DEVELOPMENT OF SUPPLEMENTAL IRRIGATION SYSTEM MODEL FOR A FARM IN SOUTHEASTERN KANSAS

by

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B.S., Seoul National University, 1974

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

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TABLE OF CONTENTS

TABLE OF CONTENTS (con'd.)

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

Special thanks are extended to Dr. Jerome J. Zovne of the Civil Engineering Department for endless guidance and assistance throughout my graduate program. Particular gratitude goes to my committee members, Dr. James Koelliker of the Civil Engineering Department and Dr. James Steichen of the Agricultural Engineering Department, who are also members of the water resources research team.

Thanks are also extended to Russell LaForce of the Agricultural Engineering Department, who has been working for the supplemental irrigation system.

And, I want to dedicate my thesis to my father-in-law, Dr. Jeong Haeng Lee and my wife.

CHAPTER I

INTRODUCTION

The boundary between sub-humid and sub-arid regions passes through Kansas near the 100° meridian. The southeastern part of Kansas is in the sub-humid region for which sufficient precipitation is received to allow crop production to reach full potential under the condition of proper rainfall distribution over the growing season. However, uncertain and poorly distributed rainfall is nearly always the case. Supplemental irrigation has been practiced to ensure uniform maximum crop yields because rainfall is inadequate in either amount or distribution, or both, in most growing seasons.

Irrigation water may be taken from wells, streams, lakes or springs and transferred to the point of application by pumping or by gravity. In this region, the water source is often surface runoff from a small watershed, while in Western Kansas, groundwater is used as the main source for irrigation. If there is a suitable site on the farm, a surface reservoir can be constructed to store runoff for later use as supplemental irrigation.

Supplemental irrigation systems have often been designed and operated without knowing the reliability of the system. An irrigation system is restricted by various factors such as the site topography, climatology, irrigable land area, watershed size, farm boundary, type of soil and crop, and so on. A continuous watershed hydrologic yield model originally developed by Zovne and Koelliker (1) and modified by Hayden (2) can be used to study the site-specific performance of a supplemental irrigation system. The model allows one to compute a continuous variation of surface runoff, interception, actual evapotranspiration, soil moisture, groundwater recharge, the flux of water to the pond, and irrigation demand, by using meteorological data and some observations on the soil and crop.

The purpose of this study is to examine the reliability of a pond water supply for irrigation and the possibility of supplemental irrigation on a specified site. By means of a multi-purpose hydrologic simulation model, the complex hydrologic interactions are analyzed. The major considerations in design of a supplemental irrigation system are runoff inputs to the pond, irrigation demands, and pond level fluctuations. To study the hydrologic balance for a pond, the variability of surface runoff yields to the pond in response to precipitation, and irrigation needs are examined, after overall hydrologic characteristics of each component are outlined as a result of a long-term simulation (1948-1970). The reliability of the pond can, thereby, be determined. The probability or risk of not enough water available for this system can be predicted based on the pond level fluctuation and irrigation demand.

In addition, a general method of crop management system adaptable to any typical cropping schedule for Southeastern Kansas is designed.

CHAPTER II

REVIEW OF KANSAS STATE UNIVERSITY HYDROLOGIC YIELD MODEL (KSUHYDRO)

The objective of this chapter is to review the basic theory and principles incorporated in each component of the hydrologic cycle adopted in a continuous simulation model, which has been developed by Zovne and Koelliker (1), and by Hayden (2).

Evapotranspiration

Transpiration is the loss of water from the stomatal openings in the leaves of plants. When evaluating water loss from a vegetated surface, it is always impossible to separate transpiration and soil surface evaporation. These two mechanisms are combined and called evapotranspiration, being synonymous with the term consumptive use in agronomy. The calculation of irrigation water requirement is based on evapotranspiration both in the planning phase of a project and in the control of water supply at the farm level.

When a vegetated surface is losing water to the atmosphere at a rate unlimited by source of water supply, it is called evapotranspiration potential. If supply water is limited, actual evapotranspiration may be less than the potential.

Several acceptable methods of computing potential and actual evapotranspiration have been developed and used. Bean (3) suggested using the Penman formula for calculating evapotranspiration potential for the simulation model. Penman (4) developed his mathematical expression predicting evapotranspiration from a vegetative cover by using energy balance and mass transfer theory. The mathematical formula, known as the Penman combination method, was calibrated by Bean and presented as (1),

$$\begin{aligned} PET = {} & 0.039\ Ta^{0.673}\ [(1-r)\ Ra\ (0.22 + 0.54\ PSUNS) - \\ & 2.010 \times 10^{-9}\ T^{4}\ (0.98 - a - b \sqrt{ES \times RHD}) \times \\ & (0.1 + 0.9\ PSUNS)] + (1 - 0.039\ Ta^{0.673}) \times \\ & 0.26\ (e + 0.01\ WVD)(ES - ES \times RHD) \text{ ------------------- } (1) \end{aligned}$$

where

PET = potential evapotranspiration, in inches

Ta = mean daily air temperature, in °F (Fahrenheit)

T = mean daily air temperature, in °K (Absolute)

r = reflectance coefficient (albedo)

Ra = solar radiation, in mm of H_2O

PSUNS = percent sunshine, in percent

ES = saturation vapor pressure of a water surface at the Ta, in mb

a,b = empirical coefficients, which can vary geographically

RHD = relative humidity, in percent

WVD = wind velocity, in miles/day

e = mass transfer coefficient

The reflectivity of a surface can be measured in the field with an inverted pyrheliometer. Albedo varies with sun altitude and cloud cover. However, in most studies, the albedo of water surface is assumed to be constant of $r = 0.05$ which can obtain evapotranspiration potential from free water surface, while the albedo for green crops varies from 0.20 to 0.25. The geographic constants of c and d can be determined approximately by using the figure explained by Zovne and

Koelliker (1), and then can be calibrated so that they may reflect the actual case of moisture deficit. Due to the lack of available data on daily basis for the variables Ra, RHD, WVD, and PSUNS, mean monthly values are used by interpolating data from nearby first order weather station, while Ta and T are computed from the daily meteorological records. The saturation vapor pressure of a water surface at the air temperature can be obtained from Equation (2).

$$ES = 33.9\ [(0.00738T + 0.8072)^{8} - 0.0019\ |1.8Ta + 48| + 0.001316] \text{ ------------------ } (2)$$

where ES, T, and Ta were previously defined.

The actual evapotranspiration rate is governed by climate, vegetation, and soil factors.

When moisture conditions in soil are suitable, the actual rate of evapotranspiration is equal to the potential for either bare soil or vegetated soil. The most common method to estimate actual evapotranspiration is through the calculation of potential evapotranspiration. If there is enough water in the soil, the two cases are equal. Otherwise, the potential rate is modified according to the amount of water in the soil as following relationship (3),

$$AET = PET \times f\left(\frac{AW}{AWC}\right) \text{ ------------------ } (3)$$

where

f = a certain function

AET = actual evapotranspiration

PET = potential evapotranspiration

AW = the available soil moisture

= (soil moisture content - permanent wilting point) x root profile depth

AWC = available water capacity

= (field capacity - permanent wilting point)
x root profile depth

The available soil moisture at any time is the amount of water held at a moisture content above the permanent wilting point. The available water capacity is defined as the difference between field capacity and permanent wilting point (6).

