DEVELOPMENT AND APPLICATION OF A GRAPHICAL INTERFACE FOR THE TR-55 HYDROLOGY MODEL

by

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ABSTRACT

Hydrosim Mk. 1.0 was developed as a graphical interface for the United States Soil Conservation Services' TR-55 watershed model to better examine the effects of land use on runoff and peak discharge for both single and combined watersheds, real or hypothetical. The need for this was the result of a relatively recent increase in sedimentation into Lake Newport, located in Mill Creek Park, Youngstown, Ohio. It is believed that this increase in sedimentation is the result of an increase in runoff and discharge due to development within the Mill Creek watershed.

Hydrosim was used to model a hypothetical watershed to determine what characteristic of a watershed has the greatest impact on runoff and peak discharge. From this model it was determined that the soil composition of the watershed and the type and location of land use change can greatly affect the amount of runoff and peak discharge. It was also determined that the impact of development can be reduced if the development takes place on soils of low infiltration rates as opposed to those of high infiltration rates and care is taken to locate the development within the watershed so as not to decrease the time of concentration.

Finally, Hydrosim was used to model Cranberry Run, a portion of the Mill Creek watershed which discharges into Lake Newport, to determine the impact of present development compared to an assumed original land use of woods. The results of the modelling showed an increase in runoff of over 95% and an increase in peak discharge of over 100%.

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CHAPTER 1

Introduction

1.1 Background

In 1928 the administrators of Mill Creek Park, located in Youngstown, Ohio, decided to create Lake Newport, a recreational lake in the southern portion of the park straddling the boundaries of Boardman Township and the City of Youngstown (Figure 1.1) with an area of greater than 100 acres. To accomplish this a dam was constructed on Mill Creek, a moderately sized stream with a drainage area of approximately 75 square miles.

By the mid-1970's it was noticed that recreational boating was being adversely affected in the southernmost portion of the lake due to an accumulation of sediment. A study conducted in 1975 determined that 74,000 cubic yards of sediment had been deposited. A later study conducted in 1987 determined that this volume had increased to 111,000 cubic yards (MRB, 1993). For the 47 year period between the creation of Lake Newport in 1928 and the first study conducted in 1975, the average rate of sedimentation in the southernmost portion of the lake was about 1,570 cubic yards per year. This rate nearly doubled to 3,083 cubic yards per year for the 12 year period between 1975 and 1987.

It is believed that the massive increase in sedimentation in Lake Newport corresponds with the development of Boardman Township. Within the past 25 years there has been a steady increase in the amount of residential and commercial development, much of which is located in the Mill Creek watershed (MRB, 1993).

The problem of lake sedimentation is not unique to Lake Newport. Sedimentation is a major concern in both reserviors and natural lakes, particularly those with watersheds undergoing development. Sedimentation is not only a museiace, but reduces reservior volume, can have adverse effects on wildlife, and can increase the stress on dams (Plummer and McGeary, 1991).

<u>Figure 1.1</u>: **Location of Lake Newport.**

1.1.1 Purpose of this Study

The purpose of this study was to determine the effects of watershed development on stream discharge. Stream discharge is important because the amount of sediment transported by a stream is closely related to the discharge. If the discharge increases, the amount of sediment transported will also increase (Bloom, 1978). This study involved an investigation to determine the effects of development on a watershed by using a watershed modelling program written specifically for this purpose. A hypothetical watershed was modelled to determine which properties of a watershed affect discharge, how development increases discharge, and if there is any way that a watershed can be developed with a minimal increase in discharge. Also, a portion of the Mill Creek watershed was modelled to determine the effects of development.

1.1.2 Hydrosim Mk. 1

Hydrosim Mk. (Mark) 1 was developed to provide an efficient and easy way to model both hypothetical and real watersheds. Hydrosim is a modification of the U.S. Soil Conservation Services (SCS) Technical Release 55 (or TR-55 as it is usually refered to) watershed model. It provides a graphical interface for data entry, better data organization, easy watershed modification, and some refinement in methodology. Both TR-55 and Hydrosim will be discussed in detail in later chapters.

1.2 Basic Surface Water Hydrology

Introduction

It is felt that some discussion of surface water hydrology should be presented for readers that are unfamiliar with the subject and to clarify terminology used in later chapters.

1.2.1 Streams, Watersheds and their Interactions

A stream, by definition, is a body of water confined to a channel that flows downhill under the influence of gravity toward some destination such as an ocean, lake or another stream. A watershed is the area of the earth's surface drained by a stream (Plummer and McGeary, 1991). What is of concern here is the interaction of the watershed with the stream, particularly how changes within the watershed affect stream flow.

Stream Flow

As mentioned earlier, a stream is a body of water flowing in a channel. Water flowing in a stream channel is derived from two sources, *surface runoff* and groundwater. The water a stream recieves from groundwater is referred to as *base flow* and is fairly constant and predictable. It may show seasonal variations but is generally not affected by development unless large quantities are removed by shallow wells (Viessman, et. al.,1977). A reduction in infiltration due to development can also affect baseflow (Khan, 1995). For the purposes of this study, baseflow will be ignored and only surface runoff, the water that flows over the ground to the stream will be considered.

Runoff

Not all of the precipitation that falls on a watershed reaches the stream. Much of it may be evaporated and absorbed by the watershed through various mechanisms such as infiltration into the soil, absorption by plants, interception by the leaves of trees, and storage in surface depressions. These mechanisms are collectively known as *initial abstractions* and vary widely depending on the watershed (Viessman, et. al., 1977). Development of a watershed changes the initial abstractions which could either increase or reduce the amount of runoff. For example, if a piece of wooded ground is cleared for a paved parking lot, the amount of runoff from that particular piece of ground will increase, but if that same piece of ground was cleared for meadow, the amount of runoff would be reduced.

The precipitation that is not taken up by initial abstractions will flow over the ground's surface to the stream. When the soil becomes saturated and cannot absorb any more precipitation, or when the precipitation is falling faster than the soil can absorb, it starts to build up. After a while it will start to flow downhill as a sheet over the ground surface. This type of flow is known as *sheet flow* (Plummer and McGeary, 1991). After a maximum distance of about 300 feet, the flow begins to consolidate into tiny channels refered to as shallow *concentrated flow* (Gupta, 1989). Collectively sheet flow and shallow concentrated flow are refered to as overland flow. When the runoff reaches the stream, the flow is refered to as open channel flow (SCS, 1986).

Stream Discharge

The *discharge* of a stream is the volume of water that flows past a given point in the stream channel in a certain interval of time. Discharge is usually expressed in terms of cubic feet per second (cfs) (Plummer and McGeary, 1991). Discharge is important because, as mentioned earlier, an increase in discharge can also increase sediment transport. If the discharge increases ten times, the amount of sediment being transported may increase one hundred to one thousand times (Bloom, 1978).

The discharge of a stream can be represented graphically by a *hydrograph*. A hydrograph is simply the discharge of a stream plotted against time. The hydrograph in Figure 1.2 shows base flow as well as runoff. For the purpose of this study, a storm hydrograph showing only discharge due to runoff, called a direct runoff hydrograph, will be used (Gupta, 1989).

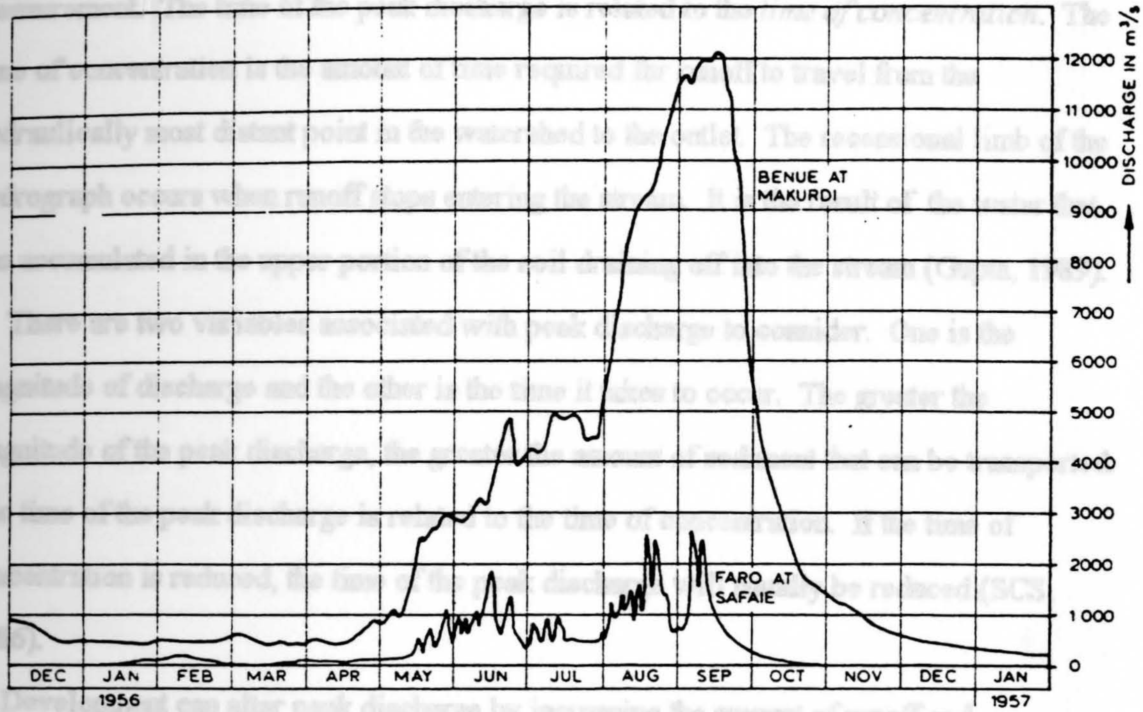


Figure 1.2: An Example of a Hydrograph.

Peak Discharge and Time of Concentration

A hydrograph can be broken into three sections, a rising limb, a crest and a recession limb. The rising limb shows the increase in discharge as runoff begins to enter the stream. The crest shows the peak or maximum discharge of the stream. The *peak discharge* occurs when runoff from all portions of the watershed contribute to the streamflow at the point of measurement. The time of the peak discharge is related to the *time of concentration*. The time of concentration is the amount of time required for runoff to travel from the hydraulically most distant point in the watershed to the outlet. The recessional limb of the hydrograph occurs when runoff stops entering the stream. It is the result of the water that has accumulated in the upper portion of the soil draining off into the stream (Gupta, 1989).

There are two variables associated with peak discharge to consider. One is the magnitude of discharge and the other is the time it takes to occur. The greater the magnitude of the peak discharge, the greater the amount of sediment that can be transported. The time of the peak discharge is related to the time of concentration. If the time of concentration is reduced, the time of the peak discharge will usually be reduced (SCS, 1986).

Development can alter peak discharge by increasing the amount of runoff and decreasing the time of concentration. This affects the amount of sediment transported in the stream in the following ways. The reduction in the time of concentration is generally due to a change in surface cover, allowing the runoff to attain a higher velocity and increasing its ability to erode and carry sediment.

Erosion and Sedimentation

The ability of a stream to carry sediment is dependent on its velocity and discharge. The velocity determines the largest size of sediment that can be transported and the discharge determines the total amount of sediment that can be transported. A stream will begin to deposit sediment if either the velocity, discharge, or both are reduced. In the case

of a stream entering a lake or reservior, the velocity of the stream, for all practical purposes, reduces to zero. The sediment carried into a lake by a stream will begin to settle out of the water and accumulate on the bottom of the lake. Over a period of time, this sediment accumulation will eventually fill the lake (Plummer and McGeary, 1991).

CHAPTER 2

An Overview of the U.S. Soil Conservation Service's TR-55 Watershed Model

2.1 Introduction

The Hydrosim Mk. 1 model developed for this study is a modification of the U.S. Soil Conservation Service's TR-55 watershed model. Therefore an overview of the theory and methods behind TR-55 is necessary.

2.2 Description

TR-55 is short for Technical Release 55 which was first released by the U.S. Soil Conservation Service (SCS) in 1975. TR-55 was developed as a simplified method to calculate runoff, peak rate of discharge, hydrographs, and storage volumes for flood water storage reserviors (SCS, 1986).

2.2.1 Runoff

TR- 55 determines runoff using the SCS Runoff Curve Number method. This method involves the use of experimentally derived rainfall vs. runoff curves (Figure 2.1). In order to determine which curve to use for a particular watershed, the hydrologic soil group, land cover, treatment, and prestorm moisture conditions must be known (Gupta, 1989).

Hydrologic Soil Group

The SCS has classified soils into four hydrologic soil groups labelled A, B, C, and D. The grouping is based on a soil's minimum rate of infiltration after a prolonged wetting. Soils belonging to Group A have the highest rate of infiltration and Group D the lowest (SCS, 1986). A description of each group is as follows:

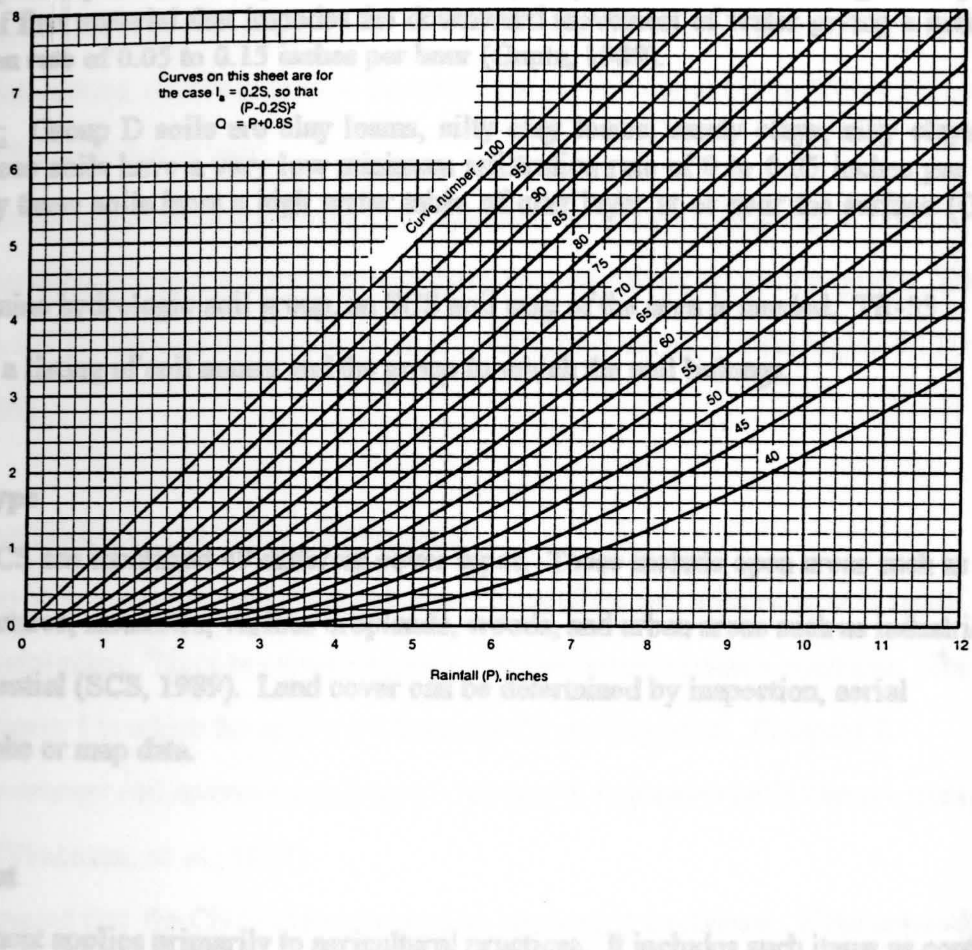


Figure 2.1: Rainfall vs. Runoff Curves (SCS, 1986)

Group A: Group A soils are typically sand, gravel, loamy sands and sandy loams that are deep and well drained. They have a minimum infiltration rate of 0.3 to 0.45 inhes per hour (Gupta, 1989).

Group B: Group B soils are usually silt loams and sand loams that are deep to moderately deep. These soils have a minimum infiltration rate of 0.15 to 0.30 inches per hour and are moderately well drained (Gupta, 1989).

Group C: Group C soils are predominately sandy clay loams. These soils generally have a layer of fine material that impedes the downward movement of water giving a minimum infiltration rate of 0.05 to 0.15 inches per hour (Gupta, 1989).

Group D: Group D soils are clay loams, silty clay loams, sandy clays, silty clays, and clay. These soils have a very low minimum infiltration rate of 0 to 0.05 inches per hour. Generally these soils have a high water table of clay layer at or near the surface (Gupta, 1989).

To determine hydrologic soil group, an SCS soil map of the area is needed. TR-55 provides a listing of soil names and the group to which the soil belongs.

Cover Type

The SCS has identified 49 different cover types. These include open areas such as parks, pastures, meadows, various croplands, woods, and urban areas such as industrial and residential (SCS, 1989). Land cover can be determined by inspection, aerial photographs or map data.

Treatment

Treatment applies primarily to agricultural practices. It includes such items as contour plowing, crop rotation, no tillage farming, etc. Treatment is not a factor for non-agricultural watersheds (SCS, 1986).

Hydrologic Condition

The hydrologic condition refers to the effects of cover type and treatment on runoff for a particular soil group. Good hydrologic condition means that the potential for runoff is low.

Fair indicates a moderate runoff potential and poor indicates a high runoff potential. Factors used to determine hydrologic condition include the density of plant cover, the amount of year-round cover, and the degree of surface roughness (SCS, 1986).

Determining Curve Number

Once the hydrologic soil group, cover type, treatment and hydrologic condition for an area are determined, a table is used to determine the curve number (CN). Table 2.1 is a portion of the table that is used.

If the area being modelled contains more than one hydrologic soil group or cover type the area has to be brocken up into segments and CNs determined for each segment. The composite CN for the area as a whole is an area-weighted average of the segment CNs (SCS, 1986).

Antecedent Moisture Condition Adjustment

The antecedent moisture condition is the condition of the soil with respect to runoff before precipitation. There are three catagories of antecedent moisture condition. The first is catagory I in which the soil is dry but not to the wilting point. Catagory II represents average soil moisture conditions. Catagory II represents soils that are already saturated (Viesmann, et. al., 1977).

It is assumed that the CN is determined under catagory II conditions. If the antecedent moisture condition is catagory I or III, the CN must be adjusted (SCS, 1986). Table 2.2 gives corrections for several CNs.

Calculation of Runoff

Runoff is calculated using the SCS runoff equation:

$$Q = (P - I_a)^2 / ((P - I_a) + S) \qquad \text{Eq. 2.1}$$

Table 2.1: Portion of Table used to Determine Curve Number (SCS, 1986).

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2.2: Corrections to Curve Numbers (CN) for Antecedent Moisture Conditions (Gupta, 1987).

Curve Number for Condition II	Corresponding Curve Number for Condition: I	III
100	100	100
95	87	99
90	78	98
85	70	97
80	63	94
75	57	91
65	45	83
60	40	79
55	35	75
50	31	70
45	27	65
40	23	60
35	19	55
30	15	50
25	12	45
20	9	39
15	7	33
10	4	26
5	2	17
0	0	0

where

Q = runoff (in.)
P = rainfall (in.)
S = potential maximum retention after runoff begins (in.)
Ia = initial abstractions (in.)

The initial abstraction term can be replaced by:

$$I_a = 0.2\ S \qquad \text{Eq. 2.2}$$

This is an empirical relationship that was developed through the study of several small agricultural watersheds and is applicable only when $P > I_a$. All CNs were calculated using this relationship. If another relationship were to be used, all CNs would have to be recalculated (SCS, 1986).

Substituting Eq. 2.2 into Eq. 2.1 gives:

$$Q = (P - 0.2\ S)^2 / (P + 0.8\ S) \qquad \text{Eq.2.3}$$

S is related to the soil and cover conditions of the watershed through the CN. S can be determined from:

$$S = (1000 / CN) - 10 \qquad \text{Eq. 2.4}$$

Once S is determined, Eq. 2.3 can be solved to give runoff for any precipitation P, > 0.25.

Limitations

There are some limitations to the SCS curve number method. The method was not designed to model runoff from historical storm events because only the amount of rainfall is used, there are no provisions for intensity and duration. Therefore the results will vary from that of an actual storm. Also, runoff from snow melt or runoff on frozen ground cannot be calculated using this method (SCS, 1986).

Probably the largest limitation is the relationship defined in Eq. 2.2. Because this relationship was developed from observations of small agricultural watersheds, it does not take in account conditions for urban watersheds. This may lead to retention values that are greater or lower than actual conditions (SCS, 1986).

2.2.2 Time of Concentration and Travel Time

The time of concentration is the amount of time required for runoff to travel from the hydraulically most distant point of the watershed to the outlet. Travel time is the time it takes runoff to travel from one point in the drainage basin to another. TR-55 calculates the time of concentration using the SCS Segment Approach. This method determines the time of concentration from the sum of the travel times for sheet flow, shallow concentrated flow, and open channel flow (SCS, 1986).

Sheet Flow

TR-55 uses Manning's Kinematic Solution to calculate the travel time for sheet flow:

$$T_t = [\, 0.007\, (n\, L)^{0.8}] \,/\, [(P_2)^{0.5}\, s^{\,0.4}] \qquad \text{Eq. 2.5}$$

where

T_t = travel time (hr.)

n = Manning's roughness coefficient

L = flow length (ft.) (300 ft. maximum)

P_2 = 2-year 24-hour rainfall (in.)
s = ground slope (ft./ft.)

Table 2.3 gives values for n for several types of surfaces.

Shallow Concentrated Flow

The travel time for shallow concentrated flow is determined by:

$$T_t = L / 3600\ V \qquad \text{Eq. 2.6}$$

where
T_t = travel time (hr.)
L = flow length (ft.)
V = average velocity (ft/s)
3600 = conversion factor from seconds to hours

The average velocity can be determined from Figure 2.2.

Open Channel Flow

The travel time for open channel flow is determined from Manning's equation:

$$V = (1.49\ r^{2/3}\ s^{1/2}) / n \qquad \text{Eq. 2.7}$$

where
V = average velocity (ft/s)
r = hydraulic radius (ft.)
s = channel slope (ft./ft.)
n = Manning's roughness coefficient for open channel flow

After V is determined, Eq. 2.6 is used to determine travel time.

2.2.3 Tabular Hydrograph Method

The SCS Tabular Hydrograph Method is a procedure to generate realistic synthetic hydrographs. The method is useful for modelling the effects of changes within a watershed

Table 2.3: Roughness Coefficients (Manning's n) for Sheet Flow (SCS, 1986).

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover $\leqslant 20\%$	0.06
Residue cover $> 20\%$	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

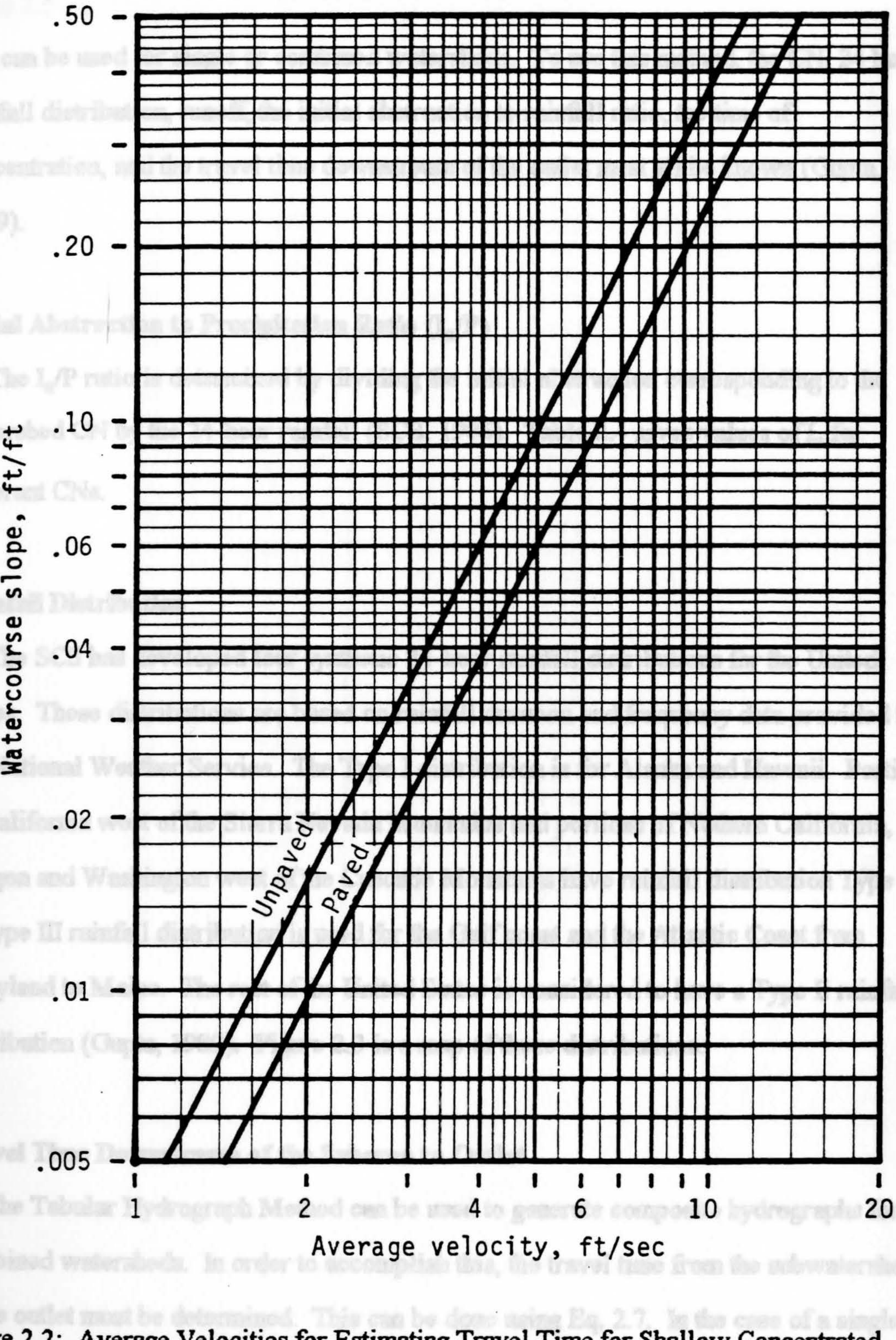


Figure 2.2: Average Velocities for Estimating Travel Time for Shallow Concentrated Flow (SCS, 1986).

and can be used for single or combined watersheds. To use this method, the CN, 24 hour rainfall distribution, runoff, the initial abstraction to rainfall ratio, the time of concentration, and the travel time downstream of the outlet must all be known (Gupta, 1989).

Initial Abstraction to Precipitation Ratio (I_a/P)

The I_a/P ratio is determined by dividing the initial abstraction corresponding to the watershed CN by the 24-hour rainfall (SCS, 1986). Table 2.4 gives values of I_a for different CNs.

Rainfall Distribution

The SCS has developed four synthetic 24-hour rainfall distributions for the United States. These distributions are based on rainfall duration and frequency data provided by the National Weather Service. The Type I distribution is for Alaska and Hawaii. Portions of California west of the Sierra Nevada Mountains and portions of Nothern California, Oregon and Washington west of the Cascade Mountains have rainfall distribution Type IA. A Type III rainfall distribution is used for the Gulf coast and the Atlantic Coast from Maryland to Maine. The rest of the United States is considered to have a Type II rainfall distribution (Gupta, 1989). Figure 2.3 is a map of these distributions.

Travel Time Downstream of the Subarea to Outlet

The Tabular Hydrograph Method can be used to generate composite hydrographs for combined watersheds. In order to accomplish this, the travel time from the subwatershed to the outlet must be determined. This can be done using Eq. 2.7. In the case of a single watershed, the travel time is considered to be zero (SCS, 1986).

Table 2.4: I_a Values for Runoff Curve Numbers (SCS,1986).

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

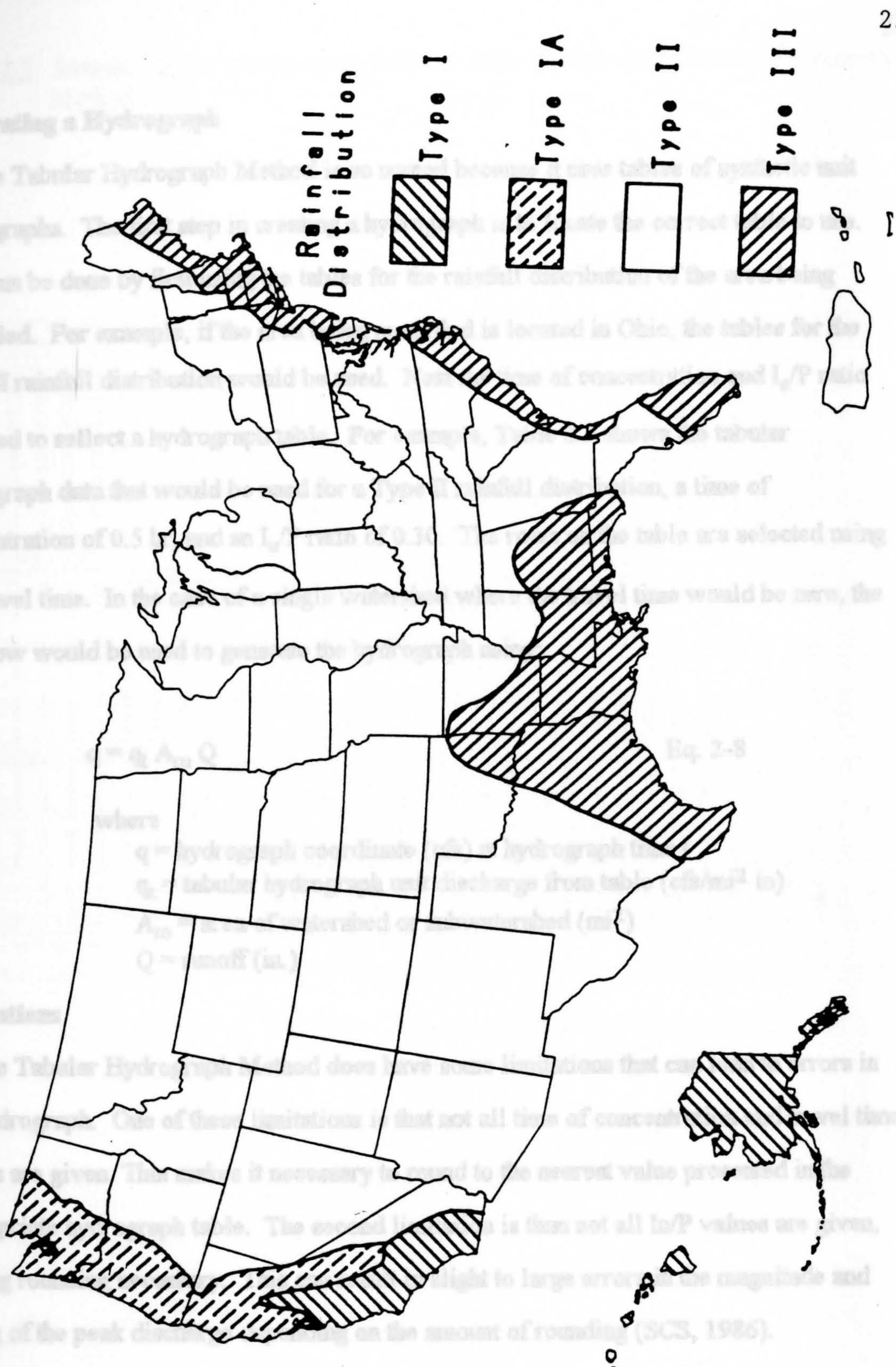


Figure 2.3: Approximate Geographic Boundaries for SCS Rainfall Distributions (SCS, 1986).

Generating a Hydrograph

The Tabular Hydrograph Method is so named because it uses tables of synthetic unit hydrographs. The first step in creating a hydrograph is to locate the correct table to use. This can be done by first using the tables for the rainfall distribution of the area being modelled. For example, if the area being modelled is located in Ohio, the tables for the Type II rainfall distribution would be used. Next the time of concentration and I_a/P ratio are used to sellect a hydrograph table. For example, Table 2.5 shows the tabular hydrograph data that would be used for a Type II rainfall distribution, a time of concentration of 0.5 hr, and an I_a/P ratio of 0.30. The rows on the table are selected using the travel time. In the case of a single watershed where the travel time would be zero, the first row would be used to generate the hydrograph using:

$$q = q_t A_m Q \qquad \text{Eq. 2-8}$$

where

q = hydrograph coordinate (cfs) at hydrograph time t
q_t = tabular hydrograph unit discharge from table (cfs/mi^2 in)
A_m = area of watershed or subwatershed (mi^2)
Q = runoff (in.)

Limitations

The Tabular Hydrograph Method does have some limitations that can lead to errors in the hydrograph. One of these limitations is that not all time of concentration and travel time values are given. This makes it necessary to round to the nearest value presented in the appropriate hydrograph table. The second limitation is than not all Ia/P values are given, making rounding necessary. This can result in slight to large errors in the magnitude and timing of the peak discharge depending on the amount of rounding (SCS, 1986).

Table 2.5: Sample Tabular Hydrograph Ordinate Table used for SCS Tabular Hydrograph Method (SCS, 1986).

HYDROGRAPH TIME (HOURS)

TRVL TIME (HR)	9.0	9.3	9.6	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	11.0	11.2	11.4	11.6	11.8	12.0	12.3	12.6	13.0	13.5	14.0	14.5	15.0	15.5	16.0	17.0	18.0	20.0	24.0
IA/P = 0.10														• • • TC =0.5 HR • • •														IA/P = 0.10				
0.0	21	28	35	56	73	111	175	247	282	271	229	136	152	108	84	71	63	58	55	51	47	44	40	35	31	30	29	28	26	25	21	14
.10	20	27	36	52	66	96	149	214	259	267	242	204	169	119	90	74	65	59	55	51	48	44	40	36	32	30	29	28	26	25	21	14
.20	17	23	31	42	49	60	84	127	185	234	256	247	219	156	112	86	72	63	58	53	49	45	41	37	33	30	29	28	27	25	22	14
.30	16	22	30	40	46	55	74	110	160	210	241	245	227	171	123	93	76	66	59	54	50	46	42	38	33	30	29	28	27	25	22	14
.40	14	19	26	35	38	43	51	67	95	138	186	222	237	210	157	115	89	73	64	57	52	47	43	39	35	31	29	29	27	25	22	15
.50	14	18	25	33	37	41	43	61	84	120	164	203	229	216	170	126	96	77	66	58	53	48	43	39	35	31	30	29	27	25	22	15
.75	11	14	19	26	29	32	35	40	48	61	83	114	148	202	210	176	137	106	84	66	57	51	46	41	37	33	30	29	28	26	22	15
1.0	10	11	15	19	21	24	26	29	32	36	41	50	65	116	176	203	190	156	122	85	67	56	49	44	40	35	32	30	28	26	23	16
1.5	7	9	11	13	14	16	17	19	21	23	25	28	31	42	67	110	157	187	133	146	104	72	55	48	43	39	35	32	29	27	24	17
2.0	4	6	7	9	10	10	11	12	13	14	15	17	18	22	27	36	53	33	123	175	175	124	77	57	49	44	40	35	30	28	25	18
2.5	3	4	5	7	7	8	8	9	9	10	11	12	13	15	18	22	27	36	53	97	146	166	119	76	57	49	44	39	32	29	25	18
3.0	1	2	3	5	5	6	6	6	7	8	8	9	9	11	12	15	17	21	27	43	76	135	158	114	75	57	48	43	35	30	26	19
IA/P = 0.30														• • • TC =0.5 HR • • •														IA/P = 0.30				
0.0	0	0	0	1	6	22	64	123	168	174	165	143	126	100	84	74	68	65	63	60	57	54	51	47	42	40	40	39	38	36	32	22
.10	0	0	0	1	5	16	48	98	144	164	165	150	134	106	87	77	70	66	63	60	58	55	51	47	42	40	40	39	38	36	32	22
.20	0	0	0	0	1	3	12	36	77	122	150	160	154	126	101	85	75	69	65	62	59	56	52	48	44	41	40	39	38	37	33	23
.30	0	0	0	0	0	2	9	27	60	101	134	151	153	132	107	89	77	70	66	63	60	56	53	49	44	41	40	40	38	37	33	23
.40	0	0	0	0	0	0	2	6	20	47	83	117	140	148	125	102	86	76	69	64	61	57	54	50	46	42	40	40	39	37	33	23
.50	0	0	0	0	0	0	1	5	15	36	68	101	127	144	130	108	90	78	71	65	62	58	54	50	46	42	40	40	39	37	33	23
.75	0	0	0	0	0	0	0	2	6	17	36	60	97	125	133	121	103	88	75	68	63	59	55	52	47	43	41	40	39	37	34	24
1.0	0	0	0	0	0	0	0	0	0	1	3	9	21	62	105	130	125	112	96	78	69	62	57	54	50	46	42	40	39	38	34	25
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	6	23	56	92	115	120	106	87	71	62	57	53	49	45	42	40	38	35	26
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	14	36	67	104	113	96	74	63	58	54	50	46	40	39	36	27
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	15	47	95	109	93	73	63	57	53	49	42	40	37	28
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	32	77	105	90	72	62	57	53	45	40	38	30
IA/P = 0.50														• • • TC =0.5 HR • • •														IA/P = 0.50				
0.0	0	0	0	0	0	0	0	1	4	10	18	26	33	41	45	47	49	50	50	50	50	50	50	50	50	50	50	49	49	48	46	33
.10	0	0	0	0	0	0	0	1	3	8	15	22	30	39	44	47	49	50	50	50	50	50	50	50	50	50	50	49	49	48	46	34
.20	0	0	0	0	0	0	0	0	2	6	12	19	26	37	43	46	48	50	50	50	50	50	50	50	50	50	50	49	49	48	46	34
.30	0	0	0	0	0	0	0	0	1	4	9	16	23	34	41	45	48	49	50	50	50	50	50	50	50	50	50	49	49	49	46	34
.40	0	0	0	0	0	0	0	0	1	3	7	13	19	31	39	44	47	49	50	50	50	50	50	50	50	50	50	49	49	49	46	34
.50	0	0	0	0	0	0	0	0	1	2	6	10	16	28	37	43	46	48	50	50	50	50	50	50	50	50	50	49	49	49	46	34
.75	0	0	0	0	0	0	0	0	0	1	3	6	10	20	30	38	43	46	48	50	50	50	50	50	50	50	50	49	49	49	47	35
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	20	30	38	43	47	49	50	50	50	50	50	50	50	49	49	47	36
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	14	23	31	41	46	49	50	50	50	50	50	50	49	49	48	38
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	13	25	36	45	49	50	50	50	50	50	49	49	48	39
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	12	23	37	46	49	50	50	50	50	50	49	48	40
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	21	37	46	49	50	50	50	50	49	48	42

RAINFALL TYPE = I • • • TC = 0.5 HR • • • SHEET 5 OF 10

CHAPTER 3

Overview of the Hydrosim Mk. 1 Watershed Modelling System

3.1 Introduction

Hydrosim was developed to provide a more efficient and easier way to model multiple land use changes within a watershed. It is a compter program based on the SCS TR-55 model described in the previous chapter.

The TR-55 model is very time consuming to use. Much of the time is spent looking items up in tables and reading numbers off of charts. All calculations are made by hand and any hydrographs have to be plotted manually. The software developed by the SCS for TR-55 handles some of the calculations and saves some time, but the process is still rather time consuming with many items for the user to keep track of.

Hydrosim Mk.1, or just Hydrosim as it will be referred to from now on, simplifies the modelling process by eliminating the need to look through tables or make manual calculations. After the initial data such as soil and land use are entered, runoff, time of concentration and hydrographs can be calculated in a matter of about five minutes. Hydrosim uses a graphical interface to allow the user to see the watershed being modelled on a computer monitor. Runoff graphs and hydrographs can be plotted on the screen and printed.

Hydrosim was written in Microsoft Quick BASIC and has a modular structure. All files generated are written in an ASCII format so they can be imported into other programs or edited if the need arises.

3.2 Description

Hydrosim uses seven program modules to perform the modelling process (Figure 3.1). Module MENU is the main menu and control center for the system. After each module

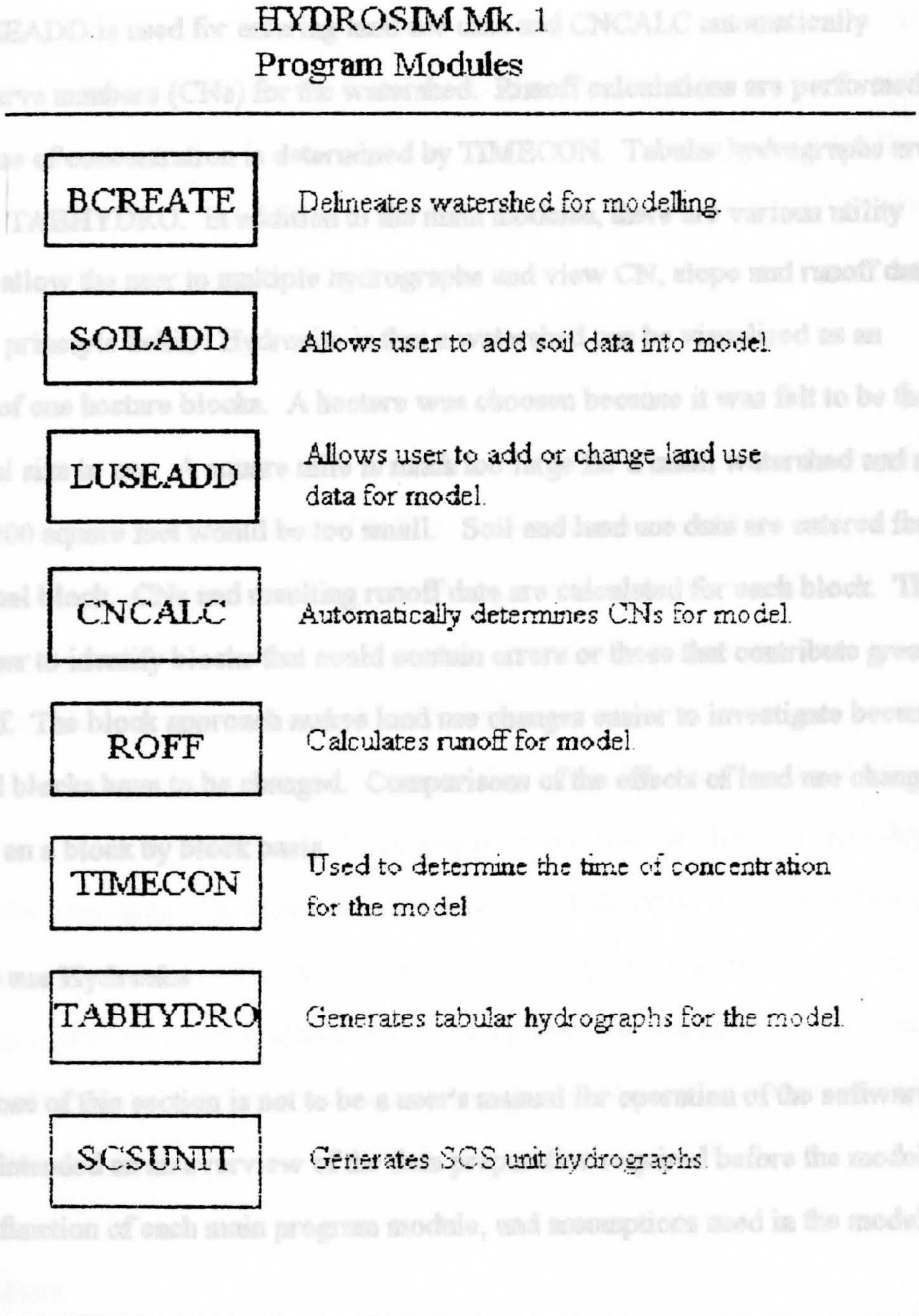


Figure 3.1: Hydrosim program modules.

executes, the user will be returned to the main menu. BCREATE is used for delineating the watershed that is to be modelled. Soil data is added to the model in the SOILADD module. LUSEADD is used for entering land use data and CNCALC automatically determines curve numbers (CNs) for the watershed. Runoff calculations are performed by ROFF and time of concentration is determined by TIMECON. Tabular hydrographs are calculated by TABHYDRO. In addition to the main modules, there are various utility modules that allow the user to multiple hydrographs and view CN, slope and runoff data.

The basic principle behind Hydrosim is that a watershed can be visualized as an arrangement of one hectare blocks. A hectare was choosen because it was felt to be the most practical size to use. A square mile is much too large for a small watershed and a block of 10,000 square feet would be too small. Soil and land use data are entered for each individual block. CNs and resulting runoff data are calculated for each block. This allows the user to identify blocks that could contain errors or those that contribute greatly to total runoff. The block approach makes land use changes easier to investigate because only selected blocks have to be changed. Comparisons of the effects of land use change can be made on a block by block basis.

3.3 How to use Hydrosim

The purpose of this section is not to be a user's manual for operation of the software. Rather, it is intended as an overview of the data preparation required before the model can be used, the function of each main program module, and assumptions used in the model.

3.3.1 Data Preparation

Maps

As with TR-55, the user will need a topographic map, soil map and land use data for the watershed being modelled. Because Hydrosim views the watershed as an arrangement of hectare blocks, a hectare grid of the same scale as the maps must be superimposed on them. In this study this was accomplished by reproducing the maps using AutoCad software version 12 by Auto Desk Inc. Alternatively, the grid can be drafted by hand on the map itself. Once the grid is in place, the origin must be located in the upper left hand corner of the grid and the grid numbered as shown in Figure 3.2. It is important that the grids look exactly the same for both the topographic map and soil map so that all the blocks correspond.

Digitizing

Hydrosim requires that coordinates of the watershed boundary, stream and topographic contours be digitized into headerless ASCII files. Hydrosim uses these files for the graphic interface and their function will be explained in later sections. If a digitizer tablet or suitable digitizing software is not avaliable, the digitized files have to be created manually. A ruler is used to measure points with care being taken to select an adequate number of points. Using an editor, these points are then entered as x,y pairs into the appropriate files. Boundary, stream, and topographic point files must have the same name but different file extensions. Boundary files must have a .BDR extention, stream files must have a .STR extension and topographic files must have a .TPO extension. These files should be named after the watershed that is to be modelled. For example if a watershed is named STREAM1, the boundary file must be named STREAM1.BDR, the stream file STREAM1.STR and the topographic file STREAM1.TPO (Figure 3.3).

Stream Gradient

For the pupose of determining travel time and time of concentration, the gradient of the stream must be known. Hydrosim uses the gross slope of the stream, which can be determined by dividing the difference between the head water elevation and the outlet elevation by the length of the stream. A utility program, STREAMCALC, was developed

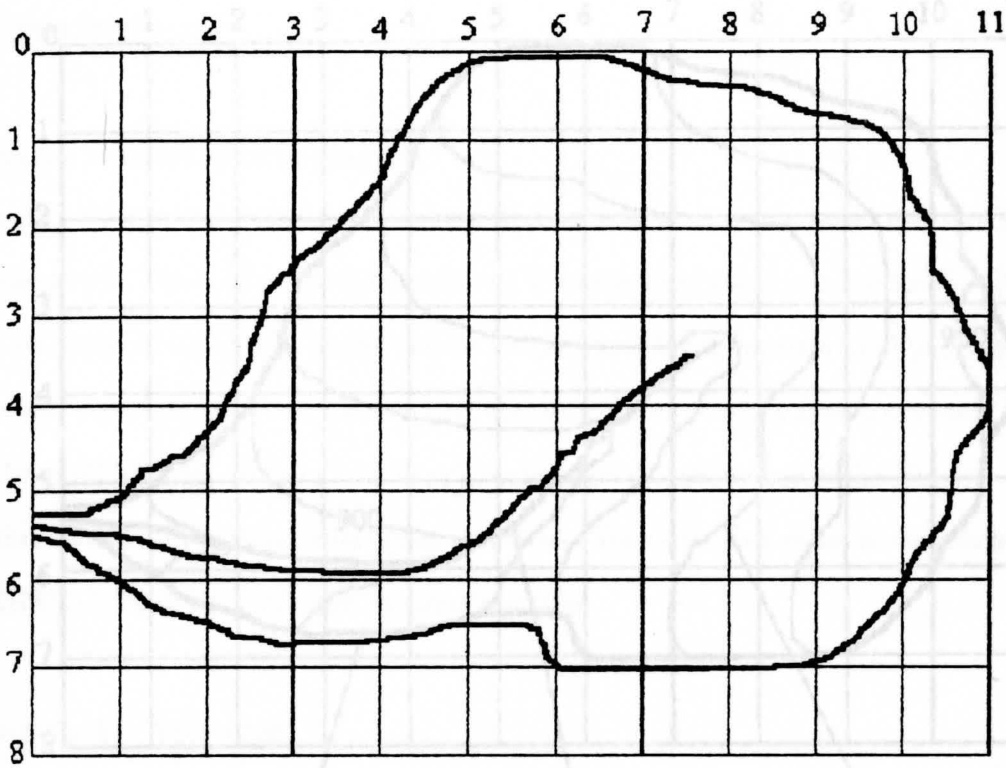
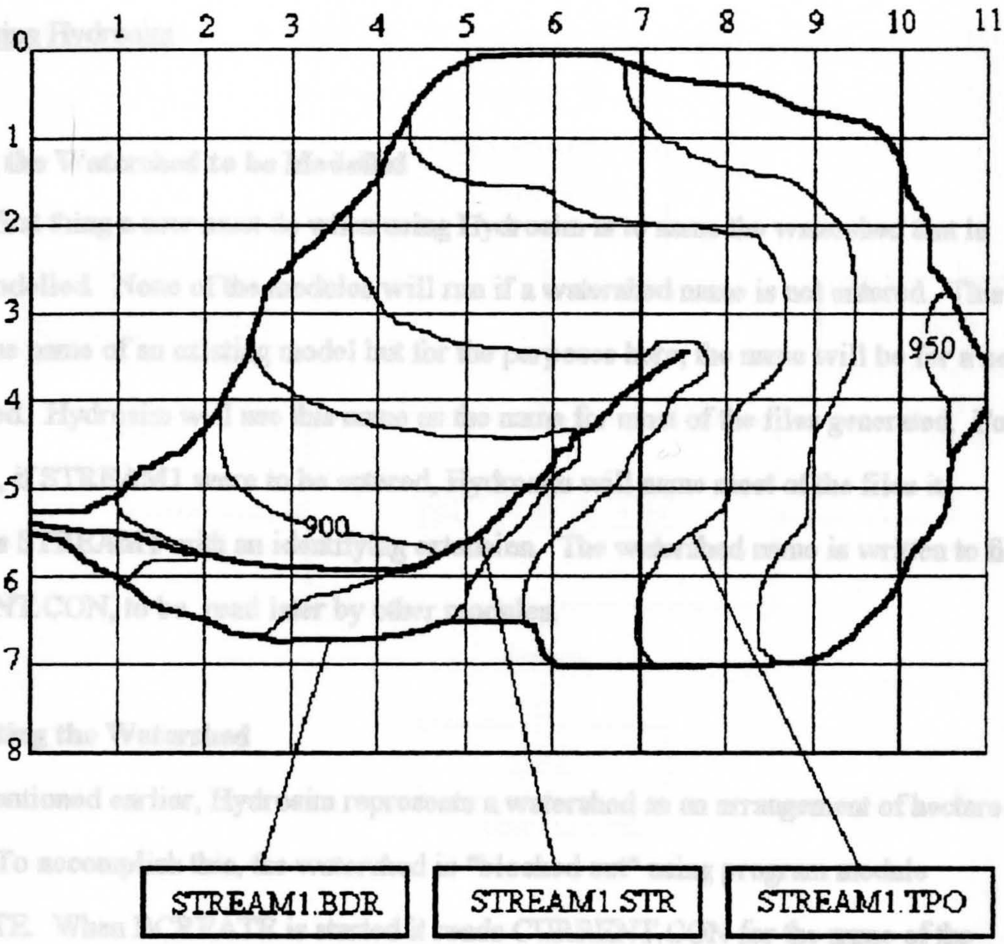


Figure 3.2: Example of Watershed with Hectare Grid..

Watershed: Stream1



<u>Figure 3.3</u>: Digitized Files Required to Run Hydrosim.

to read the .STR file and determine the length of the stream. The stream gradient should be in units of feet/feet.

3.3.2 <u>Using Hydrosim</u>

Naming the Watershed to be Modelled

The first thing a user must do when using Hydrosim is to name the watershed that is being modelled. None of the modules will run if a watershed name is not entered. This can be the name of an existing model but for the purposes here, the name will be for a new watershed. Hydrosim will use this name as the name for most of the files generated. For example, if STREAM1 were to be entered, Hydrosim will name most of the files it generates STREAM1 with an identifying extension. The watershed name is written to file CURRENT.CON, to be read later by other modules.

Delineating the Watershed

As mentioned earlier, Hydrosim represents a watershed as an arrangement of hectare blocks. To accomplish this, the watershed is "blocked out" using program module BCREATE. When BCREATE is started it reads CURRENT.CON for the name of the watershed and read the associated .BDR file (Figure 3.4). The watershed boundary is plotted on the screen with the hectare grid superimposed. The user can enlarge the grid or reduce the grid in proportion with the watershed, taking care not to enlarge beyond the boundaries of the screen. Then, the cursor keys are used to highlight a grid space and select a block (as grid spaces will be refered to from now on) using the appropriate function key indicated on the program menu. This process will be followed until the watershed is completely blocked in.

Care must be taken when selecting blocks along the watershed boundary. A rule used during this study was that when the watershed boundary cut across a block, the block

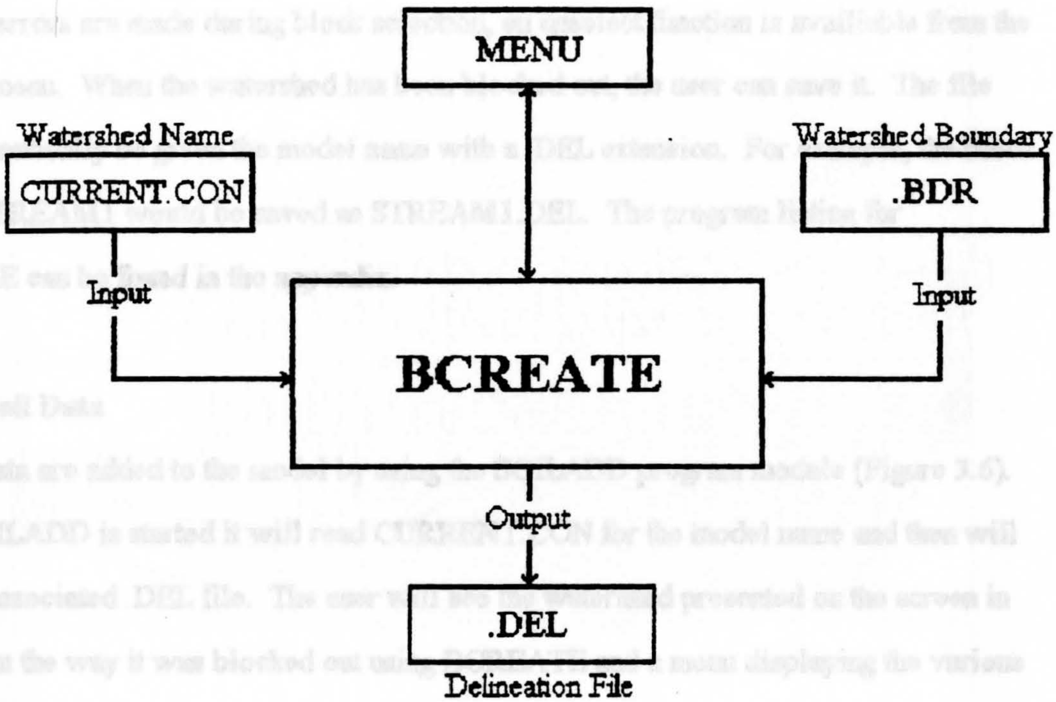


Figure 3.4: Input and Output Files for Program Module BCREATE.

would be selected if the watershed occupied at least 50% of it. Only if the block is required for continuity should a block be selected with less than 50% of it occupied by the watershed area. It is felt that the area of the watershed as blocked out in the model will be very close to that of the actual watershed (Figure 3.5). The only instance where there might be a problem is if the watershed being modelled has an area less than 10 hectares.

If any errors are made during block selection, an unselect function is availiable from the program menu. When the watershed has been blocked out, the user can save it. The file will automatically be given the model name with a .DEL extension. For example, the block file for STREAM1 would be saved as STREAM1.DEL. The program listing for BCREATE can be found in the appendix.

Adding Soil Data

Soil data are added to the model by using the SOILADD program module (Figure 3.6). When SOILADD is started it will read CURRENT.CON for the model name and then will read the associated .DEL file. The user will see the watershed presented on the screen in block form the way it was blocked out using BCREATE and a menu displaying the various functions avaliable.

Soil data is entered into the model by first using the cursor keys to select a block. Up to four different soil types can be entered into each block. Four was choosen as a maximum because it is very rare to find four different soils occupying the same hectare block. The data required are the soil symbol as presented on the county soil survey map and the percentage, as estimated by eye, of the block occupied by that soil. Care must be taken not to type in an incorrect soil symbol and to make sure that all percentages add up to 100%. If a mistake is made it can be easily corrected using the edit function. If there are several blocks with the same soil, the copy function can be used to copy the contents of one block into several others.

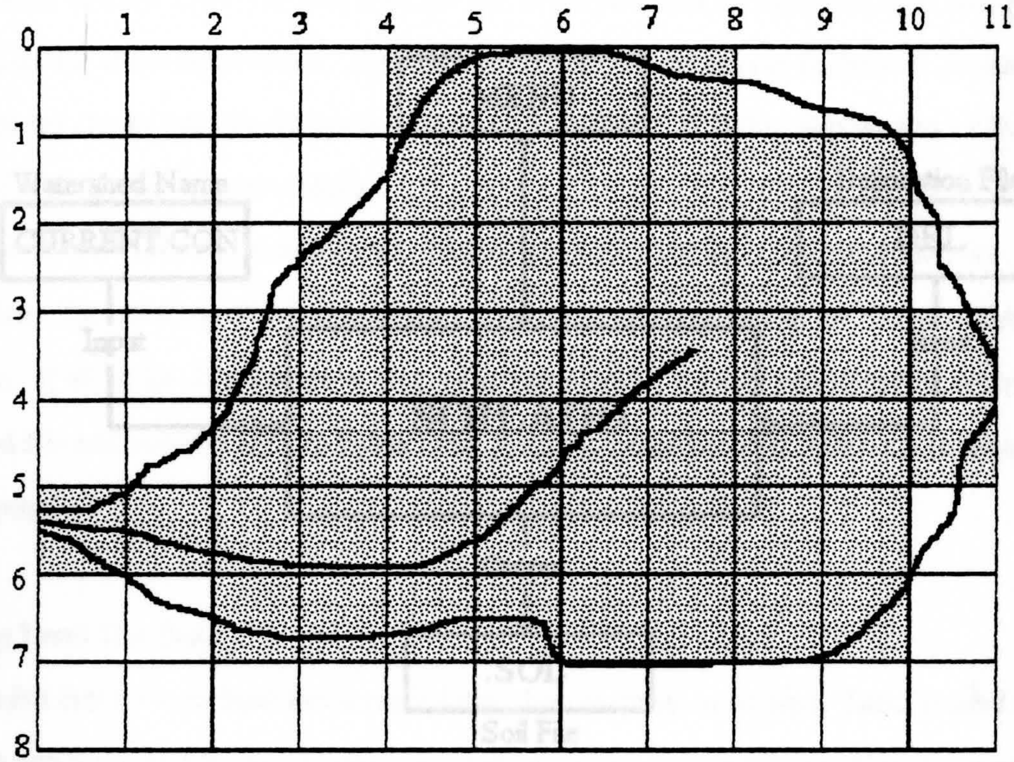


Figure 3.5: **Example of a Watershed "Blocked Out" Using BCREATE.**

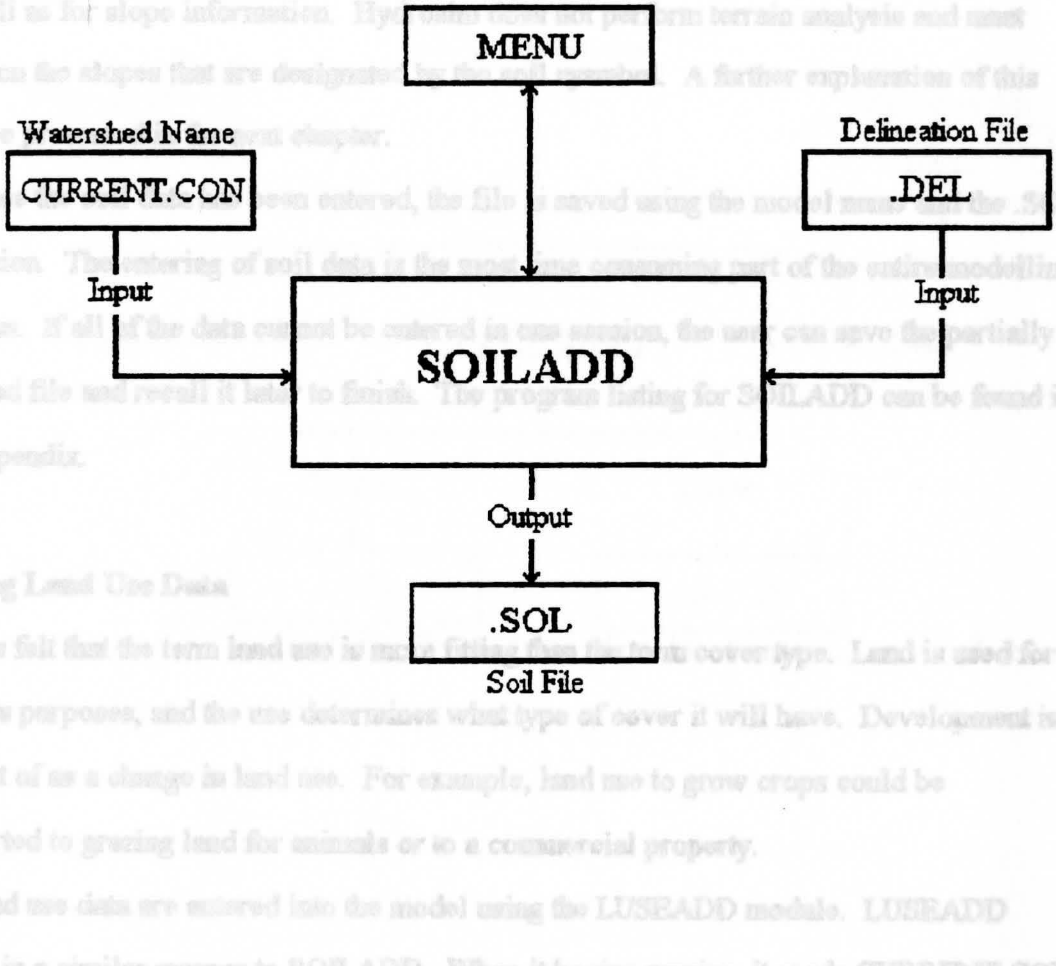


Figure 3.6: Input and Output Files for Program Module SOILADD.

