COMPUTER MODELING OF WATER YIELD FROM KINGS CREEK WATERSHED

By

Charles A. Bartlett

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Approved by:

Dr. James K. Koelliker
Major Professor

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INTRODUCTION

The hydrologic cycle describes how water moves in, out and through an ecosystem. This movement of water becomes very important to the plant and animal life of an ecosystem. If the supply, depletion and movement of this water can be simulated and ultimately predicted, then the management of the ecosystem and its biological components can be improved. For this reason, the Civil Engineering Department of Kansas State University has adapted a water budget model to describe the hydrologic cycle of the Kings Creek watershed.

The objectives of this project were to (1) build a model specifically designed for the Kings Creek watershed; (2) to develop a climatological data set to calibrate this model; (3) to predict the runoff and percolation volumes for the subplots of the watershed; (4) to predict the streamflow in Kings Creek; and (5) to predict the long term water yield for the watershed.

Kings Creek watershed is located on the long term ecological research area called the Konza Prairie. This 3,487 hectare (8,616 acre) native tallgrass prairie is managed by the Department of Biology at Kansas State for use as a natural outdoor laboratory. From 1872 to 1930 the Konza Prairie was originally a ranch owned by C. P. Dewey, a Chicago industrialist, and operated by his son, Chauncey Dewey. The ranch was kept in excellent condition with grazing and periodic burnings (Division of Biology, undated). In 1971 and 1977 the Nature Conservancy purchased the prairie with funds provided by Katharine Ordway, hoping to preserve its natural tallgrass state. It was given over to the care of the Kansas State Biology Department. Today, the objectives of the Konza Prairie Research Natural Area are to evaluate the effects of fire and natural grazers (buffalo, elk, and pronghorn antelope) versus domestic grazers on the maintenance of a tallgrass prairie (Division of Biology, undated).

Kings Creek watershed is a 1,059 hectare (2,618 acre) parcel of land completely contained within the boundaries of the Konza Prairie. With the addition of a streamflow gauging station the watershed became a part of the U.S. Geological Survey's National Hydrologic Benchmark Network (Koelliker, et al., 1985). The watershed is covered mostly with unplowed native bluestem tallgrass. A small portion of the valleys along the streambed is covered with a gallery forest consisting of bur oak and chinquapin oak trees. Burning of the various subwatersheds is conducted on prescribed intervals of 1, 2, 4 and 10 years.

Since the prairie ecosystem can be defined as a dynamic interaction between organisms, soil, climate, and fire (Division of Biology, undated) numerous variables are required to create a water budget model. The climatic conditions of the watershed are described in this report along with the acquisition of the pertinent climatological data. A description of the existing soils on the watershed is also included. Tables and figures in this report are expressed in metric units. However, it should be noted that the water budget model requires most values in English units. For this reason tables of parameters for use by the model are repeated in the appendices in English units. The equations and routines of the water budget model are covered in the second chapter. A function to describe the cyclic action of burning plots is to be added in the future, whereas a function describing the effects of grazing is not planned for the future. The results of calibrating the model are shown and discussed in the fifth chapter. Instructions in running the model, a list describing the variables, and a complete listing of the model's Fortran code are in Appendices A, B, and C, respectively. Finally, in this report the words subarea, subplot, and plot are synonymous.

With the completion of the adaption of this computer model, it is hoped that the various components of the Kings Creek watershed water budget can be accurately predicted. Those predicted values might then be used by other researchers and managers to perform such tasks as predict plant matter growth through a correlation between actual evapotranspiration and biomass production. An existing water budget model called POTYLD, developed at Kansas State University and described by Zovne and Koelliker (1979), was used as a beginning program to build upon. With the future addition of a groundwater attenuation and storage routine it is felt that a workable water budget model tailored to the needs of the Konza Prairie ecosystem will be developed.

MODELING METHODS

The computer model used in modeling the Kings Creek watershed is an adapted version of the POTYLD model developed by the Kansas State University Department of Civil Engineering and described by Zovne and Koelliker (1979). This continuous water budget model takes into account daily and average monthly climatoligical data as well as the parameters describing soils and vegetation and presents the water budget components on a monthly and yearly basis. The principal components of the water budget are precipitation, evaptranspiration, runoff, infiltration and deep percolation. Thw water budget and its components are shown schematically in Figure 1.

EVAPOTRANSPIRATION

Evapotranspiration, defined as the sum of the evaporation from soil and water surfaces and the transpiration of vegetation, can be expressed as potential and actual evapotranspiration. Potential evapotranspiration (PET) is the loss of water to the atmosphere from a vegetated surface at a rate unlimited by the water supply. If the water supply is limited by the amount of water in the soil or the vegetation's growth stage, the resulting actual evapotranspiration (AET) may be less than the PET.

PET is calculated by the Pennam Equation developed by Penman (1948) and later modified by Jensen et al. (1970). This equation was developed using the energy balance and mass transfer theory and is presented as

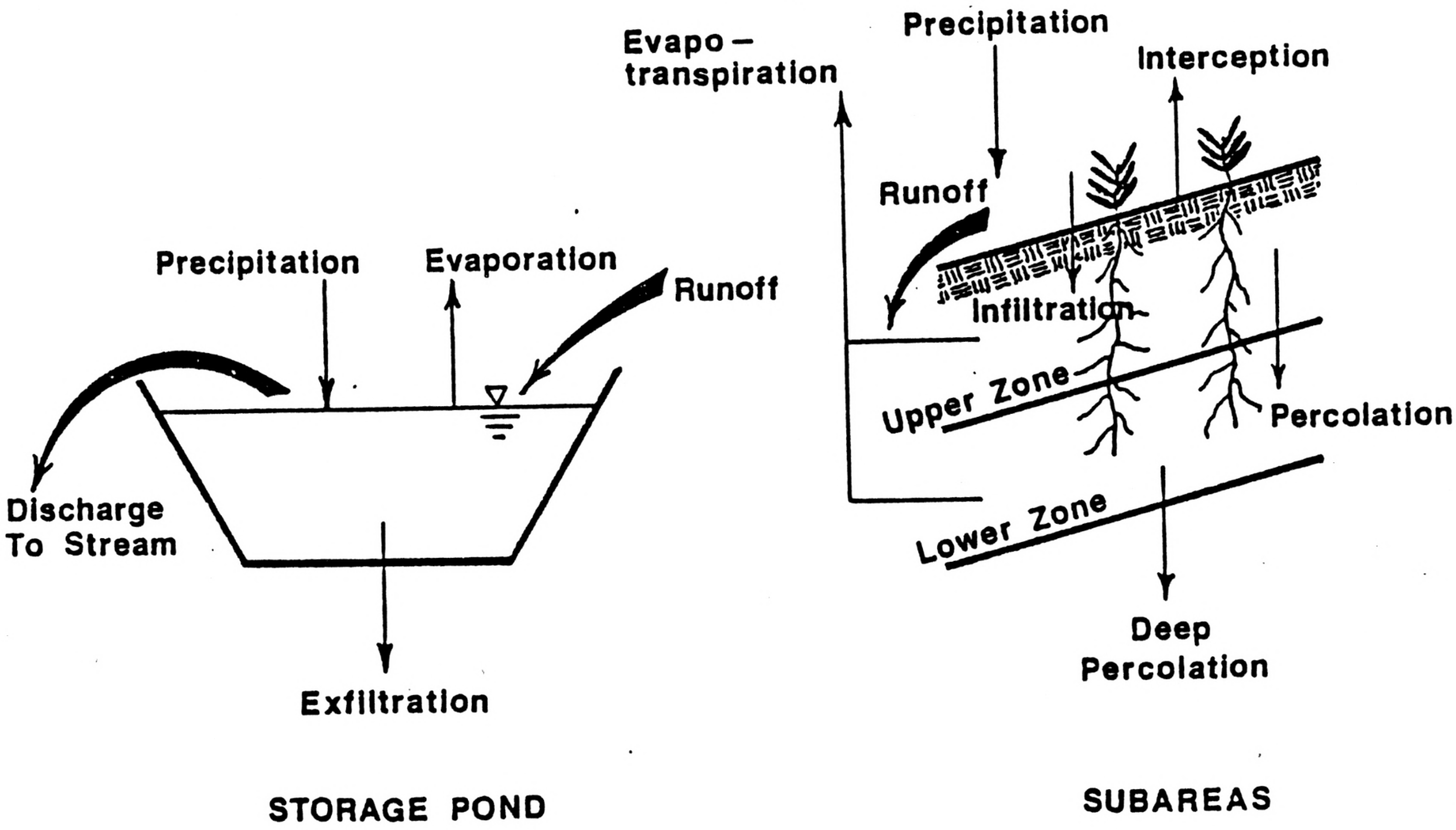

Figure 1: SCHEMATIC OF WATER BUDGET MODEL FOR KINGS CREEK WATERSHED
Source: (Zovne and Koelliker, 1979)

$$PET = 25.4 \{0.039(1.8Ta + 32)^{0.637} [(1-r) Ra (0.22 + 0.54 PSUNS)- 2.010 \times 10^{-9} x ^4 (0.98 - c - d(ES/25.4 \times RHD)^{0.5}) \times (0.1 + 0.9 PSUNS)] + (1 - 0.039(1.8Ta + 32)^{0.637}) \times 0.26 (e = 0.01 WVD/1.6093) (ES/25.4 - ES/25.4 \times RHD)\} \quad (1)$$

where

PET = potential evapotranspiration, in mm.

Ta = mean daily air temperature, in degree Celsius

T = mean daily temperature, in degree Kelvin

r = reflectance coefficient (albedo),

Ra = solar radiation, in mm. of water

PSUNS = percent sunshine

ES = saturation vapor pressure of a water surface at the mean daily air temperature, in mm.

c, d = empirical coefficient, which can vary geographically

RHD = relative humidity, in percent

WVD = wind run in km./day

e = mass transfer coefficient, assumed to be 0.75

The albedo for a free water surface is usually taken as r = 0.05. Reflectance coefficients usually range from 0.2 to 0.25 for green crops (Gray, 1973). In applications for the watershed model the albedo was assigned a value of 0.23 which is consistant with applications of the POTYLD model for crops in Colby, Kansas (Wang, 1982) and the Solomon River Basin in Kansas (Koelliker et al., 1981). The geographic constants, c and d, are determined approximately from

Figure 2, developed by Zovne and Koelliker (1979). The coefficients can be refined by making several runs of the model until the long term average PET equals the actual average lake evaporation. In the case of the Kings Creek watershed c and d were taken as 0.720 and 0.036, respectively. According to Linsley et al. (1982),

$$ES = 33.9 \, [(0.00738Ta + 0.8072)^8 - 0.000019 \, /1.8Ta + 48/ + 0.001316] \quad (2)$$

where

Ta = the mean daily air temperature in degrees Celsius.

The computer model uses average daily values of the minimum and maximum daily air temperature and daily solar radiation. Average monthly values of percent sunshine, relative humidity, and average windrun are also used and described later.

The AET, as mentioned before, is a function of the soil water content and the vegetation's growing stage. AET, based upon the Blaney-Criddle method described in USDA Soil Conservation Service Technical Release 21 (USDA, 1967), can be expressed as

$$AET = PET \times k \times K_s \quad (3)$$

where

k = the crop coefficient

K_s = 1 when SM > 0.3 SM_{mas}

K_s = $SM/0.3SM_{max}$ when SM < 0.3 SM_{max}

SM = the actual soil moisture, in mm.

SM_{max} = the maximum available soil moisture, in mm.

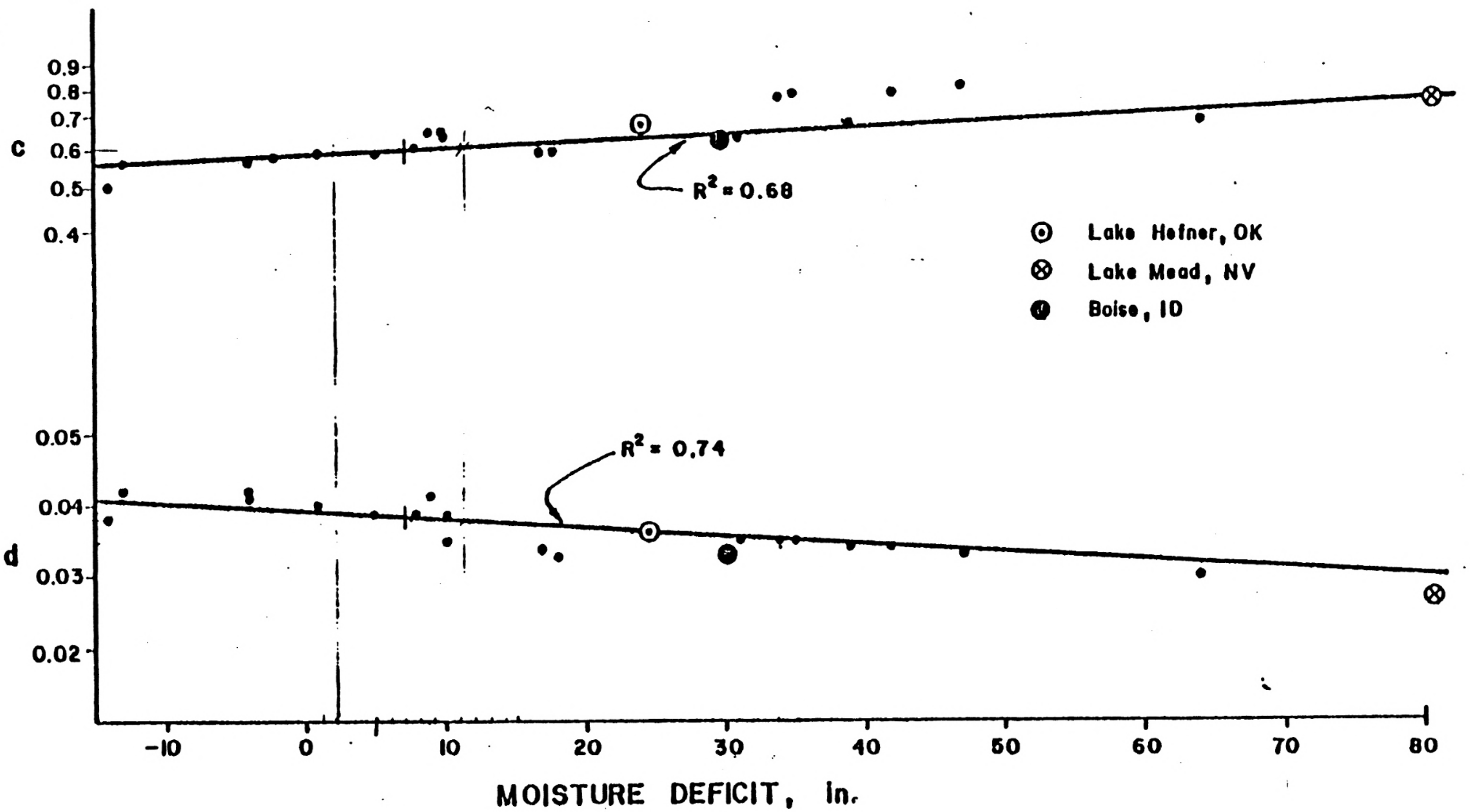

Figure 2: GRAPHICAL DETERMINATION OF GEOGRAPHIC COEFFICENTS FOR THE PENMAN EQUATION

Source: (Zovne and Koelliker, 1979)

The expression for K_s was developed by Kanemasu (1975). It is assumed that under wet conditions ET will occur at its maximum rate until the water content reaches 0.3 of the maximum water content. At this point the soil moisture starts to affect AET. Crop coefficients vary monthly to simulate the growth and decline of the plant matter throughout the year. Values used for Kings Creek watershed are shown in Table 1.

PERCOLATION AND REDISTRIBUTION

The percolation and redistribution follows a simplified version of Saxton's (1974) model for redistribution. In the Kings Creek model the percolation first fills the upper zone to 90 percent of saturation, provided the amount is sufficiently large enough. The zone is then allowed to drain to field capacity after two days, cascading the drained water into the lower zone. Any additional percolation beyond the 90 percent saturation of the upper zone is cascaded down into the lower zone. When the time between recharges of the lower zone is greater than two days the zone is allowed to drain to 90 percent field capacity. The drained soil moisture from the lower zone is lost to deep percolation (groundwater). If water entering the soil fills both the upper zone to 90 percent saturation and the lower zone to 90 percent field capacity, additional water will be lost to deep percolation (groundwater) and unavailable for AET.

RUNOFF, INFILTRATION, AND INTERCEPTION

Runoff, infiltration, and interception are all based upon the well known Soil Conservation Service equation (SCS, 1972):

Table 1: MONTHLY COEFFICIENTS AND VARIABLES USED BY WATER BUDGET MODEL

MONTH	CROP COEFFICIENT	INTERCEPT.-STORAGE COEFFICIENT	PERCENT SUNSHINE	RELATIVE HUMIDITY	WIND (km/hr)	AVERAGE MONTHLY TEMP. (°C)
January	0.01	0.01	54	77	16.9	-1.94
February	0.01	0.01	55	79	15.6	0.67
March	0.10	0.02	58	78	18.5	5.67
April	0.30	0.05	58	78	18.8	12.4
May	0.50	0.07	60	82	16.4	15.6
June	0.90	0.08	68	83	16.3	23.2
July	1.10	0.09	71	82	13.5	25.2
August	1.00	0.09	71	83	13.7	26.7
September	0.80	0.08	73	80	14.6	20.7
October	0.30	0.07	68	80	14.8	14.3
November	0.08	0.04	60	78	15.8	5.78
December	0.05	0.02	54	79	15.4	0.00

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{4}$$

where

Q = direct surface runoff in mm.

P = precipitation in mm.

S = the maximum potential difference between precipitation and runoff in mm.

However, before surface runoff can occur the initial abstraction of 0.2S, which is composed of the interception of the plants, the surface storage, and the infiltration into the soil that occurs before runoff, must be satisfied. S is defined by the equation:

$$S = \left(\frac{1000}{CN}\right)25.4 - (10)25.4 \tag{5}$$

where

CN = a curve number representing the vegetation, soil type, and antecedent moisture condition.

Since this model is continuous and operates over a range of soil moisture conditions curve numbers for all three antecedent moisture conditions are required. A description of various curve numbers for antecedent moisture condition II are shown in Table 2. Equations for estimating curve numbers for antecedent moisture conditions I (drier soil conditions) and III (wetter soil conditions) as reported by Koelliker et al.(1981) are:

$$CN_I = CN \times 0.39e^{(0.009 \times CN)} \tag{6}$$

and

$$CN_{III} = CN \times 1.95e^{(-0.00663 \times CN)}. \tag{7}$$

Table 2: CURVE NUMBERS FOR VARIOUS GROUND COVERS AND ANTECEDENT MOISTURE CONDITION II

Source: (USDA, 1972)

LAND USE	TREATMENT OR PRACTICE	HYDROLOGIC CONDITION	SOIL GROUP A	B	C	D
Fallow	Straight Row	...	77	86	91	94
Row Crops	Straight Row	poor	72	81	88	91
	Straight Row	good	67	78	85	89
	Contoured	poor	70	79	84	88
	Contoured	good	65	75	82	86
	Contoured and Terraced	poor	66	74	80	82
	Contoured and Terraced	good	62	71	78	81
Small Grain	Straight Row	poor	65	76	84	88
	Straight Row	good	63	75	83	87
	Contoured	poor	63	74	82	85
	Contoured	good	61	73	81	84
	Contoured and Terraced	poor	61	72	79	82
	Contoured and Terraced	good	59	70	78	81
Close-Seeded Legumes * or Rotation Meadow	Straight Row	poor	66	77	85	89
	Straight Row	good	58	72	81	85
	Contoured	poor	64	75	83	85
	Contoured	good	55	69	78	83
	Contoured and Terraced	poor	63	73	80	83
	Contoured and Terraced	good	51	67	76	80
Pasture or Range		poor	68	79	86	89
		fair	49	69	79	84
		good	39	61	74	80
	Contoured	poor	47	67	81	88
	Contoured	fair	25	59	75	83
	Contoured	good	6	35	70	79
Meadow		good	30	58	71	78
Woods		poor	45	66	77	83
		fair	36	60	73	79
		good	25	55	70	77
Farmsteads		...	59	74	82	86
Dirt Roads **		...	72	82	87	89
Hard Surface Roads **		...	74	84	90	92

* Close-drilled or broadcast-seeded.
** Including right-of-way

respectively, where

CN = the curve number for antecedent moisture condition II.

An interception-storage value is fixed for each month and is depleted at the potential free surface evaporation rate. The interception-storage values must be satisfied before runoff and infiltration can occur. These values, like the crop coefficients also vary monthly to simulate the changes in leaf area associated with the vegetation canopy. The interception-storage values and other monthly values used for Kings Creek watershed are listed in Table 1.

SNOW

Snow is assumed to occur during a precipitation event when the average temperature is less than or equal to zero degrees Celsius. The snow melt contributes to the water budget by being added to the precipitation term is the SCS runoff equation. Snowmelt can be formed in two ways: melting due to atmospheric conditions and melting due to rainfall. For melting by atmospheric conditions (Gray, 1973):

$$M = 1.8C \times (Ta - Tb) \tag{8}$$

where

M = the snowmelt in mm.

Ta = the mean daily temperature in degrees Celcius

Tb = the base temperature in degrees Celcius

C = a degree-day coefficient.

For snowmelt due to rainfall (Linsley, 1943):

$$MR = (1/144) \times (P/25.4) \times (1.8\ Ta) \tag{9}$$

where

MR = the snowmelt by rainfall in mm.

P = the amount of rainfall in mm.

Ta = the mean daily temperature in degrees Celsius

The total snowmelt is then the sum of the two components.

KINGS CREEK WATERSHED SOILS

The Kings Creek Watershed consists primarily of ten different soils ranging from silty loams to silty clays (USDA, 1975). These soils can be broken down further into subgroups based upon the slope of the terrain. In other words, the soils are grouped into three different subareas; the ridgetops or uplands, the sides of the hills, and the valleys. In most cases differentiation by slope is ignored except in the case of the Benfield-Florence complex. The soil descriptions are summarized in Table 3. Figure 3 shows a cross section of a typical valley on Kings Creek watershed and also gives a feel for the relative positions of the soils. The following descriptions of the soils on the Kings Creek watershed are based upon the information found in the USDA Soil Survey of Riley County (1975).

SOIL DESCRIPTION

The uplands of the watershed consist mostly of the Dwight-Irwin complex and the Benfield-Florence complex. The Dwight-Irwin complex occupys only about 15 percent of the area. Both soils support rangeland grasses.