The actual rate of evapotranspiration for either bare or vegetated soil is affected by soil and crop type. Evaporation from bare soil differs in two stages (1). First stage evaporation occurs when the soil is sufficiently wet to readily transport water to the soil surface. To estimate the first stage evaporation, Equation (1) is used for the bare soil condition with r equal to 0.20. When a threshold amount, U, is reached, hydraulic properties of the soil begin to limit the evaporation rate. The second stage evaporation from bare soil is computed by following equation (4).

$$E_S = c't^{\frac{1}{2}} - c'(t-1)^{\frac{1}{2}} \text{ -- } (4)$$

where

E_S = soil evaporation, in inches

c' = hydraulic coefficient of the soil, in inches/day$^{\frac{1}{2}}$

t = time after the first stage evaporation, in days

The rate of evapotranspiration of a crop is dependent upon atmospheric, plant, and soil factors. The atmospheric factors are incorporated in the computation of PET by the Penman method. A plant consumptive use factor, K, by Blaney-Criddle method (7) is applied to the modification of PET in accounting for a plant factor.

If a vegetated soil surface is considered, equation (5) is used to calculate evapotranspiration,

$$AET = PET \times K \times AW/0.3\ AWC \qquad (5)$$

where

AET, PET, AW, and AWC are previously defined,

K = crop consumptive use coefficient.

When the available soil moisture is greater than thirty percent of the maximum available soil moisture, evapotranspiration will occur at the maximum rate of the product of PET and crop consumptive use factor, K. When the soil moisture falls below thirty percent of the maximum available soil moisture, the actual evapotranspiration decreases linearly from the maximum rate to zero at the permanent wilting point.

The crop coefficients, K, in Equation (5) can be determined by Blaney-Criddle method described in SCS, Technical Release No. 21 (7). These coefficients incorporate K_t, a climatic coefficient which is related to the mean air temperature (t) and K_c, a coefficient reflecting stage of crop growth. According to the procedure outlined in (7), Zovne, et al. (1) developed a subroutine CROPCO to simply calculate crop coefficients as monthly average values during the growing season. Inputs to the subroutine are mean monthly air temperature, type of crop, planting, and harvesting date.

The climatic coefficients are estimated by using mean monthly air temperature. The growth stage coefficients are obtained from crop growth stage curves illustrated in (7). However, these curves are internally programmed in the subroutine CROPCO by regression analysis. Each curve has its own third or fourth order polynomial equation. The crop coefficient (KCROP) is finally generated by the product of K_t and K_c. When the soil lies fallow, or during the dormant season, the K is zero.

Surface Runoff

For a given plot, surface runoff is calculated by the method developed by the U.S. Soil Conservation Service (SCS)(8).

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \text{ -- } (6)$$

where

Q = surface runoff, in inches

P = precipitation, in inches

S = potential maximum difference between precipitation and runoff, in inches

The initial abstraction, IA, consists of interception, infiltration, and surface detention. The empirical relationship is:

$$IA = 0.2S \text{ -- } (7)$$

The unknown parameter S must be established from the soil-cover complex, which relates antecedent moisture conditions, hydrologic soil groups, land use, and conservation practices. For those soil-cover properties, the curve number CN is obtained from Table I for Antecedent Moisture Condition II (AMC II). The maximum potential difference, S, can be evaluated by the equation,

$$S = \frac{1000}{CN} - 10 \text{ -- } (8)$$

where

S = maximum potential difference, in inches

CN = runoff curve number

TABLE I** SCS RUNOFF CURVE NUMBERS FOR AMC II*

Soil Class	Row Crops	Alfalfa	Wheat	Pasture	Fallow
1	86	83	84	80	84
2	86	83	84	80	84
3	82	78	81	74	78
4	82	78	81	74	78
5	75	69	73	61	69
6	75	69	73	61	69
7	75	69	73	61	69
8	75	69	73	61	69
9	75	69	73	61	69
10	75	69	73	61	69
11	75	69	73	61	69
12	65	55	61	39	61

*AMC II - During the growing season, soil moisture in the top 1 ft is between 0.5 and 0.8 of field capacity, or for the non-growing season, 0.6 to 0.9 of field capacity.
AMC I occurs when soil moisture less than 0.5(0.6) and AMC III when soil moisture greater than 0.8(0.9).

** From BEAN(3)

TABLE II** CROP CODES USED IN THE COMPUTER PROGRAM

Crop	Reference Number
Wheat	1
Grain Sorghum	2
Corn	3
Soybeans	4
Pasture	5
Alfalfa	6
Fallow Soils	7

** From HAYDEN(2)

TABLE III** IRRIGATION DESIGN CLASS DESCRIPTIONS FOR SOILS IN THE DISPOSAL AREA (Kansas Irrigation Guide) (8)

Irrigation soil class	Profile Depth in cm (ft)	Soil class description
1	90 (3.0)	Deep soils with silt loam or silty clay loam surface layers and slowly to very slowly permeable heavy clay and claypan subsoils.
2	90 (3.0)	Deep soils with silty clay or clay textures throughout. Surface infiltration and subsoil permeability are very slow when the soil is moist. Shrinkage from drying causes extensive cracking, resulting in high infiltration rates until swelling occurs.
3	150 (5.0)	Deep soils with silt loam, loam, clay loam, or silty clay loam surface layers and clay loam, silty clay loam, or silty clay subsoils. Subsoil prmeability is slow to moderately slow. Shrinkage cracks resulting from drying in the soils with more clayey subsoil textures give a relatively high initial infiltration rate.
4	75 (2.5)	Moderately deep soils with silt loam, clay loam, or silty clay loam surface layers and clay loam or silty clay subsoils with predominantly moderately slow permeability.
5	150 (5.0)	Deep soils with silt loam, loam, clay loam, or silty clay loam surface layers and subsoils. Subsoil permeability: moderate to moderately slow
6	90 (3.0)	Moderately deep soils with silt loam or loam surface layers and loam, clay loam, or silty clay subsoils with moderate to moderately slow permeability.
7	150 (5.0)	Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils.
8	75 (2.5)	Moderately deep soils with silt clay loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam, or silt loam subsoils.
9	150 (5.0)	Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability. Available water capacity is moderate to low.
10	150 (5.0)	Soils are moderately deep over sand with sandy loam to loam surface layers and moderately rapid to rapidly permeable subsoils with low available water capacity.

Irrigation soil class	Profile Depth in cm (ft)	Soil class description
11	150 (5.0)	Deep soils with loamy fine sand or loamy sand surface layers and moderately rapid to rapidly permeable subsoils.
12	150 (5.0)	Deep rapidly permeable soils with sand or fine sand textures throughout.