It is felt that by entering the soil data hectare by hectare a more accurate estimate of the area covered by each soil type will be obtained, compared to looking at the watershed as a whole, as one would when using only TR-55. Hydrosim places more importance on soil data than TR-55 does. TR-55 only requires that the hydrologic soil group and area covered be known. Hydrosim requires the use of the soil data for the hydrologic soil group as well as for slope information. Hydrosim does not perform terrain analysis and must reley on the slopes that are designated by the soil sysmbol. A further explanation of this will be presented in the next chapter.

Once the soil data has been entered, the file is saved using the model name and the .SOL extension. The entering of soil data is the most time consuming part of the entire modelling process. If all of the data cannot be entered in one session, the user can save the partially finished file and recall it later to finish. The program listing for SOILADD can be found in the appendix.

Adding Land Use Data

It is felt that the term land use is more fitting than the term cover type. Land is used for various purposes, and the use determines what type of cover it will have. Development is thought of as a change in land use. For example, land use to grow crops could be converted to grazing land for animals or to a commercial property.

Land use data are entered into the model using the LUSEADD module. LUSEADD works in a similar manner to SOILADD. When it begins running, it reads CURRENT.CON and the model's .DEL file (Figure 3.7). The user sees the same block representation of the watershed on the screen and select blocks in the same manner as in SOILADD. The difference is that instead of being asked for soil data, the user will be asked to enter a land use number for that particular block. Table 3.1 is a list of land use numbers. The same edit and copy functions are availiable in LUSEADD as they were in SOILADD.

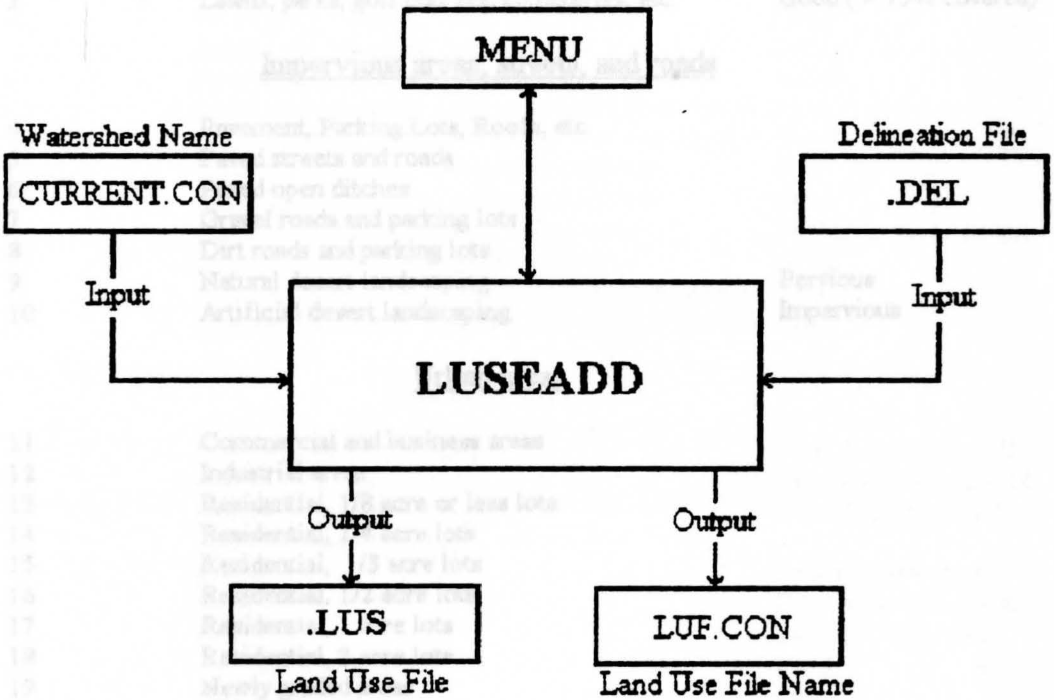


Figure 3.7: **Input and Output Files for Program Module LUSEADD.**

Table 3.1: Land Use Numbers Used by Hydrosim

Land Use Number	Cover Type	Hydraulic Condition
	Open spaces	
1	Lawns, parks, golf courses, cemeteries, etc.	Poor (< 50 % covered)
2	Lawns, parks, golf courses, cemeteries, etc.	Fair (50% to 75% cover)
3	Lawns, parks, golf courses, cemeteries, etc.	Good (> 75% covered)
	Impervious areas, streets, and roads	
4	Pavement, Parking Lots, Roofs, etc.	
5	Paved streets and roads	
6	Paved open ditches	
7	Gravel roads and parking lots	
8	Dirt roads and parking lots	
9	Natural desert landscaping	Pervious
10	Artificial desert landscaping	Impervious
	Urban areas	
11	Commercial and business areas	
12	Industrial areas	
13	Residential, 1/8 acre or less lots	
14	Residential, 1/4 acre lots	
15	Residential, 1/3 acre lots	
16	Residential, 1/2 acre lots	
17	Residential, 1 acre lots	
18	Residential, 2 acre lots	
19	Newly graded areas	
	Agriculture	
20	Fallow, bare soil	
21	Crop residue cover	Poor
22	Crop residue cover	Good
23	Row crops, straight row	Poor
24	Row crops, straight row	Good
25	Row crops, straight row with crop residue cover	Poor
26	Row crops, straight row with crop residue cover	Good
27	Row crops, contoured	Poor
28	Row crops, contoured	Good
29	Row crops, contoured with crop residue	Poor
30	Row crops, contoured with crop residue	Good
31	Row crops, contoured and terraced	Poor
32	Row crops, contoured and terraced	Good
33	Row crops, contoured and terraced w/ crop residue	Poor
34	Row crops, contoured and terraced w/ crop residue	Good
35	Small grain, straight row	Poor
36	Small grain, straight row	Good
37	Small grain, straight row with crop residue	Poor

Table 3.1: Continued

Land Use Number	Cover Type	Hydraulic Condition
38	Small grain, straight row with crop residue	Good
39	Small grain, contoured	Poor
40	Small grain, contoured	Good
41	Small grain, contoured with crop residue	Poor
42	Small grain, contoured with crop residue	Good
43	Small grain. contoured and terraced	Poor
44	Small grain, contoured and terraced	Good
45	Small grain, contoured and terraced w/ crop residue	Poor
46	Small grain, contoured and terraced w/ crop residue	Good
47	Legumes or rotation meadow, straight row	Poor
48	Legumes or rotation meadow, straight row	Good
49	Legumes or rotation meadow, contoured	Poor
50	Legumes or rotation meadow, contoured	Good
51	Legumes or rotation meadow, contoured & terraced	Poor
52	Legumes or rotation meadow, contoured & terraced	Good
	Non-crop lands	
53	Pasture, grassland or range	Poor (heavily grazed)
54	Pasture, grassland or range	Fair (not heavily grazed)
55	Pasture, grassland or range	Good (lightly grazed)
56	Meadow, mowed for hay	
57	Brush	Poor (< 50% cover)
58	Brush	Fair (50 to 75% cover)
59	Brush	Good (> 75% cover)
60	Orchard or tree farm	Poor
61	Orchard or tree farm	Fair
62	Orchard or tree farm	Good
63	Woods	Poor
64	Woods	Fair
65	Woods	Good
66	Farmsteads	

When it is time to save the land use data, the user is given the choice between saving the file under the model name or selecting a new name. The reason for this is that Hydrosim is designed to work with multiple land use files. A model will have one delineation file and one soil file but can have several landuse, runoff, time of concentration and hydrograph files. For example, if STREAM1 is going to have three different land use files, each can be given a different name and all future files generated for a particular land use will have the same name. When the file is saved it is given the .LUS extension and its name is written to LUF.CON to be read by future modules.

One of the assumptions made by LUSEADD is that a block can have only one land use. This assumption is made because it would be very difficult to work out the spatial relashionships between several soil types and land uses in the same block. Also, the block size of one hectare provides adequate resolution for land use unless the total watershed area is extremely small (e.g. less than 10 hectares). The program listing for LUSEADD can be found in the appendix.

Determining CNs

CNs are determined using the CNCALC program module. CNCALC is composed of three submodules CNCALCP1, CNCALCP2, and CNCALCP3.

When CNCALCP1 is started, it reads CURRENT.CON for the model name and reads the assiciated .SOL file (Figure 3.8). It then cross references the contents of the soil file with a file named MCSOIL.LST that relates soil symbols to hydrologic soil group and slope. Then, it writes this information to a file with the model name and the .TSS extension, and starts CNCALCP2 automatically.

CNCALCP2 reads LUF.CON to get the name of the land use file and asks the user if that is the file to be used. The user can accept that file or enter the name of another land use file. If the user enters the name of another land use file, the new name is written to LUF.CON. CNCALCP2 simply adds the contents of the selected land use file to the

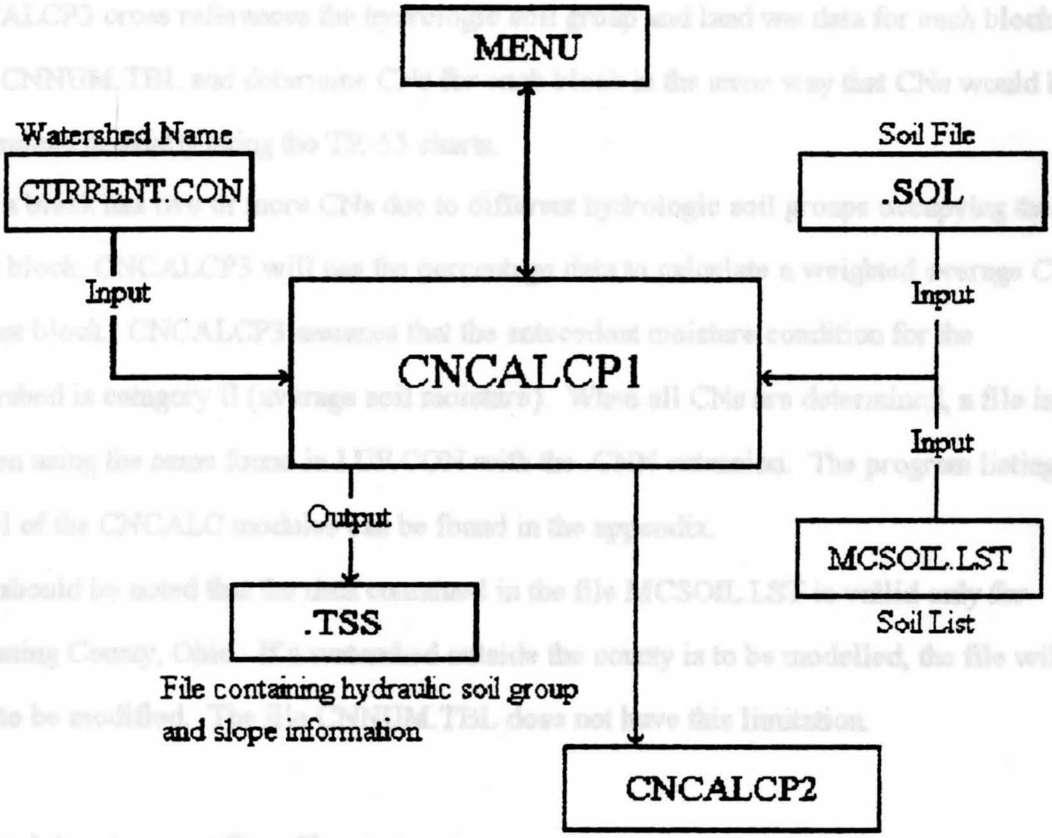


Figure 3.8: Input and Output Files for Program Module CNCALCP1.

contents of the .TSS file and writes a file with the name contained in LUF.CON with the .LSS extension (Figure 3.9). CNCALCP2 will automatically start CNCALCP3.

CNCALCP3 reads LUF.CON and open the appropriate .LSS file (Figure 3.10). Then CNCALCP3 cross references the hydrologic soil group and land use data for each block with CNNUM.TBL and determine CNs for each block in the same way that CNs would be determined manually using the TR-55 charts.

If a block has two or more CNs due to different hydrologic soil groups occupying the same block, CNCALCP3 will use the percentage data to calculate a weighted average CN for that block. CNCALCP3 assumes that the antecedent moisture condition for the watershed is catagory II (average soil moisture). When all CNs are determined, a file is written using the name found in LUF.CON with the .CNN extension. The program listing for all of the CNCALC modules can be found in the appendix.

It should be noted that the data contained in the file MCSOIL.LST is vallid only for Mahoning County, Ohio. If a watershed outside the county is to be modelled, the file will need to be modified. The file CNNUM.TBL dose not have this limitation.

Determining Average Runoff

Average runoff is calculated by the program module ROFF. When the module is run, the user enters a 24 hour rainfall amount. ROFF will read LUF.CON and open the appropriate .CNN file. Runoff values are determined for each block by using Eqs. 2.3 and 2.4. The average runoff for the watershed as a whole is determined by summing the runoff values for all blocks and dividing the totals by the number of blocks. The resulting amount is written to a file with the .ROF extension (Figure 3.11).

An additional feature of the ROFF program module is the calculation of the average runoff for a watershed using a range of precipitation amounts from 0 to six inches. This information is displayed on the screen in graph form (Figure 3.12). The graph can be printed or the runoff data can be saved to a user named file with the .DAT extension so that

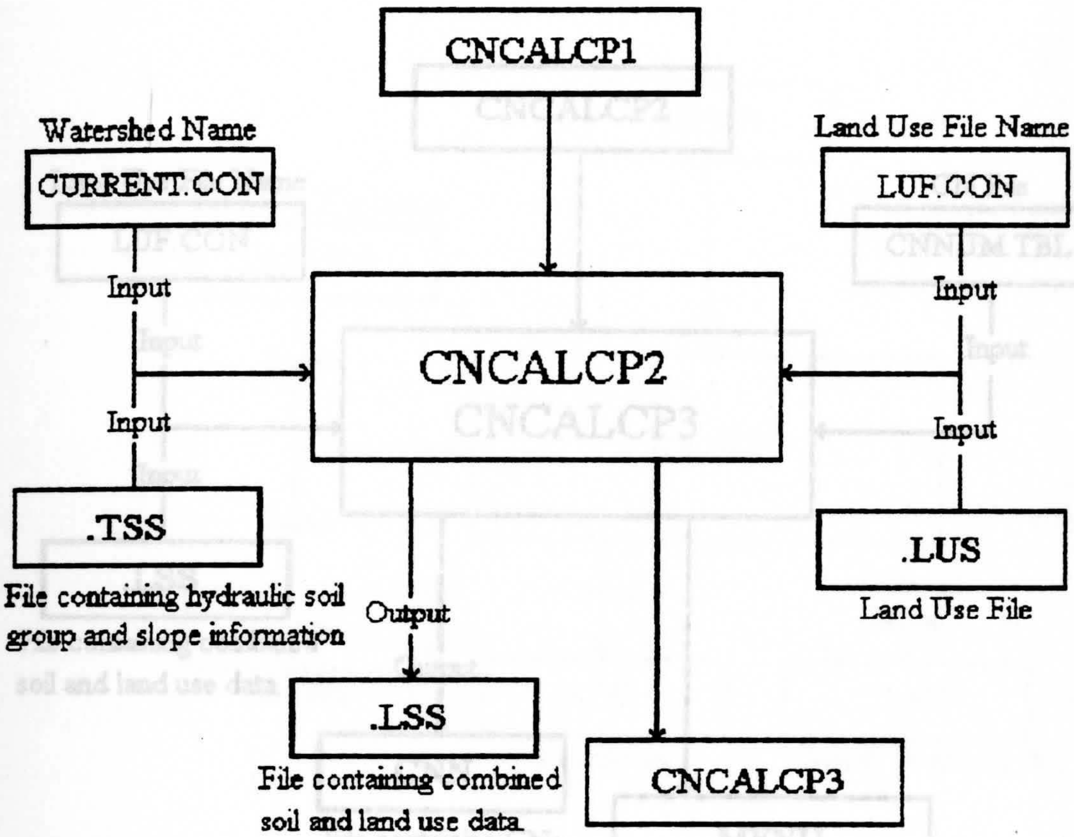


Figure 3.9: Input and Output Files for Program Module CNCALCP2.

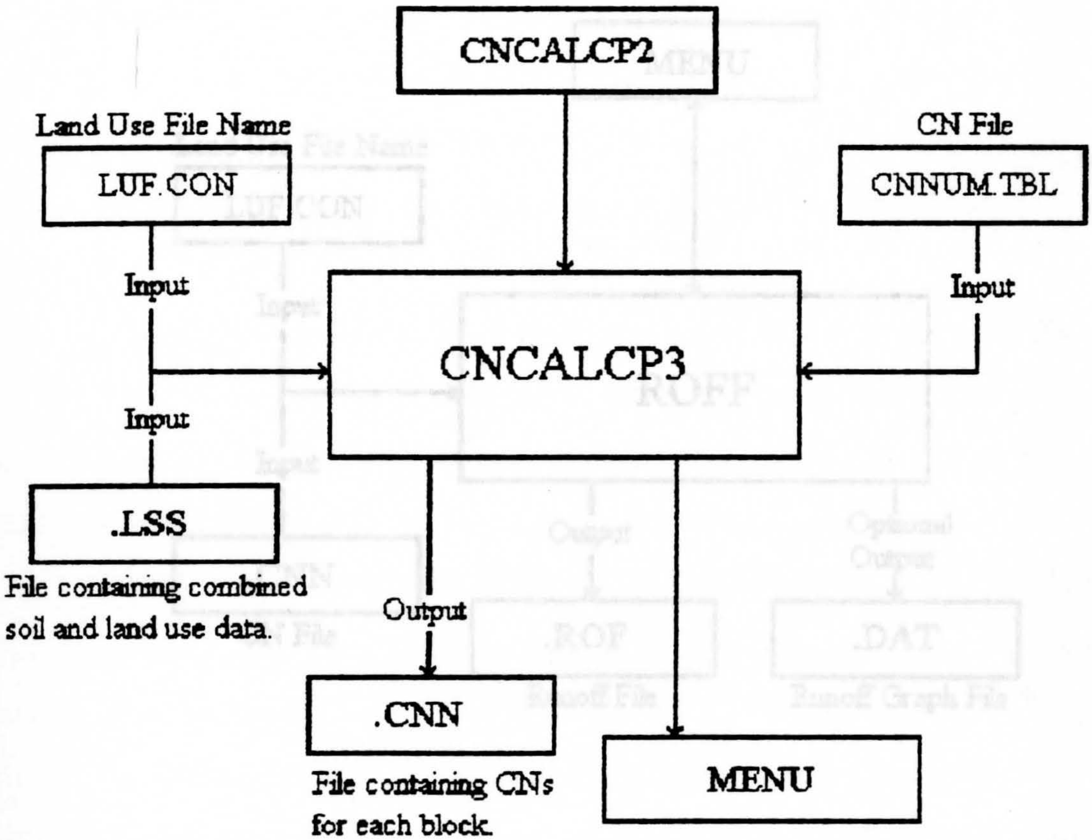


Figure 3.10: Input and Output Files for Program Module CNCALCP3.

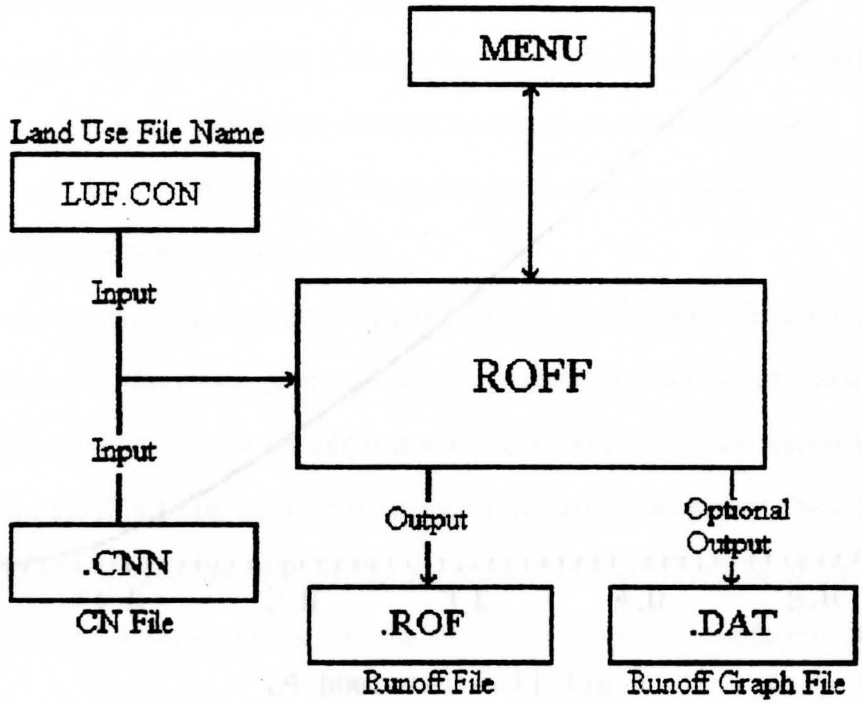


Figure 3.11: Input and Output Files for Program Module ROFF.

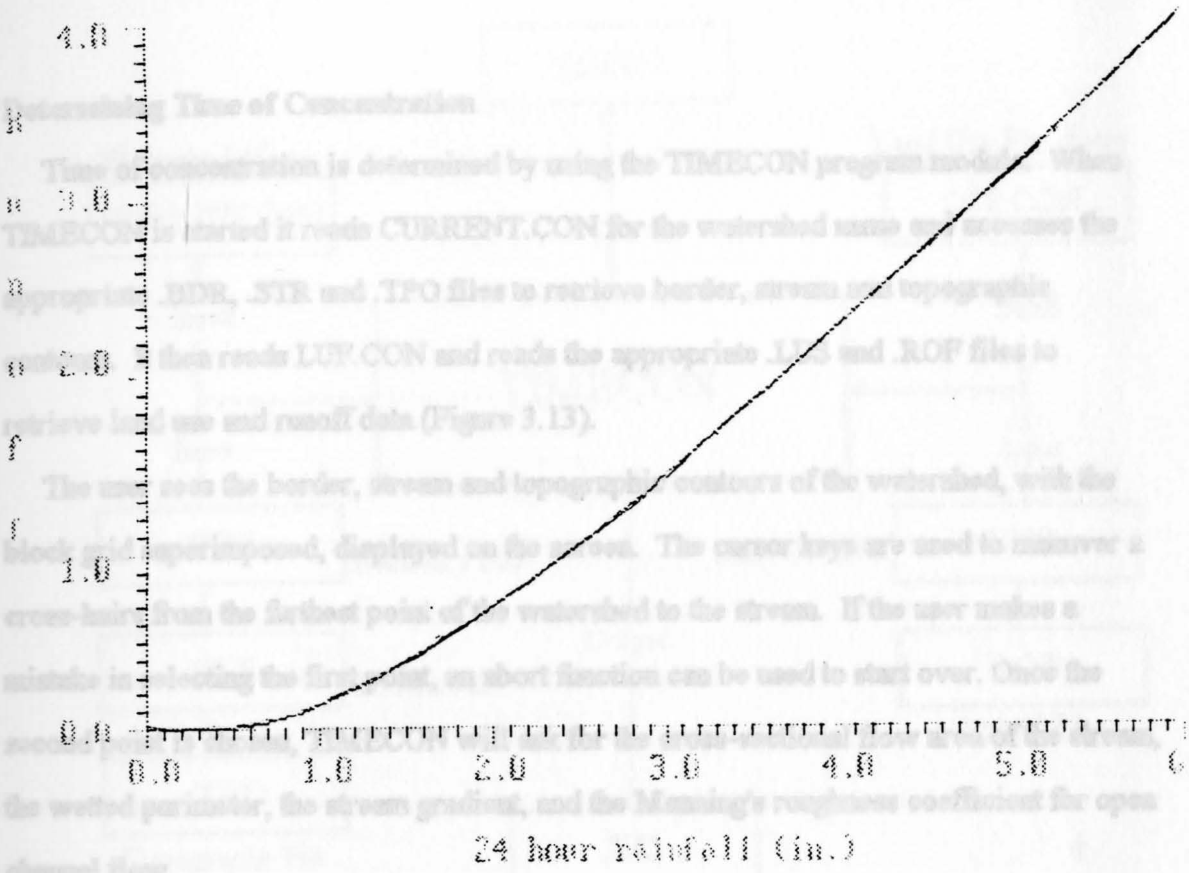


Figure 3.12: Runoff vs. Rainfall Graph Produced by Program Module ROFF.

it may be imported into other software packages. The program listing for ROFF can be found in the appendix.

Determining Time of Concentration

Time of concentration is determined by using the TIMECON program module. When TIMECON is started it reads CURRENT.CON for the watershed name and accesses the appropriate .BDR, .STR and .TPO files to retrieve border, stream and topographic contours. It then reads LUF.CON and reads the appropriate .LUS and .ROF files to retrieve land use and runoff data (Figure 3.13).

The user sees the border, stream and topographic contours of the watershed, with the block grid superimposed, displayed on the screen. The cursor keys are used to manuver a cross-hairs from the furthest point of the watershed to the stream. If the user makes a mistake in selecting the first point, an abort function can be used to start over. Once the second point is chosen, TIMECON will ask for the cross-sectional flow area of the stream, the wetted parimeter, the stream gradient, and the Manning's roughness coefficient for open channel flow.

TIMECON uses the SCS Segment Approach to calculate time of concentration. TIMECON determines sheetflow using Eq. 2.5. It assumes a flow length of 300 feet and uses a slope from the soil data that is contained in the .ROF file. Manning's roughness coefficients are determined from the land use data from the .LUS file for the blocks inwhich sheet flow occurs. Table 3.2 gives a listing of land use and associated Manning's roughness coefficients.

TIMECON determines the travel time for shallow concentrated flow using Eq. 2.6. The average velocity is determined by a numerical representation of the graph for unpaved surfaces shown in Figure 2.1. This relationship is represented by the following equation:

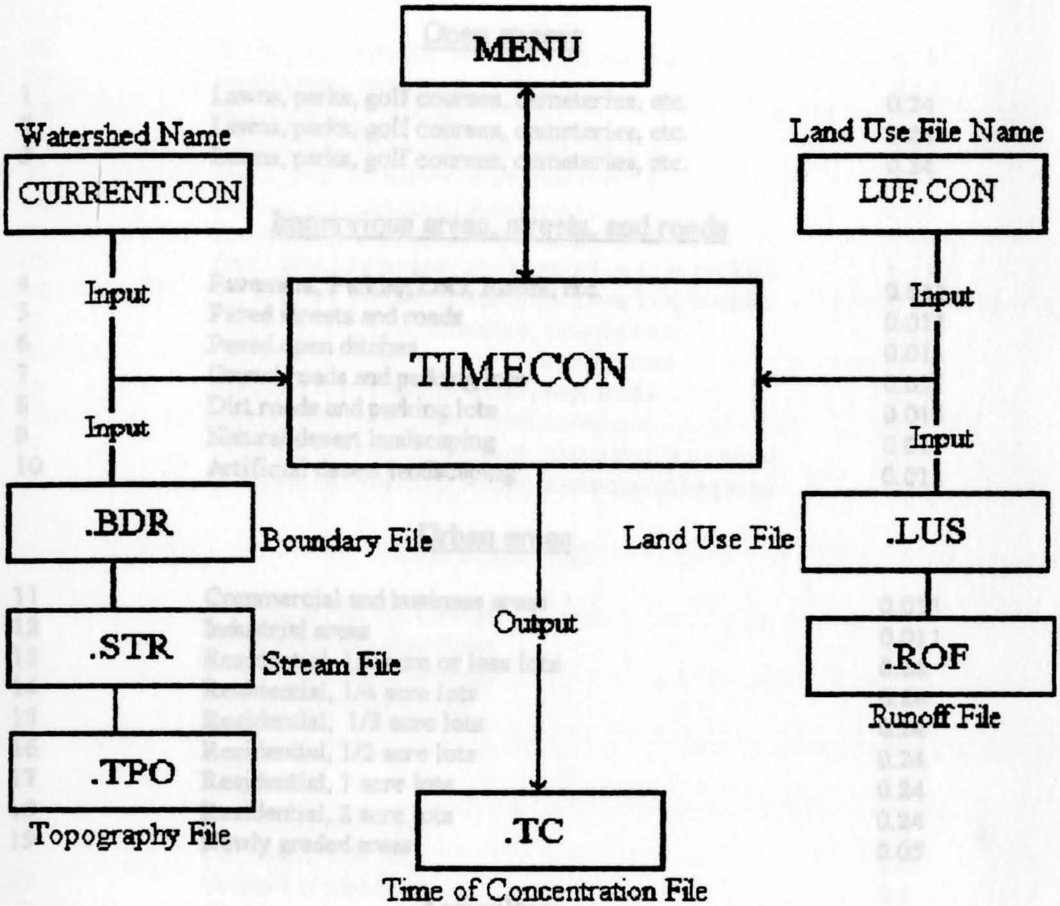


Figure 3.13: Input and Output Files for Program Module TIMECON.

Table 3.2: Manning's Roughness Coefficients for Land Use.

Land Use Number	Cover Type	Manning's roughness coefficient
	Open spaces	
1	Lawns, parks, golf courses, cemeteries, etc.	0.24
2	Lawns, parks, golf courses, cemeteries, etc.	0.24
3	Lawns, parks, golf courses, cemeteries, etc.	0.24
	Impervious areas, streets, and roads	
4	Pavement, Parking Lots, Roofs, etc.	0.011
5	Paved streets and roads	0.011
6	Paved open ditches	0.011
7	Gravel roads and parking lots	0.011
8	Dirt roads and parking lots	0.011
9	Natural desert landscaping	0.011
10	Artificial desert landscaping	0.011
	Urban areas	
11	Commercial and business areas	0.011
12	Industrial areas	0.011
13	Residential, 1/8 acre or less lots	0.24
14	Residential, 1/4 acre lots	0.24
15	Residential, 1/3 acre lots	0.24
16	Residential, 1/2 acre lots	0.24
17	Residential, 1 acre lots	0.24
18	Residential, 2 acre lots	0.24
19	Newly graded areas	0.05
	Agriculture	
20	Fallow, bare soil	0.05
21	Crop residue cover	0.05
22	Crop residue cover	0.05
23	Row crops, straight row	0.17
24	Row crops, straight row	0.17
25	Row crops, straight row with crop residue cover	0.17
26	Row crops, straight row with crop residue cover	0.17
27	Row crops, contoured	0.17
28	Row crops, contoured	0.17
29	Row crops, contoured with crop residue	0.17
30	Row crops, contoured with crop residue	0.17
31	Row crops, contoured and terraced	0.17
32	Row crops, contoured and terraced	0.17
33	Row crops, contoured and terraced w/ crop residue	0.17
34	Row crops, contoured and terraced w/ crop residue	0.17
35	Small grain, straight row	0.17
36	Small grain, straight row	0.17
37	Small grain, straight row with crop residue	0.17

Table 3.2: Continued

Land Use Number	Cover Type	Manning's Roughness Coefficient
38	Small grain, straight row with crop residue	0.17
39	Small grain, contoured	0.17
40	Small grain, contoured	0.17
41	Small grain, contoured with crop residue	0.17
42	Small grain, contoured with crop residue	0.17
43	Small grain. contoured and terraced	0.17
44	Small grain, contoured and terraced	0.17
45	Small grain, contoured and terraced w/ crop residue	0.17
46	Small grain, contoured and terraced w/ crop residue	0.17
47	Legumes or rotation meadow, straight row	0.17
48	Legumes or rotation meadow, straight row	0.17
49	Legumes or rotation meadow, contoured	0.17
50	Legumes or rotation meadow, contoured	0.17
51	Legumes or rotation meadow, contoured & terraced	0.17
52	Legumes or rotation meadow, contoured & terraced	0.17
	Non-crop lands	
53	Pasture, grassland or range	0.15
54	Pasture, grassland or range	0.15
55	Pasture, grassland or range	0.15
56	Meadow, mowed for hay	0.15
57	Brush	0.15
58	Brush	0.15
59	Brush	0.15
60	Orchard or tree farm	0.4
61	Orchard or tree farm	0.4
62	Orchard or tree farm	0.4
63	Woods	0.8
64	Woods	0.8
65	Woods	0.8
66	Farmsteads	0.011

$$V = -42878\, s^6 + 55204.9\, s^5 - 27068\, s^4 + 6599.84\, s^3 - 890.44\, s^2 + 88.5\, s + 0.76 \quad \text{Eq. 3.1}$$

where

V = average velocity (ft./s)
s = slope (ft/ft)

Eq. 3.1 was derived by digitizing points from the graph into Golden Sotware's Grapher version 1.76 graphics software and using its polynomial fitting routine to match the curve.

The relationship between slope and velocity for unpaved surfaces was applied for all land uses for various reasons. For example, a parking lot is not a perfectly smooth surface allowing water to flow over it without resistance. The surface of a parking lot can be pitted, cracked, and covered with debris, parked cars, shopping carts, etc. Also the perimeter of a parking lot is usually rough, with gravel or tall grass which would slow the flow of water travelling across it. Parking lots are usually graded to a fairly level surface. However, Hydrosim assumes the slope to be that represented by the soil survey data for the area. Thus the slope used in calculations may be greater than the actual slope for recently developed parking lots. Considering these factors, it is felt that an adequate approximation is obtained by applying the unpaved relationship between slope and flow velocity for paved surfaces (Eq. 3.1) to all surfaces.

The velocity of open channel flow is determined using the stream data entered by the user and Eq. 2.7. TIMECON determines the length of open channel flow from the .STR file for the model. The accuracy of this length depends on the number of points digitized into the .STR file. If the points are being determined by using a ruler, it is extremely important that points are not skipped.

The time of concentration is determined by summing the travel times for sheet flow, shallow concentrated flow and open channel flow. The time of concentration is automatically saved to a file with the name contained in LUF.CON with the .TC extension. The program listing for TIMECON can be found in the appendix.

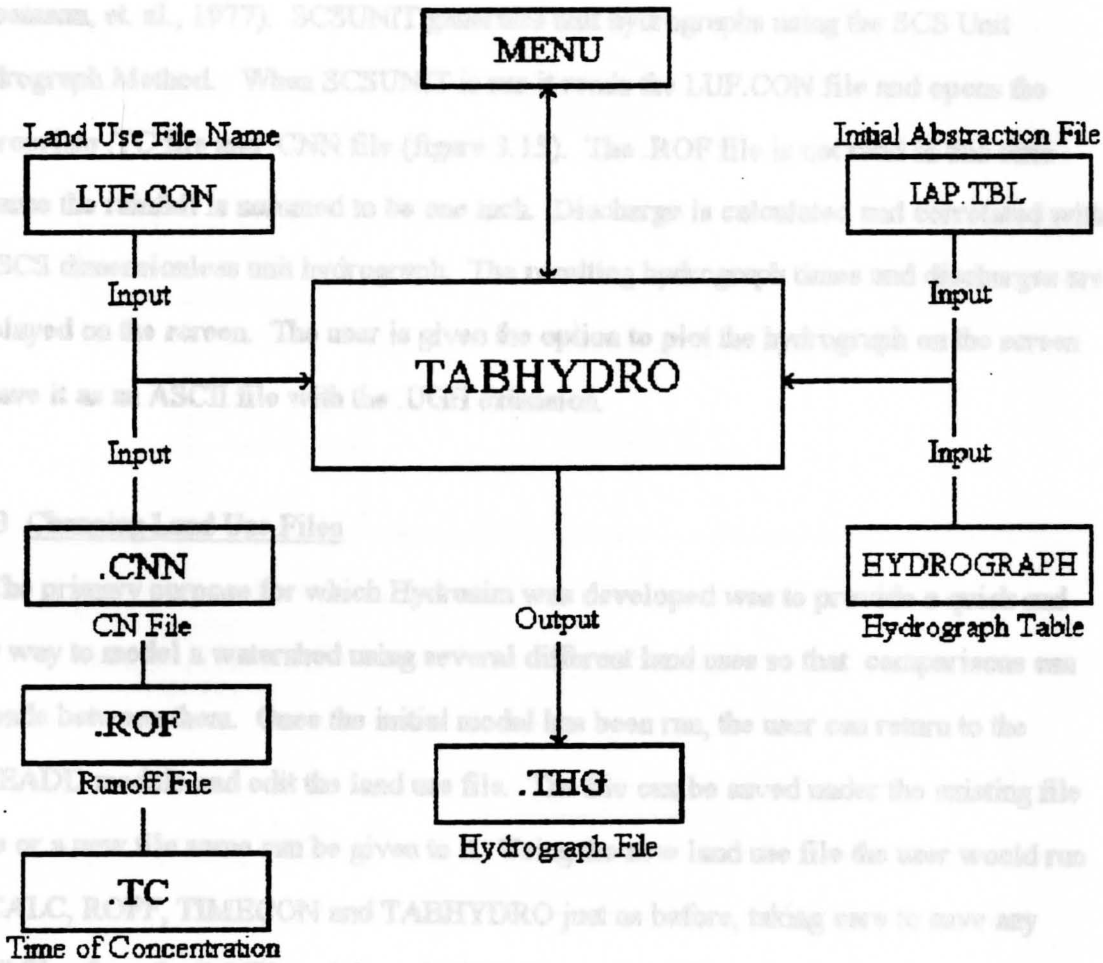
Tabular Hydrographs

Hydrosim generates hydrographs using the SCS Tabular Hydrograph method. This is performed by the TABHYDRO program module and is a fully automatic proceedure, requireing no input from the user. When TABHYDRO is run, it reads the name of the current land use file in LUF.CON, opens the appropriate .CNN file, and determines an average CN for the entire watershed. It then opens a file named IAP.TBL, which contains initial abstractions (I_a) for various CNs, and selects the proper initial abstraction for the average CN. The .ROF file is then opened and the amount of precipitation and runoff are read. The initial abstraction to precipitation ratio is determined by dividing the initial abstrction by the precipitation. The time of concentration is also read from the appropriate .TC file (Figure 3.14).

Both the time of concentration and the initial abstraction to precipitation ratio are rounded to the nearest value for which a hydrograph table exists. TABHYDRO assumes a Type II rainfall distribution since this study is being conducted in Ohio. The rounded time of concentration and initial abstraction to precipitation ratio are used to identify the appropriate hydrograph file. Values of unit runoff in cfs/mi^2 in are then read by TABHYDRO.

The area of the watershed is converted from hectares to square miles. The tabular hydrograph is calculated using Eq. 2.8. Time and discharge information is printed on the screen and the user can save the hydrograph to a .THG file and plot the hydrograph on the screen. The screen plotting function automatically adjusts the scale of the hydrograph so it will fit on the screen. The hydrograph can also be printed.

Composite hydrographs can be generated using the program COMPHY. COMPHY works in the same manner as TABHYDRO with the exception that the user enters a list of subwatersheds and travel times. The program listings for both TABHYDRO and COMPHY can be found in the appendix.



<u>Figure 3.14</u>: Input and Output Files for Program Module TABHYDRO.

Unit Hydrographs

Hydrosim can generate unit hydrographs using the program module SCSUNIT. A unit hydrograph is a hydrograph that would result from a 24-hour rainfall of one inch (Viesmann, et. al., 1977). SCSUNIT generates unit hydrographs using the SCS Unit Hydrograph Method. When SCSUNIT is run it reads the LUF.CON file and opens the appropriate .TC file and .CNN file (figure 3.15). The .ROF file is not read in this case because the rainfall is assumed to be one inch. Discharge is calculated and correlated with the SCS dimensionless unit hydrograph. The resulting hydrograph times and discharges are displayed on the screen. The user is given the option to plot the hydrograph on the screen or save it as an ASCII file with the .UGH extension.

3.3.3 <u>Changing Land Use Files</u>

The primary purpose for which Hydrosim was developed was to provide a quick and easy way to model a watershed using several different land uses so that comparisons can be made between them. Once the initial model has been run, the user can return to the LUSEADD module and edit the land use file. The file can be saved under the existing file name or a new file name can be given to it. Using the new land use file the user would run CNCALC, ROFF, TIMECON and TABHYDRO just as before, taking care to save any .DAT files from the ROFF module and .THG files under different names.

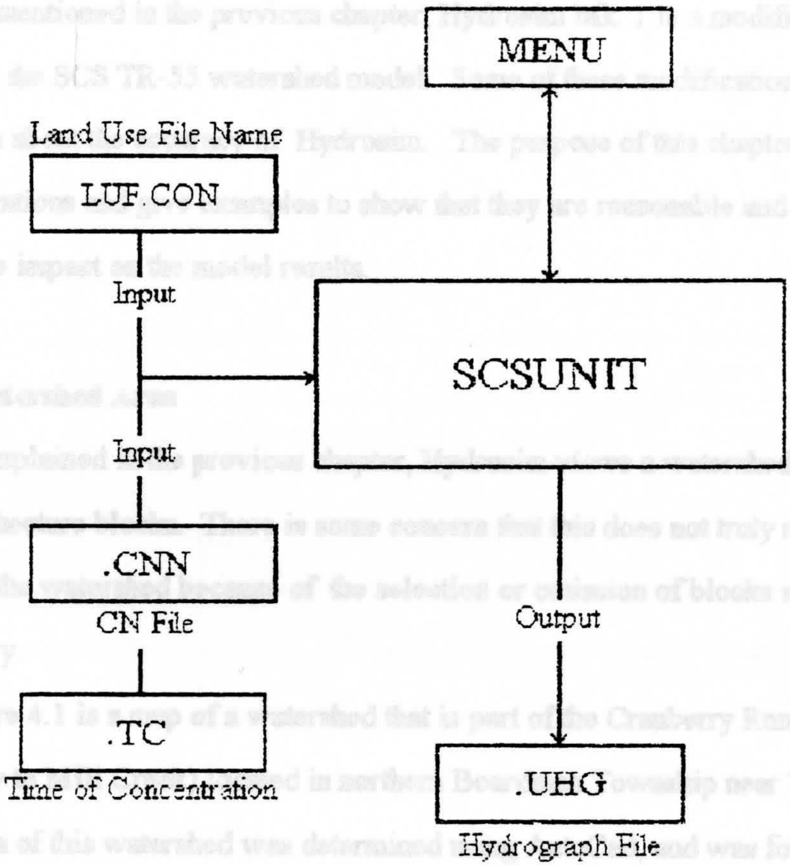


Figure 3.15: Input and output files for program module TABHYDRO.

CHAPTER 4

Explanation of Hydrosim Mk. 1 Proceedures

4.1 Introduction

As mentioned in the previous chapter, Hydrosim Mk. 1 is a modification of the methods used by the SCS TR-55 watershed model. Some of these modifications may cause some concern about the accuracy of Hydrosim. The purpose of this chapter is to explain these modifications and give examples to show that they are reasonable and do not have a negative impact on the model results.

4.2 Watershed Area

As explained in the previous chapter, Hydrosim views a watershed as an arrangement of one hectare blocks. There is some concern that this does not truly represent the actual area of the watershed because of the selection or omission of blocks along the watershed boundary.

Figure 4.1 is a map of a watershed that is part of the Cranberry Run watershed (a tributary to Mill Creek) located in northern Boardman Township near Youngstown, Ohio. The area of this watershed was determined using AutoCad, and was found to be 97.85 hectares. Figure 4.2 is a block representation of the same watershed as viewed by Hydrosim and has an area of 99 hectares. The difference between the actual are and the Hydrosim area is 1.15 hectares, a 1.18% difference. This difference of 1.15 hectares is considered acceptable in view of potential errors in the original 97.85 hectare estimate. The watershed boundaries were determined from a United States Geological Survey 7.5 minute topographic map. These maps are created from aerial surveys and are not entirely accurate. Topographic contours on these maps could have errors of plus or minus 3 to 5 feet (Richard, 1990). Thus the watershed, if surveyed, could have a larger or smaller area than 97.85 hectares.

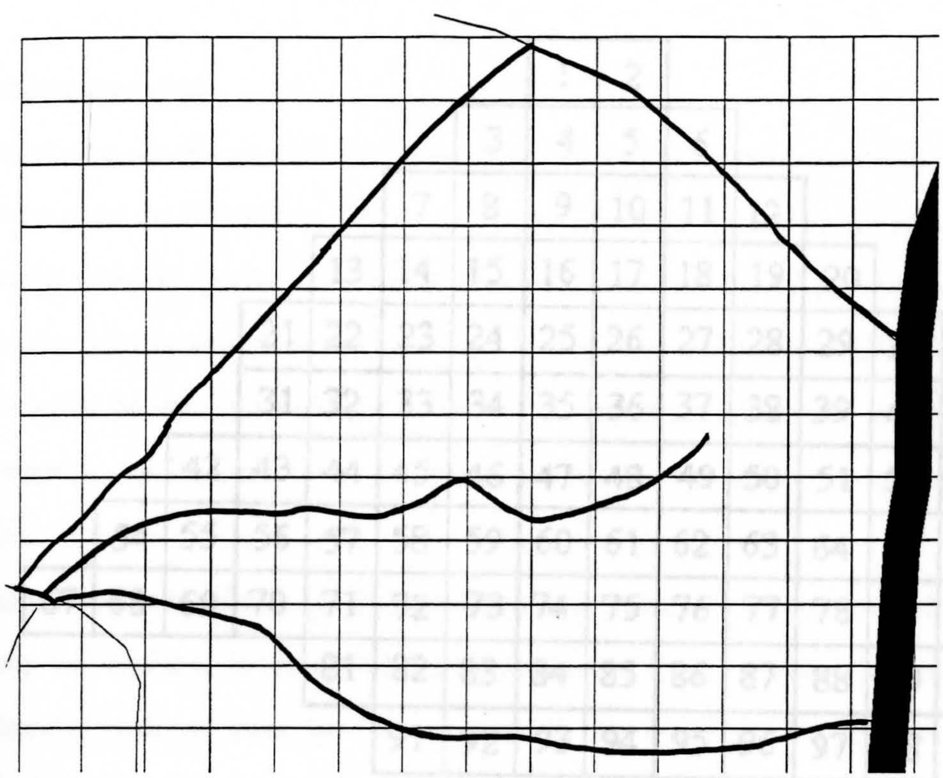


Figure 4.1: **Example Watershed used for Area Comparison.**

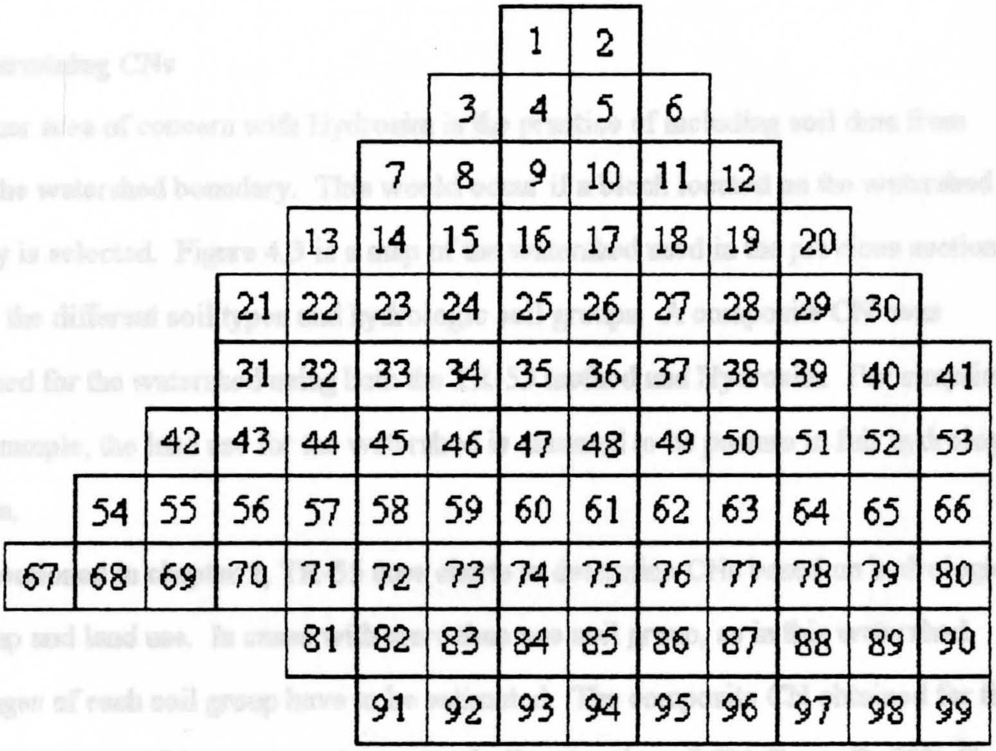


Figure 4.2: Block Representation of Example Watershed.

It is felt that for watersheds less than 10 hectares errors can increase greatly if care is not taken during the blocking out process. Hydrosim can be adjusted to use blocks that are smaller than a hectare to more accurately model smaller watersheds.

4.3 Determining CNs

Another area of concern with Hydrosim is the practice of including soil data from outside the watershed boundary. This would occur if a block located on the watershed boundary is selected. Figure 4.3 is a map of the watershed used in the previous section, showing the different soil types and hydrologic soil groups. A composite CN was determined for the watershed using both the TR-55 method and Hydrosim. For simplicity in this example, the land use for the watershed is assumed to be pasture in fair hydrologic condition.

As mentioned in chapter 2, TR-55 uses charts to determine CNs based on hydrologic soil group and land use. In cases with more than one soil group, as in this watershed, percentages of each soil group have to be estimated. The composite CN obtained for the watershed was 79. This was based on an eyeball estimation of 5% Group B, 90% Group C, and 10 % Group D. Hydrosim determines CNs for each block of the watershed (Figure 4.4). For this example, the average CN obtained for the watershed was 78.41. This shows that the method used by Hydrosim provides a reasonably accurate estimate of the CN for the watershed. In fact, it is felt that the method for determining CNs used by Hydrosim is more structured and convenient than that of TR-55. Hydrosim forces the user to estimate the percentages of each soil type for each individual block. In the previous example, the percentages where estimated 99 times. This reduces the error resulting from an incorrect estimate. The hectare grid also aids in the estimation process.

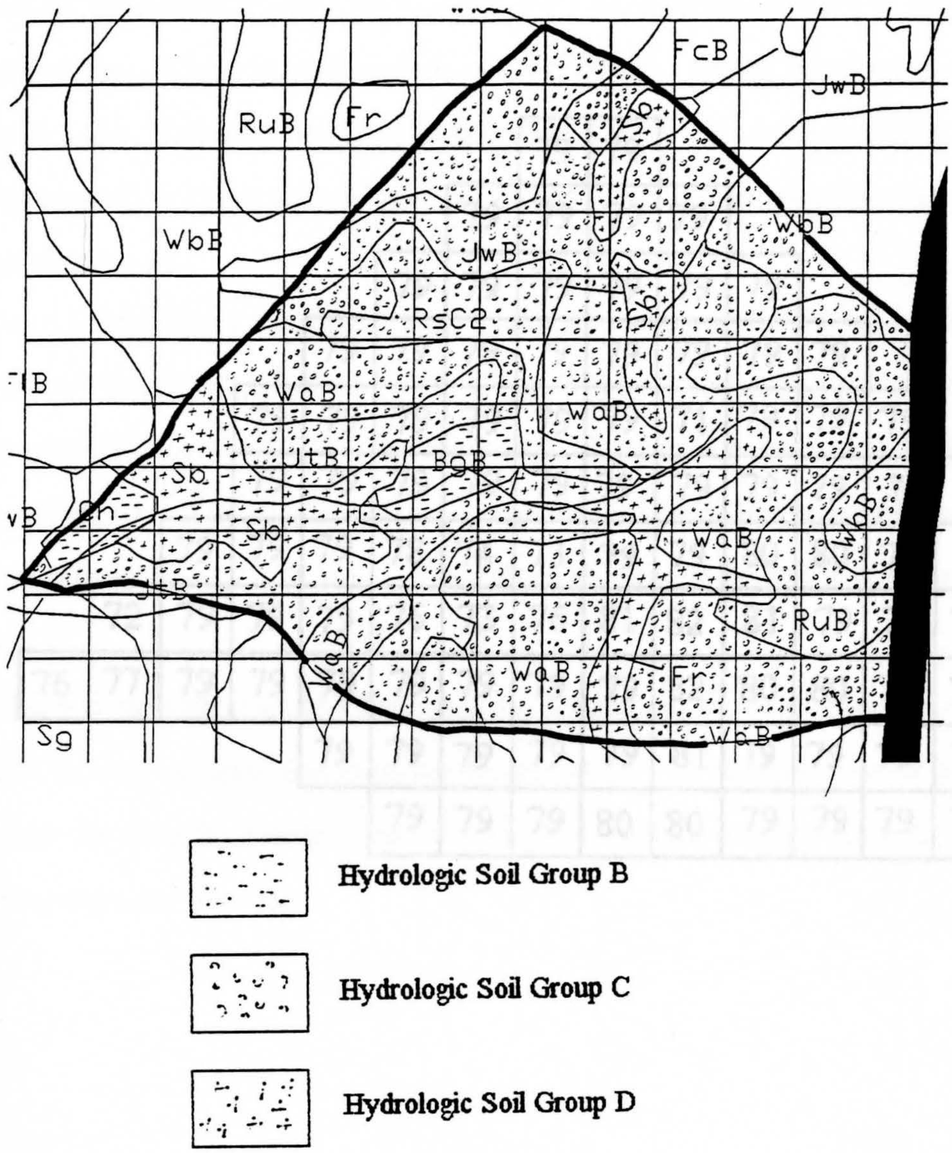


Figure 4.3: Soil Map of Example Watershed Showing Hydrologic Soil Groups.

							79	79					
						79	79	79	79				
					79	79	79	79	79	79			
				79	79	79	79	79	79	79	79		
			79	79	79	79	79	79	71	79	79	79	
			79	79	79	79	79	79	79	79	79	79	79
		79	79	79	78	74	73	79	79	80	80	79	79
	72	79	79	79	76	73	76	81	82	81	79	79	79
76	77	79	79	79	79	79	79	79	82	80	80	79	79
				79	79	79	79	79	81	79	79	79	79
					79	79	79	80	80	79	79	79	79

Figure 4.4: CNs for the Example Watershed as Determined by Hydrosim.

4.4 Time of Concentration

One of the differences between Hydrosim and TR-55 is the way that slopes are handled for overland flow. TR-55 uses the average slope of the flow path to calculate overland flow travel times. Hydrosim uses the slopes indicated by the soil symbols (Table 4.1). When Hydrosim determines the average CN for each block, it also determines the average slope for each block.

To make a comparison, the same example watershed was used but the land was assumed to be woods in fair hydrologic condition. Time of conentration was determined using an average slope of 0.02 ft./ft. and Hydrosim. The results are shown in Table 4.2. The time of concentration using the average slope is 1.71 hours. Hydrosim determined the time of concentration to be 1.73 hours. The difference between the two is 0.02 hour or 1.2 minutes.

It is felt that the method used by Hydrosim for determining the travel time of overland flow might be more accurate than using the average slope. The average slope is just that, the average. By using the average slope of each block, changes in slope along the flow path can be taken into account.

Table 4.1: Soil Slopes Used by Hydrosim (after SCS, 1971).

Soil Symbol	Soil Name	Slope (% Grade)	Hydrologic Soil Group
BeB	Bennington silt loam	4	C
BgB	Bogart loam	4	B
BgC	Bogart loam	9	B
BtB	Bogart loam, till	4	B
BtC2	Bogart loam, till, eroded	9	B
Ca	Canadice silty clay loam	1	D
CdB	Canfield silt loam	4	C
CdC	Canfield silt loam	9	C
CdC2	Canfield silt loam, eroded	9	C
CeB	Canfield, urban	4	C
CgB	Cardington silt loam	4	C
CgC2	Cardington silt loam, eroded	9	C
Ch	Carlisle muck	1	B
Ck	Chagrin loam	1	D
ClB	Chili gravelly loam	4	B
ClC	Chili gravelly loam	9	B
ClD	Chili gravely loam	15	B
CmB	Chili loam	4	B
CmC	Chili loam	9	B
CnE	Chili and Conotton gravely soil	21	B
CnF	Chili and Conotton gravely soil	35	B
CoB	Chili urban	4	B
CoC	Chili urban	9	B
Ct	Condit silt loam	1	D
Da	Damascus loam	1	B
Dc	Damascus loam	1	B
DkC	Dekalb very stony loam	9	C
DkE	Dekalb very stony loam	21	C
DkF	Dekalb very stony loam	35	C
ElB	Ellsworth silt loam	4	C
ElC	Ellsworth silt loam	9	C
ElC2	Ellsworth silt loam, eroded	9	C
ElD2	Ellsworth silt loam, eroded	15	C
ElE2	Ellsworth silt loam, eroded	21	C
ElF	Ellsworth silt loam	35	C
EsF3	Ellsworth silty clay loam	21	C
EuB	Ellsworth urban	4	C
FcA	Fitchville silt loam	1	C
FcB	Fitchville silt loam	4	C
FhB	Fitchville silt loam, till substrate	4	C
FlB	Fitchville urban	4	C

Table 4.1: Continued.

Soil Symbol	Soil Name	Slope (% Grade)	Hydrologic Soil Group
Fr	Frenchtown silt loam	1	D
GbB	Geeburg silt loam	4	C
GbB2	Geeburg silt loam, eroded	4	C
GbC	Geeburg silt loam	9	C
GbD	Geeburg silt loam	15	C
GeC2	Geeburg silty clay loam, eroded	9	C
GeC3	Geeburg silty clay loam, very eroded	9	C
GeD2	Geeburg silty clay loam, eroded	15	C
GeE2	Geeburg silty clay loam, eroded	21	C
GfB	Glenford silt loam	4	C
GfC2	Glenford silt loam, eroded	9	C
Gp	Gravel pit	0	A
HoB	Hornell silt loam	4	D
JtA	Jimtown loam	1	C
JtB	Jimtown loam	4	C
JuB	Jimtown loam, till substrate	4	C
JwB	Jimtown urban	1	C
Km	Kerston muck	1	D
Lb	Lobdell loam	1	B
Lc	Lorain silty clay loam	1	C
LdB	Loudonville loam	4	C
LdC2	Loudonville loam, eroded	9	C
LdD2	Loudonville loam, eroded	15	C
LdE2	Loudonville loam, eroded	21	C
LrB	Loudonville urban, undulating	4	C
LrC	Loudonville urban, rolling	9	C
Ls	Luray silt loam	1	C
Ly	Luray silty clay loam	1	C
MgA	Mahoning silt loam	1	D
MgB	Mahoning silt loam	4	D
MhB	Mahoning urban	4	D
Mn	Marengo silty clay loam	1	C
MsB	Muskingum channery silt loam	1	C
MsC2	Muskingum channery silt loam, ero.	9	C
MsD2	Muskingum channery silt loam, ero.	15	C
MsE2	Muskingum channery silt loam, ero.	21	C
MsF2	Muskingum channery silt loam, ero.	35	C
Od	Olmsted loam	1	C
Ov	Orville silt loam	1	C
Pa	Papakating silt loam	1	C
Pc	Papakating silt clay loam	1	C

Table 4.1: Continued.

Soil Symbol	Soil Name	Slope (% Grade)	Hydrologic Soil Group
RaA	Ravenna silt loam	1	C
RaB	Ravenna silt loam	4	C
ReA	Remsen silt loam	1	D
ReB	Remsen silt loam	4	D
RmB	Remsen urban	1	D
RsB	Rittman silt loam	4	C
RsC	Rittman silt loam	9	C
RsC2	Rittman silt loam, eroded	9	C
RsD2	Rittman silt loam, eroded	15	C
RuB	Rittman urban	4	C
Sb	Sebring silt loam	1	C
Sg	Sebring urban	1	C
SsB	Strip mine spoils, rock	4	A
SsC	Strip mine spoils, rock	9	A
SsF	Strip mine spoils, rock	35	A
StB	Strip mine spoils, loamy	4	C
StC	Strip mine spoils, loamy	9	C
StF	Strip mine spoils, loamy	35	C
SuB	Strip mine spoils, clayey	4	D
TrA	Trumbull silt loam	1	D
TrB	Trumbull silt loam	4	D
Tu	Trumbull urban	1	D
WaA	Wadsworth silt loam	1	C
WaB	Wadsworth silt loam	4	C
WbB	Wadsworth urban	4	C
Wc	Wayland silt loam	1	C
WrF2	Wooster loam, eroded	35	C
WsB	Wooster silt loam	4	C
WsC2	Wooster silt loam, eroded	9	C
WsD2	Wooster silt loam, eroded	15	C
WsE2	Wooster silt loam, eroded	22	C

Table 4.2: Results of time of concentration comparison.

