow accumulation process counts the number of cells that contribute flow to a cell using the flow direction grid. At any given cell, the drainage area to the cell (but not including the cell) is the product of the flow accumulation value and the cell area. From this grid of flow directions, a drainage network is derived as shown in Figure 3-1(d).

• **Stream Formation and Stream Network**

The overland flow forms the first phase of surface flow. As the accumulation of the overland sheet flow continues, the concentrated flow is confined in much narrower stream forms called small channel flow. Outflows of many small channel flows combine into a large channel flow called streams.
Streams are classified by their orders. The smallest recognizable streams which normally flow during wet weather are designated order one. When two streams of same order \(i\) meet, a stream of order \((i+1)\) forms. Streams are defined in a grid cell system as lines of cells whose upstream drainage area or flow accumulation exceeds a threshold value.

- **Watershed Delineation**

  The watershed is the area of land draining into a stream at a specified location. This area is normally defined as the total area flowing to a given outlet, or a pour point which is the grid cell at the outlet location. The boundary between two watersheds is referred to as a watershed boundary or drainage divide. A pour point is the point at which water flows out of an area. This is the lowest elevation point along the boundary of the watershed.

  To delineate the watershed for a given pour point, the flow direction of all cells or regions around the pour point are checked. If the downstream flow path of a point is through that pour point, that cell is recognized as being included in the watershed of the given pour point. From these surrounding cells which are already parts of the watershed, the same procedures are performed on their nearby cells to find other watershed cells. In this way, the summation of these sub-regions becomes bigger and bigger until there are no further watershed sub-regions which can be found. At this time, the entire watershed forms. The most outside cells form the watershed boundary, or drainage divide.

  From above we observe that the watershed corresponding to a pour point on a stream must be contained by the watershed corresponding to any lower pour
point on the same stream. The watershed for a given pour point is the summation of all watersheds of upstream pour points.

- **Flow Length, Longest Flow Path**

  For a point on a stream inside a watershed, the flow length upstream is the longest length from this point to the top of the drainage divide along the flow direction and the flow length downstream is the length from this point to the pour point of the watershed along the stream. The total flow length is the sum of the flow length upstream and the flow length downstream for any point inside watershed area.

  There is a unique line of cells inside a watershed whose flow length is the longest. This line of cells defines the longest flow path.

- **Hydrologic Soil Group**

  There are many types of soil and many attributes associated with each type of soil. But for hydrologic analysis purpose, soils are classified into four groups according to their water infiltration ability by the US Soil Conservation Service (1974). The four hydrologic soil groups are defined as:

  **Group A**: Soils having a low runoff potential due to high infiltration rates even when saturated (0.30 - 0.45 in/hr). These soils consist primarily of deep sands, deep loess and aggregated silts.

  **Group B**: Soils having a moderately low runoff potential due to moderate infiltration rates when saturated (0.15 - 0.30 in/hr). These soils consist primarily
of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures (shallow loess, sandy loam).

**Group C:** Soils having a moderately high runoff potential due to slow infiltration rates (0.05 - 0.15 in/hr if saturated). These soils consist primarily of soils in which a layer near the surface impedes the downward movement of water or soils with moderately fine to fine texture (clay loams, shallow sandy loams, soils low in organic content, and soils usually high in clay).

**Group D:** Soils having a high runoff potential due to very slow infiltration rates (less than 0.05 in/hr if saturated). These soils consist primarily of clays with: high swelling potential; soils with permanently high water tables; soils with a claypan or clay layer at or near the surface; shallow soils over nearly impervious parent material (soils that swell significantly when wet, heavy plastic clays, and certain saline soils).

State Soil Geographic Data Base (STATSGO) is a spatial database of soil characteristics provided by the Soil Conservation Service. STATSGO are made by generalizing the detailed soil survey data. STATSGO contains georeferenced polygon data of soil types which are available for the whole United States and are mapped on US Geological Survey 1:250 K scale topographic quadrangle maps. Each STATSGO map is linked to the Soil Interpretations Record (SIR) attribute database. The attribute database gives the proportionate extent of the component soils and their properties for each map unit. The STATSGO map units consist of 1 to 21 components each. The Soil Interpretations Record data base includes over 25 physical and chemical soil properties, interpretations, and productivity. Examples of information that can be queried from the database are water capacity, soil reaction, salinity, flooding, water table, bedrock, and interpretations for
engineering uses, cropland, woodland, rangeland, pastureland, wildlife, and recreation development.

- **Land Use Data**

  The water infiltration ability does not depend only on soil type, but also on soil pre-treatment, covering materials, and other work conditions. US Geology Survey defined the Land Use to reflect all these conditions, which are described in the Table 3-2 (Smith, 1995).

**Table 3-2: Anderson Level 2 Land Use Codes**

<table>
<thead>
<tr>
<th>Anderson Level 2 Land Use Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11  Residential</td>
</tr>
<tr>
<td>12  Commercial and Services</td>
</tr>
<tr>
<td>13  Industrial</td>
</tr>
<tr>
<td>14  Transportation, Communications and Utilities</td>
</tr>
<tr>
<td>15  Industrial and Commercial Complexes</td>
</tr>
<tr>
<td>16  Mixed Urban or Build-up land</td>
</tr>
<tr>
<td>17  Other Urban or Build-up land</td>
</tr>
<tr>
<td>21  Cropland and Pasture</td>
</tr>
<tr>
<td>22  Orchards, Groves, Nurseries, and Ornamental Horticultural Areas</td>
</tr>
<tr>
<td>23  Confined Feeding operations</td>
</tr>
<tr>
<td>24  Other Agricultural Land</td>
</tr>
<tr>
<td>31  Herbaceous Rangeland</td>
</tr>
<tr>
<td>32  Shrub and Brush Rangeland</td>
</tr>
<tr>
<td>33  Mixed Rangeland</td>
</tr>
<tr>
<td>41  Deciduous Forest Land</td>
</tr>
<tr>
<td>42  Evergreen Forest Land</td>
</tr>
<tr>
<td>43  Mixed Forest Land</td>
</tr>
<tr>
<td>51  Stream and Canals</td>
</tr>
<tr>
<td>52  Lakes</td>
</tr>
<tr>
<td>53  Reservoirs</td>
</tr>
<tr>
<td>54  Bays and Estuaries</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>61</td>
</tr>
<tr>
<td>62</td>
</tr>
<tr>
<td>71</td>
</tr>
<tr>
<td>72</td>
</tr>
<tr>
<td>73</td>
</tr>
<tr>
<td>74</td>
</tr>
<tr>
<td>75</td>
</tr>
<tr>
<td>76</td>
</tr>
<tr>
<td>77</td>
</tr>
</tbody>
</table>

- **Runoff Curve Number**

According to the SCS method, to calculate the accumulated direct runoff, the potential maximum retention must be estimated. The potential maximum retention is dependent on the soil characteristics and land use conditions. The US Soil Conservation Service (SCS) defines a concept, namely “runoff curve numbers (RCN)”, which represents the runoff potential, and can be determined by the combination of the soil characteristics and land use conditions.

To calculate RCN at a point in a watershed, the soil type and the land use code are required. Given the soil type and the land use code, RCN can be found by looking up a RCN table prepared by Smith (1995). The runoff curve number lookup table is attached in the Appendix C. In that table, for each combination of soil type and land use code, there is a corresponding RCN. For some locations on a watershed, more than one type of soil or land use appears, the RCN then becomes a weighted sum of all curve number values with various soil groups (or land use codes) by their coverage percentage. The calculation of RCN can also be
adjusted by climate conditions according to the amount of rainfall prior to the storm.

- **Flow Velocity**

  Flow velocity is a time-dependent, discharge-related and location-related hydrologic variable. But to be applicable of the unit hydrograph method for hydrologic analysis, the flow must be only location-related.

  For reality, water depth increases as water goes downstream. As water deepens, the effective resistance of the stream bed and banks on the flow diminishes because the hydraulic radius increases. To reflect this property, Maidment and Olivera (1996) presented a formula:

  \[ v = v_m \frac{S^b A^c}{\left[ S^b A^c \right]_m} \]  

  (3.2.1)

  where,

  \( v \) is the surface flow velocity (m/s),

  \( v_m \) is the average velocity of the whole watershed area,

  \( S \) is the land surface slope,

  \( A \) is the upstream drainage area,

  \( \left[ S^b A^c \right]_m \) is the average of \( (S^b A^c) \) of whole watershed area, and

  \( b, c \) are constants.

  \( A^c \) term in Eq.(3.2.1) implicitly reflects the hydraulic radius factor as water goes downstream, and \( (S^b A^c)/\left[ S^b A^c \right]_m \) modifies the mean velocity \( v_m \) to reflect local charges in land surface slope and drainage area. Because the velocity so complicated may be very large or even zero due to variations in land surface

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slope, the velocity formed from Eq.(3.2.1) is bounded between arbitrarily chosen limits \([v_{\text{min}} < v < v_{\text{max}}]\). TxDOT Hydrology Extension applies this formula for calculating flow velocity.

• Flow Travel Time and Time of Concentration

The travel time of flow from one point on a watershed to another is derived from the flow distance and the flow velocity, and is given by

\[ t = \int_0^L \frac{dl}{v(l)} \quad (3.2.2) \]

where \(L\) is the total flow distance and \(v(l)\) is the velocity on a small element or cell of length \(dl\), as given by Eq. (3.2.1)

For numerical model

\[ t = \sum_{l \in L} \frac{\Delta l}{v(l)} \quad (3.2.3) \]

where, \(v(l)\) is determined by Eq (3.2.1.) For a small time period after precipitation begins, only part of the whole watershed contributes to surface water flow. As precipitation continues, the contributing area becomes larger. The boundary of these contributing areas are called isochrones, because the flow travel times are all equal with each other for all points along any isochrones when the largest isochrone coincides with the watershed boundary, the flow travel time from the boundary to the pour point is defined as the time of concentration. This is the minimum time needed for whole watershed to contribute drainage to the outlet. This time of concentration is not necessarily equal to the drainage time along the longest flow length, because it depends on the flow velocity, so the longest time path and the longest length path are not necessarily the same.
4. GIS Implementation of the TxDOT Hydrology Extensions

A Geographic Information System (GIS) is a computer-assisted system for the capture, storage, retrieval, analysis and display of spatial data. It involves the usage of database and graphics tools. The increase of data transmission through Internet makes the application of GIS more convenient and less expensive than before. For hydrologic methods, GISs have been used to capture the specific data, to implement the modeling procedures, and to visually analyze the physical processes.

The TxDOT Hydrology Extension system is developed within the ArcView, and all the functions of the system are customized by using a high level object-oriented computer language Avenue, which is embedded in ArcView. The functions include data analysis, hydrologic modeling, and visual display of results all in a GIS environment. All procedures can be done through a user-friendly interface, through which data input, data analysis, modeling and result views are put in an integrated format. The programs are not data dependent, so that the use of extension is not limited to any specific spatial-data set. The extension allows the user to work in any other region provided that the necessary data are available. To run the TxDOT Extension, ArcView 3.0, and its extension Spatial Analyst are required. The system can be run on either PCs, or workstations with UNIX system.

4.1 GIS Terminology and its Application in Hydrology

4.1.1 GIS Terminology
**ArcView**

ArcView is a GIS software developed by the Environmental Systems Research Institute (ESRI). It has the capability to visualize, explore, query and analyze data spatially. In ArcView we work with views, tables, layouts, charts and scripts stored in a project. Projects enable the user to keep all the components together that the user needs for a specific task or application. ArcView3 has more powerful function than previous versions of ArcView, especially as its extensions offer a new range of optional high-end GIS functionality. The TxDOT Hydrology Extension uses the grid functions provided by Spatial Analyst, an extension of ArcView 3.0.

**Avenue**

Avenue is an object-oriented programming language which is used to create customized ArcView projects. The language works by creating "objects" of project documents, such as views, coverages, and tables and processing, reading, or manipulating information from these objects to create additional objects within the project. Once an Avenue script is written and compiled, it is "attached" to a menu selection or tool bar button and executed numerous times. The scripts in Avenue are based on a particular customized project. Much more functionality is accessible via Avenue than in standard ArcView, such as hydrologic analysis. Many of these hydrologic analysis functions are used in the TxDOT Hydrology Extension.
Spatial Analyst

The ArcView Spatial Analyst is a tool for helping the user discover and understand spatial relationships in spatial data. This discovery and understanding can be as simple as viewing and querying your data or as complex as creating an integrated custom application.

The main data used by the Spatial Analyst is the grid themes. A grid theme is the raster equivalent of the feature theme used by standard ArcView. With the grid theme, cell-based processing is performed. The Spatial Analyst also presents generic spatial analysis functionality on grid and feature themes, that is added to ArcView as an extension. The user interface components of the Spatial Analyst are accessible from the ArcView interface for Views.

ArcView Extension

An ArcView Extension is a set of add-on programs that provide advanced GIS functionality. It is a consistent set of documents (views, tables, charts, layouts and scripts), tools and menus assembled together to add specific user-defined capabilities to ArcView. To load and unload extensions one uses the Extensions dialog in ArcView, which is accessed by choosing the Extensions option from the File menu when the project window is active. A procedure showing how to create an ArcView extension is attached in the Appendix A.

4.1.2. GIS Application in Hydrology
For highway engineers and most engineers in other sub-fields of civil engineering, substantial efforts are made to establish and process geographic spatial data in engineering planning and management. Due to the rapid development of computer software including databases, graphics, and networks and the development of survey instruments such as global positioning systems, GIS has become a convenient, efficient approach to handle spatial data for civil engineers.

Generally speaking, the hydrologic application of GIS is to use GIS methods and programs to establish the relationship between digital spatial data, and hydrologic and hydraulic theory, to generate hydrologic output such as peak discharges and hydrographs. At the beginning of the hydrologic application of GIS, the initial focus was on the delineation of drainage boundaries and runoff flow paths using digital terrain data. Various data structures and methods of analysis of digital elevation data were developed to determine the hypothetical direction of flow, stream slope, stream length and watershed boundaries. More recently methods of relating spatial features to their hydrological properties and performing overlays of different spatial hydrological themes have been developed.

