3.1.4 Regression Methods

3.1.4.1 USGS Regressions Equations

Two sets of USGS Regression Equations are presented in this section. Table 3-9 presents urban equations intended for use in the preliminary design of culverts across streams that are depicted as blue lines (i.e., waters of the state) on USGS quadrangle maps.

Table 3-9. USGS Urban Peak Flow Regression Equations
(Source: United States Geological Survey, 1984)

Frequency[1]	Equations[2, 3]
2-year	$Q_2 = 1.76A^{0.74} IA^{0.48} P^{3.01}$
5-year	$Q_5 = 5.55A^{0.75} IA^{0.44} P^{2.53}$
10-year	$Q_{10} = 11.8A^{0.75} IA^{0.43} P^{2.12}$
25-year	$Q_{25} = 21.9A^{0.75} IA^{0.39} P^{1.89}$
50-year	$Q_{50} = 44.9A^{0.75} IA^{0.40} P^{1.42}$
100-year	$Q_{100} = 77.0A^{0.75} IA^{0.40} P^{1.10}$

A = drainage area, mi^2
IA = total impervious area, % (e.g., 30% would be input as 30 not 0.30)
P = 2-year, 24-hour rainfall (inches) = 3.30 inches for Knox County
1 - Extrapolation is required to determine the 500-year peak flow.
2 - These equations are applicable for drainage areas between 0.21 mi^2 and 24.3 mi^2.
3 - These equations are applicable for impervious areas between 4.7% and 74%.

Table 3-10 presents USGS rural equations and USGS urban "three parameter" estimating equations (USGS, 1983). These equations were utilized by TVA to calculate peak discharges for the 2006 Flood Insurance Study of Knox County, Tennessee (FEMA, not yet dated). The equations presented in Table 3-10 must be used for preparation of new, and/or updating of existing, flood elevation studies in Knox County. *Note: the designer may be required to utilize an existing HEC-1 model as opposed to using the equations presented in Table 3-10 to prepare or modify a flood elevation study in Knox County. Consult Knox County Engineering prior to beginning a flood elevation study to determine the appropriate peak discharge calculation method.*

Table 3-10. USGS Rural and Urban Three Parameter Equations
(Source: United States Geological Survey, 1983)

Frequency	Rural Equations[1]	Three Parameter Equations[1, 2, 3]
2-year	$RQ_2 = 118A^{0.753}$	$Q_2 = 13.2A^{.21}(13\text{-}BDF)^{-.43}RQ_2^{.73}$
5-year	$RQ_5 = 198A^{0.736}$	$Q_5 = 10.6A^{.17}(13\text{-}BDF)^{-.39}RQ_5^{.78}$
10-year	$RQ_{10} = 259A^{0.727}$	$Q_{10} = 9.51A^{.16}(13\text{-}BDF)^{-.36}RQ_{10}^{.79}$
25-year	$RQ_{25} = 344A^{0.717}$	$Q_{25} = 8.68A^{.15}(13\text{-}BDF)^{-.34}RQ_{25}^{.80}$
50-year	$RQ_{50} = 413A^{0.711}$	$Q_{50} = 8.04A^{.15}(13\text{-}BDF)^{-.32}RQ_{50}^{.81}$
100-year	$RQ_{100} = 493A^{0.703}$	$Q_{100} = 7.70A^{.15}(13\text{-}BDF)^{-.32}RQ_{100}^{.82}$
500-year	$RQ_{500} = 670A^{0.694}$	extrapolation required

1 - A = drainage area, mi^2
2 - BDF = basin development factor (see discussion below)
3 - RQ_x = equivalent rural discharge for an X-year event (cfs)

The three parameter equations require the determination of the basin development factor (BDF) and equivalent rural discharge (RQ_x) prior to use of the equations. These parameters are discussed in the following paragraphs.