	TR-55	Hydrosim
Sheet flow	**1.34 hr.**	**1.23 hr.**
Shallow concentrated flow	**0.25 hr.**	**0.37 hr.**
Open channel flow	**0.13 hr.**	**0.13 hr.**
Time of concentration	**1.71 hr.**	**1.73 hr.**

CHAPTER 5

Effects of Hydrologic Soil Group and Land Use on Runoff

5.1 Introduction

The purpose of this chaper is to use Hydrosim to examine the effects of hydrologic soil type and land use on runoff. A hypothetical watershed was used for this purpose.

5.2 The Watershed

The hypothetical watershed used for this analysis is shown in Figure 5.1. The watershed has an area of 10 hectares and the stream is 656 feet long with a width of 5 feet and a depth of 3 feet. The stream gradient is 0.01 ft./ft.

The watershed was modelled using each of the four hydrologic soil groups. Each soil group was applied for the entire area of the watershed. Soil groups were not mixed. Four land uses were applied to each soil group. These land uses are: woods in fair hydrologic condition (land use # 64); meadow (land use #56); homes with a lot size of 0.25 acre (land use # 14); and pavement (land use # 4). The land uses were applied to the entire area of the watershed.

The selection of the four land uses was based on a logical progression of development for the Youngstown area. Originally, the area was wooded; a fair hydrologic condition was selected to represent the average condition for the area. The first step in development in many areas was to clear away trees to create crop land, pastures and meadows. Because this area had a fair amount of agricultural activity in the past, meadow seemed like a logical selection. The next step in development was considered to be conversion of the meadow to a housing subdivision or to pavement (and/or other impervious surfaces) that would be representative of comercial development.

Figure 5.1: Hypothetical Watershed Used to Examine Effects of Hydrologic Soil Group and Land Use on Runoff.

5.3 Determining Runoff

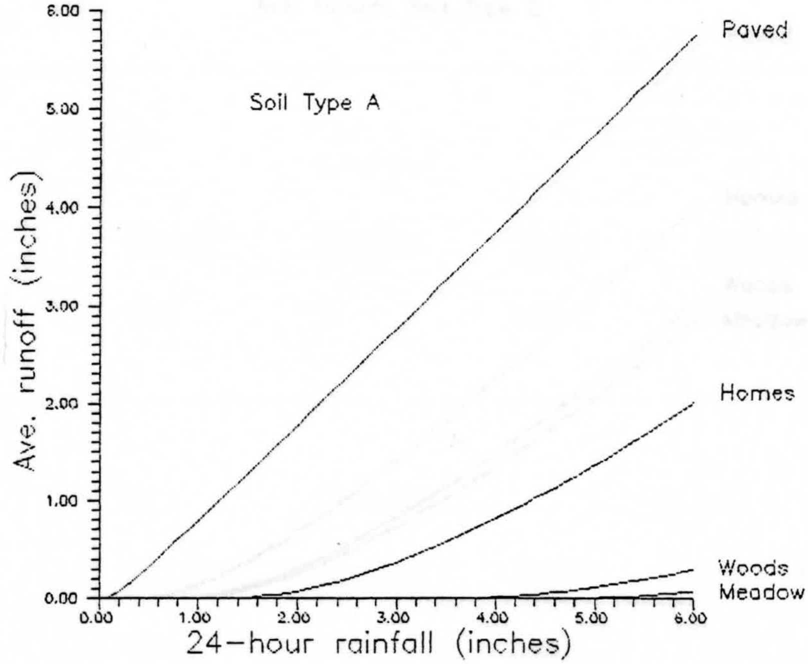
Hydrosim was used to make the runoff calculations. A 24 hour rainfall of 4 inches was used. The results of the runoff calculations can be found in Table 5.1. Figures 5.2 and 5.3 are graphs showing the average runoff for 24 hour rainfalls ranging from 0 to 6 inches.

5.4 Results

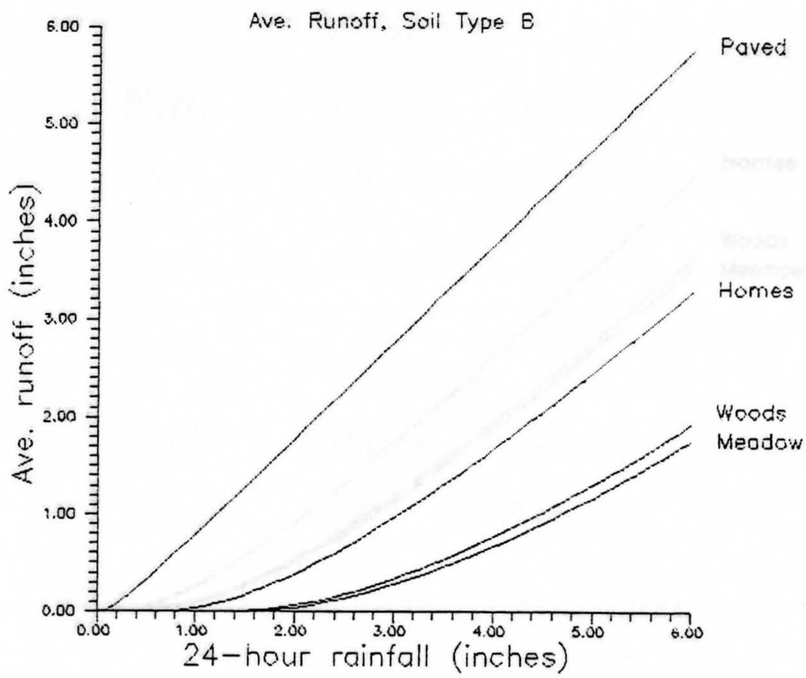
By examining Table 5.1, some expected trends can be seen. It is not surprising that the least amount of runoff is associated with soil group A and the most with soil group D. Since soil group A has the highest infiltration rate, it should have the lowest amount of runoff. It is also not surprising that the predicted runoff from the paved watershed is the same for all soil groups. The assumption is that the pavement separates the precipitation from the soil. If the pavement was severely cracked or brocken up so that the precipitation could reach the soil, then a difference between soil types would be seen.

Table 5.2 shows a comparision of the runoff predictions. From this it can be seen that, by changing the land use from woods to meadow, a reduction in the amount of runoff is predicted. This can be important because if the land use is subsequently changed from meadow to homes or pavement, the increase in runoff would have a greater relative magnitude than if the land use was changed from woods. For example, for soil group C, changing the land use from woods to homes results in a 49.67 percent increase in runoff. Changing the land use from meadow to homes increases the amount of runoff by 64.75 percent even though the ultimate amount of runoff is the same.

Of the four hydrologic soil groups, group A shows the greatest increase in runoff due to development. Changing the land use from woods to pavement increases the amount of runoff by 37,600 percent. Soil group D shows the least impact of development, with an runoff increase of 92.35 percent when the land use is changed from woods to pavement.

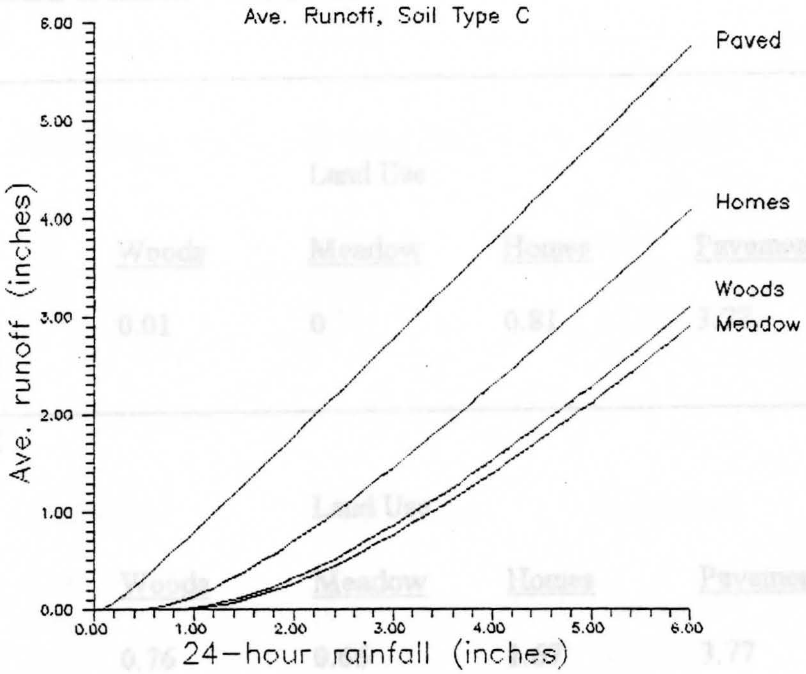


(a)

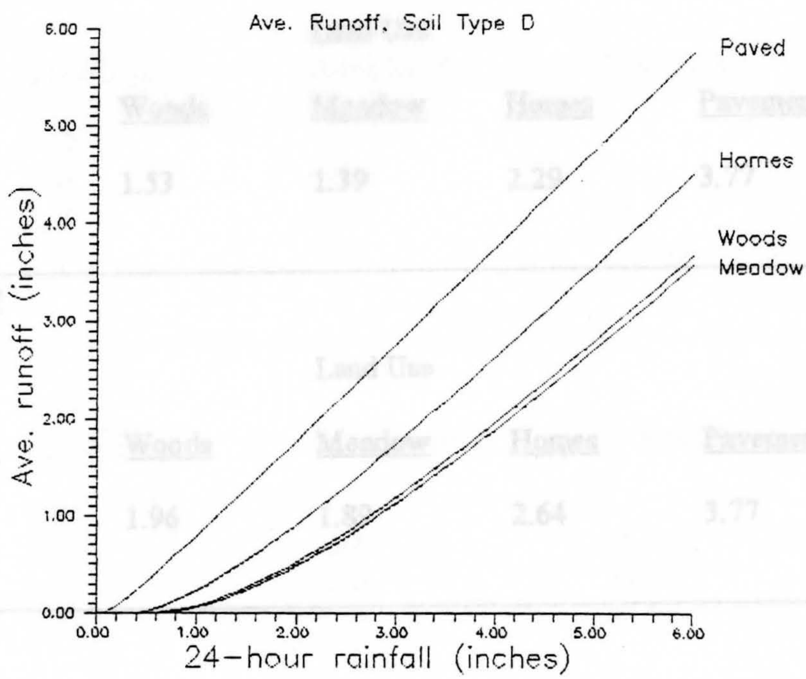


(b)

<u>Figure 5.2</u>: Runoff for a 24-hour rainfall ranging from 0 to 6 inches. (a) Hydrologic soil group A. (b) Hydrologic soil group B.



(a)



(b)

Figure 5.3: Runoff for a 24-hour rainfall ranging from 0 to 6 inches. (a) Hydrologic soil group C. (b) Hydrologic soil group D.

Table 5.1: Results of Runoff Calculations

Soil Group A

	Land Use			
	Woods	**Meadow**	**Homes**	**Pavement**
Runoff (in.)	0.01	0	0.81	3.77

Soil Group B

	Land Use			
	Woods	**Meadow**	**Homes**	**Pavement**
Runoff (in.)	0.76	0.66	1.67	3.77

Soil Group C

	Land Use			
	Woods	**Meadow**	**Homes**	**Pavement**
Runoff (in.)	1.53	1.39	2.29	3.77

Soil Group D

	Land Use			
	Woods	**Meadow**	**Homes**	**Pavement**
Runoff (in.)	1.96	1.89	2.64	3.77

Table 5.2: Analysis of Runoff

Soil Group A

Land Use	Runoff (in.)	Increase (in.)	% Increase
Woods	0.01		
Meadow	0	-0.01	-100
Homes	0.81	0.81	8,000
Pavement	3.77	3.76	37,600

Soil Group B

Land Use	Runoff (in.)	Increase (in.)	% Increase
Woods	0.76		
Meadow	0.66	-0.1	-13.16
Homes	1.67	0.91	119.74
Pavement	3.77	3.01	396.05

Soil Group C

Land Use	Runoff (in.)	Increase (in.)	% Increase
Woods	1.53		
Meadow	1.39	-0.14	-9.15
Homes	2.29	0.76	49.67
Pavement	3.77	2.24	146.41

Soil Group D

Land Use	Runoff (in.)	Increase (in.)	% Increase
Woods	1.96		
Meadow	1.89	-0.07	-3.57
Homes	2.64	0.68	34.69
Pavement	3.77	1.81	92.35

5.5 Conclusions

From this study, it can be seen that the amount of runoff from a watershed is primarily controlled by the hydrologic soil groups contained within the watershed. Soils of group A show the greatest sensitivity to development while soils of group D show the least. In an effort to control dramatic increases in runoff, development should, if possible, be done on soils of group C and D. Development of soils of group A should be avoided.

CHAPTER 6

Effects of Development on Time of Concentration, Peak Discharge, and Time of Peak Discharge

6.1 Introduction

This chapter examines the effects of development on the time of concentration, peak discharge, and time of peak discharge. The same 10 hectare watershed that was used in the previous chapter is used here. The watershed was modelled with the same soil and land use combinations as before, however, slopes ranging from 1 to 15 percent were investigated.

6.2 Time of Concentration

Hydrosim was used to determine the time of concentration using the same travel path for all combinations of ground slope and land use. A rainfall amount of 4 inches was used. Table 6.1 gives the resulting times of concentration.

From Table 6.1 it can be seen that the time of concentration is dependent upon the land use and the ground slope. The predicted time of concentration is independent of the type of soil within the watershed. Figure 6.1 is a graph of the times of concentration versus ground slope for each of the four land uses. It can be seen that pavement has the shortest time of concentration and woods the longest. It can also be seen that when the land use is changed from meadow to homes, the time of concentration is increased.

The ground slope of the watershed has an effect on the time of concentration, but this effect is not as great as changes in land use. From Figure 6.1, it can be seen that an increase in ground slope will reduce the time of concentration with the greatest amount of reduction occuring at slopes between 1 and 5 percent. This reduction continues, but is less pronounced, for greater slopes.

Table 6.1: Modelled Times of Concentration for Land Uses with Various Ground Slopes.

Land Use	Ground Slope (percent)	Time of Concentration (hours)
Woods	1	0.52
	2	0.48
	5	0.43
	10	0.41
	15	0.40
Meadow	1	0.27
	2	0.23
	5	0.20
	10	0.18
	15	0.17
Homes	1	0.31
	2	0.27
	5	0.24
	10	0.22
	15	0.21
Pavement	1	0.19
	2	0.16
	5	0.12
	10	0.11
	15	0.10

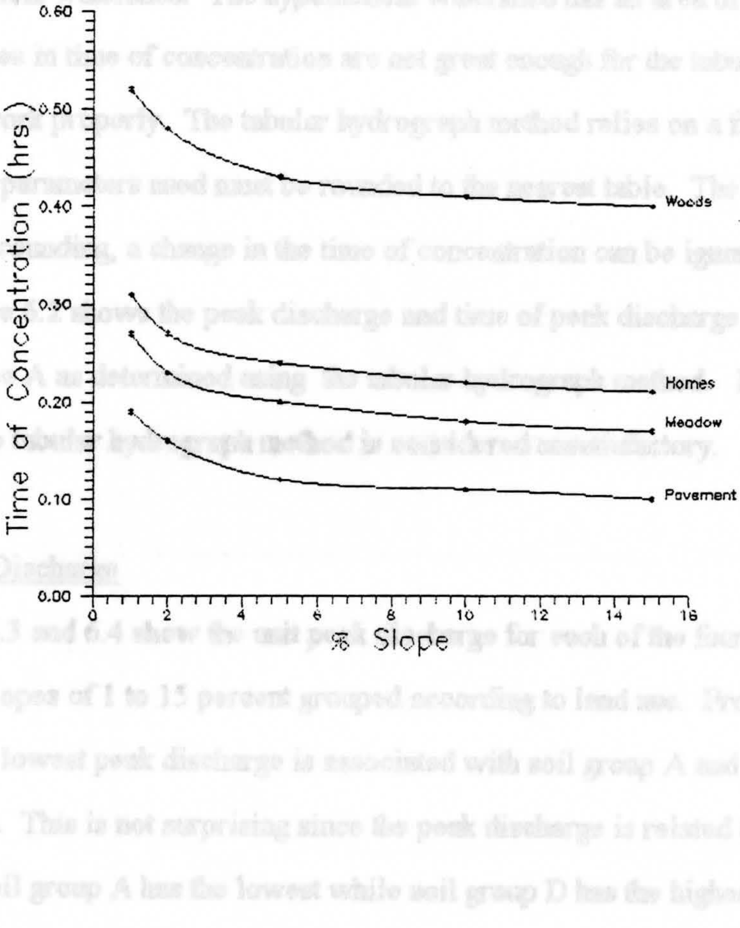


Figure 6.1: Time of Concentration for Each Land Use With Respect to Ground Slope

6.3 Peak Discharge and Time of Peak Discharge

6.3.1 Introduction

The peak discharge and the time of the peak discharge were determined using the SCS unit hydrograph method. The tabular hydrograph method proved to be unsatisfactory for the hypothetical watershed. The hypothetical watershed has an area of 10 hectares so most of the changes in time of concentration are not great enough for the tabular hydrograph method to work properly. The tabular hydrograph method relies on a fixed number of tables. The parameters used must be rounded to the nearest table. The result is that through this rounding, a change in the time of concentration can be ignored if it is not very large. Figure 6.2 shows the peak discharge and time of peak discharge for the watershed with soil type A as determined using the tabular hydrograph method. From this it can be seen why the tabular hydrograph method is considered unsatisfactory.

6.3.2 Peak Discharge

Figures 6.3 and 6.4 show the unit peak discharge for each of the four hydrologic soil groups for slopes of 1 to 15 percent grouped according to land use. From this it can be seen that the lowest peak discharge is associated with soil group A and the highest with soil group D. This is not surprising since the peak discharge is related to the amount of runoff and soil group A has the lowest while soil group D has the highest. The peak discharge for pavement is the same for all of the soil groups because it is assumed that the soil is completely covered.

The effects of slope on peak discharge can also be seen in Figures 6.3 and 6.4. Changes in ground slope have the greatest effect on soil group A and the least on group D. Just as with the time of concentration, the greatest change in peak discharge occurs when the ground slope changes from 1 to 5 percent. Of the four land uses, it appears that meadow is the most sensitive to slope changes.

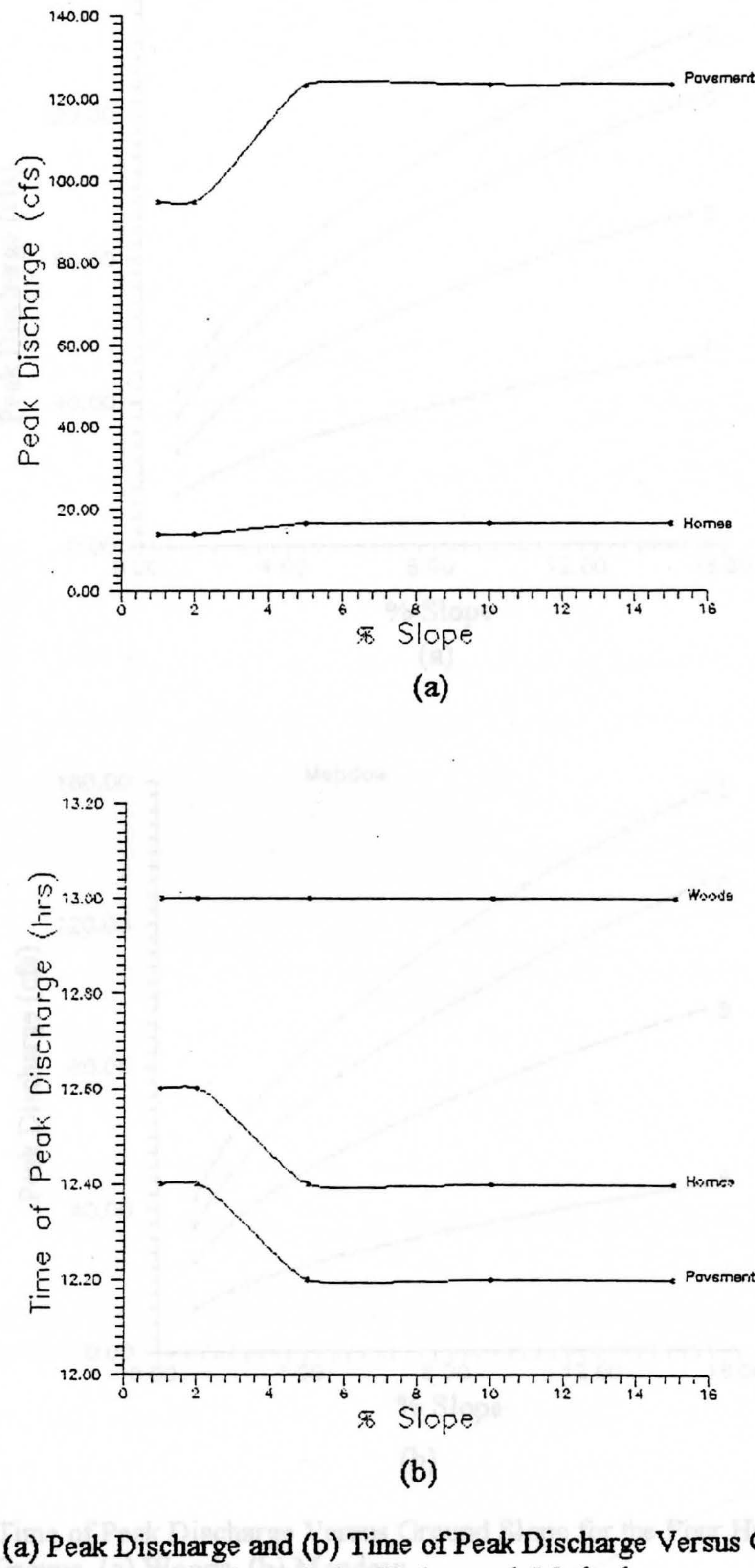
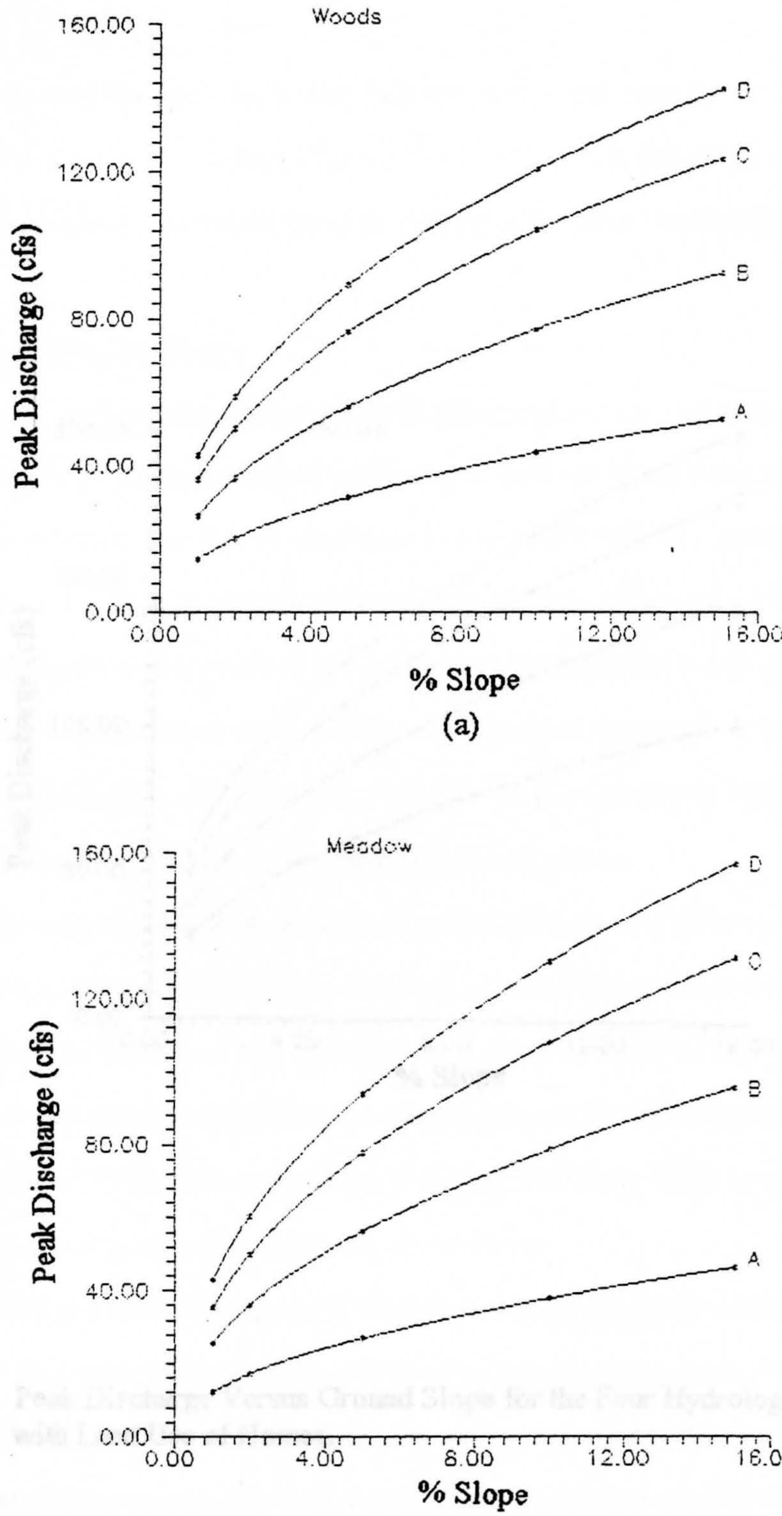


Figure 6.2: (a) Peak Discharge and (b) Time of Peak Discharge Versus Ground Slope as Determined by the Tabular Hydrograph Method.



(a)

(b)

Figure 6.3: Time of Peak Discharge Versus Ground Slope for the Four Hydrologic Soil Groups (a) Woods (b) Meadow.

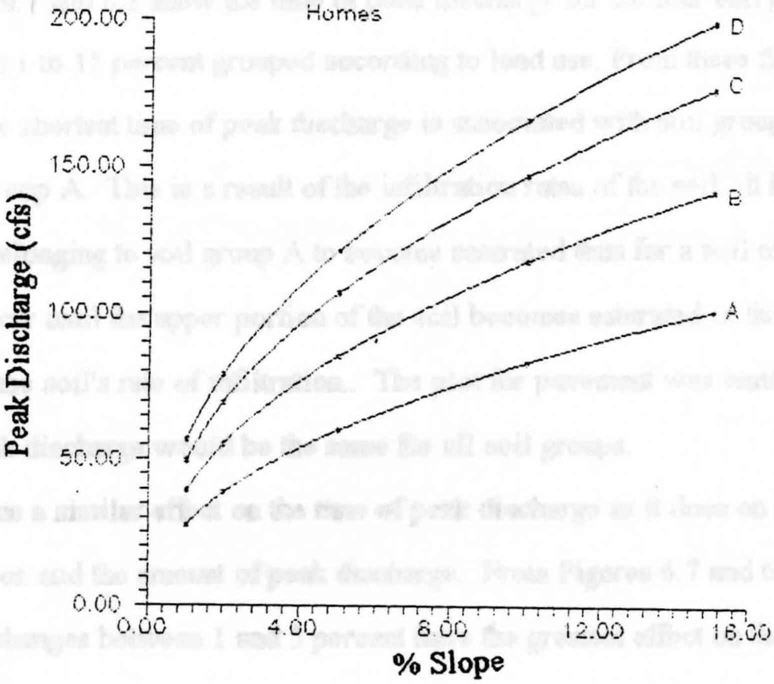


Figure 6.4: **Peak Discharge Versus Ground Slope for the Four Hydrologic Soil Groups, with Land Use of Homes.**

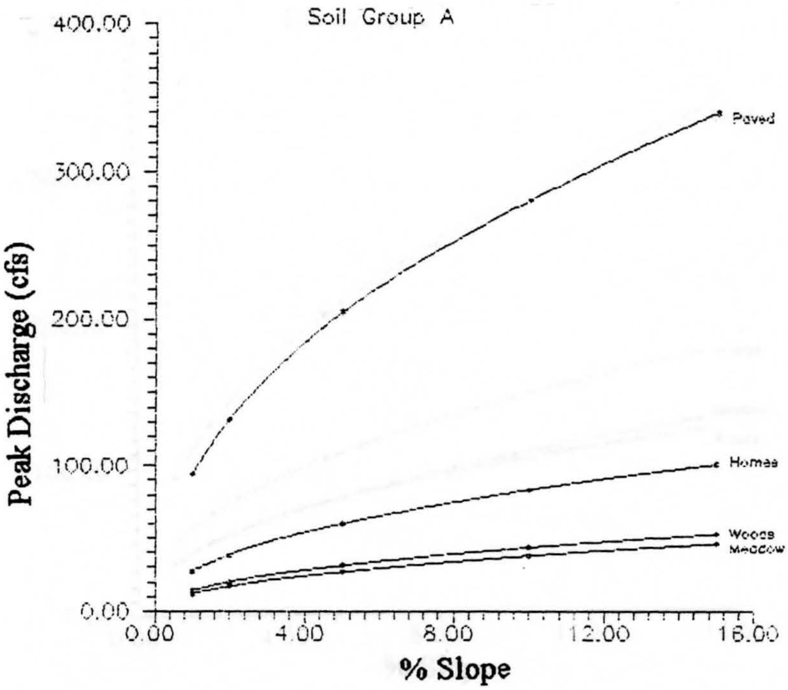
Figures 6.5 and 6.6 show the peak discharge for the four land uses grouped by hydrologic soil group. From these figures it can be seen that changing the land use to pavement dramatically increases the peak discharge for all of the hydraulic soil groups.

6.3.3 Time of Peak Discharge

Figures 6.7 and 6.8 show the time of peak discharge for the four soil groups for ground slopes from 1 to 15 percent grouped according to land use. From these figures it can be seen that the shortest time of peak discharge is associated with soil group D and the longest with soil group A. This is a result of the infiltration rates of the soil. It has to rain longer for a soil belonging to soil group A to become saturated than for a soil of group D. Runoff will not occur until the upper portion of the soil becomes saturated or the rainfall is falling faster than the soil's rate of infiltration.. The plot for pavement was omitted because the time of peak discharge would be the same for all soil groups.

Slope has a similar effect on the time of peak discharge as it does on the time of concentration and the amount of peak discharge. From Figures 6.7 and 6.8 it can be seen that slope changes between 1 and 5 percent have the greatest effect on the time of peak discharge. It can also be seen that as the slope increases the differences between each soil group decreases. Of the four soil groups, it appears that none of the groups are more sensitive to an increase in slope than any of the others.

Figures 6.9 and 6.10 show the time of peak discharge for the four land uses grouped by soil group. One item of intrest is the effects of soil group on the time of peak concentration for the land uses of woods and meadow. For soil group A, meadow has a longer time of peak discharge than woods. For soil groups B and C, the time of peak discharge are essentially the same. For soil group D, the time of peak discharge for meadow becomes shorter than that of woods.



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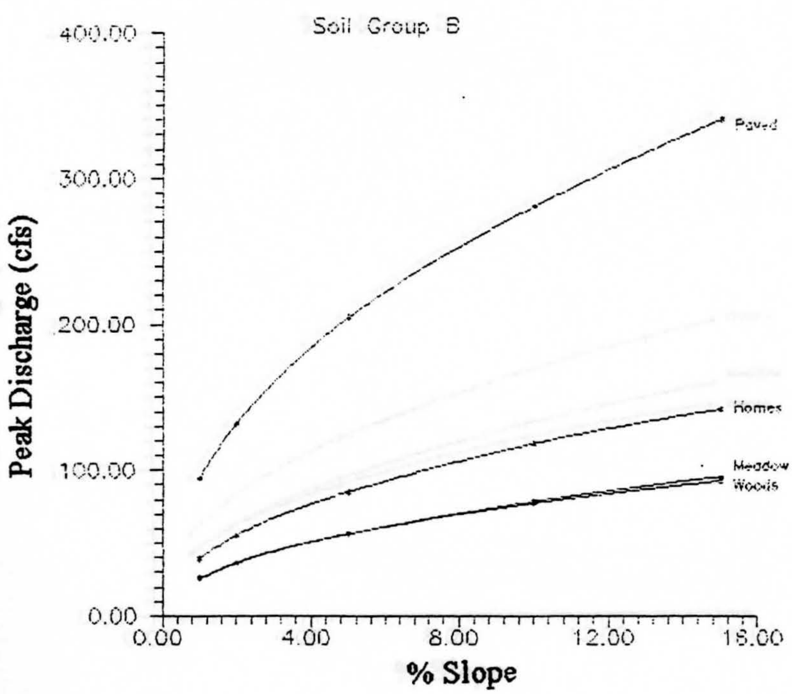


(b)

Figure 6.5: Peak Discharge Versus Ground Slope for the Four Land Uses (a) Hydrologic Soil Group A (b) Hydrologic Soil Group B.

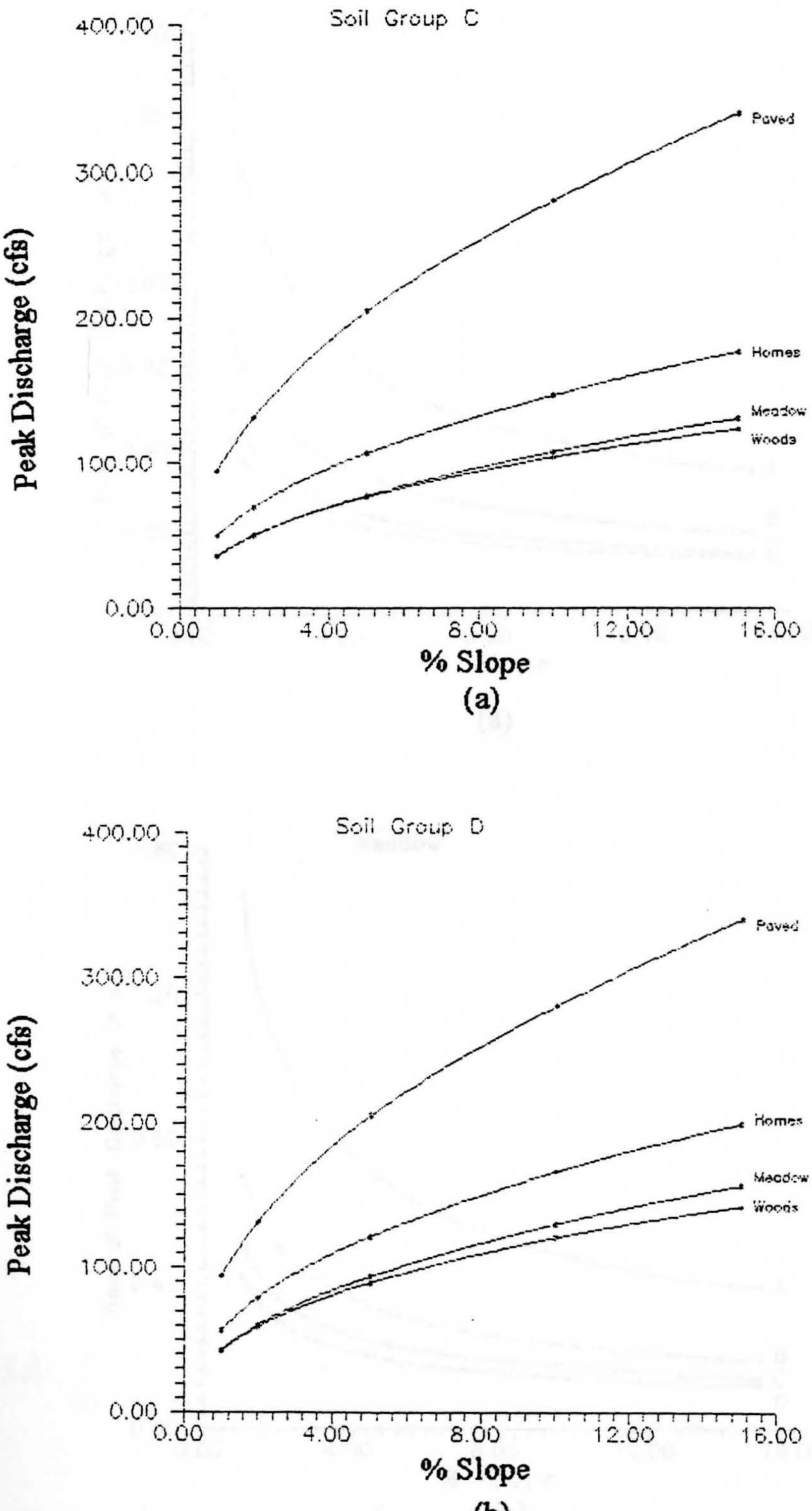
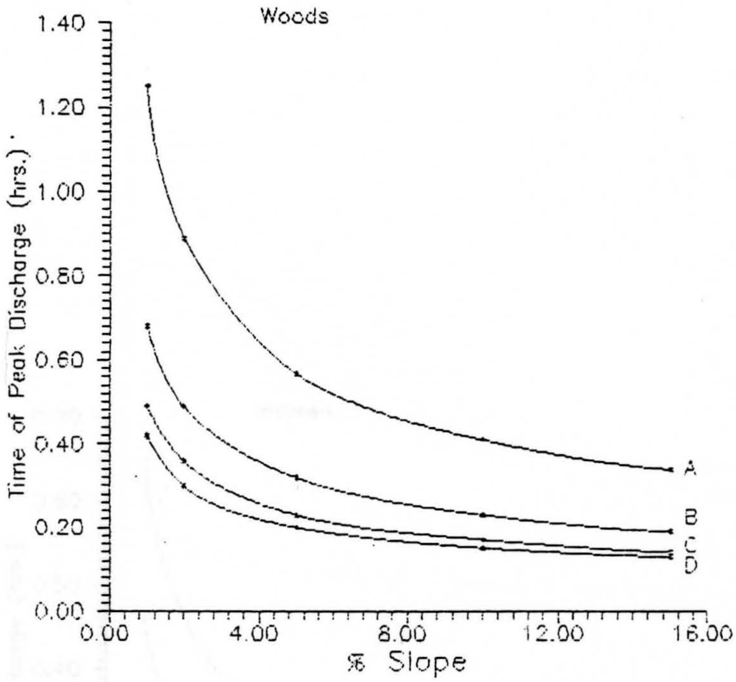


Figure 6.6: Peak Discharge Versus Ground Slope for the Four Land Uses (a) Hydrologic Soil Group C (b) Hydrologic Soil Group D.



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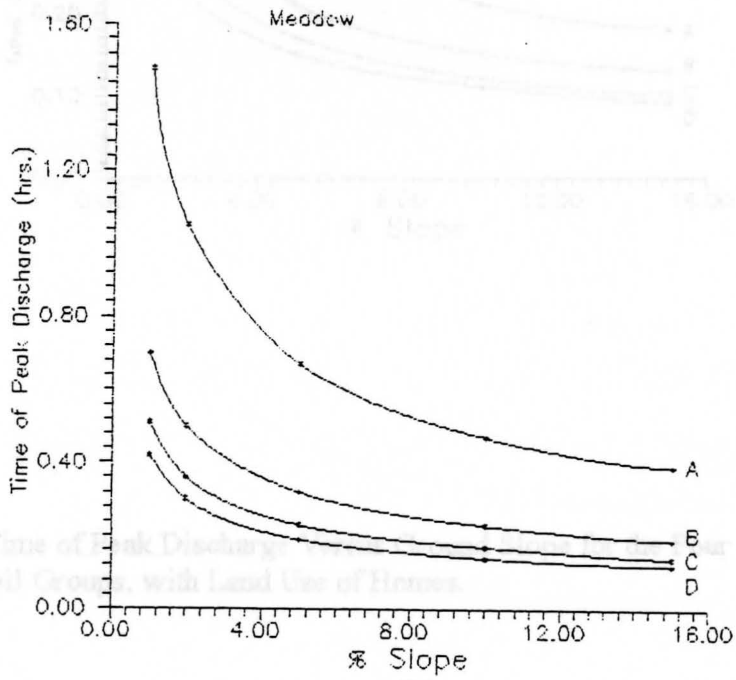

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Figure 6.7: Time of Peak Discharge Versus Ground Slope for the Four Hydrologic Soil Groups (a) Woods (b) Meadow.

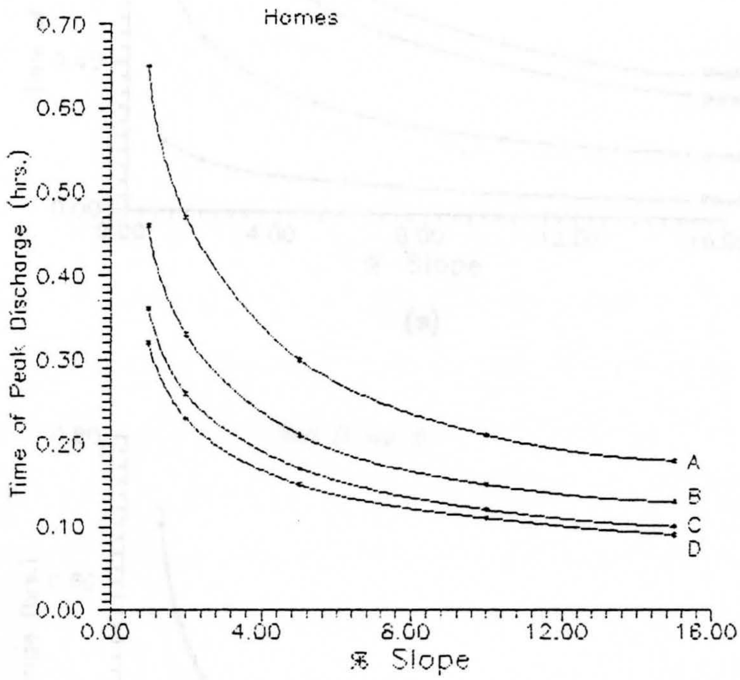
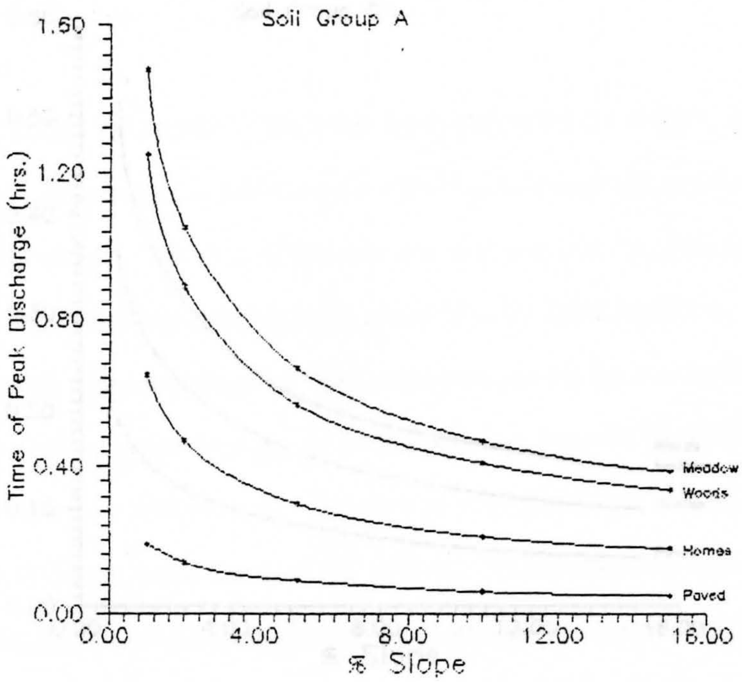
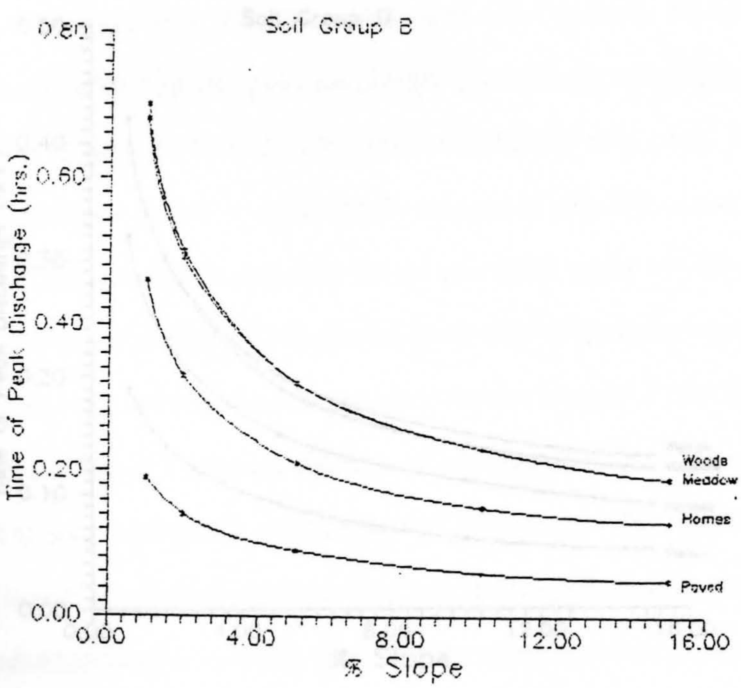


Figure 6.8: Time of Peak Discharge Versus Ground Slope for the Four Hydrologic Soil Groups, with Land Use of Homes.



(a)



(b)

Figure 6.9: Time of Peak Discharge Versus Ground Slope for the Four Land Uses (a) Hydrologic Soil Group A (b) Hydrologic Soil Group B.

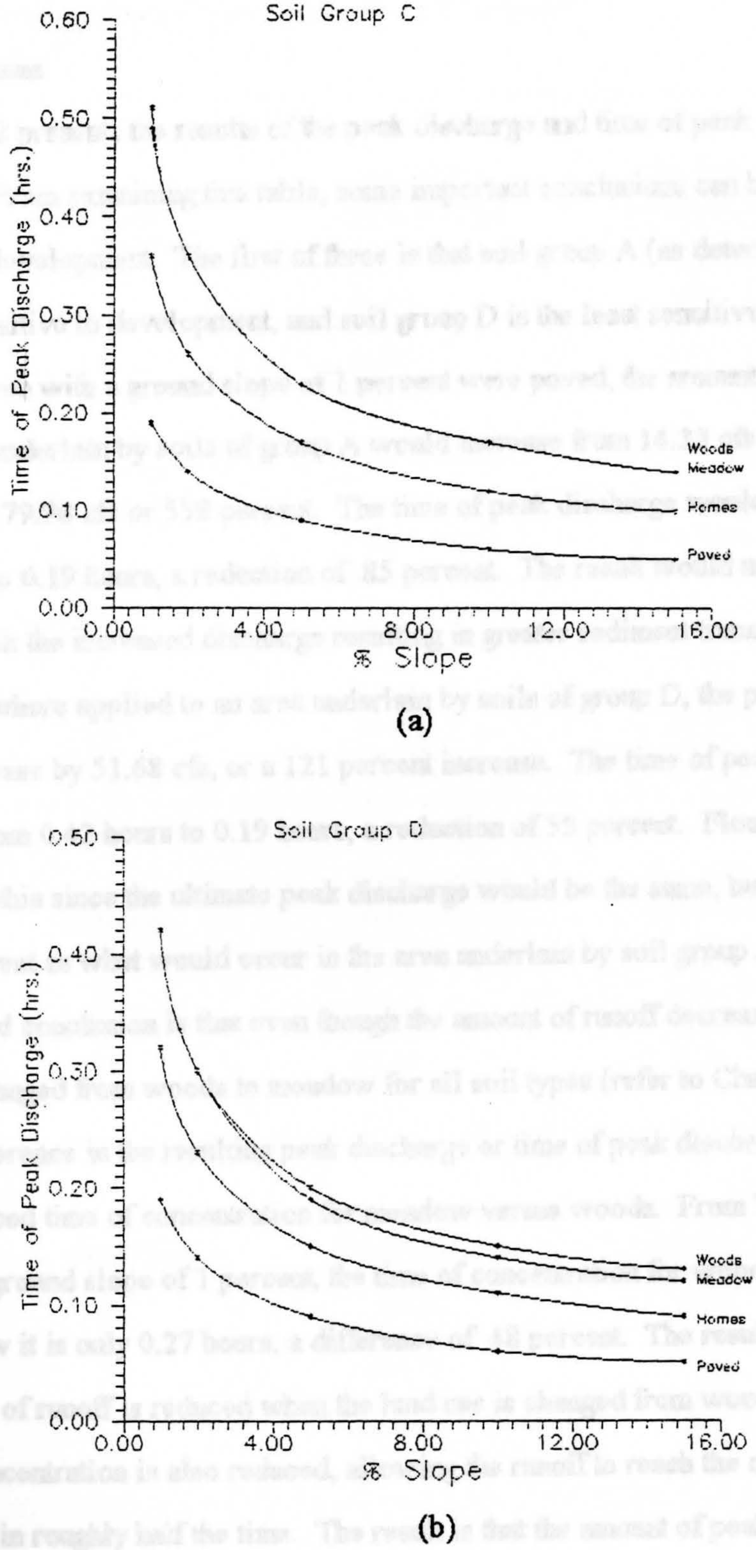


Figure 6.10: Time of Peak Discharge Versus Ground Slope for the Four Land Uses (a) Hydrologic Soil Group C (b) Hydrologic Soil Group D.

6.4 Conclusions

Table 6.2 presents the results of the peak discharge and time of peak discharge modelling. From examining this table, some important conclusions can be drawn concerning development. The first of these is that soil group A (as determined before) is the most sensitive to development, and soil group D is the least sensitive. For example, if a wooded area with a ground slope of 1 percent were paved, the amount of peak discharge for an area underlain by soils of group A would increase from 14.33 cfs to 94.31 cfs, an increase of 79.98 cfs or 558 percent. The time of peak discharge would decrease from 1.25 hours to 0.19 hours, a reduction of 85 percent. The result would most likely be flooding with the increased discharge resulting in greater sediment transport. If the same conditions where applied to an area underlain by soils of group D, the peak discharge would increase by 51.68 cfs, or a 121 percent increase. The time of peak discharge would decrease from 0.42 hours to 0.19 hours, a reduction of 55 percent. Flooding may also result from this since the ultimate peak discharge would be the same, but the change would not be as great as what would occur in the area underlain by soil group A.

A second conclusion is that even though the amount of runoff decreased when the land use was changed from woods to meadow for all soil types (refer to Chapter 5), there is not a great difference in the resulting peak discharge or time of peak discharge. This is a result of the reduced time of concentration for meadow versus woods. From Table 6.1 it can be seen for a ground slope of 1 percent, the time of concentration for woods is 0.52 hours and for meadow it is only 0.27 hours, a difference of 48 percent. The result is that even though the amount of runoff is reduced when the land use is changed from woods to meadow the time of concentration is also reduced, allowing the runoff to reach the outlet of the watershed in roughly half the time. The result is that the amount of peak discharge is not greatly reduced.

A final conclusion is that the ground slope affects the peak discharge and time of peak discharge for all soil groups and land uses equally. Different ground slopes were

Table 6.2: Peak Discharge and Time of Peak Discharge.

Soil Group A

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Woods	1	14.33	1.25
	2	20.10	0.89
	5	31.34	0.57
	10	43.60	0.41
	15	52.75	0.34

Soil Group A

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Meadow	1	12.13	1.48
	2	17.12	1.05
	5	26.92	0.67
	10	37.88	0.47
	15	46.22	0.39

Soil Group A

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Homes	1	27.41	0.65
	2	38.49	0.47
	5	59.98	0.30
	10	83.44	0.21
	15	101.14	0.18

Soil Group A

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Pavement	1	94.31	0.19
	2	131.38	0.14
	5	204.77	0.09
	10	280.75	0.06
	15	340.45	0.05

Table 6.2: Continued

Soil Group B

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Woods	1	26.22	0.68
	2	36.55	0.49
	5	56.33	0.32
	10	77.36	0.23
	15	92.64	0.19

Soil Group B

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Meadow	1	25.55	0.70
	2	35.96	0.50
	5	56.24	0.32
	10	78.66	0.23
	15	95.56	0.19

Soil Group B

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Homes	1	39.30	0.46
	2	55.01	0.33
	5	85.22	0.21
	10	117.93	0.15
	15	141.78	0.13

Soil Group B

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Pavement	1	94.31	0.19
	2	131.38	0.14
	5	204.77	0.09
	10	280.75	0.06
	15	340.45	0.05

Table 6.2: Continued

Soil Group C

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Woods	1	36.22	0.49
	2	50.21	0.36
	5	76.62	0.23
	10	104.18	0.17
	15	123.58	0.14

Soil Group C

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Meadow	1	35.48	0.51
	2	49.84	0.36
	5	77.62	0.23
	10	107.91	0.17
	15	130.80	0.14

Soil Group C

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Homes	1	49.69	0.36
	2	69.39	0.26
	5	106.79	0.17
	10	147.06	0.12
	15	176.72	0.10

Soil Group C

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Pavement	1	94.31	0.19
	2	131.38	0.14
	5	204.77	0.09
	10	280.75	0.06
	15	340.45	0.05

Table 6.2: Continued

Soil Group D

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Woods	1	42.63	0.42
	2	58.83	0.30
	5	89.38	0.20
	10	120.66	0.15
	15	142.26	0.13

Soil Group D

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Meadow	1	43.01	0.42
	2	60.32	0.30
	5	93.67	0.19
	10	130.02	0.14
	15	156.77	0.12

Soil Group D

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Homes	1	56.68	0.32
	2	79.01	0.23
	5	121.21	0.15
	10	166.21	0.11
	15	199.54	0.09

Soil Group D

Land Use	Slope (%)	Peak Dischrge (cfs)	Peak Time (hours)
Pavement	1	94.31	0.19
	2	131.38	0.14
	5	204.77	0.09
	10	280.75	0.06
	15	340.45	0.05

modelled to see if a certain soil group or land use would be more sensitive to a certain slope than others. From Table 6.2, it can be seen that the effects of increasing the ground slope are very similar for all soil groups and land uses.

CHAPTER 7

Incremental Effects of Development on a Watershed

7.1 Introduction

In the previous two chapters, the effects of development on a hypothetical watershed were examined. The land uses for this development were applied for the entire watershed area at once. In this chapter, the development is taken incrementally to examine the changes in runoff and hydrographs in an effort to determine if there is some threshold below which development can take place without seriously impacting the watershed.

7.2 The Watershed

The same hypothetical watershed that was used in the past two chapters was used here (Figure 7.1). The watershed was given a soil from hydrologic soil group C with a ground slope of 4 percent. This was choosen because it appears to be the most common soil group and slope for most of the Mill Creek watershed. The initial land was woods in fair hydrologic condition (land use number 64). A worst case scenerio was considered by changing the land use from woods to pavement (land use number 4) at 10 percent intervals.

7.3 Runoff

Hydrosim was used to model the effects of changing the land use from woods to pavement. A 24-hour rainfall of four inches was used. The results of this modelling is presented in Table 7.1. Figure 7.2 is a graph of runoff resulting from a 24-hour rainfall ranging from 0 to 6 inches for various amounts of development.

7.3.1 Analysis of Runoff Data

Table 7.2 presents an analysis of the runoff data obtained from the modelling. It can be seen from Table 7.2 that the total increase in runoff is 146.41 percent. Runoff is increased

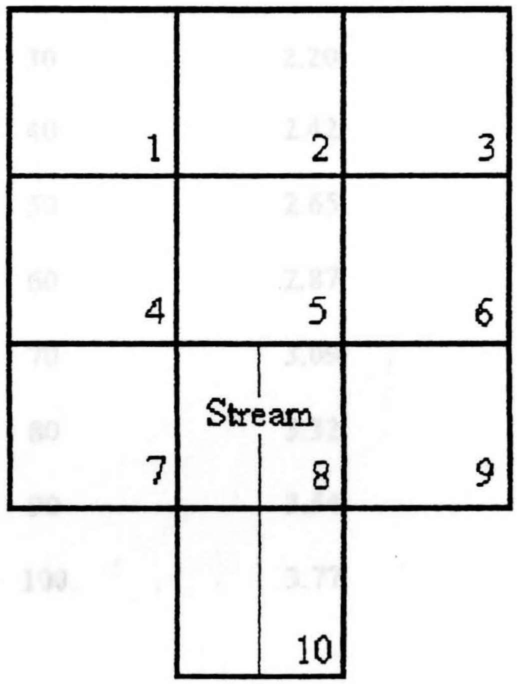
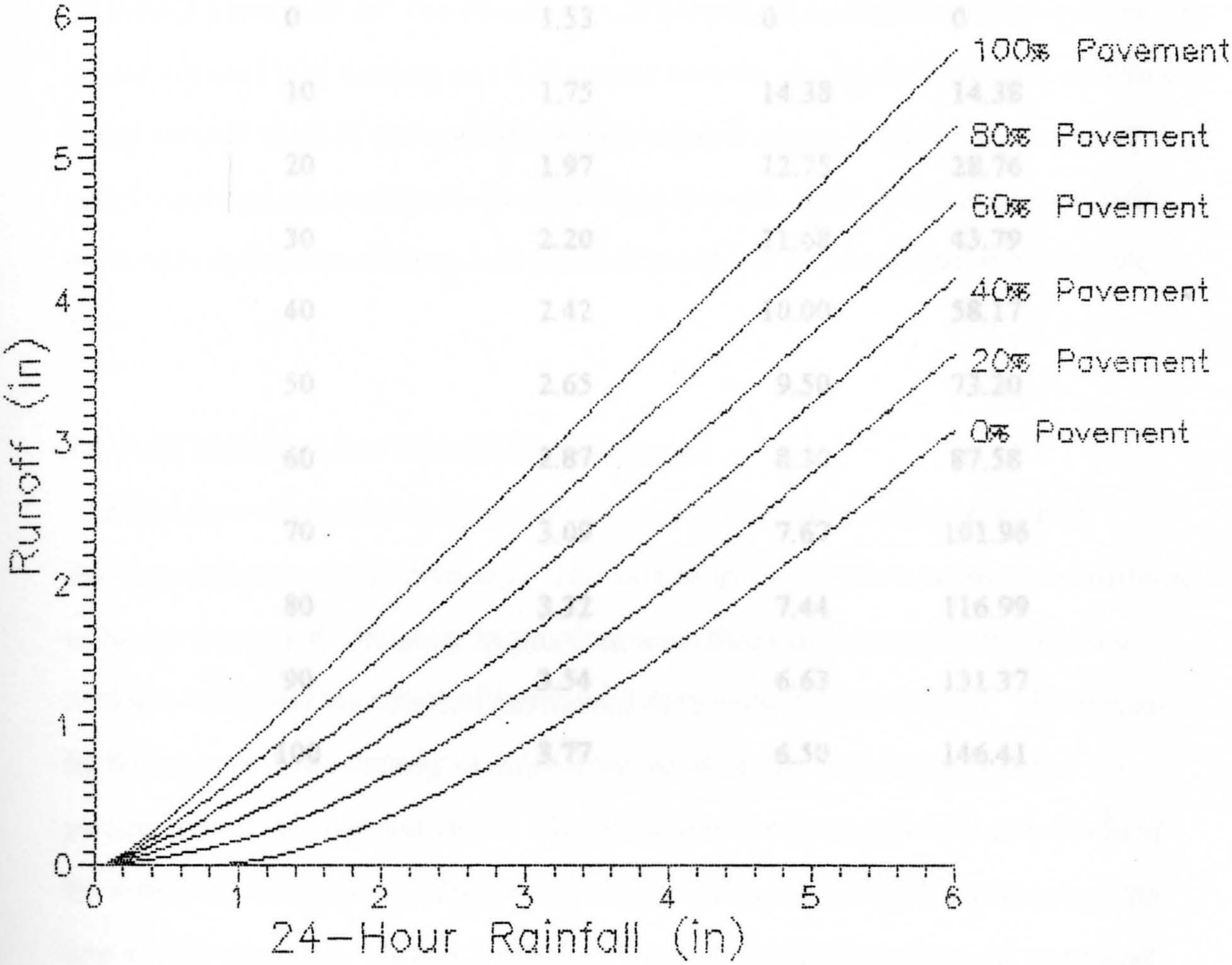


Figure 7.1: Hypothetical Watershed used for Modelling.

Table 7.1: **Results of Runoff Modelling.**

% Paved	Runnoff (inches)
0	1.53
10	1.75
20	1.97
30	2.20
40	2.42
50	2.65
60	2.87
70	3.09
80	3.32
90	3.54
100	3.77



<u>Figure 7.2</u>: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for Various Amounts of Development.

Table 7.2: **Analysis of Runoff Results.**

% Paved	Runnoff (inches)	Relative % Increase	Actual %Increase
0	1.53	0	0
10	1.75	14.38	14.38
20	1.97	12.75	28.76
30	2.20	11.68	43.79
40	2.42	10.00	58.17
50	2.65	9.50	73.20
60	2.87	8.30	87.58
70	3.09	7.67	101.96
80	3.32	7.44	116.99
90	3.54	6.63	131.37
100	3.77	6.50	146.41

14.38 percent for each 10 percent of watershed area that is paved. The relative effects of development decreases for each 10 percent increase in paved area. For example the first 10 percent paved will increase runoff by 14.38 percent. If another 10 percent is paved, the amount of runoff will increase by 12.75 percent over the previous amount but would be an actual increase of 28.76 percent from the undeveloped amount. Figure 7.3 is a plot of runoff versus percent pavement. As can be seen from this figure, the increase in runoff is linear with an increase of about 0.22 inches of runoff per 10 percent increase in paved area.

7.4 Peak Discharge and Time of Peak Discharge

It was shown in the previous chapter that development has an effect on the peak discharge and time of peak discharge. This section focuses on the location of development within the watershed. The same hypothetical watershed that was used in the previous section to determine the effects of incremental development was used here. The land use for the watershed was initially assumed to be woods in fair hydrologic condition. 30 percent of the watershed was paved. The paved area was located in various portions of the watershed to determine if this had any effect on the amount of peak discharge and the time of peak discharge. Figures 7.4 through 7.6 are maps of the hypothetical watershed showing the portions paved and the travel path used to determine the time of concentration. The SCS Unit Hydrograph method was used for the calculations. The results of the modelling are presented in Table 7.3. Figure 7.7 are the unit hydrographs for the various development configurations.