4.2 Data Sources and Data Processing

The data discussed here is the data for testing and developing the TxDOT Hydrology Extension. These data were obtained from different sources and processed in different forms. A data dictionary is attached in the Appendix D.
4.2.1 Projection and Data Resolution

An important consideration for spatial data is geo-spatial reference information such as projection parameters. All spatial data for a particular analysis must use the same geo-spatial reference parameters. The spatial data used in the TxDOT Hydrology Extension have been set up in an Albers Equal Area projection, with the parameters from the Texas State Mapping System shown below.

Projection | ALBERS
--- | ---
Datum | NAD83
Units | METERS
Spheroid | GRS1980
Parameters:
1st standard parallel | 27 25 0.000
2nd standard parallel | 34 55 0.000
central meridian | -100 0 0.000
latitude of projection’s origin | 31 10 0.000
false easting (meters) | 1000000.00000
false northing (meters) | 1000000.00000

The cell-based grid processes embedded in the Spatial Analyst (ESRI, 1997) are used in the TxDOT Hydrology Extension. The same cell size should be applied for all related grid features. Currently, a cell size of 500m*500m is used in the TxDOT Hydrology Extension.

4.2.2 Digital Elevation Model Data (DEM)
A Digital Elevation Model (DEM) consists of a sampled array of elevations for ground positions that are normally at regularly spaced intervals. A majority of the procedures developed in the TxDOT Hydrology Extension rely on the digital elevation data. The 15" USGS DEM of Texas are used for this study. The fifteen second DEM has a resolution of 500m*500m. These DEMs are available via CD-ROM (USGS Open-File Report 94-388 (CD-ROM)). The detailed instructions on to obtain the CD-ROM can be found on the website:

http://nsdi.usgs.gov/nsdi/wais/water/gcip.HTML

4.2.3 Filled and Burned DEMs

To eliminate DEM data problems such as artificial sinks and peaks, several processing steps were taken in order to create a filled and burned DEM from the raw DEM. First, the DEM was filled to remove sinks. A sink is a cell or group of cells that is lower than all of its neighboring cells. Sinks are removed so that there are no discontinuities in the drainage network derived from the DEM. The DEM was also modified so that streams delineated from the DEM are consistent with digitized streams in EPA's River Reach File 1 (RF1). This process of DEM modification is referred to as "burning in the streams." The simplest stream burn-in procedure involves (1) creating a grid representation of the digitized stream network (RF1) and identifying cells as being either stream cells or land surface cells, (2) raising the elevation of land surface cells relative to stream cells, and (3) deriving the drainage network based upon flow direction values defined by the burned DEM.
4.2.4 Digitized Stream Network

Reach File 1 (RF1) is a representation of streams in the continental United States at a scale of approximately 1:500,000. The original file was prepared by the U.S. Environmental Protection Agency (USEPA). Information about the RF1 can be found at web site:

http://h2o.er.usgs.gov/nsdi/wais/water/rf1.HTML

The structure and content of the Reach File databases were created to establish hydrologic ordering of stream segments, to perform hydrologic navigation for modeling applications and to provide a unique identifier for each surface water feature, i.e., the reach codes. In the TxDOT Hydrology Extension, the Reach File 1 is used as a base map for delineating a watershed. The delineation process starts from selecting a pour point on the stream network map.

4.2.5 Raster Map of Texas

Digital raster maps have been prepared by Horizons Technologies, Inc. by scanning the corresponding USGS topographic paper maps. The stream, county boundary and corresponding county names are shown in the scanned maps. Scanned USGS maps of the State of Texas used in the TxDOT Hydrology Extension, at a scale of 1:2,000,000, are used as background.

Information about these digital raster maps and Horizons Technologies, Inc. can be found at:

4.2.6 Hydrologic Soil Group Data

The hydrologic soil group data used in the TxDOT Hydrology Extension are the State Soil Geographic Data Base (STATSGO) from Soil Conservation Service. STATSGO contains georeferenced polygon data of soil types which are available for the whole United States and are based on a generalization of detailed soil report and are mapped on U.S. Geological Survey 1:250 K scale topographic quadrangle maps. Information about STATSGO can be found at the web site: http://www.ftw.nrcs.usda.gov/stat_data.html

The data contain an extensive array of soil attributes contained in several cross-referenced tables. The data are available in Arc/Info format but some processes were involved to extract the necessary data and to eliminate unwanted information. For this project, the soil names and percentages of occurrence of soils in each of four hydrologic soil groups (A, B, C, and D) were considered to be sufficient. Smith (1995) made the extraction of the required data from the original STATSGO coverage for HDDS. In the TxDOT Hydrology Extension, we use the same soil coverage, but project it to Albers Equal Area projection, the projection used in the TxDOT Hydrology Extension.

Soil is classified into four groups based on infiltration rate. A description of four hydrologic soil groups is listed in Section 3.2.2.

4.2.7 Land Use Data

The land use data files describe the vegetation, water, natural surface, and cultural features on the land surface. The information contains georeferenced
polygons in GIRAS format with land use codes assigned as attributes. Each land use code corresponds to a land description.

The land use data can be downloaded from the internet ftp site:

http://edcwww.cr.usgs.gov/hyper/guide/1_250lulcfig/states/TX.html

Smith (1995) has created the land use coverage of the State of Texas in HDDS. It was projected to Albers Equal Area projection, and used in the TxDOT Hydrology Extension.

4.2.8 Hydrologic Region

TxDOT statewide regional rural regression equations of peak flow versus frequency are associated with the hydrologic regions. The hydrologic region polygon coverage used in the TxDOT Hydrology Extension was obtained from U.S. Geological Survey (USGS) office in Austin:

U.S. Geological Survey
8011 Cameron Rd.
Austin, TX 78754-3898

4.2.9 Curve Number Value Lookup Table

The curve number lookup table is used to determine runoff curve number, given soil groups and land use codes. Smith (1995) prepared the curve number lookup table in GIS format which is shown in Appendix C. The most conservative range of RCNs was taken to relate the Anderson Level II code to hydrologic soil group for a design purpose.
4.3 Pre - Programs

For the expected hydrologic analysis, the TxDOT Hydrology Extension uses a set of pre-programs to prepare GIS coverages. These programs, which can be run in either Arc/Info or ArcView with Spatial Analyst, are used for sequential processing of the digital elevation data using grid functions.

4.3.1 Tracing Flow Directions

The direction with the steepest downward slope is defined as the flow direction. A Flowdirection function applied to an elevation grid yields a grid of flow directions. Binary geometric representation of flowdirection were mentioned before.

4.3.2 Calculating Flow Accumulation

The flow accumulation is the number of cells upstream of any given cell in the drainage network. A Flowaccumulation function is applied to get the flow accumulation grid.

4.3.3 Creating the Slope Grid

A slope grid stores slope for each cell in the surface represented by DEM Grid. Slope identifies the maximum rate of change in value from each cell to its neighbors. In the TxDOT Hydrology Extension the slope grid is used to calculate the flow velocity. In the TxDOT Hydrology Extension, an Avenue script called
slope was written to modify the slope grid created by ArcView3 from % format to m/m format.

4.3.4 Creating the Flow Length Grids (Upstream and Downstream)

The flow length grid represents upstream or downstream distance along a flow path for each cell. Flow length upstream represents the flow length from each cell to the top of the drainage divide. Flow length downstream represents the flow length from each cell to a sink or outlet. A FlowLength function is applied to get the flow length grid.

4.3.5 Creating the Runoff Curve Number (RCN) Grid

The curve number grid stores runoff curve number value for all cells in the grid. The derivation of runoff curve numbers is based on the land use/land cover (USGS) and hydrologic soil group (STATSGO), which are described in section 3.2.1. A RCN can be looked up from a table, given land use codes and soil groups.

The procedure of determining the curve number grid is listed below:

(1) Creating a soil grid from soil group data (STATSGO).

In the TxDOT Hydrology Extension, a 500m by 500m soil grid was created from STATSGO coverage by using statsgo-id as the grid item. The attribute table of the STATSGO was added to the attribute table of the soil grid.

Table 4-2: The Attribute Table of the Soil Grid
(2) Creating a land use grid from land use coverage.

A grid which has the same resolution as soil grid was created based on USGS land use coverage by using land use code as grid item. The curve number lookup table (which is described in Section 3.1) was joined to the value attribute table of the land use grid. Through the use of the curve number lookup table, the attribute table of the land use grid provides all curve number values respectively for four soil groups.

<table>
<thead>
<tr>
<th>Value</th>
<th>Count</th>
<th>Area</th>
<th>Perimeter</th>
<th>Statscode</th>
<th>Mod</th>
<th>Muname</th>
<th>Mra</th>
<th>A-pct</th>
<th>B-pct</th>
<th>C-pct</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>160</td>
<td>576874.59499</td>
<td>39315.39042</td>
<td>TX563</td>
<td>LIKES-CIRC</td>
<td>77E</td>
<td>75</td>
<td>22</td>
<td>0</td>
<td></td>
<td></td>
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<td>347394.40760</td>
<td>29038.47727</td>
<td>TX003</td>
<td>INNS/ACU</td>
<td>77E</td>
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<td></td>
</tr>
<tr>
<td>14</td>
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<td>336469.14975</td>
<td>28802.39210</td>
<td>TX043</td>
<td>MOBETIE-BI</td>
<td>77E</td>
<td>5</td>
<td>78</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>121</td>
<td>394168.89105</td>
<td>49497.72654</td>
<td>TX003</td>
<td>INNS/ACU</td>
<td>77E</td>
<td>0</td>
<td>89</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>43</td>
<td>299492.11945</td>
<td>10844.56921</td>
<td>TX003</td>
<td>INNS/ACU</td>
<td>77E</td>
<td>0</td>
<td>89</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>33</td>
<td>349800.74585</td>
<td>15082.82923</td>
<td>TX209</td>
<td>SPRINGER-N</td>
<td>70E</td>
<td>85</td>
<td>95</td>
<td>5.3400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>602</td>
<td>670545.56777</td>
<td>114275.39224</td>
<td>TX003</td>
<td>INNS/ACU</td>
<td>77E</td>
<td>0</td>
<td>89</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(3) Creating a Weighted Runoff Curve Number Grid.

The runoff curve number value for a given location is the weighted sum of all four curve number values corresponding to four soil groups by their coverage percentages. Using grid operations and combining the soil grid and land use grid, a runoff curve number grid of Texas was created. It is created by the docell command and by using following operation in Arc/Info.
totpct := soilg.a-pct + soilg.b-pct + soilg.c-pct + soilg.d-pct (in case total percentage is not 100%)
:: wtcella := soilg.a-pct * lusg.hyd_a / totpct
:: wtcellb := soilg.b-pct * lusg.hyd_b / totpct
:: wtcellc := soilg.c-pct * lusg.hyd_c / totpct
:: wtcelld := soilg.d-pct * lusg.hyd_d / totpct
:: RCN = wtcella + wtcellb + wtcellc + wtcelld

This curve number grid stores the curve number value at all locations in Texas.

Figure 4-1: The Grid of Runoff Curve Number in Texas

Because the land use data used here do not contain top part of Texas, the Grid of Runoff Curve Number in Texas does not cover this top part of Texas either.
From Figure 4-1, we can see the distribution of the runoff curve number in Texas. Figure 4-2 and 4-3 shows the area distribution and area percentage distribution for various runoff curve number in Texas.

Figure 4-2: Area - Curve Number Chart

Figure 4-3: Area Percentage - Curve Number Chart
4.4 Major Functions for Hydrologic Analysis

The major functions for hydrologic modeling and analysis in the TxDOT Hydrology Extension include delineating the watershed and calculating its topographic parameters around a point clicked on the river basin map, determining the peak-flow at any selected location, calculating the runoff curve number at any selected location, and calculating average flow velocity and travel time. Avenue scripts are developed for customizing these functions (see Appendix B). Table 4-4 lists scripts created for TxDOT Hydrology Extension. The implementation of these functions is described in the following.

Table 4-4: Scripts created for TxDOT Hydrology Extension

<table>
<thead>
<tr>
<th>Script Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Txdot.avgN</td>
<td>Gets the average value of a grid theme in any selected areas</td>
</tr>
<tr>
<td>Txdot.install</td>
<td>Installs TxDOT Hydrology Extension</td>
</tr>
<tr>
<td>Txdot.make</td>
<td>Makes TxDOT Hydrology Extension</td>
</tr>
<tr>
<td>Txdot.peakflow</td>
<td>Calculates Peakflow in 2yr, 5yr, 10yr, 25yr, 50yr, 100yr frequency by using Regional Regression Equations (Statewide Rural Regression Equations). And get hydrologic parameters.</td>
</tr>
<tr>
<td>Txdot.properties</td>
<td>Provides a input box for the user to input the name of essential database for calculating peakflow and hydrologic parameters.</td>
</tr>
<tr>
<td>Txdot.RCNmodi</td>
<td>Calculates a runoff curve number grid for a user-defined area with given a soil coverage, land use coverage and a land-use/curve-number look-up table.</td>
</tr>
<tr>
<td>Txdot.RCNprop</td>
<td>Provides a input box the for user to input the name of essential database for calculating runoff curve number</td>
</tr>
<tr>
<td>Txdot.uninstall</td>
<td>Quits TxDOT Hydrology Extension</td>
</tr>
<tr>
<td>Txdot.velocity</td>
<td>Calculates a flow velocity grid and flow travel time grid with given a watershed slope grid, flow length grid and user inputted parameters</td>
</tr>
</tbody>
</table>
4.4.1 Watershed Delineation

The conceptual procedure for watershed delineation has been discussed in section 3. Those procedures are implemented by using the script `Txdot.peakflow` in the TxDOT Hydrology Extension. The framework for the script `Txdot.peakflow` is shown in Figure 4-5. By running the script `Txdot.peakflow`, when a point on the river basin map is clicked as an outlet, a watershed, whose outlet is the clicked point, will be delineated automatically. A watershed polygon and flow length grid will be displayed on the View. The topographic parameters of the delineated watershed will be calculated and shown to the users through a message box. These parameters include drainage area, channel slope, longest flow path, average curve number etc. The delineation of watershed provides a basis for calculating peak flow at a selected location (corresponding to the clicked point on the river basin map).
Figure 4-4: The framework for calculating peak-flow and hydrologic parameters in TxDOT Extension.