** FROM BEAN (3)

For user convenience input CN'S shown in Table I are arranged by the crop and soil types introduced in Table II and Table III, respectively. The input CN is based on antecedent moisture condition (AMC II) two. The CN is modified for other moisture conditions (see footnote, Table I). For AMC I,

$$CN_I = CN \times 0.39 \times e^{(0.009 \times CN)}, \text{ ---------------------------- } (9)$$

and for the AMC III,

$$CN_{III} = CN \times 1.95 \times e^{(-0.00663 \times CN)}. \text{ ------------------------- } (9a)$$

Interception

All the precipitation does not reach the soil to supply plants or generate surface runoff. A certain part of the precipitation is intercepted by vegetation or other cover and is evaporated back to the atmosphere. The amount of interception depends on the nature of the surface cover, the characteristics of the rainfall. Many different kinds of interception measurement have been developed. However, for convenience in computer simulation, Bean (3) suggested using an interception-storage capacity of 2.54 mm (0.1 inch), which is evaporated at the free potential rate. The maximum amount of water stored on the wetted surface of the vegetation is called interception storage capacity. The amount of infiltration into soil is assumed to be the remainder of the maximum potential difference (S) which is not evaporated and intercepted.

Infiltration and Redistribution

Infiltration is the movement of water into the soil. Infiltration involves three interdependent processes; entry through the soil surface, storage within the soil, and transmission through the soil profile.

Bean (3) assumed that root zone is composed of two layers; the upper zone is 30 cm (one foot) thick and the lower zone is 90 cm (three feet) thick, as shown in part (a) of Figure 1. Infiltrated water would fill each layer to ninety percent of maximum storage in saturated condition and then any excess would be redistributed to the next layer by gravitational force. Since field capacity is generally defined to be a soil moisture content evaluated two days after saturation (9), the soil moisture of the upper zone is decreased to field capacity in two days, redistributing the excess moisture to the lower zone. Furthermore, if the soil moisture of the lower zone exceeds field capacity, it is decreased to ninety percent of field capacity in two days and the excess is considered to percolate out of the root zone. In this concept of moisture redistribution, the upward movement of water was neglected, but reasonable estimates of vertical movement of infiltrating water can be obtained.

Along with Bean's method, Hayden (2) developed another version of soil moisture movement by using Darcy Equation for one-dimensional flow.

$$q' = K\Delta t i \qquad (10)$$

where

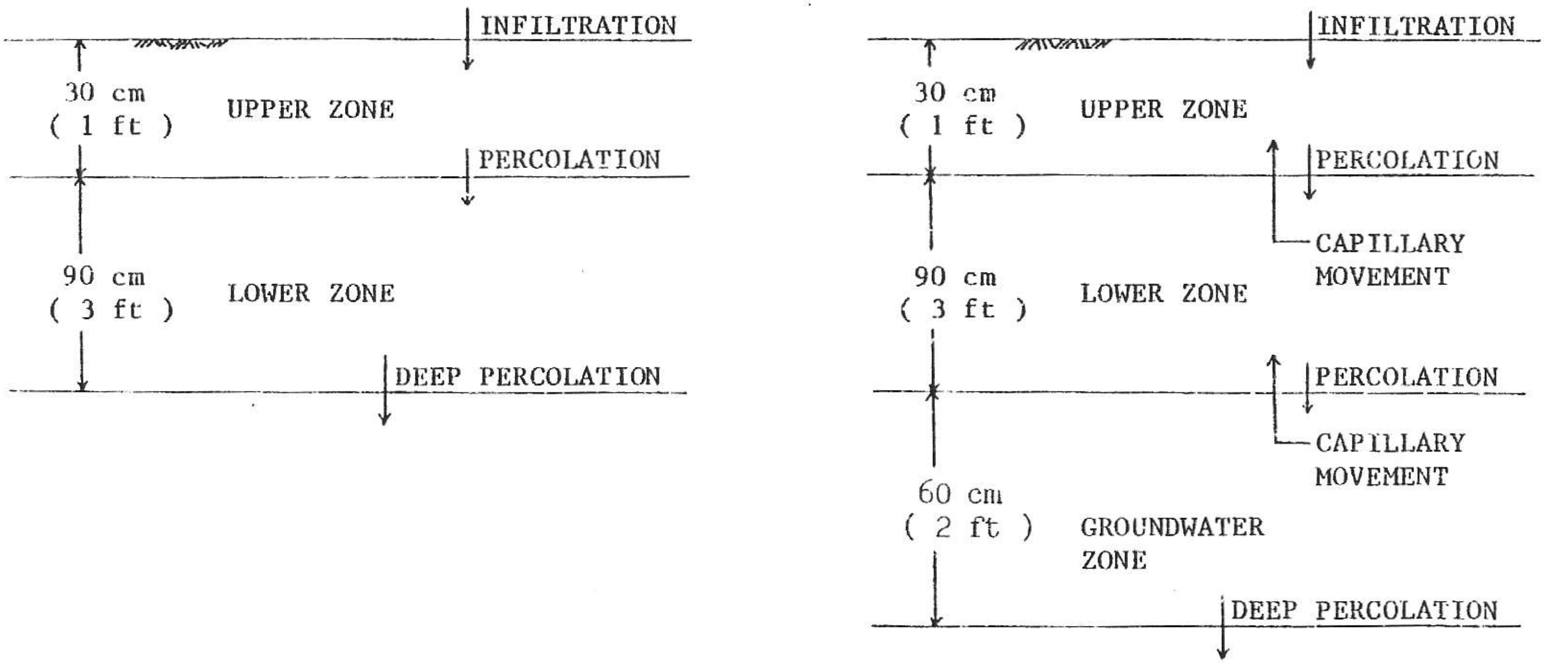
q' = volume of water movement per unit area, in inches

K = hydraulic conductivity, in inches/day

Δt = time increment, in days

i = hydraulic gradient, in feet/feet

The hydraulic conductivity, which can be evaluated from laboratory test, is a function of the water content in the soil. The value of



(a) (b)

Figure 1. Schematic View of The Subsurface Profile

** From HAYDEN(2)

hydraulic conductivity is maximum potential at saturation. As water content in the soil decreases, its value decreases steeply.

The hydraulic gradient is the sum of the gravitational gradient and the soil water potential,

$$i = \frac{\Delta z + \Delta h}{\Delta z} \quad \text{--} \quad (11)$$

where

Δz = change in elevation, in feet

Δh = change in soil water potential over distance Δz, in feet

i = hydraulic gradient

For the downward movement of water in soil, the value of the soil water potential is positive. For the upward movement of water flow, it is negative.

To evaluate the redistribution of soil moisture using Darcy's equation for one-dimensional flow, the root zone is divided into three layers; the upper layer being 30 cm (1 foot) thick, the middle being 90 cm (three feet) thick, the lower layer being 60 cm (two feet) thick. Infiltration water fills each successive layer to field capacity, and excess water, if any, eventually migrates out of root zone to groundwater recharge at the unsaturated conductivity rate. The time increment, Δt, is assumed to be equal to one day when no water infiltrates the soil surface on a given day and equal to 1/6 day when an infiltration event occurs.

Irrigation Criteria

Irrigation from storage facility to an irrigation plot is not allowed under the following conditions:

1. When water stored in pond is less than one full day's irrigation amount,
2. When the ground is frozen,
3. When the mean daily temperature is less than 0°C, and
4. When the upper zone soil moisture is greater than a specified percentage of available moisture capacity, defined as the difference between the field capacity and the permanent wilting point.