It should be noted that development of blocks 1,4, and 7 was not examined because the results are the same as those from blocks 1, 6, and 9. This is because the hypothetical watershed is symetrical. Blocks 7, 8 and 9 where not examined because they are located to near to the watersheds outlet to have any affect on the time of concentration.

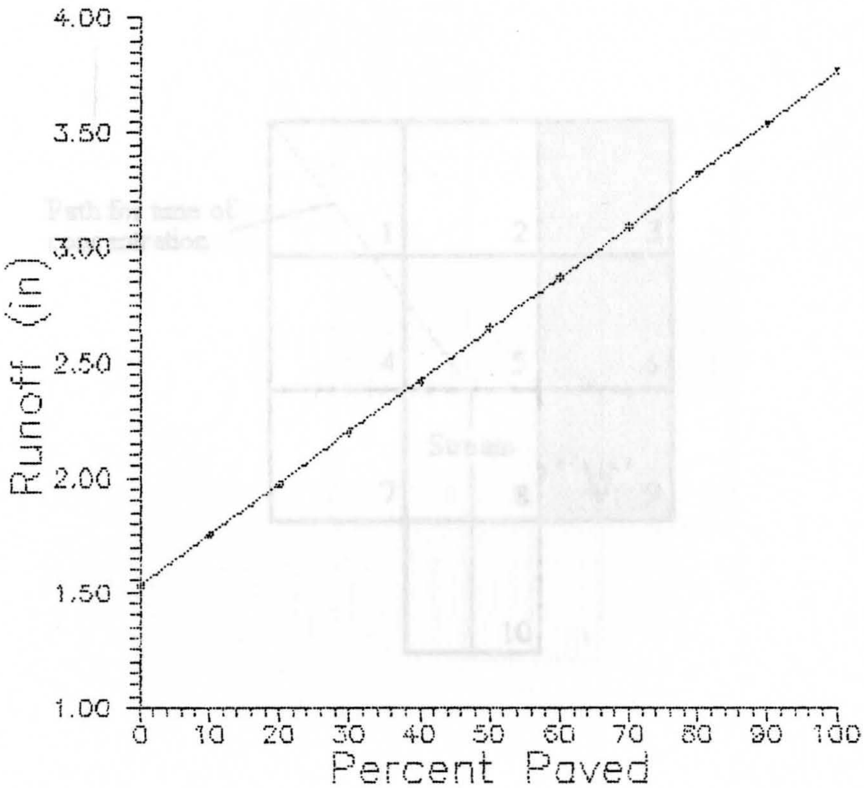


Figure 7.3: **Runoff vs. Percent Pavement for a 4 Inch 24-Hour Rainfall.**

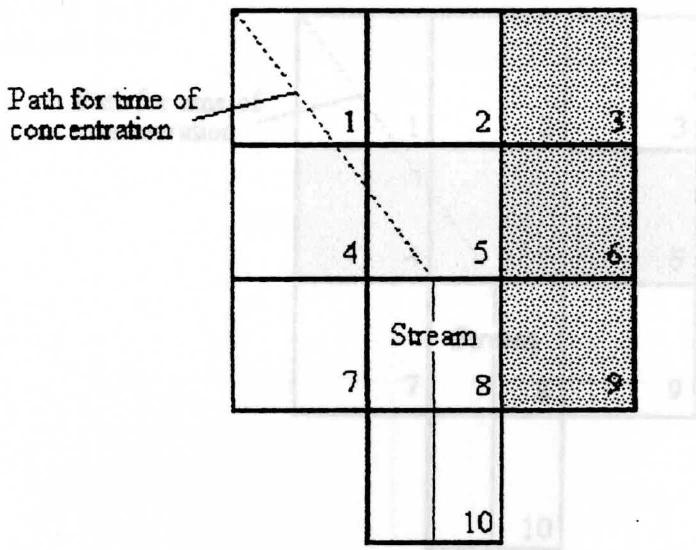


Figure 7.4: Map of Watershed Showing Blocks 3, 6 and 9 Developed.

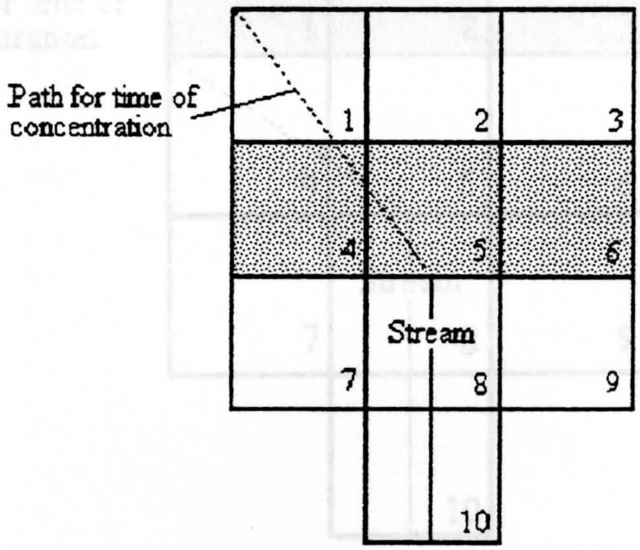


Figure 7.5: Map of Watershed Showing Blocks 4, 5 and 6 Developed.

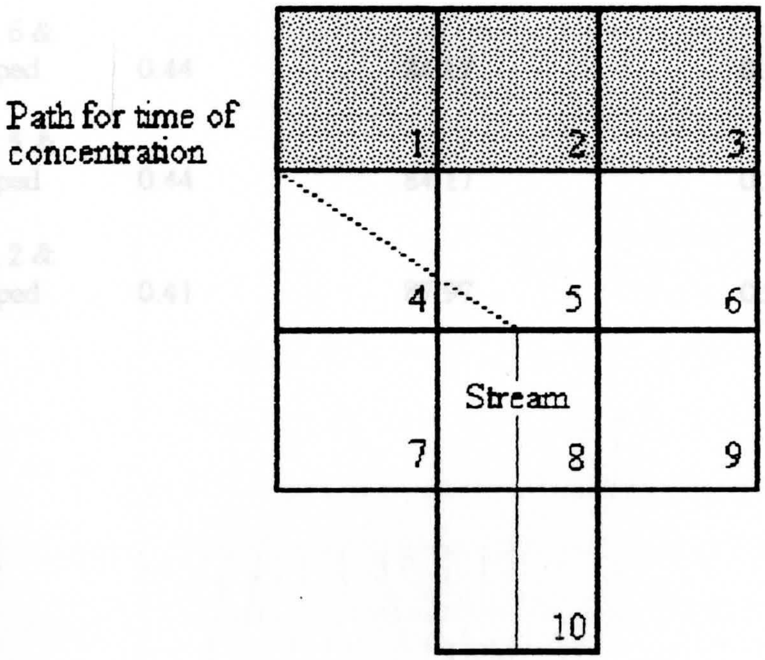


Figure 7.6: Map of Watershed Showing Blocks 1, 2 and 3 Developed.

Table 7.3: Results of Hydrograph Modelling.

	Time of Concentration (hours)	Peak Discharge (cfs)	Time of Peak Discharge (hours)
Undeveloped	0.44	69.27	0.26
Blocks 3, 6 & 9 Developed	0.44	84.17	0.21
Blocks 4, 5 & 6 Developed	0.44	84.17	0.21
Blocks 1, 2 & 3 Developed	0.41	87.97	0.20

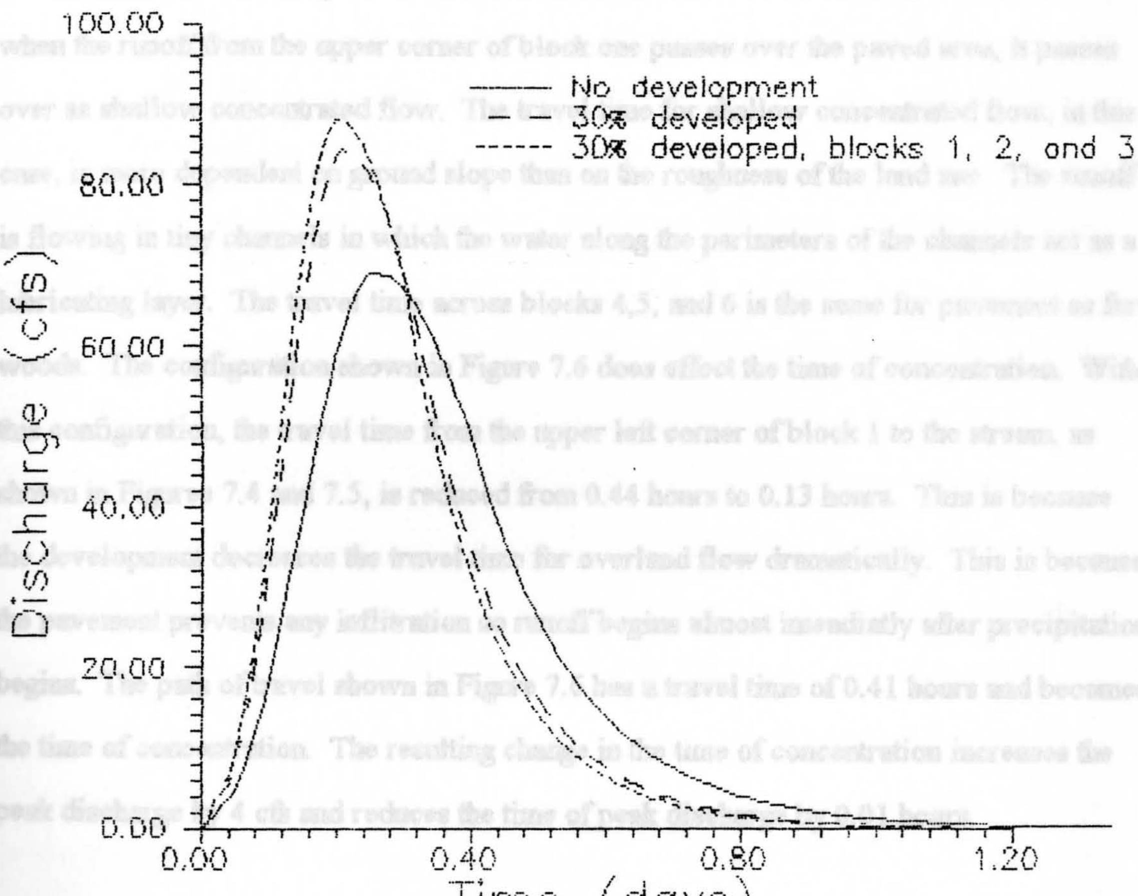


Figure 7.7: Unit Hydrographs for the Various Development Configurations.

7.4.1 <u>Analysis of Modelling Results</u>

From Table 7.3 and Figure 7.7 it can be seen that the location of the development does have an effect on the peak discharge and time of peak discharge. The increase in peak discharge is due mostly to the increased runoff resulting from the land use change. The unit hydrographs for the configurations shown in Figures 7.4 and 7.5 are the same because the development shown in Figure 7.5 does not affect the time of concentrtion. This is because when the runoff from the upper corner of block one passes over the paved area, it passes over as shallow concentrated flow. The travel time for shallow concentrated flow, in this case, is more dependent on ground slope than on the roughness of the land use. The runoff is flowing in tiny channels in which the water along the parimeters of the channels act as a lubricating layer. The travel time across blocks 4,5, and 6 is the same for pavement as for woods. The configuration shown in Figure 7.6 does effect the time of concentration. With this configuration, the travel time from the upper left corner of block 1 to the stream, as shown in Figures 7.4 and 7.5, is reduced from 0.44 hours to 0.13 hours. This is because the development decreases the travel time for overland flow dramatically. This is because the pavement prevents any inflitration so runoff begins almost imeadiatly after precipitation begins. The path of travel shown in Figure 7.6 has a travel time of 0.41 hours and becomes the time of concentration. The resulting change in the time of concentration increases the peak discharge by 4 cfs and reduces the time of peak discharge by 0.01 hours.

7.5 Conclusions

From this exercise, two observations can be made. The first is that as a watershed is developed, runoff increases linearly as a function of land area developed. Thus, there appears to be no minimum (threshold) level of development that can take place before an increase in runoff is observed. The second is that the location of development has an effect on the peak discharge and time of peak discharge. Development will increase the peak discharge and reduce the time of peak discharge but will not have its maximum effect

unless it is in a position to reduce the time of concentration. It should be noted that these models were run for a watershed with 100 percent of the soil belonging to soil group C. The effects of incremental development on runoff and the effects of the location of development may be more dramatic if soils from two or more of the various hydrologic soil groups are mixed.

CHAPTER 8

Application of Hydrosim Mk. 1 to a Portion of the Mill Creek Watershed

8.1: Introduction

In this chapter Hydrosim Mk. 1 was used to model the changes in the amount of runoff due to land use changes on a portion of the Mill Creek watershed. As mentioned in Chapter 1, Lake Newport began filling in with sediment at an increased rate after development had begun on portions of the Mill Creek watershed. The purpose of this chapter was to model a portion of the watershed in which development has already occurred and determine how much impact the present land use has on runoff comparred with possible previous land uses.

Figure 8.1 shows the location of the Mill Creek watershed used for this portion of the study. The watershed has an area of approximately 1200 hectares and is drained by a stream named Cranberry Run. The Cranberry Run watershed has been developed for some time and drains one of the oldest residential areas in Boardman Township. This watershed will be modelled using three land uses. The first land use will be woods in fair hydrologic condition (land use number 64) representing the conditions of the watershed before the area was settled. The second land use will be meadow (land use number 56) representing the conditions of the watershed when farming was being conducted in the area. It should be noted that not all of the watershed was farmland. There quite probably was development directly from woods to homes. The purpose of assuming 100% meadow is to provide a progression from the original wooded condition to the present land use. Also, since most of the southern portions of the Mill Creek watershed (south of Western Reserve Road) are rural and agricultural, the transition between meadow to present land use will provide an indication of what can be expected as these areas are developed in the future. The third land use used was the present land use of the Cranberry Run watershed. The major land use of this watershed at the present time is residential, primarily single family

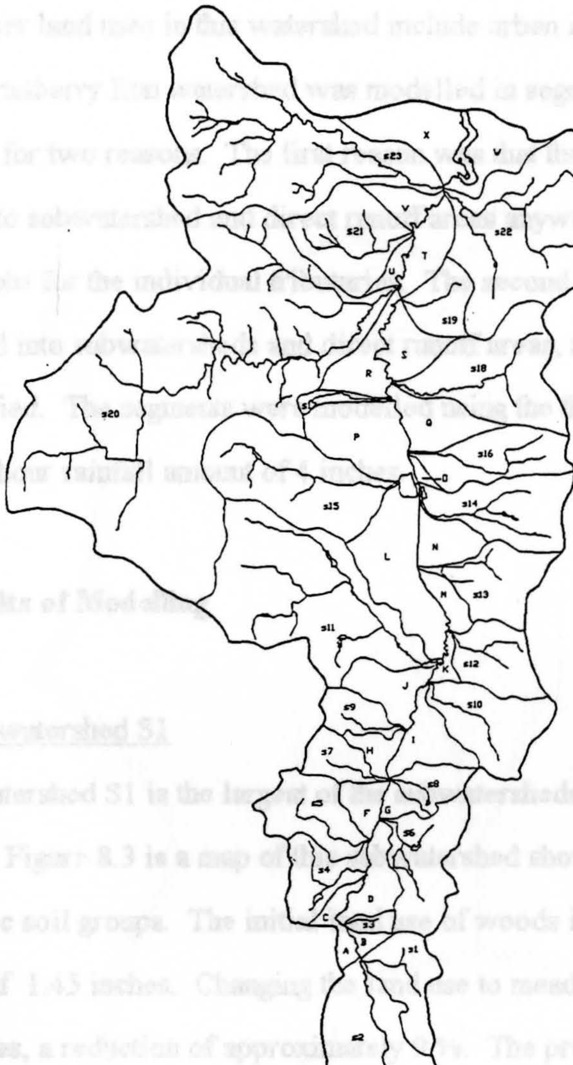


Figure 8.1: Map of the Mill Creek Watershed Showing Portion Used for Modelling.

homes on lots of a quarter of an acre or less. For these areas, land use number 13 will be used. Other land uses in this watershed include urban industrial and cemetary.

The Cranberry Run watershed was modelled in segments (Figure 8.2). This was done primarily for two reasons. The first reason was that the watershed would have to be broken into subwatershed and direct runoff areas anyway in order to determine hydrographs for the individual tributaries. The second reason is that by segmenting the watershed into subwatersheds and direct runoff areas, areas of hydrologic sensitivity might be identified. The segments were modelled using the three previously mentioned land uses and a 24-hour rainfall amount of 4 inches.

8.2 Results of Modelling

8.2.1 Subwatershed S1

Subwatershed S1 is the largest of the subwatersheds with a modelled area of 376 hectares. Figure 8.3 is a map of this subwatershed showing the various soil types and hydrologic soil groups. The initial land use of woods in fair hydrologic condition yielded a runoff of 1.45 inches. Changing the land use to meadow reduced the amount of runoff to 1.32 inches, a reduction of approximately 9 %. The present land use of this subwatershed is residential, mostly single family homes or small apartment buildings. The resulting modelled runoff for the present land use was determined to be 2.87 inches. This is an increase of approximately 99% over the wooded amount and 108% greater than the amount associated with meadow. Figure 8.4 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.2 Subwatershed S2

Subwatershed S2 is the fourth largest of the subwatershed with a modelled area of 101 hectares. This subwatershed has similar soil conditions to subwatershed S1 (Figure 8.5).

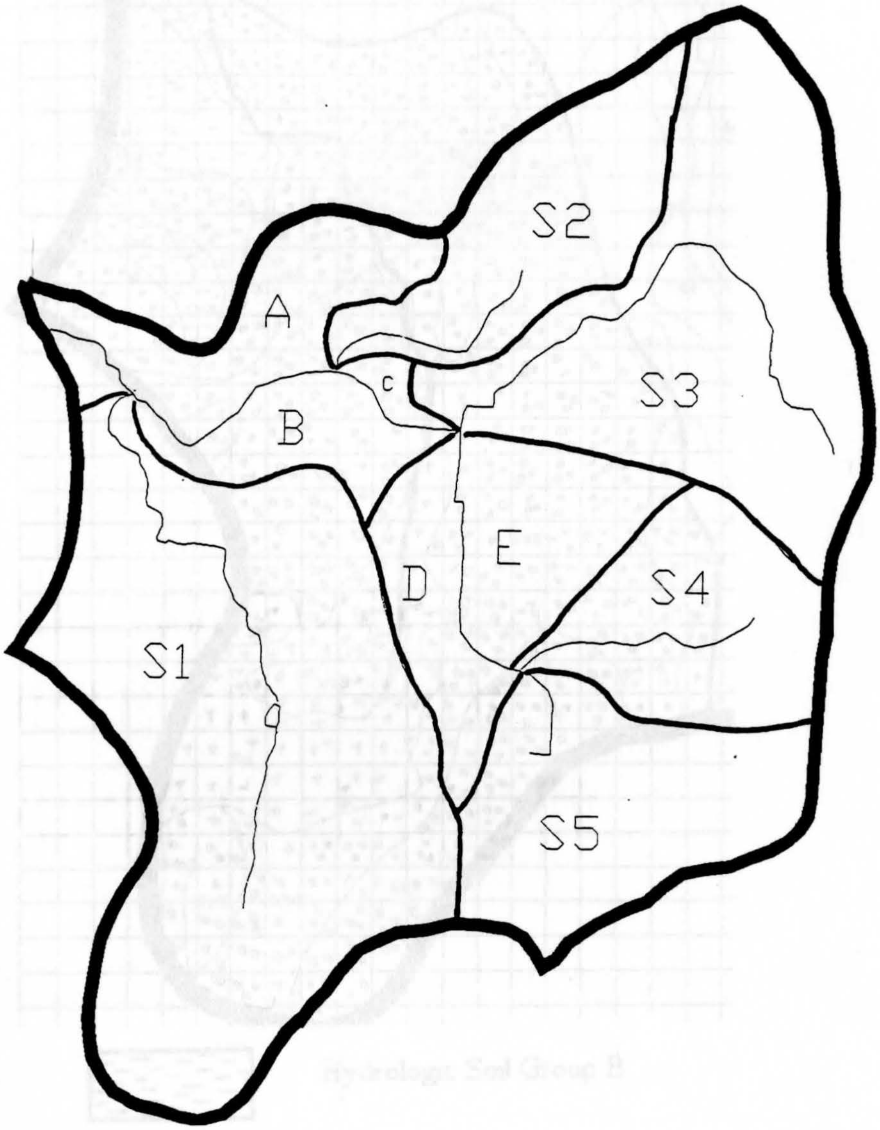
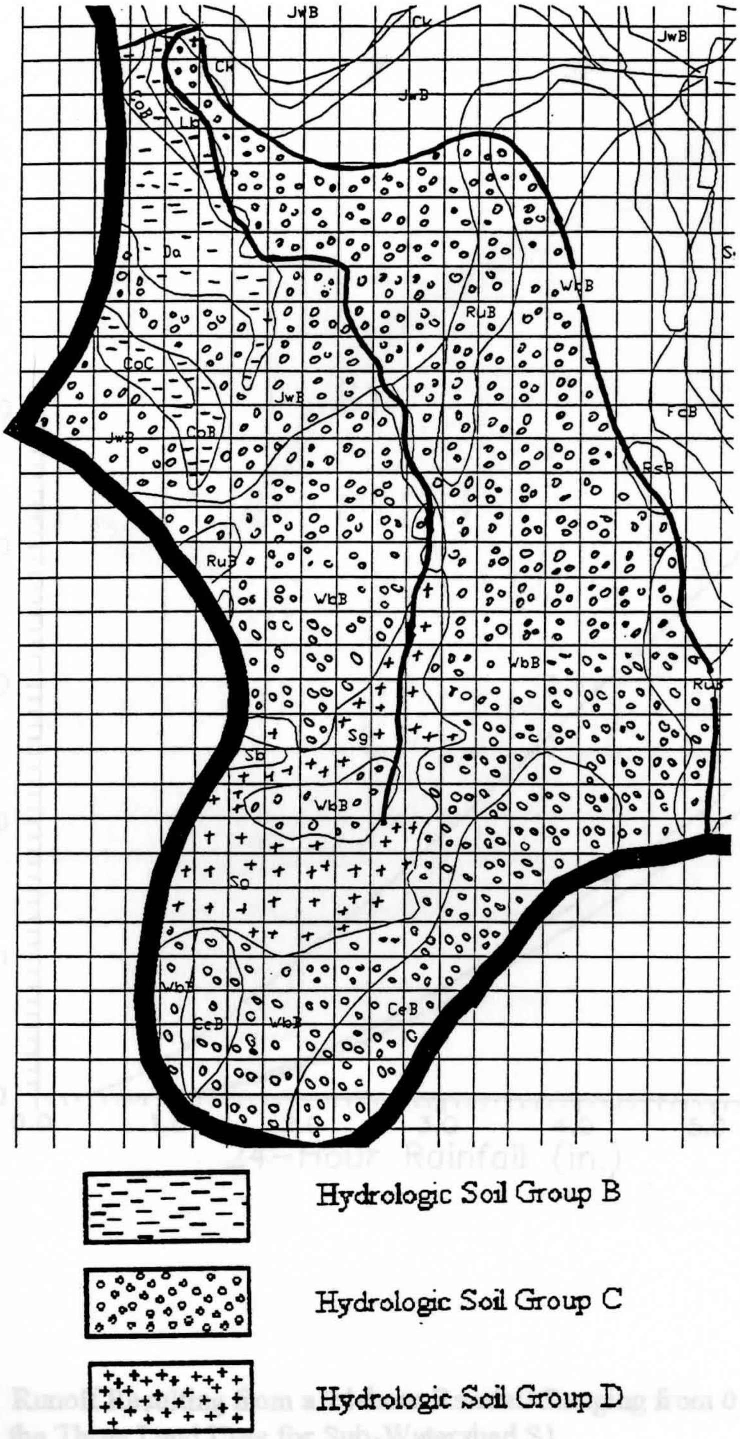


Figure 8.2: Map of the Cranberry Run Watershed Showing Sections used for Modelling.



<u>Figure 8.3</u>: Soil Map of Sub-Watershed S1.

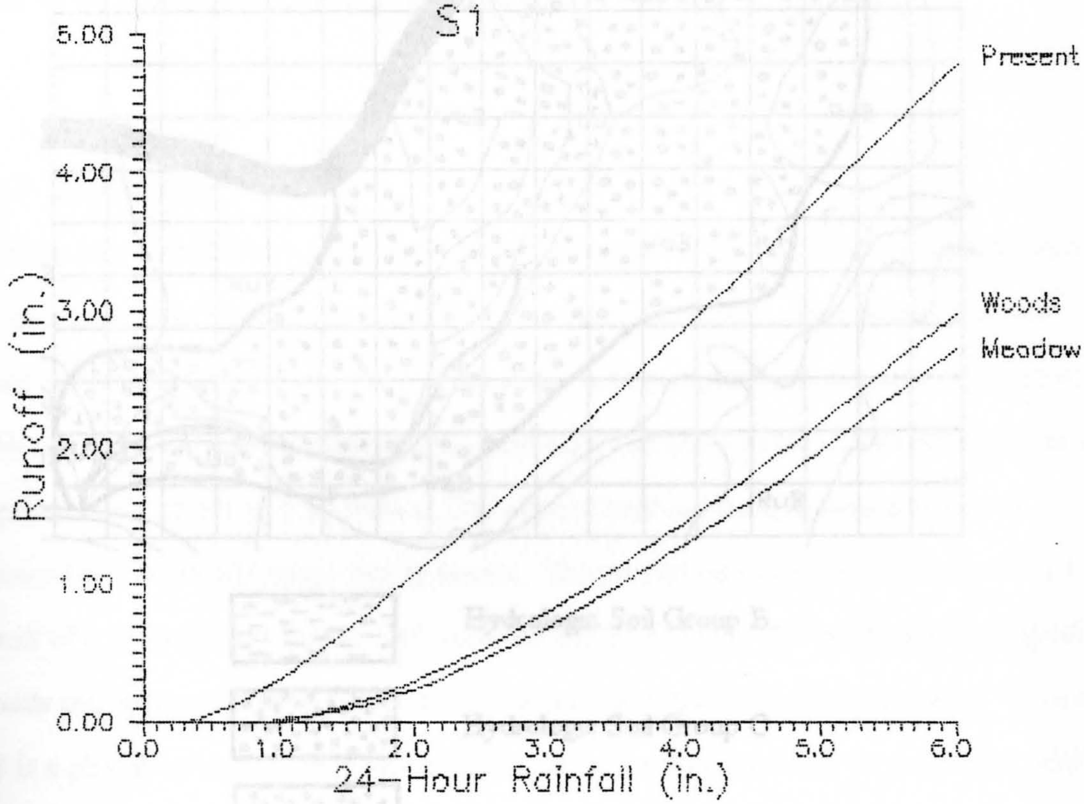


Figure 8.4: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Sub-Watershed S1.

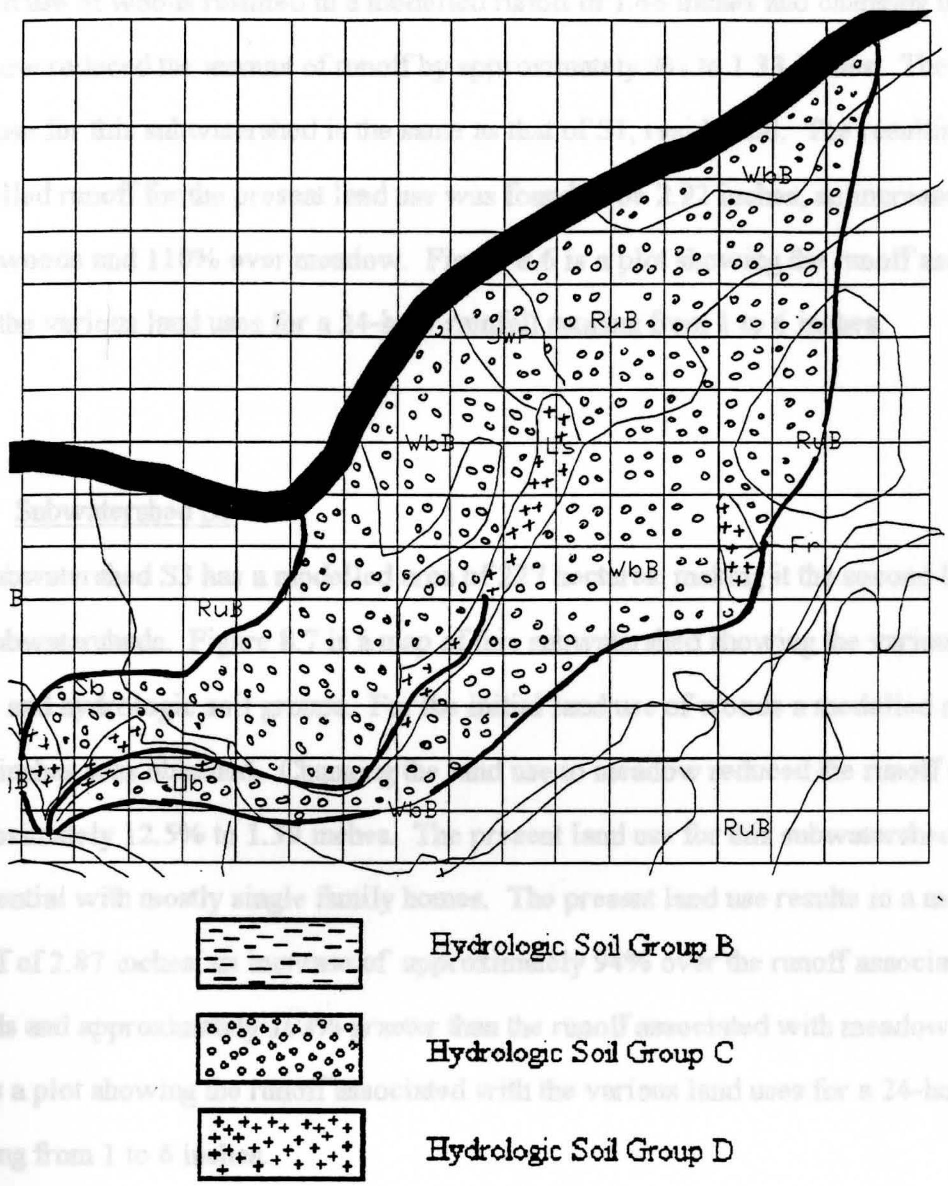


Figure 8.5: Soil Map of Sub-Watershed S2.

A land use of woods resulted in a modelled runoff of 1.46 inches and changing this to meadow reduced the amount of runoff by approximately 9% to 1.33 inches. The present land use for this subwatershed is the same as that of S1, residential. The resulting modelled runoff for the present land use was found to be 2.92 inches, an increase of 100% over woods and 110% over meadow. Figure 8.6 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.3 Subwatershed S3

Subwatershed S3 has a modelled area of 227 hectares, making it the second largest of the subwatersheds. Figure 8.7 is a map of this subwatershed showing the various soil types and hydrologic soil groups. For the initial land use of woods a modelled runoff of 1.59 inches was obtained. Changing the land use to meadow reduced the runoff amount by approximately 12.5% to 1.39 inches. The present land use for this subwatershed in residential with mostly single family homes. The present land use results in a modelled runoff of 2.87 inches, an increase of approximately 94% over the runoff associated with woods and approximately 103% graeter than the runoff associated with meadow. Figure 8.8 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.4 Subwatershed S4

This subwatershed has a modelled area of 99 hectares and is the smallest of the sub-watersheds. The various soil types and hydrologic soil groups of this watershed can be seen in Figure 8.9. The land use of woods in fair hydrologic condition produced a modelled runoff of 1.49 inches. Changing the land use to meadow reduced the amount of runoff by approximately 9% to 1.36 inches. The present land use for this subwatershed is

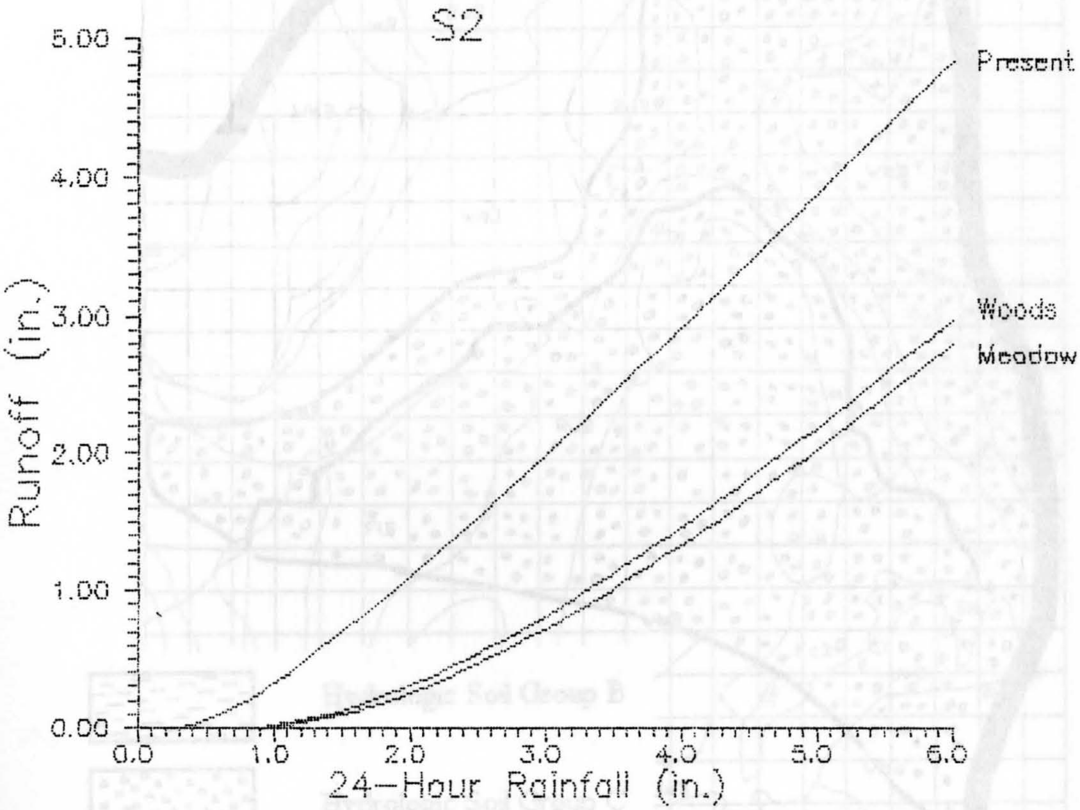
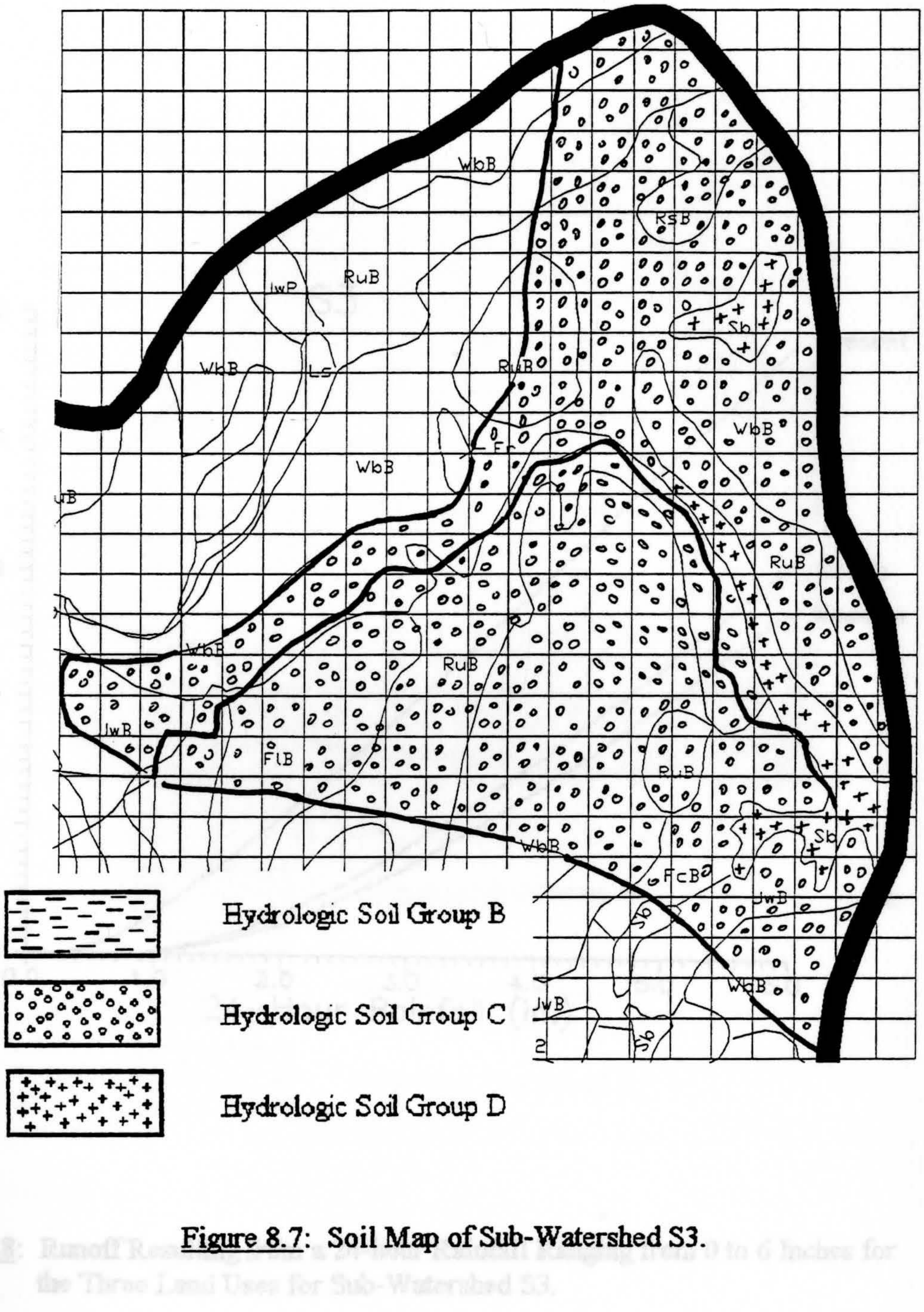


Figure 8.6: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Sub-Watershed S2.



<u>Figure 8.7</u>: Soil Map of Sub-Watershed S3.

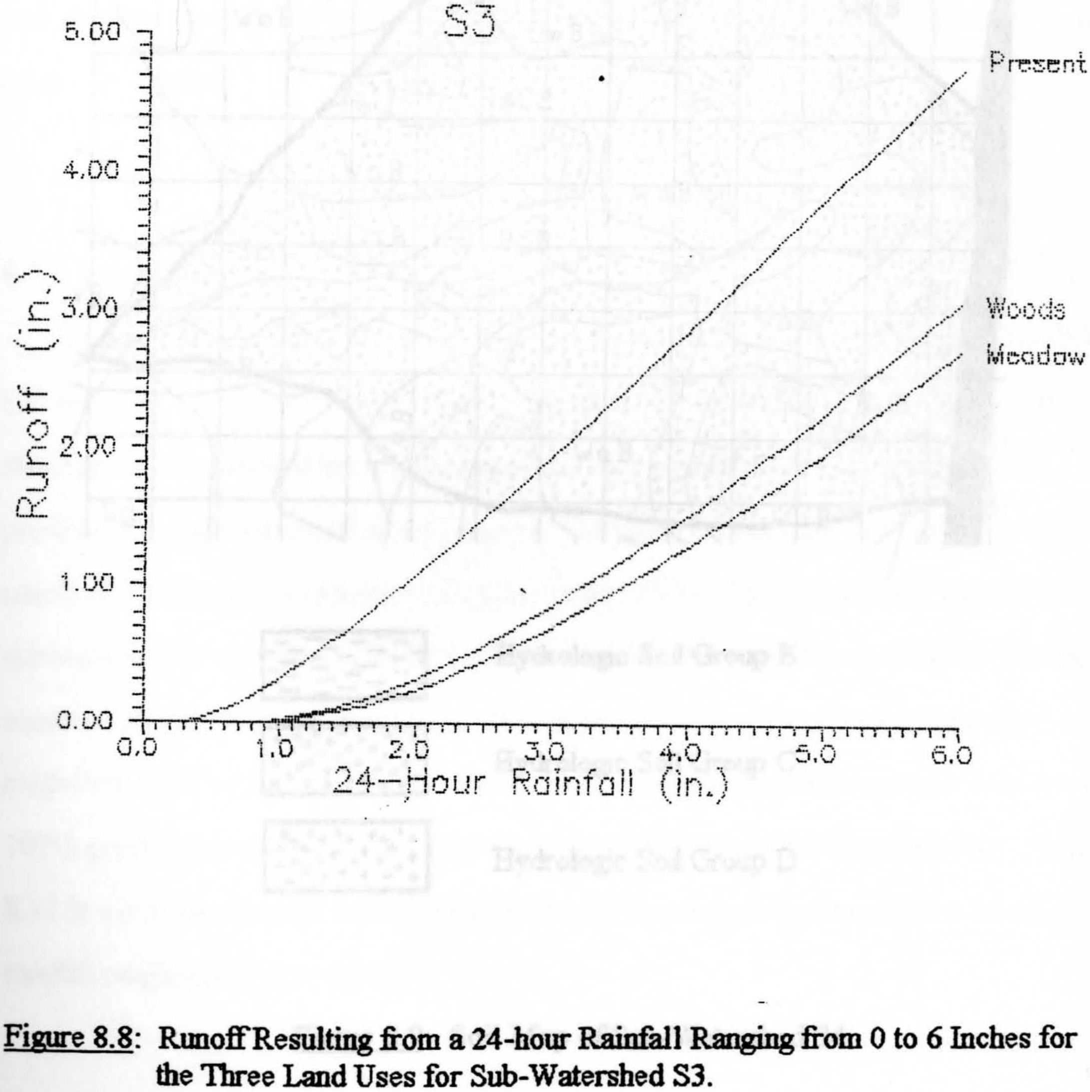


Figure 8.8: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Sub-Watershed S3.

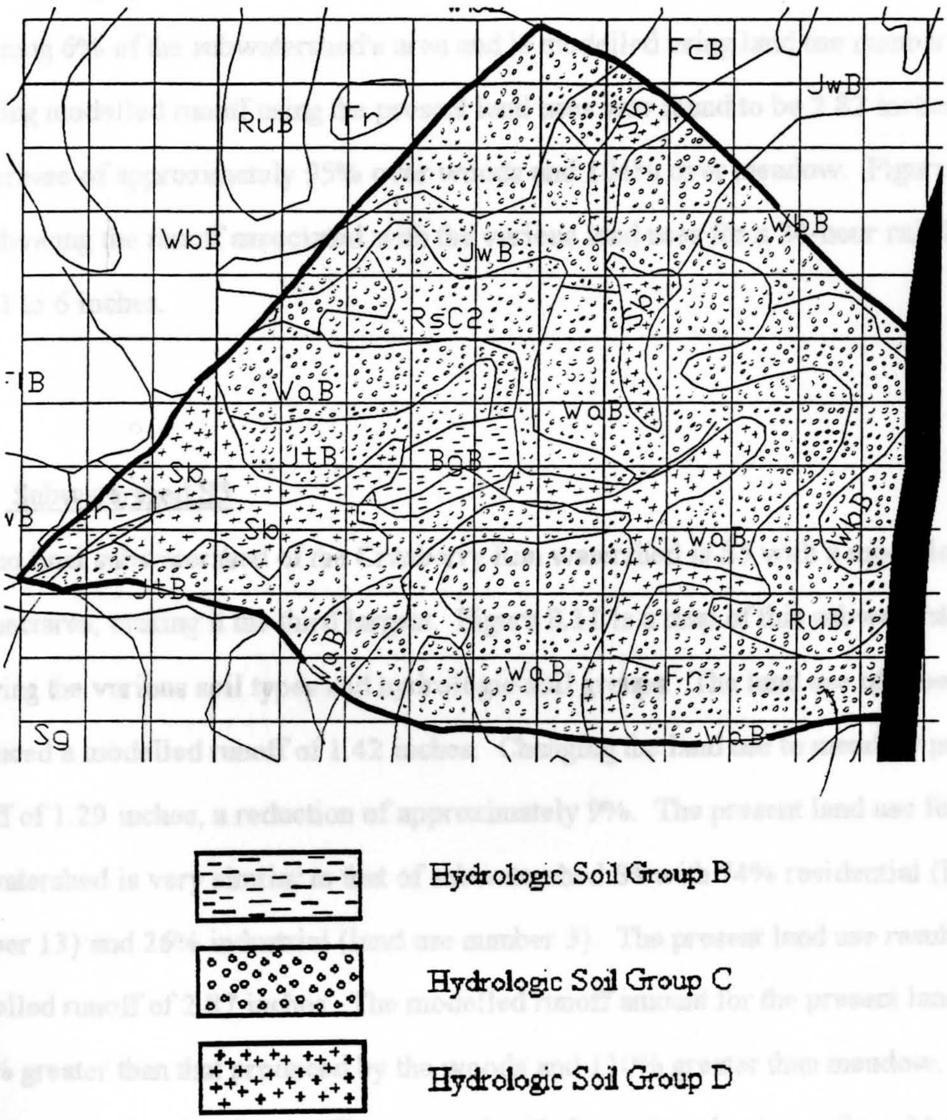


Figure 8.9: Soil Map of Sub-Watershed S4.

primarily residential with some industrial. Residential land use is primarily single family homes making up 94% of the subwatershed area. The industrial land use makes up the remaining 6% of the subwatershed's area and is modelled using land use number 12. The resulting modelled runoff using the present land uses was found to be 2.82 inches. This is an increase of approximately 95% over woods and 104% over meadow. Figure 8.10 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.5 <u>Subwatershed S5</u>

The final subwatershed of the Cranberry Run watershed is S5 with a modelled area of 135 hectares, making it the third largest. Figure 8.11 is a map of this subwatershed showing the various soil types and hydrologic soil groups. The land use of woods produced a modelled runoff of 1.42 inches. Changing the land use to meadow produced a runoff of 1.29 inches, a reduction of approximately 9%. The present land use for this subwatershed is very similar to that of subwatershed S4 with 74% residential (land use number 13) and 26% industrial (land use number 3). The present land use resulted in a modelled runoff of 2.87 inches. The modelled runoff amount for the present land use is 101% greater than that produced by the woods and 110% greater than meadow. Figure 8.12 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.6 <u>Direct Runoff Area A</u>

A direct runoff area is a portion of a watershed that lies between two or more sub-watersheds. In the case of the Cranberry Run watershed, there are 5 direct runoff areas with A being the largest with a modelled area of 85 hectares. Figure 8.13 is a soil map of

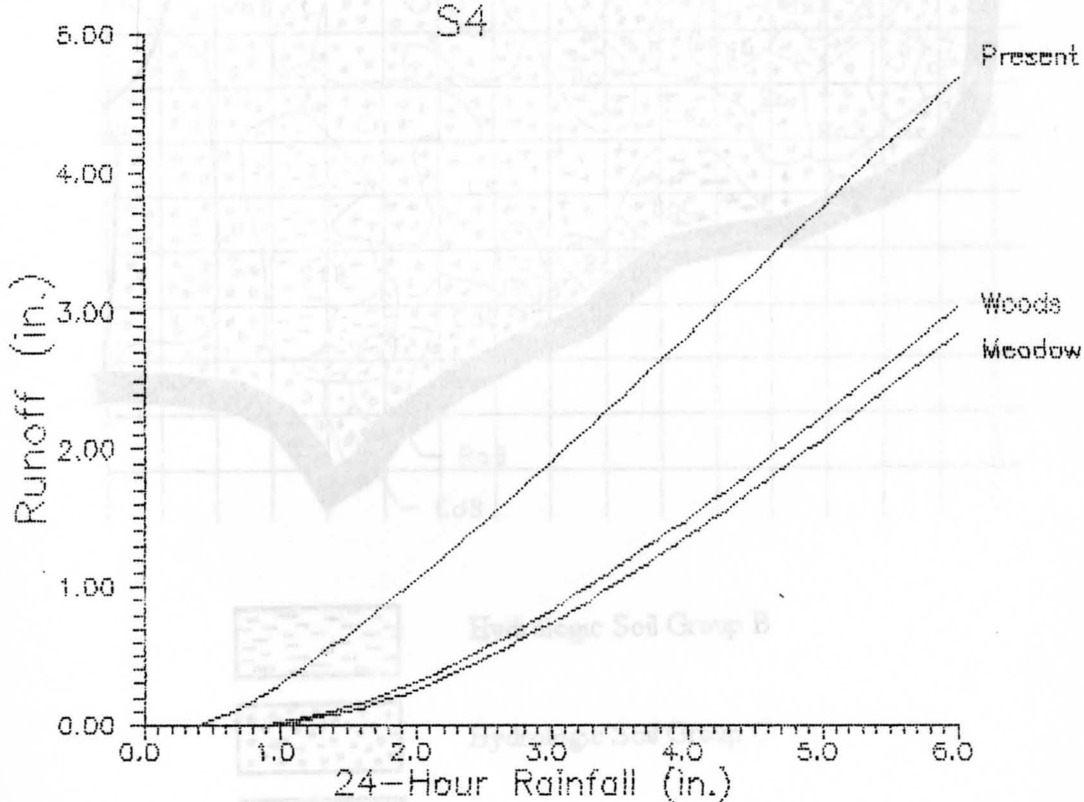


Figure 8.10: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Sub-Watershed S4.

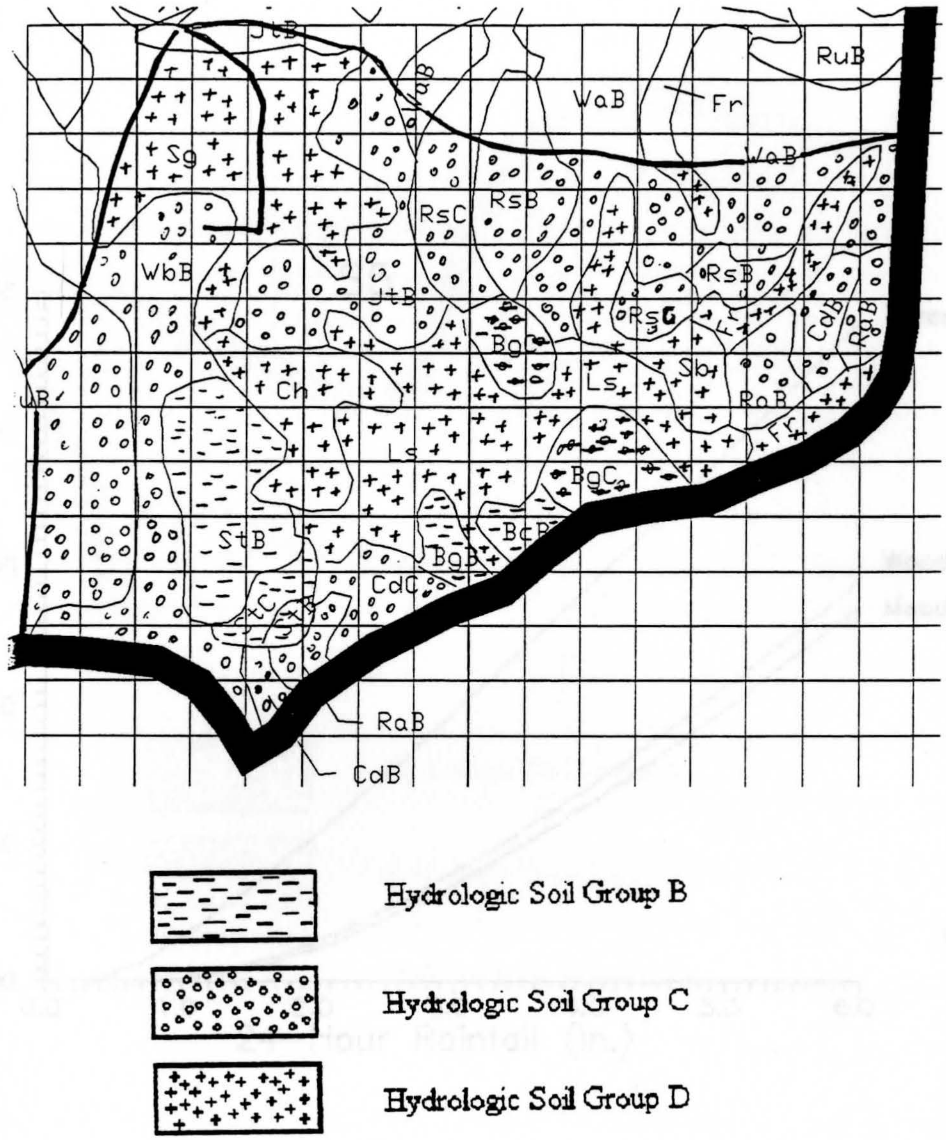


Figure 8.11: **Soil Map of Sub-Watershed S5.**

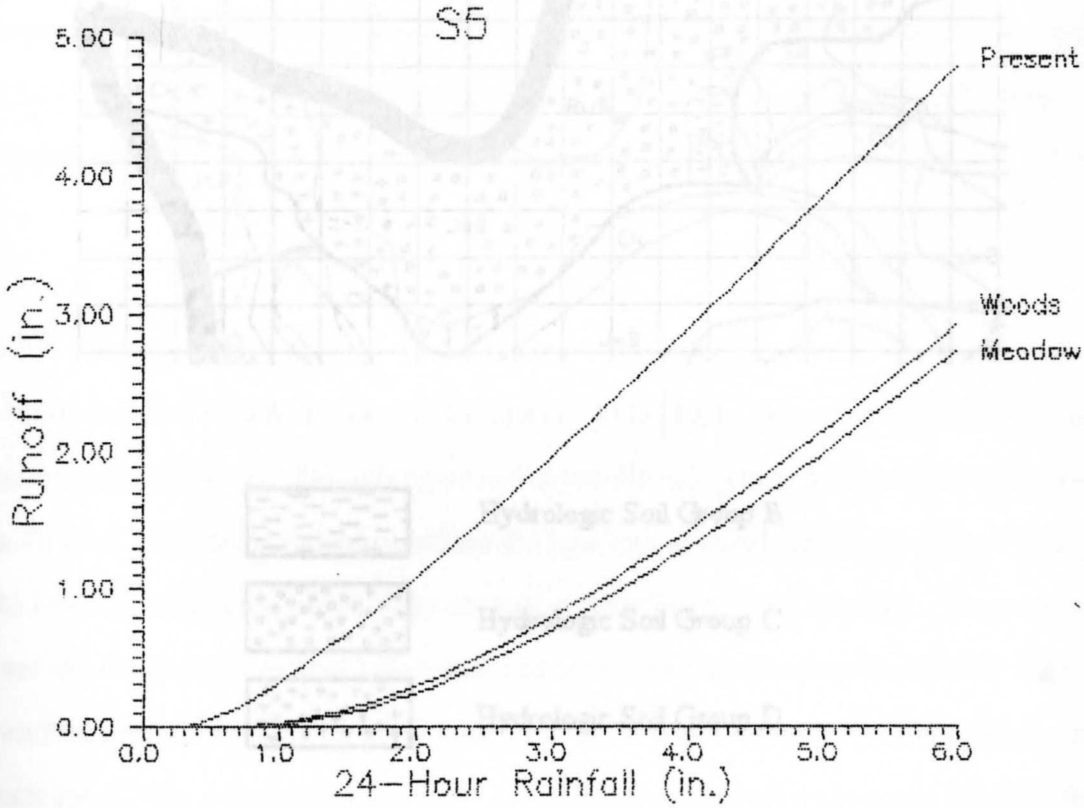


Figure 8.12: **Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Sub-Watershed S5.**

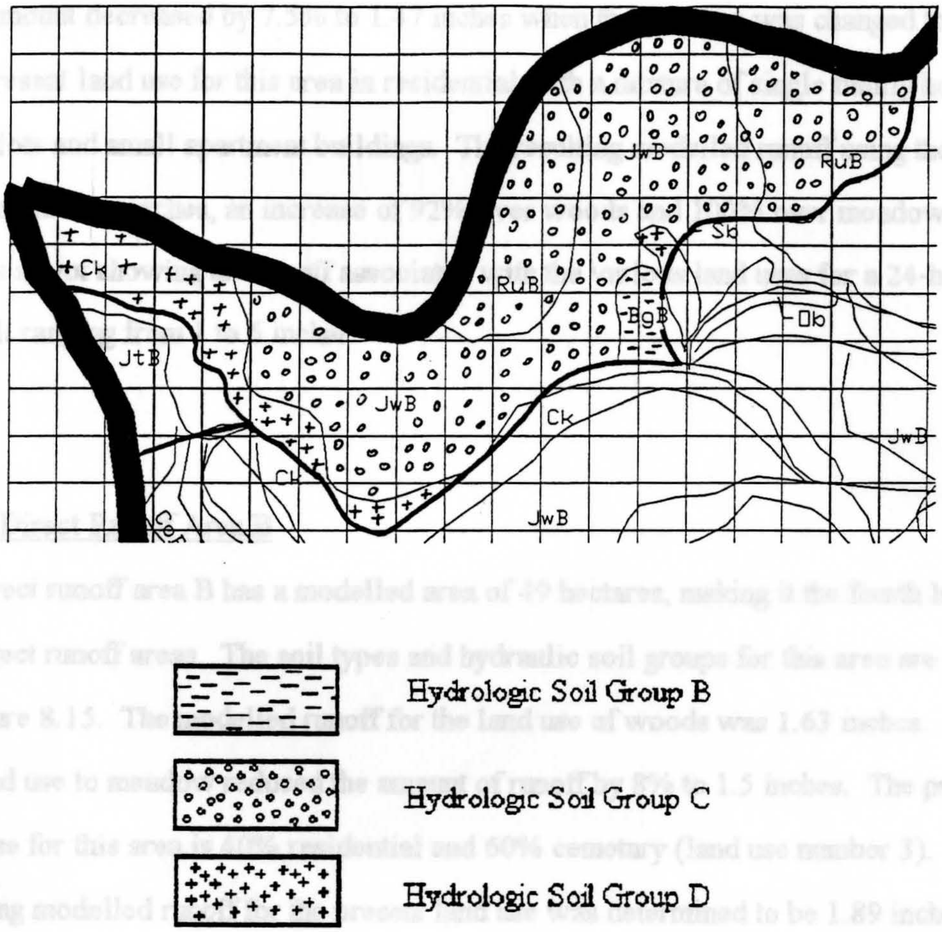


Figure 8.13: Soil Map of Direct Runoff Area A.

this direct runoff area showing the various hydrologic soil groups present. The modelled runoff for the land use of woods in fair hydrologic condition was found to be 1.59 inches. This amount decreased by 7.5% to 1.47 inches when the land use was changed to meadow. The present land use for this area in residential with a mixture of single family homes on small lots and small apartment buildings. The resulting modelled runoff using the present land use is 2.94 inches, an increase of 92% over woods and 100% over meadow. Figure 8.14 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.7 Direct Runoff Area B

Direct runoff area B has a modelled area of 49 hectares, making it the fourth largest of the direct runoff areas. The soil types and hydraulic soil groups for this area are presented in Figure 8.15. The modelled runoff for the land use of woods was 1.63 inches. Changing the land use to meadow reduced the amount of runoff by 8% to 1.5 inches. The present land use for this area is 40% residential and 60% cemetary (land use number 3). The resulting modelled runoff for the present land use was determined to be 1.89 inches, an increase of 58% over woods and 63% over meadow. Figure 8.16 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.8 Direct Runoff Area C

Direct runoff area C is the smallest of the direct runoff areas, with a modelled area of 8 hectares. Figure 8.17 shows the soil types and hydrologic soil groups that can be found in this area. The modelled runoff for the land use of woods was 1.63 inches. Changing the land use to meadow reduced the amount of runoff by 7% to 1.51 inches. The present land

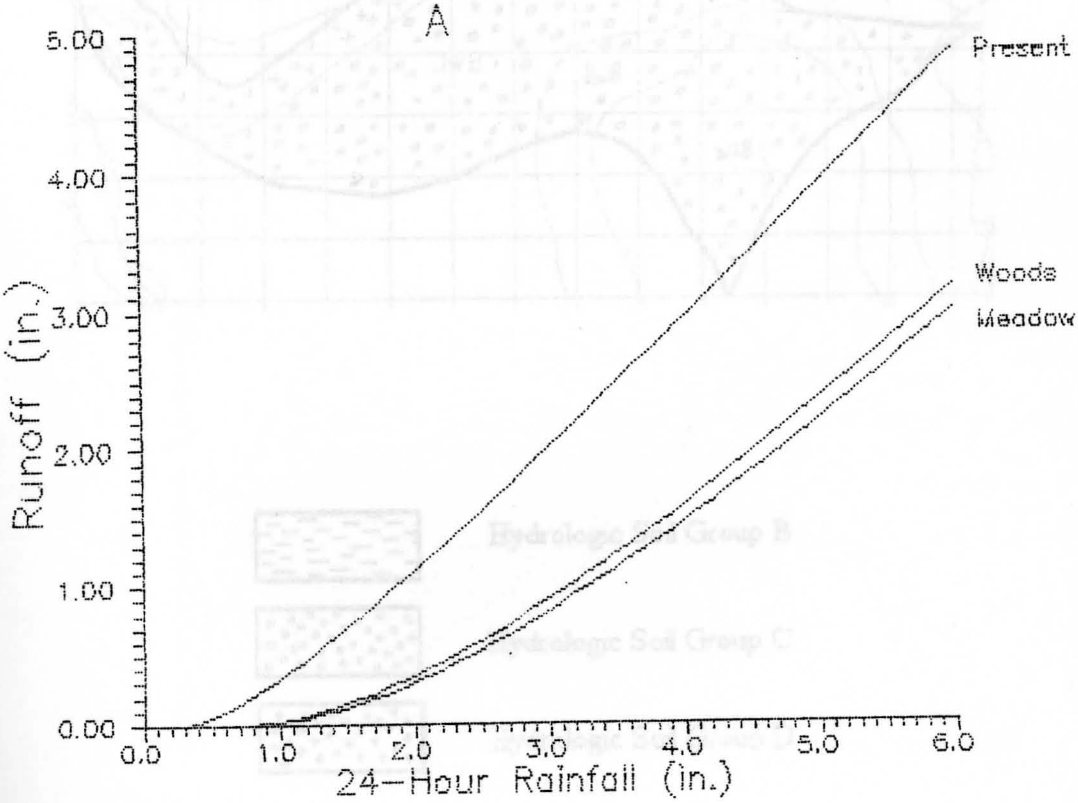


Figure 8.14: **Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Direct Runoff Area A.**

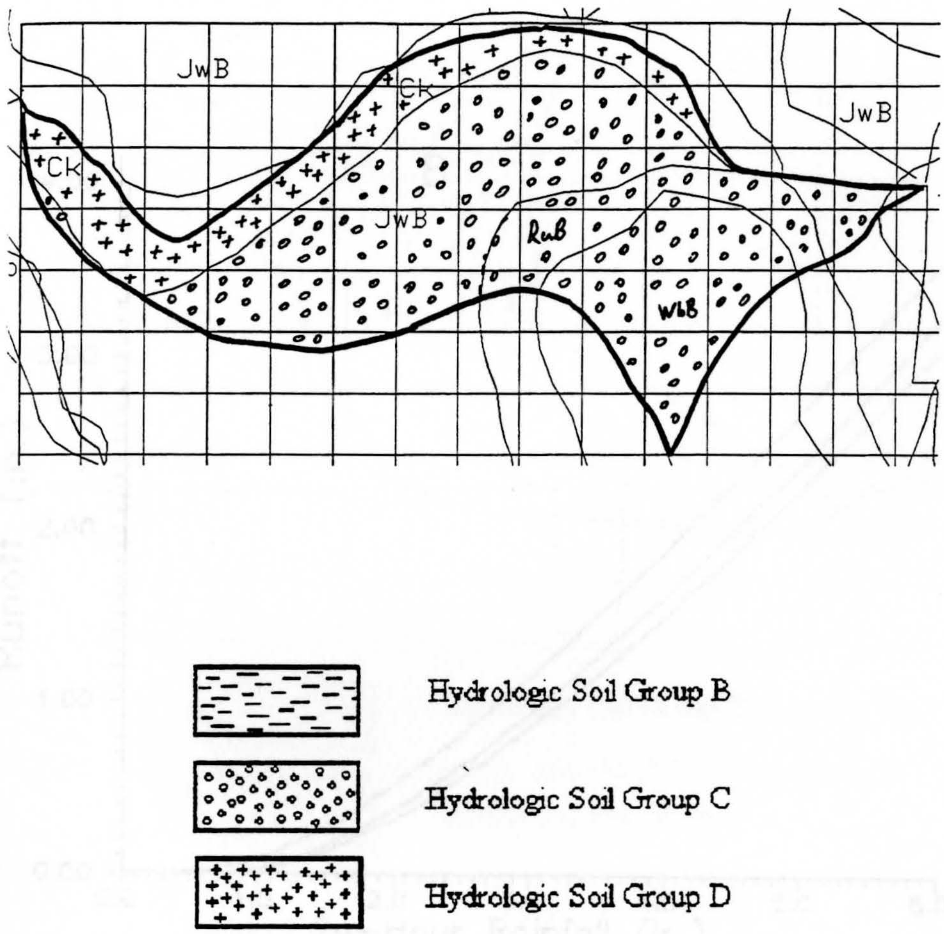
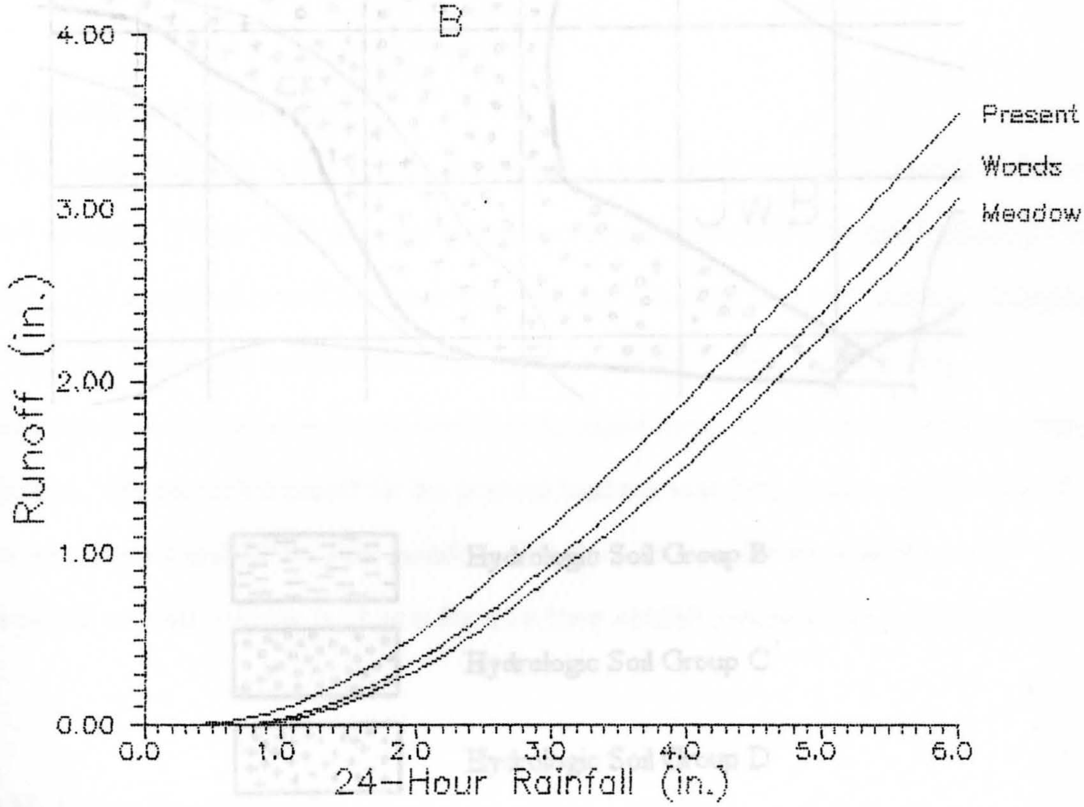


Figure 8.15: Soil Map of Direct Runoff Area B.