The Dwight-Irwin complex, which tends to be perched atop the highest hills, is a moderately shallow soil with a depth to bedrock of about 1.1 to 1.5 meters (three and one-half to five feet). Crops do not grow well on this soil due to the fine texture of the soil particles restricting root growth. The profile starts out with 100 millimeters (four inches) of silt loams on top of about 990 millimeters (39 inches) of silty clay. These layers are then underlined with about

Table 3: KINGS CREEK WATERSHED SOILS AS DESCRIBED BY SOIL CONSERVATION SERVICE SOIL SURVEY

SOIL	SCS SOIL GROUP	DEPTH TO BEDROCK (meters)	DEPTH OF LAYER (cm.)	USDA TEXTURE	PERMEABILITY (mm./hr.)	AVAILBLE WATER CAPACITY (mm./mm.)
Dwight-Irwin	D	1.1-1.5	0.0-18	Silty Clay Loam	5.1-15	0.17-0.19
			18-150	Silty Clay	1.5-5.1	0.17-0.19
Benfield-Florence	C	0.6-1.1	0.0-31	Silty Clay Loam	5.1-15	0.17-0.19
			31-66	Silty Clay	1.5-5.1	0.17-0.19
			66-89	Silty Clay Loam	2.5-15	0.17-0.19
			89	Shale		
Clime-Sogn	C/D	0.2-0.5	0.0-76	Silty Clay Loam	5.1-15	0.17-0.19
			76	Shale		
Irwin Silty Clay Loam	D	1.1-1.8	0.0-28	Silty Clay Loam	15-51	0.17-0.19
			28-140	Silty Clay	<1.5	0.17-0.19
			140	Limestone or Shale		
Irwin Silty Clay Loam (Eroded)	D	1.1-1.8	0.0-15	Silty Clay Loam	5.1-15	0.17-0.19
			15-130	Silty Clay	<1.5	0.17-0.19
			127	Limestone or Shale		
Tully Silty Clay Loam	C	>1.2	0.0-41	Silty Clay Loam	5.1-15	0.17-0.19
			41-150	Silty Clay	1.5-5.1	0.17-0.19
Tully Silty Clay Loam (Eroded) (Eroded)	C	>1.2	0.0-18	Silty Clay Loam	5.1-15	0.17-0.19
			18-150	Silty Clay	1.5-5.1	0.17-0.19
Reading Silt Loam	C	>1.2	0.0-28	Silt Loam	15-51	0.16-0.18
			28-150	Silty Clay Loam	5.1-15	0.17-0.19
Ivan and Kennebec Silt Loam	B	>1.2	0.0-18	Silt Loam	15-51	0.16-0.18
			18-150	Silty Clay Loam	15-51	0.17-0.19
Alluvial Land	C			Too Variable		

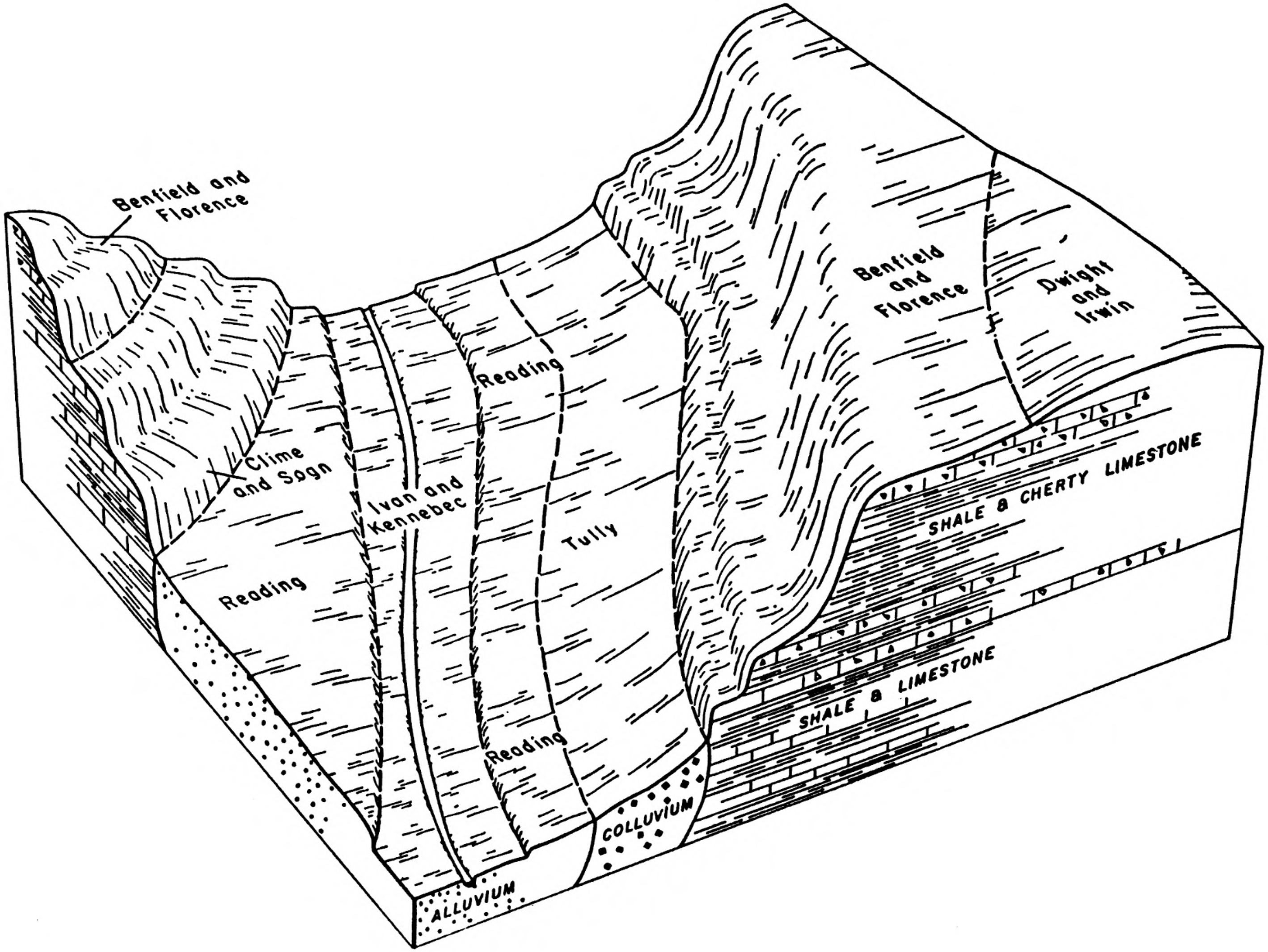

Figure 3: TYPICAL SOIL PROFILE ON KINGS CREEK WATERSHED
Source: (USDA, SCS, 1975)

130 millimeters (five inches) of shale followed by the limestone bedrock. The permeability in the upper two layers is moderately slow ranging from 15 to 1.5 millimeters per hour (0.6 to 0.06 inches per hour).

The Benfield-Florence complex, also occupying the ridge tops, is also a poor soil for crop growth due to its moderate depth and fragments of chert and limestone spread throughout the profile. With a depth of only 0.6 to 1.1 meters (two to three and one half feet) to bedrock, the profile consists of a 300 millimeter (twelve inch) layer of silty clay loam, with 300 millimeters (twelve inches) of silty clay beneath the first layer and another 300 millimeters (twelve inches) of silty clay loam on the bottom followed by shale. The permeability of the Benfield-Florence complex ranges from 1.5 to 15 millimeters per hou (0.06 to 0.60 inches per hour) with the lower values assigned to the silty clay layer.

The sides of the hills are made up of Benfield-Florence complex, Clime-Sogn complex, and Irwin soils. The Benfield-Florence complex profile is as described above except for a more shallow depth of 0.6 meters (two feet) and a steeper slope. Both soils along the side slopes are shallow and in places, the limestone formations come to surface. These outcrops allow a path for lateral percolation to return to the surface. It is assumed that these soils yield considerable runoff.

The Clime-Sogn complex is a very shallow soil with a depth to bedrock ranging from 0.2 to 0.8 meters (nine to thirty inches). This soil with its shallowness and well drained nature as well as its location on slopes of up to twenty percent is considered to yeild most of the water that results in streamflow. The only layer is a silt clay loam with a permeability of 5.1 to 15 millimeters per hour (0.2 to 0.6 inches per hour) and is underlined with shale.

The Irwin soils vary from a heavy silty clay loam to a silty clay. With a depth of 1.1 to 1.8 meters (three and one half to six feet) these soils are considerably deeper than the Benfield-Florence and Clime-Sogn complexes just described. The Irwin soils can be broken into two subgroups identified as eroded and uneroded soils. Both soils have high water holding capacity but have slow infiltration and water release rate for plant use. Thus, runoff is quite high in these soils. Both of these soils occur near the bottoms of the side slopes and are relatively flat at four to eight percent slopes.

The uneroded Irwin soil has a profile of 280 millimeters (eleven inches) of silty clay loam at the surface with a permeability of 15 to 51 millimeters per hour (0.6 to 2.0 inches per hour). This layer is followed by a 1.1 meter (44 inch) layer of silty clay with a very low permeability of less than 1.5 millimeters per hour (0.06 inches per hour). Finally, the profile is underlined with a layer of limestone or shale. This soil also appears on ridge tops in association with the Dwight-Irwin complex previously described.

The eroded Irwin soil is similar to the uneroded soil except for having finer textured particles. This soil starts out with 150 millimeters (six inches) of heavy silty clay loam and a lower permeability relative to the uneroded soil of 5.1 to 15 millimeters per hour (0.2

to 0.6 inches per hour). Silty clay follows with a 1.1 meter (44 inch) layer and a permeability of less than 1.5 millimeters per hour (0.06 inches per hour) and is followed itself with limestone or shale.

The valleys contain the remaining five soils with the majority being the alluvial land. These valley soils, as expected, are considerably deeper than those previously described. All valley soils are described as greater than 1.2 meters (four feet) in depth to bedrock. The five soils are eroded and uneroded Tully silty clay loam, Reading silt loam, Ivan and Kennebec silt loam and the alluvial land.

The Tully soils, like the Irwin soils, are similar except for one type being the eroded case. Both soils start out with an upper layer of silty clay loam with a depth of 410 millimeters (16 inches) for the uneroded soil and 180 millimeters (7 inches) for the eroded. Both have comparable permeabilities ranging from 5.1 to 15 millimeters per hour (0.2 to 0.6 inches per hour). Both soils also have a lower layer of silty clay with a depth for the uneroded soil of about 1.4 meters (53 inches) and 1.1 meters (44 inches) for the eroded soil. Both soils have permeabilities in the lower layer ranging from 1.5 to 5.1 millimeters per hour (0.06 to 0.20 inches per hour). The uneroded soil has both a high available soil water content and a high infiltration while the eroded soil tends to have a lower infiltration and thus produce more runoff.

The Reading silt loam has high available water content, and takes in and releases water for plant use well with moderate runoff. The profile starts with a 280 millimeter (eleven inch) silt loam layer and is followed with a 1.3 meter (49 inch) silty clay loam layer. The silt loam has a permeability of 15 to 50 millimeters per hour (0.6 to 2.0 inches per hour).

Finally, the alluvial land occupies mostly the floodplain. Because of its extreme variability it is hard to quantify and qualify this type of soil. The surface layer can be a silt loam, clay loam, or silty clay loam, while the sub-layers can range from silt loam to light silty clay with limestone gravel spread through one or more of the horizons.

MODEL SOIL PARAMETERS

Descriptions of the soils as input for the model were quantified as the available soil moisture, the permanent wilting point, the field capacity and the saturated moisture content, all expressed in inches. Also needed to describe the soil plots is the runoff curve number, which accounts for the soil-cover complex. The runoff curve number also takes into account the vegetation growing on the plot and the soil group permeability. Finally, the area of each soil plot is also required. The subplot profiles are divided into a 300 millimeter (twelve inch) upper zone and a lower zone with a depth equal to the remainder of the profile. The available soil moisture, permanent wilting point, field capacity, and saturated moisture content were determined for both zones of each plot and are summarized in Table 4. The Clime-Sogn plot proved to be an exception since its profile was considered only 280 millimeters (eleven inches) in depth. In this case the upper zone was taken as 250 millimeters (ten inches) and the

Table 4: SOIL PARAMETERS DEFINING SOILS OF KINGS CREEK WATERSHED TO BE USED IN WATER BUDGET MODELING

SOIL	ZONE	AVAILABLE SOIL MOISTURE (mm.)	PERMANENT WILTING POINT (mm.)	SATURATED MOISTURE CONTENT (mm.)	FIELD CAPACITY (mm.)
Dwight-Irwin	Upper	54	56	150	110
	Lower	150	170	--	320
Benfield-Florence (Ridges)	Upper	44	56	150	100
	Lower	56	90	--	146
Benfield-Florence (Side Slopes)	Upper	45	59	150	103
	Lower	39	61	--	100
Clime-Sogn	Upper	45	47	130	92
	Lower	4.5	4.7	--	9.2
Irwin Silty Clay Loam	Upper	55	57	150	112
	Lower	55	59	--	114
Irwin Silty Clay Loam (Eroded)	Upper	55	58	150	113
	Lower	55	59	--	114
Tully Silty Clay Loam	Upper	55	57	150	112
	Lower	170	160	--	330
Tully Silty Clay Loam (Eroded)	Upper	55	58	150	113
	Lower	170	180	--	350
Reading Silt Loam	Upper	52	49	150	101
	Lower	170	170	--	340
Ivan and Kennebec Silt Loam	Upper	54	50	150	104
	Lower	170	170	--	340
Alluvial Land	Upper	55	57	150	112
	Lower	170	160	--	330

lower zone as 25 millimeters (one inch). Table 5 shows the various soil variables based upon percent weight. Israelson (1965) suggests that physical soil properties can be estimated using Table 5. Since values were not listed for a silt loam and a silty clay loam, numbers were interpolated. The silt loam values were found between the loam and clay loam values and the silty clay loam was located between the clay loam and silty clay values.

The saturated moisture content was determined by multiplying the total pore space shown in Table 5 for the appropriate soil by the depth of its layer. The saturated moisture content for the entire zone is the sum of values for each layer within the zone.

The permanent wilting point was determined in a similar manner to the saturated moisture content. It was found by multiplying the percent permanent wilting shown in Table 5 by the apparent specific gravity in Table 5 and by the depth of the layer and dividing by one hundred. Again, summing the values for each layer within the zone.

The available soil moisture for each layer was determined by multiplying the depth of the layer by the percent dry weight over one hundred and by the apparent specific gravity shown in Table 5. Again, the values for each layer were summed and expressed as a single value for the zone considered.

Finally, the field capacity for each zone was determined by adding the available soil moisture to the permanent wilting point for each layer and then summing those values within the zone.

Special consideration had to be made for the Dwight-Irwin, Benfield-Florence, Clime-Sogn, and Ivan and Kennebec complexes when

Table 5: REPRESENTATIVE PHYSICAL PROPERTIES OF SOILS BY WEIGHT

Source: (Israelson, O. W. et al., 1962)

SOIL TEXTURE	TOTAL PORE SPACE %, N	APPARENT SPECIFIC GRAVITY A_s	FIELD CAPACITY % FC	PERMANENT WILTING % PW	DRY WEIGHT % P_w=FC−PW	VOLUME % $P_v=P_w a_s$
Sandy	38 (32-42)	1.65 (1.55-1.8)	9 (6-12)	4 (2-6)	5 (4-6)	8 (6-10)
Sandy Loam	43 (40-47)	1.5 (1.4-1.6)	14 (10-18)	6 (4-8)	8 (6-10)	12 (9-15)
Loam	47 (43-49)	1.4 (1.35-1.5)	22 (18-26)	10 (8-12)	12 (10-14)	17 (14-20)
Clay Loam	49 (47-51)	1.35 (1.3-1.4)	27 (23-31)	13 (11-15)	14 (12-16)	19 (16-22)
Silty Clay	51 (49-53)	1.3 (1.25-1.35)	31 (27-35)	15 (13-17)	16 (14-18)	21 (18-23)
Clay	53 (51-55)	1.25 (1.2-1.3)	35 (31-39)	17 (15-19)	18 (16-20)	23 (20-25)

determining their respective parameters since actually two or more soils exist within a plot. Therefore, based upon descriptions given in the Soil Conservation Service's Soil Survey for Riley County (SCS, 1975) the values for the complexes were determined as weighted averages of the paremeters of the component soils making up the complexes. For the Dwight-Irwin complex the soil was considered as 50 percent Dwight and 50 percent Irwin soils. The Benfield-Florence on the ridges was considered 55 percent Benfield and 45 percent Florence. The side slope Benfield-Florence was considered 60 percent Benfield and 40 percent Florence. The Clime-Sogn complex was broken into 60 percent Clime and 40 percent Sogn soils. The Ivan and Kennebec soil was considered 50 percent Ivan and 50 percent Kennebec.

With respect to the runoff curve numbers each soil was assigned one of the USDA Soil Conservation Service's classifications shown in Table 6. The Benfield-Florence complex, Tully silty clay loam soil, Reading silt loam soil, and the alluvial land were assigned soil group C classifications. While the Dwight-Irwin complex and Irwin soils were classified as soil group D. The Cline-Sogn was considered a combination of C and D soils and the Ivan and Kennebec silt loam soil was classified a B soil. The runoff curve numbers for antecedent moisture condition two were selected based upon the values in Table 2 for pasture or range in good hydrological condition. Curve numbers for antecedent moisture conditions I and III were calculated from Equations 6 and 7, respectively.

Table 6: U.S. Soil Conservation Service Soil Groupings

Source: (Hjelmfelt and Cassidy, 1975)

Group	Minimum Infiltration Rate (mm./hr.)	Soil Description
A	7.6-11	Deep sand, deep loess, aggregated silts
B	3.8-7.6	Shallow loess, sandy loam
C	1.3-3.8	Clay loams, shallow sand loam, soils low in organic content, and soils usually high in clay
D	0.0-1.3	Soils which swell significantly when wet, heavy plastic clays, and certain saline soils

CLIMATOLOGICAL DATA

Precipitation is the primary source of water for the entire watershed. Precipitation in Kansas on an annual basis ranges from less than 510 millimeters (20 inches) in western parts of the state to more than 1020 millimeters (40 inches) in the extreme southeast (Linsley et al., 1982). For the Konza prairie the precipitation normal is about 840 millimeters (33 inches) per year (National Climate Data Center). Area average annual lake evaporation is approximated at 1270 millimeters (50 inches) per year (Linsley et al., 1982). At nearby Milford reservoir the average annual lake evaporation is reported as 1360 millimeters (53.56 inches) (Knapp et al., 1984).

In addition to precipitation, other factors such as maximum and minimum daily temperatures, solar radiation, relative humidity, and percent sunshine contribute to the simulation of the water budget. Most of these parameters are used in describing the evapotranspiration phenomena. Of course, other variables such as soil descriptions relate to the water budget by affecting time variables and storage components. Soil parameters have already been discussed in a previous section.

Most of the climatological data were collected at the weather station located at the headquarters of the Konza Prairie. This data includes daily maximum and minimum temperatures, daily solar radiation, average relative humidity, total windrun and precipitation data. These values have been collected since April 21, 1982. Other precipitation values were collected at 15 minute intervals by US Geological Survey gauging stations (1980-1986) located near the stream gauging station on Kings Creek and just beyond the southeast extent of the watershed. The location of the various data collection points are shown in Figure 4.

The model has been calibrated with streamflow data collected in Kings Creek by a US Geological Survey streamflow gauging station located on the watershed (National Climate Data Center, 1980-1986). The gauging station is identified by the star in Figure 4. This stream discharge data has been collected from April, 1979 to the present.

The climatological data used to calibrate the model was a combined data set consisting of values from the Konza Headquarters, the US Geological Survey's collection stations, and the weather station for Manhattan, Kansas located on the campus of Kansas State University and reported in Climatological Data for Kansas as station 4972. This station is located approximately 12 kilometers (7.3 miles) north of the center of the watershed. Daily values of precipitation, minimum and maximum air temperatures, and solar radiation are available from the Konza Headquarters from April 21, 1982 to the present. This data was used for the bulk of the calibration data set. The US Geological Survey gauges have been operating since 1980. However, these rain gauges are only in operation during the months of April to October. When available the US Geological Survey precipitation values were weighted with the Konza Headquarters values to give more representative precipitation for the watershed. Daily values of minimum and maximum temperatures and solar radiation values from Manhattan, Kansas

KINGS CREEK WATERSHED

KONZA PRAIRIE RESEARCH NATURAL AREA

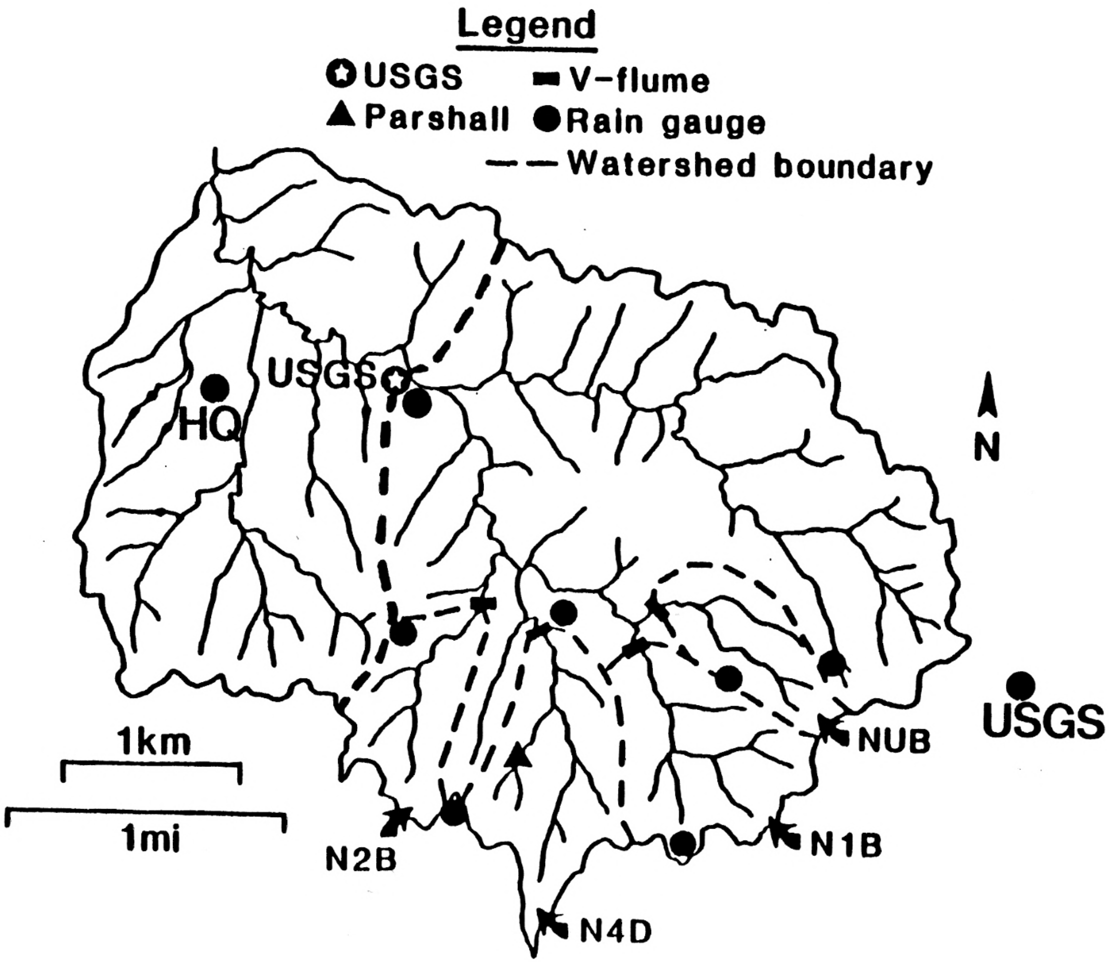

Figure 4: MAP OF KINGS CREEK WATERSHED

were used to supplement the data set from January 1, 1980 to April 20, 1982. Precipitation values for the 1980 to 1982 time period were based upon a weighted average of the US Geological Survey collected values and the Manhattan weather station values.

Percent sunshine, relative humidity, and wind velocity were entered in the program as mean monthly values. These monthly values were taken from Climates of the States (Water Information Center, Inc., 1974). Interpolation between known stations was required to find values for Kings Creek. For the watershed a weighted average of 0.6 times the Topeka, Kansas station's monthly values and 0.4 times the Concordia, Kansas station's values was used. A listing of the value used for each month is shown in Table 1. A mean monthly air temperature was also used in modifying crop coefficients.

A data set for operation of the model in the use of predicting biomass yield has also been developed for a long term simulation. This data set spans the period of 1958 to the present. Most of the data such as temperature, solar radiation and precipitation were taken from the Manhattan, Kansas weather station. However, the calibration data set just described is used for the period of 1980 to the present.

MODELING RESULTS

As mentioned before, each soil was considered its own subplot. Each subplot underwent a water budget accounting process on a daily basis. The eleven subplots produced an output showing precipitation depth, which was the same for the whole watershed, interception, percolation, runoff, PET, AET, change in soil moisture, and soil moisture. Each was expressed on a monthly basis and then summed for a annual result. The annual values for percolation and runoff for each subplot were then multiplied by the area of their respective subplots and reported in acre-feet.

In calibrating the computer model to the actual watershed, streamflow was the main output compared. It is important to note that two primary assumptions made for the model were that streamflow is the sum of deep percolation and runoff and that both appear instantaneously in the streambed. In the case of the percolation this of course is not true since the limestone and shale geology contribute to a time lag. However, for runoff volume this assumption is correct. Output values were reported on a monthly and annual basis while the runoff could have appeared in the streamflow within a day's time. Because of the percolation time lag only annual streamflow values were compared and thus validate this assumption. The predicted and reported streamflows are presented in Figure 5.