4.4.2 Peak Flow Calculation

When a watershed is delineated, the peakflow at the outlet of the watershed (the clicked point on the river basin map) can be identified. First, the program finds out which hydrologic region the watershed is in, and then according to the hydrologic region ID, watershed area (an attribute of the watershed polygon), the watershed slope, the shape factor and a user selected hydrologic frequency. The equations form Table 3-1 for peak flow calculation are selected by the program. The parameters in the equation include drainage area, average slope, shape factor, and regression coefficients related to hydrologic regions. Therefore, when a
watershed is delineated, the peak flow can be determined automatically by the Avenue program.

4.4.3 Runoff Curve Number (RCN) Calculation

The concept of RCN has been described in section 3, and the idea of creating the curve number grid in the TxDOT Hydrology Extension is almost same as the procedure needed to create a RCN grid using Arc/Info, which was described in section 4.3.5. In the TxDOT Hydrology Extension, the Avenue script \texttt{Txdot.RCNmodi} is developed to create a RCN grid for any desired area. Much reduced processing time was accomplished in the TxDOT Hydrology Extension than using Arc/Info. The flow for the script \texttt{Txdot.RCNmodi} is shown in Figure 4-6.

![Flow chart](image)

Figure 4-5: The flow chart for a creating curve number grid in the TxDOT Hydrology Extension.
4.4.4 Flow Velocity and Travel Time Calculation

This function is used to calculate flow velocity and travel time at any selected location on a stream. Based on the delineated sub-watershed, a slope grid, a flow direction grid and a flow accumulation grid are created by using the grid manipulating functions. Given these two grids, a flow velocity grid can be created by using the following equation:

\[ V = a \cdot S^b \cdot F^c \]  

(4-1)

where \( S \) is the slope, \( F \) is the flow accumulation, \( a \), \( b \), and \( c \) are constant coefficients. This equation is a simplified form of Eq.(3.2.1.) suggested by Orivera. A flow velocity grid is then used to create a travel time grid. First an inverse velocity \((1/v)\) grid is created, and then based on the inverse velocity grid and the flow direction grid, a grid function weighted flow length is directly used to create the travel time grid.
Figure 4-6: The flow chart for creating a flow velocity and travel time grid in the TxDOT Hydrology Extension.

### 4.4.5 Cross-Grid Mean Value Identification

When we create a grid, we have a value for each cell in the grid. A function is used to calculate the mean value across a grid according to the area percentages of grid values. The script `Txdot.avgN` was designed for calculating mean value of any grid inside of a polygon coverage. In the TxDOT Hydrology Extension, we can calculate mean RCN, flow velocity, and travel time.
5. TxDOT Hydrology Extension System Operation

5.1 System Requirement

The TxDOT Hydrology Extension is an ArcView Extension written in the Avenue script used in the ArcView environment. All contents of the TxDOT Hydrology Extension are stored in an extension file called txdot.avx.

To run the TxDOT Hydrology Extension
1) Arcview3,
2) Spatial Analyst Extension,
3) TxDOT Extension file(txdot.avx)
are required.

The TxDOT Extension requires a database including:
- Digital elevation model (DEM)
- Filled and burned DEM
- Flow direction grid
- Flow accumulation grid
- Flow length upstream grid
- Flow length downstream grid
- Hydrologic regions for Texas
- Curve number grid
- Slope grid
- Soil group data
- Land use coverage
Curve number look up table

A CD-ROM with this report was prepared which stores the TxDOT Hydrology Extension file txdot.avx, and its required database. This database stored in the CD-ROM is for the purpose of testing and developing the TxDOT Hydrology Extension. These items are described in Section 4.2. A different resolution of data sets and a more complete database for whole Texas will be prepared for TxDOT project in the future.

5.2. Preparation of the Project

To created a new project which can use the TxDOT Hydrology Extension, copy the Txdot Hydrology Extension file txdot.avx from CO-ROM to C: ArcView/ext32/ directory if using a PC, or to /home/ directory if working on a UNIX workstation. This step will make the Extension of TxDOT automatically appear in the Extension dialog. Then take the following steps:

1) **Open Arcview3**
2) **Open a new project**
3) **Load Extension**

Using the Extensions dialog to load the Extensions for the TxDOT Hydrology Extension. The required Extensions include Spatial Analyst and TxDOT. This dialog box is accessed by choosing the Extensions option from the File menu when the Project window is active.
From the box, select Spatial Analyst and TxDOT. Spatial Analyst is an Extension of Arcview3.0, which requires a special licence.

After loading the extension file TxDOT, the pull-down menu TXDOT and the tool button will appear on the top of the screen when the View window is active. 

a) The pull-down menu, labelled TXDOT, contains five items.

Watershed Data (Input/Update Watershed Data)
Curve Number Data (Update Curve Number Data)
Curve Number Grid (Create Curve Number Grid)
Flow Velocity and Travel Time (Create Velocity and Travel Time Grid)
Average Number (Calculate the Cross-Grid Mean Value)
b) a tool button launches the script used to calculate the watershed properties and the peak discharges.

4) **Prepare a View of TxDOT**

Open a View, change the view name to TxDOT through View Properties dialog. Add the following themes from the TxDOT Hydrology Extension CD-ROM. Each theme is related to a directory on the source disk which stores all source files for the theme.

<table>
<thead>
<tr>
<th>themes</th>
<th>corresponding data in CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row DEM theme</td>
<td>DEM</td>
</tr>
<tr>
<td>Filed and burned DEM theme</td>
<td>fil</td>
</tr>
<tr>
<td>Flow Direction theme</td>
<td>fdr</td>
</tr>
<tr>
<td>Flow Accumulation theme</td>
<td>fac</td>
</tr>
<tr>
<td>Flow length upstream theme</td>
<td>flu</td>
</tr>
<tr>
<td>Flow length downstream theme</td>
<td>fld</td>
</tr>
<tr>
<td>Hydrologic Regions theme</td>
<td>hrg</td>
</tr>
<tr>
<td>Curve Number theme</td>
<td>rcn</td>
</tr>
<tr>
<td>Watershed Slope theme</td>
<td>slope</td>
</tr>
<tr>
<td>Soil group data</td>
<td>stastgo</td>
</tr>
<tr>
<td>Land use data.</td>
<td>txlus</td>
</tr>
<tr>
<td>Raster map of Texas</td>
<td>txalb, txalb.tfw</td>
</tr>
</tbody>
</table>

The Raster map of Texas is used for building a location background.
5) Prepare the RCN Look Up Table

The RCN lookup table is needed to create a RCN grid in the TxDOT Hydrology Extension. Five fields (land use code, and RCN values corresponding to soil group A, B, C, D) are included in the table. The source for the table is a comma delimited text file (rcn.txt). The first line in the text file includes the names of the five fields, and in each of the lines below, runoff curve numbers corresponding to a land use code and each of the soil groups (A, B, C, D) are filled. Currently we use such a text file (rcn.txt) prepared by Smith (1995) for prototype system developing and testing. The user may modify this file. Having this text file in the CD-ROM, the lookup table can be added to the ArcView.

Figure 5-1: Prepared View for TxDOT Hydrology Extension.
project by using “add table” dialog box. To do that, select the source file type as “text file” in the file type option shown in the dialog. Figure 5-2 is an ArcView format table of rcn.txt.

<table>
<thead>
<tr>
<th>Locode</th>
<th>Des_a</th>
<th>Des_b</th>
<th>Hyd_a</th>
<th>Hyd_b</th>
<th>Hyd_c</th>
<th>Hyd_d</th>
<th>Vcoeff</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>increase-of-zero</td>
<td>data</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>5.00</td>
</tr>
<tr>
<td>11</td>
<td>Residential</td>
<td>Level_2</td>
<td>77</td>
<td>85</td>
<td>90</td>
<td>92</td>
<td>4.62</td>
</tr>
<tr>
<td>111</td>
<td>Residential</td>
<td>1_b_ave</td>
<td>77</td>
<td>85</td>
<td>90</td>
<td>92</td>
<td>4.62</td>
</tr>
<tr>
<td>112</td>
<td>Residential</td>
<td>1_a_ave</td>
<td>61</td>
<td>75</td>
<td>83</td>
<td>67</td>
<td>3.66</td>
</tr>
<tr>
<td>113</td>
<td>Residential</td>
<td>1_2_ave</td>
<td>67</td>
<td>72</td>
<td>81</td>
<td>66</td>
<td>3.42</td>
</tr>
<tr>
<td>114</td>
<td>Residential</td>
<td>1_2_ave</td>
<td>64</td>
<td>70</td>
<td>80</td>
<td>65</td>
<td>3.24</td>
</tr>
<tr>
<td>115</td>
<td>Residential</td>
<td>1_acre</td>
<td>51</td>
<td>68</td>
<td>79</td>
<td>64</td>
<td>3.06</td>
</tr>
<tr>
<td>116</td>
<td>Residential</td>
<td>2_acre</td>
<td>46</td>
<td>65</td>
<td>77</td>
<td>62</td>
<td>2.76</td>
</tr>
<tr>
<td>12</td>
<td>Urban_85p_ripen</td>
<td>Comm &amp; business</td>
<td>89</td>
<td>92</td>
<td>94</td>
<td>95</td>
<td>5.54</td>
</tr>
<tr>
<td>13</td>
<td>Urban_75p_ripen</td>
<td>industrial</td>
<td>61</td>
<td>88</td>
<td>91</td>
<td>93</td>
<td>4.86</td>
</tr>
<tr>
<td>14</td>
<td>Streets &amp; roads</td>
<td>Level_2</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>5.86</td>
</tr>
<tr>
<td>141</td>
<td>Paved</td>
<td>parking_base</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>5.86</td>
</tr>
<tr>
<td>142</td>
<td>Streets &amp; roads</td>
<td>Paved-curb</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>5.86</td>
</tr>
</tbody>
</table>

Figure 5-2: ArcView format table of rcn.txt.

5.3 Using TxDOT Hydrology Extension

1) Input Watershed Data:

By clicking on TxDOT/watershed data, a dialog box called Flood Flow Properties pops-up. All the empty slots should be filled with the names of the grid theme of the essential databases. The name filled in this box should be same as the name shown on the View.
2) **Run Peakflow Calculating Script:**

After the name of the watershed data file has been entered, the watershed parameters and peak discharges can be calculated by activating the button. Click any point on the view, and a report message box with the watershed parameters and peak discharges pops-up. The information shown in the report will be stored in the attribute table of the watershed polygon.
After clicking the OK button of the report message box, the watershed whose outlet is the clicked point is displayed as a transparent polygon and the longest flow-path as a grid is also shown in the View.

Figure 5-4: The message report shows the peakflow and hydrologic parameters.
Figure 5-5: The watershed and its longest flow path are shown in the View.

The click point should be on the stream. If the watershed corresponding to a clicked point that is too small, a message “The drainage area is too small relative to the grid resolution for calculation of watershed parameters” in the message box will inform the user to select another point on the stream.

3) Input Curve Number Data

By selecting TXDOT/curve number data from the menu bar, a dialog box called RCN Properties pops-up. Three empty slots should be filled with the name
of the soil group coverage, land use coverage and RCN lookup table. The name filled in this box should be same as the name shown on the View.

Figure 5-6: The Input box for calculating curve number

4) Create Curve Number Grid

After the name of the curve number data has been entered, a curve number grid is calculated by selecting the menu item TxDOT / curve number grid. An extension dialog will be showed in a project window which lets the user to define the curve number grid cell size and grid covered area.
Figure 5-7: The extension dialog lets user to define grid cell size and covered area.

After selecting the cell size and extent, click OK, and a grid of curve numbers will be created, and a grid theme will be added and displayed in the View.
5) Calculate Flow Velocity and Travel Time

The item TXDOT/ flow velocity and travel time on the TxDOT pull-down menu launches the script to create a grid of flow velocity and a grid of flow travel time. When clicking this item, an extension dialog will be shown in a project window to let the user to define the curve number grid cell size and the grid covered area. This extension dialog is the same as the dialog in Figure 5-7. After the specification, another user input box is shown to let user define the parameters to calculate the flow velocity. Then a grid of flow velocity and a grid of flow travel time will be created and displayed in the View.
Figure 5-9: The input box let user to define the parameters to calculate the flow velocity.
f) Average Number

Use the item TXDOT/ average number in the TXDOT pull-down menu to calculate the mean value of a grid inside a polygon. To run this function, the user has to make active two themes in the view. One theme should be the grid theme and the other should be the polygon theme. Then click item TXDOT/ average number. If the polygon theme contains only one polygon, a message box will show on the window which gives the selected grid theme name and the average
number. The value will be automatically stored in the attribute table of the selected polygon.

Figure 5-11: The message box shows the average value of the grid inside a polygon

If the polygon contains more than one polygon (for example, the polygon theme is a sub-watershed theme), a message of **Average values are stored in the (the grid name shown on the view) field of the polygon theme attribute table** on the message box will be shown in the view and the mean value of each polygon will be calculated and stored in the attribute table of the polygon theme.
6. Conclusion

An extreme peak flow distribution in Texas for events with recurrence period of more than one hundred years was developed in a GIS environment in the first part of this report (chapter2). In the second part of the report (Chapters 3-5), a GIS-based hydrologic analysis system, the TxDOT Hydrology Extension, was developed for determining hydrologic parameters of watersheds, and peak flows for return periods of 2 to 100 years.

In the first part, a statistical analysis was performed of stream gauging records contained in a USGS research report, and regression equations for estimating extreme peak discharge were derived for eleven hydrologic regions in Texas. A 500m grid of extreme peak discharge for Texas streams and rivers was created based on these regression equations, which provides the peak flow under extreme conditions for all locations on significantly sized streams and rivers in Texas. The results provided are very conservative estimates for the design of ordinary facilities but they can be used to check the capacity of an important facility for the extreme flow conditions.

The extreme peak flow results were presented in the ArcView environment. Grid representation of features and the associate grid calculations were applied. The Grid method is efficient in data manipulation but is limited by the grid cellsize used (500m*500m) and the range of recorded drainage area (0.1~10000 sq-mi). The recommended drainage area to provide accurate extreme peak flows is between 10 sq-mi and 10000 sq-mi. Visual display of the extreme peak flow,
of the most useful features of GIS, allows a highway engineering designer to assess and utilize the hydrologic results.

In the second part of this report, a GIS-based hydrologic analysis system, the TxDOT Hydrology Extension was created in ArcView3.0. The TxDOT Hydrology Extension includes two functions: providing peakflow based on the regression equation method, and providing functional hydrologic parameters as input for further hydrologic calculations in the GIS environment.