<u>Figure 8.16</u>: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Direct Runoff Area B.

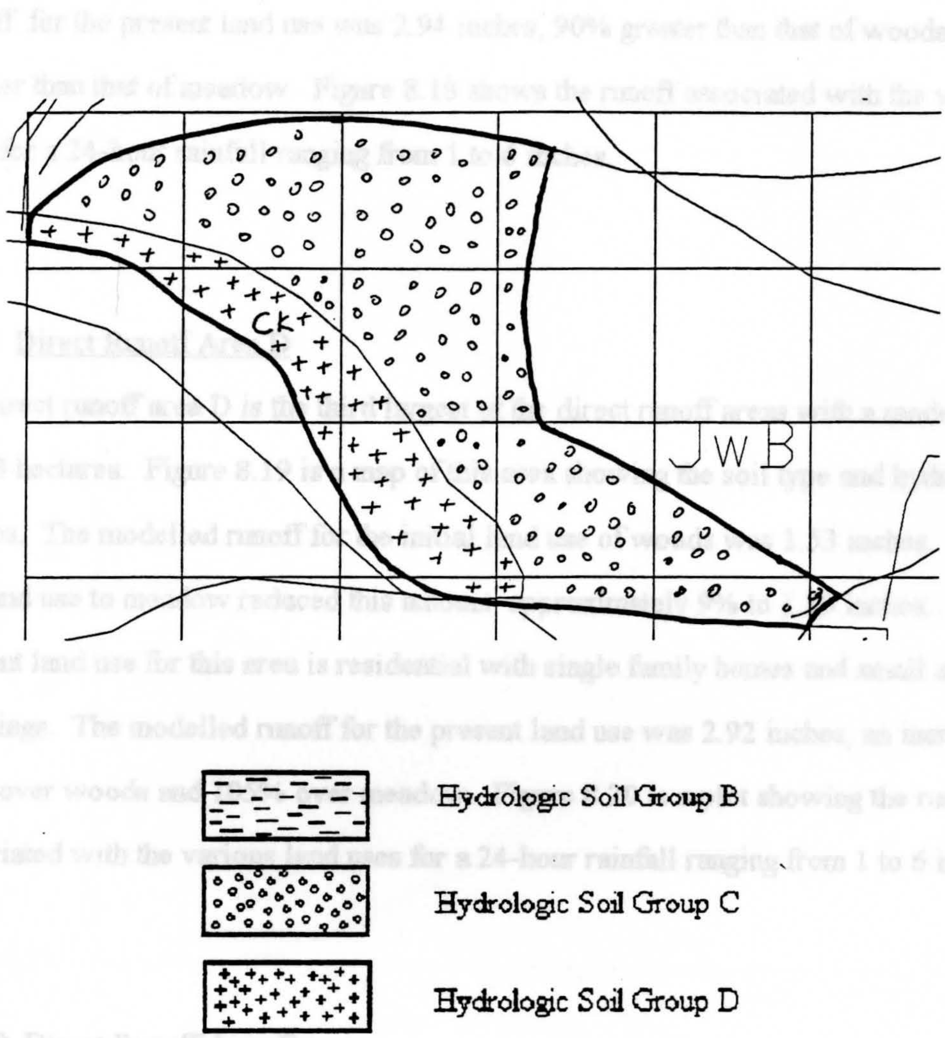


Figure 8.17: Soil Map of Direct Runoff Area C.

use for this area is residential, primarily single family homes on small lots. The modelled runoff for the present land use was 2.94 inches, 90% greater than that of woods and 97% greater than that of meadow. Figure 8.18 shows the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.9 <u>Direct Runoff Area D</u>

Direct runoff area D is the third largest of the direct runoff areas with a modelled area of 53 hectares. Figure 8.19 is a map of this area showing the soil type and hydrologic soil groups. The modelled runoff for the initial land use of woods was 1.53 inches. Changing the land use to meadow reduced this amount approximately 9% to 1.39 inches. The present land use for this area is residential with single family homes and small apartment buildings. The modelled runoff for the present land use was 2.92 inches, an increase of 95% over woods and 105% over meadow. Figure 8.20 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

8.2.10 <u>Direct Runoff Area E</u>

Direct runoff area E has a modelled area of 67 hectares, making it the second largest of the direct runoff areas. The various soil types and hydrologic soil groups found in this area are shown in Figure 8.21. The modelled runoff for the initial land use of woods was 1.51 inches. Changing the land use to meadow reduced this amount 9% to 1.38 inches. The present land use for this area is residential and the modelled runoff was 2.92 inches. This is a 97% increase over woods and a 106% increase over meadow. Figure 8.22 is a plot showing the runoff associated with the various land uses for a 24-hour rainfall ranging from 1 to 6 inches.

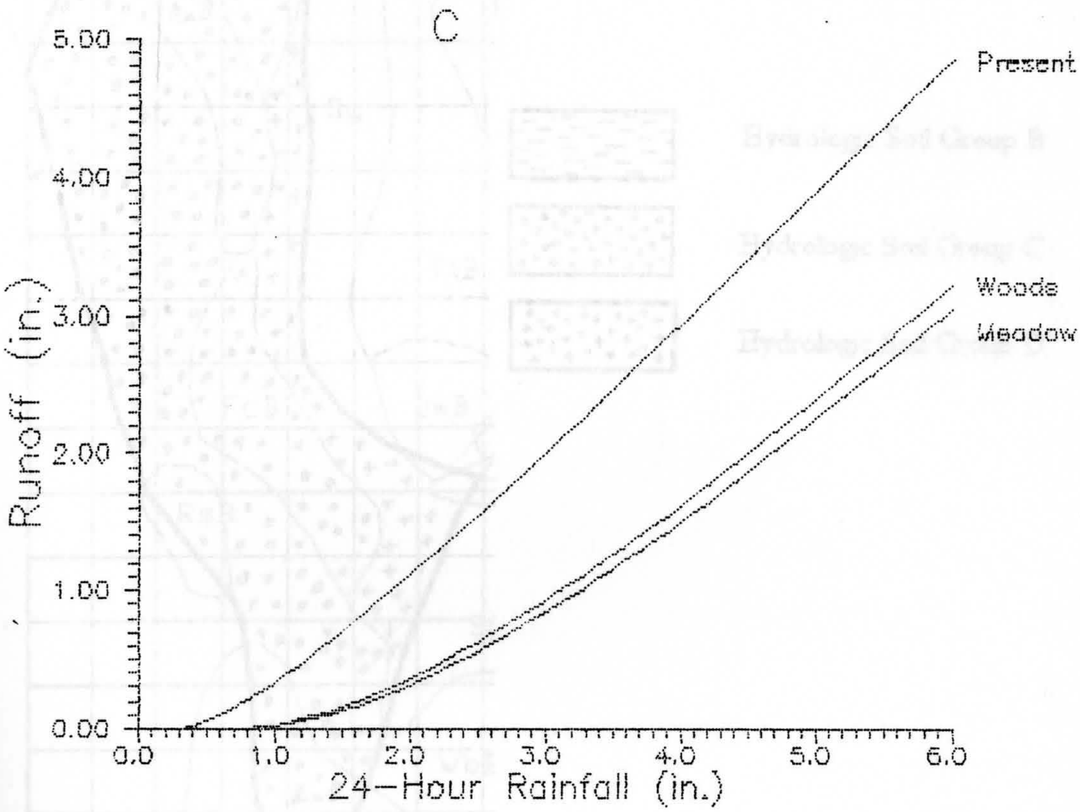


Figure 8.18: **Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Direct Runoff Area C.**

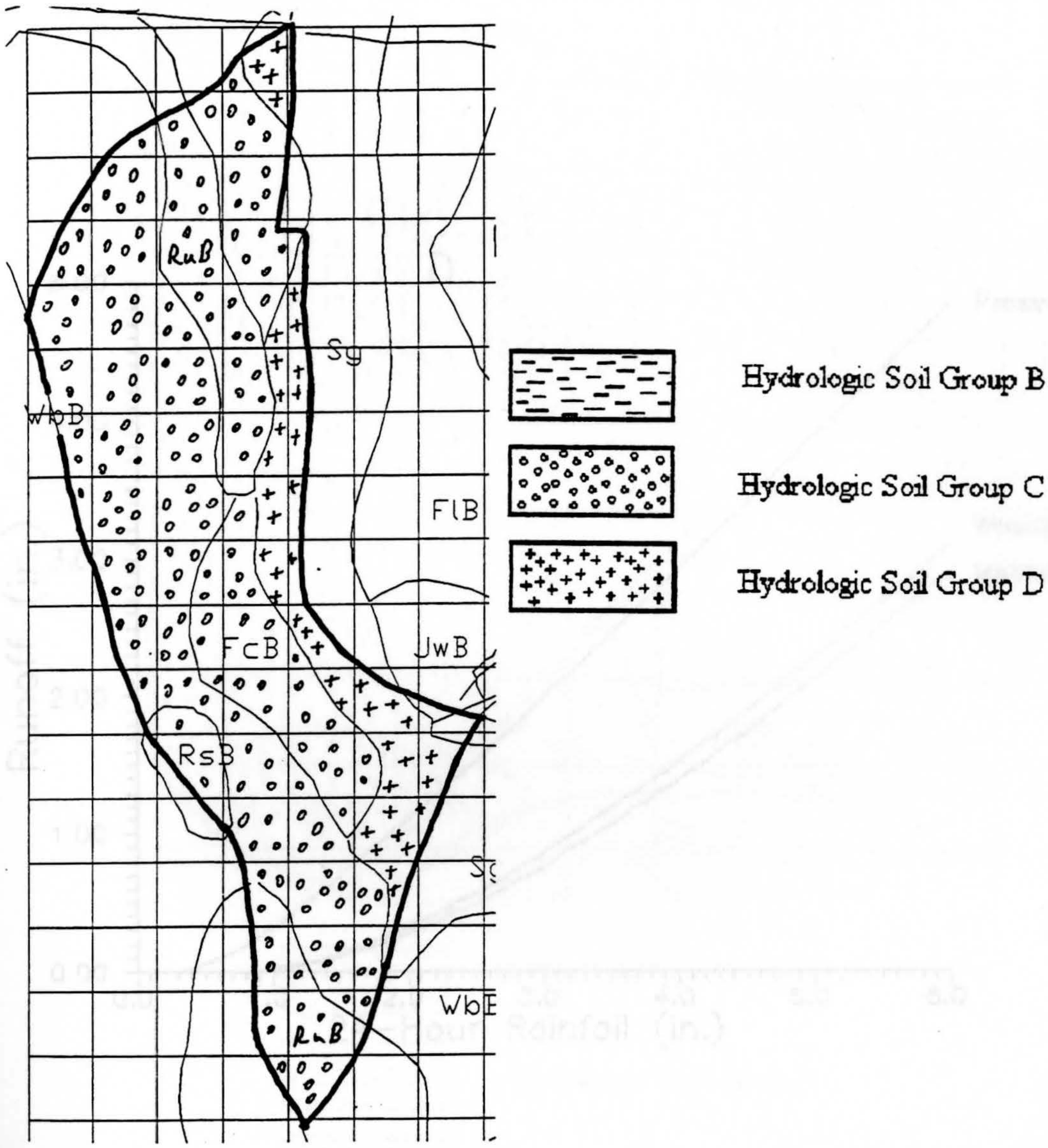


Figure 8.19: Soil Map of Direct Runoff Area D.

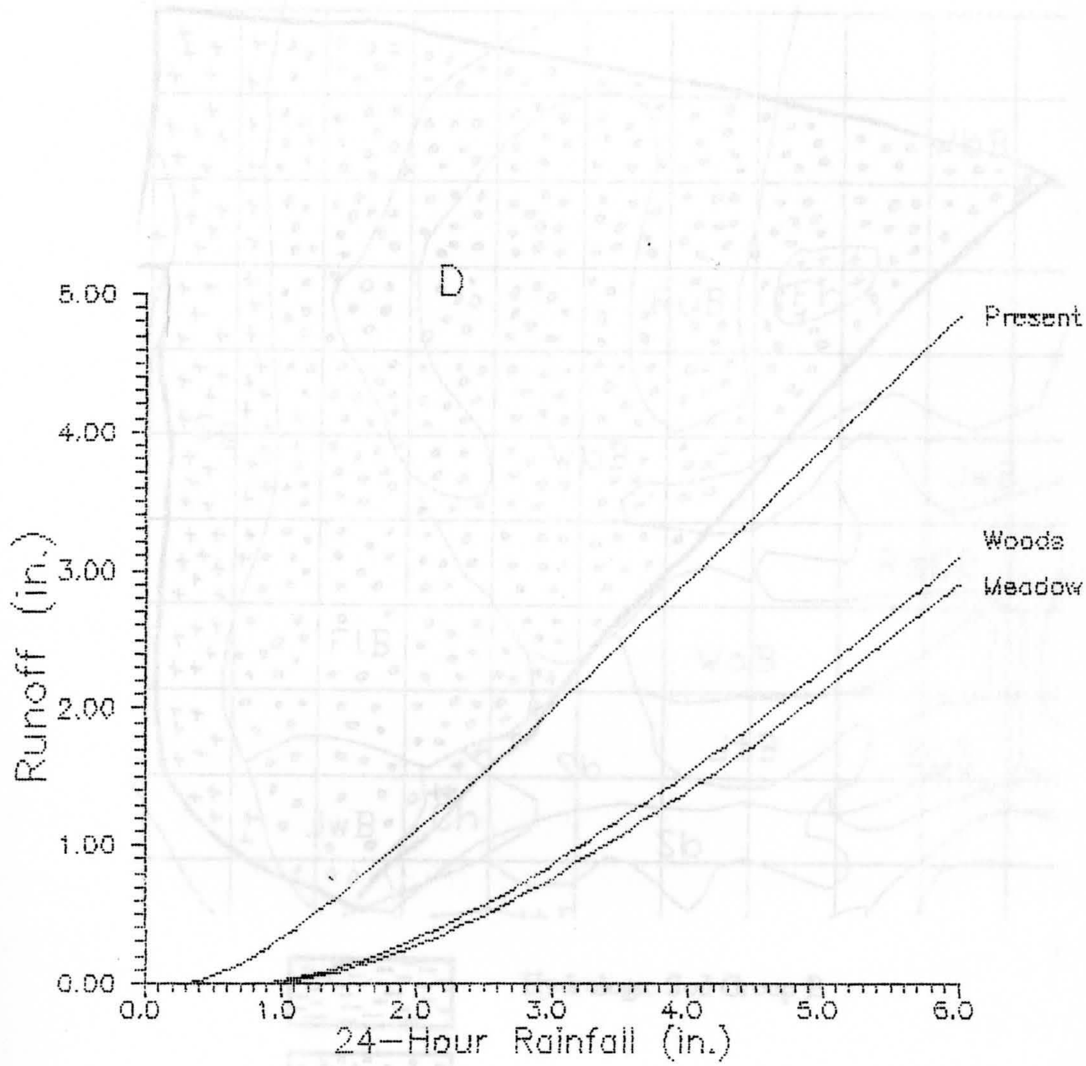


Figure 8.20: **Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Direct Runoff Area D.**

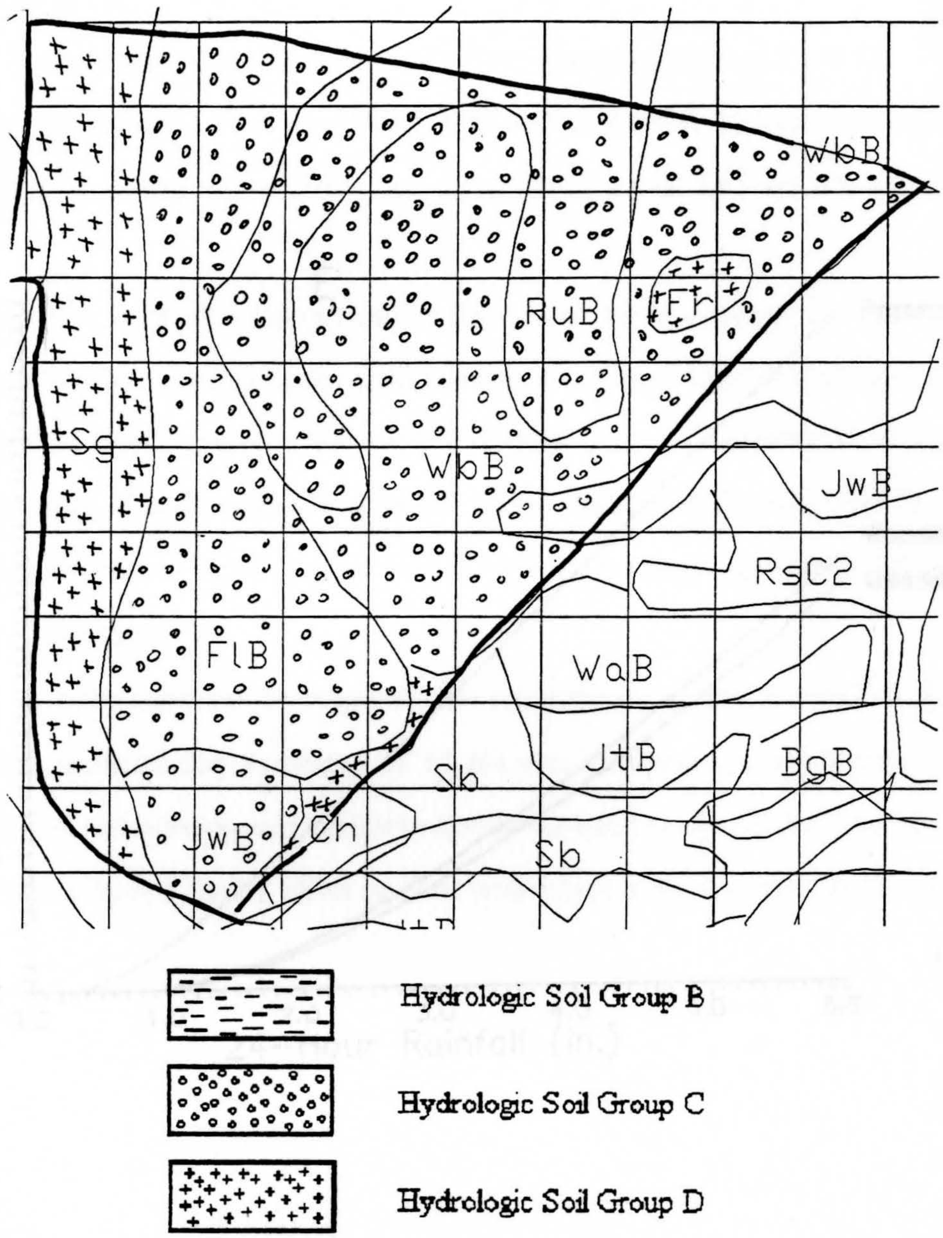


Figure 8.21: Soil Map of Direct Runoff Area E.

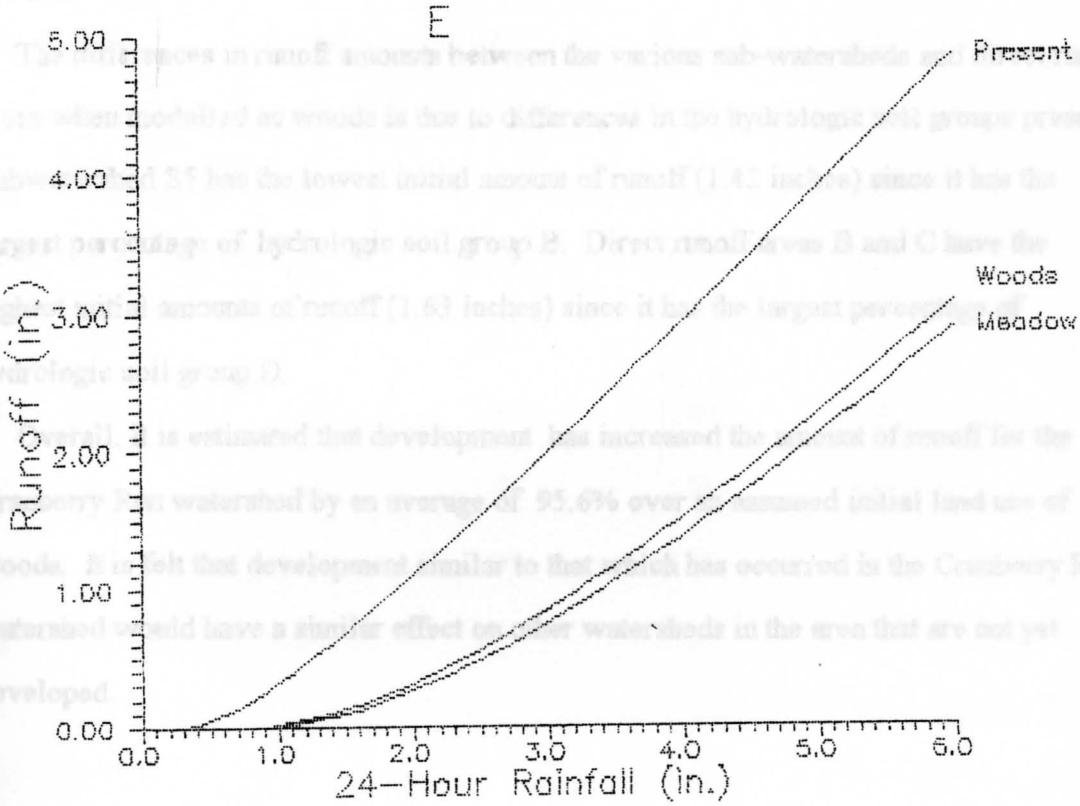


Figure 8.22: Runoff Resulting from a 24-hour Rainfall Ranging from 0 to 6 Inches for the Three Land Uses for Direct Runoff Area E.

8.3 Conclusions

Table 8.1 is a sumary of the model results. From examining Table 8.1 several observations can be made. First subwatershed S5 had the greatest increase in runoff due to development, with an increase of 101%, and direct runoff area B the least with an increase of 58%.

The differences in runoff amounts between the various sub-watersheds and direct runoff areas when modelled as woods is due to differences in the hydrologic soil groups present. Subwatershed S5 has the lowest initial amount of runoff (1.42 inches) since it has the largest percentage of hydrologic soil group B. Direct runoff areas B and C have the highest initial amounts of runoff (1.63 inches) since it has the largest percentage of hydrologic soil group D.

Overall, it is estimated that development has increased the amount of runoff for the Cranberry Run watershed by an average of 95.6% over an assumed initial land use of woods. It is felt that development similar to that which has occurred in the Cranberry Run watershed would have a similar effect on other watersheds in the area that are not yet developed.

Table 8.1: **Summary of Modelling Results - Land Use Changes in Cranberry Run Watershed.**

	Area (hectares)	Runoff Woods (inches)	Runoff Meadow (inches)	Runoff Present (inches)	Increase Over Woods (percent)
S1	376	1.45	1.32	2.87	99
S2	101	1.46	1.33	2.92	100
S3	227	1.59	1.39	2.87	94
S4	99	1.49	1.36	2.82	95
S5	135	1.42	1.29	2.87	101
A	85	1.59	1.47	2.94	92
B	49	1.63	1.50	1.89	58
C	8	1.63	1.51	2.94	97
D	53	1.53	1.39	2.92	95
E	67	1.51	1.38	2.92	97

CHAPTER 9

Application of Hydrosim Mk. 1 to Determine Time of Concentration for a Portion of the Mill Creek Watershed

9.1 Introduction

In this chapter Hydrosim Mk.1 was used to determine the changes in the time of concentration and storm hydrographs due to land use changes for a portion of the Mill Creek watershed. The Cranberry Run watershed with the same subdivisions and land use changes was used for this part of the study (Figure 9.1).

9.2 Time of Concentration

The TIMECON module of Hydrosim Mk. 1 was used to determine the times of concentration for each of the subwatersheds and direct runoff areas. When determining the times of concetration for subwatersheds, the same stream channel geometry was used before and after land use changes. This made it easier to compare differences between two subwatersheds by removing any particular features of a stream which may give misleading results, such as a waterfall or man-made lake. In reality, since land use changes are chronological (as explained in the previous chapter), it cannot be assumed that the stream of today had the same geometry as 50 years ago. However, by assuming a constant channel geometry, the effects of land use changes can be more easily compared. The stream geometry used was a rectangular cross section with a depth of three feet, a width of five feet, a slope of 0.1 feet/feet and a Manning's Roughness Coefficient of 0.05.

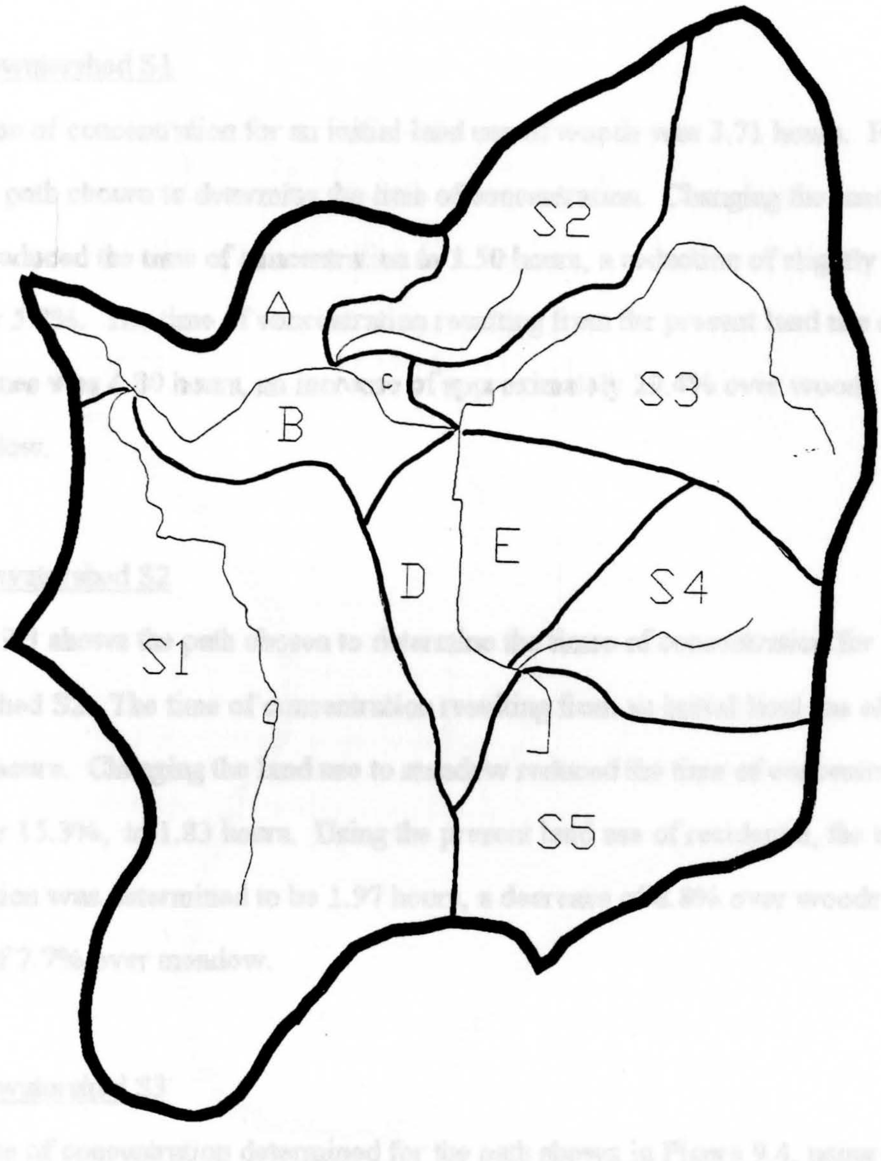


Figure 9.1: Map of the Cranberry Run Watershed Showing Sections used for Time of Concentration Determination.

9.3 Results

9.3.1 Subwatershed S1

The time of concentration for an initial land use of woods was 3.71 hours. Figure 9.2 shows the path chosen to determine the time of concentration. Changing the land use to meadow reduced the time of concentration to 3.50 hours, a reduction of slightly over 12 minutes or 5.7%. The time of concentration resulting from the present land use of single family homes was 4.80 hours, an increase of approximately 29.4% over woods and 37.1% over meadow.

9.3.2 Subwatershed S2

Figure 9.3 shows the path chosen to determine the times of concentration for subwatershed S2. The time of concentration resulting from an initial land use of woods was 2.16 hours. Changing the land use to meadow reduced the time of concentration by 20 minutes, or 15.3%, to 1.83 hours. Using the present land use of residental, the time of concentration was determined to be 1.97 hours, a decrease of 8.8% over woods and an increase of 7.7% over meadow.

9.3.3 Subwatershed S3

The time of concentration determined for the path shown in Figure 9.4, using the initial land use of woods, was determined to be 2.37 hours. Changing the land use to meadow reduced the time of concentration approximately 4.6% to 2.26 hours, or about 6.5 minutes. Using the present land use of residental, the time of concentration was determined to be 2.28 hours, a decrease of 3.8% over woods and an increase of 0.88% over meadow.

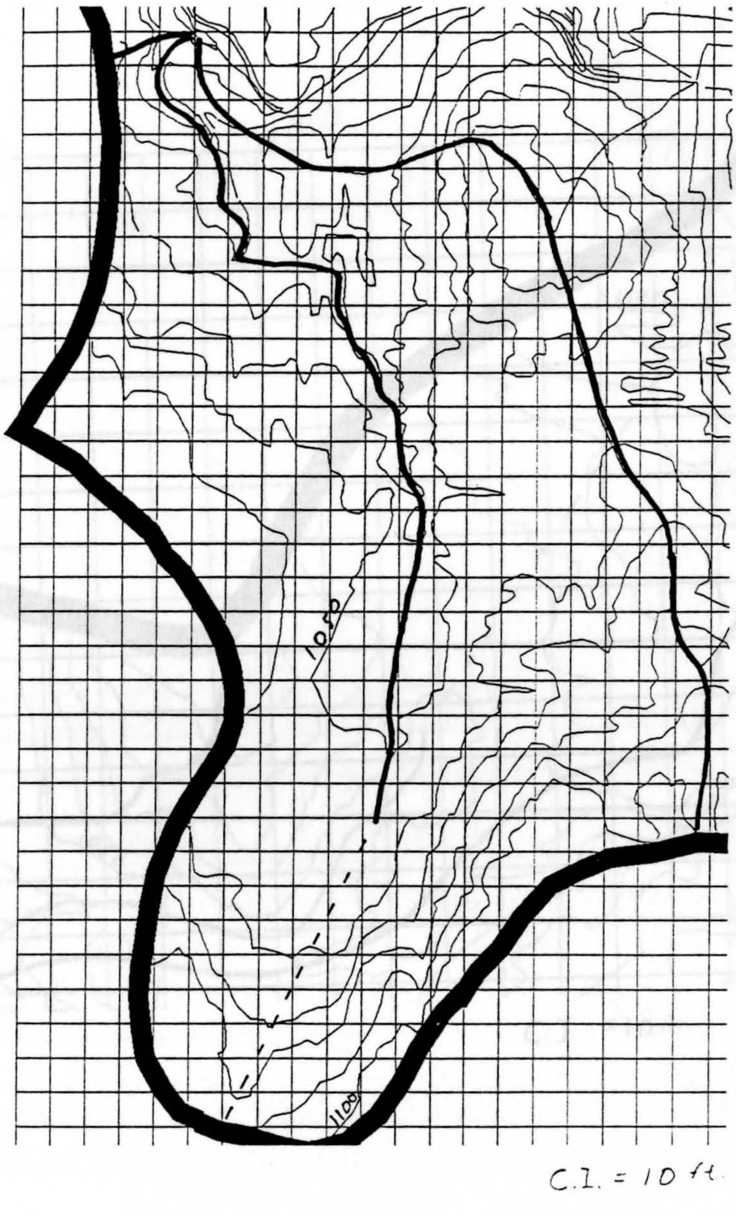


Figure 9.2: Map of Subwatershed S1 Showing Path Used for Time of Concentration Determination.

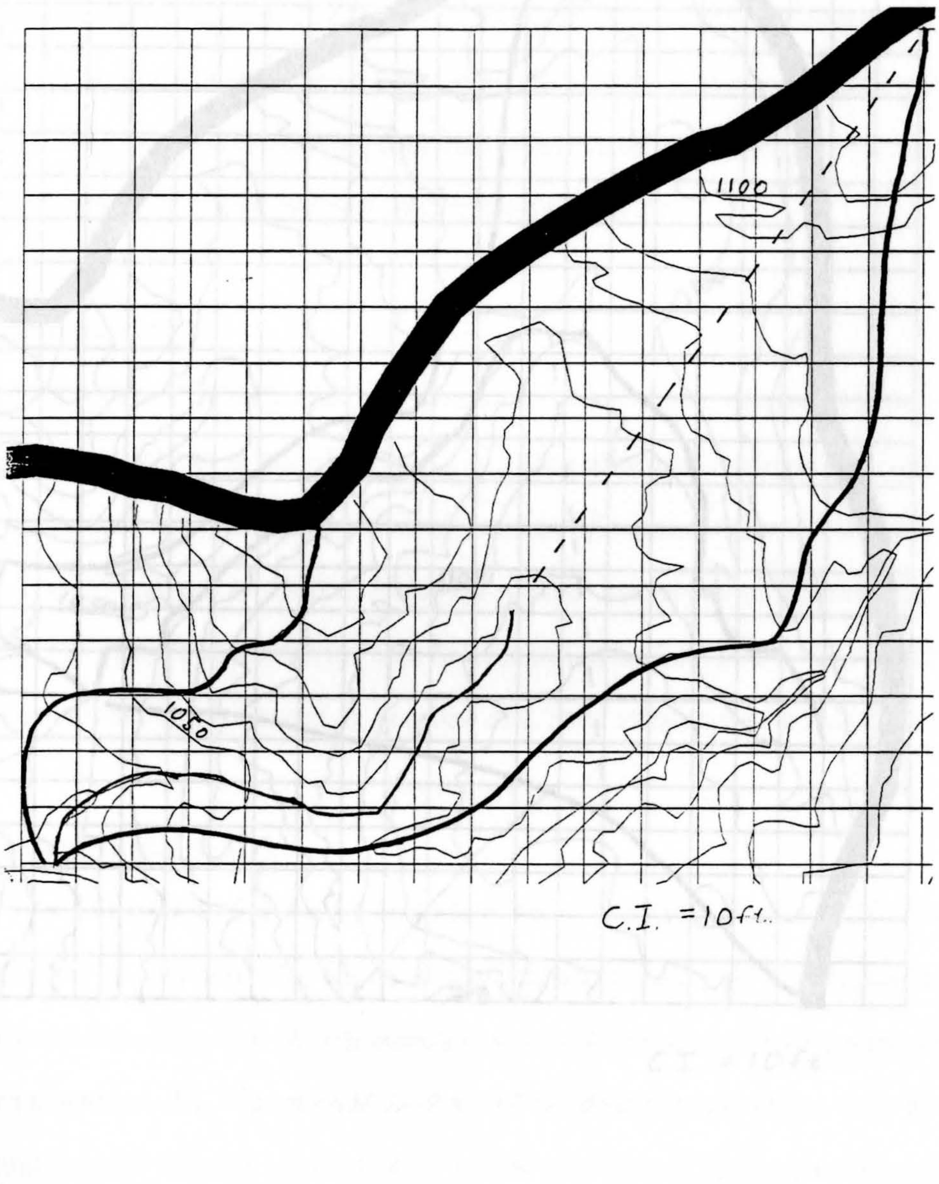


Figure 9.3: Map of Subwatershed S2 Showing Path Used for Time of Concentration Determination.

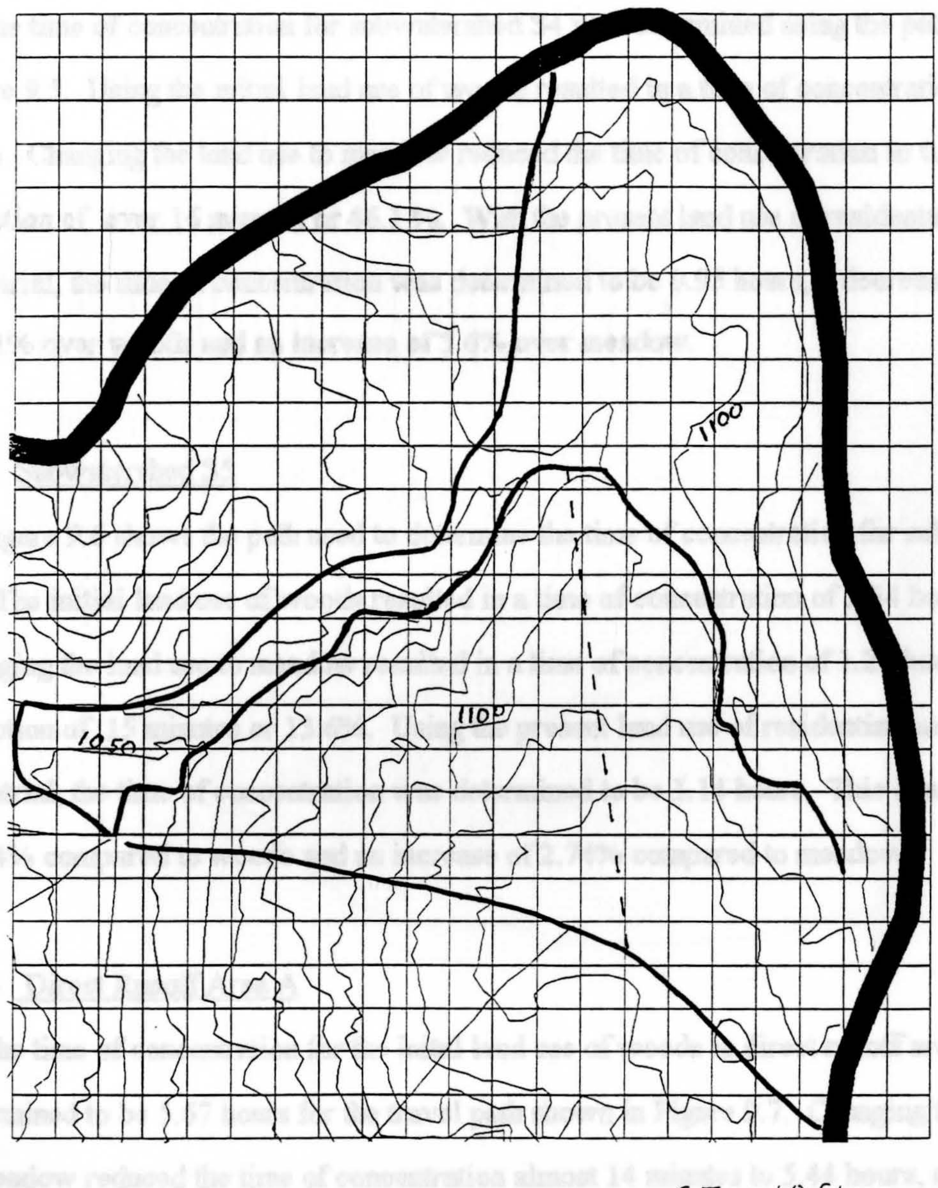


Figure 9.4: Map of Subwatershed S3 Showing Path Used for Time of Concentration Determination.

9.3.4 <u>Subwatershed S4</u>

The time of concentration for subwatershed S4 was determined using the path shown in Figure 9.5. Using the initial land use of woods resulted in a time of concentration of 1.17 hours. Changing the land use to meadow reduced the time of concentration to 0.90 hours, a reduction of over 16 minutes or 46.1 %. With the present land use of residental and urban industrial, the time of concentration was determined to be 0.95 hours, a decrease of 43.11% over woods and an increase of 5.6% over meadow.

9.3.5 <u>Subwatershed S5</u>

Figure 9.6 shows the path used to determine the time of concentration for subwatershed S5. The initial land use of woods resulted in a time of concentration of 1.54 hours. Changing the land use to meadow resulted in a time of concentration of 1.29 hours a reduction of 15 minutes or 13.6%. Using the present land use of residential and urban industrial, the time of concentration was determined to be 1.14 hours. This is a decrease of 11.24% compared to woods and an increase of 2.74% compared to meadow.

9.3.6 <u>Direct Runoff Area A</u>

The time of concentration for the inital land use of woods in direct runoff area A was determined to be 5.67 hours for the travel path shown in Figure 9.7. Changing the land use to meadow reduced the time of concentration almost 14 minutes to 5.44 hours, a reduction of approximately 4.1%. The present land use of residentail resulted in a time of concentration of 5.47 hours a reduction of 3.53% over woods and an increase of 0.55% over meadow.

9.3.7 <u>Direct Runoff Area B</u>

A time of concentration of 2.11 hours was obtained for the path shown in Figure 9.8 using the initial land use of woods. Changing the land use to meadow reduced the time of

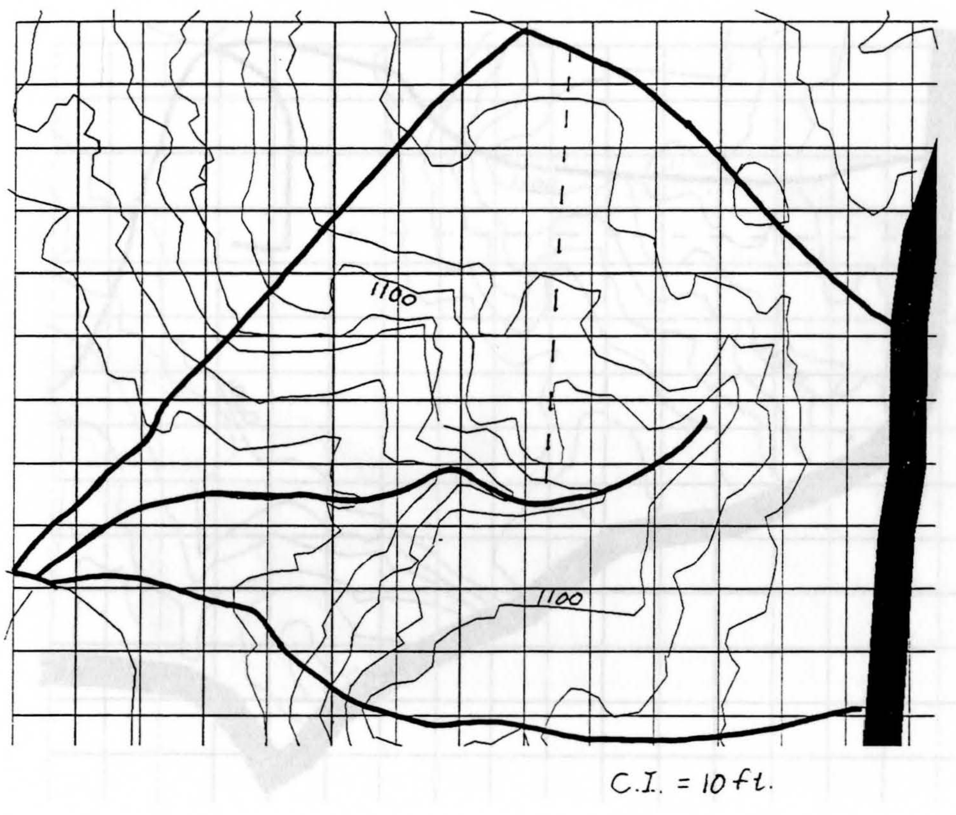


Figure 9.5: Map of Subwatershed S4 Showing Path Used for Time of Concentration Determination.

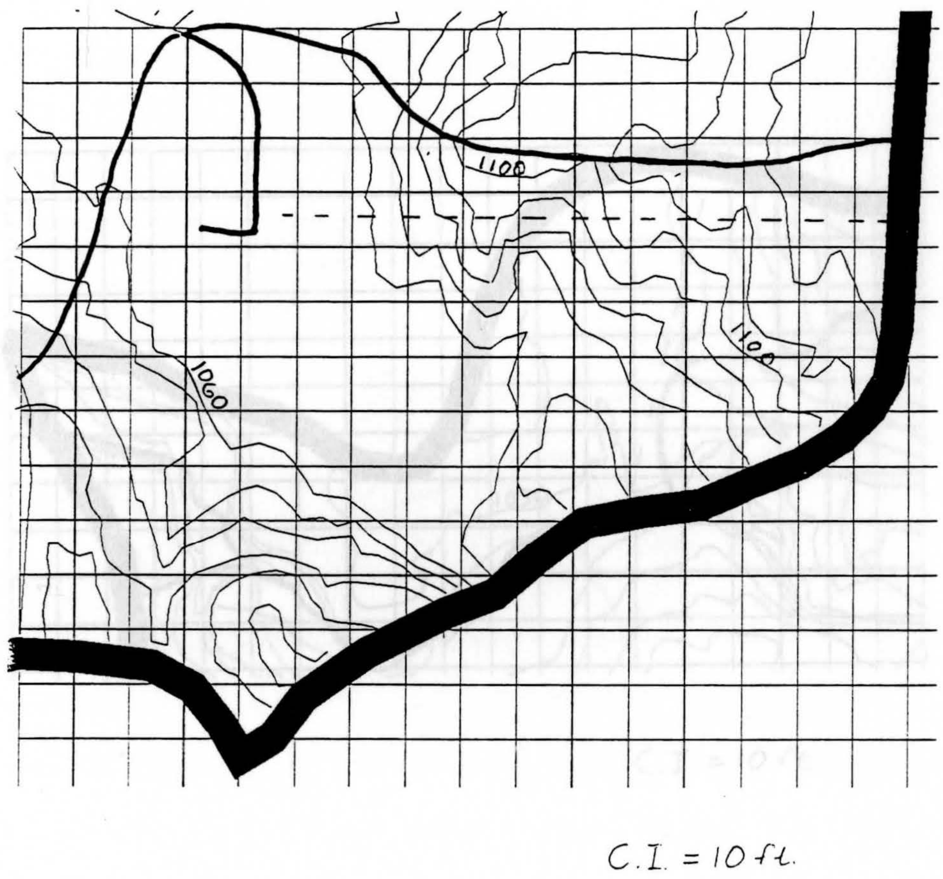


Figure 9.6: Map of Subwatershed S5 Showing Path Used for Time of Concentration Determination.

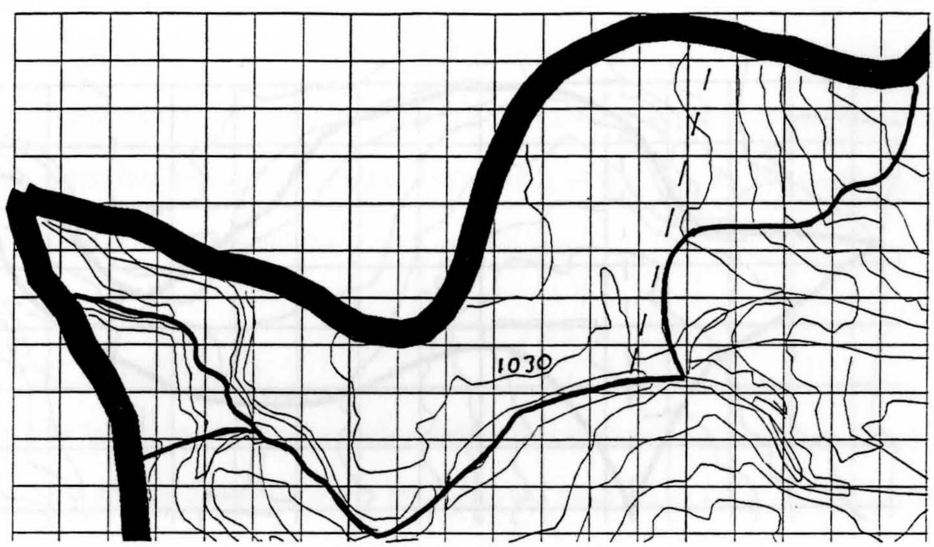


Figure 9.7: Map of Direct Runoff Area A Showing Path Used for Time of Concentration Determination.

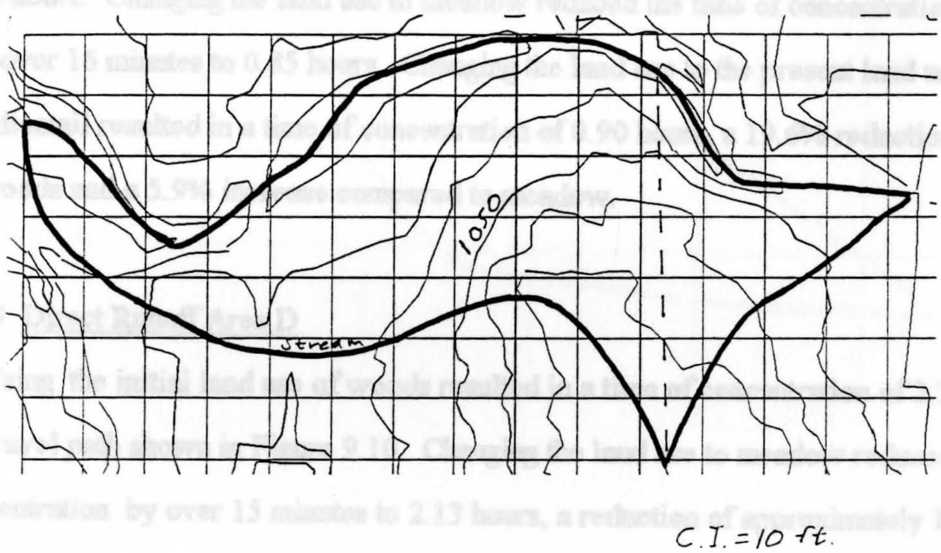


Figure 9.8: Map of Direct Runoff Area B Showing Path Used for Time of Concentration Determination.

concentration by over 15 minutes to 1.85 hours, or by 12.3%. The time of concentration for the present land use of residental and cemetary was determined to be 1.89 hours, a reduction of 10.43% from woods and an increase of 2.16% from meadow.

9.3.8 Direct Runoff Area C

Figure 9.9 shows the travel path chosen for the time of concentration in direct runoff area C. The time of concentration using the initial land use of woods was determined to be 1.12 hours. Changing the land use to meadow reduced the time of concentration by 24.1%, just over 16 minutes to 0.85 hours. Changing the land use to the present land use of residientail resulted in a time of concentration of 0.90 hours, a 19.6% reduction compared to woods and a 5.9% increase compared to meadow.

9.3.9 Direct Runoff Area D

Using the initial land use of woods resulted in a time of concentration of 2.39 hours for the travel path shown in Figure 9.10. Changing the land use to meadow reduced the time of concentration by over 15 minutes to 2.13 hours, a reduction of approximately 10.9%. The time of concentration using the present land use of residential was determined to be 2.14 hours a decrase of 10.5% over woods and an increase of approximately 0.47% over meadow.

9.3.10 Direct Runoff Area E

Figure 9.11 shows the travel path used to determine the times of concentration in direct runoff area E. The time of concentration for the initial land use of woods was determined to be 1.54 hours. Changing the land use to meadow reduced the time of concentration by 15 minutes to 1.29 hours, or by 16.2%. The time of concentration using the present land use of residential was 1.14 hours, a reduction of approximately 26% over woods and a reduction of 11.6% over meadow.

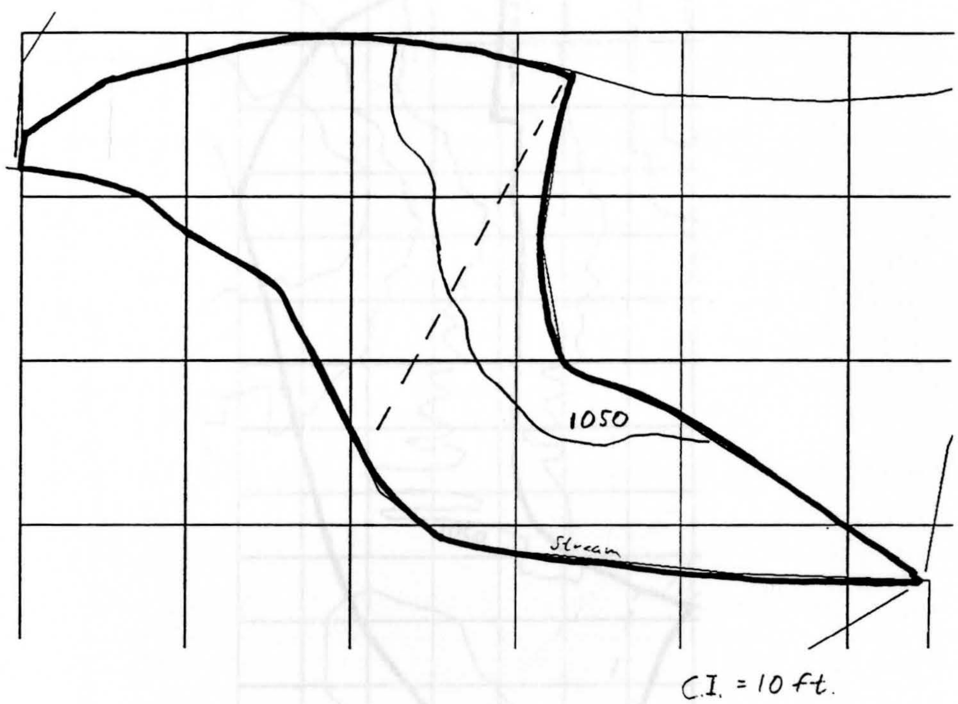


Figure 9.9: Map of Direct Runoff Area C Showing Path Used for Time of Concentration Determination.

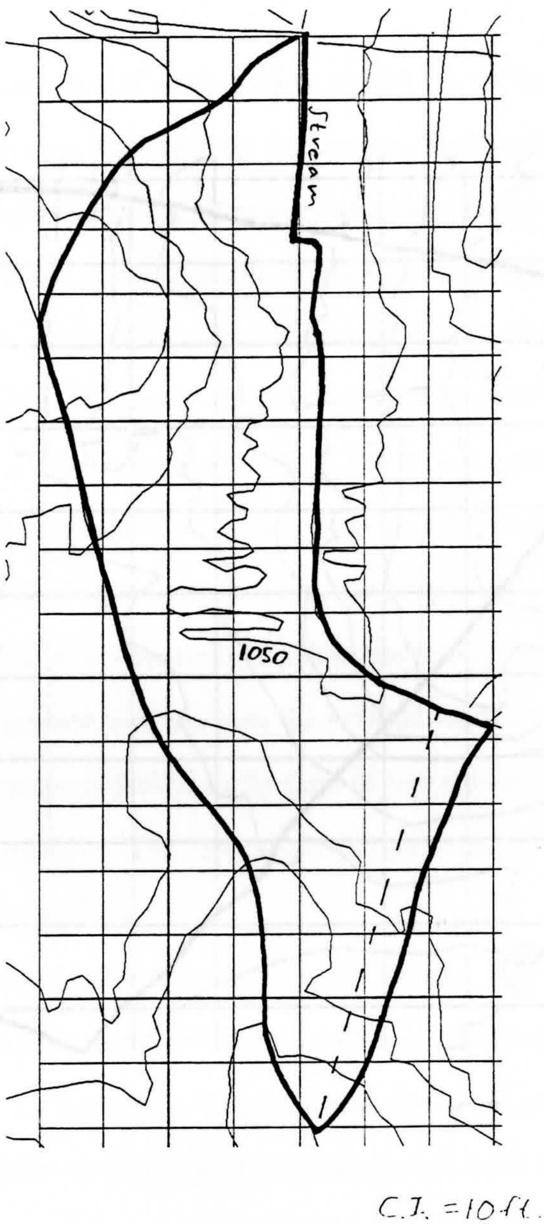


Figure 9.10: Map of Direct Runoff Area D Showing Path Used for Time of Concentration Determination.