Percolation is also assumed to not pass from one subplot to another but instead flow directly into the streambed. In actuality percolation will move laterally from one subplot to another and contribute in recharging any unoccupied groundwater storage within the

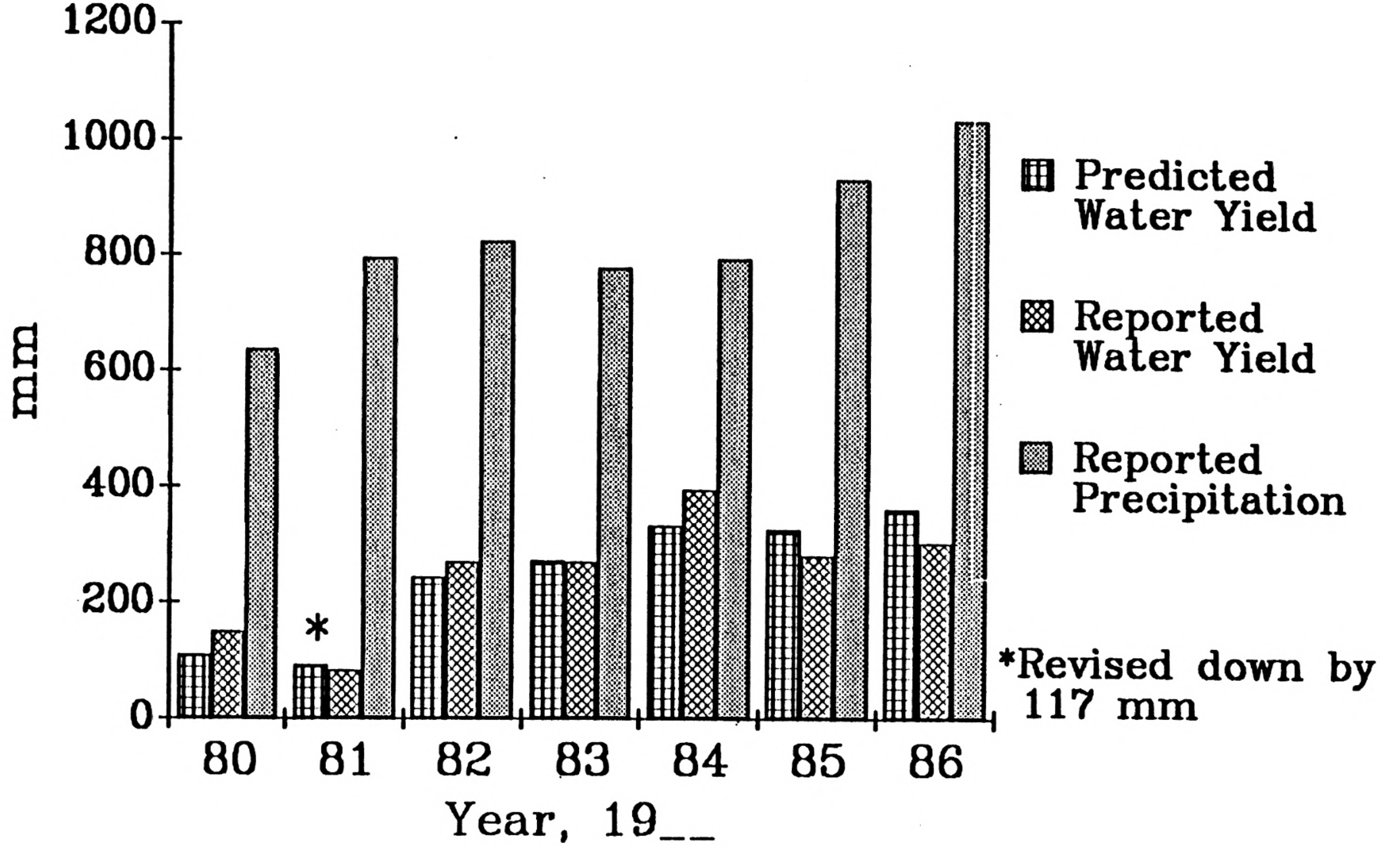

Figure 5: **Kings Creek Annual Water Yield Summary**

subplot.

Another important point is that not enough information is known about the watershed's capability for deep groundwater storage. This point becomes apparent when examining the results for 1981. The year 1980 experienced drought-like conditions which depleted most of the soil moisture within the watershed. During the months of May, June, and July the monthly precipitation averaged 74 millimeters (2.9 inches) below normal. The latter part of June and most of July produced 19 millimeters (0.74 inches) rainfall in 28 days. During 1981 normal precipitation events were used to recharge most of the deep groundwater storage before any streamflow occurred. This resulted in lower reported streamflow values than the model predicted.

At this point of development the model does not take into account the recharging effect just described. Consequently, the actual predicted streamflow for 1981 was 2.20 million cubic meters. (1810 acre-feet). A decrease of 55 percent resulted in a predicted streamflow of 1.00 million cubic meters (810 acre-feet) which matched the reported streamflow of 0.90 million cubic meters (730 acre-feet) more accurately. When the adjusted 1981 value was added to the other predicted streamflows, the resulting statistical analysis shown in Figure 6 gave a more agreeable result.

In Figure 5 a comparison is made between reported and predicted streamflows with precipitation included as a reference. Precipitation values ranged from 638 millimeters (25.1 inches) in 1980 to 1033 millimeters (40.67 inches) in 1986. Table 7 shows these minimum, maximum, average and standard deviation values for precipitation, as well

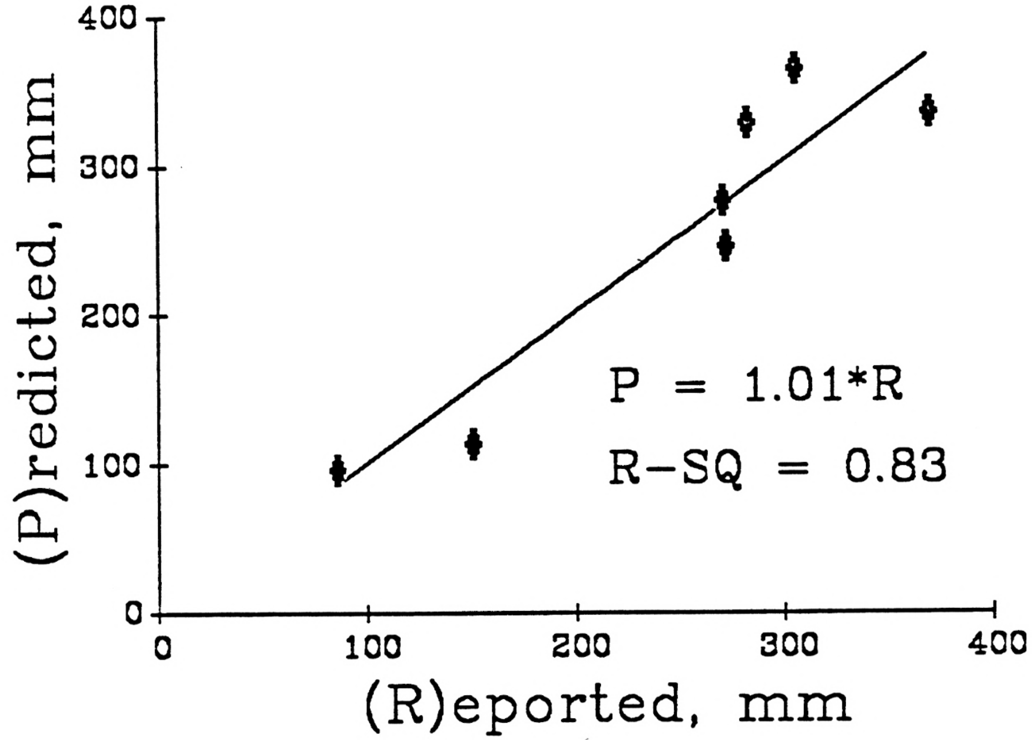

Figure 6: Annual Yield Comparison, Kings Creek 1980-86

Table 7: STATISTICAL SUMMARY OF OUTPUT FOR KINGS CREEK WATERSHED BUDGET MODEL

	PRECIPITATION (mm.)	PREDICTED STREAMFLOW ($m.^3$)	REPORTED STREAMFLOW ($m.^3$)
MINIMUM	640	1,000,000	900,000
MAXIMUM	1030	3,800,000	3,900,000
AVERAGE	830	2,600,000	2,600,000
STANDARD DEVIATION	4.90	830	920

TABLE 8: COMPARISON OF LONGTERM ANNUAL SIMULATION RESULTS WITH 1980-1986 SIMULATION RESULTS FOR KINGS CREEK WATERSHED

	1958-79	1980-86	1958-86
PRECIPITATION, mm.			
MINIMUM	378	640	378
MAXIMUM	1282	1030	1282
AVERAGE	838	830	835
STANDARD DEVIATION	209	124	190
WATER YIELD, mm.			
MINIMUM	13	85	13
MAXIMUM	657	369	657
AVERAGE	286	247	277
STANDARD DEVIATION	156	97	143

as reported and predicted streamflow values for the years 1980 to 1986. Keeping in mind that the normal precipitation for Konza Prairie is 840 millimeters (33 inches) it is easy to see the drought problems encountered in 1980 and the lack of streamflow in 1981.

In addition to the streamflow, the amounts of runoff, percolation, and evapotransiration for each plot were examined. Because of the shallow nature and therefore low water holding capacity of the soils on the side slopes it was expected that the percolation and runoff would be high. Conversely, the ridges and valleys would have less water yielding capabilities while having high evapotranspiration values. This is because of their significantly deeper soils. Figure 7 shows that the model does predict these assumptions accurately. The only exception to these assumptions was that runoff was approximately the same for all three regions. The ridges had the highest runoff at 99.0 millimeters (3.90 inches) whiles the valleys had the lowest at 94.0 millimeters (3.70 inches). Since the Irwin soils, located near the bottom of the slopes, were included in the side slope region the water available for plant use increased from 130 millimeters (5.30 inches) to 350 millimeters (14.0 inches) for the region. The available soil moisture for the ridges was 310 millimeters (12.0 inches). In other words, by including the Irwin soils in the side slope region the water storage capacity was almost equivalent to that of the ridges. Thus, more water would be stored and less runoff would occur than expected for the sides. However, based upon this conclusion the results of the model can still be considered accurate.

Average annual AET for the three regions, as expected, was higher

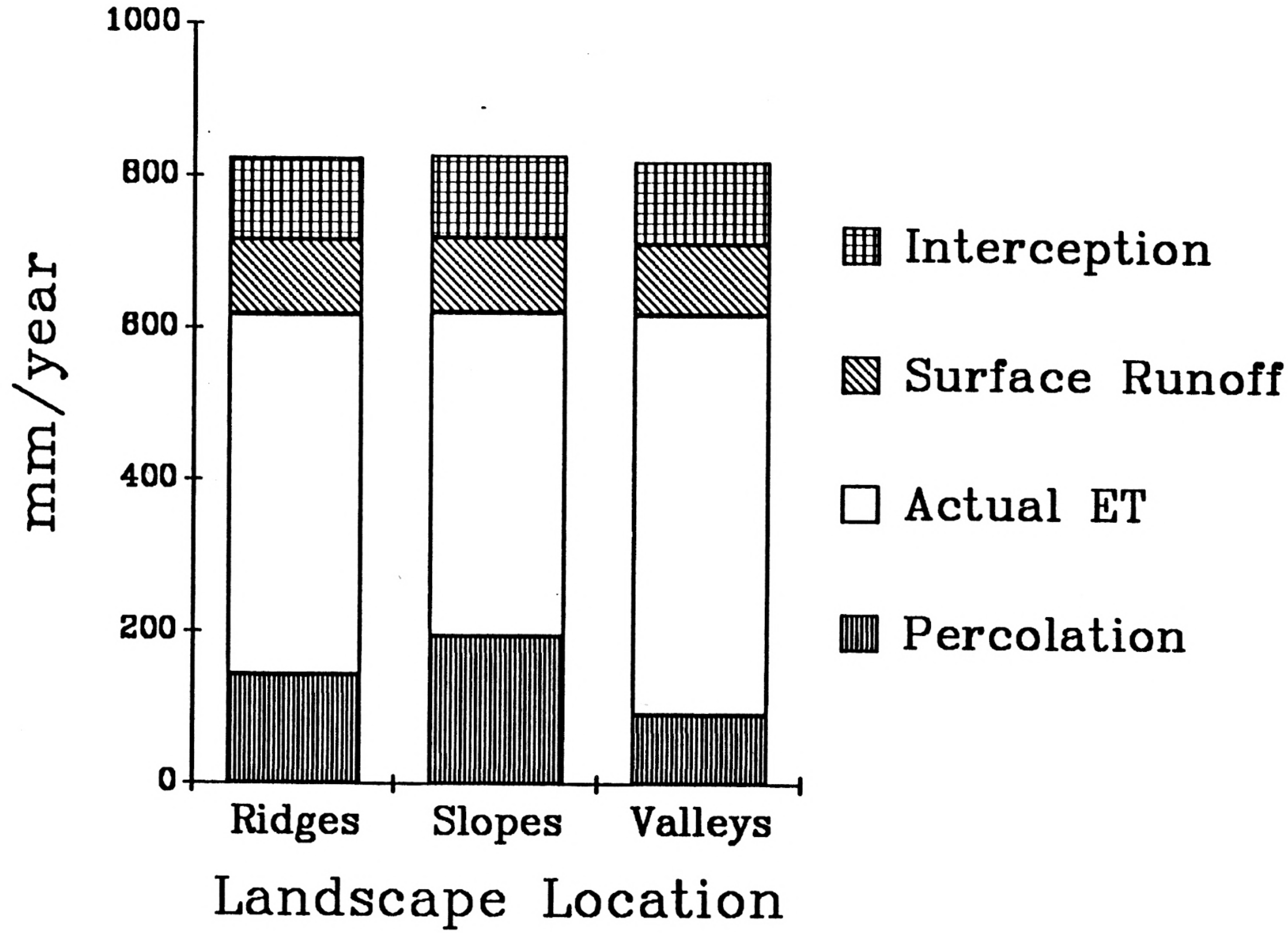

Figure 7: Predicted Average Annual Water Budget by Landscape Location at Konza Prairie

for the valleys at 530 millimeters (21.0 inches) and lower for the side slopes at 430 millimeters (17.0 inches). The ridges had an average AET value of 480 millimeters (19.0 inches).

Average annual percolation also behaved as expected with the sides having a high value of 200 millimeters (7.70 inches). The shallow Clime-Sogn and Benfield-Florence soil plots contributed most of the percolation with annual average volumes of 0.52 million cubic meters (420 acre-feet) and 0.68 million cubic meters (550 acre-feet), respectively. The percolation from these two plots accounted for 46 percent of the total average annual streamflow for the entire watershed. The Irwin soils only produced 12,700 cubic meters (100 acre-feet) of percolation on average for the side slope region. The remaining regions produced 92.0 millimeters (3.60 inches) for the valleys and 140 millimeters (5.60 inches) for the ridges.

When considering the total streamflow contributed by each region, the results are as expected. Approximately 27 percent of the average annual streamflow come from the ridges. The side slopes produce about 65 percent of the total yield and the valleys produce about 8 percent. It was expected that the slopes region would yield the majority of the streamflow because of its large area and shallow soils.

A trial run using the Manhattan, Kansas weather data set of 1958 to 1979 was executed. The results of that run are shown in Figure 8. For the most part, the model gave reasonable values. The years 1963 and 1966 had unusually low rainfall and therfore, low predicted streamflow. On the other hand, 1973 was one of the wettest years on record. Consequentially, predicted streamflow that year was in excess

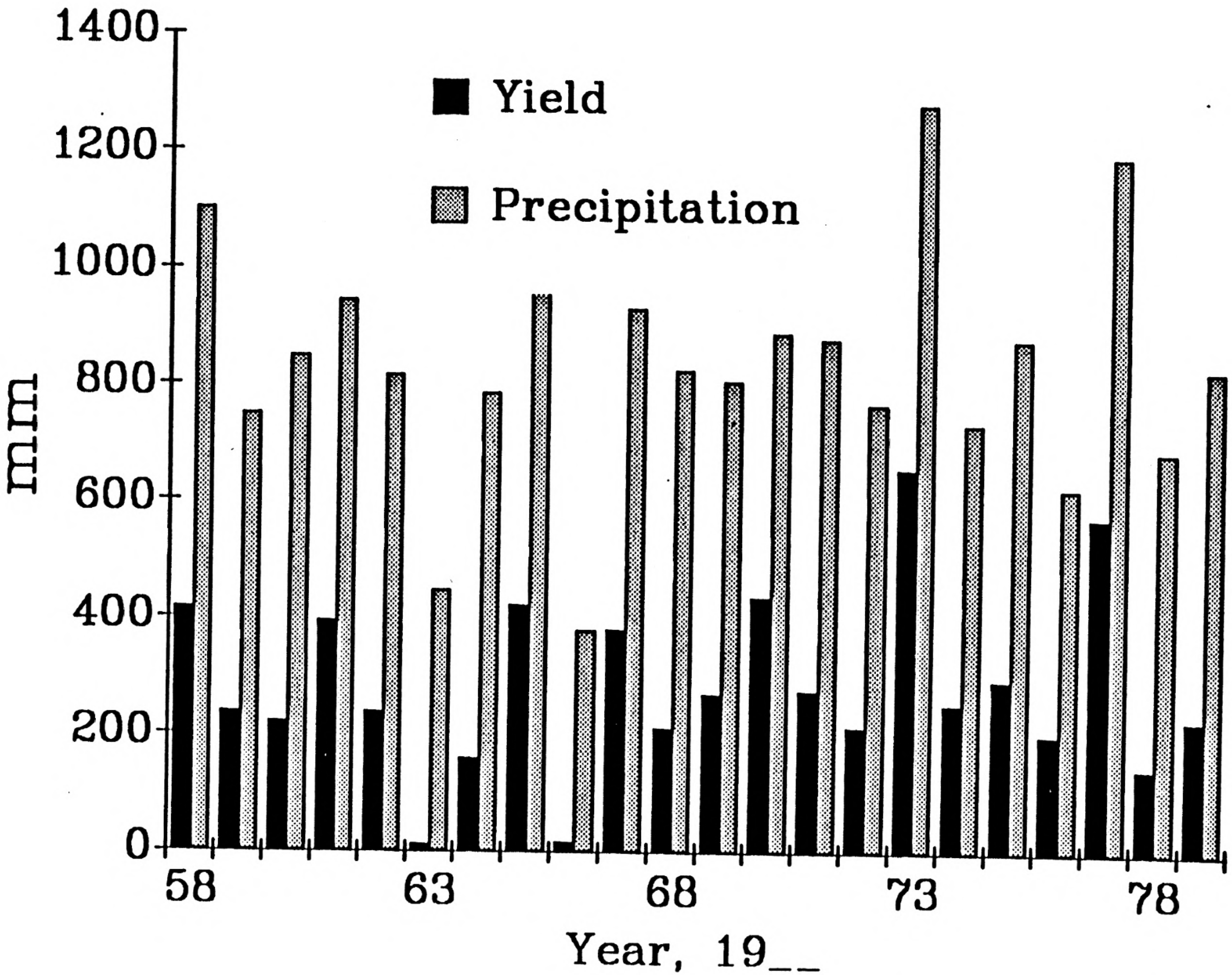

Figure 8: Simulated Long-term Water Yield from Kings Creek with Manhattan Weather Data

of 6.2 million cubic meters (5000 acre-feet). Table 8 shows the statistical comparison between the long term trial run and the short term calibration run. The average values agree fairly well. However, the standard deviations show that there is less variability in the calibration data file than in the long term data file. An increase in the number of years used in the calibration data set from seven to ten would help the variability to agree more with the long term data set.

SUMMARY AND RECOMMENDATIONS

SUMMARY

The objectives of this project were (1) to modify the POTYLD water budget model for specific use on Kings Creek watershed; (2) to develop a climatologic data set of the prairie for use in calibrating the model; (3) to predict runoff and percolation for each soil plot; (4) to predict Kings Creek streamflow and match that data with actual streamflow; and (5) predict long-term water yield.

Using climatological data from the Konza Prairie Headquarters, U.S. Geological Survey gauging stations on the prairie and the Manhattan, Kansas weather station a data set describing the climate for the last seven years has been built. Using the Soil Conservation Service's soil survey for Riley County a detailed description of the soils for the watershed has also been developed. By examining Figures 5 and 6 it can be seen that fairly good correlation between the model and the actual streamflow has been developed. The coefficient of determination (R^2) was 0.83 which indicated good results, keeping in mind the 55 percent decrease in predicted streamflow for 1981.

Predicted annual streamflow values varied from 1.00 million cubic meters (811 acre-feet) in 1981 to 3.80 million cubic meters in 1986 with an average of 2.60 million cubic meters (2140 acre-feet). The actual streamflow values averaged 2.60 million cubic meters (2120 acre-feet). Precipitation averaged 830 millimeters (32.6 inches) and varied from 640 millimeters (25.1 inches) in 1981 to 1,030 millimeters (40.67 inches) in 1986. The ridges, with a contributing area of 30 percent of the watershed, produced 27 percent of the produced streamflow. The side slopes with an area of 59 percent produced 65 percent of the predicted streamflow. The valleys with eleven percent of the watershed area produced eight percent of the predicted streamflow.

RECOMMENDATIONS

In order to increase model confidence it is recommended that another three years of climatological data be added to the calibration data set to complete a full ten years. With the addition of an algorithm describing the behavior of the groundwater system, problems like the one that occurred for 1981 should be eliminated. For the sake of simulating and predicting the biomass production of a subplot the crop coefficients used in calculating AET should be expressed as an equation based upon the time of the growing season and not as monthly values. Since the research on the prairie involves the periodic burning of the rangeland grasses, it is also recommended that a subroutine be added to describe the effects of burning on AET.

With the addition of the subroutines just described it is believed that a model describing the Kings Creek watershed will be achieved. This model can in turn be used by both the Department of Civil Engineering to describe the hydrology of the watershed and the Department of Biology to predict the amount of plant matter produced by the watershed and other information of interest to scientists studying the prairie ecosystem.

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APPENDIX A

RUNNING THE MODEL

Operation of the model requires the climatological data set and the input data set. The climatological data consists of daily values of maximum and minimum temperatures, precipitation, and solar radiation. These parameters can be gathered from the various weather stations previously mentioned. If weather data is from the Konza Prairie Headquarters the data must be reformatted by using the BASIC program CNVRTKNZ. This program reads data archived as part of the long term ecological research data base and rewrites it in a form usable for the water budget model. If the data was aquired from the Manhattan, Kansas weather station the reformatting program CNVRTMAN must be used. This program performs a similar operation as CNVRTKNZ with data from the Kansas Agricultural Experiment Weather Library. Both programs are available through the Civil Engineering Department at Kansas State University. It is important to note that in order for both conversion programs to operate correctly complete years of data must be used. Since the program takes one year to fill the soil profiles it is also recommended that a "dummy" year be added to the beginning of the climatological data set. In this report 1979 was the "dummy" year.

The input data set is shown in Figure A1. A brief description and location of the variables in the data file is also given. Some of the variables listed are used for other operations that POTYLD was originally meant to do. These variables are identified with a "Not Applicable" label and need not be altered. The monthly variables used in the program are listed in Table A1.

```
        1---5----*----5----*----5----*----5----*----5----*----5----*----5----*

1.                          KONZA (MANHATTAN)
2.      GRADIENT
3.      0.72      0.036     0.75      0.23      2     0.6
4.      0.156     9.        140.      11        8.0   140.0
5.      4399      5.59      1986      1979      2617.6
6.      0         0         0         0         0
7.      15477105285001001
.       25579 97332001001
.       35878115422010002
.       45878117543030005
.       56082102601050007
.       66883101738090008
.       77182 84774110009
.       87183 85800100009
.       97380 91692080008
.      106880 92578030007
.      116078 98424008004
.      125479 96320005002
8.      1  1 5   1.0 63. 80. 91. 04 01 10 30 1 2 1 1                          2.78
.       2  2 5   7.0 55. 74. 88. 04 01 10 30 1 1 1 1                         26.79
.       3  3 5   0.0 55. 74. 88. 04 01 10 30 1 1 1 1                         26.79
.       4  4 5   0.0 59. 77. 89. 04 01 10 30 1 1 1 1                         30.8
.       5  5 5   0.0 63. 80. 91. 04 01 10 30 1 1 1 1                           .57
.       6  6 5   0.0 63. 80. 91. 04 01 10 30 1 1 1 1                           .52
.       7  7 5   0.0 55. 74. 88. 04 01 10 30 1 1 1 1                          1.68
.       8  8 5   0.0 55. 74. 88. 04 01 10 30 1 1 1 1                           .37
.       9  9 5   0.0 55. 74. 88. 04 01 10 30 1 1 1 1                          8.72
.      10 10 5   0.0 55. 74. 88. 04 01 10 30 1 1 1 1                           .63
.      11 11 5   0.0 55. 74. 88. 04 01 10 30 1 1 1 1                           .35
```

Figure A1: INPUT DATA FILE FOR WATER BUDGET MODEL (KINGS CREEK WATERSHED)

DESCRIPTION OF VARIABLES IN INPUT FILE

Line 1
Column 21-40 Title Line

Line 2
Column 2-17 Type of terracing (Not Applicable)

Line 3
Free Format: BRUNTA - geographical constant, c, in Penman equation
BRUNTB - geographical constant, d, in Penman equation
E - wind coefficient in Penman equation
RCROP - crop reflectance (albedo)
OUTPUT - format of output, see Koelliker (1982)
CROPVAR - Global crop coefficient

Line 4
Free Format: DSEPRT - Daily exfiltration rate of pond (Not Applicable)
HMAX - Maximum depth of pond (Not Applicable)
L - Length of pond base (Not Applicable)
NPLOTS - Number of subplots
S - Side slope of pond (Not Applicable)
W - Width of pond base (Not Applicable)

Line 5
Free Format: INDST - Climatological data station identification number
STORM - 25 year, 24 hour storm in inches
YEND - Year simulation ends
YSTART - Year simulation begins
ACRES - Area of entire watershed in acres

Line 6
Free Format: JCROP - Crop indicator (Not Applicable)
MBEGIN - Beginning month of growing period (Not Applicable)
MEND - Ending month of growing period (Not Applicable)
MPOND - Monthly flag (Not Applicable)
SKPLOT - Plot to be skipped during drought (Not Applicable)

Line 7... Monthly Data
Column 1-2 Number of month, i.e. 1=Jan., 2=Feb., ...
Column 3-4 PSUNS, monthly average percent sunshine
Column 5-6 RHD, monthly average relative humidity
Column 7-9 WIND, monthly average wind speed, mph
Column 11-13 MMAT, monthly average temperature, ^{o}F
Column 14-16 KCROPVR, monthly crop coefficient
Column 17-19 ABSTIN, monthly initial abstraction

Line 8... Subplot Data

Column 1-2 Subplot number
Column 4-5 ISOIL, soil type (Customized for Kings Creek watershed)
Column 6-7 ICROP, type of crop
Column 9-13 AREA, area of subplot (Not Applicable)
Column 15-17 RCNI, runoff curve number, AMC (antecedent moisture condition) I
Column 19-21 RCNII, runoff curve number AMC II
Column 23-25 RCNIII, runoff curve number AMC III
Column 26-28 MGSBP, month growing season begins
Column 29-31 DGSBP, day growing season begins
Column 32-34 MGSEP, month growing season ends
Column 35-37 DGSEP, day growing season begins
Column 38-39 ROTATE, rotation Indicator (Not Applicable)
Column 40-41 POND, indicator for flow into pond (Not Applicable)
Column 42-43 TERR, terracing indicator (Not Applicable)
Column 44-45 MUL, stubble mulch indicator (Not Applicable)
Column 53-55 FLRCNI, fallow runoff curve number AMC I (Not Applicable)
Column 57-59 FLRCNII, fallow runoff curve number AMC II (Not Applicable)
Column 61-63 FLRCNIII, fallow runoff curve number AMC III (Not Applicable)
Column 66-70 PCTAREA, percent of watershed area occupied by subplot

Table A1: MONTHLY COEFFICIENTS AND VARIABLES USED BY WATER BUDGET MODEL

MONTH	CROP COEFFICIENT	INTERCEPT.-STORAGE COEFFICIENT	PERCENT SUNSHINE	RELATIVE HUMIDITY	WIND (MPH)	AVERAGE MONTHLY TEMP. (^{o}F)
January	0.01	0.01	54	77	10.5	28.5
February	0.01	0.01	55	79	9.7	33.2
March	0.10	0.02	58	78	11.5	42.2
April	0.30	0.05	58	78	11.7	54.3
May	0.50	0.07	60	82	10.2	60.1
June	0.90	0.08	68	83	10.1	73.8
July	1.10	0.09	71	82	8.4	77.4
August	1.00	0.09	71	83	8.5	80.0
September	0.80	0.08	73	80	9.1	69.2
October	0.30	0.07	68	80	9.2	57.8
November	0.08	0.04	60	78	9.8	42.4
December	0.05	0.02	54	79	9.6	32.0

The output format can be varied by altering the OUTPUT variable in the input data set. The various formats are: (1) Print just annual values in subarea account and (2) Print annual and monthly values in subarea account. Assigning the appropriate number to OUTPUT will give the desired format.