The TxDOT Hydrology Extension contains peak flow regression equations for six different recurrence periods: 2 years, 5 years, 10 years, 25 years, 50 years and 100 years for eleven hydrologic regions in Texas. Compared with the extreme peak flow developed in the first part of this report, the TxDOT Hydrology Extension provides more reasonable peak flow values for the practical design of drainage structures in highway engineering. A designer can select one of the six flood discharge values according to the type, purpose and degree of importance of hydraulic facility.

The TxDOT Hydrology Extension also provides hydrologic parameters including: watershed area, watershed slope, longest flow path and length, watershed shape factor, runoff curve number(RCN), and flow velocity.

The runoff potential parameter RCN is determined by the soil types and their percentage distribution, the land use code, and the RCN lookup table, through the use of relational database functions in ArcView. The RCN lookup table in the TxDOT Hydrology Extension gives very conservative RCN values. To refine the
results of the TxDOT Hydrology Extension, a more accurate and improved RCN lookup table is needed. Only the selected area corresponding to the soil grid and the land use grid is involved in RCN calculation in the TxDOT Hydrology Extension. This implementation philosophy saves execution time compared to an RCN calculation covering all of Texas.

A velocity equation was applied to account for the effect of hydraulic radius and land surface slope on flow velocity. The flow velocity and travel time results are highly dependent on the user input values for the model coefficients, but they provide first estimates that can be used to compute isochrone maps of watersheds.

Throughout the work in this report, GIS, especially the ArcView GIS on a PC, was found to be a powerful tool for developing hydrologic analysis parameters. A wide range of spatial data and parameter estimation equations are integrated in the GIS environment, which substantially improves the accuracy and reduces the effort of applying these equations. The programs in the TxDOT Hydrology Extension depend heavily on Spatial Analyst, a new extension of ArcView3.0, which is very efficient in using Grid functions that were previously only available in Arc/Info.

The TxDOT Hydrology Extension is a further development and improvement of Hydrologic Data Development System (HDDS) prepared by Smith (1995). Similar data processing and modeling analyses conducted in HDDS using Arc/Info, are carried out in the TxDOT Hydrology Extension using ArcView. This change makes the functions in HDDS available to more users, with less software cost since ArcView is much cheaper than Arc/Info, and ArcView is also easier to use. Implementation through ArcView instead of Arc/Info makes this system
accessible to most of the local TxDOT district offices where PC machines are available. To do the same analysis, the computing time in the TxDOT Hydrology Extension using ArcView is less than that in HDDS using Arc/Info.

All the tools and methods, including the grid operation algorithms and associated programs, for developing TxDOT Hydrology Extension are not dependent on the specific data illustrated in the report. Standardized file specifications are used. Therefore, the TxDOT Hydrology Extension is suitable for general application to other regions with only minor changes.
Appendix A: How to Create an ArcView Extension

An ArcView Extension is a set of add-on programs that provide advanced GIS functionality. It comprises a consistent set of documents (views, tables, charts, layouts and scripts), tools and menus assembled together to add specific user-defined capabilities to ArcView.

To load and unload extensions, the new Extensions dialog is accessed by choosing the new Extensions option from the file menu when the project window is active.

<table>
<thead>
<tr>
<th>Available Extensions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database Themes</td>
</tr>
<tr>
<td>Hydrologic Modeling</td>
</tr>
<tr>
<td>IMAGINE Image Support</td>
</tr>
<tr>
<td>JPEG (JFIF) Image Support</td>
</tr>
<tr>
<td>Network Analyst</td>
</tr>
<tr>
<td>Spatial Analyst</td>
</tr>
<tr>
<td>TxDOT</td>
</tr>
</tbody>
</table>

By using this Extension dialog the user can load and unload extensions at any time during an ArcView session. The user can also load different extensions for different projects or make the choice of extensions the default for ArcView. If the user opens a project that uses an extension that is not currently loaded, ArcView will automatically load the extension. When the extension loads, it adds new functionality to the current ArcView session.

1. Create an Extension

1.2 Create the ArcView Project

First, create a project that contains the scripts, controls, documents and any other objects which will be included in the extension. By convention, name this project .apr. (for example, "txdot.apr"). Any scripts that will be included in the extension should be named with a prefix that indicates the extension; for example, txdot.peakflow. Scripts in loaded extensions appear in the Script Manager and it is much easier to find and identify scripts when you follow this convention.

1.2 Customizing the ArcView Project

ArcView allows the user to customize ArcView's menus, button bars, tool bars and popup menus so they contain the controls.

To customize the ArcView Project
• Click Customize in the Project menu or double click on the button bar to display the Customize dialog. Modify the types with the Customize dialog by adding, deleting, rearranging or redefining the controls.

• Click Reset in the Customize dialog box.

1.3 Create the Scripts that Install, Uninstall and Make the extension.

Install Script

The install script defines how the objects in the extension are installed into the current project when the user creates or opens a project or when the user loads the extension. This script becomes a property of the extension.

Uninstall Script.

The uninstall script defines how objects in the extension are removed from the project when you close the project or unload the extension. All objects that the user adds to the project in the Install script must be removed from the project in the Uninstall script. This script becomes a property of the extension.

ESRI provides the install script and uninstall script as sample scripts in ArcView. User can use these scripts without editing.
Make Script.

This script contains the code that makes the extension object, sets its properties and populates it with the objects the user wishes to share, and finally saves the extension to file.

In the make script, the user creates the extension object with the Make request. Extension.Make has five arguments:

- **FileName.** The filename identifies where this extension is written on the disk. By convention, extension files end with the suffix .avx. (For example, Txdot.avx)
- **Name.** This name appears in the Extensions dialog. (For example, TXDOT)
- **Install Script.** It is described in this section.
- **Uninstall Script.** It is described in this section.
- **Dependencies list.** The dependencies list is a list of ArcView FileName objects; these FileNames reference either ESRI provided DLLs which define extended functionality or other extensions. ArcView ensures that all elements in the dependencies list are loaded BEFORE this extension loads. If the extension has no dependencies, then specify an empty list '{}'.

ESRI provides the script which makes the extension as sample scripts in ArcView. The make script can be found in the sample project extbuild.apr in the directory ESRI/Av_gis30/Arcview/Sample/Ext/. The user can modify the script easily to create an extension.

Below is part of Txdot Hydrology Extension make script. From this script we can see how to modify the make script to create the Txdot Extension.

```
'the Filename of the extension
theExtensionFile = "\home\bao\TxDot.avx"
'the Name of the extension to be displayed in the extension dialog
theExtensionName = "TxDOT"
'the description of the extension to be displayed in the extension dialog
theDescription = "Extension for TxDOT project"
'the version of the extension
theVersion = 3.0
'Install Script
```
' The Script to use to install the extension
' NOTE: "My Extension Install" is a prepared script for this
InScriptName="txdot.install"

' ------------------------
' Uninstall Script
' The Script to use to uninstall the extension
' NOTE: "Uninstall" is a prepared script for this
UnScriptName="txdot.uninstall"

' ------------------------
' Any document Names to include
' This is a list of any documents to include
' e.g. theDocs="View1", "Layout1"
theDocs={}

' ------------------------
' Controls (Buttons and normal Tools) to include
' Controls {GUI name, ControlType, ScriptName}
' e.g. TheControlList={"View", "ButtonBar", "View.ZoomIn"},
"View", "ToolBar", "View.Identify"}
TheControlList={"View", "ToolBar", "Txdot.peakflow"}

(The Txdot.peakflow launches the tool button)

' ------------------------
' Tool menus to include
' This is a list of which tool menus to include. Tool menus are specified
' by giving a GUI name and a script name of one of the tools in the tool menu
' Using this to locate the tool menu ALL other tools in that menu and
' their scripts will be extracted
' theToolMenu={"View", "View.PointTool"}
TheToolMenuList={}

' ------------------------
' The Menus to include (a list of menu items listing the doc, the top menu, and the script
for the menu item)
' TheMenuList {Doc name, Main Menu name, menu item Scriptname}
' e.g. TheMenuList={"View", "File", "View.Export"}
TheMenuList={"View", "TXDOT", "txdot.properties"},
"View", "TXDOT", "txdot.RCNprop"},
"View", "TXDOT", "txdot.RCNmodi"},
"View", "TXDOT", "txdot.velocity"},
"View", "TXDOT", "txdot.avgNum"}

(This part of script makes the menu bar appearing in the View GUI)
The scripts to include, not in controls or menus
`e.g. theScripts=['My.Script','View.export']`
`theScripts=['txdot.properties','Txdot.peakflow','Txdot.RCNprop','Txdot.RCNmodi','Txdot.velocity','Txdot.avgNum']`

The Dependencies
`theDependencies={}`

ATTENTION!!!!!!!!!!!!!!
• Do NOT alter the script after these lines, the remainder of this script

```
myExt.SetAbout(theDescription)
myExt.SetExtVersion(theVersion)
myExt.Commit
```

1.4 Run the Make Script to Create the Extension

After customizing the project which will be added to the extension and creating install, uninstall and make scripts, then run the make script. This step makes an extension files end with the suffix .avx. created in the C: temp/ directory in PC machine or /home/ directory if you work on UNIX workstation. The extension name is showed in the extension dialog.

2. Update the Extension

Follow the steps below, you can make any changes to the extension and update the extension.

• First take this extension off from extension dialog
• Update this project file
• Update the make script
• Rerun the make script.
3. Remove the Extension

To remove the extension, delete the extension file which end with the suffix .avx. and is stored in the C: temp/ directory in PC machine or /home/ directory if use UNIX workstation.
Appendix B: TxDOT Hydrology Extension Coding

1) Txdot.avgN

*********************************************************************
'Name: Txdot.avgN Source Code
'Description: Gets the average number of a grid over a coverage theme
'By: Juling Bao and Francisco Olivera
'Data: May 14,1997
*********************************************************************

' Getting the view ***********************************************
TheView = av.GetActiveDoc

' Getting the themes **********************************************
TheActiveThemes = TheView.GetActiveThemes

if (TheActiveThemes.Count = 0) then
    msgbox.error("No active themes found.  (Select a Grid Theme and a Polygon Theme)", "TxDOT")
    exit
end

if (theactivethemes.count = 1) then
    msgbox.error("Only one active theme found.  (Select a Grid Theme and a Polygon Theme)", "TxDOT")
    exit
end

if (theactivethemes.count > 2) then
    msgbox.error("Too many active themes found.  (Select a Grid Theme and a Polygon Theme)", "TxDOT")
    exit
end

theGtheme = TheActiveThemes.Get(0)
if (theGtheme.Is(GTHEME).not) then
    theGtheme = theactivethemes.get(1)
end

if (theGtheme = nil) then
    msgbox.error("The Grid Theme Needs to Be a Grid Theme", "TxDOT")
    exit
end

theWtheme = TheActiveThemes.get(1)
if (theWtheme.Is(FTHEME)).not) then
    theWtheme = TheActiveThemes.get(0)
end

Wvtab = theWtheme.getFtab
Wshpf = Wvtab.FindField("shape")
Wshp = Wvtab.returnValue(Wshpf,0)
if (not (Wshp.returnclass.GetClassName == "polygon")) then
    msgbox.error("The Polygon Theme Needs to Be a Feature Theme", "TxDOT")
    exit
end

'set average value name

myText = theGtheme.GetName

' Getting the polygon

N=Wvtab.GetNumRecords
' if the feature theme has only one polygon

if (N=1) then
    For each r in Wvtab
        Poly = Wvtab.ReturnValue(Wshpf, r)

    ' Getting the RCN grid

    NewGrid = theGTheme.GetGrid

    ' Reducing the RCN grid to the polygon size

    SubGrid = NewGrid.ExtractByPolygon(Poly, Prj.MakeNull, false)

    ' Getting the average curve number of the grid

    X = SubGrid.GetStatistics.get(2)

end

Wvtab.setEditable(true)
avg_myText = field.make(myText, #Field_DOUBLE, 8, 2)
Wvtab.addfields({avg_myText})
Wvtab.setValue(avg_myText,r,X)
Wvtab.setEditable(false)
Msgbox.info(myText++"= "++ x.AsString, "Average Value of the Grid inside the polygon" )

else

' if the feature theme has more than one polygon

Wvtab.setEditable(true)
avg_myText = field.make(myText, #Field_DOUBLE, 8, 2)
Wvtab.addfields({avg_myText})
For each r in Wvtab
    Poly = Wvtab.ReturnValue(Wshpf, r)
    RcnG = theGTheme.GetGrid
    SubRcnG = RcnG.ExtractByPolygon(Poly, Prj.MakeNull, false)
    X = SubRcnG.GetStatistics.get(2)
    Wvtab.setValue(avg_myText,r,X)

end
Wvtab.setEditable(false)
Msgbox.info("Average Values are stored in the"++ mytext++ "field of the polygon theme attribute table", "TxDOT")
end
2) Txdot. install

*********************************************************************
'Name: Txdot.install Source Code
'Adapted by: Juling Bao and Francisco Olivera
'Date: May 14, 1997
**********************************************************************

if (av.getproject=nil) then return(nil) end

theDocs = SELF.get(0)
theControlList = SELF.get(1)
theMenuList = SELF.get(2)
theToolMenuList = SELF.Get(3)
theProject = Av.getproject

'Add the Docs
'
for each adoc in theDocs
  theProject.addDoc(adoc)
end

'Add the Controls
'
for each totalControl in theControlList
  'The Control list
  acontrol = totalControl.get(0)

  'The physical control
  theControl = totalControl.get(1)

  'The control Index
  theCindex = totalControl.get(2)

  'Find the DocGUI
  theControlDoc = av.getproject.findGUI(aControl.get(0))
  if (theControlDoc=NIL) then
    MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.","Script Error")
    return(nil)
  end

  'This finds the control set
  thecommand=av.getproject.findGUI(""+aControl.get(0)+"").Get"+acontrol.get(1)
  thescript1=Script.Make(thecommand)
  thecontrolset=thescript1.doit"

  'Add the control to the control set
  theControlSet.Add(theControl,theCindex)
end
'Add the menus
for each totalcontrol in theMenuList

'The Control list
acontrol=totalControl.get(0)
  mDoc=acontrol.get(0)
  mMenu=acontrol.get(1)
  mMenuItem=acontrol.get(2)

