TR-20 Structure and Operation

Technical Release 20: Computer Program for Project Formulation Hydrology (TR-20) (SCS, 1983) is a hydrologic model for simulation of direct runoff hydrographs resulting from natural or synthetic rainfall occurring over a watershed. The program can be used to model complex watersheds with multiple subareas, channel reaches, and reservoirs. Hydrographs are generated for subwatersheds, combined or separated at confluence points, and routed through downstream reaches or structures.

Conceptual Description

The program is designed to simulate the rainfall-runoff process for a watershed. Figure 2-1 depicts the rainfall-runoff process used by TR-20. The unit hydrograph is the transfer function used by TR-20 to transform the rainfall excess into direct runoff. The rainfall hyetograph is convolved with the unit hydrograph to produce the direct runoff hydrograph. This process is explained below.

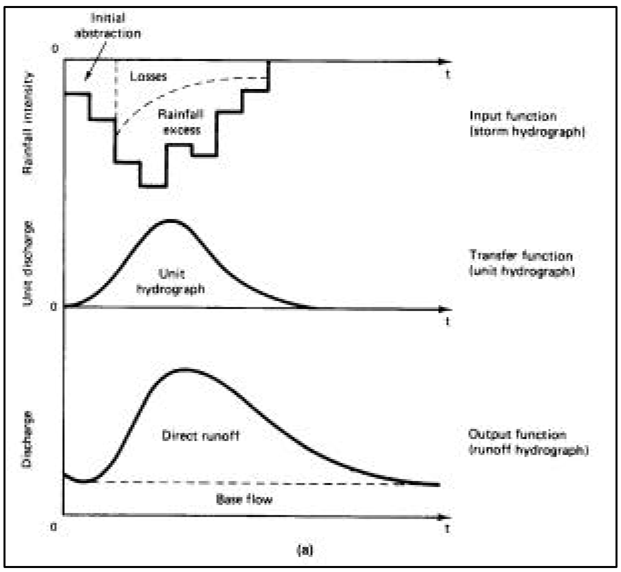


Figure 2-1: Rainfall-runoff process (McCuen, 1998).

For a specified rainfall depth and distribution, a hydrograph is developed for each subwatershed given the drainage area, time of concentration, and curve number as input. The runoff resulting from a given rainfall depth is computed from the NRCS rainfall-runoff equation:

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

where P is the precipitation in inches, Q is the runoff in inches, and S is the potential storage in inches, given by:

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

where CN is the runoff curve number. The time to peak for the direct runoff hydrograph is equal to two-thirds the time of concentration. The peak discharge of the unit hydrograph, the SCS dimensionless unit hydrograph in this case, is computed using the equation:

$$q_p = \frac{484AQ}{t_p} = \frac{726AQ}{t_c}$$

where t_p is the time to peak in hours, t_c is the time of concentration in hours, Q is the runoff of one inch for the unit hydrograph, and A is the drainage area in square miles.

The ordinates of the rainfall hyetograph are multiplied, translated, and added in time with the ordinates of the unit hydrograph to form the direct runoff hydrograph for each subwatershed. This process is called convolution. The value 484 in the above equation is called the peak rate factor and represents an empirical constant.

Hydrographs generated from upstream subwatersheds can be routed through channel reaches using the Modified Att-Kin (Attenuation – Kinematic) method. For a given stream reach, the routing procedure translates the upstream hydrograph along its length and attenuates the peak of the hydrograph to account for storage in the channel. Hydrographs can also be routed through reservoirs or other storage structures, which TR-20 uses the storage-indication method to simulate.