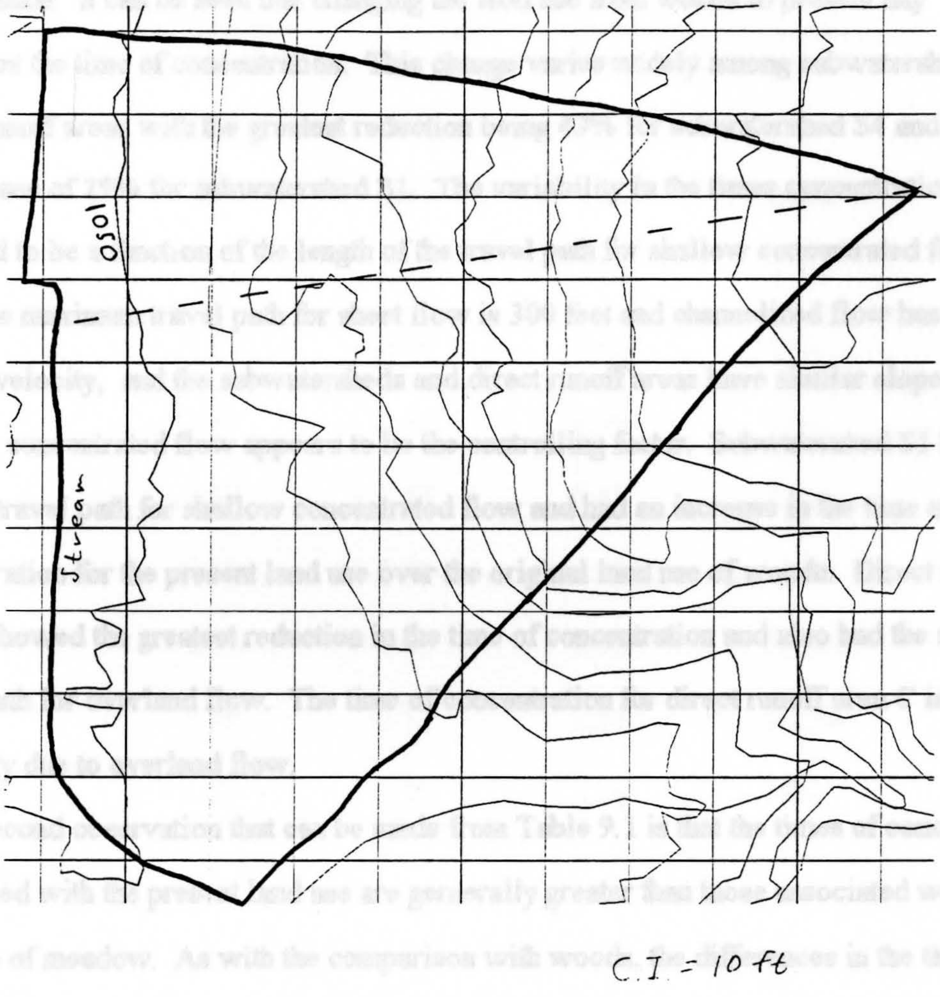


Figure 9.11: Map of Direct Runoff Area E Showing Path Used for Time of Concentration Determination.

9.4 Conclusions

Table 9.1 presents the time of concentration results. From this, several observations can be made. It can be seen that changing the land use from woods to present day decreases the time of concentration. This change varies widely among subwatersheds or direct runoff areas with the greatest reduction being 43% for subwatershed S4 and the least an increase of 29% for subwatershed S1. The variability in the times concentration is believed to be a finction of the length of the travel path for shallow concentrated flow. Since the maximum travel path for sheet flow is 300 feet and channelized flow has the highest velocity, and the subwatersheds and direct runoff areas have similar slopes, shallow concentrated flow appears to be the controlling factor. Subwatershed S1 had the longest travel path for shallow concentrated flow and had an increase in the time of concentration for the present land use over the original land use of woods. Direct runoff area E showed the greatest reduction in the time of concentration and also had the shortest travel path for overland flow. The time of concentration for direct runoff area C is primarily due to overland flow.

A second observation that can be made from Table 9.1 is that the times of concentration associated with the present land use are gernerally greater than those associated with the land use of meadow. As with the comparison with woods, the differences in the times of concentration vary. Subwatershed S1 showed an increase of 37% while direct runoff area E has a reduction of approximately 11.6%. The length of the travel path for shallow concentrated flow is believed to be the reason for this variation.

Overall, the difference between the times of concentration associated with the land use of meadow and the present day land use is not very significant. With the exception of subwatershed S1 and direct runoff area E, the increase in the times of concentration ranges from 0.47% to 7.7%. The present day land use gave a slightly longer time of concentration than meadow.

Table 9.1: **Times of Concentration for the Cranberry Run Watershed.**

Subwatershed/ Direct Runoff Area	Time of Concentration (hrs.)				
	Land Use Woods	Land Use Meadow	Land Use Present	% reduc. over woods	% incr. over meadow
S1	3.71	3.50	4.80	-29%	37%
S2	2.16	1.83	1.97	8.8%	7.7%
S3	2.37	2.26	2.28	3.8%	0.88%
S4	1.67	0.90	0.95	43%	5.6%
S5	1.69	1.46	1.50	11%	2.7%
A	5.67	5.44	5.47	3.5%	0.6%
B	2.11	1.85	1.89	10.4%	2.2%
C	1.12	0.85	0.90	19.6%	5.9%
D	2.39	2.13	2.14	10.5%	0.47%
E	1.54	1.29	1.14	26%	-11.6%

CHAPTER 10

Application of Hydrosim MK. 1 to Generate Hydrographs for a Portion of the Mill Creek Watershed

10.1 Introduction

Using data generated in the previous two chapters, Hydrosim Mk. 1 was employed to generate hydrographs for the Cranberry Run watershed. Hydrographs were generated for each individual section of the watershed as well as composite hydrographs for the watershed as a whole. The hydrographs were generated using the U. S. Soil Conservation Service Tabular Hydrograph Method (refer to Chapter 2). The Tabular Hydrograph method was used in this case because the times of concentration generated for each of the watershed's sections for each land use show enough difference that the problems with this method that were explained in previous chapters have been avoided. The Tabular Hydrograph Method was also used because the hydrographs will be based on the runoff calculated for each section from a 24-hour rainfall of 4 inches, remaining consistent with the previous two chapters.

10.2 Results of Individual Hydrographs

10.2.1 Subwatershed S1

Figure 10.1 shows the hydrographs generated for subwatershed S1. The peak discharge for the land use of woods was 390 cubic feet per second (cfs). The peak discharge for the land use of meadow was 355 cfs. The peak discharge for the present land use of residential was 942 cfs. The present level of development has increased the peak discharge 121% over that associated with woods and 133% over meadow.

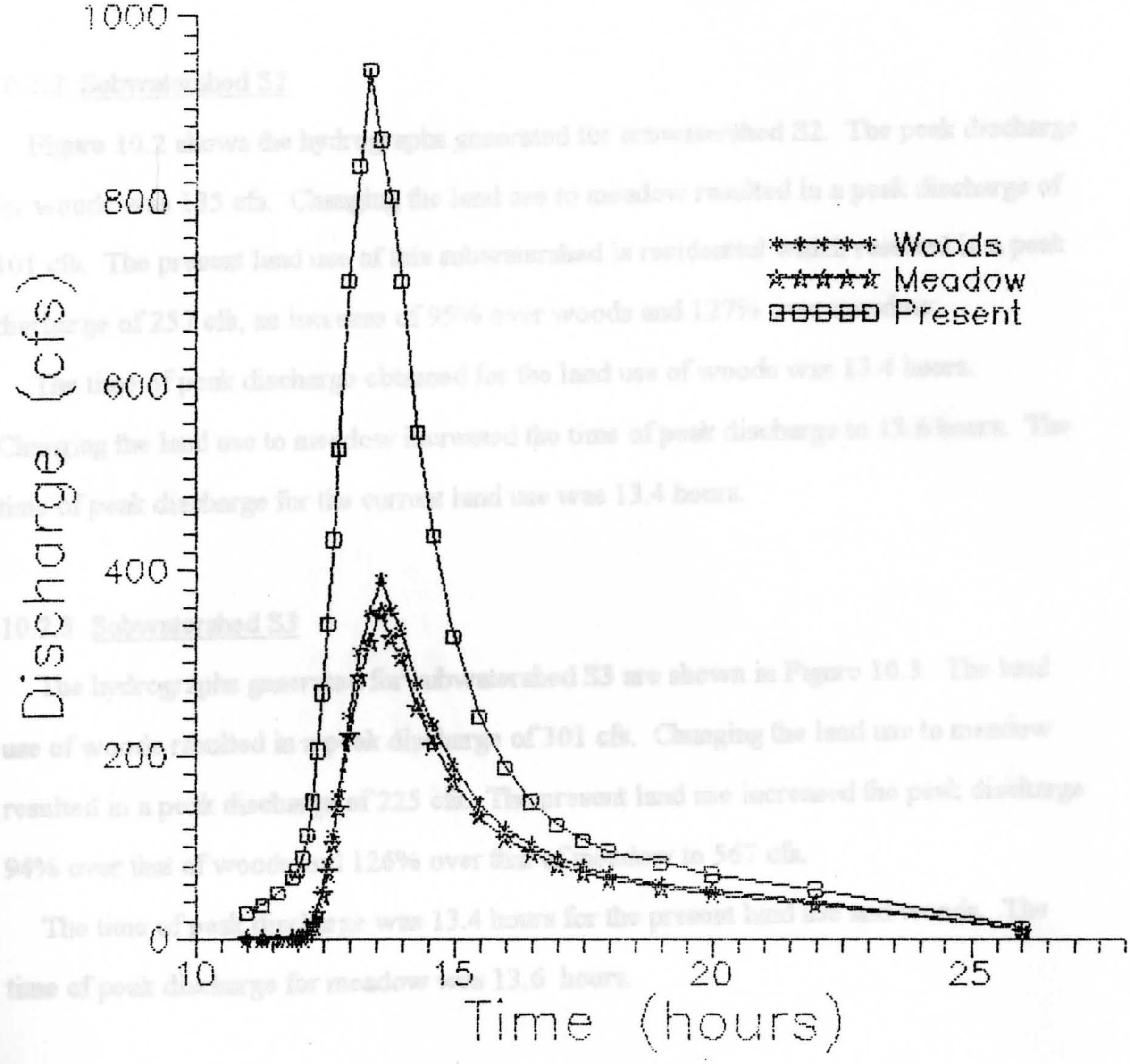


Figure 10.1: Tabular Hydrographs for Subwatershed S1.

The time of peak discharge for the land uses of woods and meadow was 13.6 hours. The time of peak discharge for the present land use was 13.4 hours.

10.2.2 Subwatershed S2

Figure 10.2 shows the hydrographs generated for subwatershed S2. The peak discharge for woods was 135 cfs. Changing the land use to meadow resulted in a peak discharge of 101 cfs. The present land use of this subwatershed is residential which resulted in a peak discharge of 257 cfs, an increase of 95% over woods and 127% over meadow.

The time of peak discharge obtained for the land use of woods was 13.4 hours. Changing the land use to meadow increased the time of peak discharge to 13.6 hours. The time of peak discharge for the current land use was 13.4 hours.

10.2.3 Subwatershed S3

The hydrographs generated for subwatershed S3 are shown in Figure 10.3. The land use of woods resulted in a peak discharge of 301 cfs. Changing the land use to meadow resulted in a peak discharge of 225 cfs. The present land use increased the peak discharge 94% over that of woods and 126% over that of meadow to 567 cfs.

The time of peak discharge was 13.4 hours for the present land use and woods. The time of peak discharge for meadow was 13.6 hours.

10.2.4 Subwatershed S4

Figure 10.4 shows the hydrographs generated for subwatershed S4. The land use of woods resulted in a peak discharge of 177 cfs. Changing the land us to woods reduced the peak discharge to 152 cfs. The present land use for this subwatershed resulted in a peak discharge of 385 cfs, an increase of 109% over woods and 127% over meadow.

The time of peak discharge for the land uses of woods and meadow was 13 hours. The time of peak discharge for the present land use was 12.8 hours.

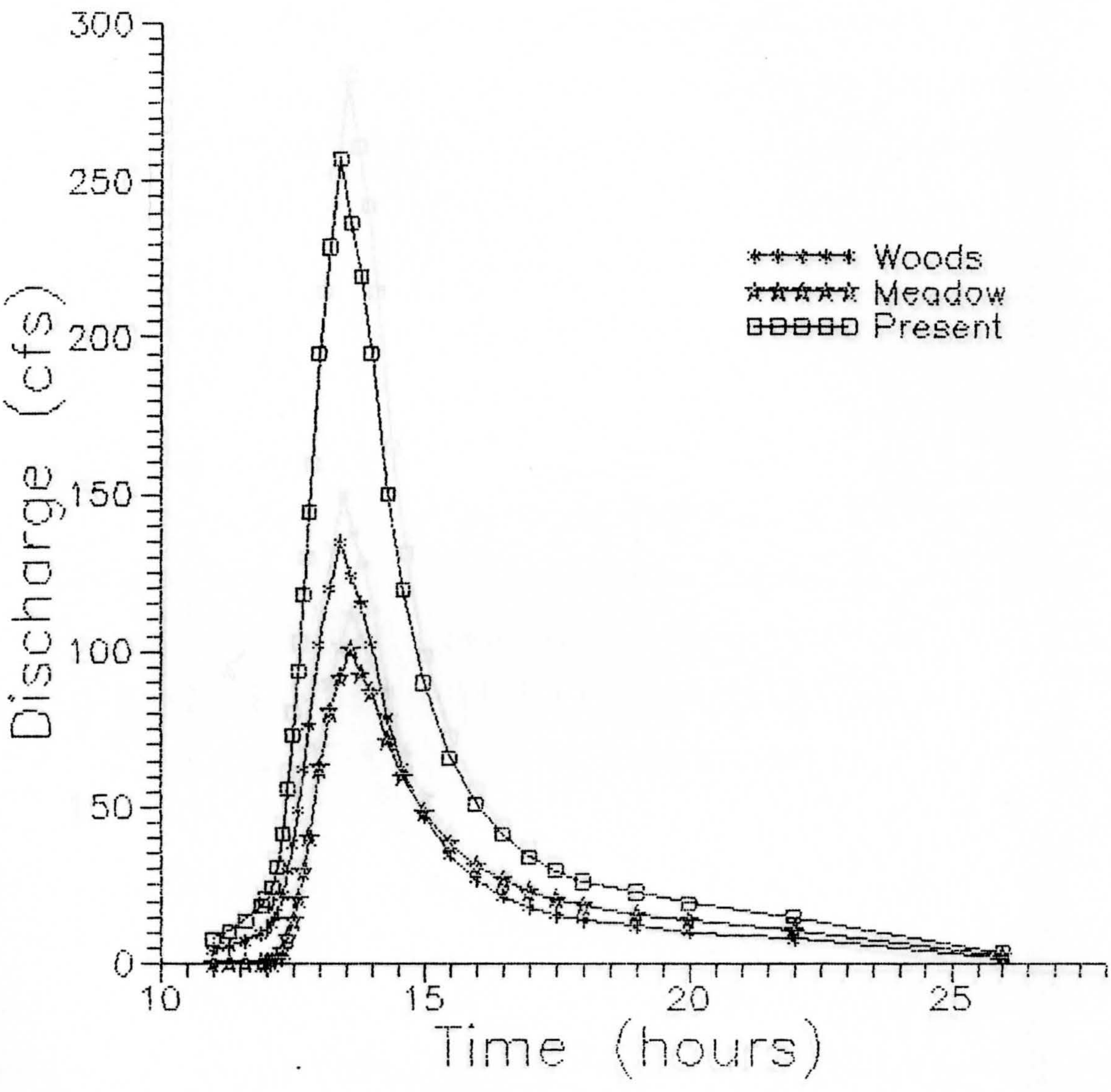


Figure 10.2: Tabular Hydrographs for Subwatershed S2.

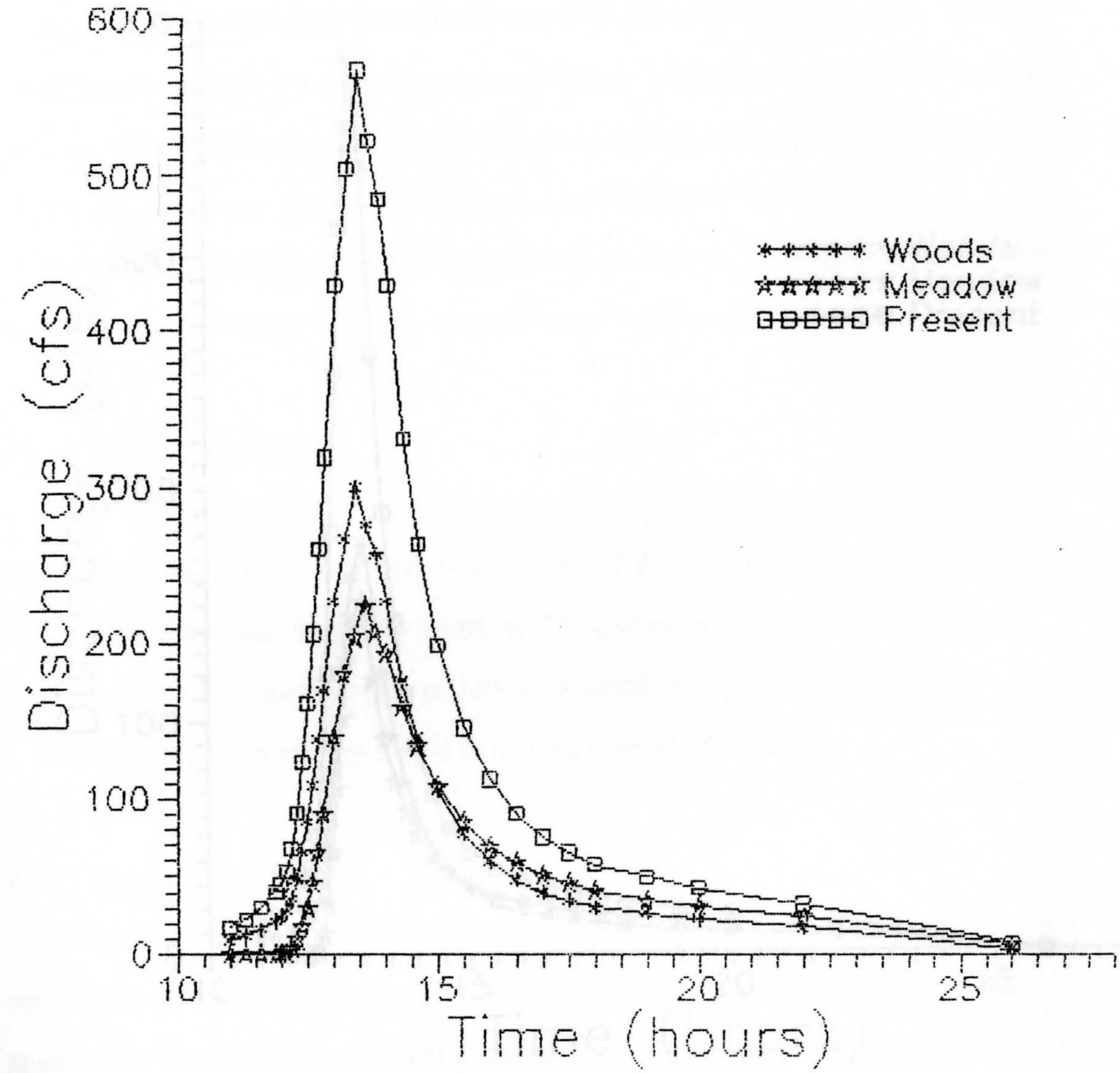


Figure 10.3: Tabular Hydrographs for Subwatershed S3.

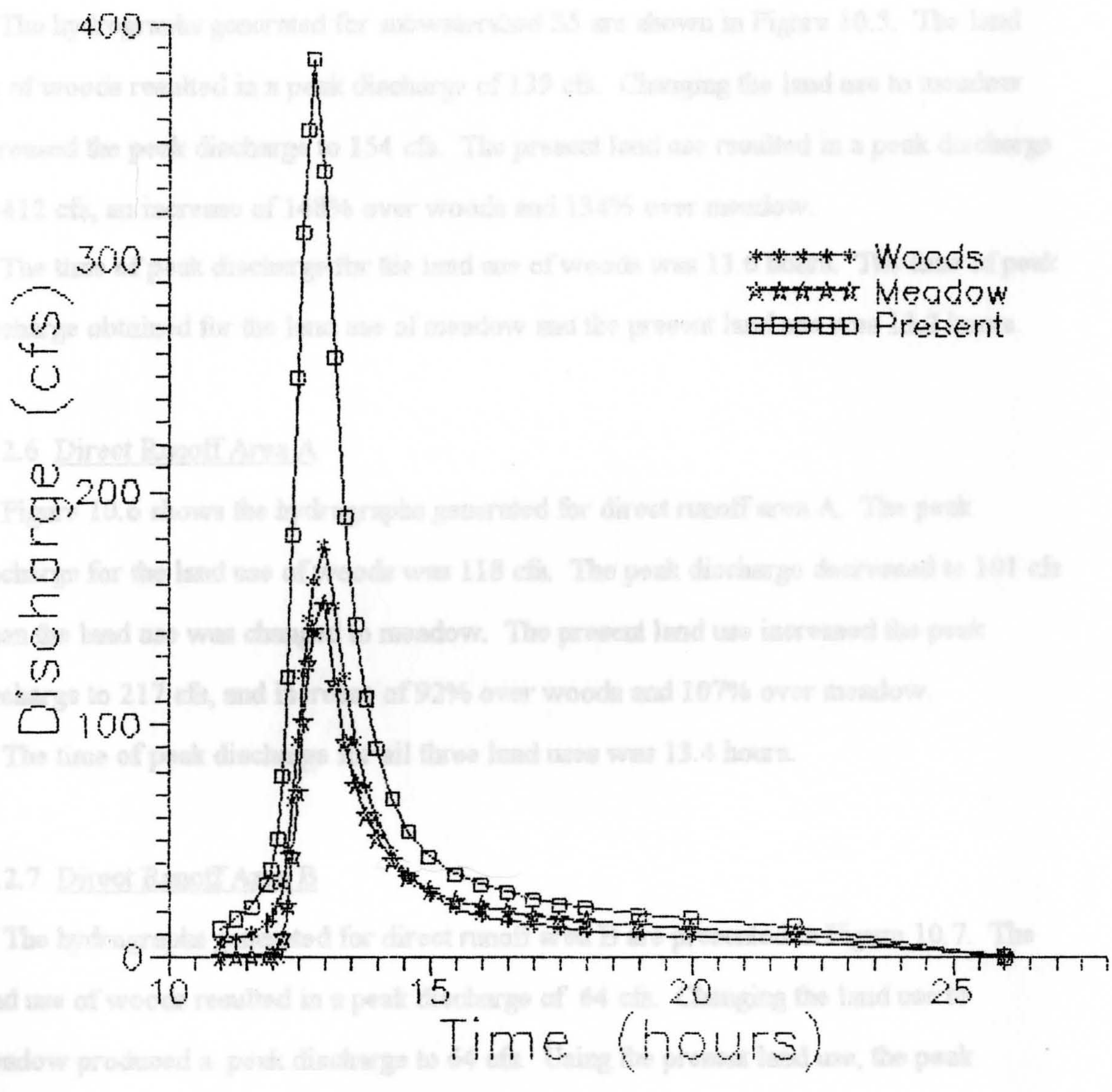


Figure 10.4: Tabular Hydrographs for Subwatershed S4.

10.2.5 Subwatershed S5

The hydrographs generated for subwatershed S5 are shown in Figure 10.5. The land use of woods resulted in a peak discharge of 139 cfs. Changing the land use to meadow increased the peak discharge to 154 cfs. The present land use resulted in a peak discharge of 412 cfs, an increase of 148% over woods and 134% over meadow.

The time of peak discharge for the land use of woods was 13.6 hours. The time of peak discharge obtained for the land use of meadow and the present land use was 13.2 hours.

10.2.6 Direct Runoff Area A

Figure 10.6 shows the hydrographs generated for direct runoff area A. The peak discharge for the land use of woods was 118 cfs. The peak discharge decreased to 101 cfs when the land use was changed to meadow. The present land use increased the peak discharge to 217 cfs, and increase of 92% over woods and 107% over meadow.

The time of peak discharge for all three land uses was 13.4 hours.

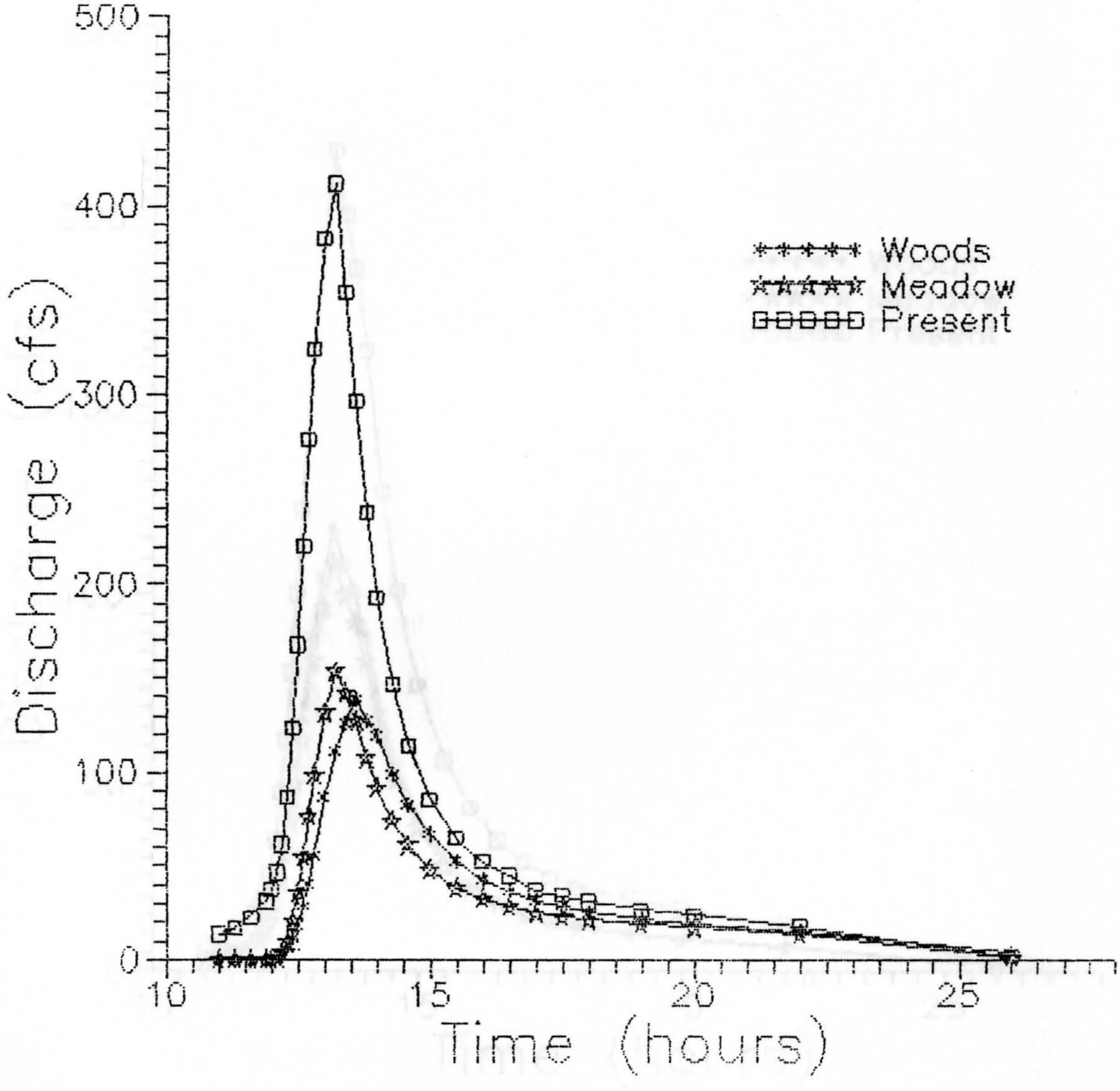
10.2.7 Direct Runoff Area B

The hydrographs generated for direct runoff area B are presented in Figure 10.7. The land use of woods resulted in a peak discharge of 64 cfs. Changing the land use to meadow produced a peak discharge to 64 cfs. Using the present land use, the peak discharge became 80 cfs, an increase of 63% over both woods and meadow.

The time of peak discharge for all three land uses was 13.4 hours.

10.2.8 Direct Runoff Area C

Figure 10.8 shows the hydrographs generated for direct runoff area C. The peak discharge associated with the initial land use of woods was 18 cfs. Changing the land use to meadow increased the peak discharge to 20 cfs. The present land use resulted in a peak



<u>Figure 10.5</u>: Tabular Hydrographs for Subwatershed S5.

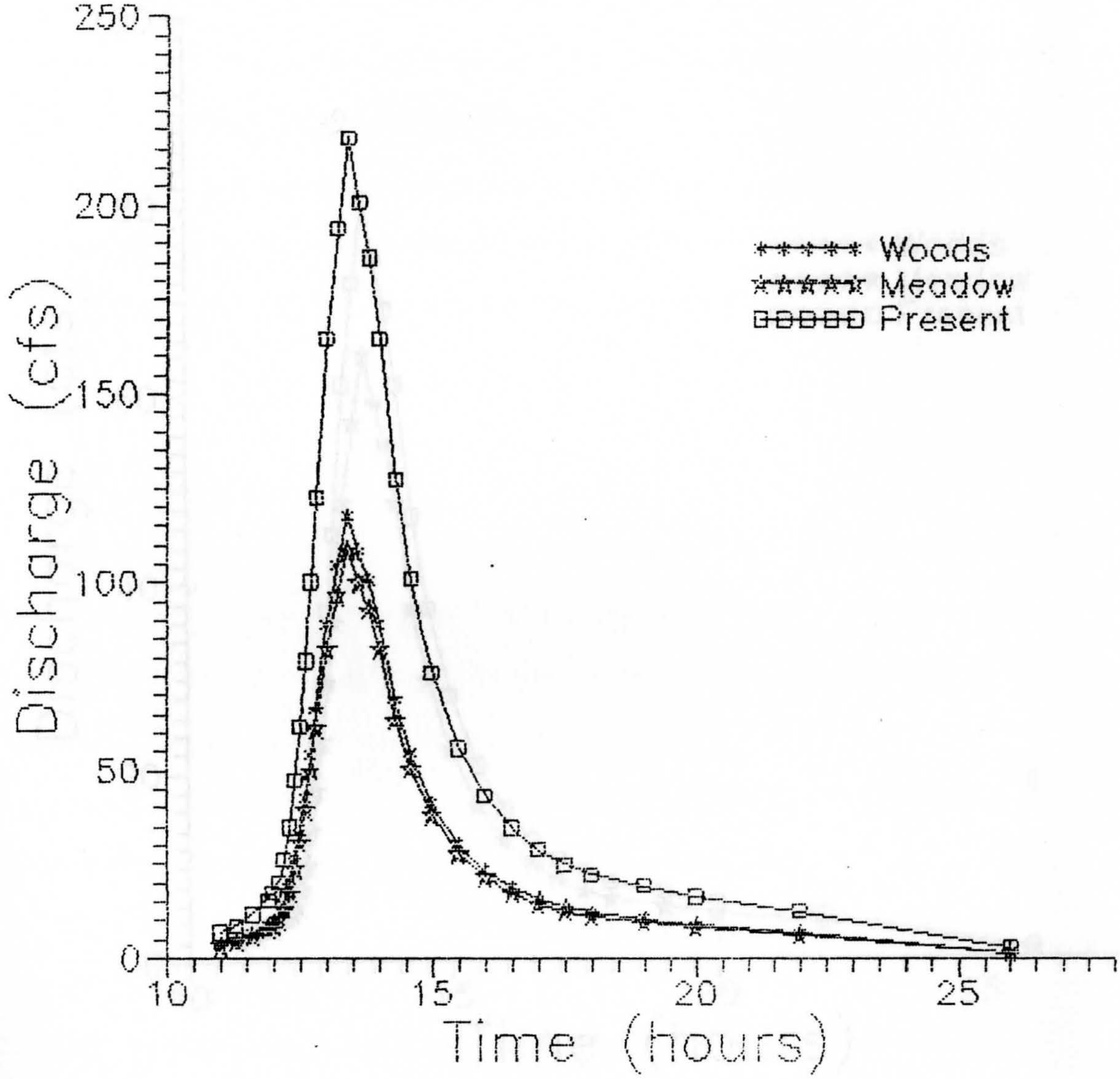


Figure 10.6: Tabular Hydrographs for Direct Runoff Area A.

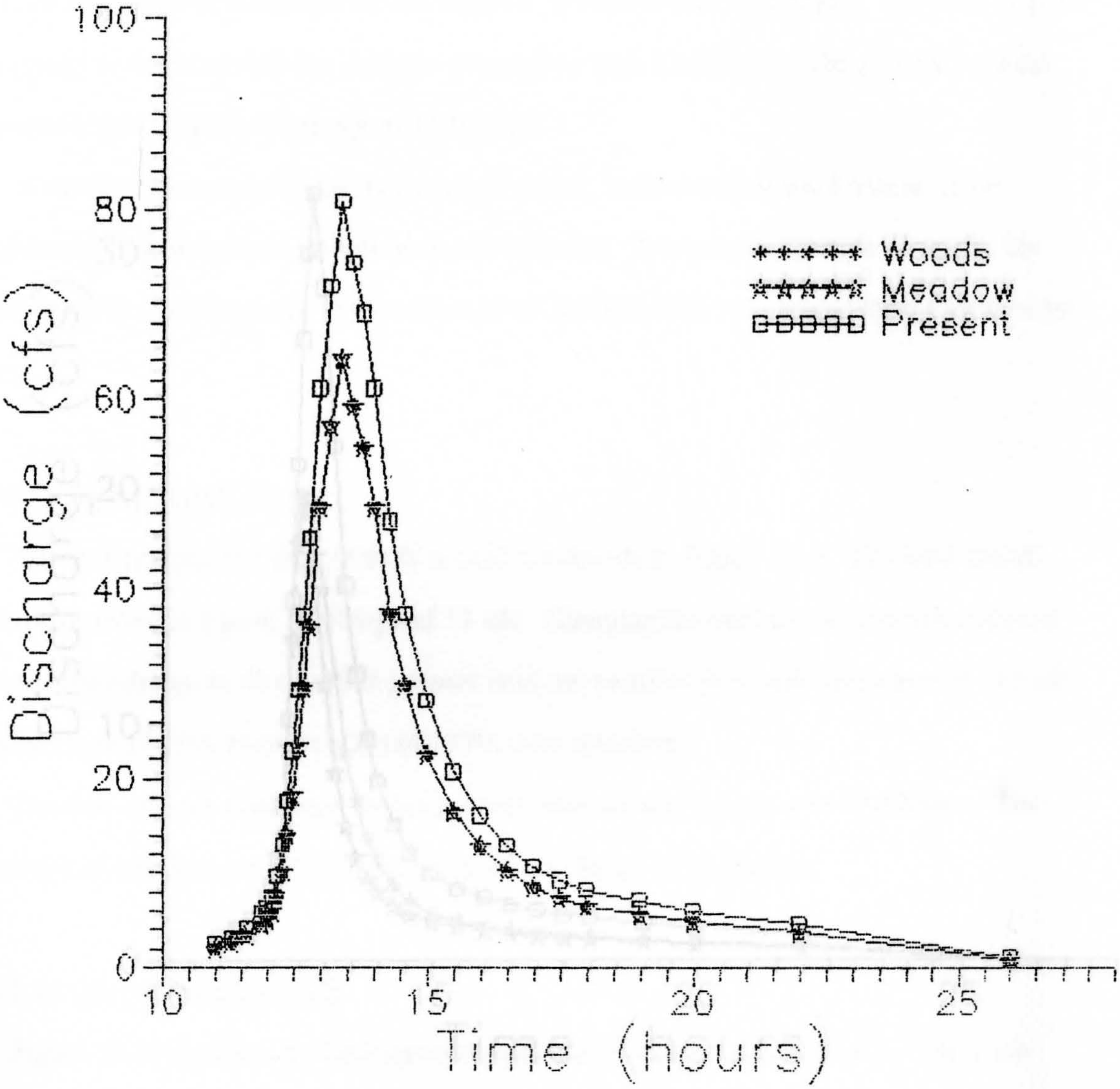


Figure 10.7: Tabular Hydrographs for Direct Runoff Area B.

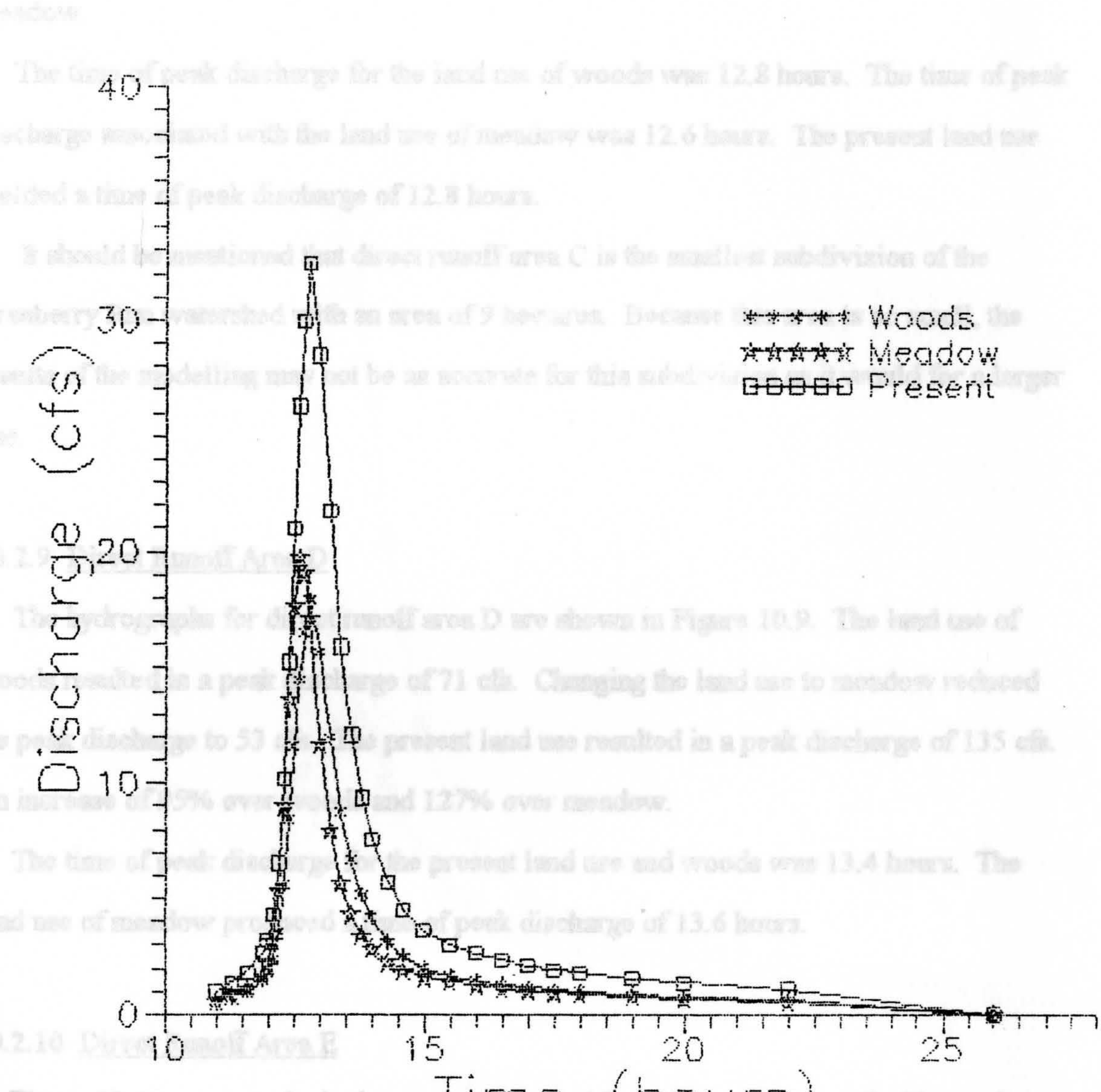


Figure 10.8: Tabular Hydrographs for Direct Runoff Area C.

discharge of 32 cfs, an increase of 89% over woods and an increase of 80% over meadow.

The time of peak discharge for the land use of woods was 12.8 hours. The time of peak discharge associated with the land use of meadow was 12.6 hours. The present land use yielded a time of peak discharge of 12.8 hours.

It should be mentioned that direct runoff area C is the smallest subdivision of the Cranberry Run watershed with an area of 9 hectares. Because this area is so small, the results of the modelling may not be as accurate for this subdivision as it would for a larger one.

10.2.9 <u>Direct Runoff Area D</u>

The hydrographs for direct runoff area D are shown in Figure 10.9. The land use of woods resulted in a peak discharge of 71 cfs. Changing the land use to meadow reduced the peak discharge to 53 cfs. The present land use resulted in a peak discharge of 135 cfs. An increase of 95% over woods and 127% over meadow.

The time of peak discharge for the present land use and woods was 13.4 hours. The land use of meadow produced a time of peak discharge of 13.6 hours.

10.2.10 <u>Direct Runoff Area E</u>

Figure 10.10 presents the hydrographs generated for direct runoff area E. The peak discharge associated with the initial land use of woods was 107 cfs. Changing the land use to meadow resulted in a peak runoff of 90 cfs. The peak discharge associated with the present land use was 206 cfs, an increase of 96% over woods and 114% over meadow.

The time of peak discharge for the present land use and woods was 13.2 hours. The land use of meadow gave a time of peak discharge of 13 hours.

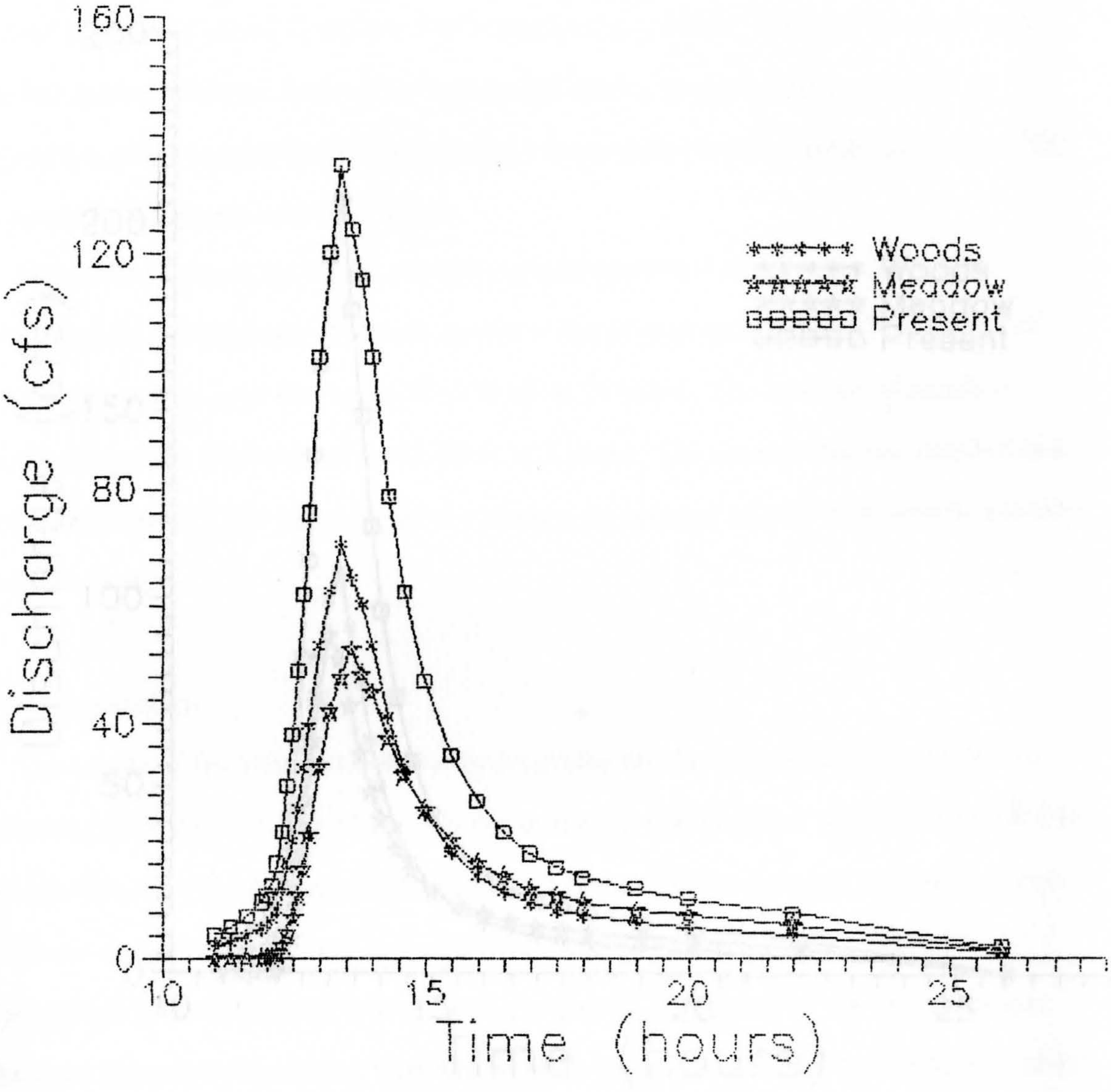


Figure 10.9: Tabular Hydrographs for Direct Runoff Area D.

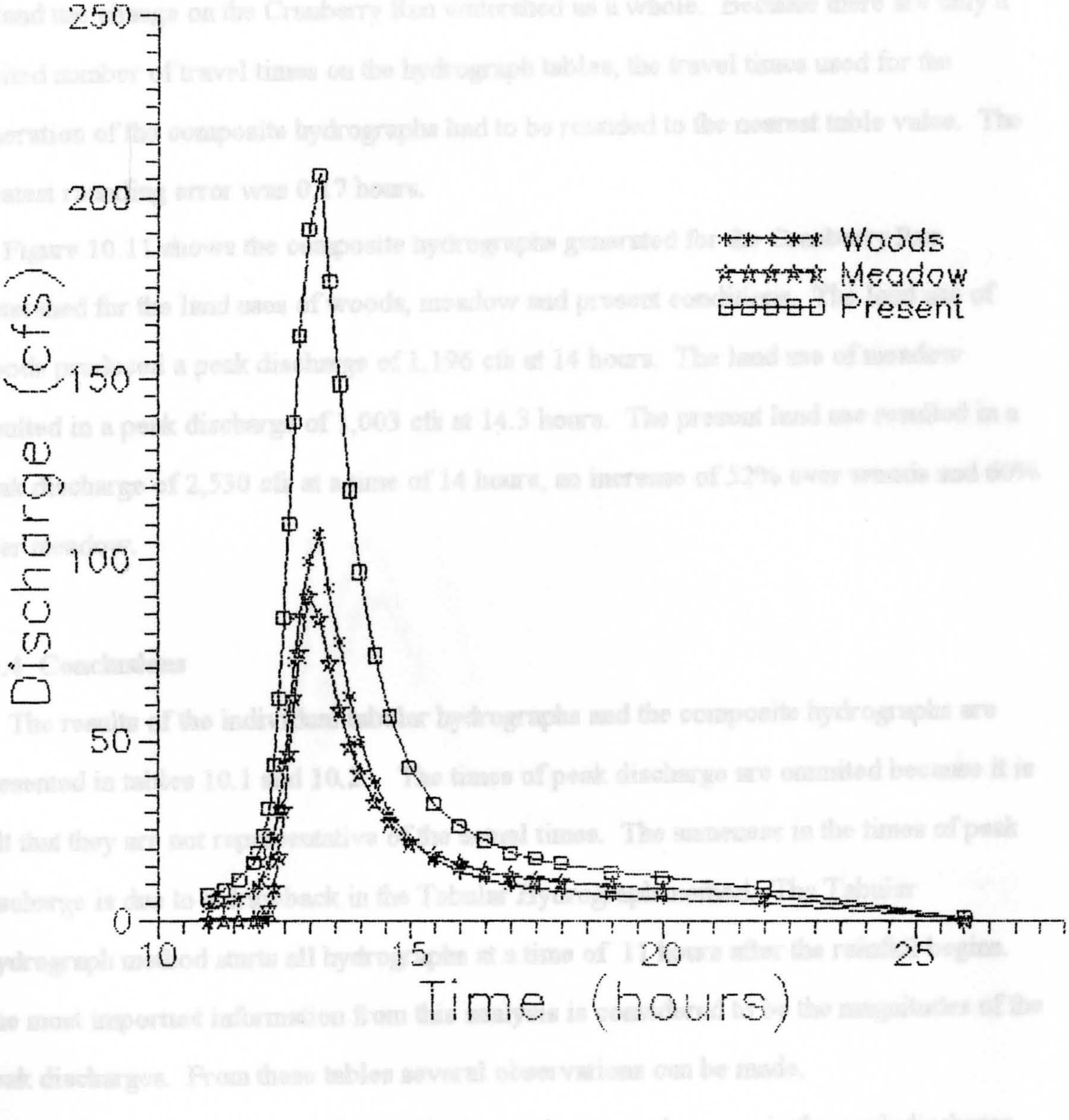


Figure 10.10: Tabular Hydrographs for Direct Runoff Area E.

10.3 Results of Composite Hydrographs

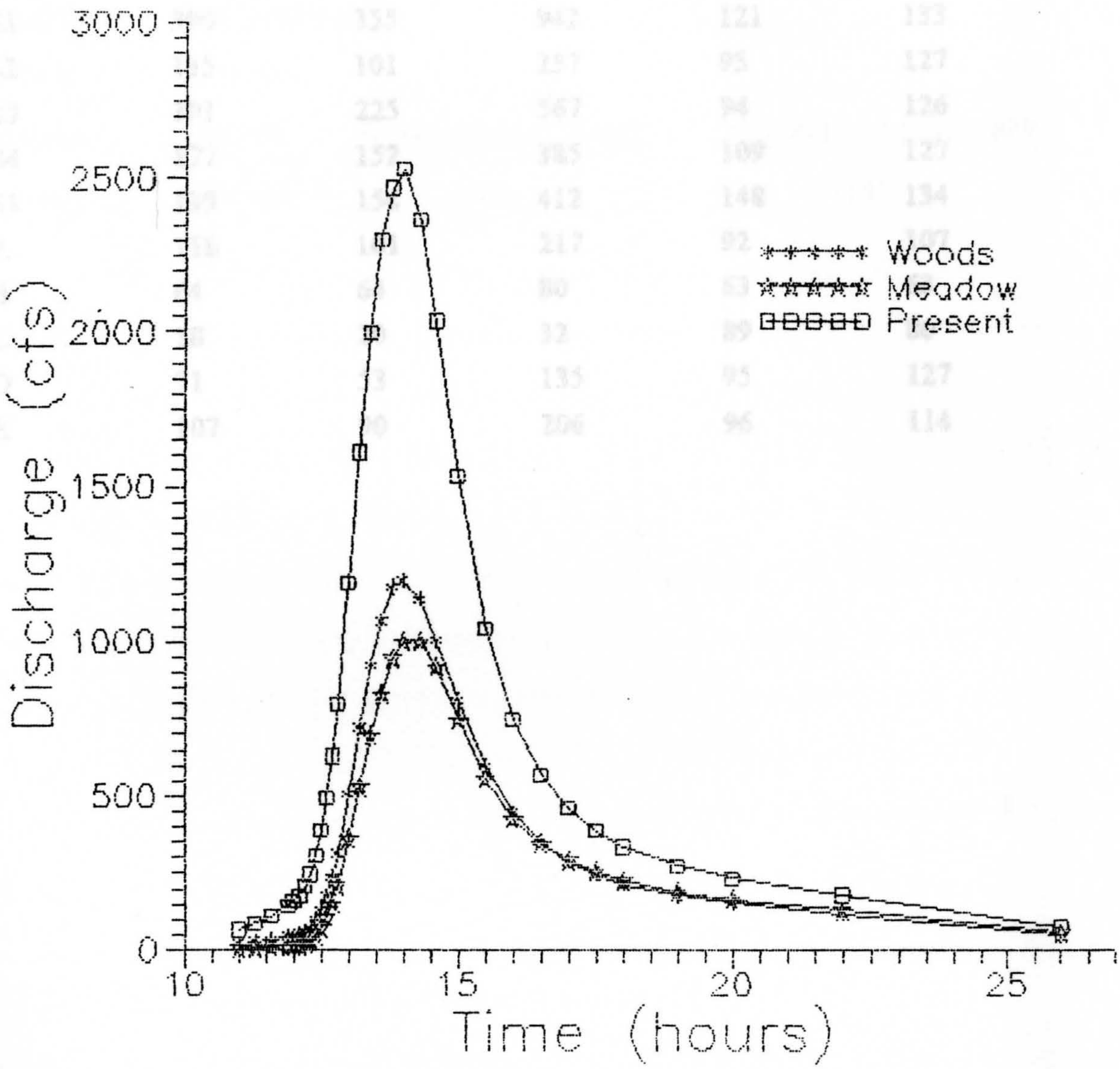
Composite hydrographs were generated using COMPHY mk. 1.0 to observe the effects of land use change on the Cranberry Run watershed as a whole. Because there are only a limited number of travel times on the hydrograph tables, the travel times used for the generation of the composite hydrographs had to be rounded to the nearest table value. The greatest rounding error was 0.17 hours.

Figure 10.11 shows the composite hydrographs generated for the Cranberry Run watershed for the land uses of woods, meadow and present conditions. The land use of woods produced a peak discharge of 1,196 cfs at 14 hours. The land use of meadow resulted in a peak discharge of 1,003 cfs at 14.3 hours. The present land use resulted in a peak discharge of 2,530 cfs at a time of 14 hours, an increase of 52% over woods and 60% over meadow.

10.4 Conclusions

The results of the individual tabular hydrographs and the composite hydrographs are presented in tables 10.1 and 10.2. The times of peak discharge are ommited because it is felt that they are not representative of the actual times. The sameness in the times of peak discharge is due to a drawback in the Tabular Hydrograph method. The Tabular Hydrograph method starts all hydrographs at a time of 11 hours after the rainfall begins. The most important information from this analysis is considered to be the magnitudes of the peak discharges. From these tables several observations can be made.

The general trend in the individual hydrographs was a decrease in the peak discharge from woods to meadow. Exceptions to this trend were observed for subwatershed S5, direct runoff area B and direct runoff area C. It is felt that the increase in peak discharge for sub watershed S5 and direct runoff area C and the lack of change for direct runoff area B is due to a combination of soil types and time of concentration travel path. The general



<u>Figure 10.11</u>: Composite Hydrographs for the Cranberry Run Watershed.

Table 10.1: Results of Individual Tabular Hydrographs

Sub Area	Peak Discharge Woods (cfs)	Peak Discharge Meadow (cfs)	Peak Discharge Present (cfs)	% Increase Over Woods	% Increase Over Meadow
S1	390	355	942	121	133
S2	135	101	257	95	127
S3	301	225	567	94	126
S4	177	152	385	109	127
S5	139	154	412	148	134
A	118	101	217	92	107
B	64	64	80	63	63
C	18	20	32	89	80
D	71	53	135	95	127
E	107	90	206	96	114

Table 10.2: Results of Composite Hydrographs

Land Use	Peak Discharge	% Increase over Woods	% Increase over Meadow
Woods	1,196 cfs		
Meadow	1,003 cfs		
Present	2,530 cfs	106%	126%

trend is also evident in the composite hydrographs, with a reduction in the peak discharge between woods and meadow.

Development substantially increased the peak discharge for both the individual and composite hydrographs. From Table 10.1 it can be seen that sub watershed S5 was the most sensitive to development with an increase in peak discharge of 148% over woods.

The average increase in peak discharge when land use was changed from woods to present development was 100%. This is in resonably good agreement with the same change shown in the composite hydrograph, an increase of 105%. The average increase in the peak discharge when the land use was changed from meadow to present land use was 114%. This is in reasonable agreement with the change shown in the composite hydrograph, an increased of 126%.

Overall, development can substantially increase the peak discharge for a watershed. This increase can lead to flooding and possible downstream sedimentation problems as more water is availiable to transport suspended sediment. The Hydrosim model predicted that peak discharges in Cranberry Run have more than doubled due to development. Similar increases have most likely occurred in other parts of the Mill Creek watershed as well..

CHAPTER 11
CONCLUSIONS

11.1 Hydrosim Mk. 1.0

From its various applications in this study, it can be seen that Hydrosim Mk. 1.0 performed according to its stated purpose. It provides for easy land use changes and modelling of the effects those changes have on a watershed. It also has the ability to model hypothetical watersheds.

As states earlier, Hydrosim Mk. 1.0 was not intended to model events exactly but to make relative comparisons between various land uses. This is because Hydrosim is based on the United States Soil Conservation Services TR-55 watershed model. The principle relationships used in TR-55 were developed from observations of small rural watersheds. Hydrosim would have to be calibrated with actual field data in order to model actual watershed events.

Overall, it can be concluded that Hydrosim Mk. 1.0 is a valid modelling system which offers flexibility and ease of operation. It is the author's hope that further improvements will be added in the future.

11.2 Effects of Development on the Mill Creek Watershed

The purpose of this study was to develop a watershed modelling system in which the effects of land use change could be easily modelled and compared. This need arose from the desire to understand the sedimentation problem in Lake Newport, located in Mill Creek Park. It had been accepted that the recent sedimentation in Lake Newport was the direct result of development within the Mill Creek watershed, but the magnitude of the effects of development on hydrology was not known.

From modelling the Cranberry Run watershed, a portion of the Mill Creek watershed, it has been determined that the present state of development essentially doubles the amount of

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runoff and the peak discharge over an assumed initial land use of woods. As development within the Mill Creek watershed continues, the problems of flooding and sedimentation will only grow worse.

From modelling performed on hypothetical watersheds, it has been determined that the impact of development can be reduced if development is carefully planned. By avoiding development on soil types with relatively high infiltration rates such as those belonging to hydrologic soil groups A and B, the amount of increase in runoff can be minimized. Also, if development is placed within a watershed so as not to cause an increase in the time of concentration, the amount of peak discharge may be minimized.