'The physical control
theControl = totalControl.get(1)

'The control Index
theCindex=totalControl.get(2)

'Find the DocGUI
theControlDoc=av.getproject.findGUI(aControl.get(0))
  if (theControlDoc=NIL) then
    MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.", "Script Error")
    return(nil)
  end

  theMbar=av.getproject.findGUI(mDoc).GetMenuBar
  themenu=theMbar.findbylabel(mMenu)
  if (themenu=NIL) then
    themenu=menu.make
    themenu.setlabel(mMenu)
    theMbar.add(themenu,999)
  end

  themenu.add(thecontrol, theCindex)
end

'Add the Tool Menus
for each totalControl in theToolMenuList
  'The Control list
  acontrol=totalControl.get(0)

  'The physical control
  theControl = totalControl.get(1)

  'The control Index
  theCindex=totalControl.get(2)

  'Find the DocGUI
  theControlDoc=av.getproject.findGUI(aControl.get(0))
  if (theControlDoc=NIL) then
    MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.", "Script Error")
    return(nil)
end

'This finds the control set
thecommand="av.getproject.findGUI("""+aControl.get(0)+"""").Get""""+acontrol.get(1)
thescript1=Script.Make(thecommand)
thecontrolset=av.getproject.findGUI(aControl.get(0)).GetToolBar

'Add the control to the control set
theControlSet.Add(theControl,theCindex)
end

av.getproject.setmodified(true)

'And the scripts add themselves
3) Txdot.make

`*********************************************************************
` Name: txdot.make - Source Code
` Topics:
`,
` Description:
`,
` Requires:
`,
`Adapted by: Juling Bao and Francisco Olivera
`*********************************************************************

`the Filename of the extension
`,
theExtensionFile = "/home/bao/TxDot1.avx"
`,
`-------------------------------
`The Name of the extension to be displayed in the
`extension dialog
theExtensionName = "TxDOT"
`,
`-------------------------------
`The description of the extension to be displayed
` in the extension dialog
theDescription = "Extension for TxDOT project"
`,
`-------------------------------
`The version of the extension
theVersion = 3.0
`,
`-------------------------------
`Install Script
` The Script to use to install the extension
`NOTE: "My Extension Install" is a pre-prepare script for this
InScriptName = "txdot.install"
`,
`-------------------------------
`Uninstall Script
` The Script to use to uninstall the extension
`NOTE: "Uninstall" is a pre-prepare script for this
UnScriptName = "txdot.uninstall"
`,
`-------------------------------
`Any document Names to include
` This is a list of any documents to include
` eg. theDocs = {"View1", "Layout1"}
theDocs = {} 
`,
`-------------------------------
`Controls (Buttons and normal Tools) to include
'Controls {GUI name, ControlType, ScriptName}
e.g. TheControlList = ["View", "ButtonBar", "View.ZoomIn"], ["View", "ToolBar", "View.Identify"]
TheControlList = ["View", "ToolBar", "Txdot.peakflow"]

'-------------------------------
'Tool menus to include
'This is a list of which tool menus to include. Tool menus are specified
'by giving a GUI name and a script name of one of the tools in the tool menu
'Using this to locate the tool menu ALL other tools in that menu and
'their scripts will be extracted
'theToolMenu = ["View", "View.PointTool"]
TheToolMenuList = []

'-------------------------------
'The Menus to include (a list of menu items listing the doc, the top menu, and the script for the menu item)
TheMenuList = {Doc name, Main Menu name, menu item Scriptname}
e.g. TheMenuList = ["View", "File", "View.Export"]

'-------------------------------
'The scripts to include, not in controls or menus
'e.g. theScripts = ["My.Script", "View.export"]

'-------------------------------
The Dependencies
cDePendencies = []

'-------------------------------
'ATTENTION!!!!!!!!!!!!!!!!!
'Do NOT alter the script after these lines, the remainder of this script
'uses the lists you provided above to build the extension object.
'

'Create a total list of the needed scripts
TheNeeded = []
for each ControlScript in thecontrolList
TheNeeded.add(ControlScript.get(2))
end
For each MenuScript in theMenuList
  theNeeded.add(MenuScript.get(2))
end

totalscripts=thescripts.merge(theNeeded)
TotalScripts.removeduplicates

theInstall=av.GetProject.FindScript(InscriptName)
if (theInstall=NIL) then
  MsgBox.Error("The install Script "+InScriptName+" was not found","Script not found")
  return(nil)
end

theUninstall=av.GetProject.FindScript(unscriptName)
if (theUninstall=NIL) then
  MsgBox.Error("The install Script "+UnScriptName+" was not found","Script not found")
  return(nil)
end

'Create the extension
' Extension.Make(ExtensionFile, theExtensionName, InstallScript, UninstallScript, Dependancies_

myExt = Extension.Make(theExtensionFile.asFilename,
  theExtensionName,
  theInstall,
  theUninstall,
  theDependencies)

TheDocList={ }
TheTotalControls={ }
TheTotalMenus={ }
theTotalToolMenus={ }

' Process the Document List
for each aDoc in TheDocs
  if ((av.getproject.findDoc(aDoc)="Null").NOT) then
    TheDocList.Add(av.GetProject.FindDoc(aDoc))
  else
    MsgBox.Warning("The Doc "+adoc.asstring+" cannot be found in the current project.","Script Error")
    return(nil)
  end
end

'Add the List of Documents
MyExt.add(TheDocList)

' Process the control List
'__________________________________________
'Controls {GUI,ControlType,Scriptname}

for each aControl in TheControlList
  theControlDoc=av.getproject.findGUI(aControl.get(0))
  if (theControlDoc=NIL) then
    MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.","Script Error")
    return(nil)
  end
  thecommand="av.getproject.findGUI("+aControl.get(0)+").Get"+acontrol.get(1)
  thescript1=Script.Make(thecommand)
  thecontrolset=thescript1.doit(""")
  theFoundControl=TheControlSet.FindbyScript(aControl.get(2))
  if (theFoundControl=NIL) then
    MsgBox.Warning("No Control found with the script "+aControl.get(2)+" in "+acontrol.get(1)+"Warning")
    return(nil)
  end
  if (theFoundControl.is(ToolMenu)) then
    MsgBox.Warning("The script "+aControl.get(2)+" in "+acontrol.get(1)+" is for a tool menu.","Not Supported")
    return(nil)
  end
  TheTotalControls.Add({aControl,thefoundControl,theControlSet.getcontrols.find(thefoundcontrol)})
end

'The MenuList {Doc, Menu, MenuScript}

For each aMenu in themenulist
  mDoc=aMenu.get(0)
  mMenu=aMenu.get(1)
  mScript=aMenu.get(2)
  themDoc=av.getproject.findGUI(mDoc)
  if (themDoc=NIL) then
    MsgBox.Warning("The GUI "+mDoc+" cannot be found in the current project.","Script Error")
    return(nil)
  end
  theMbar=av.getproject.findGUI(mDoc).GetMenuBar
  themenu=theMbar.findbylabel(mMenu)
  if (themenu=NIL) then
MsgBox.Warning("The menu named "+mMenu+" is not here.","Script Error")
return(nil)
end

themenucontrol=themenu.findByScript(mScript)

if (themenucontrol=NIL) then
    MsgBox.Warning("The script "+mScript+" not found.","Warning")
    return(nil)
end

thetotalmenus.add({amenu,themenucontrol,themenuitemidx})
end

myext.add(thetotalmenus)

'Process the Tool Menu List

for each aControl in TheToolMenuList
    theControlDoc=av.getProject.findGUI(aControl.get(0))
    if (theControlDoc=NIL) then
        MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.","Script Error")
        return(nil)
    end
    thecontrolset=theControlDoc.getToolbar
    theFoundControl=TheControlSet.FindbyScript(aControl.get(1))
    if (theFoundControl=NIL) then
        MsgBox.Warning("No Control found with the script "+aControl.get(1)+" in "+acontrol.get(1),"Warning")
        return(nil)
    end
    if (theFoundControl.is(ToolMenu).not) then
        MsgBox.Warning("The script "+aControl.get(1)+" is NOT for a tool menu.","User Error")
        return(nil)
    end
    TheTotalToolMenus.Add({aControl,thefoundControl,thecontrolset.getcontrols.find(thefoundcontrol)})
end

myext.add(thetotalToolmenus)

'Process the Script list

for each ascript in TotalScripts
   if ((av.getproject.findscript(ascript)="Null").NOT) then
      myExt.Add(av.GetProject.FindScript(ascript))
   else
      MsgBox.Warning("The script "+ascript+" cannot be found in the current project.", "Script Error")
      return(nil)
   end
end

myExt.SetAbout(theDescription)
myExt.SetExtVersion(theVersion)
myExt.Commit
4) Txdot. peakflow

`**********************************************************************************
' Name: Txdot.peakflow  Source Code
' Description: Using Regional Regression Equations (Statewide Rural Regression Equations)
' Calculates Peakflow in 2yr, 5yr, 10yr, 25yr, 50yr,100yr frequency. And get hydrologic parameters.
' Avenue script developed by Francisco Olivera and Juling Bao

**********************************************************************************

' Get themes from extension preferences ***********************************************

' Identifying the extension

floodqExt = Extension.Find("TxDOT")
if (floodqExt = NIL) then
    MsgBox.Error("Cannot find extension!","TxDOT")
    return NIL
end

'demGridName = floodqExt.GetPreferences.Get("Raw DEM Property")
filGridName = floodqExt.GetPreferences.Get("Burned and Filled DEM Property")
fdrGridName = floodqExt.GetPreferences.Get("Flow Direction Property")
facGridName = floodqExt.GetPreferences.Get("Flow Accumulation Property")
fluGridName = floodqExt.GetPreferences.Get("Flow Length Upstream Property")
fldGridName = floodqExt.GetPreferences.Get("Flow Length Downstream Property")
hyrGridName = floodqExt.GetPreferences.Get("Hydrologic Regions Property")
rcnGridName = floodqExt.GetPreferences.Get("Curve Number Property")

' Getting started **********************************************************

av.UseWaitCursor
theView = av.GetActiveDoc
theDisplay = theView.GetDisplay

' Getting data grids **********************************************************

theDEMGrid = theView.FindTheme(demGridName).GetGrid
theFILGrid = theView.FindTheme(filGridName).GetGrid
theFDRGrid = theView.FindTheme(fdrGridName).GetGrid
theFACGrid = theView.FindTheme(facGridName).GetGrid
theFLUGrid = theView.FindTheme(fluGridName).GetGrid
theFLDGrid = theView.FindTheme(fldGridName).GetGrid
theHYRGrid = theView.FindTheme(hyrGridName).GetGrid
theRCNGrid = theView.FindTheme(rcnGridName).GetGrid

' Identifying the Ungaged Site *****************************************************

theGridTheme = theView.FindTheme(facGridName)
theGrid = theGridTheme.GetGrid
p = theDisplay.ReturnUserPoint
mPoint = MultiPoint.MakeNull
mPoint = MultiPoint.Make({p})
theSrcGrid = theGrid.ExtractByPoints(mPoint, Prj.MakeNull, FALSE)

' Delineating the watershed ****************************************************************

' $$$ -> 500 corresponds to the cell size of the Texas 500-m DEM <- $$$
theOutlet = theSrcGrid.SnapPourPoint(theFACGrid, 500)
theWSHGrid = theFDRGrid.Watershed(theOutlet)
if (theWSHGrid.HasError) then return NIL end
theWSHOneGrid = (theWSHGrid <= 0).SetNull(1.AsGrid)

' Calculating the area of the watershed in sq-Km
WshAreaGrid = (theOutlet / theOutlet) * theFACGrid
' $$$ -> 1000 to convert the cell size in meters into Km <- $$$
DrArea = WshAreaGrid.GetStatistics.Get(1) * (theFDRGrid.GetCellSize / 1000) *
      (theFDRGrid.GetCellSize / 1000)

' Creating a grid theme for the Watershed
' theWSHTHEME = GTheme.Make(theWSHGrid)
' theWSHTHEME.SetName("WatershedGr")
' theView.AddTheme(theWSHTHEME)
' theWSHTHEME.SetVisible(True)

' Creating a (polygon) theme for the watershed
cutFN = av.GetProject.GetWorkDir.MakeTmp("wshply","shp")
SubFtab = theWSHGrid.AsPolygonFTab(cutFN,False,Prj.MakeNull)
if (SubFtab.HasError) then return NIL end
WSHPCtheme=FTheme.Make(SubFtab)
WSHPCtheme.SetName("WatershedPC")
theView.AddTheme(WSHPCtheme)
WSHPCtheme.SetVisible(True)

theLegend = WSHPCtheme.GetLegend
NewColor = color.Make
NewColor.SetTransparent(TRUE)
theLegend.GetSymbols.UniformColor(NewColor)
WSHPCtheme.UpdateLegend

' Identifying longest flowpath in the watershed ***************************************

theWSHFLUGrid = theWSHOneGrid * theFLUGrid
Temp1Grid = theWSHOneGrid * theFLDGrid
StatList1 = Temp1Grid.GetStatistics
theWSHFLDGrid = Temp1Grid - StatList1.Get(0)
FLPlusGrid = theWSHFLUGrid + theWSHFLDGrid
StatList2 = FLPlusGrid.GetStatistics
' $$$ -> This 0.999 may be changed <- $$$
TestGrid = FLPlusGrid - (0.999 * StatList2.Get(1))
FlowPathOneGrid = (TestGrid < 0).SetNull(1.AsGrid)

' Creating a theme for the flow path

theFlowPathTheme = GTheme.Make(FlowPathOneGrid)
theFlowPathTheme.SetName("Flow Path")

' Calculating the length of the longest flow-path in Km

' $$$ -> 1000 to convert the cell size in meters into Km <- $$$
Length = StatList2.Get(1) / 1000
if (length*1000 < (3 * FlowPathOneGrid.GetCellsize)) then
    MsgBox.error("The drainage area is too small relative to the grid resolution for calculation of watershed parameters", "TxDOT")
    exit
end
theView.AddTheme(theFlowPathTheme)
theFlowPathTheme.SetVisible(True)