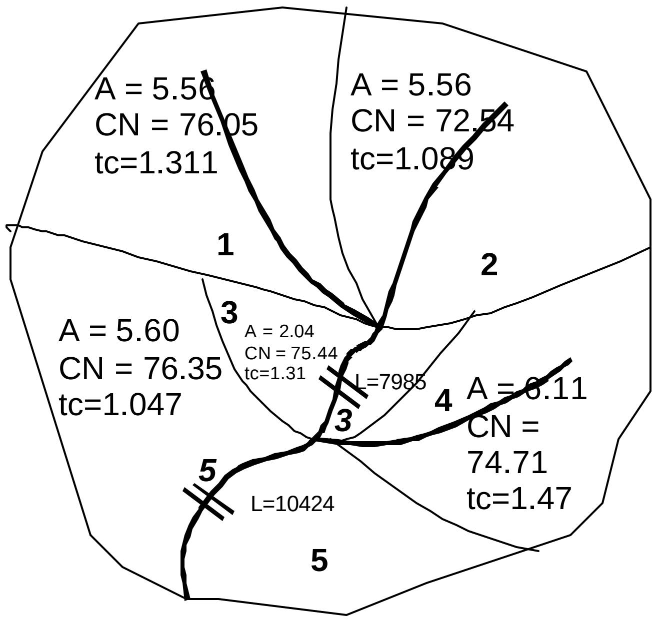
Simplified Example

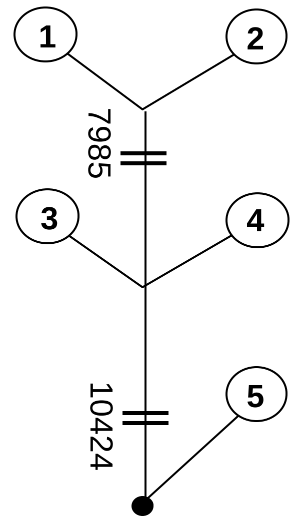
The best way to illustrate the overall process of developing a TR-20 model is to walk through a simplified example. The example that follows gives a 24.9 mi^2 watershed divided into five subwatersheds. It contains two reach routings in the lower potion of the main channel. At the outlet, the peak discharge resulting from 4.25-in of rainfall is simulated for the 24-hr Type II storm.

In order to develop a simulated runoff hydrograph for each subwatershed, a minimum amount of information is required. The area, time of concentration, and curve number must be specified for each subwatershed. In order to route upstream hydrographs to downstream locations, a representative cross section is needed from which a stage-discharge-end area relationship can be produced.

Watershed Configuration

Consider the following arrangement of subwatersheds for the example TR-20 model:





Hydrographs are generated for each of the subareas and are combined *in time* at the junction points. The difference in the timing of runoff for each subarea (i.e. time of concentration) controls how the peak discharge will be affected when the hydrographs are combined. If the times are very close, the times to peak of each of the hydrographs will be similar and a larger peak discharge will result. If the times are substantially different, the peaks will not coincide and a reduced peak will result. The consideration of increased peak does not ignore volume considerations. Regardless of the timing of runoff, the volume of runoff generated by a real or synthetic rainfall distribution will eventually be translated in time through the watershed.

