Overview of NRCS (SCS) TR-20 – By Dr. R.M. Ragan

TR-20 is a computer program for the simulation of runoff occurring from a single storm event. The program develops flood hydrographs from runoff and routes the flow through stream channels and reservoirs. Hydrographs, peak discharges, and peak elevations can be obtained at any cross section along the stream, at the outlet of a subwatershed or a structure.

The program combines information from the watershed to be modeled including: structures or reservoirs if present within the watershed, stream channel properties, and rainfall depth/distribution data. The watershed, channel, storage, and rainfall information is used to generate a flood hydrograph.

A key phase in the design of bridge openings, culverts, and other hydraulic structures involves the use of physically based hydrologic models to compute the discharges in terms of the land use, soil and typography of the watershed above the drainage facility. Physically based models generally provide good estimates of flow rates when the land-based input parameters are correctly defined. Such models are especially attractive as deisgn aides because the engineer using the mode can vary the input parameters to simulate the impacts od land use or other watershed changes on the discharges or quality of the water coming from the basin.

The Maryland State Highway Administration (MDSHA) has selected the models developed by the Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service, SCS) as their primary tools for conducting watershed analyses. In the NRCS family of models, the combination of land use and one of four hydrologic soil types on a parcel of land defines a form of runoff coefficient, the curve number (CN). By summing the areas assigned to each CN, a weighted CN for the watershed or subwatershed is obtained. The curve number allows the engineer to estimate the volume of surface runoff that will take place as the result of a 24-hour duration rainfall event, the typical design-storm duration used in Maryland. This volume of runoff, Q, can be obtained from:

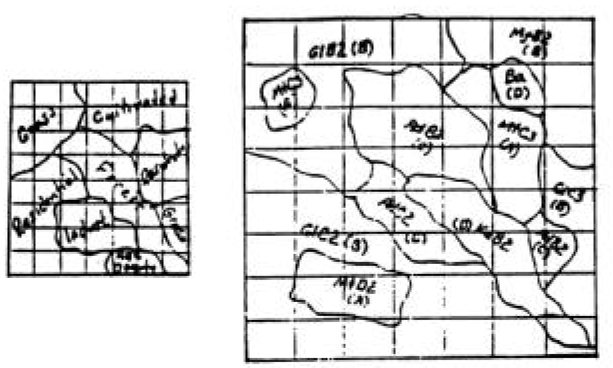
$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where P is the volume of runoff and S is a watershed storage term that is estimated from:

$$S = \frac{1000}{CN} - 10$$

A major problem with the use of hydrologic models is that are defined in terms of spatially distributed watershed characteristics is that **the definition of the model parameters is a difficult, tedious, time consuming and expensive task.** The reader can gain some insight into the magnitude of the problems associated with parameter definition from the following simplified example:

Suppose we want to determine the curve number for a small rectangular area within a watershed that is illustrated in Figure 1-1. Figure 1-1A is a land use map that could have been developed by drawing polygons around areas of homogeneous land use interpreted from an areal photograph.



(A) (B)

Figure 1-1: Portions of Land use and Soils Maps Used to Define Curve Numbers

Figure 1-1B is a simplification of a segment that one would find on a soil sheet published in an SCS County Soil Series Map. Figure 1-1A and Figure 1-1B are different in size because, in the usual case, these two resources will not be of the same scale. Another resource that we would have is illustrated by Table 1-1 which is a simplified example of the tables published by SCS that shows the curve number for various land use categories on hydrologic soils A, B, C, D. The engineer must develop a weighted, or average, curve number for the area shown in Figure 1-1. In order to accomplish this, the engineer must determine the number of acres of each land use on each soil within the area of interest. Curve numbers for each of these land/soil complexes are selected from Table 1-1 and then tabulated to develop an average for the overall area.

In a typical approach, the engineer may lay a transparent mylar grid over the areas as shown in Figures 1-1A and 1-1B. The next task is to determine what hydrologic soil group is associated with the soil series on the map. For example, the upper left portion of Figure 1-1B has the soil class, GIB2. The engineer goes to a table in the County soil map which shows that this is a Glennelg soil. He or she then goes to another table which shows that this is a B hydrologic soil. This procedure is repeated until each of the soils has been assigned to a hydrologic soil group. The soil polygons on the map are then either colored or letter-coded, such as the (A), (B), (C), (D) coding illustrated in Figure 1-1B, to show the distribution of the hydrologic soils. The overlaid cells are then counted and a worksheet such as Table 1-2 may be used to manage the count. Table 1-3 illustrates a method of consolidating the count to produce the weighted curve number.

For example, in Table 1-2, there are five residential cells that have been built on A soil. Table 1-1 shows that the curve number for this land/soil complex is 57. Thus, in Table 1-3, one part of the computation is 5 X 57. The computations of Table 1-3 are quite simple and can be accomplished very quickly. However, an examination of the counting associated with the development of Table 1-2 illustrates just how difficult this task can become when the watershed is several square miles in area.