The soil is considered to be frozen if the sum of the previous two days average temperature is less than 64°F (0.0°C), while thawing is assumed if the sum of the temperatures for any consecutive three day period is greater than 114°F (10.0°C).

The percentage of available moisture capacity in the upper zone, PAVLU, initiates an irrigation scheme. PAVLU can vary from zero, which means a "non-irrigation" scheme. PAVLU = 0.90 tests an intensive irrigation, while PAVLU = 0.50 tests a normal application of irrigation.

The application rate of irrigation water is arbitrarily determined by the irrigation rate (DSRATE). It can vary from zero to a certain rate not to cause direct surface runoff unless rainfall occurs on an irrigation day. When DSRATE = 0, irrigation is not performed. Intake rate family of the soil and pump sizes are important considerations in setting DSRATE.

A watershed concerned can be divided up to nine sub-areas depending upon crop and soil type, or irrigation implementation plan. After an arbitrary number of plots are selected, an irrigation plan on each plot is made. The order of application of water to each plot on an irrigation day is automatically assigned by the loop mechanism in the program. If a storage pond has a water volume less than a designated percent

(PCVMAX) of the maximum capacity after the first-ordered field area is irrigated, the second-ordered plot will not be irrigated.

It is more reasonable not to irrigate on a rainy day, but, by the KSUHYDRO model, irrigation may or may not occur depending upon the amount of precipitation. If one day has enough rainfall to meet the fourth criteria for irrigation, water from the pond is not applied to a plot. Otherwise, irrigation water is added to compensate for the soil moisture deficit even on a rainy day.

Crop Management

Three schemes are used in crop management. The first is to have only one crop on each plot throughout the period, which is called continuous cropping. The second is to implement an annual crop/fallow rotation, with fallow the first year followed by a crop, or crop on the first year followed by fallow. The third is a multiple cropping rotation which allows three crops in two years and other very flexible options as discussed in detail in Chapter III.

Storage Facility

A storage pond in the shape of an inverted frustrum of a pyramid stores water from direct precipitation and from runoff, or optionally from municipal waste water and other external sources. By specifying the length, width, and side slope of the pond, the surface area can be computed for any storage volume. The volumetric equation for a general prismatiod is:

$$V = \frac{1}{6} h \ (B_1 + 4Bm + B_2) \text{ -- } (12)$$

where

V = volume

h = depth

B_1 = bottom surface area

Bm = area of a plane at h/2 above the bottom

B_2 = top surface area.

Even if seepage through the reservoir bottom is suspected, a sealed or zero exfiltration is assumed because of the difficulty in knowing seepage rates. Outputs from the facility consist of irrigation, overflow, and surface evaporation.

Program Options

The KSUHYDRO model possesses multiple capabilities to simulate actual field conditions. The model simulates climatological conditions by using previously recorded daily precipitation and temperature patterns for a specified location. In addition, the model can be used to predict the effects of weather modification by cloud seeding. The modified precipitation pattern is obtained from subroutine WTRMOD, which contains four options designated variable name MODEL. When MODEL is equal to 1, there will be no modification of the precipitation data. When MODEL is equal to 2, the 'B-Zero' modification is implemented. When MODEL = 3 is used, rainfall is increased by any specified percentage represented by variable name WPCNT. The integer 4, indicates the implementation of the 'B-Zero' modified alteration scheme.

Not only variations in terms of area, soil and crop type for each irrigation plot, but capability of yielding runoff to the storage facility and an irrigation plan can also be incorporated in the program. Each plot can be characterized under the following three conditions:

1. A plot which yields runoff as inflow to the storage facility and on which irrigation is not implemented,
2. A plot which yields runoff as inflow to the storage facility and on-which irrigation is implemented, and
3. A plot on which only irrigation is implemented, without runoff yield to the pond.

The model can also be used for the study of feedlot runoff and/or municipal waste water control. The variable BYPASS establishes feedlot runoff and/or municipal waste as a source of inflow to the facility. BYPASS is represented by the integer 1,2,3, or 4 with each integer establishing the following options:

1. BYPASS = 1; no feedlot runoff nor municipal waste,
2. BYPASS = 2; feedlot runoff,
3. BYPASS = 3; municipal waste, and
4. BYPASS = 4; both feedlot runoff and municipal waste.

When DARCEQ is equal to 1, the redistribution of soil moisture within the soil profile is evaluated by the Darcy equation for one-dimensional unsaturated flow. When DARCEQ is equal to 2, soil moisture redistribution is analyzed by the simplified method described previously.

CHAPTER III

DEVELOPMENT OF CROP MANAGEMENT FUNCTIONS

This chapter provides a descriptive account of the development of a flexible technique for crop management which allows multiple crop rotations with single or double cropping for use in KSUHYDRO. This was the major objective of this research.

To be able to simulate prevailing irrigation field plot operations, and to examine a number of crop management alternatives for an individual farmer, a very flexible crop management plan is required in KSUHYDRO. Seven crops can be selected in the continuous simulation model and various combinations of these crops can be used corresponding to the crop management of interest.

Due to the variability in climate and soils in eastern Kansas, a variety of cropping practices exist, although generally restricted to one crop per year in dryland operations. However, it is possible for farmers to adopt double cropping operations to obtain a greater return from their investment with irrigation.

For the single-cropping management, a specified crop for every year is practiced on a farm field, depending upon crop rotation plan, which may be continuously same crop, biennially two different crops, three different crops, or up to seven different types as already defined in KSUHYDRO. In addition to that, more flexible crop rotation combinations can be made: for example,

1. One crop in the first year, another crop for the next two years, with this sequence repeated throughout the simulation, and

2. Two different crops for two years, followed by fallow, followed by two different crops for two years, with this five-year sequence repeated throughout the simulation.

For the double-cropping management, only wheat can be selected as a winter crop, which can be combined with some crops chosen from the summer row crop group to make the double-cropping concept. The wheat crop as a counterpart to any summer crop is usually rotated with fallow, so this flexibility is needed in the program.

A subroutine ROTATN for crop scheduling is developed with these concepts in mind. Its generalized flow chart is illustrated in Figure 2. The purpose of this subroutine is to provide much more flexibility in simulating supplemental irrigation systems. Subroutine ROTATN is optional if the programmer desires this flexibility. Firstly, a watershed is divided into several irrigation or runoff plots, currently dimensioned up to nine, and then crop management on each area is scheduled. Various rotation patterns can be decided by the variable name RCYCLE. Since seven kinds of crops, including fallow, are incorporated, it is capable of defining rotation schedules having up to seven different crops. For instance, by specifying the value of RCYCLE equal to seven, and arranging the sequence of crops in the following way; corn - corn - corn - soybeans - soybeans - soybeans - soybeans, this rotation would be repeated every seven years. Likewise, any irregular combination of less than seven years can be made, such as corn - soybeans - soybeans - corn - sorghum - corn - sorghum. Following the specification of rotation cycle RCYCLE on an area, the variable name DOUBLE provides for double-cropping. The term of double-cropping is typically characterized by a winter wheat-fallow rotation combined with a summer crop rotation. When an irrigation area is to be double-cropped, the name IFALWT specifies whether the simulation starts with a fallow term in January of the first year, or begins with winter wheat. To avoid some