The variables describing the soils are listed in Table A2. These variables are used in a data statement within the program. These values can be altered by editing the source code and then recompiling the program with Lahey Fortran (Lahey Computer Systems, 1987). The variable names are: AVLFCL = available soil moisture in the lower zone, AVLFCU = available soil moisture in the upper zone, FCL = field capacity in the lower zone, FCU = field capacity in the upper zone, PWPLZ = permanent wilting point in the lower zone, PWPUZ = permanent wilting point in the upper zone, and SMSATU = saturated moisture content in the upper zone.

It is recommended that the input file and climatological file are both on the same disk. The program is started by typing LPOTYLD followed by a carriage return. The user will be prompted first for the input data file. At this point the file name is entered. If it does not exist an error will occur. Next the user is asked for the name of the climatological data file. Again the file must exist. In the case of Kings Creek watershed the input and climatological files are KZAPLOT.DAT and KNZSHRT.DAT, respectively. The extensions to the file names must be included. Finally the user is asked for the name of an output file. If the file already exists an error will occur. This is to prevent previous model runs from being destroyed. Once the

Table A2: SOIL PARAMETERS DEFINING SOILS OF KINGS CREEK WATERSHED TO BE USED IN WATER BUDGET MODELING

SOIL	ZONE	AVAILABLE SOIL MOISTURE (in.)	PERMANENT WILTING POINT (in.)	SATURATED MOISTURE CONTENT (in.)	FIELD CAPACITY (in.)
Dwight-Irwin	Upper	2.14	2.22	6.01	4.36
	Lower	6.03	6.54	--	12.57
Benfield-Florence (Ridges)	Upper	1.73	2.20	5.97	3.93
	Lower	2.19	3.56	--	5.75
Benfield-Florence (Side Slopes)	Upper	1.78	2.32	5.98	3.98
	Lower	1.54	2.38	--	3.92
Clime-Sogn	Upper	1.76	1.83	4.91	3.59
	Lower	0.176	0.183	--	0.359
Irwin Silty Clay Loam	Upper	2.16	2.24	6.01	4.40
	Lower	2.16	2.34	--	4.50
Irwin Silty Clay Loam (Eroded)	Upper	2.16	2.28	6.06	4.44
	Lower	2.16	2.34	--	4.50
Tully Silty Clay Loam	Upper	2.16	2.23	6.00	4.39
	Lower	6.48	6.24	--	12.72
Tully Silty Clay Loam (Eroded)	Upper	2.16	2.27	6.05	4.43
	Lower	6.48	7.02	--	13.50
Reading Silt Loam	Upper	2.05	1.92	5.78	3.97
	Lower	6.48	6.68	--	13.16
Ivan and Kennebec Silt Loam	Upper	2.13	1.97	5.81	4.09
	Lower	6.48	6.60	--	13.08
Alluvial Land	Upper	2.16	2.23	6.00	4.39
	Lower	6.48	6.24	--	13.64

final carriage return is entered the program will begin operating while printing the month and year of the simulation on the screen.

The program output allows for examination of month by month simulation results for each subplot as well as a total volume of flow for each year. Figure A2 shows a sample of one plot's output for one year and Figure A3 shows the input file echoed back by the computer. Provided the appropriate format is requested in the input file, all eleven plots have a table similar to Figure A2 for each year. As can be guessed the number of tables generated for a long continuous simulation can take up a lot of paper or disk space. For the simulation of 1980 to 1986, 266,000 bytes of information were stored.

In order to quickly check the program during calibration streamflow summaries were printed at the end of the output file. Figure A4 shows an example for one year of simulation. While the monthly plot information is reported in inches the yearly summaries in Figure A4 are reported in acre-feet since the actual Kings Creek streamflow is reported in acre-feet.

The subplots are identified as: plot 1 is Dwight-Irwin; plot 2 is Benfield-Florence (ridge); plot 3 is Benfield-Florence (sides); plot 4 is Clime-Sogn; plot 5 is Irwin Silty Clay Loam; plot 6 is Irwin Silty Clay Loam (eroded); plot 7 is Tully Silty Clay Loam; plot 8 is Tully Silty Clay Loam (eroded); plot 9 is Alluvial Land; plot 10 is Reading Silt Loam; and plot 11 is Ivan and Kennebec Silt Loam.

SUBAREA NO. 2

AREA-- 7. ACRES SOIL TYPE-- 2 CROP--pasture RUNOFF CURVE NUMBERS: AMCI--55. AMCII--74. AMCIII--88.
no FLOW INTO POND TERRACES--none
WATER BALANCE (INCHES) IN THE SUBAREA - 1982

	INPUTS	OUTPUTS						
MONTH	PRECIPITATION	INTERCEPT.	PRECIP. EXCESS	PERC.	PET	AET	CHANGE IN SM	SOIL MOISTURE
JAN.	1.13	0.03	0.00	0.10	0.18	0.35	0.45	9.03
FEB.	1.17	0.05	0.01	1.04	0.78	0.95	-0.68	8.36
MAR.	2.24	0.14	0.11	0.27	2.72	1.77	-0.05	8.31
APR.	1.23	0.23	0.00	0.00	4.04	0.61	0.39	8.70
MAY	6.93	0.98	0.76	3.26	4.65	1.35	0.57	9.27
JUNE	6.78	1.11	1.34	0.55	4.91	3.40	0.37	9.65
JULY	3.26	0.41	0.43	1.15	6.63	4.89	-3.62	6.03
AUG.	2.68	0.81	0.00	0.00	4.64	1.88	-0.01	6.02
SEPT	3.32	0.67	0.07	0.00	3.35	1.25	1.33	7.35
OCT.	1.74	0.28	0.21	0.00	2.58	0.39	0.86	8.21
NOV.	0.99	0.24	0.00	0.00	1.18	1.11	-0.36	7.84
DEC.	0.99	0.08	0.00	0.00	0.83	0.73	0.18	8.02
TOT.	32.46	5.03	2.93	6.37	36.49	18.69	-0.56	8.02

Figure A2: EXAMPLE OF ANNUAL REPORT BY MONTH FOR ONE PLOT ON KINGS CREEK WATERSHED

```
0                                        DUMP OF INPUT VALUES
brunta= 0.720    bruntb= 0.036    e= 0.750    rcrop= 0.230    output=  2    CROPVAR=0.80
dseprt= 0.156    hmax= 9.000    l=140.000    nplots= 11    s=  8.00    w=140.00
indst= 4399    storm=  5.59    yend= 1986    ystart= 1979    AREA=  2617.60
jcrop=  0    mbegin=  0    mend=  0    mpond=  0    skplot=  0
```

psuns	rhd	wind	mmat	kcropvr	abstin
0.54	77.	10.5	28.5	0.01	0.01
0.55	79.	9.7	33.2	0.01	0.01
0.58	78.	11.5	42.2	0.10	0.02
0.58	78.	11.7	54.3	0.30	0.05
0.60	82.	10.2	60.1	0.50	0.07
0.68	83.	10.1	73.8	0.90	0.08
0.71	82.	8.4	77.4	1.10	0.09
0.71	83.	8.5	80.0	1.00	0.09
0.73	80.	9.1	69.2	0.80	0.08
0.68	80.	9.2	57.8	0.30	0.07
0.60	78.	9.8	42.4	0.08	0.04
0.54	79.	9.6	32.0	0.05	0.02

1	5	1.	63.	80.	91.	4	1	10	30	1	2	1	1	0.	0.	0.	2.78
2	5	7.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	26.79
3	5	0.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	26.79
4	5	0.	59.	77.	89.	4	1	10	30	1	1	1	1	0.	0.	0.	30.80
5	5	0.	63.	80.	91.	4	1	10	30	1	1	1	1	0.	0.	0.	0.57
6	5	0.	63.	80.	91.	4	1	10	30	1	1	1	1	0.	0.	0.	0.52
7	5	0.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	1.68
8	5	0.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	0.37
9	5	0.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	8.72
10	5	0.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	0.63
11	5	0.	55.	74.	88.	4	1	10	30	1	1	1	1	0.	0.	0.	0.35

Figure A3: COMPUTER DUMP OF INPUT VARIABLES USED FOR KINGS CREEK WATERSHED

YEAR = 1982.

	PERCOLATION, AC-FT	RUNOFF, AC-FT	TOTAL, AC-FT	PET, AC-FT	AET, AC-FT	INTERCEPTION, AC-FT
PLOT 1	15.08	26.68	41.75	221.27	128.68	30.50
PLOT 2	372.37	170.97	543.34	2132.30	1092.09	293.94
PLOT 3	408.88	142.22	551.10	2132.30	1045.30	293.94
PLOT 4	488.85	228.91	717.76	2451.46	1106.01	337.94
PLOT 5	5.99	5.62	11.61	45.37	23.23	6.25
PLOT 6	5.47	5.13	10.60	41.39	21.19	5.71
PLOT 7	17.97	10.99	28.96	133.72	76.52	18.43
PLOT 8	3.93	2.42	6.35	29.45	16.88	4.06
PLOT 9	100.80	57.06	157.85	694.05	394.28	95.68
PLOT 10	7.31	4.05	11.36	50.14	28.54	6.91
PLOT 11	4.22	2.24	6.45	27.86	15.64	3.84
TOTAL YEARLY FLOW IN ACRE-FT			2087.14			

Figure A4: SAMPLE ANNUAL SUMMARY OUTPUT FOR WATERSHED MODEL

APPENDIX B

Description of Variables for Water Budget Model
(Variables added to program for this report are in bold print.)

MAIN PROGRAM

VARIABLE NAME	TYPE	DESCRIPTION
A1	R*4	Area of pond base (ft^2)
A2	R*4	S(L+W)
A3	R*4	$4S^2/3$
A4	R*4	2A2
A5	R*4	$4S^2$
AAETRS	R*4	Average annual evapotranspiration for subarea (in.)
ABIN	R*4	Dummy variable for monthly initial abstraction coefficient
ABSTIN	R*4	Monthly initial abstraction coefficient
ACHSOM	R*4	Average annual change in soil moisture for subareas (in.)
ACRES	R*4	Area of watershed (ac.)
ADYD	R*4	Average number of discharges per year having a discharge
AET	R*4	Actual evapotranspiration (in.)
AETL	R*4	Actual evapotranspiration from lower zone (in.)
AETLZ	R*4	Actual evapotranspiration from lower zone (in.)
AETU	R*4	Actual evapotranspiration from upper zone (in.)
AETUZ	R*4	Actual evapotranspiration from upper zone (in.)
AETVOL	R*4	Volume of actual evapotranspiration (ac-ft.)
AINTER	R*4	Average annual interception for subarea (in.)
AMONTH	R*4	Literal fields for month names
AND	R*4	Station identifier literal
APETRS	R*4	Average annual potential evapotranspiration for a subarea (in.)
APPREC	R*4	Average annual precipitation (in.)
AREA	R*4	Area of particular land use which drains into pond (ac.)
ASTAT	R*4	Literal field for statistical summary
AVAILL	R*4	Percent of available moisture remaining in lower zone (in.)
AVAILU	R*4	Percent of available moisture remaining in upper zone (in.)
AVANDC	R*4	Average discharge volume per year having a discharge (ac-in.)
AVGMD	R*4	Average annual moisture deficit (in.)
AVGT	R*4	Average daily temperature (°F.)
AVLFCL	R*4	Available water holding capacity for lower zone (in.)

AVLFCU	R*4	Available water holding capacity for upper zone (in.)
B2	R*4	Pond surface area (ft^2)
BLANK	C*16	Literal field for table
BLNK	R*4	Literal field for table
BRUNTA	R*4	Geographic constant for solar radiation calculations
C	R*4	Degree-day coefficient (^oF-day)
CITY	R*4	Literal field for station identifier
CNTR	R*4	Cumulative number of times runoff occurred from subarea
CONTRL	R*4	Percent of runoff to be controlled by pond
CROPVR	R*4	Global coefficient for monthly crop coefficients
CROP	I*4	Crop type code
CTP	R*4	Percent of days rainfall exceeded given frequency
CTPDAY	I*4	Cumulative total days precipitation occurred
CTPR	R*4	Cumulative days runoff exceeded given frequency
CTR	R*4	Number of days runoff exceeded given frequency
CTRDAY	R*4	Number of days runoff occurred from plot during simulation
DA	R*4	Drainage area of pond (ac.)
DASEEP	R*4	Daily seepage volume
DAYLD	R*4	Discharge volume from pond expressed as depth over watershed (in.)
DELTA	R*4	Slope of saturated vapor pressure-temperature curve
DBSB	I*4	Day growing season begins
DGSBP	I*4	Day growing season begins for the subarea
DGSE	I*4	Day growing season ends
DGSEP	I*4	Day growing season ends for the subarea
DIM	R*4	Dimensions of square base of pond large enough to control discharge (ft.)
DPERC	R*4	Amount of percolation out of lower zone (in.)
DRY	R*4	Lowest annual precipitation amount (in.)
DSCHRG	R*4	Discharge from pond (ac-in.)
DSCRG	R*4	Average daily discharge volume (ac-in.)
DSCRGA	R*4	Average annual discharge volume (ac-in.)
DSCVOL	R*4	Total discharge volume during simulation run (ac-in.)
DSEPRT	R*4	Daily exfiltration rate (in/day)
DSNOW	R*4	Change in snow storage (in.)
DSPERC	R*4	Average annual percolation for subarea (in.)
DSRNFF	R*4	Average annual precipitation excess from subarea (in.)
DV	R*4	Difference between actual and calculated pond volume ($ft.^3$)
DVDH	R*4	Difference between actual and calculated pond volume with respect to the difference between actual and calculated height of pond

E	R*4	Wind coefficient for calculating potential ET
EO	R*4	Difference between field capacity and actual soil moisture
EPRIM	R*4	e' factor in Penman equation for lake evaporation
EVAP	R*4	Average annual lake evaporation (in.)
EVAPA	R*4	Average annual volume of evaporation from pond (ac-in.)
EVAPLK	R*4	Sum of annual lake evaporation amounts (in.)
EVAPT	R*4	Sum of annual volumes of evaporation from pond (ac-in.)
EXCESS	R*4	Gravitational water in upper zone (in.)
EXFILA	R*4	Average annual exfiltration from pond (ac-in.)
FCL	R*4	Field capacity of lower zone (in.)
FCU	R*4	Field capacity of upper zone (in.)
FLOW	R*4	Sum of percolation and precipitation excess for a plot
FLOWTT	R*4	Annual streamflow
FLRCN1	R*4	Fallow runoff curve number for AMC I
FLRCN2	R*4	Fallow runoff curve number for AMC II
FLRCN3	R*4	Fallow runoff curve number for AMC III
FREQ	R*4	Literal fields for statistical summary output
FROZE	I*4	Indicator for frozen soil
GAMMA	R*4	Pychometric constant
H	R*4	Depth in pond (ft.)
HAPRX	R*4	Approximate pond depth (ft.)
HMAX	R*4	Maximum depth of pond (ft.)
I3	I*4	Do-loop increment counter
I	I*4	Do-loop increment counter
IA	R*4	Initial abstraction amount (in.)
IAET	R*4	Evapotranspiration deducted from initial abstraction (in.)
ICROP	I*4	Crop type code
IDAYLD	I*4	Annual discharge from pond expressed as depth over watershed (in.)
II	I*4	Do-loop increment counter
INCROP	I*4	Initial crop type code
INDST	I*4	Weather station index number (4-digit code)
INRCN1	R*4	Input runoff curve number for AMC I
INRCN2	R*4	Input runoff curve number for AMC II
INRCN3	R*4	Input runoff curve number for AMC III
INTVOL	R*4	Volume of precipitation intercepted (ac-ft.)
INUM1	I*4	Do-loop increment counter
INUM	I*4	Do-loop increment counter
IPEACT	I*4	Integer form of PEACCT
IPLOT	I*4	Do-loop increment counter
IPLUS1	I*4	Do-loop increment counter
IROT	I*4	Rotation indicator

ISOIL	I*4	SCS soil irrigation class code
J	I*4	Do-loop increment counter
JJ	I*4	Do-loop increment counter
K	I*4	Do-loop increment counter
KAN	I*4	Two-digit state code for meteorological data
KCROP	R*4	Crop coefficient
KCROPVR	R*4	Monthly crop coefficient
KI	I*4	Do-loop increment counter
KROP	C*16	Literal field for crop type
KROPKO	R*4	Crop coefficient
KT	I*4	Do-loop increment counter
L	R*4	Pond base length (ft.)
LAKEVP	R*4	Estimated lake evaporation (in.)
LKACCT	R*4	Array of annual lake evaporation (in.)
LKEVPT	R*4	Total estimated lake evaporation (in.)
MAXVOL	I*4	Maximum volume of pond (ac-in.)
MGSB	I*4	Month growing season begins array
MGSBP	I*4	Month growing season begins for the subarea
MGSE	I*4	Month growing season ends array
MGSEP	I*4	Month growing season ends for the subarea
MLIT	C*16	Literal field to describe stubble mulching
MMAT	R*4	Mean monthly air temperature (^{o}F.)
MONTH	I*4	Month read from input tape (or disk)
MP	I*4	Do-loop increment counter
MSTART	I*4	Month in which simulation starts
MUL	I*4	Stubble-mulching indicator
N1	I*4	Do-loop increment counter
N2	I*4	Do-loop increment counter
N3	I*4	Do-loop increment counter
NAME	I*4	Literal field for climatological station identification
ND	I*4	Daily do-loop increment counter
NDAYS	I*4	Number of days in month
NDIM	I*4	Number of days in month
NDPERC	R*4	Amount of deep percolation (in.)
NIA	R*4	Initial abstraction amount
NM	I*4	Monthly do-loop increment counter
NO	I*4	Literal field
NODSCH	I*4	Total number of discharges in simulation run
NONE	C*16	Literal field
NPLOTS	I*4	Number of subareas in simulation
NRNOF	R*4	Precipitation excess amount (in.)
NY	I*4	Yearly do-loop increment counter
NYDSCH	I*4	Number of years with pond discharge

OF	R*4	Literal field for climatological station identification
OUTPUT	I*4	Indicator for output format
PACK	R*4	Moisture stored in snowpack (in.)
PACKPY	R*4	Moisture stored in snowpack at end of previous year (in.)
PCNTRL	R*4	Percent of precipitation excess to be controlled by pond
PCROP	R*4	Crop type code
PCTAREA	R*4	Percent of watershed taken up by a subplot
PDACCT	R*4	Pond account output array (ac-in.)
PDT	R*4	Previous day's average temperature (^{o}F.)
PDVOL	R*4	Previous day's pond volume (ac-in.)
PEACCT	R*4	Precipitation excess amount array (in.)
PEAK	R*4	Largest discharge volume from pond (ac-in.)
PEINA	R*4	Average annual precipitation excess flowing into pond (ac-in.)
PEINT	R*4	Sum of precipitation excess flowing into pond (ac-in.)
PERC	R*4	Amount of water which infiltrates into the soil (in.)
PERCL	R*4	Water cascaded to lower zone for storage (in.)
PERCVOL	R*4	Volume of percolation (ac-ft.)
PET	R*4	Potential evapotranspiration (in.)
PETBS	R*4	Potential evapotranspiration from bare soil (in.)
PETVOL	R*4	Volume of potential evaporation (ac-ft.)
PLAREA	R*4	Area of subarea (ac.)
PLIT	R*4	Literal field
POND	I*4	Indicator for subarea that flows into pond
PONVOL	R*4	Pond volume (ac-in.)
PRCPA	R*4	Average annual direct precipitation volume (ac-in.)
PRCPT	R*4	Sum of direct precipitation volume (ac-in.)
PRCPVL	R*4	Volume of direct precipitation falling into pond (ac-in.)
PREC	R*4	One month's daily precipitation values (in.)
PRECAC	R*4	Accumulated precipitation by month (in.)
PRECIP	R*4	Daily precipitation kamount (in.)
PREVYR	I*4	Previous year
PSAREA	R*4	Maximum pond surface area (ac.)
PSUNS	R*4	Monthly average of percentage of possible sunshine
PWPLZ	R*4	Permanent wilting point of lower zone array (in.)
RA	R*4	Daily solar radiation (LY)
RAIN	R*4	Sum of daily precipitation and daily snowmelt (in.)
RANGE	R*4	Range of annual precipitation amounts (in.)
RCN1	R*4	Runoff curve number for AMC I
RCN2	R*4	Runoff curve number for AMC II
RCN3	R*4	Runoff curve number for AMC III
RCNI	R*4	Runoff curve number for AMC I
RCNII	R*4	Runoff curve number for AMC II

RCNIII	R*4	Runoff curve number for AMC III
RCROP	R*4	Shortwave reflectance coefficient for crops
RHD	R*4	Monthly average relative humidity
RNOF	R*4	Precipitation excess calculated by SCS Equation (in.)
ROTATE	I*4	Rotation indicator
RUNACC	R*4	Runoff account for statistical summary (in.)
RUNVOL	R*4	Volume of precipitation excess (ac-ft.)
S	R*4	Side slope of pond, run:rise (ft/ft.)
SEVAP	R*4	Surface evaporation from pond (ft^3)
SM	R*4	Soil moisture in growing zone (in.)
SMACCT	R*4	Soil moisture account (in.)
SMGWZ	R*4	Soil moisture stored in groundwater zone (in.)
SMLZ	R*4	Soil moisture stored in lower zone (in.)
SMMAXL	R*4	Percent of maximum available water in lower zone (in.)
SMMAXU	R*4	Percent of maximum available water in upper zone (in.)
SMPD	R*4	Soil moisture on previous day (in.)
SMSATU	R*4	Soil moisture at saturation in upper zone (in.)
SMUZ	R*4	Soil moisture stored in upper zone array (in.)
SNOVAP	R*4	Reduction in moisture stored in snowpack due to sublimation (in.)
SOIL	I*4	SCS irrigation soil class code
STATE	R*4	Literal field for climatological station identification
STIND	I*4	Climatological station index number read from tape (4 digit code)
STORM	R*4	25-year, 24-hour rainfall (in.)
STRNOF	R*4	Precipitation excess flowing into pond expressed as depth over watershed (in.)
STRVOL	R*4	Volume of precipitation excess flowing into pond (ac-in.)
STUB	C*16	Literal field to describe stubble-mulching
T	I*16	Number of days since precipitation occurred
TAVG	R*4	Average daily temperature (^oF)
TERR	I*4	Terraciang indicator for subarea
TERTYP	I*16	Literal field to describe terrace type
TLIT	C*16	Literal field to describe terracing
TMAX	R*4	Maximum daily temperature (^oF)
TMIN	R*4	Minimum daily temperature (^oF)
TPAREA	R*4	Total area of all subareas (ac.)
TPREC	R*4	Sum of annual precipitation amounts (in.)
TTAET	R*4	Array of annual actual evapotranspiration for a subplot (in.)
TTINT	R*4	Array of annual precipitation intercepted for a subplot (in.)
TTPERC	R*4	Array of annual percolation for a subplot (in.)
TTPET	R*4	Array of annual potential evapotranspiration for a subplot (in.)