TABLE I-1
ILLUSTRATION OF TABULAR APPROACH OF SCS RELATING LAND/SOIL COMPLEXES TO THE CURVE NUMBER

LANDUSE	CURVE NUMBER FOR SOIL			
	A	B	C	D
RESIDENTIAL	57	72	81	86
GRASS	30	58	71	78
FOREST	25	55	70	77
INDUSTRIAL	81	88	91	93
HIGH DENSITY	77	85	90	92
CULTIVATED	62	71	78	81

TABLE I-2
EXAMPLE OF TYPE OF TABULATION USED TO DEFINE COUNTS FOR CURVE NUMBER DEFINITION

	A	B	C	D	Σ
GRASS	/	///// ///	//		11
RESIDENTIAL	/////	///// // /////	//		19
FOREST			///// /	////	10
INDUSTRIAL	/	///	/		5
HIGH DENSITY		//			2
CULTIVATED	/	////	//	/	9
					56

TABLE I-3
EXAMPLE OF WEIGHTED CURVE NUMBER COMPUTATION FOR WATERSHED

GRASS	1(30) + 8(58) + 2(71)	=	462
RESIDENTIAL	5(57) + 12(72) + 2(81)	=	1311
FOREST	6(70) + 4(77)	=	728
INDUSTRIAL	1(81) + 3(88) + 1(91)	=	334
HIGH DENSITY	2(85)	=	170
CULTIVATED	1(62) + 2(71) + 2(78) + 1(81)	=	654
			3659

WEIGHTED CURVE NUMBER = 3659/56 = 65.3

56 cells - Each is 22.86 Acres

ESTIMATE VOLUME OF RUNOFF AND PEAK DISCHARGE IF
A = 2.0 sq. miles ; Time of Concentration = 1.8 hours
Precip = 4.5 inches in 24 Hrs

1) $S = \frac{1000}{65.3} - 10 = 5.3$ 2) $Q = \frac{(4.5 - .2(5.3))^2}{(4.5 + .8(5.3))} = 1.35$ inches

3) From Fig 9 pg L-15 $q_p = 200$ cfs/mi²/inch of runoff
∴ $Q_p = 200(2)(1.35) = 540$ cfs

Another problem is that the definition of the curve number is only part of the overall task. The engineer must also define the time of concentration for the watershed. This typically involves map measurements to determine the length, slope, and type of surface involved in an overland flow plane which may drain into a swale which has another length, slope and surface characteristic. In turn, the swale may then drain into a stream network which requires a definition of the slope, length, roughness coefficient, and bank-full cross section. Thus, it can be seen that a significant portion of the resources available to conduct a project can be used up by the parameter definition tasks.

At this point, only the curve numbers have been defined. The subwatershed area is relatively simple to obtain with a mechanical planimeter or similar device. But, the time of concentration (t_c) becomes another major task. For the best estimate, the length, slope, Manning roughness coefficient and a representative cross section should be defined for the longest section of a stream in each subwatershed so these travel times can be compared with:

$$V = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

the manning equation, as part of the time of concentration where v is the velocity in feet per second, n is the manning roughness coefficient, R is the hydraulic radius, and S is the friction slope in ft/ft. The engineer may then be required to input the length, slope and surface condition for a representative swale that may convey flow into the upper sections of the stream.

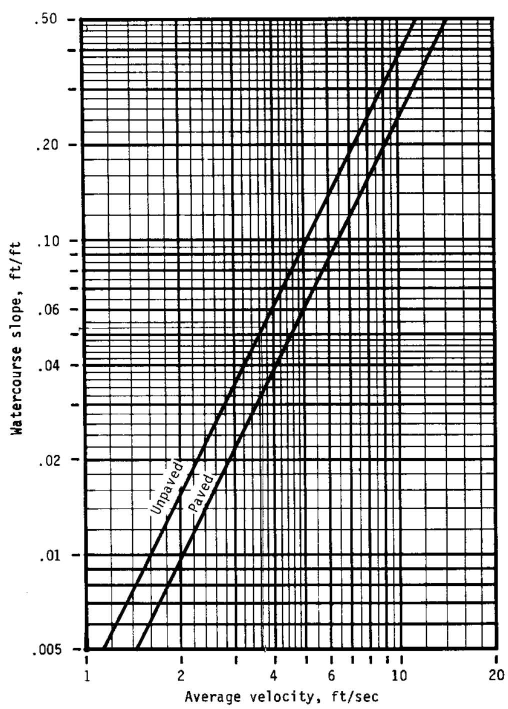


Figure 2-6: SCS Graph for estimating velocity of flow in a swale

This information will allow him or her to use a chart such as Figure II-6 to estimate a velocity of flow in the swale and, knowing the length, compute the travel time through the swale. Finally, if the subwatershed is relatively small, the engineer will need to define the length, slope, and Manning roughness for the overland flow that may drain into the swale or channel. With these data he or she can use:

$$T_t = \frac{0.007(nL)^{0.8}}{P_{24}^{\ 0.5} S^{0.4}}$$

where P_{24} is the 24-hr, two year storm (approx. 3 inches for Maryland), S is the slope in ft/ft, L is the length in feet, *n* is the Manning roughness coefficient ant T_t is the overland flow travel time in hours. Thus, the time of concentration is the sum of the channel, swale and overland flow travel times.

After all these data are assembled, it is a relatively straight forward task to type it into the SCS TR-20 computer program input file. Indeed, there are a number of utilities available from vendors that provide considerable assistance in inputting the data. The problem, as illustrated above, is defining the numbers to be typed in. If the numbers are not accurate the results of the model become very questionable. Further, it should be apparent from the above discussion that the overlay and counting manipulation required to define the curve numbers and the measurements required to compute the times of concentration are many orders of magnitude greater than the times required to type them into the computer and obtain the results.