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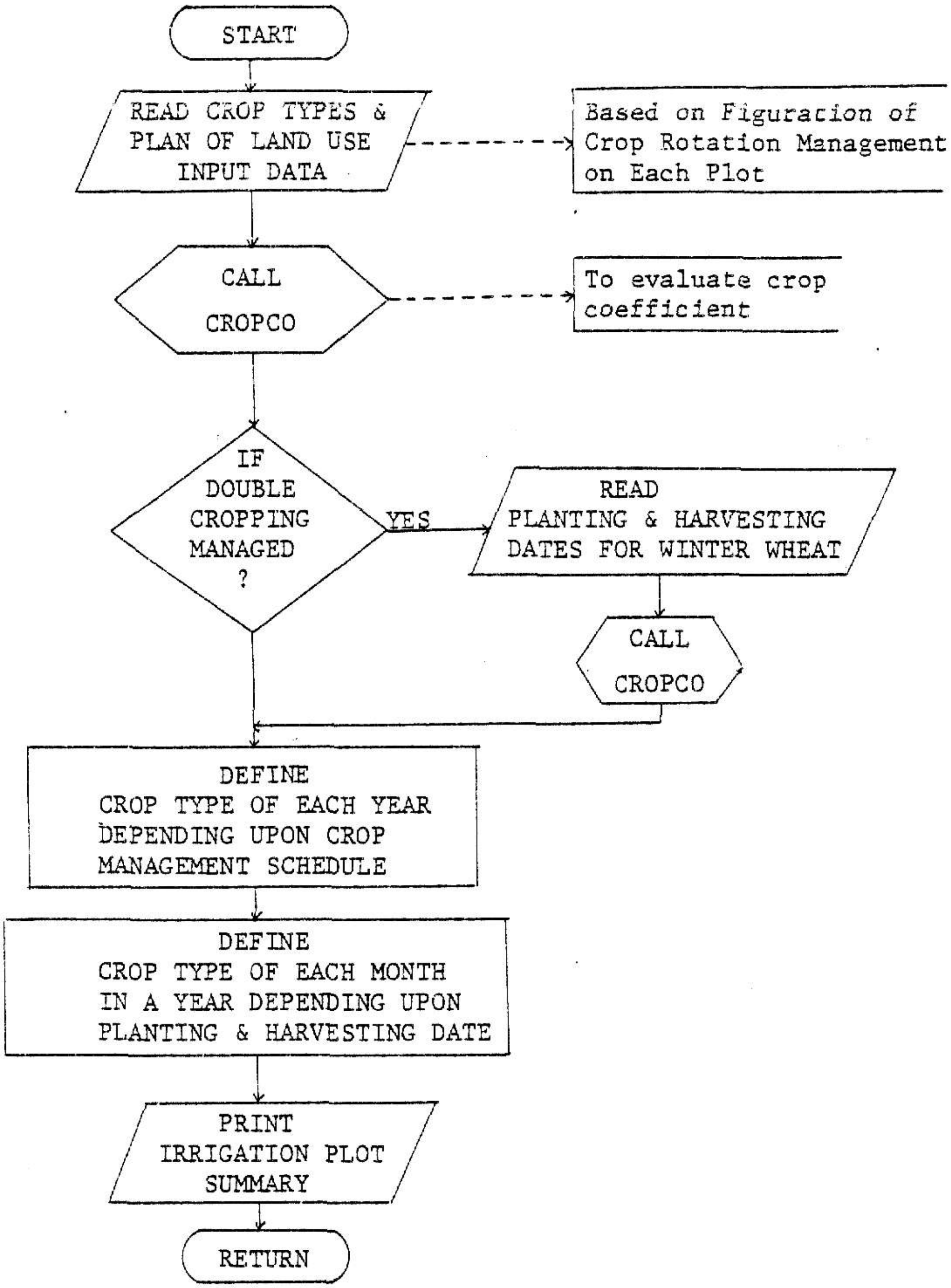


Figure 2. Generalized Flowchart for Crop Management
(Subroutine ROTATN)

inconvenience in using the computer program, the area, soil type, and irrigation implementation plan for each irrigation area can also be read in the subroutine ROTATN rather than in the main program. Crop type, planting month and day, and harvesting month and day are represented by NRCROP, MGSBP, DGSBP, MGSEP, and DGSEP, respectively. The planting and harvesting dates and monthly average temperature data are used to evaluate the monthly average crop coefficients necessary in the estimation of the evapotranspiration on the irrigation or runoff plot under consideration.

In addition to those irrigation management criteria mentioned in the previous chapter, an irrigation plot should not be irrigated in the dormant season. This season is therefore defined as one with zero value of crop coefficients.

CHAPTER IV

CASE STUDY FOR FELT FARM

A continuous simulation model has been developed by Zovne, et al. (1), to provide a means of designing various disposal control facilities. This model is easily adapted to small watersheds for the particular soil, climate and farm management operations that exist at that location. The computer program, KSUHYDRO, is composed of the main program and several subroutines which have various options as can be seen in Appendix (I). Hayden (2) made a detailed description of program usage and on the properties of each subroutine. From the generalized flow chart on KSUHYDRO illustrated in Appendix (I), the characteristics of the program can be found.

Guideline for input data necessary to handle this multi-purposed hydrologic yield model is prepared in Appendix (II), and definitions of the variable names used in the program are arranged in alphabetical order in Appendix (III), so as to be helpful to quickly understand the program.

The main function of KSUHYDRO is to optimize the size of a surface storage facility of a supplemental irrigation or land treatment system which regulates various water sources of precipitation, feedlot input, runoff from a watershed, municipal waste water, and external water supply. It can be used to test the dependable supply of water by examining interaction of components in the system. Accordingly, possibility of water catchment from a specific watershed to meet a supplemental irrigation requirement can be studied by means of the KSUHYDRO.

In this chapter, the data required to run KSUHYDRO is discussed in order to simulate the operation of Ronnie Felt's farm in Bourbon County, Kansas.

Climatological Data

The sub-humid, continental climate of Bourbon County (94°59'W, 37°51'N) is characterized by abundant precipitation, warm to hot summers, generally mild winters, moderate to high humidity, light to moderate winds, and low annual snowfall (10).

The selected experimental farm is about 10 miles to the north of Uniontown located in the center of this County. Since this specific location does not have good meteorological data, Fort Scott, the county seat, is chosen as a representative place to obtain daily precipitation, and maximum and minimum daily air temperatures, which can be secured from tapes provided by the National Weather Service Climatic Center in Asheville, North Carolina.

As directed in (1), the 12 monthly values of relative humidity (RHD), percent sunshine (PSUNS), wind velocity (WIND), and mean air temperature (MMAT) are obtained from published records (11). These are necessarily estimated through interpolation by using the records of Topeka and Springfield, the nearest first-order weather stations whose values are available in (11). The interpolated data are shown in Table IV.