TTRNFF	R*4	Array of annual precipitation excess for a subplot
U	R*4	Upper limit for stage 2 soil evaporation (in.)
UZEVAP	R*4	Evaporation from upper zone (in.)
V	R*4	Pond volume (ft^3)
VC1	R*4	Square Root of VC
VC	R*4	Approximate pond volume based on HAPRX (ac-in.)
VCB	R*4	2(S)(HMAX)
VCC	R*4	$4/3\ S^2$ - [(VOLMX1)(3630)/HMAX]
VCD	R*4	VCB^2 - 4(VCC)
VOLCHG	R*4	Pond volume change (ac-in.)
VOLMX1	R*4	Size of pond to control discharge (ac-in.)
W	R*4	Pond base width (ft.)
WATER	R*4	Sum of precipitation and snowmelt (in.)
WET	R*4	Greatest annual precipitation amount (in.)
WIND	R*4	Monthly average wind-speed (mi/hr.)
XIAET	R*4	Temporary storage for IAET (in.)
XYEAR	R*4	Counter for years
YEAR	I*4	Year read from input tape (or disk)
YEARS	I*4	Number of years in simulation
YEND	I*4	Year in which simulation ends
YSTART	I*4	Year in which simulation starts
ZAVFCV	R*4	Temporary storage for AVFCU (in.)
ZFCU	R*4	Temporary storage for FCU (in.)
ZIAET	R*4	Temporary storage for IAET (in.)
ZPSUNS	R*4	Temporary storage for PSUNS
ZPWPUZ	R*4	Temporary storage for PWPUZ (in.)
ZRA	R*4	Temporary storage for RA
ZRHD	R*4	Temporary storage for RHD
ZSM	R*4	Temporary storage for SM (in.)
ZSMUZ	R*4	Temporary storage for SMUZ (in.)
ZWIND	R*4	Temporary storage for WIND (in.)

SUBROUTINE CROPCO

VARIABLE NAME	TYPE	DESCRIPTION
A	R*4	Coefficient in regression equation
ACC	R*4	Accumulated days in growing season
B	R*4	Coefficient in regression equation
C	R*4	Coefficient in regression equation
CROP	I*4	Crop code
D	R*4	Coefficient in regression equation
DBMD	R*4	Days between mid-dates
DGSB	I*4	Day growing season begins
DGSE	I*4	Day growing season ends
E	R*4	Coefficient in regression equation
J	I*4	Do-loop increment counter
KCROP	R*4	Crop coefficient storage array
KT	R*4	Climatic coefficient
MGSB	I*4	Month growing season begins
MGSB1	I*4	Temporary storage for MGSB
MGSE	I*4	Month growing season ends
MGSE1	I*4	Temporary storage for MGSE
MID	R*4	Median dates of months in growing season
MMAT	R*4	Mean monthly average temperature (^{o}F.)
N	I*4	Do-loop increment counter
NDIM	I*4	Number of days in month
NMINUS	I*4	Do-loop increment parameter
NN	I*4	Subscript variable
NPLUS	I*4	Do-loop increment parameter
PCGS	R*4	Percent of growing season reached at mid-dates
PCGS1	R*4	Temporary storage for PCGS
SHIFT	I*4	Amount of shift used for calculations when growing season extends through two calendar years
XBAR	R*4	Middle of growing season, i.e., 50%
Z	R*4	Difference between XBAR and PCGS, independent variable in regression equation

SUBROUTINE IART

VARIABLE NAME	TYPE	DESCRIPTION
IA	R*4	Initial abstraction amount (in.)
IAET	R*4	Evapotranspiration from initial abstraction (in.)
IASTOR	I*4	Amount left in interception storage after evapotranspiration has been deducted (in.)
KROPKO	R*4	Monthly crop coefficient
P	R*4	Daily precipitation amount (in.)
PET	R*4	Potential evapotranspiration (in.)
PETBS	R*4	Potential evapotranspiration from bare soil (in.)
XIAET	R*4	Value of IAET to be used in next day's simulation (in.)

SUBROUTINE PETRT

VARIABLE NAME	TYPE	DESCRIPTION
ABST	R*4	Average daily temperature (^{o}K.)
AVGT	R*4	Average daily temperature (^{o}F.)
BLOW	R*4	Mean monthly wind speed (mi/hr.)
BRUNTA	R*4	Geographical constant for solar radiation calculations
BRUNTB	R*4	Geographical constant for solar radiation calculations
CENT	R*4	Average daily temperature (^{o}C.)
DELTA	R*4	Slope of saturated vapor pressure-temperature curve
E	R*4	Wind coefficient for calculating potential ET
EA	R*4	Convective losses (mm water)
EALAKE	R*4	Convective losses for large body of water (mm water)
EPRIM	R*4	e' factor for Penman equation, wind coefficient for calculating lake evaporation
ES	R*4	Daily calculated actual saturated vapor pressure (m bars)
ESA	R*4	Daily calculated actual vapor pressure (m bars)
GAMMA	R*4	1-DELTA, psychometric constant
HUM	R*4	Monthly average relative humidity

LAKEVP	R*4	Potential evapotranspiration from large body of water (in.)
PACK	R*4	Moisture stored in snowpack (in.)
PDT	R*4	Previous day's average temperature (^{o}F.)
PET	R*4	Potential evapotranspiration (in.)
PETBS	R*4	Potential evapotranspiration from bare soil (in.)
R	R*4	Shortwave reflectance coefficient
RAD	R*4	Daily solar radiation (cal/cm^2)
RADM	R*4	Daily solar radiation (mm water)
RCROP	R*4	Shortwave reflectance coefficient for a crop
RN	R*4	Daily calculated net solar radiation (mm water)
RNLAKE	R*4	Daily calculated net solar radiation on large body of water (mm water)
RNSOIL	R*4	Daily calculated net solar radiation on bare soil (mm water)
SUN	R*4	Mean monthly percent sunshine
WINDD	R*4	Monthly average of daily wind run at 2 meters height (mi/day)

SUBROUTINE RNOFRT

VARIABLE NAME	TYPE	DESCRIPTION
AVLFCU	R*4	Available field capacity in upper zone (in.)
CN	R*4	Runoff curve number
FCU	R*4	Field capacity in upper zone (in.)
KROPKO	R*4	Monthly crop coefficient for subarea
NUM	R*4	Numerator of SCS Equation
P	R*4	Daily precipitation routed through SCS Equation (in.)
PWPUZ	R*4	Permanent wilting point of upper zone (in.)
RCN1	R*4	Runoff curve number for AMC I
RCN2	R*4	Runoff curve number for AMC II
RCN3	R*4	Runoff curve number for AMC III
RNOF	R*4	Runoff amount calculated by the SCS equation (in.)
S	R*4	$\frac{1000}{CN} - 10$
SM	R*4	Soil moisture in growing zone (in.)
SMUZ	R*4	Soil moisture in upper zone (in.)

SUBROUTINE SEEPGE

VARIABLE NAME	TYPE	DESCRIPTION
B2	R*4	Surface area of pond (ft^2)
DASEEP	R*4	Daily seepage volume (ac-in.)
DSEPRT	R*4	Daily seepage rate (in/day)
PONVOC	R*4	Volume stored in pond (ac-in.)

SUBROUTINE SNOWRT

VARIABLE NAME	TYPE	DESCRIPTION
M	R*4	Total snowmelt (in.)
MA	R*4	Snowmelt due to atmospheric conditions (in.)
MR	R*4	Snowmelt due to rain (in.)
PACK	R*4	Moisture stored in snowpack (in.)
PET	R*4	Potential evapotranspiration (in.)
PRECIP	R*4	Daily precipitation (in.)
SNOVAP	R*4	Reduction in snowpack due to sublimation (in.)
TEMPAV	R*4	Average daily temperature ($^oF.$)
WATER	R*4	Sum of daily precipitation and snowmelt (in.)

SUBROUTINE VOLRT

VARIABLE NAME	TYPE	DESCRIPTION
A1	R*4	Bottom area of pond (ft^2)
A2	R*4	$S*(L+W)$
A3	R*4	$\frac{4S^2}{3}$
A4	R*4	$2A2$
A5	R*4	$4S^2$
HMAX	R*4	Maximum depth in pond (ft.)
L	R*4	Base length of pond (ft.)
PSAREA	R*4	Maximum pond surface area (ac.)

S	R*4	Side slope of pond, run:rise (ft/ft.)
VOLMAX	R*4	Maximum volume of pond (ac-in.)
W	R*4	Base width of pond (ft.)