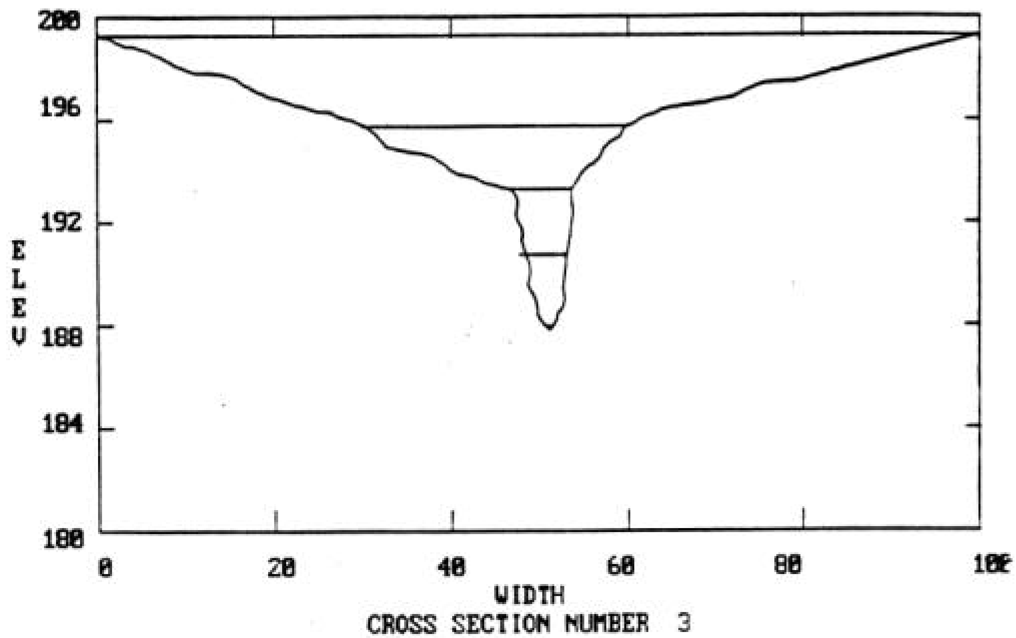
Cross Sections

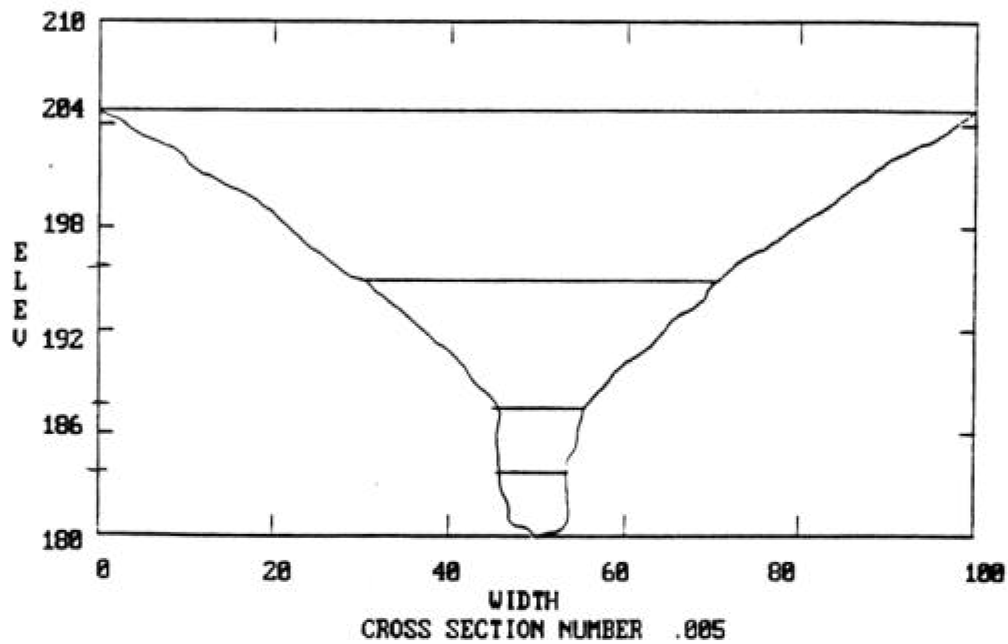
Cross sections control not only translation of upstream hydrographs but also attenuation. The attenuation is based on the storage available to runoff while in the channel/floodplain.

Two cross sections are identified in the watershed that will be used to route hydrographs. Cross Section 3 (L = 7985 ft.) will be used to route the combined hydrograph from subwatersheds 1 and 2. Cross Section 5 (L= 10424 ft.) will be used to route the combine hydrograph resulting from subwatersheds 3 and 4 and the routed hydrograph through Cross Section 3.

Representative cross sectional geometry was determined for each of the sections for the channel and overbank. Additionally, roughness characteristics, given in terms of

Manning roughness coefficients were determined for Section 3 (channel n: 0.035, left n: 0.07, and right n: 0.09) and for Section 5 (channel n: 0.035, left n: 0.07, right n: 0.09). The sections are shown below:





Rating Table Calculation

For each of the cross sections shown above, a stage-discharge-end area relationship must be developed. This information is used by the TR-20 model in the Modified-Att-Kin reach routing procedure. At incremental depths, values of stage, discharge and end area are computed. The relationship below can be used to develop the reach rating table for a complex cross section involving a center channel, left and right overbank.