Moisture deficit (MD) is defined as the long-term average annual lake evaporation minus the long-term average precipitation. The MD can be computed using charts or figures provided by the U.S. Weather Bureau. This value can be used to select tentative values of geographical coefficients, c and d, for the Penman Combination Equation, by

TABLE IV MONTHLY CLIMATOLOGICAL DATA

Station : Fort Scott
L=37° 51′ N

Month	Percent Sunshine (%)	Wind Velocity in km/h (mph)	Relative Humidity (%)	Mean Monthly Air Temp. in °C (°F)	Solar Radiation (mmH_2O/day)
	PSUNS	WIND	RHD	MMAT	RA
Jan.	50	19.0 (11.8)	77	-0.3 (31.4)	6.54
Feb.	54	19.2 (11.9)	78	1.9 (35.5)	8.77
Mar.	56	21.7 (13.5)	78	6.3 (43.4)	11.37
Apr.	57	21.2 (13.2)	79	12.8 (55.1)	14.09
May.	60	18.3 (11.4)	84	17.9 (64.2)	15.92
Jun.	65	17.7 (11.0)	86	23.3 (74.0)	16.66
Jul.	66	15.0 (9.3)	87	26.1 (79.0)	16.28
Aug.	70	15.1 (9.4)	87	25.4 (77.8)	14.91
Sep.	72	16.3 (10.1)	86	21.0 (69.8)	12.48
Oct.	67	17.1 (10.6)	82	14.9 (58.9)	9.73
Nov.	57	18.8 (11.7)	80	6.6 (43.9)	7.22
Dec.	51	18.8 (11.7)	79	1.5 (34.7)	6.02

* PSUNS, WIND, RHD, MMAT - Obtained from Climates of the States, Vol. 2, Water Information Center, Inc. Port Washington, N.Y., 1974

** RA - Irrigation Principles and Practices, O.W. Israelson and V.E. Hansen, John Wiley and Sons, Inc. , N.Y., 1962 using Figure 3 in Zovne (1). After running the program several times, the values c and d are adjusted slightly so that the average annual lake evaporation for the simulation period corresponds to the published value. An increase in c of 0.01 results in a 25.4± 6.4 mm (1.0± 0.25 in.) increase in lake evaporation while an increase in d of 0.001 results in an increase of 10.2± 2.5 mm (0.4± 0.1 in.) (1). For the Fort Scott location the moisture deficit is found to be 177.8 mm (7 inches) using the evaporation charts (12) and (11). The geographic coefficients eventually result in $c = 0.64$ and $d = 0.04$.

Data for Soils

The drainage area of interest has gently rolling topography like the prairie soils regions. They are characterized by a dark colored silty loam to silty clay loam A horizon, a heavy silty clay loam B_1 horizon, and a B_2 horizon which is very high in clay content and forms a layer which is very slowly permeable. The experimental site is contained in the series of claypan soils prevailing from northeastern to southwestern part of Missouri (13).

The claypan soils have a moderate available moisture holding capacity and crop yields are often low in seasons of deficient rainfall. Also, claypan soils can cause the problems of excess moisture, and relatively greater runoff during the rainy season. The soil types are generally classified by the Soil Conservation Service as having land capability units II or III, which means that soils have moderate or severe limitations that reduce the choice of plants or require moderate or special conservation practices so as to be quite productive (10).

It is difficult to select a typical soil type which can be representative for a watershed area. The total drainage area in question, including the pond, covers 166 hectares (410 acres) excluding 34.4 irrigated hectares (85 acres) which do not drain back into the pond. The drainage area of concern is broken down in Table V according to the area and the soil series located in Figure 3. Table V indicates that more than half of the drainage area consists of D hydrologic soil group, while a quarter of the total area is C group and another quarter B group. In other words, most of the area is composed of soil type 1 as defined in Kansas Irrigation Guide (8). Even though watershed should be subdivided according to various types of soil, it is more convenient to use a prevailing type throughout the area. Thus, soil type 1 is used in the program.

Crop Management and Irrigation Practice

The watershed area is subdivided into 6 plots according to various cropping and irrigation practices. Crops commonly grown in the county are corn, wheat, soybeans, and alfalfa. Sorghums are grown both for ensilage and for grain. The cropping plans in Table VI for the plots shown in Figure 3 were made simply on the basis of the owner's intention. It is not common to practice double-cropping in this area, but for plot 1 double-cropping is managed in order to get early return on the investment in irrigation facilities. The corn crop is planted in April of the first simulation year. Winter wheat is planted immediately following the corn crop which is harvested the next summer. After wheat harvest, soybeans are planted, followed by a fallow term during the winter season. On finishing one cycle of rotation, corn is planted again. Care should be taken in selecting proper planting and harvesting dates for a preceding crop and for a following crop on a plot, in order