' Calculate channel slope in m/m

' $$$ -> For 10% from the outlet use 0.90 instead of 0.99 <- $$$
' $$$ -> For 85% from the outlet use 0.15 instead of 0.01 <- $$$
fl10pct = 0.99 * StatList2.Get(1)
fl85pct = 0.01 * StatList2.Get(1)

DSGrid = (((FlowPathOneGrid * theWSHFLUGrid) - fl10pct).Abs < (0.75 * theWSHFLUGrid.GetCellSize)).con(1.AsGrid,0.AsGrid)
USGrid = (((FlowPathOneGrid * theWSHFLUGrid) - fl85pct).Abs < (0.75 * theWSHFLUGrid.GetCellSize)).con(1.AsGrid,0.AsGrid)

DSElevGrid = DSGrid * theDEMGrid
USElevGrid = USGrid * theDEMGrid

StatList3 = DSElevGrid.GetStatistics
StatList4 = USElevGrid.GetStatistics

' $$$ -> 0.98 = 0.99 - 0.01. It would change if the slope is defined from <- $$$
' $$$ -> 10% to 85% of the distance to the outlet, and would be 0.75 = 0.85 - 0.10 <- $$$
' $$$ -> 0.3048 because the Z-units are feet and the XY-units are meters <- $$$
slope = (Drop / (0.98 * StatList2.Get(1))) * 0.3048
' $$$ -> 1000 to convert dimensionless slope in to m/Km
kslope = slope * 1000

' Calculate the watershed shape factor

ShapeF = (Length * Length) / DrArea

' Determining the hydrologic region

**********************************************************************
OutletHydrReg = ((theOutlet / theOutlet) * theHYRGrid).GetStatistics.Get(2)

' Determining the average runoff curve number
************************************************

WVTab = WshPCTheme.GetFTab
WshP = WVTab.FindField("shape")
For each r in WVTab
    Poly = WVTab.ReturnValue(WshP,r)
end
SubRCNG = theRCNGrid.ExtractByPolygon(Poly,Prj.MakeNull,false)
RCN = SubRCNG.GetStatistics.Get(2)

' Determining peak flows in m3/s for different return periods **********

if(OutletHydrReg = 1) then
    Q2 = 0.1694 * (DrArea ^ 1.040) * (ShapeF ^ (-0.537))
    Q5 = 0.6054 * (DrArea ^ 0.958) * (ShapeF ^ (-0.444))
    Q10 = 1.1315 * (DrArea ^ 0.921) * (ShapeF ^ (-0.400))
    Q25 = 2.1712 * (DrArea ^ 0.885) * (ShapeF ^ (-0.356))
    Q50 = 3.2727 * (DrArea ^ 0.864) * (ShapeF ^ (-0.330))
    Q100 = 4.6920 * (DrArea ^ 0.847) * (ShapeF ^ (-0.307))
end

if(OutletHydrReg = 2) then
    Q2 = 0.0445 * (DrArea ^ 0.376) * (ShapeF ^ (0.869)) * (slope ^ (-0.689))
    Q5 = 0.0435 * (DrArea ^ 0.372) * (ShapeF ^ (0.738)) * (slope ^ (-0.933))
    Q10 = 0.0445 * (DrArea ^ 0.369) * (ShapeF ^ (0.673)) * (slope ^ (-1.050))
    Q25 = 0.0411 * (DrArea ^ 0.366) * (ShapeF ^ (0.604)) * (slope ^ (-1.190))
    Q50 = 0.0405 * (DrArea ^ 0.363) * (ShapeF ^ (0.566)) * (slope ^ (-1.270))
    Q100 = 0.0411 * (DrArea ^ 0.361) * (ShapeF ^ (0.531)) * (slope ^ (-1.340))
end

if((OutletHydrReg = 3) and (DrArea < 83)) then
    Q2 = 1.9183 * (DrArea ^ 0.592)
    Q5 = 3.9218 * (DrArea ^ 0.629)
    Q10 = 5.6791 * (DrArea ^ 0.652)
    Q25 = 8.3991 * (DrArea ^ 0.679)
    Q50 = 10.8281 * (DrArea ^ 0.698)
    Q100 = 13.5939 * (DrArea ^ 0.715)
end

if((OutletHydrReg = 3) and (DrArea >= 83)) then
    Q2 = 34.2746 * (DrArea ^ 0.668) * (ShapeF ^ 0.189) * (slope ^ 0.659)
    Q5 = 89.8174 * (DrArea ^ 0.626) * (slope ^ 0.574)
    Q10 = 149.6630 * (DrArea ^ 0.579) * (slope ^ 0.537)
    Q25 = 237.2570 * (DrArea ^ 0.523) * (slope ^ 0.476)
    Q50 = 305.7774 * (DrArea ^ 0.484) * (slope ^ 0.425)
    Q100 = 374.8059 * (DrArea ^ 0.447) * (slope ^ 0.372)
end

if((OutletHydrReg = 4) and (DrArea < 83)) then
    Q2 = 1.5154 * (DrArea ^ 0.626)
    Q5 = 2.9899 * (DrArea ^ 0.65) * (ShapeF ^ 0.257)
Q10  = 4.2741 * (DrArea ^ 0.697) * (ShapeF ^ 0.281)
Q25  = 6.3650 * (DrArea ^ 0.741) * (ShapeF ^ 0.311)
Q50  = 74.2031 * (DrArea ^ 0.927) * (ShapeF ^ 0.333) * (slope ^ 0.558)
Q100 = 124.0603 * (DrArea ^ 0.968) * (ShapeF ^ 0.353) * (slope ^ 0.627)
end

if((OutletHydrReg = 4) and (DrArea >= 83)) then
  Q2   = 3301.6992 * (DrArea ^ 1.29) * (slope ^ 2.09)
  Q5   = 24056.4457 * (DrArea ^ 1.24) * (slope ^ 2.18)
  Q10  = 55048.3692 * (DrArea ^ 1.2) * (slope ^ 2.18)
  Q25  = 124899.2199 * (DrArea ^ 1.16) * (slope ^ 2.18)
  Q50  = 227873.0495 * (DrArea ^ 1.13) * (slope ^ 2.19)
  Q100 = 352574.9115 * (DrArea ^ 1.11) * (slope ^ 2.19)
end

if((OutletHydrReg = 5) and (DrArea < 83)) then
  Q2   = 2.3572 * (DrArea ^ 0.683)
  Q5   = 5.3735 * (DrArea ^ 0.779)
  Q10  = 8.0970 * (DrArea ^ 0.829)
  Q25  = 12.3829 * (DrArea ^ 0.88)
  Q50  = 68.2492 * (DrArea ^ 0.993) * (slope ^ 0.37)
  Q100 = 102.8256 * (DrArea ^ 1.03) * (slope ^ 0.417)
end

if((OutletHydrReg = 5) and (DrArea >= 83)) then
  Q2   = 6.6461 * (DrArea ^ 0.498)
  Q5   = 21.6345 * (DrArea ^ 0.534) * (ShapeF ^ (-0.145))
  Q10  = 38.6826 * (DrArea ^ 0.552) * (ShapeF ^ (-0.221))
  Q25  = 71.2097 * (DrArea ^ 0.571) * (ShapeF ^ (-0.307))
  Q50  = 104.8700 * (DrArea ^ 0.583) * (ShapeF ^ (-0.366))
  Q100 = 147.7025 * (DrArea ^ 0.594) * (ShapeF ^ (-0.42))
end

if(OutletHydrReg = 6) then
  Q2   = 1.0293 * (DrArea ^ 0.63) * (ShapeF ^ (-0.423))
  Q5   = 0.5242 * (DrArea ^ 0.424) * (slope ^ (-0.41))
  Q10  = 0.9085 * (DrArea ^ 0.41) * (slope ^ (-0.4190))
  Q25  = 1.6273 * (DrArea ^ 0.398) * (slope ^ (-0.428))
  Q50  = 2.3506 * (DrArea ^ 0.391) * (slope ^ (-0.434))
  Q100 = 33.1599 * (DrArea ^ 0.44)
end

if((OutletHydrReg = 7) and (DrArea < 83)) then
  Q2   = 1.1925 * (DrArea ^ 0.568) * (slope ^ (-0.285))
  Q5   = 9.2543 * (DrArea ^ 0.61)
  Q10  = 13.3959 * (DrArea ^ 0.592)
  Q25  = 19.5756 * (DrArea ^ 0.576)
  Q50  = 24.8688 * (DrArea ^ 0.566)
  Q100 = 30.6700 * (DrArea ^ 0.558)
end

if((OutletHydrReg = 7) and (DrArea >= 83)) then
  Q2   = 47.7294 * (DrArea ^ 0.578) * (slope ^ 0.364)
  Q5   = 300.2844 * (DrArea ^ 0.605) * (slope ^ 0.578)
Q_{10} = 1092.4994 \times (\text{DrArea}^{0.644}) \times (\text{ShapeF}^{(-0.239)}) \times (\text{slope}^{0.699})
Q_{25} = 2583.4202 \times (\text{DrArea}^{0.651}) \times (\text{ShapeF}^{(-0.267)}) \times (\text{slope}^{0.776})
Q_{50} = 4367.0970 \times (\text{DrArea}^{0.653}) \times (\text{ShapeF}^{(-0.291)}) \times (\text{slope}^{0.817})
Q_{100} = 6883.4736 \times (\text{DrArea}^{0.654}) \times (\text{ShapeF}^{(-0.316)}) \times (\text{slope}^{0.849})

\text{end}

\text{if}(\text{OutletHydrReg} = 8) \text{ then}
\text{Q}_2 = 122.6319 \times (\text{DrArea}^{0.627}) \times (\text{slope}^{0.652})
\text{Q}_5 = 113.3012 \times (\text{DrArea}^{0.668}) \times (\text{slope}^{0.52})
\text{Q}_{10} = 117.0641 \times (\text{DrArea}^{0.675}) \times (\text{slope}^{0.475})
\text{Q}_{25} = 126.1105 \times (\text{DrArea}^{0.69}) \times (\text{slope}^{0.444})
\text{Q}_{50} = 135.9037 \times (\text{DrArea}^{0.703}) \times (\text{slope}^{0.433})
\text{Q}_{100} = 147.5524 \times (\text{DrArea}^{0.718}) \times (\text{slope}^{0.429})
\text{end}

\text{if}(\text{OutletHydrReg} = 9) \text{ then}
\text{Q}_2 = 4.7719 \times (\text{DrArea}^{0.526})
\text{Q}_5 = 33.2386 \times (\text{DrArea}^{0.645}) \times (\text{ShapeF}^{(-0.246)}) \times (\text{slope}^{0.22})
\text{Q}_{10} = 97.1374 \times (\text{DrArea}^{0.691}) \times (\text{ShapeF}^{(-0.321)}) \times (\text{slope}^{0.343})
\text{Q}_{25} = 289.5838 \times (\text{DrArea}^{0.743}) \times (\text{ShapeF}^{(-0.413)}) \times (\text{slope}^{0.466})
\text{Q}_{50} = 570.3826 \times (\text{DrArea}^{0.778}) \times (\text{ShapeF}^{(-0.477)}) \times (\text{slope}^{0.541})
\text{Q}_{100} = 1042.2502 \times (\text{DrArea}^{0.811}) \times (\text{ShapeF}^{(-0.539)}) \times (\text{slope}^{0.607})
\text{end}

\text{if}(\text{OutletHydrReg} = 10) \text{ and } (\text{DrArea} < 83) \text{ then}
\text{Q}_2 = 8.0270 \times (\text{DrArea}^{0.788}) \times (\text{slope}^{0.279})
\text{Q}_5 = 17.4696 \times (\text{DrArea}^{0.835}) \times (\text{slope}^{0.33})
\text{Q}_{10} = 26.6161 \times (\text{DrArea}^{0.86}) \times (\text{slope}^{0.359})
\text{Q}_{25} = 42.0374 \times (\text{DrArea}^{0.887}) \times (\text{slope}^{0.39})
\text{Q}_{50} = 55.7797 \times (\text{DrArea}^{0.904}) \times (\text{slope}^{0.408})
\text{Q}_{100} = 72.2851 \times (\text{DrArea}^{0.92}) \times (\text{slope}^{0.426})
\text{end}

\text{if}(\text{OutletHydrReg} = 10) \text{ and } (\text{DrArea} \geq 83) \text{ then}
\text{Q}_2 = 174.8257 \times (\text{DrArea}^{0.798}) \times (\text{slope}^{0.777})
\text{Q}_5 = 401.3713 \times (\text{DrArea}^{0.79}) \times (\text{slope}^{0.795})
\text{Q}_{10} = 580.9288 \times (\text{DrArea}^{0.775}) \times (\text{slope}^{0.785})
\text{Q}_{25} = 821.1726 \times (\text{DrArea}^{0.752}) \times (\text{slope}^{0.76})
\text{Q}_{50} = 990.4262 \times (\text{DrArea}^{0.733}) \times (\text{slope}^{0.735})
\text{Q}_{100} = 1160.9910 \times (\text{DrArea}^{0.713}) \times (\text{slope}^{0.708})
\text{end}

\text{if}(\text{OutletHydrReg} = 11) \text{ then}
\text{Q}_2 = 2.3820 \times (\text{DrArea}^{0.669}) \times (\text{ShapeF}^{(-0.262)})
\text{Q}_5 = 8.4989 \times (\text{DrArea}^{0.696}) \times (\text{ShapeF}^{(-0.186)}) \times (\text{slope}^{0.13})
\text{Q}_{10} = 18.9170 \times (\text{DrArea}^{0.718}) \times (\text{ShapeF}^{(-0.151)}) \times (\text{slope}^{0.221})
\text{Q}_{25} = 42.2418 \times (\text{DrArea}^{0.713}) \times (\text{slope}^{0.313})
\text{Q}_{50} = 75.6556 \times (\text{DrArea}^{0.735}) \times (\text{slope}^{0.38})
\text{Q}_{100} = 129.9534 \times (\text{DrArea}^{0.755}) \times (\text{slope}^{0.442})
\text{end}