$$Q = \sum \Delta Q = A_L V_L + A_c V_c + A_R V_R$$

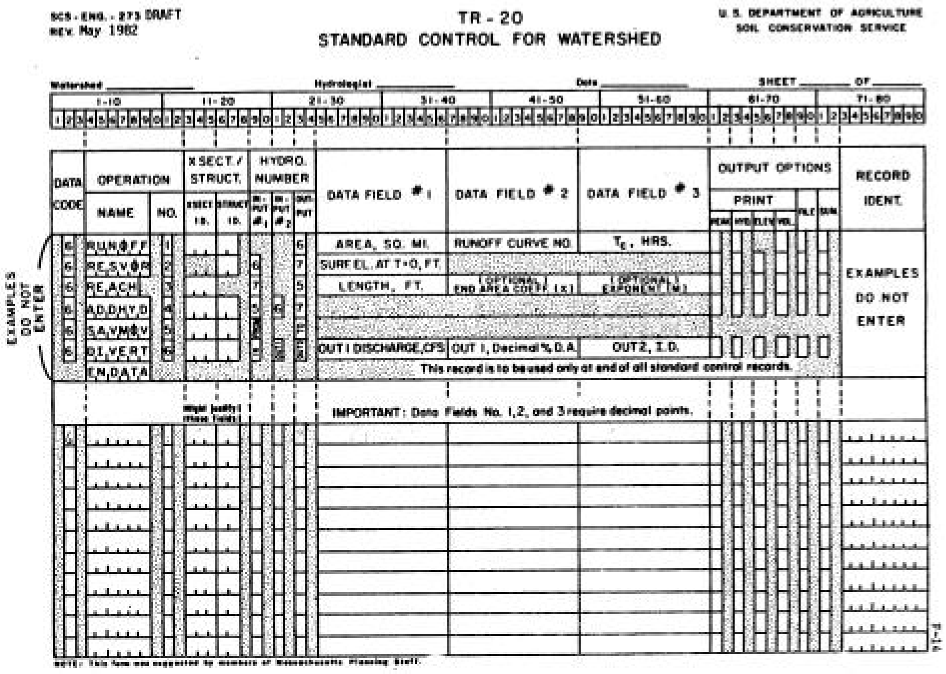
where V is the velocity from Manning's Equation:

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

Input File

The TR-20 input file is arranged in cards of job and header information, structure and reach tables, standard control statements, and executive control statements. The input "cards" (they really aren't cards anymore, although they used to be in the early days of the program) contain all of the configuration and parameter values necessary to produce a runoff hydrograph.

The formatting of the input files is somewhat rigid and may take some getting used to. Data is placed in specific fields based on horizontal column location. The following three figures are input forms for listing the contents of the input file:



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TR - 20
STANDARD CONTROL FOR WATERSHED

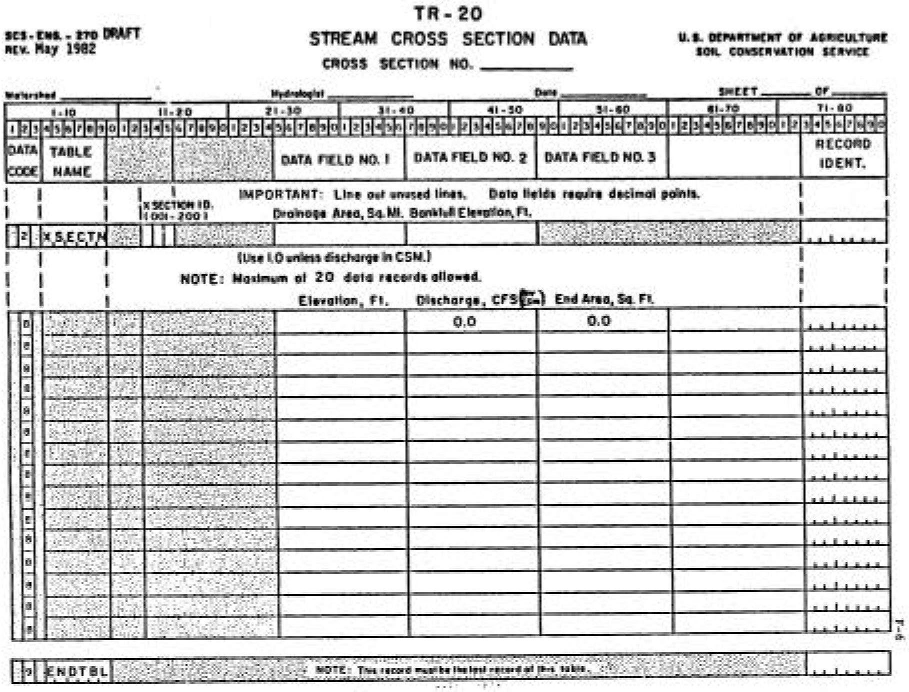
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Watershed ______ Hydrologist ______ Date ______ SHEET ______ OF ______