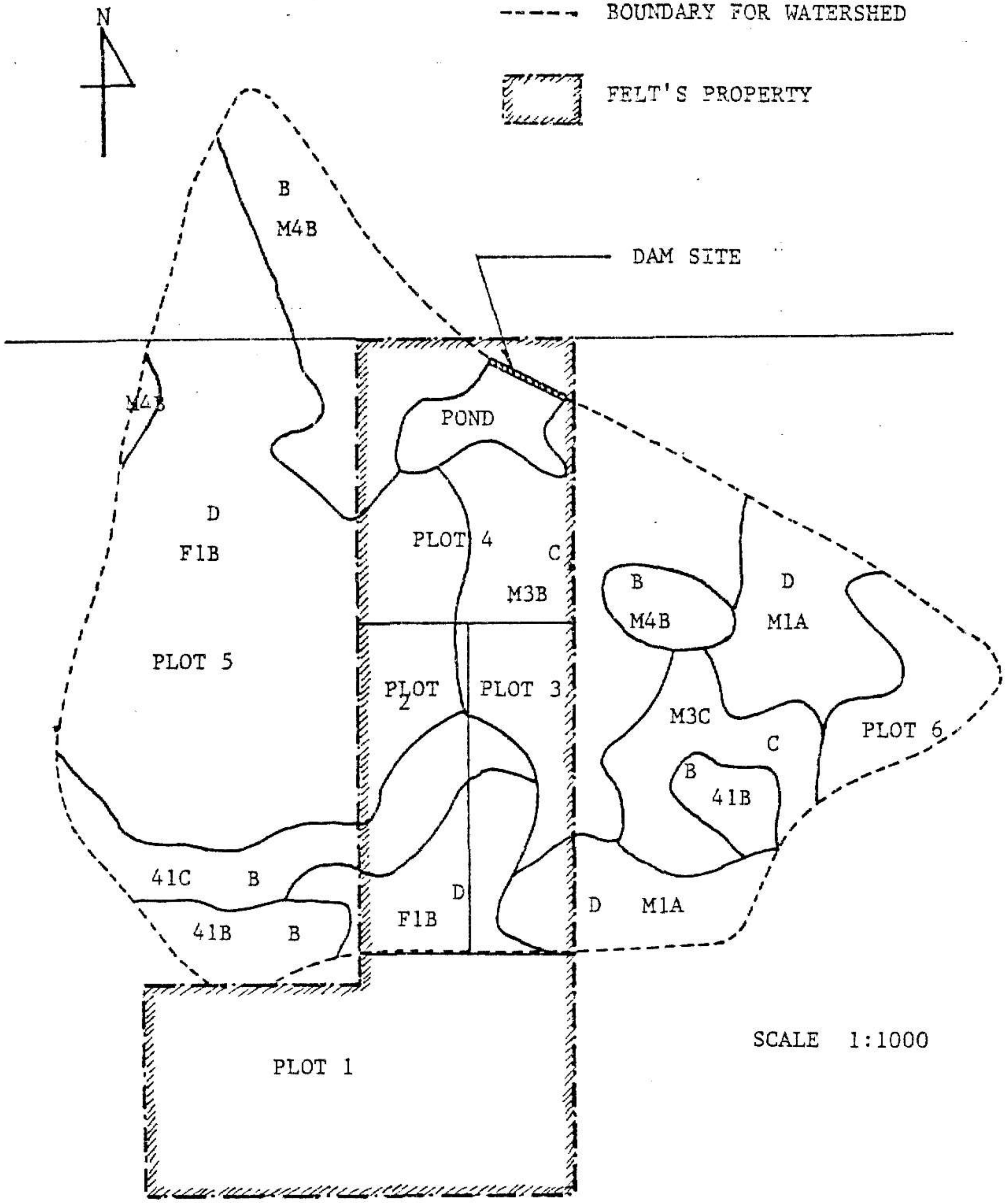


Figure 3. General Layout of Drainage Area

TABLE V CLASSIFICATION OF SOIL TYPES FOR DRAINAGE AREA

Mapping Unit	Irrigation Soil Group (1)	SCS Hydro Group	LCU (2)	Percent of Drain Area	Area in ha (acres)
Kenoma silt loam	1	D	IIIe-3	39.8	66 (163.1)
Dennis silt loam 1-3. %	3	C	IIe-1	16.6	27.5 (68.0)
Catoose silt loam	6	B	IIe-2	12.8	21.3 (52.7)
Parsons silt loam	1	D	IIIe-3	10.7	17.7 (43.7)
Bates loam 4-7 %	8	B	IIIe-1	6.0	10.0 (24.8)
Dennis silt loam 3-6 %	3	C	IIIe-4	5.3	8.8 (21.8)
Bates loam 1-4 %	8	B	IIe-2	4.4	7.4 (18.2)
Unknown				4.3	7.2 (17.7)

(1) Kansas Irrigation Guide, Irrigation Soil Group (8)

(2) Land Capability Units, Soil Conservation Service (10)

TABLE VI LAND USE PLAN AND CROP MANAGEMENT

Plot	Area in ha (acres)	Irrigation Plan Implemented	Soil Type (SCS Group)	Crop Management	
1	34.4 (85)	Irrigation Only	1	Corn-Wheat-Soybeans	*(1)
2	12.1 (30)	Runoff & Irrigation	1	Corn-------Sorghum	**(2)
3	12.1 (30)	Runoff & Irrigation	1	Soybeans	***(3)
4	76.9 (190)	Runoff Only	1	Pasture	***(3)
5	48.6 (120)	Runoff Only	1	Corn	***(3)
6	16.2 (40)	Runoff Only	1	Sorghum	***(3)

*(1) Double-cropping with biennially repeated rotation
**(2) Single-cropping with biennially repeated rotation
***(3) Single-cropping with continually same crop

TABLE VII PLANTING AND HARVESTING DATES

Crop	Planting Date	Harvesting Date
Corn	April 10	September 20
Soybeans	June 30	October 30
Sorghum	June 15	October 10
Wheat	October 10	June 20

not to have them overlapped. Planting and harvesting dates for the crops are given in Table VII. On the plots except plot 1, a single-cropping is practiced with only plot 2 crop-rotated.

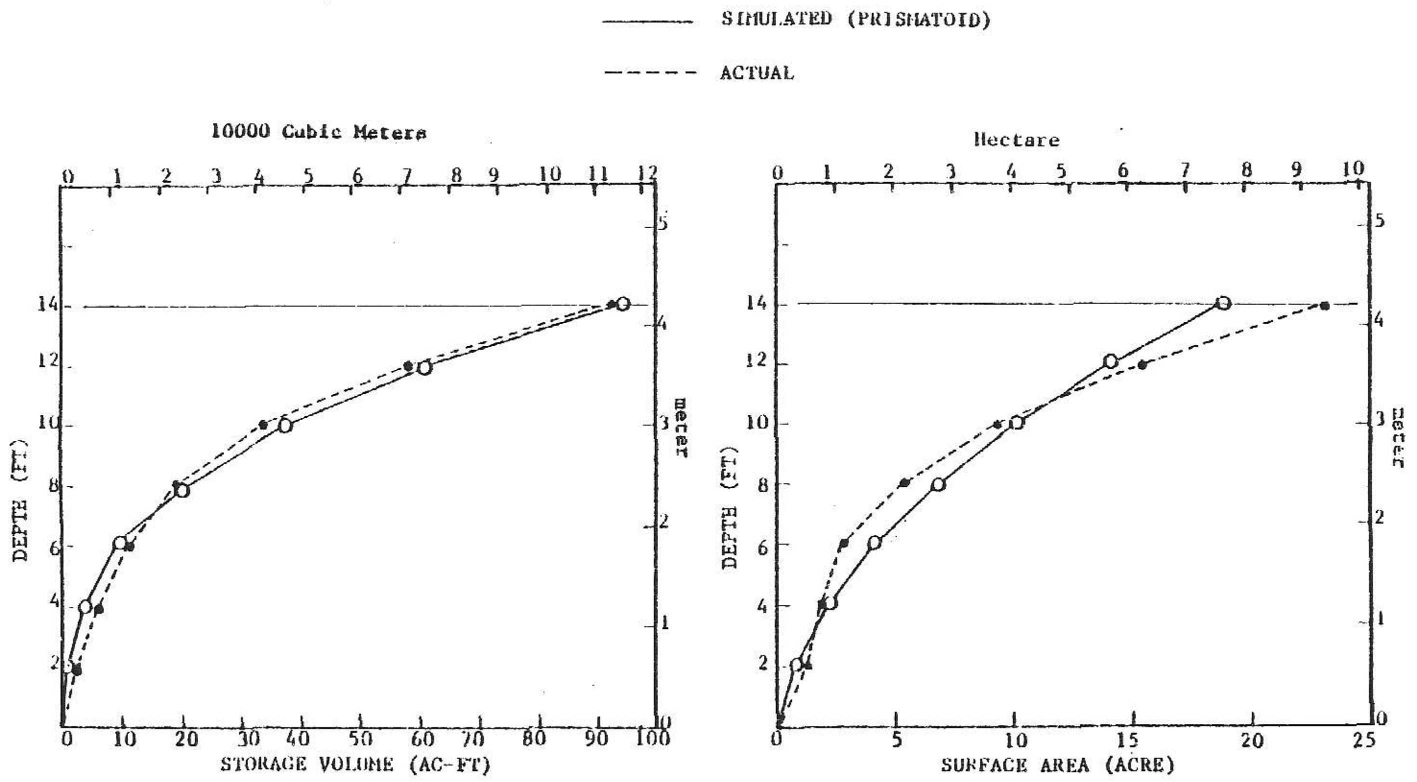
The irrigation plan for each plot is illustrated in Table VI. A watershed area of 410 acres contributes runoff to the storage pond corresponding to plots 2-6 on Figure 3 and Table VI. Irrigation water from the pond is applied to the area of 58.7 hectares (145 acres) (plots 1-3) at a specified rate depending upon the previously described irrigation criteria. When the pond storage on a day is less than 5 percent of its maximum storage capacity (PCVMAX = 0.05), when the upper zone soil moisture is greater than 50 percent of maximum available moisture (PAVLU = 0.5), or when the temperature is below freezing, irrigation is not allowed.