\text{Displaying Results}
***************************************************************************
DrArea.SetFormatPrecision(2)
kslope.SetFormatPrecision(2)
Length.SetFormatPrecision(2)
ShapeF.SetFormatPrecision(2)
RCN.SetFormatPrecision(2)
Q2.SetFormatPrecision(2)
Q5.SetFormatPrecision(2)
Q10.SetFormatPrecision(2)
Q25.SetFormatPrecision(2)
Q50.SetFormatPrecision(2)
Q100.SetFormatPrecision(2)

msgbox.Report("WATERSHED PROPERTIES"+NL+
"Drainage area = "+DrArea.AsString+" Km2"+NL+
"Channel slope = "+kslope.AsString+" m/Km"+NL+
"Length of Longest Flow-Path = "+Length.AsString+" Km"+NL+
"Watershed Shape Factor = "+ShapeF.AsString+NL+
"Average curve number = "+RCN.AsString+NL+
"Hydrologic Region = "+OutletHydrReg.AsString+NL+

"FLOOD DISCHARGES"+NL+
"Q2   = "+Q2.AsString+" m3/s"+NL+
"Q5   = "+Q5.AsString+" m3/s"+NL+
"Q10  = "+Q10.AsString+" m3/s"+NL+
"Q25  = "+Q25.AsString+" m3/s"+NL+
"Q50  = "+Q50.AsString+" m3/s"+NL+
"Q100 = "+Q100.AsString+" m3/s",
"TxDOT Statewide Regional Rural Regression Equations")

'Add fields to the WSHPCtheme ********************************************

WSHPCVtab = WSHPCtheme.GetFtab

mylist = list.make
mylist.Add(field.Make("Area(Km2)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Slope(m/Km)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Length(Km)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("ShapeFactor", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("CurveNumber", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("HydrRegion", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Q2(m3/s)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Q5(m3/s)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Q10(m3/s)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Q25(m3/s)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Q50(m3/s)", #Field_DOUBLE, 10,2))
mylist.Add(field.Make("Q100(m3/s)", #Field_DOUBLE, 10,2))

outFlist=mylist.DeepClone

if(WSHPCVtab.CanEdit) then
    WSHPCVtab.SetEditable(True)
else
    msgbox.info("Can not add fields to the watershed polygon coverage attribute table (WSHPCVtab)", "Error")
WSHPCVtab.AddFields(outFlist)

Area=WSHPCVtab.FindField("Area(Km2)")
slope=WSHPCVtab.FindField("Slope(m/Km)")
lengthF=WSHPCVtab.FindField("Length(Km)")
shapefactor=WSHPCVtab.FindField("ShapeFactor")
curvenumber=WSHPCVtab.FindField("CurveNumber")
region=WSHPCVtab.FindField("HydrRegion")
Q2F=WSHPCVtab.FindField("Q2(m3/s)")
Q5F=WSHPCVtab.FindField("Q5(m3/s)")
Q10F=WSHPCVtab.FindField("Q10(m3/s)")
Q25F=WSHPCVtab.FindField("Q25(m3/s)")
Q50F=WSHPCVtab.FindField("Q50(m3/s)")
Q100F=WSHPCVtab.FindField("Q100(m3/s)"

for each rec  in WSHPCVtab
    WSHPCVtab.SetValue(Area,rec,DrArea)
    WSHPCVtab.SetValue(slope,rec,kslope)
    WSHPCVtab.SetValue(lengthF,rec,length)
    WSHPCVtab.SetValue(shapefactor,rec,ShapeF)
    WSHPCVtab.SetValue(curvenumber,rec,RCN)
    WSHPCVtab.SetValue(region,rec,OutletHydrReg)
    WSHPCVtab.SetValue(Q2F,rec,Q2)
    WSHPCVtab.SetValue(Q5F,rec,Q5)
    WSHPCVtab.SetValue(Q10F,rec,Q10)
    WSHPCVtab.SetValue(Q25F,rec,Q25)
    WSHPCVtab.SetValue(Q50F,rec,Q50)
    WSHPCVtab.SetValue(Q100F,rec,Q100)
end

WSHPCVtab.SetEditable(false)
5) Txdot.properties

' Properties script
' Based on the Hydrologic Modeling extension script hydro.properties
' Adapted by Francisco Olivera and Juling Bao

theView = av.GetActiveDoc

' grab current settings from preference dictionary
floodqExt = Extension.Find("TxDOT")
if (floodqExt = NIL) then
    MsgBox.Error("Cannot find extension!", "ERROR")
    return NIL
end

RawDEMGThemeName = floodqExt.GetPreferences.Get("Raw DEM Property")
if (RawDEMGThemeName = NIL) then
    RawDEMGThemeName = ""
elseif (theView.FindTheme(RawDEMGThemeName) = NIL) then
    RawDEMGThemeName = ""
end

BFDEMGThemeName = floodqExt.GetPreferences.Get("Burned and Filled DEM Property")
if (BFDEMGThemeName = NIL) then
    BFDEMGThemeName = ""
elseif (theView.FindTheme(BFDEMGThemeName) = NIL) then
    BFDEMGThemeName = ""
end

FDirGThemeName = floodqExt.GetPreferences.Get("Flow Direction Property")
if (FDirGThemeName = NIL) then
    FDirGThemeName = ""
elseif (theView.FindTheme(FDirGThemeName) = NIL) then
    FDirGThemeName = ""
end

FAccGThemeName = floodqExt.GetPreferences.Get("Flow Accumulation Property")
if (FAccGThemeName = NIL) then
    FAccGThemeName = ""
elseif (theView.FindTheme(FAccGThemeName) = NIL) then
    FAccGThemeName = ""
end

FLUpGThemeName = floodqExt.GetPreferences.Get("Flow Length Upstream Property")
if (FLUpGThemeName = NIL) then
    FLUpGThemeName = ""
elseif (theView.FindTheme(FLUpGThemeName) = NIL) then
    FLUpGThemeName = ""
end

FLDownGThemeName = floodqExt.GetPreferences.Get("Flow Length Downstream Property")
if (FLDownGThemeName = NIL) then
    FLDownGThemeName = ""
elseif (theView.FindTheme(FLDownGThemeName) = NIL) then
    FLDownGThemeName = ""
end

HyRegGThemeName = floodqExt.GetPreferences.Get("Hydrologic Regions Property")
if (HyRegGThemeName = NIL) then
    HyRegGThemeName = ""
elseif (theView.FindTheme(HyRegGThemeName) = NIL) then
    HyRegGThemeName = ""
end

RCNGThemeName = floodqExt.GetPreferences.Get("Curve Number Property")
if (RCNGThemeName = NIL) then
    RCNGThemeName = ""
elseif (theView.FindTheme(RCNGThemeName) = NIL) then
    RCNGThemeName = ""
end

SlopGThemeName = floodqExt.GetPreferences.Get("Watershed Slope Property")
if (SlopGThemeName = NIL) then
    SlopGThemeName = ""
elseif (theView.FindTheme(SlopGThemeName) = NIL) then
    SlopGThemeName = ""
end

' flowDirGThemeName = floodqExt.GetPreferences.Get("Flow Direction Property")
' if (flowDirGThemeName = NIL) then
'    flowDirGThemeName = ""
' elseif (theView.FindTheme(flowDirGThemeName) = NIL) then
'    flowDirGThemeName = ""
' end
'
' get new properties
status = TRUE
while (status)
    propertiesList = MsgBox.MultiInput("Enter properties:", "Flood Flow Properties",
    {"Raw DEM Theme:", "Burned and Filled DEM Theme:, "Flow Direction Theme:;", "Flow Accumulation Theme:;", "Flow Length Upstream Theme:;", "Flow Length Downstream Theme:;",
    "Hydrologic Regions Theme:;", "Curve Number Theme:;", "Watershed Slope Theme:",
    [RawDEMThemeName, BFDEMThemeName, FDirGThemeName, FAccGThemeName,
    FLUpGThemeName, FLDownGThemeName, HyRegGThemeName, RCNGThemeName,
    SlopGThemeName])
    if (propertiesList.Count < 2) then return NIL end
    newRawDEMThemeName = propertiesList.Get(0)
    newBFDEMThemeName = propertiesList.Get(1)
    newFDirGThemeName = propertiesList.Get(2)
    newFAccGThemeName = propertiesList.Get(3)
    newFLUpGThemeName = propertiesList.Get(4)
newFLDownGThemeName = propertiesList.Get(5)
newHyRegGThemename = propertiesList.Get(6)
newRCNGThemename = propertiesList.Get(7)
newSlopGThemename = propertiesList.Get(8)

if (theView.FindTheme(newRawDEMGThemeName) <> NIL) then
    RawDEMOK = TRUE
    RawDEMGThemeName = newRawDEMGThemeName
else
    RawDEMOK = FALSE
    MsgBox.Error("Raw DEM Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newBFDEMGThemeName) <> NIL) then
    BFDEMOK = TRUE
    BFDEMGThemeName = newBFDEMGThemeName
else
    BFDEMOK = FALSE
    MsgBox.Error("Burned and Filled DEM Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newFDirGThemeName) <> NIL) then
    FDirOK = TRUE
    FDirGThemeName = newFDirGThemeName
else
    FDirOK = FALSE
    MsgBox.Error("Flow Direction Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newFAccGThemeName) <> NIL) then
    FAccOK = TRUE
    FAccGThemeName = newFAccGThemeName
else
    FAccOK = FALSE
    MsgBox.Error("Flow Accumulation Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newFLUpGThemeName) <> NIL) then
    FLUpOK = TRUE
    FLUpGThemeName = newFLUpGThemeName
else
    FLUpOK = FALSE
    MsgBox.Error("Flow Length Upstream Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newFLDownGThemeName) <> NIL) then
    FLDownOK = TRUE
    FLDownGThemeName = newFLDownGThemeName
else
    FLDownOK = FALSE
    MsgBox.Error("Flow Length Downstream Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newHyRegGThemeName) <> NIL) then
HyRegOK = TRUE
HyRegGThemeName = newHyRegGThemeName
else
    HyRegOK = FALSE
    MsgBox.Error("Hydrologic Regions Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newRCNGThemeName) <> NIL) then
    RCNK = TRUE
    RCNGThemeName = newRCNGThemeName
else
    RCNK = FALSE
    MsgBox.Error("RCN Theme not found in View","TxDOT Properties")
end

if (theView.FindTheme(newSlopGThemeName) <> NIL) then
    SlopOK = TRUE
    SlopGThemeName = newSlopGThemeName
else
    SlopOK = FALSE
    MsgBox.Error("Watershed Slope Theme not found in View","TxDOT Properties")
end

if (RawDEMOK and BFDEMOK and FDirOK and FAccOK and FLUpOK and FLDownOK and
    HyRegOK and RCNOK and SlopOK) then
    status = FALSE
else
    status = TRUE
end

' set properties
floodqExt.GetPreferences.Set("Raw DEM Property",RawDEMGThemeName)
floodqExt.GetPreferences.Set("Burned and Filled DEM Property",BFDEMGThemeName)
floodqExt.GetPreferences.Set("Flow Direction Property",FDirGThemeName)
floodqExt.GetPreferences.Set("Flow Accumulation Property",FAccGThemeName)
floodqExt.GetPreferences.Set("Flow Length Upstream Property",FLUpGThemeName)
floodqExt.GetPreferences.Set("Flow Length Downstream Property",FLDownGThemeName)
floodqExt.GetPreferences.Set("Hydrologic Regions Property",HyRegGThemeName)
floodqExt.GetPreferences.Set("Curve Number Property",RCNGThemeName)
floodqExt.GetPreferences.Set("Watershed Slope Property",SlopGThemeName)
6) Txdot.RCNmodi

'*******************************************************************************
' Name: Txdot.RCNmodi Source Code
' Description: Given a soil coverage, land use coverage and a land-use/curve-number look-up table, 
' the script calculates a runoff curve number grid for a user-defined area.
' Input data requirements:
' (1) Land use (Anderson's codes) is defined in the "lucode" field of the attribute table.
' (2) Soils are defined by the fields A-pct, B-pct, C-pct and D-pct (percentage of hydrologic soil 
' group) in the attribute table.
' (3) Curve number look-up table is comma delimited, with the headings in the first line.
' The land use (Anderson's codes) has the heading "lucode". The curve number for each soil 
' group has the heading Hyd_A, Hyd_B, Hyd_C and Hyd_D.
' By: Juling Bao and Francisco Olivera
' Data: May 14, 1997
'*******************************************************************************

' Identifying the extension **************************************************************************

floodqExt = Extension.Find("TxDOT")
if (floodqExt = NIL) then
    MsgBox.Error("Cannot find extension!","TxDOT")
    return NIL
end

' Get themes from extension preferences *********************************************************

SoilCname = floodqExt.GetPreferences.Get("Soil Coverage Property")
LusC = floodqExt.GetPreferences.Get("Land Use Coverage Property")
RCNtab = floodqExt.GetPreferences.Get("RCN Table Property")

' Getting started  ************************************************************************************

Proj=av.GetProject
theView = av.GetActiveDoc
soilTheme=theview.Findtheme(SoilCname)
lusTheme=theview.Findtheme(LusC)

soilFtab=soilTheme.getFtab

'lJoining the look up table to the land use attribute table **************************************

lusFtab=lusTheme.getFtab

' Set analysis extent  ********************************************************************************

theAE = theView.GetExtension(AnalysisEnvironment)
theExtent = Rect.Make(0@0,1@1)
theCellSize = 1
if ((theAE.GetExtent(theExtent) <> #ANALYSISENV_VALUE) or
    (theAE.GetCellSize(theCellSize) <> #ANALYSISENV_VALUE)) then
    theCE = AnalysisPropertiesDialog.Show(theView,TRUE,"Conversion Extent")
    if (theCE = NIL) then
        return NIL
    end
    theCE.GetCellSize(theCellSize)
    theCE.GetExtent(theExtent)
end

' Defining a new polygon the size of the analysis extent window *******************
area=theExtent.AsPolygon
areaX = av.GetProject.GetWorkDir.MakeTmp("areaX","shp")
newFtab = Ftab.Makenew(areaX, Polygon)
idfld = Field.Make("id", #FIELD_BYTE, 6, 0)
newFtab.AddFields({idfld})
num = newFtab.AddRecord
shpfld = newFtab.FindField("shape")
newFtab.Setvalue(shpfld, num, area)
newFtab.Setvalue(idfld, num, num)
newtheme = Ftheme.Make(newFtab)
'theView.Addtheme(newtheme)
' newTheme.Setvisible(true)