DATA CODE	OPERATION NAME	NO.	XSECT. ID.	STRUCT. ID.	IN-PUT #1	IN-PUT #2	OUT-PUT	DATA FIELD #1	DATA FIELD #2	DATA FIELD #3	OUTPUT OPTIONS	RECORD IDENT.
6	RUNØFF	1					6	AREA, SQ. MI.	RUNOFF CURVE NO.	T_c, HRS.		EXAMPLES DO NOT ENTER
6	RESVØR	2			6		7	SURF. EL. AT T=0, FT.				
6	REACH	3			7		5	LENGTH, FT.	(OPTIONAL) END AREA COEFF. (X)	(OPTIONAL) EXPONENT (M)		
6	ADDHYD	4			5	6	7					
6	SAVMØV	5										
6	DIVERT	6						OUT 1 DISCHARGE, CFS	OUT 1, Decimal % D.A.	OUT 2, I.D.		
	ENDATA							This record is to be used only at end of all standard control records.				

EXAMPLES DO NOT ENTER

IMPORTANT: Data Fields No. 1, 2, and 3 require decimal points.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TR-20
STREAM CROSS SECTION DATA
CROSS SECTION NO. ________

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

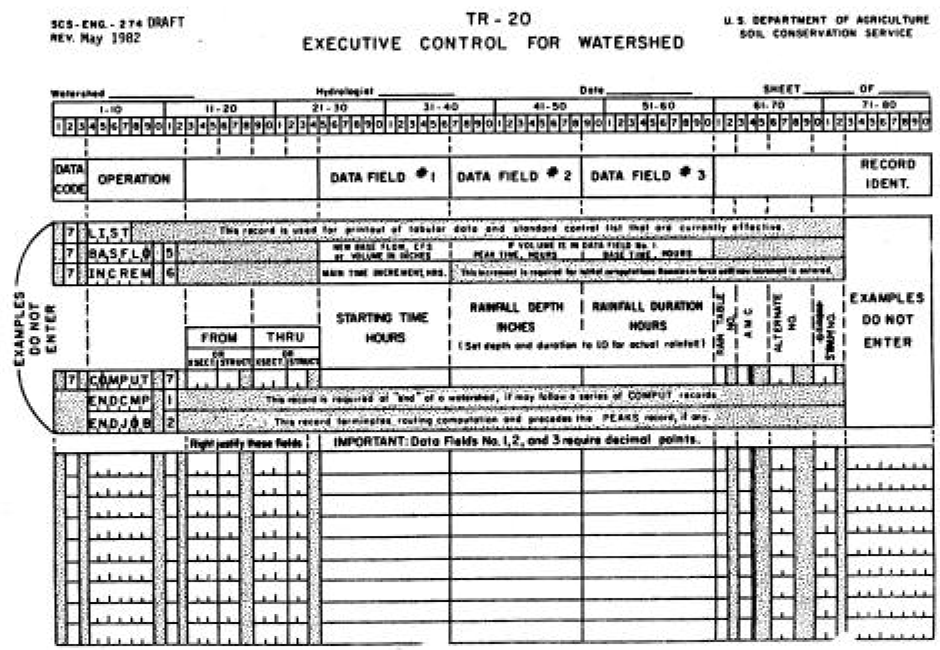
Watershed ________ Hydrologist ________ Date ________ SHEET ____ OF ____

DATA CODE	TABLE NAME			DATA FIELD NO. 1	DATA FIELD NO. 2	DATA FIELD NO. 3		RECORD IDENT.
			X SECTION ID. (001-200)	Drainage Area, Sq.Mi.	Bankfull Elevation, Ft.			
2	XSECTN							
				Elevation, Ft.	Discharge, CFS (CSM)	End Area, Sq. Ft.		
8					0.0	0.0		
9	ENDTBL	NOTE: This record must be the last record of this table.						

IMPORTANT: Line out unused lines. Data fields require decimal points.

(Use 1.0 unless discharge in CSM.)