APPENDIX C

FORTRAN PROGRAM LISTING

```
C     *****   POTENTIAL YIELD MODEL MODIFIED FOR SPECIFICALLY KINGS
C     *****   CREEK WATERSHED ON THE KONZA PRAIRIE
C     *****
C     *****   KANSAS STATE UNIVERSITY
C     *****
C     *****   APRIL 22, 1988
C     *****
C     *****
C     *****
      INTEGER CROP,DGSB,DGSBP,DGSE,DGSEP,FROZE,OUTPUT
      INTEGER POND,PREVYR,ROTATE,SOIL,STIND,T,TERR
      INTEGER YEAR,YEARS,YEND,YSTART
      INTEGER SMDI,PERS,SPER,SKPLOT
      REAL IA,IAET,INRCN1,INRCN2,INRCN3,INTVOL,KCROP,KROPKO
      REAL L,LAKEVP,LKEVPT,MMAT,NIA,NDPERC,NRNOF,LKACCT,KCROPVR
      DIMENSION AAETRS(18), ACHSOM(18), AETL(18), AETU(18)
      DIMENSION AETVOL(25,18), AINTER(18), AMONTH(13), APETRS(18)
      DIMENSION AREA(18), ASTAT(25),AVLFCL(12), AVLFCU(12)
      DIMENSION ABSTIN(12), C(12), CTP(25)
      DIMENSION CTPR(25), CTRDAY(04), DGSBP(18)
      DIMENSION DGSEP(18), DSPERC(18), DSRNFF(18), EO(18)
      DIMENSION FCL(12), FCU(12), FLRCN1(18), FLRCN2(18)
      DIMENSION FLRCN3(18), FREQ(25), IAET(18), ICROP(18)
      DIMENSION INCROP(18), INRCN1(18), INRCN2(18), INRCN3(18)
      DIMENSION INTVOL(25,18), IPEACT(18), ISOIL(18),KCROPVR(12)
      DIMENSION MGSBP(18), MGSEP(18), MMAT(12), MUL(18)
      DIMENSION NDIM(12), NDPERC(18), NIA(18), NRNOF(18)
      DIMENSION PCROP(18), PCTAREA(18), PEACCT(18), PERCVOL(25,18)
      DIMENSION PETVOL(25,18), POND(18), PREC(31)
      DIMENSION PSUNS(12), PWPLZ(12), PWPUZ(12), RA(31)
      DIMENSION RCNI(18), RCNII(18), RCNIII(18), RHD(12)
      DIMENSION ROTATE(18), SM(18), SMGWZ(18), SMLZ(18)
      DIMENSION SMPD(18), SMSATU(12), SMUZ(18), T(18), RUNVOL(25,18)
      DIMENSION TAVG(31), TERR(18), TMAX(31), TMIN(31), TTAET(25,18)
      DIMENSION TTINT(25,18), TTPERC(25,18), TTPET(25,18)
      DIMENSION TTRNFF(25,18), U(12), WIND(12)
      DIMENSION CTR(25,4), KCROP(7,12), PDACCT(13,7), PRECAC(25,3)
      DIMENSION RUNACC(25,25), SMACCT(13,8,18),krop(7),LKACCT(25)
      character*16 mlit,stub,tertyp,tlit,krop
      character*4  name,of,city,and,state
      character*4 amonth,astat,blank,blnk,no,none,PLIT
      character*11 xfile,yfile,zfile
      data blank/'  '/
      data blnk/'  '/
```

```
      data no/' no '/
      data none/'none'/
      data krop/'wheat','sorghum','corn','soy beans','pasture',
     1'alfalfa','fallow'/
      DATA AMONTH/'JAN.','FEB.','MAR.','APR.','MAY ','JUNE','JULY','AUG.
     1','SEPT','OCT.','NOV.','DEC.','TOT.'/
      DATA ASTAT/'>0.0','>0.1','>0.2','>0.3','>0.4','>0.5','>0.6','>0.7'
     1,'>0.8','>0.9','>1.0','>1.1','>1.2','>1.3','>1.4','>1.5','>1.6','>
     21.7','>1.8','>1.9','>2.0','>3.0','>4.0','>5.0','>10.'/
      DATA AVLFCL/6.03,2.19,1.54,.176,2.16,2.16,6.48,6.48,6.48,6.48,
     16.48,2.5/
      DATA AVLFCU/2.14,1.73,1.78,1.76,2.16,2.16,2.16,2.16,2.16,2.15,
     12.13,1.0/
      DATA C/0.2,0.2,0.177,0.177,0.177,0.177,0.159,0.159,0.138,0.138,0.1
     134,0.131/
      DATA FCL/12.57,5.75,3.92,.359,4.5,4.5,13.5,12.72,13.64,13.16,
     113.08,4.3/
      DATA FCU/4.36,3.93,3.98,3.59,4.4,4.44,4.43,4.39,4.39,3.97,4.09,
     11.7/
      DATA FREQ/0.0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2,1.3,
     11.4,1.5,1.6,1.7,1.8,1.9,2.0,3.0,4.0,5.0,10.0/
      DATA NDIM/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA PWPLZ/6.54,3.56,2.38,.183,2.34,2.34,7.02,6.24,7.16,6.68,
     16.6,1.8/
      DATA PWPUZ/2.22,2.2,2.32,1.83,2.24,2.28,2.27,2.23,2.23,1.92,
     11.97,0.7/
      DATA SMSATU/6.01,5.97,5.98,4.91,6.01,6.06,6.05,6.,6.,5.78,5.81,
     14.8/
      DATA U/0.47,0.47,0.39,0.39,0.39,0.39,0.35,0.35,0.31,0.31,0.28,0.24
     1/
      DATA CONTRL,EPRIM,PDT,SMMAXL/1.0,0.5,37.5,2.2/
      DATA CROP,FROZE,NODSCH,NYDSCH,SOIL/5*0/
      DATA STUB/'STUBBLE MULCHED'/
      DATA AET,AETLZ,AETUZ,AVAILL,AVAILU,CTP/30*0.0/
      DATA CTPDAY,CTPR,CTR,CTRDAY,DA,DPERC/132*0.0/
      DATA DSCVOL,EVAPLK,EVAPT,EXCESS,EXFILT,H/6*0.0/
      DATA IA,PACK,PACKPY,PDVOL,PEAK,PEINT/6*0.0/
      DATA PERC,PONVOL,PRCPT,SM,TPAREA/22*0.0/
      DATA XIAET,WATER,WET/3*0.0/
      DATA TPREC/0.0/
C     *****    FOLLOWING LINES REVISED IN JUNE 1987
C     *****       ***** INPUTS *****
C     *****
      write(*,5)
    5 format(' Enter the name of the file with meteorological variables
     1and plot information.'/' This file must reside on the disk.  '/)
      read *,xfile
      open(2,file=xfile,status='old')
      write(*,6)
    6 format(' Enter the name of the file with daily weather data.'/
     1' This file must reside on the disk.  '/)
```

```
      read *,yfile
      open(3,file=yfile,status='old')
      open(4,file='deplete.dat',status='unknown')
      write(*,7)
    7 format(' Enter the name of the output file for this program.'/
     1' This file must not exist on the disk or an error will occur.'/
     2' This is to ensure that a previous output file is not destroyed.
     3 '/)
      read *,zfile
      open(5,file=zfile, status='new')
      read (2,10) name,of,city,and,state
   10 FORMAT (20X,5A4)
      read (2,20) TERTYP
   20 FORMAT (1X,A16)
C     *****   READ SUBAREA AND POND PARAMETERS
      read (2,*)brunta,bruntb,e,rcrop,output,CROPVAR
      read (2,*)dseprt,hmax,l,nplots,s,w
      read (2,*)indst,storm,yend,ystart,ACRES
      read (2,*)jcrop,mbegin,mend,mpond,skplot
      write(5,30)
   30 FORMAT ('0',50X,'DUMP OF INPUT VALUES')
C     *****   ECHO PRINT NAMELIST VALUES
      write (5,31)brunta,bruntb,e,rcrop,output,CROPVAR
      write (5,32)dseprt,hmax,l,nplots,s,w
      write (5,33)indst,storm,yend,ystart,ACRES
      write (5,34)jcrop,mbegin,mend,mpond,skplot
   31 format(1x,'brunta=',f6.3,5x,'bruntb=',f6.3,5x,'e=',f6.3,5x,
     1        'rcrop='f6.3,5x,'output=',i3,5X,'CROPVAR=',F4.2)
   32 format(1x,'dseprt=',f6.3,5x,'hmax=',f6.3,5x,'l=',f7.3,5x,
     1        'nplots=',i3,5x,'s=',f6.2,5x,'w=',f6.2)
   33 format(1x,'indst=',i5,5x,'storm='f6.2,5x,'yend='i5,5x,'ystart='i5,
     1        5X,'AREA=',F9.2)
   34 format(1x,'jcrop='i3,5x,'mbegin=',i3,5x,'mend='i3,5x,'mpond='i3,
     1        5x,'skplot='i3)
C     *****   PUNCH CARDS FOR DEPLETE PROGRAM
      IF (OUTPUT.GT.2) WRITE (4,10) NAME,OF,CITY,AND,STATE
      IF (OUTPUT.GT.2) WRITE (4,20) TERTYP
      IF (OUTPUT.GT.2) WRITE (4,40) NPLOTS,YSTART,YEND
   40 FORMAT (I2,1X,I4,1X,I4)
      PREVYR = YSTART
C     *****   READ THE MONTHLY AVERAGE METEOROLOGICAL DATA
      READ (2,50) (PSUNS(I),RHD(I),WIND(I),MMAT(I),KCROPVR(I),
     1ABSTIN(I),I=1,12)
   50 FORMAT (2X,F2.2,F2.0,F3.1,F3.1,F3.2,F3.2)
C     *****   ECHO PRINT MONTHLY METEOROLOGICAL VALUES
      write(5,51)
   51 format(1x,'psuns',5x,'rhd',5x,'wind',5x,'mmat',5X,'kcropvr',
     15X,'abstin')
      WRITE (5,60) (PSUNS(I),RHD(I),WIND(I),MMAT(I),KCROPVR(I),
     1ABSTIN(I),I=1,12)
   60 FORMAT (1x,F4.2,5x,F3.0,5x,F4.1,5x,F4.1,6x,F4.2,7X,F4.2)
```

```
C     *****
C     *****   READ SUBAREA PARAMETERS
C     *****        ISOIL=SCS IRRIGATION SOIL CLASS
C     *****        ICROP=CROP TYPE
C     *****        AREA=AREA IN ACRES
C     *****        RCNI=RCN FOR AMC I
C     *****        RCNII=RCN FOR AMC II
C     *****        RCNIII=RCN FOR AMC III
C     *****        MGSBP=MONTH GROWING SEASON BEGINS
C     *****        DGSBP=DAY OF MONTH GROWING SEASON BEGINS
C     *****        MGSEP=MONTH GROWING SEASON ENDS
C     *****        DGSEP=DAY OF MONTH GROWING SEASON ENDS
C     *****        ROTATE=WHEAT/FALLOW ROTATION INDICATOR
C     *****          CONSERVATION PRACTICE INDICATORS
C     *****             1=PRACTICE DOES NOT APPLY
C     *****             2=PRACTICE DOES APPLY
C     *****                  POND=INDICATOR FOR SUBAREA FLOWING
C     *****                   INTO POND
C     *****                  TERR=INDICATOR FOR TERRACES
C     *****                  MUL=INDICATOR FOR STUBBLE MULCHING
C     *****        FLRCN1=FALLOW RCN FOR AMC I (IF NEEDED)
C     *****        FLRCN2=FALLOW RCN FOR AMC II (IF NEEDED)
C     *****        FLRCN3=FALLOW RCN FOR AMC III (IF NEEDED)
      DO 80 I=1,NPLOTS
      READ (2,70) ISOIL(I),ICROP(I),AREA(I),RCNI(I),RCNII(I),RCNIII(I),M
     1GSBP(I),DGSBP(I),MGSEP(I),DGSEP(I),ROTATE(I),POND(I),TERR(I),MUL(I
     2),FLRCN1(I),FLRCN2(I),FLRCN3(I),PCTAREA(I)
   70 FORMAT (3X,I2,I2,1X,F5.0,3(1X,F3.0),4I3,4I2,6X,3(1X,F3.0),1X,F6.2)
C     *****   ECHO PRINT SUBAREA INPUT PARAMETERS
      WRITE (5,70) ISOIL(I),ICROP(I),AREA(I),RCNI(I),RCNII(I),RCNIII(I),
     1MGSBP(I),DGSBP(I),MGSEP(I),DGSEP(I),ROTATE(I),POND(I),TERR(I),MUL(
     2I),FLRCN1(I),FLRCN2(I),FLRCN3(I),PCTAREA(I)
C     *****   PUNCH SUBAREA PARAMETERS FOR DEPLETE
      IF (OUTPUT.GT.2) WRITE (4,70) ISOIL(I),ICROP(I),AREA(I),RCNI(I),RC
     1NII(I),RCNIII(I),MGSBP(I),DGSBP(I),MGSEP(I),DGSEP(I),ROTATE(I),PON
     2D(I),TERR(I),MUL(I),FLRCN1(I),FLRCN2(I),FLRCN3(I)
   80 CONTINUE
C     *****   SUBROUTINE VOLRT CALCULATES THE DIMENSIONS OF THE
C     *****    THE POND USING THE GIVEN INPUT INFORMATION.
      CALL VOLRT (A1,A2,A3,A4,A5,L,PSAREA,S,VOLMAX,W,HMAX)
C     *****   CALCULATE THE CROP COEFFICIENTS
      DO 90 K=1,NPLOTS
      MGSB = MGSBP(K)
      DGSB = DGSBP(K)
      MGSE = MGSEP(K)
      DGSE = DGSEP(K)
      CROP = ICROP(K)
C     *****   SUBROUTINE CROPCO CALCULATES THE MONTHLY CROP
C     *****    COEFFICIENTS FOR EACH SUBAREA.
      CALL CROPCO (CROP,MGSB,DGSB,MGSE,DGSE,KCROP,NDIM,MMAT,CROPVAR,
     1KCROPVR)
```

```
      INCROP(K) = ICROP(K)
      INRCN1(K) = RCNI(K)
      INRCN2(K) = RCNII(K)
      INRCN3(K) = RCNIII(K)
   90 CONTINUE
C     *****   INITIALIZE VARIABLES
      DO 110 I=1,25
      DO 100 J=1,8
  100 RUNACC(I,J) = 0.0
  110 CONTINUE
      DO 115 I=1,25
      DO 116 J=1,3
  116 PRECAC(I,J) = 0.0
  115 CONTINUE
      DO 120 J=1,12
  120 KCROP(7,J) = 0.0
      DO 130 II=1,NPLOTS
      IF (POND(II).NE.1) DA = DA+AREA(II)
      TPAREA = TPAREA+AREA(II)
      T(II) = 0.0
      EO(II) = 0.0
      IAET(II) = 0.0
      DSRNFF(II) = 0.0
      AINTER(II) = 0.0
      APETRS(II) = 0.0
      AAETRS(II) = 0.0
      ACHSOM(II) = 0.0
      DSPERC(II) = 0.0
C     *****  THE FOLLOWING LINE WAS ADDED IN SEPTEMBER, 1982
      SOIL = ISOIL(II)
C     *****   FOLLOWING 2 LINES REVISED SEPTEMBER, 1982
      SMLZ(II) = 0.5*AVLFCL(SOIL) + PWPLZ(SOIL)
      SMUZ(II) = 0.5*AVLFCU(SOIL) + PWPUZ(SOIL)
      SMGWZ(II) = 6.30
      SMPD(II) = SMLZ(II)+SMUZ(II)
C     *****   ESTABLISH FALLOW SUBAREAS FOR BEGINNING OF SIMULATION
  130 IF (ROTATE(II).EQ.2) ICROP(II) = 7
C     *****   PUNCH VALUE OF DA FOR DEPLETE
      IF (OUTPUT.GT.2) WRITE (4,140) DA
  140 FORMAT (F10.2)
      YEARS = YEND-YSTART+1
C     *****
C     *****   PRINT INPUT PARAMETERS
C     *****
      WRITE (5,150) NAME,OF,CITY,AND,STATE,YSTART,YEND,STORM,L,W,S,HMAX,
     1VOLMAX,PSAREA,DSEPRT,DA
  150 FORMAT ('1',10X////10X,'STATION:',3X,5A4,10X,I4,'    TO    ',I4////
     110X,'SIZE OF CRITICAL EVENT:   ',F4.2,'  INCHES'////10X,'POND VARIA
     1BLES:'//25X,'(A) BASE ','DIMENSIONS-- ',F7.2,' FEET BY',F7.2,' FEE
     1T'//25X,'(B) ','SIDE SLOPE--  RUN:RISE = ',F3.0,' : 1'//25X,'(C) M
     1AXIMUM',' DEPTH--   ',F5.2,'  FEET'//25X,'(D) MAXIMUM POND VOLUME',
```

```
     1'-- ',F9.2,' ACRE-INCHES'//25X,'(E) MAXIMUM POND SURFACE',' AREA--
     1  ',F8.2,' ACRES'//25X,'(F) DAILY SEEPAGE RATE--',1X,F10.5,' INCHE
     1S/DAY'//25X,'(G) DRAINAGE AREA--',F10.2,' ACRES'//'1',10X,'AREA VA
     1RIABLES:')
      DO 180 J=1,NPLOTS
      PLAREA = AREA(J)
      CROP = INCROP(J)
      SOIL = ISOIL(J)
      PLIT = NO
      IF (POND(J).GT.1) PLIT = BLNK
      TLIT = NONE
      IF (TERR(J).GT.1) TLIT = TERTYP
      MLIT = BLANK
      IF (MUL(J).GT.1) MLIT = STUB
      WRITE (5,160) J,PLAREA,KROP(CROP),SOIL,PLIT,TLIT,MLIT,RCNI(J),RCNI
     1I(J),RCNIII(J)
  160 FORMAT (//15X,'SUBAREA ',I2//25X,'(A) AREA--  ',F6.2,'   ACRES'//2
     15X,'(B) CROP--  ',A16//25X,'(C) SOIL TYPE--  ',I3,'  (SCS SOIL TYP
     1E)'//25X,'(D) CONSERVATION PRACTICES--  ',A4,' FLOW INTO POND',5X,
     1'TERRACES--',A16,5X,A16//25X,'(E) RUNOFF CURVE NUMBERS:',5X,'ANTEC
     1EDENT MOISTURE CONDITION I',3X,F3.0//55X,'ANTECEDENT MOISTURE COND
     1ITION II  ',F3.0//55X,'ANTECEDENT MOISTURE CONDITION III ',F3.0)
      IF (ROTATE(J).NE.1) WRITE (*,170) FLRCN1(J),FLRCN2(J),FLRCN3(J)
  170 FORMAT (/25X,'(F) CROP ROTATION WITH --  FALLOW'//35X,'FALLOW RUNO
     1FF CURVE NUMBERS: AMC I   ',F3.0//64X,'AMC II  ',F3.0//64X,'AMC II
     1I ',F3.0)
  180 CONTINUE
C     *****
C     *****   ***** ENTER YEARLY LOOP *****
C     *****
      DO 960 NY=1,YEARS
C     *****
C     *****   INITIALIZE VARIABLES
      SMDI = 0
      PERS = 0
      SPER = 0
      MAXVOL = 0.0
      LKEVPT = 0.0
      VOLCHG = 0.0
C     ***** A LINE WAS REMOVED AT THIS POINT IN SEPTEMBER, 1982
      DO 210 J=1,8
      DO 200 I=1,13
      DO 190 K=1,NPLOTS
  190 SMACCT(I,J,K) = 0.0
  200 PDACCT(I,J) = 0.0
  210 CONTINUE
      DO 220 K=1,NPLOTS
      PCROP(K) = ICROP(K)
  220 PEACCT(K) = 0.0
C     *****   ESTABLISH CROP ROTATIONS
      DO 250 K=1,NPLOTS
```

```
      IROT = ROTATE(K)
      GO TO (250,230,240), IROT
C     *****   ROTATE=3 FOR WHEAT PLANTING YEAR ('FALLOW YEAR')
C     *****   THE FALLOW RCN'S ARE ASSUMED TO BE REPRESENTATIVE
C     *****    THROUGHOUT THE FALLOW YEAR.
  230 ROTATE(K) = 3
      RCNI(K) = FLRCN1(K)
      RCNII(K) = FLRCN2(K)
      RCNIII(K) = FLRCN3(K)
      GO TO 250
C     *****   ROTATE=2 FOR WHEAT HARVESTING YEAR ('WHEAT YEAR')
C     *****   THE WHEAT RCN'S ARE ASSUMED TO BE REPRESENTATIVE
C     *****    THROUGHOUT THE WHEAT YEAR.
  240 ROTATE(K) = 2
      RCNI(K) = INRCN1(K)
      RCNII(K) = INRCN2(K)
      RCNIII(K) = INRCN3(K)
  250 CONTINUE
      WRITE (5,260)
  260 FORMAT (////'1',52X,'**** ANNUAL SUMMARY ****')
C     *****
C     *****
C     *****   ***** ENTER MONTHLY LOOP *****
C     *****
C     *****  MONTHLY LOOP ALTERED IN SEPTEMBER, 1982 TO ELIMINATE
C     *****  MSTART FROM THE VARIABLE LIST (NAMELIST OMEGA).
C     *****   FOLLOWING LINE REVISED IN SEPTEMBER, 1982
      DO 710 NM=1,12
C     *****
C     *****   ESTABLISH CROP ROTATIONS FOR WHEAT
      DO 290 II=1,NPLOTS
      IROT = ROTATE(II)
      GO TO (290,270,280), IROT
C     *****   IROT=2 FOR A WHEAT HARVESTING YEAR ('WHEAT YEAR')
  270 IF (NM.GT.MGSEP(II)) ICROP(II) = 7
      GO TO 290
C     *****   IROT=3 FOR A WHEAT PLANTING YEAR ('FALLOW YEAR')
  280 IF (NM.GE.MGSBP(II)) ICROP(II) = INCROP(II)
  290 CONTINUE
C     *****   READ DAILY METEOROLOGICAL DATA FOR ONE MONTH
  300 READ (3,310,END=970) KAN,STIND,YEAR,MONTH,(PREC(I),I=1,31),(TMAX(I
     1),I=1,31),(TMIN(I),I=1,31),(RA(I),I=1,31)
  310 FORMAT (I2,I4,2I2,31F4.2,62F3.0,31F4.1)
      jkyear=year+1900
      write(*,311) jkyear,nm
  311 format(' Now reading daily weather data for the year',2x,i5,' and
     1month',2x,i2)
      IF (STIND.NE.INDST) GO TO 300
      IF (YEAR.LT.YSTART-1900) GO TO 300
      IF (YEAR.GT.YEND-1900) GO TO 970
C     *****  A LINE WAS REMOVED AT THIS POINT IN SEPTEMBER, 1982
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C     *****   FOLLOWING LINE REVISED IN SEPTEMBER, 1982
      IF (MONTH.GT.NM.AND.YEAR.EQ.(YSTART-1900)) GOTO 320
      GO TO 340
  320 IPLUS1 = YSTART+1
C     *****   FOLLOWING 3 LINES REVISED SEPTEMBER, 1982
      WRITE (5,330) MONTH,YSTART,IPLUS1
  330 FORMAT (///'MONTHLY WEATHER DATA STARTS IN ',I2,'/',I4,'.  THE SIM
     1ULATION PERIOD WILL START IN 01/',I4,'.')
      YSTART = YSTART+1
      GO TO 300
  340 NDIM(2) = 28
      IF (NM.EQ.2.AND.TMAX(29).LT.900) NDIM(2) = 29
      NDAYS = NDIM(NM)
C     *****
C     *****
C     *****   ***** ENTER DAILY LOOP *****
C     *****
      DO 670 ND=1,NDAYS
C     *****
C     *****   THE FOLLOWING STATEMENTS CORRECT FOR MISSING DATA
C     *****    ON INPUT TAPE.
      IF (TMAX(ND).GT.250.0) TMAX(ND) = PDT+100.0
      IF (TMIN(ND).GT.250.0) TMIN(ND) = PDT+100.0
      IF (PREC(ND).GT.99.97) PREC(ND) = 0.0
C     *****   TAVG=AVERAGE DAILY AIR TEMPERATURE, DEGREES FAHRENHEIT
      TAVG(ND) = (TMAX(ND)+TMIN(ND))/2.0-100.0
C     *****   THE FOLLOWING CARD EVALUATES WHETHER THE 24 HOUR
C     *****    DESIGN STORM HAS BEEN EXCEEDED.
      IF (PREC(ND).GE.STORM/1.14) WRITE (5,350) NM,ND,YEAR,PREC(ND)
  350 FORMAT (20X,I2,'/',I2,'/',I2,'  CRITICAL EVENT EXCEEDED  ',2X,F10.
     12,'  INCH STORM  ')
C     *****   SUBROUTINE PETRT CALCULATES THE POTENTIAL ET,
C     *****    THE BARE SOIL EVAPORATION, AND THE LAKE EVAPORATION.
      ZWIND = WIND(NM)
      ZRHD = RHD(NM)
      ZRA = RA(ND)
      ZPSUNS = PSUNS(NM)
      AVGT = TAVG(ND)
C

      CALL PETRT (ZPSUNS,ZRA,ZRHD,AVGT,ZWIND,BRUNTA,BRUNTB,DELTA,E,EPRIM
     1,GAMMA,LAKEVP,PACK,PDT,PET,PETBS,RCROP)
C
C
C     *****   SUBROUTINE SNOWRT CALCULATES THE MOISTURE ADDED TO THE
C     *****    SUBAREA DUE TO SNOWMELT ON THE AREA
      PRECIP = PREC(ND)
      SNOVAP = 0.0
      WATER = PRECIP
      CALL SNOWRT (PRECIP,WATER,PACK,PET,TAVG(ND),SNOVAP)
C     *****
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C       *****    **** EVALUATION OF SOIL MOISTURE AND CALCULATION
C       *****                 OF ACTUAL EVAPOTRANSPIRATION ***
C       *****
        STRVOL = 0.0
        RAIN = WATER
C       *****
C       *****    ***** ENTER SUBAREA LOOP *****
C       *****
        DO 580 JJ=1,NPLOTS
C       *****
        STRNOF = 0.0
        CROP = ICROP(JJ)
        SOIL = ISOIL(JJ)
        KROPKO = KCROP(CROP,NM)
        ZSMUZ = SMUZ(JJ)
C       *****    FOLLOWING 2 LINES REVISED SEPTEMBER, 1982
        ZPWPUZ = PWPUZ(SOIL)
        ZAVFCU = AVLFCU(SOIL)
        RCN1 = RCNI(JJ)
        RCN2 = RCNII(JJ)
        RCN3 = RCNIII(JJ)
        ZFCU = FCU(SOIL)
        ZIAET = IAET(JJ)
        ZSM = SM(JJ)
        IF (RAIN) 370,370,360
C       *****    SUBROUTINE RNOFRT EVALUATES PRECIPITATION EXCESS USING
C       *****     THE SCS EQUATION.
  360   CALL RNOFRT (ZAVFCU,ZFCU,KROPKO,ZPWPUZ,RAIN,RCN1,RCN2,RCN3,RNOF,ZS
     1M,ZSMUZ)
        ABIN = ABSTIN(NM)
C       *****    SUBROUTINE IART EVALUATES THE INTERCEPTION STORAGE.
        CALL IART (IA,ZIAET,KROPKO,RAIN,PET,PETBS,XIAET,ABIN)
        IAET(JJ) = ZIAET
        GO TO 380
  370   RNOF = 0.0
        IA = 0.0
C       *****
C       *****    EVALUATE INFILTRATION INTO THE UPPER ZONE
  380   PERC = RAIN-RNOF-IA
        UZEVAP = 0.0
C       *****    CALCULATE PRESENT STORAGE AVAILABLE IN UPPER ZONE
        SMMAXU = 0.9*SMSATU(SOIL)-SMUZ(JJ)
C       *****    EVALUATE WATER CASCADED TO LOWER ZONE FOR STORAGE
        PERCL = PERC-SMMAXU
        IF (PERC.GT.SMMAXU) PERC = SMMAXU
        IF (PERCL.LT.0.0) PERCL = 0.0
        IF (SMUZ(JJ).GT.FCU(SOIL)) GO TO 390
        EXCESS = 0.0
        GO TO 400
C       *****    EVALUATE GRAVITATIONAL WATER IN UPPER ZONE
  390   EXCESS = SMUZ(JJ)-FCU(SOIL)
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C     *****
C     *****   IF THE CROP IS DORMANT OR THE SOIL LIES FALLOW, SOIL
C     *****    EVAPORATION IS EVALUATED
  400 IF (KCROP(CROP,NM).LE.0.0) GO TO 510
      T(JJ) = 0.0
C     *****   MODIFY PET BY THE PLANT CONSUMPTIVE USE COEFFICIENT
      AET = KCROP(CROP,NM)*PET
      IF (PET.LE.IAET(JJ)) AET = 0.0
C     *****   CHECK WHETHER SOIL MOISTURE LIMITS AET FROM THE UPPER ZONE
  405 IF (SMUZ(JJ)-(0.3*(AVLFCU(SOIL))+PWPUZ(SOIL))) 410,410,440
C     *****   CALCUATE AET FROM THE UPPER ZONE WHEN LIMITED BY SOIL
C     *****    MOISTURE.
  410 AVAILU = SMUZ(JJ)-PWPUZ(SOIL)
      IF (AVAILU.LE.0.0) AVAILU = 0.0
      AETUZ = 0.7*AET*(AVAILU/(0.3*AVLFCU(SOIL)))
C     *****   EVALUATE AVAILABLE WATER IN THE LOWER ZONE
      AVAILL = SMLZ(JJ)-PWPLZ(SOIL)
      IF (AVAILL.LE.0.0) AVAILL = 0.0
C     *****   CHECK WHETHER SOIL MOISTURE LIMITS AET FROM THE LOWER ZONE
      IF (SMLZ(JJ)-(0.3*(AVLFCL(SOIL))+PWPLZ(SOIL))) 420,420,430
C     *****   CALCUATE AET FROM THE LOWER ZONE WHEN LIMITED BY SOIL
C     *****    MOISTURE.
  420 AETLZ = 0.3*AET*(AVAILL/(0.3*AVLFCL(SOIL)))
      GO TO 450
  430 AETLZ = AET-AETUZ
      GO TO 450
C     *****   EVALUATE AET FROM BOTH ZONES UNDER WET CONDITIONS
  440 AETUZ = 0.7*AET
      AETLZ = 0.3*AET
      AVAILL = SMLZ(JJ)-PWPLZ(SOIL)
      IF (SMLZ(JJ).LE.0.3*(AVLFCL(SOIL))+PWPLZ(SOIL)) GO TO 420
  450 IF (PERC-SMMAXU) 460,470,470
C     *****
C     *****   EVALUATE SOIL MOISTURE
  460 SMUZ(JJ) = SMUZ(JJ)+PERC-AETUZ-EXCESS
      SMLZ(JJ) = SMLZ(JJ)-AETLZ+EXCESS
      GO TO 560
  470 SMUZ(JJ) = SMUZ(JJ)+SMMAXU-EXCESS-AETUZ
  480 SMMAXL = 0.9*FCL(SOIL)-SMLZ(JJ)
      IF (PERCL+EXCESS-SMMAXL) 490,490,500
  490 SMLZ(JJ) = SMLZ(JJ)+PERCL-AETLZ+EXCESS
      GO TO 560
  500 SMLZ(JJ) = SMLZ(JJ)+SMMAXL-AETLZ
      DPERC = PERCL+EXCESS-SMMAXL
      GO TO 570
C     *****   CALCULATE EVAPORATION FROM BARE SOIL SURFACE FOR MONTHS
C     *****    OCTOBER THROUGH MARCH OR WHEN THE SUBAREA IS FALLOW.
  510 AETUZ = 0.0
      AETLZ = 0.0
      IF (PACK.GT.0.0) GO TO 540
      IF (SMUZ(JJ).LT.(FCU(SOIL)-U(SOIL))) GO TO 520
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      EO(JJ) = FCU(SOIL)-SMUZ(JJ)
      IF (SMUZ(JJ).GE.FCU(SOIL)) EO(JJ) = 0.0
C     *****   CALCULATE STAGE 1 SOIL EVAPORATION
      UZEVAP = PETBS
      EO(JJ) = EO(JJ)+UZEVAP
      IF (EO(JJ).GT.U(SOIL)) UZEVAP = EO(JJ)-U(SOIL)
      T(JJ) = 0.0
      GO TO 530
C     *****   CALCULATE STAGE 2 SOIL EVAPORATION
  520 T(JJ) = T(JJ)+1
      UZEVAP = C(SOIL)*SQRT(T(JJ))-C(SOIL)*SQRT(T(JJ)-1)
  530 IF (UZEVAP.GT.(PETBS-IAET(JJ))) UZEVAP = PETBS-IAET(JJ)
      IF (UZEVAP.LT.0.0) UZEVAP = 0.0
      IF (SMUZ(JJ)-PWPUZ(SOIL).LT.UZEVAP) UZEVAP = SMUZ(JJ)-PWPUZ(SOIL)
      GO TO 550
  540 UZEVAP = 0.0
  550 SMUZ(JJ) = SMUZ(JJ)-UZEVAP+PERC-EXCESS
      IF (SMUZ(JJ).LE.PWPUZ(SOIL)) SMUZ(JJ) = PWPUZ(SOIL)
      GO TO 480
  560 IF (SMLZ(JJ).LT.PWPLZ(SOIL)) AETLZ = AETLZ-(PWPLZ(SOIL)-SMLZ(JJ))
      IF (SMLZ(JJ).LE.PWPLZ(SOIL)) SMLZ(JJ) = PWPLZ(SOIL)
      DPERC = SMLZ(JJ)-0.9*FCL(SOIL)
      IF (DPERC.LT.0.0) DPERC = 0.0
      IF (SMLZ(JJ).GT.0.9*FCL(SOIL)) SMLZ(JJ) = 0.9*FCL(SOIL)
  570 AETUZ = AETUZ+UZEVAP
C     *****   SM=SOIL MOISTURE IN THE GROWING ZONE, IN INCHES
C     *****   IAET=AMOUNT OF ET DEDUCTED FROM INTERCEPTION
C     *****    STORAGE (IN.)
C     *****   AETU=ET AMOUNT FROM THE UPPER ZONE (IN.)
C     *****   AETL=ET AMOUNT FROM THE LOWER ZONE (IN.)
C     *****   NDPERC=AMOUNT OF DEEP PERCOLATION (IN.)
C     *****   NIA=INITIAL ABSTRACTION AMOUNT (IN.)
C     *****   NRNOF=PRECIPITATION EXCESS AMOUNT (IN.)
C     *****   STRNOF=PRECIPITATION EXCESS AMOUNT WHICH FLOWS
C     *****    INTO POND (IN.)
C     *****   STRVOL=PRECIPITATION EXCESS VOLUME WHICH FLOWS
C     *****    INTO THE POND (ACRE-INCHES)
      SM(JJ) = SMUZ(JJ)+SMLZ(JJ)
C     *****SOIL MOISTURE DROUGHT INDEX ROUTINE
C     *****THE FOLLOWING CALCULATIONS DETERMINE A SOIL MOISTURE
C     *****DROUGHT INDEX FOR A GIVEN CROP DURING A PREDETERMINED
C     *****GROWING PERIOD - MBEGIN TO MEND.  IT SUMS THE NUMBER
C     *****OF DAYS THAT SOIL MOISTURE IN THE UPPER ZONE IS LESS THAN
C     *****30 PERCENT OF FIELD CAPACITY AND THE MAXIMUM NUMBER OF
C     *****DAYS THE CONDITION PERSISTS DURING EACH YEAR.
      IF (JJ.EQ.SKPLOT) GOTO 575
      IF (CROP.NE.JCROP) GOTO 575
      IF (NM.LT.MBEGIN.OR.NM.GT.MEND) GOTO 575
      IF (SMUZ(JJ).GE.(0.3*(AVLFCU(SOIL))+PWPUZ(SOIL))) GOTO 574
      SMDI=SMDI+1
      PERS=PERS+1
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      IF (PERS.GT.SPER) SPER=PERS
      GOTO 575
  574 PERS=0
  575 IAET(JJ) = XIAET
      AETU(JJ) = AETUZ
      AETL(JJ) = AETLZ
      NDPERC(JJ) = DPERC
      NIA(JJ) = IA
      NRNOF(JJ) = RNOF
      IF (POND(JJ).GT.1) STRNOF = RNOF
      STRVOL = STRVOL+STRNOF*AREA(JJ)
  580 CONTINUE
C     *****
C     *****
C     *****   **** CALCULATION OF SURFACE AREA AND DETERMINATION OF
C     *****           SURFACE EVAPORATION FROM STORAGE FACILITY ***
C     *****
      IF (PONVOL.LE.0.0) GO TO 600
C     *****   THE FOLLOWING CALCULATION EXPRESSES THE VOLUME OF WATER
C     *****    IN THE POND IN CUBIC FEET.
      V = PONVOL*3630
C     *****        THE FOLLOWING CALCULATIONS DETERMINE THE SURFACE
C     *****   AREA OF THE POND AS A FUNCTION OF THE STORAGE VOLUME.
C     *****   AREA IS IN SQUARE FEET AND VOLUME IS IN CUBIC FEET.
C     *****   THE POND IS SHAPED LIKE AN INVERTED FRUSTRUM OF A
C     *****   PYRAMID. INPUT PARAMETERS TO SIZE THE FACILITY ARE
C     *****   LENGTH (L) AND WIDTH (W) OF THE BASE IN FEET, AND SIDE
C     *****   SLOPES EXPRESSED AS A RATIO OF RUN:RISE.
C     *****        INPUTS TO THE POND INCLUDE PRECIPITATION EXCESS
C     *****   AND DIRECT PRECIPITATION ONTO THE SURFACE. LOSSES
C     *****   INCLUDE EVAPORATION, EXFILTRATION, AND OVERFLOWS.
C     *****
C     *****   B2 IS THE AREA OF THE SURFACE LIQUID IN SQUARE FEET.
      HAPRX = (PONVOL/VOLMAX)*HMAX
  590 VC = A1*HAPRX+A2*HAPRX**2+A3*HAPRX**3
      DV = V-VC
      DVDH = A1+A4*HAPRX+A5*HAPRX**2
      H = HAPRX+DV/DVDH
      IF (ABS(H-HAPRX).LT.0.1) GO TO 600
      HAPRX = H
      GO TO 590
  600 IF (H.GT.HMAX) H = HMAX
      B2 = (W+2.*S*H)*(L+2.*S*H)
      IF (FROZE.EQ.1) LAKEVP = 0.0
      LKEVPT = LKEVPT+LAKEVP
      SEVAP = B2*(LAKEVP/12)
C     *****   SEVAP IS THE VOLUME OF WATER EXTRACTED FROM THE STORAGE
C     *****     FACILITY BY FREE SURFACE EVAPORATION.
      IF ((SEVAP/3630).GT.PONVOL) SEVAP = PONVOL*3630
      PONVOL = PONVOL-(SEVAP/3630)
      IF (PONVOL.LE.0.0) PONVOL = 0.0
```