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APPENDIX

Source Code for Hydrosim mk. 1 Program Modules

Source Code for BCREATE mk. 1

```
************ Basin Create  mk. 1.0 *******************

CLS
SCREEN 12
'************ Initialize variables *********************
a = 1
b = 1
sl = 20
x = 1
y = 1
z = 1

'************ Get input File ************************
GOSUB fscreen
OPEN "\model\data\current.con" FOR INPUT AS #1
INPUT #1, sb$, a$
CLOSE #1

'************ Dimension Arrays *********************
DIM xx(1 TO 10000) AS INTEGER
DIM yy(1 TO 10000) AS INTEGER
total = 0

'**************** Main ***************************
GOSUB getborder
GOSUB dlines
GOSUB sidebar
GOSUB drawb
GOSUB drawborder

WHILE move$ <> "e"
  GOSUB tstore

  ON KEY(13) GOSUB right
  KEY(13) ON
  ON KEY(12) GOSUB left
  KEY(12) ON
  ON KEY(14) GOSUB down
  KEY(14) ON
  ON KEY(11) GOSUB up
  KEY(11) ON
  ON KEY(1) GOSUB sel
```

```
  KEY(1) ON
  ON KEY(2) GOSUB unsel
  KEY(2) ON
  ON KEY(3) GOSUB fileout
  KEY(3) ON
  ON KEY(4) GOSUB upscale
  KEY(4) ON
  ON KEY(5) GOSUB dnscale
  KEY(5) ON

  move$ = INKEY$
WEND
CLOSE #1
GOSUB escreen
RUN "MENU"
END
'*************************************************

drawb:
  LINE (a, b)-(a + sl, b), 4
  LINE (a, b)-(a, b + sl), 4
  LINE (a, b + sl)-(a + sl, b + sl), 4
  LINE (a + sl, b + sl)-(a + sl, b), 4
  LOCATE 25, 67
  PRINT "X = "; x
  LOCATE 27, 67
  PRINT "Y = "; y
RETURN
'*********************************
eraseb:
  LINE (ta, tb)-(ta + sl, tb), 7
  LINE (ta, tb)-(ta, tb + sl), 7
  LINE (ta, tb + sl)-(ta + sl, tb + sl), 7
  LINE (ta + sl, tb + sl)-(ta + sl, tb), 7
RETURN
'**********************************
tstore:
  ta = a
  tb = b
RETURN
'**********************************
dlines:
  CLS
  FOR i = 1 TO INT(500 / sl) * sl STEP sl
    LINE (i, 1)-(i, (INT(460 / sl) * sl) - sl), 7
  NEXT i
```

```
  FOR i = 1 TO INT(460 / sl) * sl STEP sl
    LINE (1, i)-((INT(500 / sl) * sl) - sl, i), 7
  NEXT i
RETURN
'************************************
sel:
  GOSUB drawb
  PAINT (a + 1, b + 1), 2, 4
  xx(z) = x
  yy(z) = y
  total = total + 1
  GOSUB drawborder
RETURN
'************************************
unsel:
  GOSUB eraseborder
  PAINT (a + 1, b + 1), 0, 4
  PAINT (a + sl - 1, b + sl - 1), 0, 4
  PAINT (a + sl - 1, b + 1), 0, 4
  PAINT (a + 1, b + sl - 1), 0, 4
  xx(z) = 0
  yy(z) = 0
  total = total - 1
  GOSUB drawborder
RETURN
'************************************
right:
  GOSUB tstore
  a = a + sl
  z = z + 1
  x = ((a - 1) / sl) + 1
  IF x > INT(500 / sl) - 1 THEN GOSUB rlimit
  IF ta <> a THEN GOSUB eraseb
  IF tb <> b THEN GOSUB eraseb
  GOSUB drawb
RETURN
'************************************
left:
  GOSUB tstore
  a = a - sl
  z = z - 1
  x = ((a - 1) / sl) + 1
  IF x < 1 THEN GOSUB llimit
  IF ta <> a THEN GOSUB eraseb
  IF tb <> b THEN GOSUB eraseb
```

```
 GOSUB drawb
RETURN
'*****************************************
down:
 GOSUB tstore
 b = b + sl
 y = ((b - 1) / sl) + 1
 z = z + (INT(500 / sl) - 1)
 IF y > INT(460 / sl) - 1 THEN GOSUB dlimit
 IF ta <> a THEN GOSUB eraseb
 IF tb <> b THEN GOSUB eraseb
 GOSUB drawb
RETURN
'*****************************************
up:
 GOSUB tstore
 b = b - sl
 y = ((b - 1) / sl) + 1
 z = z - (INT(500 / sl) - 1)
 IF y < 1 THEN GOSUB ulimit
 IF ta <> a THEN GOSUB eraseb
 IF tb <> b THEN GOSUB eraseb
 GOSUB drawb
RETURN
'*****************************************
rlimit:
 BEEP
 a = a - sl
 z = z - 1
 x = ((a - 1) / sl) + 1
RETURN
'*****************************************
llimit:
 BEEP
 a = a + sl
 z = z + 1
 x = ((a - 1) / sl) + 1
RETURN
'*****************************************
dlimit:
 BEEP
 b = b - sl
 y = ((b - 1) / sl) + 1
 z = z - (INT(500 / sl) - 1)
RETURN
'*****************************************
```

```
ulimit:
 BEEP
 b = b + sl
 y = ((b - 1) / sl) + 1
 z = z + (INT(500 / sl) - 1)
RETURN
'*********************************************
sidebar:
  LINE (505, 1)-(505, 460), 1
  LINE (505, 1)-(620, 1), 1
  LINE (620, 1)-(620, 460), 1
  LINE (505, 460)-(620, 460), 1
  PAINT (510, 3), 1, 1
  LOCATE 2, 67
  PRINT name$
  LOCATE 4, 67
  PRINT "up    "; CHR$(24)
  LOCATE 5, 67
  PRINT "down  "; CHR$(25)
  LOCATE 6, 67
  PRINT "right "; CHR$(26)
  LOCATE 7, 67
  PRINT "left  "; CHR$(27)
  LOCATE 9, 65
  PRINT "F1  select"
  LOCATE 11, 65
  PRINT "F2  unselect"
  LOCATE 13, 65
  PRINT "F3  save    "
  LOCATE 15, 65
  PRINT "F4  scale up"
  LOCATE 17, 65
  PRINT "F5  scale dn"
  LOCATE 19, 65
  PRINT "e   to end  "
RETURN
'****************************************
upscale:
  sl = sl + 2
  GOSUB refresh
RETURN
'****************************************
dnscale:
  sl = sl - 2
  GOSUB refresh
RETURN
```

```
'*******************************************
refresh:
  GOSUB dlines
  GOSUB sidebar
  GOSUB drawborder
  a = 1: b = 1
  x = 1: y = 1
  GOSUB drawb
RETURN
'********************************************
fileout:
  LOCATE 25, 65
  PRINT "Saving"
  OPEN "\model\data\" + sb$ + ".del" FOR OUTPUT AS #1
  WRITE #1, water$
  WRITE #1, name$
  WRITE #1, sl
  WRITE #1, "del"
  WRITE #1, total

  FOR i = 1 TO 10000
   IF xx(i) <> 0 THEN WRITE #1, xx(i), yy(i)
  NEXT i
  CLOSE #1
  LOCATE 25, 65
  PRINT "     "
RETURN
'*******************************************
fscreen:
  LINE (40, 1)-(40, 460), 1
  LINE (40, 1)-(620, 1), 1
  LINE (620, 1)-(620, 460), 1
  LINE (40, 460)-(620, 460), 1
  PAINT (51, 2), 4, 1

  LOCATE 2, 32
  PRINT "Basin Create   mk.1"
  LOCATE 4, 20
  INPUT "Enter watershed name: "; water$
  LOCATE 6, 20
  INPUT "Enter basin name: "; name$
RETURN
'********************************************
escreen:
  CLS
  LINE (40, 1)-(40, 460), 1
```

```
  LINE (40, 1)-(620, 1), 1
  LINE (620, 1)-(620, 460), 1
  LINE (40, 460)-(620, 460), 1
  PAINT (51, 2), 4, 1

  LOCATE 2, 20
  PRINT "Watershed: "; water$
  LOCATE 4, 20
  PRINT "Basin: "; name$
  LOCATE 6, 20
  PRINT "No. of blocks: "; total
  LOCATE 8, 20
  PRINT "Number of hectares: "; total
  LOCATE 10, 20
  PRINT "Number of square meters: "; (total * 100 ^ 2)
  LOCATE 12, 20
  PRINT "Number of acres: "; (total / 2.61)
  LOCATE 18, 20
  PRINT "Press e to exit"
  WHILE m$ <> "e"
    m$ = INKEY$
  WEND
RETURN
'************************************************************
getborder:
  yz = 0
  OPEN "\model\files\" + sb$ + ".bdr" FOR INPUT AS #1
    WHILE NOT EOF(1)
      INPUT #1, ww, qq
      yz = yz + 1
    WEND
  CLOSE #1
  DIM bx!(1 TO yz)
  DIM by!(1 TO yz)
  DIM px!(1 TO yz)
  DIM py!(1 TO yz)
  OPEN "\model\files\" + sb$ + ".bdr" FOR INPUT AS #1
  FOR k = 1 TO yz
    INPUT #1, bx!(k), by!(k)
  NEXT k
  CLOSE #1
RETURN
'************************************************************
drawborder:
  FOR k = 1 TO yz
    px!(k) = (bx!(k) * sl)
```

```
    py!(k) = (by!(k) * sl)
  NEXT k
  GOSUB borderpost
RETURN
'*******************************************
borderpost:
  FOR k = 1 TO yz - 1
    LINE (px!(k), py!(k))-(px!(k + 1), py!(k + 1)), 1
  NEXT k
  LINE (px!(yz), py!(yz))-(px!(1), py!(1)), 1
RETURN
'*******************************************************
eraseborder:
  FOR k = 1 TO yz - 1
    LINE (px!(k), py!(k))-(px!(k + 1), py!(k + 1)), 4
  NEXT k
  LINE (px!(yz), py!(yz))-(px!(1), py!(1)), 4
RETURN
```

Source Code for SOILADD mk. 1

```
'************** Soil Add  mk. 1 ******************
CLS
SCREEN 12

'************ Get Input File *******************

GOSUB start
GOSUB getdata
GOSUB dlines
GOSUB sidebar
GOSUB post
GOSUB initvar
GOSUB drawb

WHILE move$ <> "e"
  GOSUB tstore

  ON KEY(13) GOSUB right
  KEY(13) ON
  ON KEY(12) GOSUB left
  KEY(12) ON
  ON KEY(14) GOSUB down
  KEY(14) ON
  ON KEY(11) GOSUB up
  KEY(11) ON
  ON KEY(1) GOSUB sel
  KEY(1) ON
  ON KEY(2) GOSUB copy
  KEY(2) ON
  ON KEY(3) GOSUB fileout
  KEY(3) ON
  ON KEY(4) GOSUB edit
  KEY(4) ON
  move$ = INKEY$
WEND
RUN "MENU"
END
'*********************************************
start:
  LINE (200, 10)-(400, 10), 3
  LINE (200, 10)-(200, 40), 3
  LINE (200, 40)-(400, 40), 3
  LINE (400, 40)-(400, 10), 3
```

```
 PAINT (205, 15), 1, 3
 LOCATE 2, 31
 PRINT "Soil Add  mk. 1"
 OPEN "\model\data\current.con" FOR INPUT AS #1
 INPUT #1, sb$, a$
 CLOSE #1
RETURN
'****************************************

initvar:
 a = 1
 b = 1
 z = 1
 xx = 1
 yy = 1
RETURN
'*****************************************

sidebar:
 LINE (505, 1)-(505, 460), 4
 LINE (505, 1)-(620, 1), 4
 LINE (620, 1)-(620, 460), 4
 LINE (505, 460)-(620, 460), 4
 PAINT (510, 3), 4, 4
 LOCATE 2, 67
 PRINT name$
 LOCATE 4, 67
 PRINT "up    "; CHR$(24)
 LOCATE 5, 67
 PRINT "down    "; CHR$(25)
 LOCATE 6, 67
 PRINT "right   "; CHR$(26)
 LOCATE 7, 67
 PRINT "left  "; CHR$(27)
 LOCATE 9, 65
 PRINT "F1    Select"
 LOCATE 11, 65
 PRINT "F2  Copy"
 LOCATE 13, 65
 PRINT "F3  Save"
 LOCATE 15, 65
 PRINT "F4  Edit"
 LOCATE 18, 65
 PRINT "e  Exit"
RETURN
'**********************************************
```

```
dlines:
  CLS
  FOR i = 1 TO INT(500 / sl) * sl STEP sl
    LINE (i, 1)-(i, (INT(460 / sl) * sl) - sl), 7
  NEXT i
  FOR i = 1 TO INT(460 / sl) * sl STEP sl
    LINE (1, i)-((INT(500 / sl) * sl) - sl, i), 7
  NEXT i
RETURN
'**************************************************
getdata:
  IF a$ = "n" THEN GOSUB fonew
  IF a$ = "e" THEN GOSUB foedt

  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, fid$
  INPUT #1, blk

  DIM x(1 TO blk)  AS INTEGER
  DIM y(1 TO blk)   AS INTEGER
  DIM mark(1 TO blk) AS INTEGER
  DIM numsoil(1 TO blk) AS INTEGER
  DIM soil(1 TO blk, 1 TO 4) AS STRING * 4
  DIM perc(1 TO blk, 1 TO 4) AS INTEGER
  DIM slope(1 TO blk, 1 TO 4) AS INTEGER
  DIM csoil(1 TO blk, 1 TO 4) AS STRING * 4
  DIM cperc(1 TO blk, 1 TO 4) AS INTEGER
  DIM ctar(1 TO blk)

  IF fid$ = "del" THEN GOSUB getdel
  IF fid$ = "sol" THEN GOSUB getsol
  CLOSE #1
RETURN
'**********************************************
fonew:
  OPEN "\model\data\" + sb$ + ".del" FOR INPUT AS #1
RETURN
'**********************************************
foedt:
  OPEN "\model\data\" + sb$ + ".sol" FOR INPUT AS #1
RETURN
```

```
'**********************************************
getdel:
  FOR i = 1 TO blk
    INPUT #1, x(i)
    INPUT #1, y(i)
    mark(i) = 0
  NEXT i
RETURN
'**********************************************
getsol:
  FOR i = 1 TO blk
    INPUT #1, w, x(i), y(i)
    INPUT #1, numsoil(i)
    FOR j = 1 TO numsoil(i)
      INPUT #1, soil(i, j), perc(i, j)
    NEXT j
    IF numsoil(i) <> 0 THEN mark(i) = 1
    IF numsoil(i) = 0 THEN mark(i) = 0
  NEXT i
RETURN
'**********************************************
post:
 FOR i = 1 TO blk
  a = ((x(i) - 1) * sl) + 1
  b = ((y(i) - 1) * sl) + 1
  IF mark(i) = 1 THEN
   PAINT (a + 1, b + 1), 1, 7
  ELSE
   PAINT (a + 1, b + 1), 2, 7
  END IF
 NEXT i
RETURN
'**********************************************
drawb:
 LINE (a, b)-(a + sl, b), 4
 LINE (a, b)-(a, b + sl), 4
 LINE (a, b + sl)-(a + sl, b + sl), 4
 LINE (a + sl, b + sl)-(a + sl, b), 4
 LOCATE 25, 67
 PRINT "X = "; xx
 LOCATE 27, 67
 PRINT "Y = "; yy
RETURN
'************************************************
eraseb:
 LINE (ta, tb)-(ta + sl, tb), 7
```

```
  LINE (ta, tb)-(ta, tb + sl), 7
  LINE (ta, tb + sl)-(ta + sl, tb + sl), 7
  LINE (ta + sl, tb + sl)-(ta + sl, tb), 7
RETURN
'**************************************************
tstore:
  ta = a
  tb = b
RETURN
'**************************************************
right:
  GOSUB tstore
  a = a + sl
  z = z + 1
  xx = ((a - 1) / sl) + 1
  IF xx > INT(500 / sl) - 1 THEN GOSUB rlimit
  IF ta <> a THEN GOSUB eraseb
  IF tb <> b THEN GOSUB eraseb
  GOSUB drawb
RETURN
'**************************************************
left:
  GOSUB tstore
  a = a - sl
  z = z - 1
  xx = ((a - 1) / sl) + 1
  IF xx < 1 THEN GOSUB llimit
  IF ta <> a THEN GOSUB eraseb
  IF tb <> b THEN GOSUB eraseb
  GOSUB drawb
RETURN
'**************************************************
down:
  GOSUB tstore
  b = b + sl
  yy = ((b - 1) / sl) + 1
  z = z + (INT(500 / sl) - 1)
  IF yy > INT(460 / sl) - 1 THEN GOSUB dlimit
  IF ta <> a THEN GOSUB eraseb
  IF tb <> b THEN GOSUB eraseb
  GOSUB drawb
RETURN
'***********************************************
up:
  GOSUB tstore
  b = b - sl
```

```
  yy = ((b - 1) / sl) + 1
  z = z - (INT(500 / sl) - 1)
  IF yy < 1 THEN GOSUB ulimit
  IF ta <> a THEN GOSUB eraseb
  IF tb <> b THEN GOSUB eraseb
  GOSUB drawb
RETURN
'*****************************************************
rlimit:
  BEEP
  a = a - sl
  z = z - 1
  xx = ((a - 1) / sl) + 1
RETURN
'*****************************************************
llimit:
  BEEP
  a = a + sl
  z = z + 1
  xx = ((a - 1) / sl) + 1
RETURN
'*****************************************************
dlimit:
  BEEP
  yy = ((b - 1) / sl) + 1
  z = z - (INT(500 / sl) - 1)
RETURN
'*****************************************************
ulimit:
  BEEP
  b = b + sl
  yy = ((b - 1) / sl) + 1
  z = z + (INT(500 / sl) - 1)
RETURN
'************************************************
sel:
  PAINT (a + 1, b + 1), 1, 4

  FOR i = 1 TO blk
    ck = 0
    IF x(i) = xx THEN ck = ck + 1
    IF y(i) = yy THEN ck = ck + 1
    IF ck = 2 THEN blknum = i
  NEXT i
  GOSUB dataget
```

```
  GOSUB refresh
RETURN
'*********************************************
dataget:
  LINE (10, 100)-(450, 100), 6
  LINE (10, 100)-(10, 400), 6
  LINE (450, 100)-(450, 400), 6
  LINE (10, 400)-(450, 400), 6
  PAINT (111, 111), 6, 6

  LOCATE 8, 5
  PRINT "Bock # "; blknum
  LOCATE 10, 5
  INPUT "Enter number of soil types: "; numsoil(blknum)
  f = 5
  FOR i = 1 TO numsoil(blknum)
     LOCATE 12, f
     INPUT "SS: "; soil(blknum, i)
     LOCATE 14, f
     INPUT " %: "; perc(blknum, i)
     f = f + 12
  NEXT i
  LOCATE 18, 15
  PRINT "Press e to Enter"
  WHILE INKEY$ <> "e"
  WEND
  mark(blknum) = 1
RETURN
'*********************************************
refresh:
  CLS
  cura = a: curb = b
  GOSUB dlines
  GOSUB sidebar
  GOSUB post
  a = cura: b = curb
  GOSUB drawb
RETURN
'***************************************************************
copy:
  c = 0

  GOSUB refresh
  GOSUB csidebar
```

```
  WHILE INKEY$ <> "e"
   GOSUB tstore
    ON KEY(13) GOSUB right
    KEY(13) ON
    ON KEY(12) GOSUB left
    KEY(12) ON
    ON KEY(14) GOSUB down
    KEY(14) ON
    ON KEY(11) GOSUB up
    KEY(11) ON
    ON KEY(1) GOSUB cmark
    KEY(1) ON
    ON KEY(2) GOSUB copyto
    KEY(2) ON
    ON KEY(3) GOSUB doc
    KEY(3) ON
  WEND
  GOSUB refresh
RETURN
'**************************************************
csidebar:
  LINE (505, 1)-(505, 460), 6
  LINE (505, 1)-(620, 1), 6
  LINE (620, 1)-(620, 460), 6
  LINE (505, 460)-(620, 460), 6
  PAINT (510, 2), 6, 6
  LOCATE 2, 67
  PRINT name$
  LOCATE 4, 67
  PRINT "up    "; CHR$(24)
  LOCATE 5, 67
  PRINT "down   "; CHR$(25)
  LOCATE 6, 67
  PRINT "right  "; CHR$(26)
  LOCATE 7, 67
  PRINT "left    "; CHR$(27)
  LOCATE 9, 65
  PRINT "F1 Copy From"
  LOCATE 11, 65
  PRINT "F2 Copy Too "
  LOCATE 13, 65
  PRINT "F3 Copy "
  LOCATE 15, 65
  PRINT "e to end"
RETURN
```

```
'*****************************************************
cmark:
 FOR i = 1 TO blk
  ck = 0
  IF x(i) = xx THEN ck = ck + 1
  IF y(i) = yy THEN ck = ck + 1
  IF ck = 2 THEN blknum = i
 NEXT i
 sblock = blknum
 FOR i = 1 TO 4
  csoil(sblock, i) = soil(blknum, i)
  cperc(sblock, i) = perc(blknum, i)
 NEXT i
 cnumsoil = numsoil(blknum)
 PAINT (a + 1, b + 1), 5, 4
RETURN
'*************************************************
copyto:
 FOR i = 1 TO blk
  ck = 0
  IF x(i) = xx THEN ck = ck + 1
  IF y(i) = yy THEN ck = ck + 1
  IF ck = 2 THEN blknum = i
 NEXT i
 c = c + 1
 PAINT (a + 1, b + 1), 14, 4
 ctar(c) = blknum
RETURN
'*************************************************
doc:
 FOR i = 1 TO c
  k = ctar(i)
  numsoil(k) = cnumsoil
  FOR j = 1 TO 4
   soil(k, j) = csoil(sblock, j)
   perc(k, j) = cperc(sblock, j)
  NEXT j
  mark(k) = 1
 NEXT i
RETURN
'*****************************************************************
fileout:

 LINE (200, 200)-(200, 300), 4
 LINE (200, 200)-(400, 200), 4
 LINE (400, 200)-(400, 300), 4
```

```
  LINE (200, 300)-(400, 300), 4
  PAINT (210, 210), 9, 4

  LOCATE 14, 36
  PRINT "Save"
  LOCATE 18, 34
  PRINT "Saving " + sb$ + ".sol"

  OPEN "\model\data\" + sb$ + ".sol" FOR OUTPUT AS #1
  WRITE #1, water$
  WRITE #1, name$
  WRITE #1, sl
  WRITE #1, "sol"
  WRITE #1, blk
   FOR i = 1 TO blk
     WRITE #1, i, x(i), y(i)
     WRITE #1, numsoil(i)
     FOR j = 1 TO numsoil(i)
       WRITE #1, soil(i, j), perc(i, j)
     NEXT j
   NEXT i
  CLOSE #1
  GOSUB refresh
RETURN
'************************************************************************
edit:
  FOR i = 1 TO blk
   ck = 0
   IF x(i) = xx THEN ck = ck + 1
   IF y(i) = yy THEN ck = ck + 1
   IF ck = 2 THEN blknum = i
  NEXT i
  GOSUB dispcon
  ans$ = INKEY$
  WHILE ans$ <> "q"
   IF ans$ = "e" THEN GOSUB changel
   IF ans$ = "d" THEN GOSUB deletel
   IF ans$ = "a" THEN GOSUB addl
   ans$ = INKEY$
  WEND

   GOSUB refresh
 RETURN

dispcon:
  LINE (10, 100)-(450, 100), 9
```

```
 LINE (10, 100)-(10, 400), 9
 LINE (450, 100)-(450, 400), 9
 LINE (10, 400)-(450, 400), 9
 PAINT (101, 101), 9, 9
 LOCATE 8, 4
 PRINT "Block "; blknum
 LOCATE 9, 4
 PRINT "Soil #    Sym          % "
 LOCATE 10, 4
 PRINT "==================================="
 FOR i = 1 TO numsoil(blknum)
   LOCATE 10 + i, 4
   PRINT i, soil(blknum, i), perc(blknum, i)
 NEXT i
 LOCATE 10 + i, 4
 PRINT "==================================="
 LOCATE 17, 4
 PRINT "e = edit line  d = delete line  a = add line"
 LOCATE 18, 4
 PRINT " **** q = quit **** "

RETURN


changel:
  LOCATE 19, 4
  INPUT "Enter line number to change: "; ln
  ss$ = ""

  LOCATE 20, 4
  INPUT "Enter soil symbol: "; ss$
  LOCATE 21, 4
  INPUT "Enter % of block: "; pp
  IF pp = 0 THEN pp = perc(blknum, ln)
  IF ss$ <> "" THEN soil(blknum, ln) = ss$
  IF pp <> perc(blknum, ln) THEN perc(blknum, ln) = pp
  GOSUB refresh
  GOSUB dispcon
RETURN

deletel:
  LOCATE 19, 4
  INPUT "Enter the number of the line to delete: "; ln
  z = numsoil(blknum) - ln
  FOR t = 1 TO z
```

```
    soil(blknum, ln) = soil(blknum, ln + 1)
    perc(blknum, ln) = perc(blknum, ln + 1)
    ln = ln + 1
  NEXT t
  numsoil(blknum) = numsoil(blknum) - 1
  GOSUB refresh
  GOSUB dispcon
RETURN

addl:
  LOCATE 19, 4
  g = numsoil(blknum) + 1
  INPUT "Enter soil symbol: "; soil(blknum, g)
  LOCATE 20, 4
  INPUT "Enter percent of block: "; perc(blknum, g)
  numsoil(blknum) = g
  GOSUB refresh
  GOSUB dispcon
RETURN
```

Source Code for LUSEADD mk. 1

```
'************** Luse Add  mk. 1 *******************
CLS
SCREEN 12

'************ Get Input File ********************

GOSUB start
GOSUB getdata
GOSUB dlines
GOSUB sidebar
GOSUB post
GOSUB initvar
GOSUB drawb

WHILE move$ <> "e"
  GOSUB tstore

  ON KEY(13) GOSUB right
  KEY(13) ON
  ON KEY(12) GOSUB left
  KEY(12) ON
  ON KEY(14) GOSUB down
  KEY(14) ON
  ON KEY(11) GOSUB up
  KEY(11) ON
  ON KEY(1) GOSUB sel
  KEY(1) ON
  ON KEY(2) GOSUB copy
  KEY(2) ON
  ON KEY(3) GOSUB fileout
  KEY(3) ON
  ON KEY(4) GOSUB edit
  KEY(4) ON
  move$ = INKEY$
WEND
RUN "\model\menu"
END
'*************************************************
start:
  LINE (200, 10)-(400, 10), 3
  LINE (200, 10)-(200, 40), 3
  LINE (200, 40)-(400, 40), 3
  LINE (400, 40)-(400, 10), 3
```

```
 PAINT (205, 15), 1, 3
 LOCATE 2, 31
 PRINT "Luse Add  mk. 1"
 OPEN "\model\data\current.con" FOR INPUT AS #1
 INPUT #1, sb$, a$
 CLOSE #1
RETURN
'****************************************

initvar:
 a = 1
 b = 1
 z = 1
 xx = 1
 yy = 1
RETURN

'****************************************
sidebar:
 LINE (505, 1)-(505, 460), 4
 LINE (505, 1)-(620, 1), 4
 LINE (620, 1)-(620, 460), 4
 LINE (505, 460)-(620, 460), 4
 PAINT (510, 3), 4, 4
 LOCATE 2, 67
 PRINT name$
 LOCATE 4, 67
 PRINT "up    "; CHR$(24)
 LOCATE 5, 67
 PRINT "down  "; CHR$(25)
 LOCATE 6, 67
 PRINT "right   "; CHR$(26)
 LOCATE 7, 67
 PRINT "left    "; CHR$(27)
 LOCATE 9, 65
 PRINT "F1   Select"
 LOCATE 11, 65
 PRINT "F2  Copy"
 LOCATE 13, 65
 PRINT "F3  Save"
 LOCATE 15, 65
 PRINT "F4  Edit"
 LOCATE 18, 65
 PRINT "e Exit"
RETURN
'**************************************************
```

```
dlines:
 CLS
 FOR i = 1 TO INT(500 / sl) * sl STEP sl
  LINE (i, 1)-(i, (INT(460 / sl) * sl) - sl), 7
 NEXT i
 FOR i = 1 TO INT(460 / sl) * sl STEP sl
  LINE (1, i)-((INT(500 / sl) * sl) - sl, i), 7
 NEXT i
RETURN
'*********************************************
getdata:

  IF a$ = "n" THEN GOSUB fonew
  IF a$ = "e" THEN GOSUB foedt
  IF a$ = "c" THEN GOSUB foedt
  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, fid$
  INPUT #1, blk

  DIM x(1 TO blk)  AS INTEGER
  DIM y(1 TO blk)   AS INTEGER
  DIM mark(1 TO blk) AS INTEGER
  DIM luse(1 TO blk) AS INTEGER
  DIM cluse(1 TO blk) AS INTEGER
  DIM ctar(1 TO blk)

  IF fid$ = "lu" THEN GOSUB lusget
  IF fid$ = "del" THEN GOSUB delget
  CLOSE #1
RETURN
'*****************************************
fonew:
  OPEN "\model\data\" + sb$ + ".del" FOR INPUT AS #1
RETURN
'*****************************************
foedt:
  OPEN "\model\data\" + sb$ + ".lus" FOR INPUT AS #1
RETURN
'*****************************************
delget:
  FOR i = 1 TO blk
    INPUT #1, x(i)
    INPUT #1, y(i)
```

```
    mark(i) = 0
  NEXT i
RETURN
'*********************************************
lusget:
  FOR i = 1 TO blk
    INPUT #1, junk
    INPUT #1, x(i)
    INPUT #1, y(i)
    INPUT #1, luse(i)
    IF luse(i) <> 0 THEN mark(i) = 1
  NEXT i
RETURN
'*********************************************
bcount:
  blk = 0
  OPEN infile$ FOR INPUT AS #1
  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, fid$

  WHILE NOT EOF(1)
   INPUT #1, junk, x, y
   blk = blk + 1
  WEND
  CLOSE #1
RETURN
'****************************************

post:
 FOR i = 1 TO blk
  a = ((x(i) - 1) * sl) + 1
  b = ((y(i) - 1) * sl) + 1
  IF mark(i) = 1 THEN
    PAINT (a + 1, b + 1), 1, 7
   ELSE
    PAINT (a + 1, b + 1), 2, 7
   END IF
 NEXT i
RETURN
'*********************************************
drawb:
 LINE (a, b)-(a + sl, b), 4
 LINE (a, b)-(a, b + sl), 4
```

```
 LINE (a, b + sl)-(a + sl, b + sl), 4
 LINE (a + sl, b + sl)-(a + sl, b), 4
 LOCATE 25, 67
 PRINT "X = "; xx
 LOCATE 27, 67
 PRINT "Y = "; yy
RETURN
'*********************************************
eraseb:
 LINE (ta, tb)-(ta + sl, tb), 7
 LINE (ta, tb)-(ta, tb + sl), 7
 LINE (ta, tb + sl)-(ta + sl, tb + sl), 7
 LINE (ta + sl, tb + sl)-(ta + sl, tb), 7
RETURN
'*******************************************
tstore:
 ta = a
 tb = b
RETURN
'*******************************************
right:
 GOSUB tstore
 a = a + sl
 z = z + 1
 xx = ((a - 1) / sl) + 1
 IF xx > INT(500 / sl) - 1 THEN GOSUB rlimit
 IF ta <> a THEN GOSUB eraseb
 IF tb <> b THEN GOSUB eraseb
 GOSUB drawb
RETURN
'*********************************************
left:
 GOSUB tstore
 a = a - sl
 z = z - 1
 xx = ((a - 1) / sl) + 1
 IF xx < 1 THEN GOSUB llimit
 IF ta <> a THEN GOSUB eraseb
 IF tb <> b THEN GOSUB eraseb
 GOSUB drawb
RETURN
'********************************************
down:
 GOSUB tstore
 b = b + sl
 yy = ((b - 1) / sl) + 1
```

```
 z = z + (INT(500 / sl) - 1)
 IF yy > INT(460 / sl) - 1 THEN GOSUB dlimit
 IF ta <> a THEN GOSUB eraseb
 IF tb <> b THEN GOSUB eraseb
 GOSUB drawb
RETURN
'*******************************************
up:
 GOSUB tstore
 b = b - sl
 yy = ((b - 1) / sl) + 1
 z = z - (INT(500 / sl) - 1)
 IF yy < 1 THEN GOSUB ulimit
 IF ta <> a THEN GOSUB eraseb
 IF tb <> b THEN GOSUB eraseb
 GOSUB drawb
RETURN
'*******************************************
rlimit:
 BEEP
 a = a - sl
 z = z - 1
 xx = ((a - 1) / sl) + 1
RETURN
'*****************************************
llimit:
 BEEP
 a = a + sl
 z = z + 1
 xx = ((a - 1) / sl) + 1
RETURN
'*****************************************
dlimit:
 BEEP
 yy = ((b - 1) / sl) + 1
 z = z - (INT(500 / sl) - 1)
RETURN
'*******************************************
ulimit:
 BEEP
 b = b + sl
 yy = ((b - 1) / sl) + 1
 z = z + (INT(500 / sl) - 1)
RETURN
'*******************************************
sel:
```

```
  PAINT (a + 1, b + 1), 1, 4

  FOR i = 1 TO blk
    ck = 0
    IF x(i) = xx THEN ck = ck + 1
    IF y(i) = yy THEN ck = ck + 1
    IF ck = 2 THEN blknum = i
  NEXT i

  GOSUB dataget
  GOSUB refresh
RETURN
'********************************************
dataget:
  LINE (10, 100)-(350, 100), 6
  LINE (10, 100)-(10, 200), 6
  LINE (350, 100)-(350, 200), 6
  LINE (10, 200)-(350, 200), 6
  PAINT (111, 111), 6, 6

  LOCATE 8, 5
  PRINT "Bock # "; blknum
  LOCATE 10, 5
  INPUT "Enter land use number: "; luse(blknum)
  LOCATE 12, 15
  PRINT "Press e to Enter"
  WHILE INKEY$ <> "e"
  WEND
  mark(blknum) = 1
RETURN
'**********************************************
refresh:
  CLS
  cura = a: curb = b
  GOSUB dlines
  GOSUB sidebar
  GOSUB post
  a = cura: b = curb
  GOSUB drawb
RETURN
'**************************************************************
copy:
  c = 0

  GOSUB refresh
```

```
 GOSUB csidebar
 WHILE INKEY$ <> "e"
  GOSUB tstore
   ON KEY(13) GOSUB right
   KEY(13) ON
   ON KEY(12) GOSUB left
   KEY(12) ON
   ON KEY(14) GOSUB down
   KEY(14) ON
   ON KEY(11) GOSUB up
   KEY(11) ON
  ON KEY(1) GOSUB cmark
   KEY(1) ON
   ON KEY(2) GOSUB copyto
   KEY(2) ON
   ON KEY(3) GOSUB doc
   KEY(3) ON
 WEND
 GOSUB refresh
RETURN
'******************************************
csidebar:
 LINE (505, 1)-(505, 460), 6
 LINE (505, 1)-(620, 1), 6
 LINE (620, 1)-(620, 460), 6
 LINE (505, 460)-(620, 460), 6
 PAINT (510, 2), 6, 6
 LOCATE 2, 67
 PRINT name$
 LOCATE 4, 67
 PRINT "up      "; CHR$(24)
 LOCATE 5, 67
 PRINT "down    "; CHR$(25)
 LOCATE 6, 67
 PRINT "right   "; CHR$(26)
 LOCATE 7, 67
 PRINT "left  "; CHR$(27)
 LOCATE 9, 65
 PRINT "F1 Copy From"
 LOCATE 11, 65
 PRINT "F2 Copy Too "
 LOCATE 13, 65
 PRINT "F3 Copy "
 LOCATE 15, 65
```

```
  PRINT "e to end"
RETURN
'***************************************
cmark:
  FOR i = 1 TO blk
    ck = 0
    IF x(i) = xx THEN ck = ck + 1
    IF y(i) = yy THEN ck = ck + 1
    IF ck = 2 THEN blknum = i
  NEXT i
  sblock = blknum
  cluse(sblock) = luse(blknum)
  PAINT (a + 1, b + 1), 5, 4
RETURN
'***************************************
copyto:
  FOR i = 1 TO blk
    ck = 0
    IF x(i) = xx THEN ck = ck + 1
    IF y(i) = yy THEN ck = ck + 1
    IF ck = 2 THEN blknum = i
  NEXT i
  c = c + 1
  PAINT (a + 1, b + 1), 14, 4
  ctar(c) = blknum
RETURN
'***************************************
doc:
  FOR i = 1 TO c
    k = ctar(i)
    luse(k) = cluse(sblock)
    mark(k) = 1
  NEXT i
RETURN
'******************************************************************
fileout:

  LINE (200, 200)-(200, 350), 4
  LINE (200, 200)-(500, 200), 4
  LINE (500, 200)-(500, 350), 4
  LINE (200, 350)-(500, 350), 4
  PAINT (210, 210), 9, 4

  LOCATE 14, 30
  PRINT "F6: To save under current name."
  LOCATE 15, 30
```

```
  PRINT "F7: To save under new name.  "
  LOCATE 16, 30
  PRINT " s: Save and return.         "
  WHILE INKEY$ <> "s"
    ON KEY(6) GOSUB kname
    KEY(6) ON
    ON KEY(7) GOSUB newn
    KEY(7) ON
  WEND
  LOCATE 20, 30
  PRINT "Saving " + sb$ + ".lus"

  OPEN "\model\data\" + sb$ + ".lus" FOR OUTPUT AS #1
  WRITE #1, water$
  WRITE #1, name$
  WRITE #1, sl
  WRITE #1, "lu"
  WRITE #1, blk
   FOR i = 1 TO blk
     WRITE #1, i, x(i), y(i)
     WRITE #1, luse(i)

   NEXT i
  CLOSE #1
  GOSUB refresh
RETURN
'*************************************************************************
kname:
   IF a$ = "c" THEN GOSUB newn
RETURN
'*********************
newn:
  LOCATE 18, 30
  INPUT "Name to save under: "; sb$
RETURN
'***********************
edit:
 FOR i = 1 TO blk
   ck = 0
   IF x(i) = xx THEN ck = ck + 1
   IF y(i) = yy THEN ck = ck + 1
   IF ck = 2 THEN blknum = i
 NEXT i
 GOSUB dispcon
 ans$ = INKEY$
 WHILE ans$ <> "q"
```

```
   IF ans$ = "e" THEN GOSUB changel
   ans$ = INKEY$
  WEND

  GOSUB refresh
 RETURN
'*********************************************
dispcon:
 LINE (10, 100)-(280, 100), 9
 LINE (10, 100)-(10, 250), 9
 LINE (280, 100)-(280, 250), 9
 LINE (10, 250)-(280, 250), 9
 PAINT (101, 105), 9, 9

 LOCATE 8, 4
 PRINT "Block "; blknum
 LOCATE 9, 4
 PRINT "Landuse number: "; luse(blknum)
 LOCATE 11, 4
 PRINT "e = edit line  q = quit"
RETURN
'*********************************************
changel:
  LOCATE 13, 4
  INPUT "Enter new landuse number: "; lu
  IF lu = 0 THEN lu = luse(blknum)
  IF lu <> luse(blknum) THEN luse(blknum) = lu
  GOSUB refresh
  GOSUB dispcon
RETURN
'*****************************************
```

Source Code for CNCALCP1 mk. 1

```
'************ cncalcp1 ****************
CLS
SCREEN 12
GOSUB start
GOSUB getsol
GOSUB stable
GOSUB corel
GOSUB fileout
RUN "\model\CNCALCP2"
END

'************************************

start:
  LINE (200, 10)-(400, 10), 3
  LINE (200, 10)-(200, 40), 3
  LINE (200, 40)-(400, 40), 3
  LINE (400, 40)-(400, 10), 3
  PAINT (205, 15), 1, 3
  LOCATE 2, 31
  PRINT "CN_Calc mk. 1"
  LINE (150, 100)-(450, 100), 4
  LINE (150, 200)-(450, 200), 4
  LINE (150, 100)-(150, 200), 4
  LINE (450, 100)-(450, 200), 4
  PAINT (151, 101), 4, 4
  LOCATE 10, 20
  PRINT " F1: Use current land use file."
  LOCATE 12, 20
  PRINT " F2: Change land use file.     "
  LOCATE 14, 20
  PRINT " c : Continue.                 "
  WHILE INKEY$ <> "c"
    ON KEY(1) GOSUB same
    KEY(1) ON
    ON KEY(2) GOSUB cfile
    KEY(2) ON
  WEND
RETURN
'**************************************
same:
RETURN
'**************************************
```

```
getsol:
  OPEN "\model\data\current.con" FOR INPUT AS #1
  INPUT #1, sb$
  CLOSE #1
  OPEN "\model\data\" + sb$ + ".sol" FOR INPUT AS #1

  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, f$
  INPUT #1, blk
  DIM x(1 TO blk) AS INTEGER
  DIM y(1 TO blk) AS INTEGER
  DIM numsoil(1 TO blk) AS INTEGER
  DIM soil(1 TO blk, 1 TO 4) AS STRING * 4
  DIM perc(1 TO blk, 1 TO 4) AS INTEGER
  DIM slope(1 TO blk, 1 TO 4) AS INTEGER
  DIM hytype(1 TO blk, 1 TO 4) AS INTEGER

  FOR i = 1 TO blk
    INPUT #1, g, x(i), y(i)
    INPUT #1, numsoil(i)
    FOR j = 1 TO numsoil(i)
      INPUT #1, soil(i, j), perc(i, j)
    NEXT j
  NEXT i
  CLOSE #1
  RETURN
'*********************************************
stable:
  OPEN "/model/files/mcsoil.lst" FOR INPUT AS #1
  z = 0
  WHILE NOT EOF(1)
   INPUT #1, a$, b$, a, b
   z = z + 1
  WEND
  CLOSE #1
  DIM sym(1 TO z) AS STRING * 4
  DIM sp(1 TO z) AS INTEGER
  DIM hy(1 TO z)  AS INTEGER

  OPEN "/model/files/mcsoil.lst" FOR INPUT AS #1
  FOR i = 1 TO z
    INPUT #1, sym(i)
      INPUT #1, a$
```

```
    INPUT #1, sp(i)
    INPUT #1, hy(i)
  NEXT i
  CLOSE #1
  RETURN
'*********************************************************
corel:
  FOR i = 1 TO blk
  GOSUB status
   FOR q = 1 TO numsoil(i)
     FOR j = 1 TO z
       IF soil(i, q) = sym(j) THEN GOSUB add
     NEXT j
   NEXT q
  NEXT i
RETURN
'*********************************************************
add:
  slope(i, q) = sp(j)
  hytype(i, q) = hy(j)
RETURN
'**********************************************************
fileout:
   OPEN "\model\data\" + sb$ + ".sst" FOR OUTPUT AS #1
   WRITE #1, water$
   WRITE #1, name$
   WRITE #1, sl
   WRITE #1, "sst"
   WRITE #1, blk

   FOR i = 1 TO blk
     WRITE #1, i, x(i), y(i)
     WRITE #1, numsoil(i)
     FOR j = 1 TO numsoil(i)
       WRITE #1, soil(i, j), perc(i, j), hytype(i, j), slope(i, j)
     NEXT j
   NEXT i
   CLOSE #1
 RETURN
'***************************************************
conout:
  OPEN "\model\data\current.con" FOR OUTPUT AS #1
  WRITE #1, sb$
  CLOSE #1
RETURN
```

```
'**************************************************
status:
  LINE (150, 200)-(450, 200), 1
  LINE (150, 250)-(450, 250), 1
  LINE (150, 200)-(150, 250), 1
  LINE (450, 200)-(450, 250), 1
  PAINT (160, 210), 1, 1
  LOCATE 15, 23
  PRINT "Processing block: "; i
RETURN
'**************************************************
```

Source Code for CNCALCP2 mk. 1

```
'********** CN_Calc part 2 **************
CLS
SCREEN 12
GOSUB luse
GOSUB ladd
GOSUB lufout
RUN "CNCALCP3"
END
'****************************
luse:
  GOSUB getfile
  GOSUB getluf
  OPEN "\model\data\" + z$ + ".lus" FOR INPUT AS #1
  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, f$
  INPUT #1, blk
  DIM lu(1 TO blk) AS INTEGER

  FOR i = 1 TO blk
   INPUT #1, a, x, y
   INPUT #1, lu(i)
  NEXT i
  CLOSE #1
RETURN
'******************************
ladd:
  OPEN "\model\data\" + sb$ + ".sst" FOR INPUT AS #1
  OPEN "\model\data\" + z$ + ".lss" FOR OUTPUT AS #2
  CLS
  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, f$
  INPUT #1, blk

   WRITE #2, water$
   WRITE #2, name$
   WRITE #2, sl
   WRITE #2, "LSS"
   WRITE #2, blk
```

```
  FOR i = 1 TO blk
   GOSUB status
   INPUT #1, a, x, y
   INPUT #1, ns
   WRITE #2, a, x, y
   WRITE #2, ns
   WRITE #2, lu(i)
   FOR j = 1 TO ns
    INPUT #1, soil$, perc, hytype, slope
    WRITE #2, soil$, perc, hytype, slope
   NEXT j
  NEXT i
  CLOSE #1
  CLOSE #2
RETURN
'****************************************
getfile:
  OPEN "\model\data\current.con" FOR INPUT AS #1
  INPUT #1, sb$
  CLOSE #1
RETURN
'****************************************
status:
  LINE (150, 200)-(450, 200), 2
  LINE (150, 250)-(450, 250), 2
  LINE (150, 200)-(150, 250), 2
  LINE (450, 200)-(450, 250), 2
  PAINT (160, 210), 2, 2
  LOCATE 15, 23
  PRINT "Processing block: "; i
RETURN
'****************************************
getluf:
   z$ = sb$
   LINE (100, 100)-(400, 100), 4
   LINE (100, 300)-(400, 300), 4
   LINE (100, 100)-(100, 300), 4
   LINE (400, 100)-(400, 300), 4
   PAINT (101, 101), 4, 4
   LOCATE 8, 15: COLOR 11
   PRINT "Current landuse file: " + sb$ + ".LUS"
   LOCATE 11, 15: COLOR 2
   PRINT "F1: Change landuse file."
   LOCATE 16, 15: COLOR 1
   PRINT "R:      Run program. "
   WHILE INKEY$ <> "r"
```

```
    ON KEY(1) GOSUB change
    KEY(1) ON
  WEND
RETURN
'*********************************************
change:
  LOCATE 13, 15: COLOR 6
  INPUT "File name: "; z$
RETURN
'*********************************************
lufout:
  OPEN "\model\data\luf.con" FOR OUTPUT AS #1
  WRITE #1, z$
  CLOSE #1
RETURN
'*********************************************
```

Source Code for CNCALCP3 mk. 1

```
'*************** cncalcp3 *************************
CLS
SCREEN 12
GOSUB getfile
GOSUB gettable
GOSUB detcn
RUN "\model\menu"
END
'******************************************
getfile:
  OPEN "\model\data\luf.con" FOR INPUT AS #1
  INPUT #1, sb$
  CLOSE #1
RETURN
'******************************************
gettable:
  DIM cn(1 TO 81, 1 TO 4) AS INTEGER
  OPEN "\model\files\cnnum.tbl" FOR INPUT AS #1
  DO WHILE NOT EOF(1)
    INPUT #1, j
    FOR i = 1 TO 4
      INPUT #1, cn(j, i)
    NEXT i
  LOOP
  CLOSE #1
RETURN
'******************************************
detcn:
  OPEN "\model\data\" + sb$ + ".lss" FOR INPUT AS #1
  OPEN "\model\data\" + sb$ + ".cnn" FOR OUTPUT AS #2
  CLS
  DIM perc(1 TO 4) AS INTEGER
  DIM slope(1 TO 4) AS INTEGER
  DIM htype(1 TO 4) AS INTEGER
  DIM cnn(1 TO 4) AS INTEGER

  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, sl
  INPUT #1, a$
```

```
  INPUT #1, blk

  WRITE #2, water$
  WRITE #2, name$
  WRITE #2, sl
  WRITE #2, "CNN"
  WRITE #2, blk

  FOR i = 1 TO blk
    GOSUB status
    INPUT #1, a, x, y
    INPUT #1, ns
    INPUT #1, lu

      FOR j = 1 TO ns
        INPUT #1, s$, perc(j), htype(j), slope(j)
        cnn(j) = cn(lu, htype(j))
      NEXT j
    avcn = 0
    avslope = 0
      FOR j = 1 TO ns
        avcn = avcn + (cnn(j) * perc(j))
        avslope = avslope + (slope(j) * perc(j))
      NEXT j
    avcn = avcn / 100
    avslope = avslope / 100

    WRITE #2, a, x, y, INT(avcn), INT(avslope)
  NEXT i
  CLOSE #1
  CLOSE #2
RETURN
'***********************************************
status:
  LINE (150, 200)-(450, 200), 4
  LINE (150, 250)-(450, 250), 4
  LINE (150, 200)-(150, 250), 4
  LINE (450, 200)-(450, 250), 4
  PAINT (160, 210), 4, 4
  LOCATE 15, 23
  PRINT "Processing block: "; i
RETURN
'***********************************************
```

Source Code for ROFF mk. 1

```
'************* ROFF mk. 1 *******************
CLS
SCREEN 12
GOSUB getfile
GOSUB menu
WHILE INKEY$ <> "e"
  ON KEY(1) GOSUB getrain
  KEY(1) ON
  ON KEY(2) GOSUB srun
  KEY(2) ON
  ON KEY(3) GOSUB grun
  KEY(3) ON
WEND
RUN "\model\menu"
END
'*****************************
menu:
   CLS
   x1 = 50
   x2 = 600
   y1 = 20
   y2 = 400
   c = 2
   GOSUB dbox
   x1 = 150
   x2 = 450
   y1 = 20
   y2 = 60
   c = 1
   GOSUB dbox
   LOCATE 3, 28
   PRINT "*** ROFF  mk.1 ***"
   x1 = 150
   x2 = 200
   y1 = 80
   y2 = 370
   c = 6
   GOSUB dbox
   LOCATE 7, 21
   PRINT " F1 "
   LOCATE 10, 21
   PRINT " F2 "
   LOCATE 16, 21
```

```
   PRINT " F3 "
   LOCATE 22, 21
   PRINT "  E "

   x1 = 250
   x2 = 550
   y1 = 80
   y2 = 370
   c = 4
   GOSUB dbox
   LOCATE 7, 35
   PRINT "Enter rainfall amount in inches."
   LOCATE 10, 35
   PRINT "Run model with single amount.   "
   LOCATE 11, 35
   PRINT "(Output will be used in later   "
   LOCATE 12, 35
   PRINT "modelling calculations).        "
   LOCATE 16, 35
   PRINT "Run model with a rainfall range "
   LOCATE 17, 35
   PRINT "of 0 to 6 inches and show a     "
   LOCATE 18, 35
   PRINT "graph of the results.           "
   LOCATE 19, 35
   PRINT "Write output in ASCII .DAT file."
   LOCATE 22, 35
   PRINT "Exit program and return to main."
RETURN
'***************************
dbox:
   LINE (x1, y1)-(x2, y1), c
   LINE (x1, y2)-(x2, y2), c
   LINE (x1, y1)-(x1, y2), c
   LINE (x2, y1)-(x2, y2), c
   PAINT (x1 + 1, y1 + 1), c, c
RETURN
'***************************
getfile:
   OPEN "\model\data\luf.con" FOR INPUT AS #1
   INPUT #1, sb$
   CLOSE #1
   OPEN "\model\data\" + sb$ + ".cnn" FOR INPUT AS #1
   INPUT #1, water$
   INPUT #1, name$
   INPUT #1, sl
```

```
  INPUT #1, a$
  INPUT #1, blk

  DIM x(1 TO blk) AS INTEGER
  DIM y(1 TO blk) AS INTEGER
  DIM cn(1 TO blk) AS INTEGER
  DIM slope(1 TO blk) AS INTEGER
  DIM q!(1 TO blk)

  FOR i = 1 TO blk
   INPUT #1, a, x(i), y(i), cn(i), slope(i)
  NEXT i
  CLOSE #1
RETURN
'**************************************
getrain:
  CLS
  x1 = 100
  x2 = 400
  y1 = 100
  y2 = 200
  c = 3
  GOSUB dbox
  LOCATE 8, 16
  PRINT "Enter rainfall amount in inches."
  LOCATE 11, 16
  INPUT ; rf
  GOSUB menu
RETURN
'**************************************
srun:
  CLS
  x1 = 100
  x2 = 350
  y1 = 100
  y2 = 140
  c = 4
  GOSUB dbox
  FOR i = 1 TO blk
   s = (1000 / cn(i)) - 10
   q(i) = ((rf - (.2 * s)) ^ 2) / (rf + (.8 * s))
   LOCATE 8, 16
   PRINT "Processing block: "; i
  NEXT i
  GOSUB broff
  x1 = 100
```

```
  x2 = 500
  y1 = 200
  y2 = 300
  c = 2
  GOSUB dbox
  LOCATE 15, 16
  PRINT "Total runoff for model area = "
  LOCATE 15, 48: PRINT USING "##.##"; averoff
  LOCATE 15, 54: PRINT "in."
  LOCATE 18, 16
  PRINT "Hit e to exit"
  WHILE INKEY$ <> "e"
  WEND
  GOSUB outfile
  GOSUB menu
RETURN
'**********************************************

grun:
  CLS
  DIM rn!(1 TO 60)
  DIM avrofo!(1 TO 60)
  GOSUB axis
  z = 1
  v = 0
  FOR r! = 0 TO 6 STEP .1
   FOR i = 1 TO blk
    s = (1000 / cn(i)) - 10
    q!(i) = ((r! - (.2 * s)) ^ 2) / (r! + (.8 * s))
    IF r! < .2 * s THEN q!(i) = 0
   NEXT i
   GOSUB broff
   IF v <> 0 THEN GOSUB post
   rt! = r!
   trof! = averoff!
   v = 1
  NEXT r!
  GOSUB choice
  GOSUB menu
RETURN
'*******************************

broff:
  qt! = 0
  FOR i = 1 TO blk
   qt! = qt! + q!(i)
```

```
  NEXT i
  averoff! = qt! / blk
RETURN
'********************************
outfile:
  OPEN "\model\data\" + sb$ + ".rof" FOR OUTPUT AS #1
  WRITE #1, water$
  WRITE #1, name$
  WRITE #1, sl
  WRITE #1, "ROF"
  WRITE #1, rf
  WRITE #1, averoff!
  WRITE #1, blk
  FOR i = 1 TO blk
   WRITE #1, i, x(i), y(i), slope(i), q!(i)
  NEXT i
  CLOSE #1
RETURN
'********************************
post:
  LINE (rt!, trof!)-(r!, averoff!), 4
  rn!(z) = r!
  avrofo!(z) = averoff!
  z = z + 1
RETURN
'**********************************
axis:
  SCREEN 12
  WINDOW (-1, -2)-(7, 5)
  LINE (0, 0)-(0, 4), 3
  LINE (0, 0)-(6, 0), 3
  FOR i! = 0 TO 3
   LINE (-.1, i!)-(0, i!), 3
    FOR j! = .1 TO 1 STEP .1
     LINE (-.05, i! + j!)-(0, i! + j!), 1
    NEXT j!
  NEXT i!
  LINE (-.1, 4)-(0, 4), 3
  FOR i! = 0 TO 5
   LINE (i!, -.1)-(i!, 0), 3
    FOR j! = .1 TO 1 STEP .1
     LINE (i! + j!, -.05)-(i! + j!, 0), 1
    NEXT j!
  NEXT i!
  LINE (6, -.1)-(6, 0), 3
  COLOR 6
```

```
  LOCATE 5, 6
  PRINT "4.0"
  LOCATE 9, 6
  PRINT "3.0"
  LOCATE 13, 6
  PRINT "2.0"
  LOCATE 18, 6
  PRINT "1.0"
  LOCATE 22, 6
  PRINT "0.0"
  LOCATE 23, 10
  PRINT "0.0"
  LOCATE 23, 20
  PRINT "1.0"
  LOCATE 23, 30
  PRINT "2.0"
  LOCATE 23, 40
  PRINT "3.0"
  LOCATE 23, 50
  PRINT "4.0"
  LOCATE 23, 60
  PRINT "5.0"
  LOCATE 23, 70
  PRINT "6.0"
  COLOR 2
  LOCATE 25, 30
  PRINT "24 hour rainfall (in.)"
  DIM ya(1 TO 6)  AS STRING * 1
  ya(1) = "R": ya(2) = "u": ya(3) = "n": ya(4) = "o"
  ya(5) = "f": ya(6) = "f"
  FOR i = 1 TO 6
    LOCATE (i * 2) + 5, 3
    PRINT ya(i)
  NEXT i
  COLOR 7
RETURN
'********************************************
choice:
  LOCATE 28, 10
  PRINT "<F1> save results to file   <e> to exit   <Prnt Scr> hardcopy"
  WHILE INKEY$ <> "e"
    ON KEY(1) GOSUB gout
    KEY(1) ON
  WEND
RETURN
```

```
'*********************************************
gout:
  LOCATE 30, 5
  INPUT "Enter name of data file: "; df$
  LOCATE 30, 40
  PRINT "Saving "; df$; ".dat"
  OPEN "\model\data\" + df$ + ".dat" FOR OUTPUT AS #1
  FOR i = 1 TO 60
    WRITE #1, rn!(i), avrofo!(i)
  NEXT i
  CLOSE #1
RETURN
'*********************************************
```