NOTE: Maximum of 20 data records allowed.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REV. May 1982

TR-20
EXECUTIVE CONTROL FOR WATERSHED

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Watershed ________ Hydrologist ________ Date ________ SHEET ____ OF ____

DATA CODE	OPERATION		DATA FIELD #1	DATA FIELD #2	DATA FIELD #3		RECORD IDENT.
7	LIST	This record is used for printout of tabular data and standard control list that are currently effective.					
7	BASFLO 5		NEW BASE FLOW, CFS or VOLUME IN INCHES	PEAK TIME, HOURS (If volume is in data field No. 1)	BASE TIME, HOURS		
7	INCREM 6		MAIN TIME INCREMENT, HRS.				
		FROM (XSECT / STRUCT) THRU (XSECT / STRUCT)	STARTING TIME HOURS	RAINFALL DEPTH INCHES	RAINFALL DURATION HOURS (Set depth and duration to 1.0 for actual rainfall)	RAIN TABLE NO. / A M C / ALTERNATE NO.	EXAMPLES DO NOT ENTER
7	COMPUT 7						
	ENDCMP 1	This record is required at "end" of a watershed, it may follow a series of COMPUT records.					
	ENDJOB 2	This record terminates routing computation and precedes the PEAKS record, if any.					

EXAMPLES DO NOT ENTER

Right justify these fields. IMPORTANT: Data Fields No. 1, 2, and 3 require decimal points.

When entered completely, the TR-20 input file for the sample watershed will look like:

```
JOB TR-20                    FULLPRINT                        NOPLOTS
TITLE       OUTLET OF BASIN AT WATERSHED #5
TITLE
 2 XSECTN   003                   1.0      193.29
 8                               188.       0.000        0.000
 8                               190.7     20.071        8.203
```

```
 8                              193.29     85.823     24.671
 8                              195.78    247.063     70.625
 8                              199.28    923.957    297.058
 9 ENDTBL
 2 XSECTN   005                    1.0     187.39
 8                                180.      0.000      0.000
 8                              183.69     95.543     21.501
 8                              187.39    333.701     55.523
 8                              194.86   1730.803    242.722
 8                              204.79   7160.793    935.737
 9 ENDTBL
 6 RUNOFF 1   1       1         5.5599     76.048      1.311
 6 RUNOFF 1   2       2         5.5599     72.541      1.089
 6 ADDHYD 4   9   1 2 3
 6 RUNOFF 1   3       1         2.0411     75.444      1.314
 6 REACH  3   8   3   2          7985.
 6 ADDHYD 4   9   1 2 3
 6 RUNOFF 1   4       4         6.1100     74.710      1.470
 6 ADDHYD 4   7   4 3 2
 6 REACH  3   6   2   1         10424.
 6 RUNOFF 1   5       5         5.6000     76.350      1.047
 6 ADDHYD 4  10   1 5 4                                        1
   ENDATA
 7 INCREM 6                        0.1
 7 COMPUT 7 001   010              0.0       4.25        1.02 2   1   1
   ENDCMP 1
   ENDJOB 2
```

Output File.

TR-20 creates an output file which reports the desired output options (hydrographs, peaks, elevations, volumes) at desired locations within the watershed. The output file for the sample watershed is shown below:

```
1
 TR20 -----------------------------------------------------------------
--- SCS -
                        OUTLET OF BASIN AT WATERSHED #5
VERSION
 03/10/**
2.04TEST
 13:10:42                    PASS   1   JOB NO.   1
PAGE   1

 OPERATION ADDHYD   XSECTION  10
         INPUT HYDROGRAPHS 1,5     OUTPUT HYDROGRAPH 4

    PEAK TIME(HRS)            PEAK DISCHARGE(CFS)          PEAK
ELEVATION(FEET)
       13.30                       6818.4                          (NULL)

    RUNOFF ABOVE BASEFLOW  (BASEFLOW =    .00 CFS)
                   1.85 WATERSHED INCHES;   29746 CFS-HRS;    2458.2
ACRE-FEET.
1
```

```
 TR20 -----------------------------------------------------------------
--- SCS -
                        OUTLET OF BASIN AT WATERSHED #5
VERSION
 03/10/**
2.04TEST
 13:10:42                    PASS   2   JOB NO.   1
```