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C      *****    SUBROUTINE SEEPGE CALCULATES THE DAILY AMOUNT OF
C      *****     EXFILTRATION FORM THE POND
       CALL SEEPGE (B2,PONVOL,DASEEP,DSEPRT)
C      *****
C      *****    THE VOLUMES OF CALCULATED RUNOFF AND DIRECT PRECIPITATION
C      *****     ARE ADDED TO THE POND VOLUME
       PRCPVL = PRECIP*B2/43560.0
C      *****    THE VOLUME OF WATER REMAINING AT THE END OF THE DAY IS
C      *****     EXPRESSED IN ACRE-INCHES.
       PONVOL = PONVOL+PRCPVL+STRVOL
C      *****
C      *****    THE FOLLOWING STATEMENTS DETERMINE WHETHER THE POND HAS
C      *****    OVERFLOWED AND IF SO, THE QUANTITY DISCHARGED
       DSCHRG = 0.0
       IF (PONVOL-VOLMAX) 630,630,610
  610  DSCHRG = PONVOL-VOLMAX
       IF (DSCHRG.GE.PEAK) PEAK = DSCHRG
C      *****    NODSCH=TOTAL NUMBER OF DISCHARGE DAYS
       NODSCH = NODSCH+1
       DSCVOL = DSCVOL+DSCHRG
C      *****    VOLUME CALCULATIONS TO INCREASE THE POND SIZE FOR 100%
C      *****     CONTROL
       PCNTRL = CONTRL*100.0
       VOLCHG = CONTRL*PONVOL-VOLMAX+VOLCHG
       VOLMX1 = VOLMAX+VOLCHG
       VCB = 2*S*HMAX
       VCC = ((4./3.)*S**2.0)-(VOLMX1*3630./HMAX)
       VCD = VCB**2-(4.*VCC)
       VC1 = SQRT(VCD)
       DIM = (VC1-VCB)/2.0
C      *****    WRITE DAILY DISCHARGE MESSAGE
       WRITE (5,620) NM,ND,YEAR,DSCHRG,VOLMX1,PCNTRL,DIM
  620  FORMAT (/,1X,I2,'/',I2,'/',I2,' - DISCHARGE OF ',F7.2,' ACRE-IN ',
      1'REQUIRES VOLUME OF',F8.2,' ACRE-IN FOR ',F6.2,' % CONTROL WHERE L
      2 = W = ',F8.2)
       PONVOL = VOLMAX
  630  CONTINUE
C      *****
C      *****                  UPDATE SOIL MOISTURE ACCOUNTS
C      *****
       DO 640 I3=1,NPLOTS
       SMACCT(NM,1,I3) = SMACCT(NM,1,I3)+PRECIP
       SMACCT(NM,2,I3) = SMACCT(NM,2,I3)+NIA(I3)
       SMACCT(NM,3,I3) = SMACCT(NM,3,I3)+NRNOF(I3)
       SMACCT(NM,4,I3) = SMACCT(NM,4,I3)+NDPERC(I3)
       SMACCT(NM,5,I3) = SMACCT(NM,5,I3)+PET
       SMACCT(NM,6,I3) = SMACCT(NM,6,I3)+AETU(I3)+AETL(I3)+SNOVAP
       SMACCT(NM,7,I3) = SMACCT(NM,7,I3)+SM(I3)-SMPD(I3)
  640  SMPD(I3) = SM(I3)
C      *****
C      *****                  UPDATE POND ACCOUNT
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C     *****
      PDACCT(NM,1) = PDACCT(NM,1)+PRCPVL
      PDACCT(NM,2) = PDACCT(NM,2)+STRVOL
      PDACCT(NM,3) = PDACCT(NM,3)+SEVAP/3630.0
      PDACCT(NM,4) = PDACCT(NM,4)+DASEEP
      PDACCT(NM,5) = PDACCT(NM,5)+DSCHRG
      PDACCT(NM,6) = PDACCT(NM,6)+(PONVOL-PDVOL)
      IF (ND.EQ.NDAYS) PDACCT(NM,7) = H
      PDVOL = PONVOL
      IF (PONVOL.GT.MAXVOL) MAXVOL = PONVOL
C     *****  STATISTICAL PRECIPITATION AND RUNOFF FREQUENCY
C     *****    CALCULATIONS
      IF (PREC(ND).GT.0.0) CTPDAY = CTPDAY+1.0
      IPLOT = NPLOTS
      IF (NPLOTS.GT.4) NPLOTS = 4
      DO 660 II=1,25
      IF (PREC(ND).GT.FREQ(II)) CTP(II) = CTP(II)+1.0
      CNTR = 0.0
      DO 650 KI=1,NPLOTS
      IF (NRNOF(KI).GT.0.0.AND.II.EQ.1) CTRDAY(KI) = CTRDAY(KI)+1.0
      IF (NRNOF(KI).GT.0.0) CNTR = 1.0
  650 IF (NRNOF(KI).GT.FREQ(II)) CTR(II,KI) = CTR(II,KI)+1.0
  660 IF (PREC(ND).GT.FREQ(II).AND.CNTR.EQ.1.0) CTPR(II) = CTPR(II)+1.0
      NPLOTS = IPLOT
      IF (NM.EQ.MPOND.AND.ND.EQ.1) VOLPER=100.*PONVOL/VOLMAX
  670 CONTINUE
C     *****
C     *****  ***** EXIT DAILY LOOP *****
C     *****
C     *****  UPDATE ACCOUNTS
      DO 680 J=1,6
      PDACCT(13,J) = PDACCT(13,J)+PDACCT(NM,J)
  680 CONTINUE
      DO 700 MP=1,NPLOTS
      SMACCT(NM,8,MP) = SM(MP)
      DO 690 J=1,8
  690 SMACCT(13,J,MP) = SMACCT(13,J,MP)+SMACCT(NM,J,MP)
  700 CONTINUE
  710 CONTINUE
C     *****
C     *****  ***** EXIT MONTHLY LOOP *****
C     *****
      DO 720 MP=1,NPLOTS
      SMACCT(13,8,MP) = SMACCT(12,8,MP)
  720 CONTINUE
C     *****  DSNOW=CHANGE IN SNOWPACK STORAGE (IN.)
C     *****  PACKPY=SNOWPACK STORAGE FOR NEXT YEAR'S CALCULATIONS (IN)
C     *****  DSRNFF=ANNUAL PRECIPITATION EXCESS FROM EACH SUBAREA (IN.)
C     *****  AINTER=ANNUAL INTERCEPTION AMOUNT FOR EACH SUBAREA (IN.)
C     *****  AAETRS=ANNUAL ACTUAL ET FROM EACH SUBAREA (IN.)
C     *****  ACHSOM=ANNUAL CHANGE IN SOIL MOISTURE FOR EACH
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C      *****     SUBAREA (IN.)
C      *****    DSPERC=ANNUAL DEEP PERCOLATION AMOUNT FOR EACH
C      *****     SUBAREA (IN.)
C      *****    PEACCT=ANNUAL PRECIPITATION EXCESS FROM EACH SUBAREA (IN.)
C      *****    TPREC=TOTAL PRECIPITATION FOR SIMULATION RUN (IN.)
C      *****    DRY=LOWEST ANNUAL PRECIPITATION AMOUNT (IN.)
C      *****    WET=GREATEST ANNUAL PRECIPITATION AMOUNT (IN.)
C      *****    NYDSCH=TOTAL NUMBER OF YEARS HAVING A DISCHARGE
C      *****    PRCPT=TOTAL VOLUME OF DIRECT PRECIPITATION ON THE
C      *****     POND SURFACE DURING THE SIMULATION RUN (ACRE-INCHES)
C      *****    PEINT=TOTAL VOLUME OF PRECIPITATION EXCESS FLOWING INTO
C      *****     POND DURING THE SIMULATION RUN (ACRE-INCHES)
C      *****    EVAPT=TOTAL VOLUME OF EVAPORATION FROM THE POND SURFACE
C      *****     DURING THE SIMULATION RUN (ACRE-INCHES)
C      *****    EXFILT=TOTAL VOLUME OF EXFILTRATION FROM THE POND
C      *****     DURING THE SIMULATION RUN (ACRE-INCHES)
C      *****    MAXVOL=MAXIMUM % OF POND VOLUME UTILIZED DURING THE
C      *****     SIMULATION RUN
C      *****    EVAPLK=TOTAL CALCULATED LAKE EVAPORATION FOR SIMULATION
C      *****     RUN (INCHES)
C      *****    DAYLD=VOLUME OF PRECIPITATION EXCESS FROM THE POND
C      *****     WATERSHED (INCHES)
      PDACCT(13,7) = PDACCT(12,7)
      DSNOW = PACK-PACKPY
      PACKPY = PACK
      DO 730 KT=1,NPLOTS
      DSRNFF(KT) = DSRNFF(KT)+SMACCT(13,3,KT)
      AINTER(KT) = AINTER(KT)+SMACCT(13,2,KT)
      APETRS(KT) = APETRS(KT)+SMACCT(13,5,KT)
      AAETRS(KT) = AAETRS(KT)+SMACCT(13,6,KT)
      ACHSOM(KT) = ACHSOM(KT)+SMACCT(13,7,KT)
      DSPERC(KT) = DSPERC(KT)+SMACCT(13,4,KT)
      PEACCT(KT) = SMACCT(13,3,KT)
      TTPERC(NY,KT) = SMACCT(13,4,KT)
      TTRNFF(NY,KT) = SMACCT(13,3,KT)
      TTAET(NY,KT) = SMACCT(13,6,KT)
      TTPET(NY,KT) = SMACCT(13,5,KT)
      TTINT(NY,KT) = SMACCT(13,2,KT)
  730 CONTINUE
      TPREC = TPREC+SMACCT(13,1,1)
      IF ((YEAR+1900).EQ.YSTART) DRY = SMACCT(13,1,1)
      IF (SMACCT(13,2,1).GE.WET) WET = SMACCT(13,1,1)
      IF (SMACCT(13,2,1).LE.DRY) DRY = SMACCT(13,1,1)
      IF (PDACCT(13,5).GT.0.0) NYDSCH = NYDSCH+1
      PRCPT = PRCPT+PDACCT(13,1)
      PEINT = PEINT+PDACCT(13,2)
      EVAPT = EVAPT+PDACCT(13,3)
      EXFILT = EXFILT+PDACCT(13,4)
      MAXVOL = MAXVOL*100.0/VOLMAX
      LKACCT(NY) = LKEVPT
      EVAPLK = EVAPLK+LKEVPT
```

```
      DAYLD = PDACCT(13,5)/DA
C     *****
C     *****
C     *****                              PRINT POND ACCOUNT
C     *****
      GO TO (740,770,740,770), OUTPUT
C     *****
C     *****                 PRINT POND ACCOUNT ANNUAL VALUES ONLY
C     *****
  740 WRITE (5,750) YEAR
  750 FORMAT (/'0',39X,'WATER ACCOUNT FOR THE POND IN ACRE-INCHES',9X,'1
     19',I2//10X,112('-')/22X,'INFLOWS',40X,'OUTFLOWS'/10X,31('-'),10X,4
     14('-')/10X,'PRECIPITATION',4X,'PRECIP. ','EXCESS',10X,'SURFACE EVA
     1P.',5X,'EXFILTRATION',5X,'DISCHARGE',5X,'VOL. CHANGE',5X,'HEIGHT')
      WRITE (5,760) (PDACCT(13,K),K=1,7)
  760 FORMAT (9X,F11.1,7X,F11.1,12X,F11.1,6X,F11.1,4X,F11.1,4X,F11.1,7X,
     1F6.2)
      GO TO 800
C     *****
C     *****                 PRINT POND ACCOUNT ON MONTHLY BASIS
C     *****
  770 WRITE (5,780) YEAR
  780 FORMAT ('0',39X,'WATER ACCOUNT FOR THE POND IN ACRE-INCHES    -
     1 19',I2//5X,122('-')/27X,'INFLOWS',40X,'OUTFLOWS'/15X,31('-'),12X,
     245('-')/5X,'MONTH',5X,'PRECIPITATION',4X,'PRECIP. EXCESS',12X,'SUR
     3FACE EVAP.',4X,'EXFILTRATION',7X,'DISCHARGE',4X,'VOL. CHANGE',3X,'
     4HEIGHT')
      WRITE (5,790) (AMONTH(I),(PDACCT(I,K),K=1,7),I=1,13)
  790 FORMAT (6X,A4,6X,F11.1,6X,F11.1,13X,F11.1,6X,F11.1,5X,F11.1,4X,F11
     1.1,4X,F6.2)
  800 WRITE (5,810) PACK,YEAR,DSNOW
  810 FORMAT (//////10X,'SNOW MOISTURE INFORMATION:'//15X,'MOISTURE ','S
     1TORED IN SNOW PACK ON DEC. 31---',F5.2,5X,'CHANGE IN ','SNOW STORA
     1GE DURING 19',I2,'---',2X,F5.2//15X,'CHANGE ','IN SOIL MOISTURE =
     1(INPUTS) - (OUTPUTS) - (CHANGE IN ','SNOW STORAGE)')
      WRITE (5,820)
  820 FORMAT ('1')
      DO 920 N3=1,NPLOTS
      PLIT = NO
      IF (POND(N3).GT.1) PLIT = BLNK
      TLIT = NONE
      IF (TERR(N3).GT.1) TLIT = TERTYP
      MLIT = BLANK
      IF (MUL(N3).GT.1) MLIT = STUB
      CROP = PCROP(N3)
      SOIL = ISOIL(N3)
      WRITE (5,830) N3,AREA(N3),SOIL,KROP(CROP),RCNI(N3),RCNII(N3),RCNII
     1I(N3),PLIT,TLIT,MLIT
  830 FORMAT (///58X,'SUBAREA NO.',I3//2X,'AREA--',F9.0,' ACRES',5X,'SOI
     1L TYPE--',I2,5X,'CROP--',A8,13X,'RUNOFF CURVE NUMBERS:','  AMCI--'
     1,F3.0,2X,'AMCII--',F3.0,2X,'AMCIII--',F3.0/30X,A4,' FLOW INTO POND
```

```
     1',10X,'TERRACES--',2A8,10X,2A8)
      GO TO (840,870,840,870), OUTPUT
C     *****
C     *****       PRINT SOIL MOISTURE ACCOUNT ANNUAL TOTALS ONLY
C     *****
  840 WRITE (5,850) YEAR
  850 FORMAT (' ',35X,'WATER BALANCE (INCHES) IN THE SUBAREA - 19',I2,/2
     10X,93('-')/16X,'INPUTS',32X,'OUTPUTS'/12X,13('-'),5X,55('-')/12X,'
     2PRECIPITATION',5X,'INTERCEPTION   PRECIP. EXCESS   ','PERCOLATION'
     3,9X,'AET',8X,'CHANGE IN SM',3X,'SOIL MOISTURE')
      WRITE (5,860) (SMACCT(13,N2,N3),N2=1,8)
  860 FORMAT (16X,F5.2,13X,F5.2,10X,F5.2,11X,F5.2,11X,F5.2,10X,F5.2,10X,
     1F5.2)
      IF (CROP.NE.JCROP) GOTO 920
      IF (SKPLOT.EQ.N3) GOTO 920
      WRITE (5,865) SMDI,SPER,AMONTH(MBEGIN),AMONTH(MEND)
  865 FORMAT ('0',9X,'SOIL MOISTURE DROUGHT INDEX = ',I4,' DAYS, WITH ',
     1I4,' CONSECUTIVE DAYS'/,10X,'WITH LESS THAN ADEQUATE SOIL MOISTURE
     2 DURING ',A4,' THROUGH ',A4)
      WRITE (5,866) VOLPER,AMONTH(MPOND)
  866 FORMAT (10X,'POND WAS ',F6.2,'% FULL AT BEGINNING OF 'A4)
      GO TO 920
C     *****
C     *****       PRINT SOIL MOISTURE ACCOUNTS ON MONTHLY BASIS
C     *****
  870 WRITE (5,880) YEAR
  880 FORMAT (35X,'WATER BALANCE (INCHES) IN THE SUBAREA - 19',I2/8X
     1,120('-')/22X,'INPUTS',32X,'OUTPUTS'/18X,13('-'),6X,57('-')/8X,'MO
     2NTH',5X,'PRECIPITATION',6X,'INTERCEPT.  ','PRECIP. EXCESS  PERC.',
     36X,'PET  ',7X,'AET '8X'CHANGE IN SM',3X,'SOIL MOISTURE')
      DO 900 N1=1,13
      WRITE (5,890) AMONTH(N1),(SMACCT(N1,N2,N3),N2=1,8)
  890 FORMAT (9X,A4,11X,F5.2,11X,F5.2,7X,F5.2,7X,F5.2,7X,F5.2,7X,F5.2,7X,
     1F5.2,10X,F5.2)
  900 CONTINUE
      WRITE (5,910)
  910 FORMAT (///)
  920 CONTINUE
      GO TO (960,960,930,930), OUTPUT
C     *****
C     *****    PUNCH DATA CARDS FOR DEPLETION PROGRAM
C     *****
  930 DO 940 I=1,NPLOTS
      IPEACT(I) = PEACCT(I)*100.0
      IDAYLD = DAYLD*100.0
  940 CONTINUE
      WRITE (4,950) YEAR,IDAYLD,(IPEACT(I),I=1,NPLOTS)
  950 FORMAT (I2,I4,18I4)
  960 CONTINUE
C     *****
C     *****
```