' Selecting the polygons of the soils coverage and of the land use coverage ********
' that intersect the analysis extent. *****************************************************************
thebitmapS=soilFtab.Getselection
thebitmapS.clearAll
thebitmapL=soilFtab.Getselection
thebitmapL.clearAll
soiltheme.selectbytheme(newTheme, #FTAB_RELTYPE_INTERSECTS , 0, #VTAB_SELTYPE_NEW)
lustheme.selectbytheme(newTheme, #FTAB_RELTYPE_INTERSECTS , 0, #VTAB_SELTYPE_NEW)

' Getting four grids out of the small size soil coverage and four grids out of the
' small size land use coverage
'find fields from soil coverage ********************************************************************************
pct_a=soilFtab.FindField("A-pct")
pct_b=soilFtab.FindField("B-pct")
pct_c=soilFtab.FindField("C-pct")
pct_d=soilFtab.FindField("D-pct")

'find fields from land use coverage ********************************************************************************
hyd_a=lusFtab.FindField("hyd_a")
hyd_b=lusFtab.FindField("hyd_b")
hyd_c=lusFtab.FindField("hyd_c")
hyd_d=lusFtab.FindField("hyd_d")
' get four grids from soil coverage  ***********************************************
soilG_a=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_a,{theCellsize, theExtent})
soilG_b=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_b,{theCellsize, theExtent})
soilG_c=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_c,{theCellsize, theExtent})
soilG_d=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_d,{theCellsize, theExtent})

' get four grids from land use coverage  *********************************************
lusG_a=Grid.MakeFromFTab(lusFtab,Prj.MakeNull,hyd_a,{theCellsize, theExtent})
lusG_b=Grid.MakeFromFTab(lusFtab,Prj.MakeNull,hyd_b,{theCellsize, theExtent})
lusG_c=Grid.MakeFromFTab(lusFtab,Prj.MakeNull,hyd_c,{theCellsize, theExtent})
lusG_d=Grid.MakeFromFTab(lusFtab,Prj.MakeNull,hyd_d,{theCellsize, theExtent})

' get runoff curve number grid based on grids Operation ****************************
RCNg=((soilG_a * lusG_a) + (soilG_b * lusG_b) + (soilG_c * lusG_c) + (soilG_d * lusG_d)) / (soilG_a+soilG_b+soilG_c+soilG_d)

'set the runoff curve number grid to the view  *************************************
RCNGTheme=GTheme.make(RCNg)
RCNGTheme.SetName("Curve Number")
TheView.addTheme(RCNGTheme)
RCNGTheme.SetVisible(True)
lusFtab.UnJoinAll
7) Txdot.RCNprop

`theView = av.GetActiveDoc`

`floodqExt = Extension.Find("TxDOT")`
if (floodqExt = NIL) then
    MsgBox.Error("Cannot find extension!","ERROR")
    return NIL
end

SoilcovName = floodqExt.GetPreferences.Get("Soil Coverage:"
if (SoilcovName = NIL) then
    SoilcovName = ""
elseif (theView.FindTheme(SoilcovName) = NIL) then
    SoilcovName = ""
end

luscovName = floodqExt.GetPreferences.Get("Land Use Coverage:"
if (luscovName = NIL) then
    luscovName = ""
elseif (theView.FindTheme(luscovName) = NIL) then
    luscovName = ""
end

rcntableName = floodqExt.GetPreferences.Get("RCN Table:"
if (rcntableName = NIL) then
    rcntableName = ""
elseif (theView.FindTheme(rcntableName) = NIL) then
    rcntableName = ""
end

' Get new properties*****************************************************************************

status = TRUE
while (status)
    RCNpropertiesList = MsgBox.MultiInput("Enter properties:", "RCN Properties",
    {"Soil Coverage:", "Land Use Coverage:", "RCN table:"},
    {SoilcovName, luscovName, rcntableName})
    if (RCNpropertiesList.Count < 2) then return NIL end

    newSoilcovName = RCNpropertiesList.Get(0)
    newluscovName = RCNpropertiesList.Get(1)
    rcntableName = RCNpropertiesList.Get(2)

    if (newSoilcovName = "") then
        SoilcovName = newSoilcovName
    end
    if (newluscovName = "") then
        luscovName = newluscovName
    end
    if (rcntableName = "") then
        rcntableName = rcntableName
    end

    status = MsgBox.YesNo("Are you sure?", "Confirmation")
    if (status = true) then
        MsgBox.Inform("Properties updated!", "Confirmation")
        break
    end
end`
newrcntableName = RCNpropertiesList.Get(2)

if (theView.FindTheme(newSoilcovName) <> NIL) then
    soilcovOK = TRUE
    SoilcovName = newSoilcovName
else
    soilcovOK = FALSE
    MsgBox.Error("Soil coverage theme not found in View","RCN Properties")
end

if (theView.FindTheme(newluscovName) <> NIL) then
    luscovOK = TRUE
    luscovName = newluscovName
else
    luscovOK = FALSE
    MsgBox.Error("Land use coverage theme not found in View","RCN Properties")
end

if (av.Getproject.findDOC(newrcntableName) <> NIL) then
    rcntabOK = TRUE
    rcntableName = newrcntableName
else
    rcntabOK = FALSE
    MsgBox.Error("RCN table not found","RCN Properties")
end

if (soilcovOK and luscovOK and rcntabOK) then
    status = FALSE
else
    status = TRUE
end

end

' set properties
floodqExt.GetPreferences.Set("Soil Coverage Property",SoilcovName)
floodqExt.GetPreferences.Set("Land Use Coverage Property",luscovName)
floodqExt.GetPreferences.Set("RCN Table Property",RCNtableName)
8) Txdot.uninstall

'*********************************************************************
'Name: Txdot.uninstall Source Code
'Adapted by: Juling Bao and Francisco Olivera
'Date: May 14, 1997
'**********************************************************************

'DO NOT EDIT!!!

'The SELF is the Extension

theDocs = SELF.get(0)
theControlList = SELF.get(1)
theMenuList = SELF.get(2)
theToolMenuList = SELF.get(3)
theProject = Av.getproject

'Add the Docs
'
for each adoc in theDocs
    If (theProject.finddoc(adoc.getname)<>NIL) then
        theAnswer=msgbox.yesno("Remove the Document "+adoc.getname+"?","Remove Document?",TRUE)
        if (theAnswer=TRUE) then theProject.RemoveDoc(adoc) end
    end
end

'Remove the Controls
'
for each totalControl in theControlList
    'Get the control list from the Ext
    acontrol=totalControl.get(0)

    'Get the physical Control
    theControl = totalControl.get(1)

    'Get the Controls Index
    theCindex = totalControl.get(2)

    'Find the DocGUI for the Control
    theControlDoc=av.getproject.findGUI(aControl.get(0))
    if (theControlDoc=NIL) then
        MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.","Script Error")
        return(nil)
    end

    'This sequence finds the appropriate control set
    thecommand="av.getproject.findGUI(""+aControl.get(0)+"").Get""+acontrol.get(1)
    thescript1=Script.Make(thecommand)
    thecontrolset=thescript1.doit("")
'See if the control is in the set, if so remove it
if (theControlSet.GetControls.find(theControl)<>NIL) then
  theControlSet.remove(theControl)
if (thecontrol = "ToolBar") then
  theControlSet.selectdefault
end
end
end

'Remove the Menus
'
for each totalcontrol in theMenuList
  'The Control list
  acontrol=totalControl.get(0)
mDoc=acontrol.get(0)
mMenu=acontrol.get(1)
mMenuItem=acontrol.get(2)

  'The physical control
  theControl = totalControl.get(1)

  'The control Index
  theCindex=totalControl.get(2)

  'Find the DocGUI
  theControlDoc=av.getproject.findGUI(aControl.get(0))
  if (theControlDoc=NIL) then
    MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.","Script Error")
    return(nil)
  end

  theMbar=av.getproject.findGUI(mDoc).GetMenuBar
  themenu=theMbar.findbylabel(mMenu)
  if (themenu=NIL) then
    MsgBox.Warning("The menu named "+mMenu+" is not here.","Script Error")
    return(nil)
  else
    thething=themenu.getcontrols.find(thecontrol)
    if (thething<>NIL) then
      themenu.remove(thecontrol)
    end
    'msgbox.info(themenu.GetControls.count.asstring,"")
    if (themenu.GetControls.count<1) then
      theMbar.remove(themenu)
    end
  end

for each totalControl in theToolMenuList
  'Get the control list from the Ext
acontrol=totalControl.get(0)

'Get the physical Control
theControl = totalControl.get(1)

'Get the Controls Index
theCindex=totalControl.get(2)

'Find the DocGUI for the Control
theControlDoc=av.getproject.findGUI(aControl.get(0))
if (theControlDoc=NIL) then
    MsgBox.Warning("The GUI "+aControl.get(0)+" cannot be found in the current project.","Script Error")
    return(nil)
end

'This sequence finds the appropriate control set
thecontrolset=av.getproject.findGUI(aControl.get(0)).GetToolBar

'See if the control is in the set, if so remove it
if (theControlSet.GetControls.find(theControl)<>NIL) then
    theControlSet.remove(theControl)
    theControlSet.selectdefault
end
end

'And the scripts delete themselves

av.getproject.setmodified(true)
9) **Txdot.velocity**

`**********************************************************************************
Name: Txdot.velocity Source Code
Description: Given a watershed slope grid, Flow length grid and user inputed parameters,
the script calculates a flow vilosity grid and Flow trave time grid
for a user-defined area.
Default values for user Input data: a = 1, b = 0.5  c = 0.5
By: Juling Bao and Francisco Olivera
Data: May 30, 1997
*********************************************************************************

' Get themes from extension preferences

' Identifying the extension
floodqExt = Extension.Find("TxDOT")
if (floodqExt = NIL) then
    MsgBox.Error("Cannot find extension!","TxDOT")
    return NIL
end

' Getting the theme names
facThememane = floodqExt.GetPreferences.Get("Flow Accumulation Property")
FdrThemename = floodqExt.GetPreferences.Get("Flow Direction Property")
SlopeThemename = floodqExt.GetPreferences.Get("Watershed Slope Property")

' Getting started
Proj=av.GetProject
theView = av.GetActiveDoc
slopeTheme = theview.Findtheme(SlopeThemename)
facTheme = theview.Findtheme(facThememane)
FdrTheme = theview.Findtheme(FdrThemename)

' Set analysis extent
theAE = theView.GetExtension(AnalysisEnvironment)
theExtent = Rect.Make(0@0,1@1)
theCellSize = 1
if ((theAE.GetExtent(theExtent) <> #ANALYSIS_ENV_VALUE) or
    (theAE.GetCellSize(theCellSize) <> #ANALYSIS_ENV_VALUE)) then
    theCE = AnalysisPropertiesDialog.Show(theView,TRUE,"Conversion Extent")
    ' check for Cancel from dialog
    if (theCE = NIL) then
        return NIL
    end
    theCE.GetCellSize(theCellSize)
    theCE.GetExtent(theExtent)
end
Grid.SetAnalysisExtent (#GRID_ENVTYPE_VALUE, theExtent)
'set input data

labels = { "a = ", "b = ", "c = ", "Vmin = ", "Vmax = " }
defaults = { "1", "0.5", "0.5", "0.1", "10.0" }
inpList = msgbox.MultiInput("V(m/s) = a slope ^b fac^c", "Input Parameters to Calculate Flow Velocity", labels, defaults)

if (inpList.Count<4) then
  msgbox.info("No enoght input parameters, exiting.""
  exit
end

'calculate the grid of flow velocity

a = InpList.Get(0).AsNumber
b = InpList.Get(1).AsNumber
c = InpList.Get(2).AsNumber
vmin = InpList.Get(3).AsNumber
vmax = InpList.Get(4).AsNumber

Gridslope = slopeTheme.GetGrid
GridFdr = FdrTheme.GetGrid
Gridfac = facTheme.GetGrid

if (b=0 and c=0) then
  GridVel = a
else if (b=0) then
  GridVel = (Gridfac^c)*a
else if (c=0) then
  GridVel = (Gridslope^b)*a
else
  GridVel = (Gridslope^b)*(Gridfac^c)*a
end
end

GridVel2 = (GridVel > vmin).Con(( GridVel < vmax ).Con ( GridVel, vmax.AsGrid), vmin.AsGrid)

' set velocity grid to the view

VleGTheme = GTheme.make(GridVel2)
VleGTheme.SetName("Velocity (m/s)"
TheView.addTheme(VleGTheme)
VleGTheme.SetVisible(True)

'calculate the grid of flow trave time

grid1 = Grid.MakeFromNumb(1)
Gridweight = grid1/GridVel2

'WeiGTheme = GTheme.make(Gridweight)
'WeiGTheme.SetName("weightGrid"
'TheView.addTheme(weiGTheme)
'weiGTheme.SetVisible(True)

'GridTime1 = GridLength*Gridweight
GridTime1 = GridFdr.Flownlength(Gridweight,False)
GridTime = GridTime1.int

'calculate the flow travel time in mints*******************************************

GridtimeM = GridTime/60
TimeGTheme=GTheme.make(GridTimeM)
TimeGThemeSetName("Flow Time (min)")
TheView.addTheme(TimeGTheme)
TimeGTheme.SetVisible(True)
### Appendix C: Runoff Curve Numbers Lookup Table

<table>
<thead>
<tr>
<th>Lucode</th>
<th>Des_A</th>
<th>Des_B</th>
<th>Hyd_A</th>
<th>Hyd_B</th>
<th>Hyd_C</th>
<th>Hyd_D</th>
<th>Vcoef</th>
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<tbody>
<tr>
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<td>Incase-of-zero</td>
<td>data</td>
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<td>100</td>
<td>100</td>
<td>100</td>
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<td>85</td>
<td>90</td>
<td>92</td>
<td>4.62</td>
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<td>1/8_acre</td>
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<td>85</td>
<td>90</td>
<td>92</td>
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<td>83</td>
<td>87</td>
<td>3.66</td>
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<td>Residential</td>
<td>1/3_acre</td>
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<td>72</td>
<td>81</td>
<td>86</td>
<td>3.42</td>
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<td>85</td>
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<td>94</td>
<td>95</td>
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<td>91</td>
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<td>94</td>
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<td>91</td>
<td>94</td>
<td>4.62</td>
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<td>General</td>
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<td>grass50%-75%</td>
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<td>39</td>
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<td>74</td>
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<td>70</td>
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<td>80</td>
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Reference