Basin Development Factor (BDF): The BDF is a somewhat subjective parameter that is intended to account for the effects of urbanization in a watershed (USGS, 1984). The BDF index range from a minimum value of zero for a drainage area with very little development, to a maximum value of 12 for a drainage area with a high level of development. Four urbanization factors that are considered in the development of a BDF are channel improvements, channel linings, storm drains and curbed streets. For drainage areas that have BDF values of zero, the rural regression equations should be used to determine peak discharges for flood elevation studies. The urban three parameter equations should be used for drainage areas that have a BDF that is greater than zero.

When using the USGS three parameter estimating equations to update an existing flood elevation study, the nature and size of the development will determine if the BDF that was determined for the existing flood elevation study should be increased to reflect the increased urbanization of the drainage areas to the stream. Knox County Engineering should be consulted prior to peak discharge calculation to determine if existing BDF's should be increased. Consult the USGS reference document (USGS, 1984) for more information on the determination of the BDF for any one basin.

Equivalent Rural Discharge (RQ_x): The RQ_x parameter is determined using the USGS rural regression equations presented in Table 3-10.

3.1.4.2 USGS Dimensionless Hydrograph

The USGS has developed a dimensionless hydrograph that can be used to simulate flood hydrographs for rural and urban streams for East Tennessee streams having drainage areas of less than 500 mi^2. Table 3-11 lists the time and discharge ratios for the dimensionless hydrograph.

Table 3-11. Dimensionless USGS Hydrograph

(Source: United States Geological Survey, 1986)

(t/T_L)	(Q/Q_p)	(t/T_L)	(Q/Q_p)
0.25	0.12	1.35	0.62
0.30	0.16	1.40	0.56
0.35	0.21	1.45	0.51
0.40	0.26	1.50	0.47
0.45	0.33	1.55	0.43
0.50	0.40	1.60	0.39
0.55	0.49	1.65	0.36
0.60	0.58	1.70	0.33
0.65	0.67	1.75	0.30
0.70	0.76	1.80	0.28
0.75	0.84	1.85	0.26
0.80	0.90	1.90	0.24
0.85	0.95	1.95	0.22
0.90	0.98	2.00	0.20
0.95	1.00	2.05	0.19
1.00	0.99	2.10	0.17
1.05	0.96	2.15	0.16

(t/T_L)	(Q/Q_p)	(t/T_L)	(Q/Q_p)
1.10	0.92	2.20	0.15
1.15	0.86	2.25	0.14
1.20	0.80	2.30	0.13
1.25	0.74	2.35	0.12
1.30	0.68	2.40	0.11

A lag time equation is utilized with the dimensionless unit hydrograph to determine peak discharge, and a runoff hydrograph if needed. Equation 3-11 presents the rural lag time equation. An urban lag time equation has not been developed for East Tennessee.

Equation 3-11

$$T_L = 1.26L^{0.85}$$

where:

T_L = lag time (hours)
L = channel length (miles)

The rural lag time equation should only be used for drainage areas greater than 1.1 mi^2, and less than 518 mi^2, and main channel slopes greater than 4.21 ft/mile and less than 694.44 ft/mile.

3.1.4.3 TVA Regression Equations

TVA developed a set of regression equations in the 1970s that can be used to calculate peak discharges in Knox County. These equations, shown in Table 3-12, can be used for the preliminary design of culverts across streams that are depicted as blue lines (waters of the state) on USGS quadrangle maps.

Table 3-12. TVA Regional Regressions Relationships for Natural Streams

(Source: City of Knoxville, 2003)

Frequency[1]	Equations[2, 3]
2-year	$Q_2 = 107\ A^{.804}\ I^{0.30}$
10-year	$Q_{10} = 217\ A^{.802}\ I^{0.26}$
50-year	$Q_{50} = 344\ A^{.796}\ I^{0.22}$
50-year	$Q_{100} = 402\ A^{.796}\ I^{0.20}$
500-year	$Q_{500} = 556\ A^{.795}\ I^{0.16}$

A = drainage area, mi^2
I = percent of contributing drainage area that is impervious, %