Source Code for TIMECON mk. 1

```
'******** TIMECON.BAS **********
CLS
SCREEN 12
GOSUB getdata
GOSUB getstr
GOSUB getbdr
GOSUB gettopo
GOSUB drawb
GOSUB topodraw
GOSUB strdraw
GOSUB bdrdraw
GOSUB sidebar
xx = 100: yy = 100
fpnt = 0
GOSUB crosshair

WHILE INKEY$ <> "e"
  ON KEY(13) GOSUB right
  KEY(13) ON
  ON KEY(12) GOSUB left
  KEY(12) ON
  ON KEY(14) GOSUB down
  KEY(14) ON
  ON KEY(11) GOSUB up
  KEY(11) ON
  ON KEY(1) GOSUB selfp
  KEY(1) ON
  ON KEY(2) GOSUB selsp
  KEY(2) ON
  ON KEY(3) GOSUB cansel
  KEY(3) ON
  ON KEY(8) GOSUB outfile
  KEY(8) ON
WEND
RUN "\model\menu"
END
'*****************************************************************
'**************** CROSSHAIR CONTROL ***************************
'*****************************************************************
crosshair:
   LINE (xx - 20, yy)-(xx + 20, yy), 13
   LINE (xx, yy - 20)-(xx, yy + 20), 13
   IF fpnt = 1 THEN GOSUB pathl
```

```
RETURN
'**************************************************
pathl:
   LINE (fxp!, fyp!)-(xx, yy), 6
RETURN
'**************************************************
rpathl:
   IF fpnt = 0 THEN RETURN
   LINE (fxp!, fyp!)-(xx, yy), 0
RETURN
'**************************************************
rcrosshair:
   LINE (xx - 20, yy)-(xx + 20, yy), 0
   LINE (xx, yy - 20)-(xx, yy + 20), 0
   GOSUB drawb
   GOSUB strpost
   GOSUB topopost
RETURN
'**************************************************
right:
   GOSUB rcrosshair
   GOSUB rpathl
   xx = xx + 5
   GOSUB crosshair
RETURN
'**************************************************
left:
   GOSUB rcrosshair
   GOSUB rpathl
   xx = xx - 5
   GOSUB crosshair
RETURN
'**************************************************
up:
   GOSUB rcrosshair
   GOSUB rpathl
   yy = yy - 5
   GOSUB crosshair
RETURN
'**************************************************
down:
   GOSUB rcrosshair
   GOSUB rpathl
   yy = yy + 5
   GOSUB crosshair
RETURN
```

```
'**************************************************
selfp:
   fxp! = xx
   fyp! = yy
   fpnt = 1
RETURN
'**************************************************
selsp:
   sxp! = xx
   syp! = yy
   fpnt = 0
   GOSUB calctt
   GOSUB pullout
   GOSUB insidebar
   IF length < 300 THEN GOSUB short
   IF length = 300 THEN GOSUB short
   IF length > 300 THEN GOSUB normal

RETURN
'**************************************************
cansel:
   GOSUB rpathl
   fpnt = 0
RETURN
'****************************************************************
'****************************************************************
sidebar:
   LINE (505, 1)-(505, 460), 3
   LINE (505, 1)-(620, 1), 3
   LINE (620, 1)-(620, 460), 3
   LINE (505, 460)-(620, 460), 3
   PAINT (510, 3), 3, 3
   LOCATE 2, 66
   PRINT "TIMECON MK1"
   LOCATE 4, 67
   PRINT "up      "; CHR$(24)
   LOCATE 6, 67
   PRINT "down    "; CHR$(25)
   LOCATE 8, 67
   PRINT "right   "; CHR$(26)
   LOCATE 10, 67
   PRINT "left    "; CHR$(27)
   LOCATE 15, 65
   PRINT "F1  1st point"
   LOCATE 17, 65
```

```
    PRINT "F2  2nd point"
    LOCATE 19, 65
    PRINT "F3      Cancel"
    LOCATE 25, 65
    PRINT "e    To Exit"
RETURN
'*************************************************************
insidebar:
    LINE (505, 1)-(505, 460), 2
    LINE (505, 1)-(660, 1), 2
    LINE (660, 1)-(660, 460), 2
    LINE (505, 460)-(660, 460), 2
    PAINT (510, 3), 2, 2
    LOCATE 2, 66
    PRINT "Variables"
    LOCATE 7, 65
    PRINT "Cross-sectional"
    LOCATE 8, 65
    PRINT "flow area ft^2 "
    LOCATE 9, 65
    INPUT area!
    LOCATE 11, 65
    PRINT "Wetted perimeter"
    LOCATE 12, 65
    INPUT "ft. "; wp!
    LOCATE 14, 65
    PRINT "Channel slope "
    LOCATE 15, 65
    INPUT "ft/ft "; cslope!
    LOCATE 17, 65
    PRINT "Manning's coef."
    LOCATE 18, 65
    PRINT "for channel"
    LOCATE 19, 65
    INPUT man!
RETURN
'*************************************************************
'**************** GET INPUT FILE ****************************
'*************************************************************
getdata:
   OPEN "\model\data\luf.con" FOR INPUT AS #1
   INPUT #1, lu$
   CLOSE #1
   OPEN "\model\data\" + lu$ + ".rof" FOR INPUT AS #1
   INPUT #1, water$
   INPUT #1, name$
```

```
  INPUT #1, sl
  INPUT #1, f$
  INPUT #1, r
  INPUT #1, q
  INPUT #1, blk

  DIM x(1 TO blk) AS INTEGER
  DIM y(1 TO blk) AS INTEGER
  DIM slope(1 TO blk) AS INTEGER

  FOR i = 1 TO blk
    INPUT #1, a, x(i), y(i), slope(i), l!
  NEXT i
  CLOSE #1
  OPEN "\model\data\" + lu$ + ".lus" FOR INPUT AS #1
  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, a
  INPUT #1, f$
  INPUT #1, blk
  DIM luse(1 TO blk) AS INTEGER
  FOR i = 1 TO blk
   INPUT #1, a, a, a, luse(i)
  NEXT i
  CLOSE #1
  '************** Get Rainfall ****************
  OPEN "\model\data\" + lu$ + ".rof" FOR INPUT AS #1
  INPUT #1, water$
  INPUT #1, name$
  INPUT #1, a
  INPUT #1, f$
  INPUT #1, p!
  CLOSE #1
RETURN
'*************************************************************
'************ GET STREAM ************************************
'*************************************************************
getstr:
   OPEN "\model\data\current.con" FOR INPUT AS #1
     INPUT #1, sb$
   CLOSE #1
   OPEN "\model\files\" + sb$ + ".str" FOR INPUT AS #1
    zz = 0
    WHILE NOT EOF(1)
      INPUT #1, ww, qq
      zz = zz + 1
```

```
    WEND
    CLOSE #1

    DIM sx!(1 TO zz)
    DIM sy!(1 TO zz)
    OPEN "\model\files\" + sb$ + ".str" FOR INPUT AS #1
    FOR i = 1 TO zz
      INPUT #1, sx!(i), sy!(i)
    NEXT i
    CLOSE #1
RETURN
'**************************************************************
'************ GET BORDER ***************************************
'**************************************************************
getbdr:
    yz = 0
    OPEN "\model\files\" + sb$ + ".bdr" FOR INPUT AS #1
     WHILE NOT EOF(1)
      INPUT #1, ww, qq
      yz = yz + 1
     WEND
    CLOSE #1

    DIM bx!(1 TO yz)
    DIM by!(1 TO yz)
    OPEN "\model\files\" + sb$ + ".bdr" FOR INPUT AS #1
    FOR i = 1 TO yz
      INPUT #1, bx!(i), by!(i)
    NEXT i
    CLOSE #1
RETURN
'**************************************************************
gettopo:
    tz = 0
    OPEN "\model\files\" + sb$ + ".tpo" FOR INPUT AS #1
     WHILE NOT EOF(1)
      INPUT #1, ww, qq
      tz = tz + 1
     WEND
    CLOSE #1

    DIM tx!(1 TO tz)
    DIM ty!(1 TO tz)
    OPEN "\model\files\" + sb$ + ".tpo" FOR INPUT AS #1
    FOR i = 1 TO tz
      INPUT #1, tx!(i), ty!(i)
```

```
    NEXT i
    CLOSE #1
RETURN
'************************************************************
'************ DRAW BASIN ************************************
'************************************************************
drawb:
  FOR i = 1 TO blk
    xl = x(i) * sl
    yl = y(i) * sl
    LINE (xl, yl)-(xl + sl, yl), 15
    LINE (xl, yl + sl)-(xl + sl, yl + sl), 15
    LINE (xl, yl)-(xl, yl + sl), 15
    LINE (xl + sl, yl)-(xl + sl, yl + sl), 15
  NEXT i
RETURN
'************************************************************
strdraw:
   FOR i = 1 TO zz
     sx!(i) = (sx!(i) * sl) + sl
     sy!(i) = (sy!(i) * sl) + sl
   NEXT i
   GOSUB strpost
RETURN
'************************************
strpost:
   FOR i = 1 TO zz - 1
     LINE (sx!(i), sy!(i))-(sx!(i + 1), sy!(i + 1)), 1
   NEXT i
RETURN
'************************************************************
bdrdraw:
   FOR i = 1 TO yz
     bx!(i) = (bx!(i) * sl) + sl
     by!(i) = (by!(i) * sl) + sl
   NEXT i
   GOSUB bdrpost
RETURN
'************************************
bdrpost:
   FOR i = 1 TO yz - 1
     LINE (bx!(i), by!(i))-(bx!(i + 1), by!(i + 1)), 4
   NEXT i
   LINE (bx!(yz), by!(yz))-(bx!(1), by!(1)), 4
RETURN
```

```
'*******************************************************************
topodraw:
   FOR i = 1 TO tz
     IF tx(i) = 0 THEN i = i + 1
       tx!(i) = (tx!(i) * sl) + sl
       ty!(i) = (ty!(i) * sl) + sl
   NEXT i
   GOSUB topopost
RETURN
'*******************************************************************
topopost:
   FOR i = 2 TO tz - 1
     IF tx!(i + 1) <> 0 THEN GOSUB tdraw
     IF tx!(i + 1) = 0 THEN i = i + 2
   NEXT i
   i = tz
   GOSUB tdraw
RETURN
'******************************
tdraw:
   LINE (tx!(i), ty!(i))-(tx!(i - 1), ty!(i - 1)), 2
RETURN
'*******************************************************************
'*********** CALCULATIONS ************************************
'*******************************************************************
callength:
   xc = ABS(fxp! - sxp!)
   yc = ABS(fyp! - syp!)
   lengthl = SQR(xc ^ 2 + yc ^ 2)
   length = (lengthl / sl) * 100
   length = length / .3048
RETURN
'*********************************************
'*******Calculate travel time ***************
'*********************************************
calctt:
   GOSUB callength
   GOSUB strlength
RETURN
'*********************************************
strlength:
  FOR i = 1 TO zz - 1
    IF sxp! > sx!(i) AND sxp! < sx!(i + 1) THEN sint = i
    IF sxp! = sx!(i) THEN sint = i - 1                'remove line
  NEXT i
  IF sint = 0 THEN sint = 1
```

```
  xc! = ABS(sxp! - sx!(sint))
  yc! = ABS(syp! - sy!(sint))
  slength! = SQR((xc!) ^ 2 + (yc!) ^ 2)
  FOR i = sint TO zz - 1
    xc! = ABS(sx!(i) - sx!(i + 1))
    yc! = ABS(sy!(i) - sy!(i + 1))
    slength! = slength! + SQR((xc!) ^ 2 + (yc!) ^ 2)
  NEXT i
    slength! = (slength! / sl) * 100
    slength! = slength! / .3048
RETURN
'************************************************************
'************* PULLOUT ***************************************
'************************************************************
pullout:
   GOSUB getblk
   GOSUB consolp
   DIM xp!(1 TO count + 2)
   DIM yp!(1 TO count + 2)
   IF (starty - endy) < 0 THEN GOSUB bpty1
   IF (starty - endy) > 0 THEN GOSUB bpty2
   IF (startx - endx) < 0 THEN GOSUB bptx1
   IF (startx - endx) > 0 THEN GOSUB bptx2
   IF starty > endy THEN GOSUB sortp
   IF starty < endy THEN GOSUB sortn
   GOSUB lencalc
RETURN
'**************************************************
getblk:
   startx! = fxp!
   starty! = fyp!
   endx! = sxp!
   endy! = syp!
   numpts = INT(lengthl / (sl / 20))

   DIM sss!(1 TO (numpts + 2))
   DIM ttt!(1 TO numpts + 2)
   DIM blkn(1 TO numpts + 2)
   GOSUB bafill

   FOR j = 1 TO numpts + 2
    tx! = sss!(j)
    ty! = ttt!(j)
    GOSUB findblk
   blkn(j) = block
   NEXT j
```

```
RETURN
'*****************************************************************
findblk:
   b1x = 0
   b1y = 0
   i = 1

   WHILE b1x = 0
    IF tx! >= x(i) * sl AND tx! <= ((x(i) * sl) + sl) THEN b1x = x(i)
    i = i + 1
   WEND
   i = 1
   WHILE b1y = 0
    IF ty! >= y(i) * sl AND ty! <= ((y(i) * sl) + sl) THEN b1y = y(i)
    i = i + 1
   WEND
    FOR i = 1 TO blk
     IF x(i) = b1x AND y(i) = b1y THEN block = i
    NEXT i
RETURN
'**********************************************************************
bafill:
   delx! = (startx - endx) / numpts
   dely! = (starty - endy) / numpts

   sss!(1) = startx
   ttt!(1) = starty
   sss!(numpts + 2) = endx
   ttt!(numpts + 2) = endy

   FOR i = 2 TO numpts + 1
     sss!(i) = sss!(i - 1) - delx!
     ttt!(i) = ttt!(i - 1) - dely!
   NEXT i
RETURN
'**********************************************************************
consolp:
   count = 1
   FOR i = 1 TO numpts - 1
     IF blkn(i) <> blkn(i + 1) THEN count = count + 1
   NEXT i
     IF blkn(numpts) <> blkn(numpts - 1) THEN count = count + 1

   DIM blkt(1 TO count)
   DIM blklen!(1 TO count)
```

```
  DIM btx!(1 TO count)
  DIM bty!(1 TO count)
  k = 2
  hold = 1
  FOR i = 2 TO numpts - 1
    IF blkn(i) = blkn(hold) THEN GOSUB dummy
    IF blkn(i) <> blkn(hold) THEN GOSUB place
    IF blkn(i) = blkn(numpts) THEN GOSUB dummy
  NEXT i
  GOSUB placeend
RETURN
'*******************************************
dummy:
RETURN
'********************************************
place:

  blkt(k) = blkn(i)
  btx!(k) = sss!(i)
  bty!(k) = ttt!(i)
  k = k + 1
  hold = i
RETURN
'********************************************
placeend:
  blkt(1) = blkn(1)
  btx!(1) = sss!(1)
  bty!(1) = ttt!(1)
  blkt!(count) = blkn(numpts)
  btx!(count) = sss!(numpts)
  bty!(count) = ttt!(numpts)
RETURN
'********************************************************
bpty1:
  r! = (startx - endx) / (starty - endy)
  yp!(1) = starty
  xp!(1) = startx
  dy! = (((y(blkt(1)) * sl) + sl) - starty)
  dx! = r! * dy!
  yp!(2) = yp!(1) + dy!
  xp!(2) = xp!(1) + dx!
  j = 3
  WHILE ABS(yp!(j - 1) - endy) > sl
   yp!(j) = yp!(j - 1) + sl
   dy! = sl
   dx! = r! * dy!
```

```
    xp!(j) = x(j - 1) + dx
    j = j + 1
  WEND
  yp!(j) = endy
  xp!(j) = endx
RETURN
'**************************************************
bptx1:
 'Find x intercepts
  j = j + 1
  IF (starty - endy) = 0 THEN j = 2
  IF count = 1 THEN j = 3
  dx! = ((x(blkt(1)) * sl) + sl) - startx
  IF (starty - endy) = 0 THEN r! = 1
  dy! = dx! / r!
  IF (starty - endy) = 0 THEN dy! = 0
  xp!(j) = startx + dx!
  yp!(j) = starty + dy!
  j = j + 1
  WHILE ABS(xp!(j - 1) - endx) > sl
    xp!(j) = xp!(j - 1) + sl
    dx! = sl
    dy! = dx! / r!
    IF (starty - endy) = 0 THEN dy! = 0
    yp!(j) = yp!(j - 1) + dy!
    j = j + 1
  WEND
  j = j - 1
RETURN
'***********************************************
bpty2:
  r! = (startx - endx) / (starty - endy)
  yp!(1) = starty
  xp!(1) = startx
  dy! = (starty - (y(blkt(1)) * sl))
  dx! = r! * dy!
  yp!(2) = yp!(1) - dy!
  xp!(2) = xp!(1) - dx!
  j = 3
  WHILE ABS(yp!(j - 1) - endy) > sl
    yp!(j) = yp!(j - 1) - sl
    dy! = sl
    dx! = r! * dy!
  xp!(j) = x(j - 1) + dx
    j = j + 1
  WEND
```

```
  yp!(j) = endy
  xp!(j) = endx
RETURN
'*************************************************
bptx2:
 'Find x intercepts
  j = j + 1
  IF (starty - endy) = 0 THEN j = 2
  IF count = 1 THEN j = 3
  dx! = startx - ((x(blkt(1)) * sl))
  IF (starty - endy) = 0 THEN r! = 1
  dy! = dx! / r!
  IF (starty - endy) = 0 THEN dy! = 0
  xp!(j) = startx - dx!
  yp!(j) = starty - dy!
  j = j + 1
  WHILE ABS(xp!(j - 1) - endx) > sl
   xp!(j) = xp!(j - 1) - sl
   dx! = sl
   dy! = dx! / r!
   IF (starty - endy) = 0 THEN dy! = 0
   yp!(j) = yp!(j - 1) + dy!
   j = j + 1
  WEND
  j = j - 1
RETURN
'*************************************************
sortp:
  FOR i = 1 TO j
    FOR k = 1 TO j
      IF yp!(k) < yp!(i) THEN GOSUB exchange
    NEXT k
  NEXT i
RETURN
'*******************************
sortn:
  FOR i = 1 TO j
   FOR k = 1 TO j
     IF yp!(k) > yp!(i) THEN GOSUB exchange
   NEXT k
  NEXT i
RETURN
'*******************************
exchange:
   ytemp! = yp!(i)
   xtemp! = xp!(i)
```

```
  yp!(i) = yp!(k)
  xp!(i) = xp!(k)
  yp!(k) = ytemp!
  xp!(k) = xtemp!
RETURN
'*************************************************************
lencalc:
  FOR i = 1 TO count
    blklen!(i) = SQR((yp!(i) - yp!(i + 1)) ^ 2 + (xp!(i) - xp!(i + 1)) ^ 2)
    blklen!(i) = (blklen!(i) / sl) * 100
    blklen!(i) = blklen!(i) / .3048
  NEXT i
RETURN
'*************************************************************
'*************************************************************
short:
  GOSUB sheetwashs
  GOSUB chanflow
  GOSUB outscreen
RETURN
'*************************************************************
normal:
  GOSUB sheetwash
  GOSUB shallowcon
  GOSUB chanflow
  GOSUB outscreen
RETURN
'********************************************
sheetwash:
  i = 1
  swl! = 0
  WHILE swl! < 300
    swl! = swl! + blklen!(i)
    i = i + 1
  WEND
  i = i - 1
  swt! = 0
  FOR j = 1 TO i - 1
    GOSUB getn
    fl! = blklen!(j)
    GOSUB swcalc
  swt! = swt! + tt!
  NEXT j
  j = i
  GOSUB getn
  fl! = blklen!(j) - (swl! - 300)
```

```
    GOSUB swcalc
    swt! = swt! + tt!
RETURN
'***********************************************************
sheetwashs:
    swt! = 0
    FOR j = 1 TO count
      GOSUB getn
      fl! = blklen!(j)
      GOSUB swcalc
      swt! = swt! + tt!
    NEXT j
RETURN
'*************************************************************
getn:
  IF luse(blkt(j)) < 4 THEN n = .24
  IF luse(blkt(j)) > 3 AND luse(blkt(j)) < 13 THEN n! = .011
  IF luse(blkt(j)) > 12 AND luse(blkt(j)) < 19 THEN n! = .24
  IF luse(blkt(j)) > 18 AND luse(blkt(j)) < 23 THEN n! = .05
  IF luse(blkt(j)) > 22 AND luse(blkt(j)) < 53 THEN n! = .17
  IF luse(blkt(j)) > 52 AND luse(blkt(j)) < 60 THEN n! = .15
  IF luse(blkt(j)) > 59 AND luse(blkt(j)) < 63 THEN n! = .4
  IF luse(blkt(j)) > 62 AND luse(blkt(j)) < 66 THEN n! = .8
  IF luse(blkt(j)) = 66 THEN n! = .011
RETURN
'***********************************************************
swcalc:
   s! = slope(blkt(j)) / 100
   tt! = (.007 * (n! * fl!) ^.8) / (p! ^.5 * s! ^ .04)
RETURN
'***********************************************************
'***********************************************************
shallowcon:
   sft! = 0
   fl! = blklen!(j) - fl!
   GOSUB shallowcalc
   sft! = sft! + tt!
   FOR i = j + 1 TO count
     fl! = blklen!(i)
     GOSUB shallowcalc
     sft! = sft! + tt!
   NEXT i
RETURN
'**********************************************************
shallowcalc:
   s! = slope(blkt(i)) / 100
```

```
    vup! = -42878.5 * s! ^ 6 + 55204.9 * s! ^ 5 - 27068 * s! ^ 4
    vup! = vup! + 6599.84 * s! ^ 3 - 890.441 * s! ^ 2 + 88.4938 * s!
    vup! = vup! + .757359
    tt! = fl! / (3600 * vup!)
RETURN
'*************************************************************
chanflow:
    hr! = area! / wp!
    sv! = (1.49 * hr! ^ .66667 * cslope! ^ .5) / man!
    sct! = slength! / (3600 * sv!)
RETURN
'*************************************************************
outscreen:
    CLS
    SCREEN 9
    LINE (10, 5)-(625, 5), 3
    LINE (10, 5)-(10, 500), 3
    LINE (10, 500)-(625, 500), 3
    LINE (625, 5)-(625, 500), 3
    PAINT (15, 15), 3, 3
    LOCATE 2, 15
    COLOR 1, 3
    PRINT "*********  Timecon Mk1  Output  **********"
    LOCATE 4, 10
    COLOR 4
    PRINT "SHEETWASH"
    LOCATE 6, 10
    swl! = 300
    IF length < 300 THEN swl! = length
    COLOR 1
    PRINT "Flow length:"
    LOCATE 7, 10: PRINT "Travel time:"
    LOCATE 8, 10: PRINT "Ave. Velocity:"
    LOCATE 6, 26: PRINT USING "###.##"; swl!
    LOCATE 7, 27: PRINT USING "##.##"; swt!
    LOCATE 8, 25: PRINT USING "####.##"; swl / swt!
    LOCATE 6, 33: PRINT "ft."
    LOCATE 7, 33: PRINT "hr."
    LOCATE 8, 33: PRINT "ft/hr"
    u = 10
    IF length > 300 THEN GOSUB outscf
    COLOR 4
    LOCATE u, 10: PRINT "OPEN CHANNEL FLOW"
    COLOR 1
    LOCATE u + 2, 10: PRINT "Flow length:"
    LOCATE u + 3, 10: PRINT "Travel time:"
```

```
   LOCATE u + 4, 10: PRINT "Ave. Velocity:"
   LOCATE u + 2, 24: PRINT USING "#####.##"; slength!
   LOCATE u + 3, 27: PRINT USING "##.##"; sct!
   LOCATE u + 4, 25: PRINT USING "#######"; slength! / sct!
   LOCATE u + 2, 33: PRINT "ft."
   LOCATE u + 3, 33: PRINT "hr."
   LOCATE u + 4, 33: PRINT "ft/hr"
   u = u + 6
   COLOR 4
   LOCATE 22, 10: PRINT "TIME OF CONCENTRATION:";
   COLOR 1
   LOCATE 22, 34: PRINT USING "###.##"; sct! + swt! + sft!
   LOCATE 22, 42: PRINT "hr."
   COLOR 6
   LOCATE 24, 10
   PRINT "F8: Save results to file    e: to end"
RETURN
'*************************************************************
outscf:
   COLOR 4
   LOCATE u, 10: PRINT "SHALLOW CONCENTRATED FLOW"
   COLOR 1
   LOCATE u + 2, 10: PRINT "Flow Length:"
   LOCATE u + 3, 10: PRINT "Travel time:"
   LOCATE u + 4, 10: PRINT "Ave. Velocity:"
   LOCATE u + 2, 24: PRINT USING "#####.##"; length - 300
   LOCATE u + 3, 27: PRINT USING "##.##"; sft!
   LOCATE u + 4, 25: PRINT USING "####.##"; (length - 300) / sft!
   LOCATE u + 2, 33: PRINT "ft."
   LOCATE u + 3, 33: PRINT "hr."
   LOCATE u + 4, 33: PRINT "ft/hr"
   u = u + 6
RETURN
'*******************************************************************
'*******************************************************************
outfile:
   OPEN "\model\data\" + lu$ + ".tc" FOR OUTPUT AS #1
   WRITE #1, sct! + swt! + sft!
   CLOSE #1
RETURN
'*******************************************************************
```

Source Code for TABHYDRO mk. 1

```
'***************** TABHYDRO mk. 1 ******************************
CLS
GOSUB getb
GOSUB getcn
GOSUB getarea
GOSUB getia
GOSUB getrunoff
GOSUB gettc
GOSUB roundtc
GOSUB getiap
GOSUB roundiap
GOSUB gettabfile
GOSUB loadtable
GOSUB gettable
GOSUB calhydro
GOSUB disphydro
WHILE INKEY$ <> "e"
  ON KEY(1) GOSUB fileout
  KEY(1) ON
  ON KEY(3) GOSUB plothydro
  KEY(3) ON
WEND
RUN "\model\menu"
END
'***************************
getb:
  OPEN "\model\data\luf.con" FOR INPUT AS #1
    INPUT #1, sb$
  CLOSE #1
RETURN
'***************************
getcn:
  OPEN "\model\data\" + sb$ + ".cnn" FOR INPUT AS #1
    INPUT #1, water$
    INPUT #1, name$
    INPUT #1, sl
    INPUT #1, f$
    INPUT #1, blk
    tcn = 0
    FOR i = 1 TO blk
      INPUT #1, a, b, c, d, e
      tcn = tcn + d
    NEXT i
```

```
    CLOSE #1
    cn = INT(tcn / blk)
RETURN
'**************************
getarea:
   area! = blk * .003861
RETURN
'**************************
getia:
   OPEN "\model\files\iap.tbl" FOR INPUT AS #1
    found = 0
    WHILE found = 0
      INPUT #1, n, ia!
      IF cn = n THEN found = 1
    WEND
   CLOSE #1
RETURN
'*************************
getrunoff:
   OPEN "\model\data\" + sb$ + ".rof" FOR INPUT AS #1
    INPUT #1, a$
    INPUT #1, b$
    INPUT #1, a
    INPUT #1, f$
    INPUT #1, precip!
    INPUT #1, runoff!
   CLOSE #1
RETURN
'************************
gettc:
  OPEN "\model\data\" + sb$ + ".tc" FOR INPUT AS #1
   INPUT #1, tc!
  CLOSE #1
RETURN
'************************
roundtc:
   IF tc! > 0 AND tc! < .15 THEN tcc = .1
   IF tc! > .15 AND tc! < .25 THEN tcc = .2
   IF tc! > .25 AND tc! < .35 THEN tcc = .3
   IF tc! > .35 AND tc! < .45 THEN tcc = .4
   IF tc! > .45 AND tc! < .625 THEN tcc = .5
   IF tc! > .625 AND tc! < .85 THEN tcc = .75
   IF tc! > .85 AND tc! < 1.15 THEN tcc = 1
   IF tc! > 1.15 AND tc! < 1.35 THEN tcc = 1.25
   IF tc! > 1.35 AND tc! < 1.65 THEN tcc = 1.5
   IF tc! > 1.65 THEN tcc = 2
```

```
RETURN
'*****************************
getiap:
   iap! = ia! / precip!
RETURN
'*****************************
roundiap:
   IF iap! < .2 THEN riap! = .1
   IF iap! > .2 AND iap! < .4 THEN riap! = .3
   IF iap! > .4 THEN riap! = .5
RETURN
'*****************************
gettabfile:
   IF tcc = .1 AND riap! = .1 THEN ft$ = "a"
   IF tcc = .1 AND riap! = .3 THEN ft$ = "b"
   IF tcc = .1 AND riap! = .5 THEN ft$ = "c"
   IF tcc = .2 AND riap! = .1 THEN ft$ = "d"
   IF tcc = .2 AND riap! = .3 THEN ft$ = "e"
   IF tcc = .2 AND riap! = .5 THEN ft$ = "f"
   IF tcc = .3 AND riap! = .1 THEN ft$ = "g"
   IF tcc = .3 AND riap! = .3 THEN ft$ = "h"
   IF tcc = .3 AND riap! = .5 THEN ft$ = "i"
   IF tcc = .4 AND riap! = .1 THEN ft$ = "j"
   IF tcc = .4 AND riap! = .3 THEN ft$ = "k"
   IF tcc = .4 AND riap! = .5 THEN ft$ = "l"
   IF tcc = .5 AND riap! = .1 THEN ft$ = "m"
   IF tcc = .5 AND riap! = .3 THEN ft$ = "n"
   IF tcc = .5 AND riap! = .5 THEN ft$ = "o"
   IF tcc = .75 AND riap! = .1 THEN ft$ = "p"
   IF tcc = .75 AND riap! = .3 THEN ft$ = "q"
   IF tcc = .75 AND riap! = .5 THEN ft$ = "r"
   IF tcc = 1 AND riap! = .1 THEN ft$ = "s"
   IF tcc = 1 AND riap! = .3 THEN ft$ = "t"
   IF tcc = 1 AND riap! = .5 THEN ft$ = "u"
   IF tcc = 1.25 AND riap! = .1 THEN ft$ = "v"
   IF tcc = 1.25 AND riap! = .3 THEN ft$ = "w"
   IF tcc = 1.25 AND riap! = .5 THEN ft$ = "x"
   IF tcc = 1.5 AND riap! = .1 THEN ft$ = "y"
   IF tcc = 1.5 AND riap! = .3 THEN ft$ = "z"
   IF tcc = 1.5 AND riap! = .5 THEN ft$ = "aa"
   IF tcc = 2 AND riap! = .1 THEN ft$ = "bb"
   IF tcc = 2 AND riap! = .3 THEN ft$ = "cc"
   IF tcc = 2 AND riap! = .5 THEN ft$ = "dd"
RETURN
'***********************************
loadtable:
```

```
    DIM ht!(1 TO 32)
    DIM tt!(1 TO 12)
    DIM x(1 TO 12, 1 TO 32)
    OPEN "\model\files\" + ft$ + ".tbl" FOR INPUT AS #1
     FOR i = 1 TO 32
       INPUT #1, ht!(i)
     NEXT i
     FOR i = 1 TO 12
      INPUT #1, tt!(i)
      FOR j = 1 TO 32
       INPUT #1, x(i, j)
      NEXT j
     NEXT i
    CLOSE #1
RETURN
'***********************************
gettable:
    DIM table(1 TO 32)
    i = 1
    tcc = 0
    WHILE tcc <> tt!(i)
     i = i + 1
    WEND
    FOR j = 1 TO 32
      table(j) = x(i, j)
    NEXT j
RETURN
'***********************************
calhydro:
    DIM hydro!(1 TO 32)
    FOR i = 1 TO 32
      hydro!(i) = table(i) * area! * runoff!
    NEXT i
RETURN
'***********************************
disphydro:
    SCREEN 9
    PAINT (1, 1), 7
    COLOR 4, 7
    LOCATE 1, 15
    PRINT "TABHYDRO mk. 1  SCS Tabular Hydrograph Method"
    COLOR 8, 7
    LOCATE 4, 6
    PRINT "Time (hrs.)"
    LOCATE 4, 20
    PRINT "Q (cfs)"
```

```
    LOCATE 4, 36
    PRINT "Time (hrs.)"
    LOCATE 4, 50
    PRINT "Q (cfs)"
    COLOR 1, 7
    FOR i = 1 TO 16
      LOCATE 5 + i, 10
      PRINT USING "##.#"; ht!(i)
      LOCATE 5 + i, 20
      PRINT USING "###.##"; hydro!(i)
      LOCATE 5 + i, 40
      PRINT USING "##.##"; ht!(16 + i)
      LOCATE 5 + i, 50
      PRINT USING "###.##"; hydro!(16 + i)
    NEXT i
    COLOR 6, 7
    LOCATE 23, 2: PRINT "F1: Save to file"
    COLOR 4
    LOCATE 23, 20: PRINT "F3: Show plot"
    COLOR 5
    LOCATE 23, 36: PRINT "e: to exit"
    COLOR 1
    LOCATE 23, 50: PRINT "Print Screen: Hardcopy"
RETURN
'*************************************
fileout:
    CLS
    COLOR 3, 1
    LOCATE 12, 18
    PRINT "Save Hydrograph"
    LOCATE 14, 14
    PRINT "If you wish hydrograph to be"
    LOCATE 15, 14
    PRINT "saved as "; sb$; ".thg then "
    LOCATE 16, 14
    PRINT "hit return, else enter file"
    LOCATE 17, 14
    INPUT "name: "; outfile$
    IF outfile$ = "" THEN out$ = sb$
    IF outfile$ <> "" THEN out$ = outfile$
    OPEN "\model\data\" + out$ + ".thg" FOR OUTPUT AS #1
      WRITE #1, water$
      WRITE #1, name$
      WRITE #1, sl
      WRITE #1, "thg"
      WRITE #1, blk
```

```
      FOR i = 1 TO 32
        WRITE #1, ht!(i), hydro!(i)
      NEXT i
      CLOSE #1
    GOSUB disphydro
RETURN
'*************************************
plothydro:
    GOSUB findmaxq
    GOSUB getscale
    SCREEN 12
    WINDOW (15, -12)-(55, 60)
    LINE (19.5, 0)-(52, 0), 3
    LINE (20, -1)-(20, 50), 3
    FOR i = 22 TO 52 STEP 2
      LINE (i, 0)-(i, -1), 2
    NEXT i
    FOR i = 0 TO 50 STEP 5
      LINE (19.5, i)-(20, i), 2
    NEXT i
    LOCATE 26, 10: PRINT "10"
    LOCATE 26, 18: PRINT "12"
    LOCATE 26, 26: PRINT "14"
    LOCATE 26, 34: PRINT "16"
    LOCATE 26, 42: PRINT "18"
    LOCATE 26, 50: PRINT "20"
    LOCATE 26, 58: PRINT "22"
    LOCATE 26, 66: PRINT "24"
    LOCATE 26, 74: PRINT "26"

    LOCATE 25, 8: PRINT "0"
    LOCATE 5, 5: PRINT 100 * sc
    LOCATE 9, 6: PRINT 80 * sc
    LOCATE 13, 6: PRINT 60 * sc
    LOCATE 17, 6: PRINT 40 * sc
    LOCATE 21, 6: PRINT 20 * sc
    COLOR 6
    LOCATE 10, 5: PRINT "Q"
    LOCATE 12, 5: PRINT "c"
    LOCATE 13, 5: PRINT "f"
    LOCATE 14, 5: PRINT "s"
    LOCATE 27, 30: PRINT "Hours"
    COLOR 4
    LOCATE 28, 10: PRINT "e: Exit"
    LOCATE 28, 30: PRINT "Print Screen: Hardcopy"
```

```
    FOR i = 1 TO 31
      LINE ((ht!(i) * 2), (hydro!(i) / z))-((ht!(i + 1) * 2), (hydro!(i + 1) / z)), 4
    NEXT i
    WHILE INKEY$ = ""
    WEND
    GOSUB disphydro
RETURN
'*****************************************
findmaxq:
   max! = hydro!(1)
   FOR i = 2 TO 26
     IF hydro!(i) > max! THEN max! = hydro!(i)
   NEXT i
RETURN
'*****************************************
getscale:
   IF max! > 100 AND max! < 200 THEN z = 4
   IF max! > 100 AND max! < 200 THEN sc = 2
   IF max! > 50 AND max! < 100 THEN z = 2
   IF max! > 50 AND max! < 100 THEN sc = 1
   IF max! > 25 AND max! < 50 THEN z = 1
   IF max! > 25 AND max! < 50 THEN sc = .5
   IF max! > 0 AND max! < 25 THEN z = .5
   IF max! > 0 AND max! < 25 THEN sc = .25
RETURN
'*****************************************
```

Source Code for SCSUNIT mk. 1

```
'******************** SCSUNIT .BAS   MK. 1 *************************
CLS
GOSUB getb
GOSUB gettc
GOSUB getarea
GOSUB calc
GOSUB hydro
GOSUB hout
WHILE INKEY$ <> "e"
  ON KEY(1) GOSUB fileout
  KEY(1) ON
  ON KEY(3) GOSUB plothydro
  KEY(3) ON
WEND
RUN "\model\menu"
END

'*********************************************
getb:
  OPEN "\model\data\luf.con" FOR INPUT AS #1
    INPUT #1, sb$
  CLOSE #1
RETURN
'*********************************************
gettc:
  OPEN "\model\data\" + sb$ + ".tc" FOR INPUT AS #1
    INPUT #1, tc!
  CLOSE #1
RETURN
'*********************************************
getarea:
  OPEN "\model\data\" + sb$ + ".cnn" FOR INPUT AS #1
    INPUT #1, water$
    INPUT #1, name$
    INPUT #1, sl
    INPUT #1, f$
    INPUT #1, blk
  CLOSE #1
  area! = blk * .003861
RETURN
'*********************************************
calc:
```

```
  t1! = .54 * (area! ^ .6)
  D! = .133 * tc!
  tp! = (D! / 2) + t1!
  qp! = (484 * area!) / tp!
RETURN
'*********************************************
hydro:
  i = 1
  DIM time!(1 TO 500)
  DIM discharge!(1 TO 500)
  FOR t! = 0 TO tp! * 5 STEP .01
    IF t! / tp! < 1 THEN GOSUB h1
    IF t! / tp! = 1 THEN GOSUB h1
    IF t! / tp! > 1 AND t! / tp! < 1.4 THEN GOSUB h2
    IF t! / tp! > 1.4 THEN GOSUB h3
    IF t! / tp! = 1.4 THEN GOSUB h3
    time!(i) = t!
    i = i + 1
  NEXT t!
RETURN
'*********************************************
h1:
  tt! = t! / tp!
  discharge!(i) = -3.05167 * tt! ^ 3 + 4.78147 * tt! ^ 2 - .808 * tt! + .0766667
  discharge!(i) = discharge!(i) * qp!
RETURN
'*********************************************
h2:
  tt! = t! / tp!
  discharge!(i) = -1.07143 * tt! ^ 2 + 2.00143 * tt! + 7.456989999999999D-02
  discharge!(i) = discharge!(i) * qp!
RETURN
'*********************************************
h3:
  tt! = t! / tp!
  discharge!(i) = 2.718282 ^ (-1.69447 * tt!) * 8.52855
  discharge!(i) = discharge!(i) * qp!
RETURN
'*********************************************
hout:
  CLS
  SCREEN 9
  COLOR 4, 7
  LOCATE 1, 25: PRINT "**** SCS UNIT HYDROGRAPH ****"
  COLOR 1
  LOCATE 3, 6: PRINT "Hours"
```

```
  LOCATE 3, 14: PRINT "CFS"
  IF i < 90 THEN w = 2
  IF i > 90 THEN w = 3
  IF i > 120 THEN w = 4
  IF i > 180 THEN w = 5
  k = 5
  COLOR 8
  FOR j = 1 TO i / 3 STEP w
   LOCATE k, 5:
   PRINT USING "##.##"; time!(j)
   LOCATE k, 13:
   PRINT USING "####.##"; discharge!(j)
   k = k + 1
  NEXT j
  COLOR 1
  LOCATE 3, 27: PRINT "Hours"
  LOCATE 3, 35: PRINT "CFS"
  k = 5
  COLOR 8
  FOR j = i / 3 TO 2 * i / 3 STEP w
   LOCATE k, 27: PRINT USING "##.##"; time!(j)
   LOCATE k, 35: PRINT USING "####.##"; discharge!(j)
   k = k + 1
  NEXT j
  COLOR 1
  LOCATE 3, 49: PRINT "Hours"
  LOCATE 3, 57: PRINT "CFS"
  k = 5
  COLOR 8
  FOR j = 2 * i / 3 TO i STEP w
   LOCATE k, 49: PRINT USING "##.##"; time!(j)
   LOCATE k, 57: PRINT USING "####.##"; discharge!(j)
   k = k + 1
  NEXT j
  COLOR 6
  LOCATE 23, 5: PRINT "F1: Save to file"
  COLOR 1
  LOCATE 23, 23: PRINT "F3: Show plot"
  COLOR 2
  LOCATE 23, 38: PRINT "e: to exit"
  COLOR 4
  LOCATE 23, 50: PRINT "Print Screen: Hardcopy"
RETURN
'**********************************************
fileout:
  CLS
```

```
  COLOR 3, 1
  LOCATE 12, 18
  PRINT "Save Hydrograph"
  LOCATE 14, 14
  PRINT "If you wish hydrograph to be"
  LOCATE 15, 14
  PRINT "saved as "; sb$; ".uhg then"
  LOCATE 16, 14
  PRINT "hit return, else enter file"
  LOCATE 17, 14
  INPUT "name: "; outfile$
  IF outfile$ = "" THEN out$ = sb$
  IF outfile$ <> "" THEN out$ = outfile$
  OPEN "\model\data\" + out$ + ".uhg" FOR OUTPUT AS #1
   WRITE #1, water$
   WRITE #1, name$
   WRITE #1, sl
   WRITE #1, "uhg"
   WRITE #1, blk
   FOR j = 1 TO i - 1
     WRITE #1, time!(j), discharge!(j)
   NEXT j
  CLOSE #1
  GOSUB hout
RETURN
'***************************************************
plothydro:
  GOSUB findmaxq
  maxtime! = time!(i - 1)
  GOSUB getscale
  SCREEN 12
  WINDOW (-8, -25)-(55, 110)
  LINE (-1, 0)-(50, 0), 4
  LINE (0, -2)-(0, 100), 4
  FOR k = 10 TO 100 STEP 10
   LINE (-1, k)-(0, k), 1
  NEXT k
  FOR k = 5 TO 50 STEP 5
   LINE (k, -2)-(k, 0), 1
  NEXT k
  LOCATE 25, 8: PRINT "0"
  LOCATE 14, 5: PRINT 50 * sc
  LOCATE 3, 5: PRINT 100 * sc
  LOCATE 26, 11: PRINT "0"
  LOCATE 26, 21: PRINT 10 / tz
```

```
  LOCATE 26, 34: PRINT 20 / tz
  LOCATE 26, 47: PRINT 30 / tz
  LOCATE 26, 60: PRINT 40 / tz
  LOCATE 26, 72: PRINT 50 / tz
  COLOR 6
  LOCATE 27, 30: PRINT "HOURS"
  LOCATE 10, 3: PRINT "C"
  LOCATE 13, 3: PRINT "F"
  LOCATE 16, 3: PRINT "S"

  FOR j = 1 TO i - 2
    IF time!(j + 1) * tz > 50 THEN EXIT FOR
    LINE (time!(j) * tz, discharge!(j) / z)-(time!(j + 1) * tz, discharge!(j + 1) / z), 2
  NEXT j
  COLOR 3
  LOCATE 28, 10: PRINT "Press e to exit"
  LOCATE 28, 40: PRINT "Press Print Screen to print"
  WHILE INKEY$ <> "e"
  WEND
  GOSUB hout
RETURN
'*********************************************************
findmaxq:
  max! = discharge!(1)
  FOR j = 2 TO i - 1
    IF discharge!(j) > max! THEN max! = discharge!(j)
  NEXT j
RETURN
'*********************************************************
getscale:
  IF max! > 400 AND max! < 500 THEN z = 5
  IF max! > 400 AND max! < 500 THEN sc = 5
  IF max! > 300 AND max! < 400 THEN z = 4
  IF max! > 300 AND max! < 400 THEN sc = 4
  IF max! > 200 AND max! < 300 THEN z = 3
  IF max! > 200 AND max! < 300 THEN sc = 3
  IF max! > 100 AND max! < 200 THEN z = 2
  IF max! > 100 AND max! < 200 THEN sc = 2
  IF max! > 50 AND max! < 100 THEN z = 1
  IF max! > 50 AND max! < 100 THEN sc = 1
  IF max! < 50 THEN z = .5
  IF max! < 50 THEN sc = .5
  IF maxtime! < .6 THEN tz = 100
  IF maxtime! < 1 AND maxtime! > .5 THEN tz = 50
  IF maxtime! < 2 AND maxtime! > 1 THEN tz = 50
RETURN
```

Source Code for COMPHY mk. 1

```
'***************** COMPHY  mk. 1 ******************************

  CLS
  PRINT "   COMPHY mk. 1.0"
  INPUT "Enter number of sub areas: "; sa
  DIM area$(1 TO sa)
  DIM travel(1 TO sa)
  DIM ht!(1 TO 32)
  DIM tt!(1 TO 12)
  DIM x(1 TO 12, 1 TO 32)
  DIM table(1 TO 32)
  DIM hydro!(1 TO sa, 1 TO 32)
  DIM shydro!(1 TO 32)

  CLS
  COLOR 2
  LOCATE 1, 1
  PRINT "Sub Area Name"
  LOCATE 1, 20
  PRINT "Travel Time To Outlet"
  PRINT
  FOR i = 1 TO sa
    LOCATE i + 2, 1
    INPUT area$(i)
    LOCATE i + 2, 20
    INPUT travel(i)
  NEXT i
  CLS
FOR qq = 1 TO sa
  sb$ = area$(qq): PRINT area$(qq)
  GOSUB getcn
  GOSUB getarea
  GOSUB getia
  GOSUB getrunoff
  GOSUB gettc
  GOSUB roundtc
  GOSUB getiap
  GOSUB roundiap
  GOSUB gettabfile
  GOSUB loadtable
  GOSUB gettable
  GOSUB calhydro
NEXT qq
```

```
GOSUB sumhy
GOSUB disphydro
WHILE INKEY$ <> "e"
  ON KEY(1) GOSUB fileout
  KEY(1) ON
  ON KEY(3) GOSUB plothydro
  KEY(3) ON
WEND
RUN "\model\menu"
END
'**************************
getcn:
  OPEN "\model\data\" + sb$ + ".cnn" FOR INPUT AS #1
    INPUT #1, water$
    INPUT #1, name$
    INPUT #1, sl
    INPUT #1, f$
    INPUT #1, blk
    tcn = 0
    FOR i = 1 TO blk
      INPUT #1, a, b, c, d, e
      tcn = tcn + d
    NEXT i
    CLOSE #1
    cn = INT(tcn / blk)
RETURN
'**************************
getarea:
  area! = blk * .003861
RETURN
'**************************
getia:
  OPEN "\model\files\iap.tbl" FOR INPUT AS #1
   found = 0
   WHILE found = 0
     INPUT #1, n, ia!
     IF cn = n THEN found = 1
   WEND
  CLOSE #1
RETURN
'*************************
getrunoff:
  OPEN "\model\data\" + sb$ + ".rof" FOR INPUT AS #1
   INPUT #1, a$
   INPUT #1, b$
   INPUT #1, a
```

```
      INPUT #1, ft$
      INPUT #1, precip!
      INPUT #1, runoff!
    CLOSE #1
RETURN
'************************
gettc:
   OPEN "\model\data\" + sb$ + ".tc" FOR INPUT AS #1
     INPUT #1, tc!
   CLOSE #1
RETURN
'************************
roundtc:
    IF tc! > 0 AND tc! < .15 THEN tcc = .1
    IF tc! > .15 AND tc! < .25 THEN tcc = .2
    IF tc! > .25 AND tc! < .35 THEN tcc = .3
    IF tc! > .35 AND tc! < .45 THEN tcc = .4
    IF tc! > .45 AND tc! < .625 THEN tcc = .5
    IF tc! > .625 AND tc! < .85 THEN tcc = .75
    IF tc! > .85 AND tc! < 1.15 THEN tcc = 1
    IF tc! > 1.15 AND tc! < 1.35 THEN tcc = 1.25
    IF tc! > 1.35 AND tc! < 1.65 THEN tcc = 1.5
    IF tc! > 1.65 THEN tcc = 2
RETURN
'***************************
getiap:
    iap! = ia! / precip!
RETURN
'****************************
roundiap:
    IF iap! < .2 THEN riap! = .1
    IF iap! > .2 AND iap! < .4 THEN riap! = .3
    IF iap! > .4 THEN riap! = .5
RETURN
'****************************
gettabfile:
    IF tcc = .1 AND riap! = .1 THEN ft$ = "a"
    IF tcc = .1 AND riap! = .3 THEN ft$ = "b"
    IF tcc = .1 AND riap! = .5 THEN ft$ = "c"
    IF tcc = .2 AND riap! = .1 THEN ft$ = "d"
    IF tcc = .2 AND riap! = .3 THEN ft$ = "e"
    IF tcc = .2 AND riap! = .5 THEN ft$ = "f"
    IF tcc = .3 AND riap! = .1 THEN ft$ = "g"
    IF tcc = .3 AND riap! = .3 THEN ft$ = "h"
    IF tcc = .3 AND riap! = .5 THEN ft$ = "i"
    IF tcc = .4 AND riap! = .1 THEN ft$ = "j"
```

```
    IF tcc = .4 AND riap! = .3 THEN ft$ = "k"
    IF tcc = .4 AND riap! = .5 THEN ft$ = "l"
    IF tcc = .5 AND riap! = .1 THEN ft$ = "m"
    IF tcc = .5 AND riap! = .3 THEN ft$ = "n"
    IF tcc = .5 AND riap! = .5 THEN ft$ = "o"
    IF tcc = .75 AND riap! = .1 THEN ft$ = "p"
    IF tcc = .75 AND riap! = .3 THEN ft$ = "q"
    IF tcc = .75 AND riap! = .5 THEN ft$ = "r"
    IF tcc = 1 AND riap! = .1 THEN ft$ = "s"
    IF tcc = 1 AND riap! = .3 THEN ft$ = "t"
    IF tcc = 1 AND riap! = .5 THEN ft$ = "u"
    IF tcc = 1.25 AND riap! = .1 THEN ft$ = "v"
    IF tcc = 1.25 AND riap! = .3 THEN ft$ = "w"
    IF tcc = 1.25 AND riap! = .5 THEN ft$ = "x"
    IF tcc = 1.5 AND riap! = .1 THEN ft$ = "y"
    IF tcc = 1.5 AND riap! = .3 THEN ft$ = "z"
    IF tcc = 1.5 AND riap! = .5 THEN ft$ = "aa"
    IF tcc = 2 AND riap! = .1 THEN ft$ = "bb"
    IF tcc = 2 AND riap! = .3 THEN ft$ = "cc"
    IF tcc = 2 AND riap! = .5 THEN ft$ = "dd"
RETURN
'*************************************
loadtable:
   OPEN "\model\files\" + ft$ + ".tbl" FOR INPUT AS #1
    FOR i = 1 TO 32
      INPUT #1, ht!(i)
    NEXT i
    FOR i = 1 TO 12
     INPUT #1, tt!(i)
     FOR j = 1 TO 32
      INPUT #1, x(i, j)
     NEXT j
    NEXT i
   CLOSE #1
RETURN
'*************************************
gettable:
   i = 1
   tcc = travel(qq)
   WHILE tcc <> tt!(i)
    i = i + 1
   WEND
   FOR j = 1 TO 32
     table(j) = x(i, j)
   NEXT j
RETURN
```

```
'*************************************
calhydro:
  FOR i = 1 TO 32
    hydro!(qq, i) = table(i) * area! * runoff!
  NEXT i
RETURN
'*************************************
sumhy:
  FOR i = 1 TO sa
   FOR j = 1 TO 32
    shydro!(j) = shydro!(j) + hydro!(i, j)
   NEXT j
  NEXT i
RETURN
'*************************************
disphydro:
  SCREEN 9
  PAINT (1, 1), 7
  COLOR 4, 7
  LOCATE 1, 15
  PRINT "TABHYDRO mk. 1  SCS Tabular Hydrograph Method"
  COLOR 8, 7
  LOCATE 4, 6
  PRINT "Time (hrs.)"
  LOCATE 4, 20
  PRINT "Q (cfs)"
  LOCATE 4, 36
  PRINT "Time (hrs.)"
  LOCATE 4, 50
  PRINT "Q (cfs)"
  COLOR 1, 7
  FOR i = 1 TO 16
    LOCATE 5 + i, 10
    PRINT USING "##.#"; ht!(i)
    LOCATE 5 + i, 20
    PRINT USING "###.##"; shydro!(i)
    LOCATE 5 + i, 40
    PRINT USING "##.##"; ht!(16 + i)
    LOCATE 5 + i, 50
    PRINT USING "###.##"; shydro!(16 + i)
  NEXT i
  COLOR 6, 7
  LOCATE 23, 2: PRINT "F1: Save to file"
  COLOR 4
  LOCATE 23, 20: PRINT "F3: Show plot"
  COLOR 5
```

```
   LOCATE 23, 36: PRINT "e: to exit"
   COLOR 1
   LOCATE 23, 50: PRINT "Print Screen: Hardcopy"
RETURN
'**************************************
fileout:
   CLS
   COLOR 3, 1
   LOCATE 12, 18
   PRINT "Save Hydrograph"
   LOCATE 14, 14
   PRINT "If you wish hydrograph to be"
   LOCATE 15, 14
   PRINT "saved as "; sb$; ".thg then "
   LOCATE 16, 14
   PRINT "hit return, else enter file"
   LOCATE 17, 14
   INPUT "name: "; outfile$
   IF outfile$ = "" THEN out$ = sb$
   IF outfile$ <> "" THEN out$ = outfile$
   OPEN "\model\data\" + out$ + ".thg" FOR OUTPUT AS #1
    WRITE #1, water$
    WRITE #1, name$
    WRITE #1, sl
    WRITE #1, "thg"
    WRITE #1, blk
    FOR i = 1 TO 32
      WRITE #1, ht!(i), shydro!(i)
    NEXT i
    CLOSE #1
   GOSUB disphydro
RETURN
'**************************************
plothydro:
   GOSUB findmaxq
   GOSUB getscale
   SCREEN 12
   WINDOW (15, -12)-(55, 60)
    LINE (19.5, 0)-(52, 0), 3
   LINE (20, -1)-(20, 50), 3
   FOR i = 22 TO 52 STEP 2
     LINE (i, 0)-(i, -1), 2
   NEXT i
   FOR i = 0 TO 50 STEP 5
     LINE (19.5, i)-(20, i), 2
   NEXT i
```

```
    LOCATE 26, 10: PRINT "10"
    LOCATE 26, 18: PRINT "12"
    LOCATE 26, 26: PRINT "14"
    LOCATE 26, 34: PRINT "16"
    LOCATE 26, 42: PRINT "18"
    LOCATE 26, 50: PRINT "20"
    LOCATE 26, 58: PRINT "22"
    LOCATE 26, 66: PRINT "24"
    LOCATE 26, 74: PRINT "26"

    LOCATE 25, 8: PRINT "0"
    LOCATE 5, 5: PRINT 100 * sc
    LOCATE 9, 6: PRINT 80 * sc
    LOCATE 13, 6: PRINT 60 * sc
    LOCATE 17, 6: PRINT 40 * sc
    LOCATE 21, 6: PRINT 20 * sc
    COLOR 6
    LOCATE 10, 5: PRINT "Q"
    LOCATE 12, 5: PRINT "c"
    LOCATE 13, 5: PRINT "f"
    LOCATE 14, 5: PRINT "s"
    LOCATE 27, 30: PRINT "Hours"
    COLOR 4
    LOCATE 28, 10: PRINT "e: Exit"
    LOCATE 28, 30: PRINT "Print Screen: Hardcopy"

    FOR i = 1 TO 31
      LINE ((ht!(i) * 2), (shydro!(i) / z))-((ht!(i + 1) * 2), (shydro!(i + 1) / z)), 4
    NEXT i
    WHILE INKEY$ = ""
    WEND
    GOSUB disphydro

RETURN
'*******************************************
findmaxq:
  max! = hydro!(qq, 1)
  FOR i = 2 TO 26
    IF hydro!(qq, i) > max! THEN max! = hydro!(qq, i)
  NEXT i
RETURN
'*******************************************
getscale:
  IF max! > 100 AND max! < 200 THEN z = 4
  IF max! > 100 AND max! < 200 THEN sc = 2
  IF max! > 50 AND max! < 100 THEN z = 2
```

```
   IF max! > 50 AND max! < 100 THEN sc = 1
   IF max! > 25 AND max! < 50 THEN z = 1
   IF max! > 25 AND max! < 50 THEN sc = .5
   IF max! > 0 AND max! < 25 THEN z = .5
   IF max! > 0 AND max! < 25 THEN sc = .25
RETURN
'*******************************************
```

Source Code for OSCREEN mk. 1

```
'************** OScreen ****************
CLS
SCREEN 12
LINE (10, 5)-(600, 5), 1
LINE (10, 500)-(600, 500), 1
LINE (10, 5)-(10, 500), 1
LINE (600, 5)-(600, 500), 1
PAINT (11, 15), 1, 1

LINE (100, 20)-(510, 20), 4
LINE (100, 50)-(510, 50), 4
LINE (100, 20)-(100, 50), 4
LINE (510, 20)-(510, 50), 4
PAINT (101, 21), 4, 4
LOCATE 2.7, 25
PRINT "H Y D R O S I M    mk. 1.0"

LINE (100, 100)-(510, 100), 2
LINE (100, 200)-(510, 200), 2
LINE (100, 100)-(100, 200), 2
LINE (510, 100)-(510, 200), 2
PAINT (101, 101), 2, 2
LOCATE 8, 25
PRINT "Written by Harry C. Bircher"
LOCATE 10, 15
PRINT "Department of Environmental and Civil Engineering"
LOCATE 12, 17
PRINT "Youngstown State University, Youngstown, Ohio"
LINE (100, 250)-(510, 250), 3
LINE (100, 350)-(510, 350), 3
LINE (100, 250)-(100, 350), 3
LINE (510, 250)-(510, 350), 3
PAINT (101, 251), 3, 3
LOCATE 18, 17
PRINT "Program to model urban and rural run-off"
LOCATE 20, 17
PRINT "for single or combined watersheds.      "
LOCATE 28, 25
PRINT "Press any key to begin."
DO WHILE INKEY$ = ""
LOOP
RUN "MENU"
END
```

Source Code for MENU mk. 1

```
'**************** Menu mk1. ***********************
CLS
SCREEN 12
GOSUB main

WHILE INKEY$ <> "e"
  ON KEY(1) GOSUB setb
  KEY(1) ON
  ON KEY(2) GOSUB delin
  KEY(2) ON
  ON KEY(3) GOSUB soil
  KEY(3) ON
  ON KEY(4) GOSUB luse
  KEY(4) ON
  ON KEY(5) GOSUB cnn
  KEY(5) ON
  ON KEY(6) GOSUB roff
  KEY(6) ON
  ON KEY(7) GOSUB tcon
  KEY(7) ON
  ON KEY(8) GOSUB hydro
  KEY(8) ON
  ON KEY(9) GOSUB util
  KEY(9) ON
  GOSUB main
WEND
END
'*********************************
main:

  LINE (10, 5)-(600, 5), 1
  LINE (10, 500)-(600, 500), 1
  LINE (10, 5)-(10, 500), 1
  LINE (600, 5)-(600, 500), 1
  PAINT (11, 15), 1, 1

  LINE (100, 20)-(510, 20), 4
  LINE (100, 50)-(510, 50), 4
  LINE (100, 20)-(100, 50), 4
  LINE (510, 20)-(510, 50), 4
  PAINT (101, 21), 4, 4
  LOCATE 3, 26
  PRINT "HYDROSIM   MAIN   MENU"
```

```
LINE (110, 60)-(160, 60), 2
LINE (110, 400)-(160, 400), 2
LINE (110, 60)-(110, 400), 2
LINE (160, 60)-(160, 400), 2
PAINT (111, 101), 2, 2
LOCATE 6, 16
PRINT "F1 "
LOCATE 8, 16
PRINT "F2 "
LOCATE 10, 16
PRINT "F3 "
LOCATE 12, 16
PRINT "F4 "
LOCATE 14, 16
PRINT "F5 "
LOCATE 16, 16
PRINT "F6 "
LOCATE 18, 16
PRINT "F7 "
LOCATE 20, 16
PRINT "F8 "
LOCATE 22, 16
PRINT "F9 "
LOCATE 24, 16
PRINT " E "
LINE (180, 60)-(500, 60), 6
LINE (180, 400)-(500, 400), 6
LINE (180, 60)-(180, 400), 6
LINE (500, 60)-(500, 400), 6
PAINT (181, 101), 6, 6
LOCATE 6, 25
PRINT "Set or change area to model.    "
LOCATE 8, 25
PRINT "Delineate area to model.        "
LOCATE 10, 25
PRINT "Enter or edit soil data.        "
LOCATE 12, 25
PRINT "Enter or edit landuse data.     "
LOCATE 14, 25
PRINT "Calculate run-off curve numbers."
LOCATE 16, 25
PRINT "Calculate average run-off.      "
LOCATE 18, 25
PRINT "Determine time of concentration."
LOCATE 20, 25
```

```
  PRINT "Hydrographs.                "
  LOCATE 22, 25
  PRINT "Utilities.          "
  LOCATE 24, 25
  PRINT "To exit program.              "
  x1 = 180
  x2 = 500
  y1 = 420
  y2 = 460
  c = 5
  GOSUB dbox
  LOCATE 28, 25
  OPEN "\model\data\current.con" FOR INPUT AS #1
  INPUT #1, sb$
  CLOSE #1
  PRINT "Current area: "; sb$
RETURN
'*********************************************
setb:
  CLS
  x1 = 100
  x2 = 400
  y1 = 100
  y2 = 200
  c = 3
  GOSUB dbox
  LOCATE 8, 18
  PRINT "Set or change area to model."
  LOCATE 10, 18
  PRINT "Enter name or a to abort. "
  LOCATE 12, 18
  INPUT ; sb$
  IF sb$ <> "a" THEN GOSUB writeb
RETURN
'*********************************************
delin:
  RUN "\model\bcreate"
RETURN
'*********************************************
soil:
  CLS
  x1 = 100
  x2 = 400
  y1 = 100
  y2 = 200
  c = 6
```

```
  GOSUB dbox
  LOCATE 8, 20
  PRINT "Enter or edit soil data."
  LOCATE 10, 20
  PRINT "F1: Enter data in new model"
  LOCATE 11, 20
  PRINT "F2: Edit current model     "
  LOCATE 12, 20
  PRINT " e: Return to main menu    "
  WHILE INKEY$ <> "e"
    ON KEY(1) GOSUB rsoil
    KEY(1) ON
    ON KEY(2) GOSUB esoil
    KEY(2) ON
  WEND
  CLS
RETURN
'*********************************************
luse:
  CLS
  x1 = 125
  x2 = 425
  y1 = 100
  y2 = 250
  c = 2
  GOSUB dbox
  LOCATE 8, 20
  PRINT "Enter or edit land use data."
  LOCATE 10, 20
  PRINT "F1: Enter data in new model."
  LOCATE 11, 20
  PRINT "F2: Edit current model.    "
  LOCATE 12, 20
  PRINT "F3: Create compare file.    "
  LOCATE 13, 20
  PRINT " e: Return to main menu.    "
  WHILE INKEY$ <> "e"
    ON KEY(1) GOSUB rluse
    KEY(1) ON
    ON KEY(2) GOSUB eluse
    KEY(2) ON
    ON KEY(3) GOSUB cluse
  WEND
  CLS
RETURN
```

```
'*********************************************
cnn:
  RUN "\model\cncalcp1"
RETURN
'*********************************************
roff:
  RUN "\model\roff"
RETURN
'*********************************************
dbox:
  LINE (x1, y1)-(x2, y1), c
  LINE (x1, y2)-(x2, y2), c
  LINE (x1, y1)-(x1, y2), c
  LINE (x2, y1)-(x2, y2), c
  PAINT (x1 + 1, y1 + 1), c, c
RETURN
'*******************************************
writeb:
  OPEN "\model\data\current.con" FOR OUTPUT AS #1
  WRITE #1, sb$, "n"
  CLOSE #1
RETURN
'*******************************************
rsoil:
  RUN "\model\soiladd"
RETURN
'*******************************************
esoil:
  OPEN "\model\data\current.con" FOR INPUT AS #1
  INPUT #1, sb$, m$
  CLOSE #1
  OPEN "\model\data\current.con" FOR OUTPUT AS #1
  WRITE #1, sb$, "e"
  CLOSE #1
  RUN "\model\soiladd"
RETURN
'********************************************
rluse:
  RUN "\model\luseadd"
RETURN
'********************************************
eluse:
  OPEN "\model\data\current.con" FOR INPUT AS #1
  INPUT #1, sb$, m$
  CLOSE #1
  OPEN "\model\data\current.con" FOR OUTPUT AS #1
```

```
  WRITE #1, sb$, "e"
  CLOSE #1
  RUN "\model\luseadd"
RETURN
'*********************************************
cluse:
  OPEN "\model\data\current.con" FOR INPUT AS #1
  INPUT #1, sb$, m$
  CLOSE #1
  OPEN "\model\data\current.con" FOR OUTPUT AS #1
  WRITE #1, sb$, "c"
  CLOSE #1
  RUN "\model\luseadd"
RETURN
'*********************************************
tcon:
  RUN "\model\timecon"
RETURN
'*********************************************
hydro:
  CLS
  x1 = 125
  x2 = 425
  y1 = 100
  y2 = 260
  c = 2
  GOSUB dbox
  LOCATE 8, 20
  PRINT "     Hydrographs      "
  LOCATE 10, 20
  PRINT "F1: SCS Tabular Hydrograph  "
  LOCATE 12, 20
  PRINT "F2: SCS Unit Hydrograph     "
  LOCATE 14, 20
  PRINT "F3: Composite Hydrograph    "
  LOCATE 16, 20
  PRINT " e: Return to main menu.    "
  WHILE INKEY$ <> "e"
   ON KEY(1) GOSUB thydro
   KEY(1) ON
   ON KEY(2) GOSUB uhydro
   KEY(2) ON
   ON KEY(3) GOSUB chydro
   KEY(3) ON
  WEND
  CLS
```

```
RETURN
'****************************************
thydro:
  RUN "\model\tabhydro"
RETURN
'****************************************
uhydro:
  RUN "\model\scsunit"
RETURN
'****************************************
chydro:
  RUN "\model\comphy"
RETURN
'****************************************
util:
  CLS
  x1 = 125
  x2 = 425
  y1 = 50
  y2 = 100
  c = 9
  GOSUB dbox
  x1 = 125: x2 = 200: y1 = 100: y2 = 400: c = 14
  GOSUB dbox
  x1 = 200: x2 = 425: y1 = 100: y2 = 400: c = 12
  GOSUB dbox
  LOCATE 5, 28: PRINT "HYDROSIM MK.1"
  LOCATE 6, 30: PRINT "UTILITIES"
  LOCATE 8, 20: PRINT "F1: "
  LOCATE 8, 28: PRINT "View CN Numbers"
  LOCATE 10, 20: PRINT "F2: "
  LOCATE 10, 28: PRINT "View Slopes    "
  LOCATE 12, 20: PRINT "F3: "
  LOCATE 12, 28: PRINT "View Run-off  "
  LOCATE 14, 20: PRINT "F4: "
  LOCATE 14, 28: PRINT "Compare Run-off"
  LOCATE 16, 20: PRINT "F5: "
  LOCATE 16, 28: PRINT "Compare tab. hydrographs"
  LOCATE 18, 20: PRINT "F6: "
  LOCATE 18, 28: PRINT "Compare unit hydrographs"
  LOCATE 20, 20: PRINT "F7 : "
  LOCATE 20, 28: PRINT "Stream Calculator"
  LOCATE 24, 20: PRINT " E: "
  LOCATE 24, 28: PRINT "Return to Main Menu"

  WHILE INKEY$ <> "e"
```

```
    ON KEY(1) GOSUB vc
    KEY(1) ON
    ON KEY(2) GOSUB vs
    KEY(2) ON
    ON KEY(3) GOSUB vro
    KEY(3) ON
    ON KEY(4) GOSUB cro
    KEY(4) ON
    ON KEY(5) GOSUB cth
    KEY(5) ON
    ON KEY(6) GOSUB cuh
    KEY(6) ON
    ON KEY(7) GOSUB scal
    KEY(7) ON
  WEND
  CLS
RETURN
'*******************************************
vc:
 RUN "\model\cnview"
RETURN
'*******************************************
vs:
 RUN "\model\slopview"
'*******************************************
vro:
 RUN "\model\roview"
RETURN
'*******************************************
cuh:
 RUN "\model\compunit"
RETURN
'*******************************************
cth:
 RUN "\model\compthg"
RETURN
'*******************************************
cro:
 RUN "\model\roffgraph"
RETURN
'*******************************************
scal:
 RUN "\model\strcalc"
RETURN
'*******************************************
```