```
C      *****    ***** EXIT YEARLY LOOP *****
C      *****
C      *****
C      *****    CALCULATE AVERAGE ANNUAL VALUES
C      *****    RANGE=RANGE OF ANNUAL PRECIPITATION AMOUNTS (IN.)
C      *****    AVGMD=AVERAGE MOISTURE DEFICIT (IN.)
C
C      *****    THE FOLLOWING LINES ARE ADDED TO CALCULATE THE
C      *****    DISCHARGE OF KINGS CREEK ON THE KONZA PRAIRIE IN
C      *****    ACRE-FEET
C
      DO 963 I=1,YEARS
      DO 965 J=1,NPLOTS
        PERCVOL(I,J) = TTPERC(I,J)/12*ACRES*PCTAREA(J)/100
        RUNVOL(I,J) = TTRNFF(I,J)/12*ACRES*PCTAREA(J)/100
        AETVOL(I,J) = TTAET(I,J)/12*ACRES*PCTAREA(J)/100
        PETVOL(I,J) = TTPET(I,J)/12*ACRES*PCTAREA(J)/100
        INTVOL(I,J) = TTINT(I,J)/12*ACRES*PCTAREA(J)/100
  965 CONTINUE
  963 CONTINUE
  970 EVAP = EVAPLK/YEARS
      APREC = TPREC/YEARS
      RANGE = WET-DRY
      AVGMD = EVAP-APREC
      PRCPA = PRCPT/YEARS
      PEINA = PEINT/YEARS
      EVAPA = EVAPT/YEARS
      EXFILA = EXFILT/YEARS
      DSCRGA = DSCVOL/YEARS
      IF (NYDSCH) 990,990,980
C      *****    ADYD=AVG. NUMBER OF DISCHARGES/YEARS HAVING A DISCHARGE
C      *****    AVANDC=AVERAGE ANNUAL DISCHARGE VOLUME
  980 ADYD = NODSCH/NYDSCH
      AVANDC = DSCVOL/NYDSCH
      DSCRG = DSCVOL/NODSCH
      GO TO 1000
  990 ADYD = 0.0
      DSCRG = 0.0
      AVANDC = 0.0
 1000 DO 1010 J=1,NPLOTS
      DSPERC(J) = DSPERC(J)/YEARS
      DSRNFF(J) = DSRNFF(J)/YEARS
      ACHSOM(J) = ACHSOM(J)/YEARS
      AINTER(J) = AINTER(J)/YEARS
      APETRS(J) = APETRS(J)/YEARS
 1010 AAETRS(J) = AAETRS(J)/YEARS
      IF (NPLOTS.GT.4) NPLOTS = 4
      DO 1030 J=1,25
      PRECAC(J,2) = CTP(J)
      IF (CTPDAY.GT.0.0) CTP(J) = CTP(J)/CTPDAY*100.0
      PRECAC(J,1) = CTP(J)
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```
      PRECAC(J,3) = CTPR(J)
      DO 1020 I=1,NPLOTS
      INUM1 = 4+I
      RUNACC(J,INUM1) = CTR(J,I)
      IF (CTRDAY(I).GT.0.0) CTR(J,I) = CTR(J,I)/CTRDAY(I)*100.0
 1020 RUNACC(J,I) = CTR(J,I)
 1030 CONTINUE
      NPLOTS = IPLOT
      WRITE (5,1031)
 1031 FORMAT (/8X,'TOTAL LAKE EVAP.')
      XYEAR = YSTART
      DO 1033 I = 1,YEARS
      WRITE (5,1035) XYEAR,LKACCT(I)
 1035 FORMAT (3X,I4,7X,F6.2)
      XYEAR = XYEAR+1
 1033 CONTINUE
C
C     ***** PRINTS OUT STREAM FLOW FOR EACH PLOT *****
C
      XYEAR = YSTART
      DO 1036 I = 1,YEARS
      WRITE (5,1037) XYEAR
 1037 FORMAT (//5X,'YEAR =',1X,F5.0/15X,'PERCOLATION, AC-FT',3X,
     1'RUNOFF, AC-FT',5X,'TOTAL, AC-FT',10X,'PET, AC-FT',3X,
     2'AET, AC-FT',2X,'INTERCEPTION, AC-FT')
      FLOWTT = 0.0
      FLOW = 0.0
      DO 1038 J = 1,NPLOTS
      FLOW = PERCVOL(I,J)+RUNVOL(I,J)
      WRITE (5,1039) J,PERCVOL(I,J),RUNVOL(I,J),FLOW,PETVOL(I,J),
     1AETVOL(I,J),INTVOL(I,J)
 1039 FORMAT (5X,'PLOT ',I2,8X,F8.2,12X,F8.2,11X,F8.2,9X,F8.2,
     15X,F8.2,9X,F8.2)
      FLOWTT = FLOWTT + FLOW
 1038 CONTINUE
      WRITE (5,1041) FLOWTT
 1041 FORMAT(5X,'TOTAL YEARLY FLOW IN ACRE-FT',25X,F8.2)
      XYEAR = XYEAR+1
 1036 CONTINUE
C     *****
C     *****   PRINT FINAL SUMMARY
C     *****
      WRITE (5,1040)
 1040 FORMAT (/'1',52X,'***** FINAL SUMMARY *****')
      WRITE (5,1060)
      WRITE (5,1050) NAME,OF,CITY,AND,STATE,YSTART,YEND,YEARS
 1050 FORMAT ('0',20X,'STATION:',3X,5A4,10X,I4,'  TO  ',I4,10X,I2,' TOTA
     1L YEARS')
 1060 FORMAT ('0',10X,'METEOROLOGICAL SUMMARY')
      WRITE (5,1070) EVAP
 1070 FORMAT ('0',25X,'AVERAGE ANNUAL LAKE EVAPORATION=',F6.2,' INCHES')
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      WRITE (5,1080) APREC
 1080 FORMAT ('0',25X,'AVERAGE ANNUAL PRECIPITATION=',F6.2,' INCHES')
      WRITE (5,1090) RANGE,DRY,WET
 1090 FORMAT ('0',25X,'PRECIPITATION RANGE=',F6.2,' INCHES   (FROM A LOW
     1 OF',F6.2,' INCHES  TO A HIGH OF ',F6.2,' INCHES)')
      WRITE (5,1100) AVGMD
 1100 FORMAT ('0',25X,'AVERAGE MOISTURE DEFICIT=',F6.2,' INCHES')
      WRITE (5,1110)
 1110 FORMAT ('0',10X,'SUMMARY OF POND OPERATIONS')
      WRITE (5,1120) NYDSCH
 1120 FORMAT ('0',25X,'NUMBER OF YEARS HAVING A DISCHARGE = ',I4)
      WRITE (5,1130) ADYD
 1130 FORMAT ('0',25X,'AVERAGE NUMBER OF DISCHARGES PER YEAR HAVING A DI
     1SCHARGE = ',F6.2)
      WRITE (5,1140) DSCRG
 1140 FORMAT ('0',25X,'AVERAGE DAILY DISCHARGE VOLUME = ',F12.2,' ACRE-I
     1NCHES')
      WRITE (5,1150) PEAK
 1150 FORMAT ('0',25X,'MAXIMUM DAILY DISCHARGE VOLUME =',F12.2,' ACRE-IN
     1CHES')
      WRITE (5,1160) AVANDC
 1160 FORMAT ('0',25X,'AVERAGE DISCHARGE VOLUME PER YEAR HAVING A DISCHA
     1RGE = ',F12.2,' ACRE-INCHES')
      WRITE (5,1170) DSCVOL
 1170 FORMAT ('0',25X,'TOTAL DISCHARGE VOLUME=',F12.2,' ACRE-INCHES')
      WRITE (5,1180) PRCPA
 1180 FORMAT ('0',25X,'AVERAGE ANNUAL DIRECT PRECIPITATION VOLUME=',F12.
     12,' ACRE-INCHES')
      WRITE (5,1190) PEINA
 1190 FORMAT ('0',25X,'AVERAGE ANNUAL PRECIPITATION EXCESS VOLUME FLOWIN
     1G INTO POND=',F12.2,' ACRE-INCHES')
      WRITE (5,1200) EVAPA
 1200 FORMAT ('0',25X,'AVERAGE ANNUAL EVAPORATION VOLUME=',F12.2,' ACRE-
     1INCHES')
      WRITE (5,1210) EXFILA
 1210 FORMAT ('0',25X,'AVERAGE ANNUAL EXFILTRATION=',F12.2,' ACRE-INCHES
     1')
      WRITE (5,1220) DSCRGA
 1220 FORMAT ('0',25X,'AVERAGE ANNUAL DISCHARGE VOLUME = ',F12.2,' ACRE-
     1INCHES')
      WRITE (5,1230)
 1230 FORMAT ('1')
      WRITE (5,1240)
 1240 FORMAT ('0',10X,'SUMMARY OF WATERSHED SUBAREAS')
      DO 1310 J=1,NPLOTS
      WRITE (5,1250) J
 1250 FORMAT ('0',15X,'SUBAREA NO.',I3)
      WRITE (5,1260) DSRNFF(J)
 1260 FORMAT ('0',25X,'AVERAGE ANNUAL PRECIPITATION EXCESS =',F6.2,' INC
     1HES')
      WRITE (5,1270) DSPERC(J)
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 1270 FORMAT ('0',25X,'AVERAGE ANNUAL PERCOLATION =',F6.2,' INCHES')
      WRITE (5,1280) AINTER(J)
 1280 FORMAT ('0',25X,'AVERAGE ANNUAL INTERCEPTION =',F6.2,' INCHES')
      WRITE (5,1285) APETRS(J)
 1285 FORMAT ('0',25X,'AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION =',
     1F6.2,' INCHES')
      WRITE (5,1290) AAETRS(J)
 1290 FORMAT ('0',25X,'AVERAGE ANNUAL EVAPOTRANSPIRATION =',F6.2,' INCHE
     1S')
      WRITE (5,1300) ACHSOM(J)
 1300 FORMAT ('0',25X,'AVERAGE ANNUAL CHANGE IN SOIL MOISTURE =',F6.2,'
     1INCHES')
 1310 CONTINUE
C     *****
C     ***** PRINT STATISTICAL SUMMARY
C     *****
      WRITE (5,1320)
 1320 FORMAT ('1',10X,'SUMMARY OF STATISTICAL DATA')
      WRITE (5,1330)
 1330 FORMAT ('0',41X,'PRECIPITATION FREQUENCY DATA',//27X,'INTENSITY',5
     1X,'FREQUENCY',5X,'FREQUENCY',5X,'RUNOFF FREQ.',/29X,'(IN.)',10X,'(
     2%)',9X,'(DAYS)',10X,'(DAYS)',/)
      WRITE (5,1340) (ASTAT(I),(PRECAC(I,J),J=1,3),I=1,25)
 1340 FORMAT (29X,A4,3F15.2)
      WRITE (5,1350)
 1350 FORMAT ('1',///60X,'RUNOFF FREQUENCY DATA',//27X,'INTENSITY',15X,'
     1FREQUENCY (%)',26X,'FREQUENCY (DAYS)',/29X,'(IN.)',7X,'PLOT 1   PL
     2OT 2   PLOT 3   PLOT 4',8X,'PLOT 1   PLOT 2   PLOT 3   PLOT 4',/)
      WRITE (5,1360) (ASTAT(I),(RUNACC(I,J),J=1,8),I=1,25)
 1360 FORMAT (29X,A4,5X,4F9.2,4X,4F9.2)
      STOP
      END
      SUBROUTINE CROPCO (CROP,MGSB,DGSB,MGSE,DGSE,KCROP,NDIM,MMAT,
     1CROPVAR,KCROPVR)
C     SUBROUTINE CROPCO CALCULATES THE CROP COEFFICIENTS FOR USE IN
C     THE MAIN PROGRAM.  THE CROP COEFFICIENTS ARE CALCULATED BY THE
C     PROCEDURES OUTLINED IN TECHNICAL RELEASE NO 21, IRRIGATION
C     WATER REQUIREMENTS, UNITED STATES DEPARTMENT OF AGRICULTURE,
C     SOIL CONSERVATION SERVICE, ENGINEERING DIVISION, APRIL 1967.
C     SLIGHT MODIFICATIONS HAVE BEEN MADE FOR ADAPTAION TO THE MODEL.
C     EQUATIONS FOR THE CROP GROWTH STAGE COEFFICIENT CURVES WERE
C     DEVELOPED WHICH ELIMINATES THE NECESSITY OF READING THE VALUES
C     FROM THE CURVES.  INPUTS TO THE SUBROUTINE INCLUDE THE CROP,
C     MONTH AND DAY GROWING BEGINS AND ENDS, NUMBER OF DAYS IN EACH
C     MONTH, AND THE MEAN MONTHLY AVERAGE TEMPERATURES IN FAHRENHEIT
C     DEGREES.
      INTEGER CROP,DGSB,DGSE
      INTEGER NDIM(12),SHIFT
C     FOLLOWING LINE REVISED IN SEPTEMBER, 1982
      REAL MID(12),DBMD(12),ACC(12),PCGS(12)
      REAL MMAT(12),KT(12),KCROP(7,12),PCGS1(12),KCROPVR(12)
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C      ACC=ACCUMULATIVE DAYS IN GROWING SEASON                            0
C      MGSB=MONTH GROWING SEASON BEGINS EXPRESSED NUMERICALLY IE 1-12     0
C      DGSB=DAY GROWING SEASON BEGINS EXPRESSED NUMERICALLY               0
C      MGSE=MONTH GROWING SEASON ENDS EXPRESSED NUMERICALLY IE 1-12       0
C      DGSE=DAY GROWING SEASON ENDS EXPRESSED NUMERICALLY                 0
C      MID=MEDIAN DATES OF THE MONTHS IN THE GROWING SEASON
C      DBMD=DAYS BETWEEN MID DATES                                        0
C      PCGS=PERCENT OF GROWING SEASON REACHED AT MID DATES                0
C      MMAT=MEAN MONTHLY AVERAGE TEMPERATURES
C      MGSB1=TEMPORARY STORAGE FOR MGSB
C      MGSE1=TEMPORARY STORAGE FOR MGSE
C      PCGS1=TEMPORARY STORAGE FOR PCGS
C
C      THE FOLLOWING LOOP (DO 5) WAS ADDED IN SEPTEMBER, 1982 TO ZERO
C      THE ARRAYS LOCAL TO CROPCO FOR EACH CALL TO THE SUBROUTINE.
       DO 5 I=1,12
       PCGS(I) = 0.0
       PCGS1(I) = 0.0
       MID(I) = 0.0
       DBMD(I) = 0.0
       ACC(I) = 0.0
    5 CONTINUE
       MGSB1 = MGSB
       MGSE1 = MGSE
       IF (MGSB.GT.MGSE) GO TO 10
       GO TO 20
C      WHEN MGSB IS GREATER THAN MGSE SUCH AS IN WINTER WHEAT THE
C      SUBROUTINE "SHIFTS" OR ADDS 1 TO MGSB AND MGSE UNTIL MGSB = 13
C      WHICH CORRESPONDS TO JANUARY.  THIS SHIFT WAS NECESSARY TO
C      FACILITATE PROGRAM LOOPING.  AFTER CALCULATIONS ARE MADE THE
C      CROP COEFFICIENTS ARE  "SHIFTED" BACK TO THEIR ORIGINAL MONTHS.
C      ****************************************************************
C      ****************************************************************
C      ****************************************************************
C
C
C      *** CAUTION TO USER ***  THIS ROUTINE WILL NOT WORK IF THE
C      GROWING SEASON EXCEEDS ONE YEAR.
C
C
C      ****************************************************************
C      ****************************************************************
C      ****************************************************************
   10 SHIFT = 13-MGSB
      MGSE = MGSE+SHIFT
      MGSB = 1
   20 NPLUS = MGSB+1
      NMINUS = MGSE-1
      MID(MGSB) = ((NDIM(MGSB)-DGSB)/2.)+DGSB
      DO 30 N=NPLUS,NMINUS
   30 MID(N) = NDIM(N)/2.0
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      MID(MGSE) = DGSE/2.0
      DBMD(MGSB) = MID(MGSB)-DGSB
      DO 40 N=NPLUS,NMINUS
   40 DBMD(N) = NDIM(N-1)-MID(N-1)+MID(N)
      DBMD(MGSE) = NDIM(MGSE-1)-MID(MGSE-1)+DGSE
      ACC(MGSB) = DBMD(MGSB)
      DO 50 N=NPLUS,MGSE
   50 ACC(N) = ACC(N-1)+DBMD(N)
      ACC(MGSE) = ACC(MGSE)-MID(MGSE)
      DO 60 N=MGSB,MGSE
   60 PCGS(N) = (ACC(N)*100.)/(ACC(MGSE)+MID(MGSE))
      IF (MGSB1.LE.MGSE1) GO TO 100
      DO 80 N=1,12
      NN = N-SHIFT
      IF (NN.LE.0) NN = NN+12
      IF (NN.GT.MGSE1.AND.NN.LT.MGSB1) GO TO 70
      PCGS1(NN) = PCGS(N)
      GO TO 80
   70 PCGS1(NN) = 0.0
   80 CONTINUE
      DO 90 N=1,12
   90 PCGS(N) = PCGS1(N)
  100 MGSB = MGSB1
      MGSE = MGSE1
      DO 110 J=1,12
C     KT IS A CLIMATIC COEFFICIENT APPLIED TO THE CROP GROWTH
C      COEFFICIENT.  IT IS CALCULATED BY THE FOLLOWING EQUATION:
      KT(J) = .0173*MMAT(J)-.314
      IF (MMAT(J).LT.36.) KT(J) = .3
  110 CONTINUE
C     *****   CROP=1 FOR WHEAT
C     *****   CROP=2 FOR SORGHUM
C     *****   CROP=3 FOR CORN
C     *****   CROP=4 FOR SOYBEANS
C     *****   CROP=5 FOR PASTURE
C     *****   CROP=6 FOR ALFALFA
C     *****   CROP=7 FOR FALLOW
      GO TO (120,130,140,150,160,180,200), CROP
  120 XBAR = 50.
      A = 1.39093399
      B = -0.00368378
      C = -0.00004976
      D = -0.00000233
      E = -0.00000004
      GO TO 210
  130 XBAR = 50.
      A = 1.05528355
      B = 0.00198600
      C = -0.00051577
      D = 0.00000045
      E = 0.00000011
```

```
      GO TO 210
  140 XBAR = 50.
      A = 1.02805328
      B = 0.00880046
      C = -0.00031919
      D = -0.00000194
      E = 0.00000007
      GO TO 210
  150 XBAR = 50.
      A = 0.74790430
      B = 0.01474796
      C = -0.00013486
      D = -0.00000443
      E = 0.
      GO TO 210
C     FOR PERENNIAL CROPS SUCH AS ALFALFA AND PASTURE, VALUES OF THE
C     CROP COEFFICIENTS ARE BEST PLOTTED ON A MONTHLY BASIS. THEREFORE
C     EQUATIONS WERE NOT DEVELOPED.  MONTHLY VALUES WERE INTEGRATED
C     WITHIN THE ROUTINE FOR PASTURE AND ALFALFA.  REVISED 2/25/88 FOR
C     WARM SEASON GRASSES, PER JKK.
  160 KCROP(5,1) = CROPVAR*KCROPVR(1)
      KCROP(5,2) = CROPVAR*KCROPVR(2)
      KCROP(5,3) = CROPVAR*KCROPVR(3)
      KCROP(5,4) = CROPVAR*KCROPVR(4)
      KCROP(5,5) = CROPVAR*KCROPVR(5)
      KCROP(5,6) = CROPVAR*KCROPVR(6)
      KCROP(5,7) = CROPVAR*KCROPVR(7)
      KCROP(5,8) = CROPVAR*KCROPVR(8)
      KCROP(5,9) = CROPVAR*KCROPVR(9)
      KCROP(5,10) = CROPVAR*KCROPVR(10)
      KCROP(5,11) = CROPVAR*KCROPVR(11)
      KCROP(5,12) = CROPVAR*KCROPVR(12)
      DO 170 J=1,12
      KCROP(5,J) = KCROP(5,J)*KT(J)
      IF (PCGS(J).LE.0.0) KCROP(5,J) = 0.0
  170 CONTINUE
      GO TO 230
  180 KCROP(6,1) = 0.63
      KCROP(6,2) = 0.73
      KCROP(6,3) = 0.86
      KCROP(6,4) = 0.99
      KCROP(6,5) = 1.08
      KCROP(6,6) = 1.13
      KCROP(6,7) = 1.11
      KCROP(6,8) = 1.06
      KCROP(6,9) = 0.99
      KCROP(6,10) = 0.91
      KCROP(6,11) = 0.78
      KCROP(6,12) = 0.64
      DO 190 J=1,12
      KCROP(6,J) = KCROP(6,J)*KT(J)
```

```
  190 IF (PCGS(J).LE.0.0) KCROP(6,J) = 0.0
      GO TO 230
  200 XBAR = 0.
      A = 0.
      B = 0.
      C = 0.
      D = 0.
      E = 0.
  210 DO 220 J=1,12
      Z = PCGS(J)-XBAR
      KCROP(CROP,J) = (A+B*Z+C*Z**2+D*Z**3+E*Z**4)*KT(J)
      IF (PCGS(J).LE.0.0) KCROP(CROP,J) = 0.0
  220 CONTINUE
  230 CONTINUE
C     SINCE THE MAIN PROGRAM APPLIES THE CROP COEFFICIENT (KCROP) TO
C     THE ENTIRE MONTH, THE KCROP WAS PROPORTIONED ACCORDINGLY TO
C     COMPENSATE FOR THIS.  THE NEXT TWO CARDS DO THIS.
      KCROP(CROP,MGSB) = KCROP(CROP,MGSB)*(NDIM(MGSB)-DGSB+1)/NDIM(MGSB)
      KCROP(CROP,MGSE) = KCROP(CROP,MGSE)*DGSE/NDIM(MGSE)
      RETURN
      END
      SUBROUTINE IART (IA,IAET,KROPKO,P,PET,PETBS,XIAET,ABIN)
C     *****   SUBROUTINE IART CALCULATES:
C     *****     1. THE EVAPOTRANSPIRATION AMOUNT WHICH IS DEDUCTED
C     *****        FROM INTERCEPTION STORAGE, IAET
C     *****     2. THE AMOUNT OF PRECIPITATION WHICH IS INTERCEPTED
C     *****     3. THE VALUE OF IAET FOR THE NEXT DAY'S SIMULATION
C     *****   IA=INITIAL ABSTRACTION, ASSUMED TO BE 0.1 INCH OR LESS
C     *****   IASTOR=AMOUNT IN INTERCEPTION STORAGE (INCHES)
C     *****   IAET=AMOUNT OF EVAPOTRANSPIRATION WHICH IS DEDUCTED FROM
C     *****    INTERCEPTION STORAGE (INCHES)
C     *****   XIAET=VALUE OF IAET FOR NEXT DAY'S SIMULATION (INCHES)
      REAL IA,IAET,IASTOR,KROPKO
      IA = ABIN
      IASTOR = IAET-PET
C     *****   FOLLOWING LINE REVISED IN SEPTEMBER, 1982
      IF (KROPKO.LE.0.0) IASTOR = IAET-PETBS
      IF (IASTOR.GT.ABIN) IASTOR = ABIN
      IF (IASTOR.LE.0.0) IASTOR = 0.0
      IF (IA.GT.P) IA = P
      IF ((IA+IASTOR).GE.ABIN) IA = ABIN-IASTOR
      XIAET = IAET+IASTOR
      RETURN
      END
C
C
C
      SUBROUTINE PETRT (SUN,RAD,HUM,AVGT,BLOW,BRUNTA,BRUNTB,DELTA,E,EPRI
     1M,GAMMA,LAKEVP,PACK,PDT,PET,PETBS,RCROP)
      REAL LAKEVP
      R = RCROP
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C
C
C     *****
C     *****   CALCULATION OF POTENTIAL EVAPOTRANSPIRATION BY MEANS OF
C     *****                    PENMAN EQUATION
C     *****   THE FOLLOWING CARD CHECKS FOR SNOW COVER
      IF (PACK.GT.0.1) R = 0.70
C     *****   THE NEXT TWO CARDS CONVERT TAVG TO ABSOLUTE (DEGREES K)
      CENT = (AVGT-32.0)*100.0/180.0
      ABST = CENT+273.16
C     *****   ES=DAILY CALCULATED SATURATED VAPOR PRESSURE (MILLIBARS)
      ES = 33.9*((0.00738*CENT+0.8072)**8-0.000019*ABS(1.8*CENT+48)+0.00
     11316)
      IF (ES.LE.0.0) ES = 0.0
C     *****   ESA=DAILY CALCULATED ACTUAL VAPOR PRESSURE (MILLIBARS)
      ESA = ES*HUM/100.0
C     *****   RN=CALCULATED DAILY NET RADIATION (MM OF WATER)
      RADM = RAD/58.6
      RN = (1-R)*RADM-2.010E-09*ABST**4*(0.98*(1.-BRUNTA
     1-BRUNTB*SQRT(ESA)))*(0.1+0.9*SUN)
      IF (RN.LT.0.0) RN = 0.0
C     *****   WINDD=MONTHLY AVERAGE WIND RUN AT 2 METERS HEIGHT (MI/DAY)
      WINDD = (BLOW*24)*0.555
C     *****   EA=CONVECTIVE LOSSES (MM WATER)
      EA = 0.26*(E+0.01*WINDD)*(ES-ESA)
      EALAKE = 0.26*(EPRIM+0.01*WINDD)*(ES-ESA)
      IF (AVGT) 10,10,20
   10 DELTA = 0.0
      GO TO 30
   20 DELTA = 0.039*AVGT**0.673
   30 GAMMA = 1-DELTA
      PET = ((DELTA*RN)+(GAMMA*EA))/25.4
C     *****
C     *****   CALCULATE LAKE AND BARE SOIL EVAPORATION
C     *****
      RNSOIL = RN*((1.0-0.20)/(1.0-R))
      RNLAKE = RN*((1.0-0.05)/(1.0-R))
      PETBS = ((DELTA*RNSOIL)+(GAMMA*EA))/25.4
      LAKEVP = ((DELTA*RNLAKE)+(GAMMA*EALAKE))/25.4
      PDT = AVGT
      IF (AVGT.LT.20.0) PET = 0.0
      IF (AVGT.LT.20.0) PETBS = 0.0
      IF (AVGT.LT.20.0) LAKEVP = 0.0
C
C
      RETURN
      END
      SUBROUTINE RNOFRT (AVLFCU,FCU,KROPKO,PWPUZ,P,RCN1,RCN2,RCN3,RNOF,S
     1M,SMUZ)
C     *****   SUBROUTINE RNOFRT CALCULATES THE RUNOFF FROM THE SUBAREA
C     *****   USING THE SCS EQUATION:
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C     *****          RNOF=((P-0.2*S)**2)/(P+0.8*S)
C     *****     WHERE
C     *****          P=PRECIPITATION AMOUNT, INCLUDING SNOWMELT (INCHES)
C     *****          S=(1000/CN)-10
C     *****          CN=RUNOFF CURVE NUMBER
C     *****          RNOF=CALCULATED RUNOFF AMOUNT (INCHES)
      REAL KROPKO,NUM
      IF (KROPKO) 20,20,10
   10 IF (SMUZ.LT.(PWPUZ+0.5*AVLFCU)) GO TO 30
      IF (SMUZ.GT.(PWPUZ+0.8*AVLFCU)) GO TO 50
      GO TO 40
   20 IF (SMUZ.LT.0.6*FCU) GO TO 30
      IF (SMUZ.GT.0.9*FCU) GO TO 50
      GO TO 40
C     *****     ANTECEDENT MOISTURE CONDITION I
   30 CN = RCN1
      GO TO 60
C     *****     ANTECEDENT MOISTURE CONDITION II
   40 CN = RCN2
      GO TO 60
C     *****     ANTECEDENT MOISTURE CONDITION III
   50 CN = RCN3
   60 S = 1000.0/CN-10.0
      NUM = P-0.2*S
      IF (NUM) 70,70,80
   70 RNOF = 0.0
      GO TO 90
   80 RNOF = NUM**2/(P+0.8*S)
   90 RETURN
      END
      SUBROUTINE SEEPGE (B2,PONVOL,DASEEP,DSEPRT)
C     *****       SUBROUTINE SEEPGE CALCULATES THE VOLUME OF EXFILTRATION
C     *****     FROM THE POND EACH DAY. THE EXFILTRATION FUNCTION IS
C     *****     ASSUMED TO BE A CONSTANT RATE (DSEPRT) IN INCHES/DAY. THE
C     *****     VOLUME IS FOUND BY MULTIPLYING THIS RATE BY THE POND'S
C     *****     SURFACE AREA. THIS EXFILTRATION VOLUME IS THEN SUBTRACTED
C     *****     FROM THE POND VOLUME.
C     *****     B2=POND SURFACE AREA (SQUARE FEET)
C     *****     DASEEP=DAY'S EXFILTRATION VOLUME (ACRE-INCHES)
C     *****     PONVOL=POND VOLUME (ACRE-INCHES)
      DASEEP = B2*DSEPRT/43560.0
      IF (DASEEP.GT.PONVOL) DASEEP = PONVOL
      PONVOL = PONVOL-DASEEP
      IF (PONVOL.LT.0.0) PONVOL = 0.0
      RETURN
      END
      SUBROUTINE SNOWRT (PRECIP,WATER,PACK,PET,TEMPAV,SNOVAP)
C     *****
C     *****     SUBROUTINE SNOWRT CALCULATES THE MOISTURE ADDED TO THE
C     *****      SUBAREA DUE TO MELT OF THE SNOWPACK
C     *****
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      REAL M,MA,MR
      M = 0.0
C     *****   SNOVAP=DEDUCTION FROM THE MOISTURE STORED IN THE
C     *****     SNOWPACK DUE TO SUBLIMATION (INCHES)
      IF (PACK.GT.0.1) SNOVAP = PET
C     *****  THE FOLLOWING LINE WAS ADDED IN SEPTEMBER, 1982
      IF (SNOVAP.GT.PACK) SNOVAP=PACK
      PACK = PACK-SNOVAP
      IF (SNOVAP.GT.0.0) PET = 0.0
      IF (TEMPAV-32.) 10,10,20
   10 IF (PRECIP) 70,70,30
   20 IF (PACK) 90,90,40
   30 PACK = PACK+PRECIP
      WATER = 0.0
      GO TO 90
C     *****   MA=SNOWMELT DUE TO ATMOSPHERIC CONDITIONS (INCHES)
   40 MA = 0.05*(TEMPAV-34.)
      IF (MA.LT.0.0) MA = 0.0
      IF (PACK-MA) 60,60,50
C     *****   MR=SNOWMELT DUE TO RAIN (INCHES)
   50 MR = (PRECIP*(TEMPAV-32.))/144
C     *****   M=TOTAL SNOWMELT (INCHES)
      M = MR+MA
      IF (PACK-M) 60,70,70
   60 M = PACK
      PACK = 0.0
      GO TO 80
   70 PACK = PACK-M
C     *****   WATER=SUM OF PRECIPITAION ON THE AREA AND SNOWMELT (IN.)
   80 WATER = M+PRECIP
   90 RETURN
      END
      SUBROUTINE VOLRT (A1,A2,A3,A4,A5,L,PSAREA,S,VOLMAX,W,HMAX)
      REAL L
C     *****
C     *****   SIZING POND VOLUME ROUTINE
      A1 = L*W
      A2 = S*(L+W)
      A3 = 4./3.*S**2
      A4 = 2.*A2
      A5 = 4.*S**2
C     *****   VOLMAX=MAXIMUM STORAGE VOLUME IN THE POND (ACRE-IN.)
      VOLMAX = (A1*HMAX+A2*HMAX**2+A3*HMAX**3)/3630.0
C     *****   PSAREA=MAXIMUM POND SURFACE AREA (ACRES)
      PSAREA = ((W+2.*S*HMAX)*(L+2.*S*HMAX))/43560
      RETURN
      END
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COMPUTER MODELING OF WATER YIELD
FROM KINGS CREEK WATERSHED

By

Charles A. Bartlett

B. S., Kansas State University, 1986

AN ABSTACT OF A MASTER'S THESIS

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The Konza Prairie ecosystem is a dynamic interaction of soil, water, fire, and organisms. If it were possible to describe this interaction with a computer model, the management of the ecosystem could be improved. With a water budget model describing the prairie, researchers and managers would be able to perform such tasks as predicting hydrological events and correlating plant matter growth with actual evapotranspiration. Kings Creek watershed, located entirely on the Konza Prairie, was selected as an ideal location to model.

The objectives of this project were to (1) modify the existing POTYLD water budget model for specific use on Kings Creek watershed, (2) develop a climatological data set of the prairie for use in calibrating the model, (3) predict runoff and percolation for each soil plot, (4) predict Kings Creek streamflow and match that data with actual streamflow, and (5) predict long-term water yield form the watershed. These objectives were met by developing a weather data set from Manhattan, Kansas and Konza Prairie weather data from 1980 to 1986 and applying it to an adapted water budget model with the soils of the watershed already incorporated. A long-term run from 1958 to 1979 was also reported.

The results of the model when compared with actual annual streamflow for Kings Creek showed a coefficient of determination of 0.83. The average predicted annual streamflow was 2.6 million cubic meters (2140 acre-feet). The average actual reported annual streamflow was also 2.6 million cubic meters (2120 acre-feet). The predicted streamflow ranged from 1.00 million cubic meters (811 acre-feet) in 1981 to 3.80 million cubic meters in 1986.