Study of Storage Facility

Although the water sources for a pond can be direct rainfall on the surface area, inflow from municipal disposal, feedlot runoff, and surface runoff from the drainage area, only precipitation and runoff are considered as water sources for storage.

Information on the small farm reservoir was secured from Agricultural Engineering Associates, Inc., Uniontown, Kansas, which participated in construction in 1976. Figure 4 shows the relationships of volume-depth and area-depth for this reservoir.

In order to obtain pond parameters readily adaptable to the computer program, the irregular shape of reservoir was modified to the shape of an inverted prismatiod with the surface area and the volume at each level of depth reflecting actual conditions as far as possible. It is



(a) Volume-Depth Curve

(b) Area-Depth Curve

Figure 4. Reservoir Storage Capability

necessary to adjust actual dimensions for each reservoir to make use of the pond facility scheme already programmed in KSUHYDRO whenever a case study on a specific site is pursued.

The desired dimensions were selected by a trial and error method to minimize area-depth and volume-depth differences between the actual and simulated pond. The dimensions of base width W = 19.5 meters (65 ft.), base length, L = 19.5 meters (65 ft.), side slope, S = 30, and maximum height, HMAX = 4.2 meters (14 ft.) resulted in the correspondence shown in Figure 4. The maximum surface area is reduced from an actual value of 9.27 hectares (22.91 acres) to 7.61 hectares (18.81 acres) in the model, while the maximum volume increases from an actual value of 11.42 ha-m (92.6 acre-ft) to 11.65 ha-m (94.5 acre-ft) in the model. Accordingly, it can be supposed that the reduction of maximum surface area causes relatively a small decrease in evaporation loss from the surface because of the small moisture deficit in the area.

The outputs from storage reservoir that are taken into account are overflows over spillway, evaporation, irrigation to the disposal area, and seepage. The last factor, seepage, is difficult to estimate because the storage-depth relationship is unique for each reservoir. Under assumption that the reservoir was well-constructed by sealing pond bottom with highly impermeable material like bentonite, zero seepage was considered in this study.

CHAPTER V

RESULTS AND DISCUSSION

The capability of a farm irrigation supply pond may be restricted by various factors, such as meteorology, the site topography, the size of the irrigable crop land, the drainage area size, vegetation, and so forth. Observations on Felt's farm were made for a 23-year simulation period (1948-1970). This chapter presents the results obtained from this simulation. Hydrologic simulation is a tool that can be used to manage or predict water budget between the income of water from precipitation, and snowmelt and the outflow of water by evaporation, transpiration, irrigation withdrawal, groundwater recharge, and streamflow. Water balance calculations are made on long-term-average climatic data to obtain an approximate picture of the seasonal or annual trend of hydrologic characteristics.

The possibility of supplemental irrigation in Southeastern Kansas, the main point of this study, was examined under three different conditions with varying irrigation rates of 0.00, 6.35 (0.25), and 12.7 mm/day (0.50 inches/day).

In the first part of this chapter, general hydrologic aspects of each irrigation rate are discussed, and then an interpretation on irrigation demand is made combined with reservoir water budget.

GENERAL HYDROLOGY

The purpose of irrigation may be to increase crop yield by supplementing rainfall. Irrigation is an artificial method to overcome deficiencies in the natural rainfall pattern. These deficiencies may stem from lack of precipitation, or for other factors related with

TABLE VIII SUMMARY OF LONG-TERM SIMULATION RESULTS (a)

Station : Fort Scott Simulation Period : 1948-1970
Critical Event : 168 mm (6.6 inches) PAVLU : 0.5
Soil Type : 1
Irrigation Rate:6.35 mm (0.25 inches/day)

Precipitation in mm/yr (in/yr)	977 (38.45)
High	1533 (60.36)
Low	669 (26.35)
Moisture Deficit in mm/yr (in/yr)	174 (6.86)
Lake Evaporation in mm/yr (in/yr)	1151 (45.31)
Maximum Pond Depth in meters (ft)	4.2 (14)
Maximum Pond Volume in ha-m (ac-in)	11.66 (1133.98)
Pond Dimensions in meters (ft)	19.5 X 19.5 (65X65)
Direct Receiving Area in ha (ac)	7.6 (18.8)
Minimum Pond Depth in meters (ft)	1.17 (3.91)
Pond Discharges--No. of Years	23
Total No. of Discharges	668
Total Discharge in ha-m (ac-in)	797 (77542.63)

	Plots					
	1	2	3	4	5	6
Crop	C-W-B	C-S	B	P	C	S **
Area in hectares (acres)	34.4 (85)	12.1 (30)	12.1 (30)	76.9 (190)	48.6 (120)	16.2 (40)
Irrigation in cm/yr (in/yr)	12.6 (4.95)	16.1 (6.32)	4.3 (1.68)	0	0	0
Runoff in cm/yr (in/yr)	29.6 (11.66)	32.6 (12.82)	32.8 (12.92)	19.6 (7.73)	28.8 (11.34)	30.8 (12.12)
Percolation in cm/yr (in/yr)	2.7 (1.06)	3.5 (1.37)	3.4 (1.32)	4.0 (1.59)	2.0 (0.80)	3.5 (1.37)
Evapotranspiration in cm/yr (in/yr)	56.6 (22.28)	55.1 (21.68)	47.0 (18.49)	56.6 (22.27)	49.5 (19.48)	46.1 (18.14)
Interception in cm/yr (in/yr)	21.5 (8.45)	22.7 (8.95)	18.9 (7.44)	17.5 (6.88)	17.5 (6.88)	17.5 (6.88)
Change in Soil moisture in cm/yr (in/yr)	-0.15 (-0.06)	-0.13 (-0.05)	-0.13 (-0.05)	-0.10 (-0.03)	-0.13 (-0.05)	-0.15 (-0.06)
No. of Irrigation Days	19.8	25.3	6.7	-	-	-

** C-Corn, W-Wheat, S-Sorghum, B-Soybeans, P-Pasture, F-Fallow

TABLE VIII SUMMARY OF LONG-TERM SIMULATION RESULTS (b)

Station : Fort Scott Simulation Period : 1948-1970
Critical Event : 168 mm (6.6 inches) PAVLU : 0.5
Soil Type : 1
Irrigation Rate: 12.7 mm (0.50 inches/day)

Precipitation in mm/yr (in/yr)	977 (38.45)
High	1533 (60.36)
Low	669 (26.35)
Moisture Deficit in mm/yr (in/yr)	174 (6.86)
Lake Evaporation in mm/yr (in/yr)	1151 (45.31)
Maximum Pond Depth in meters (ft)	4.2 (14)
Maximum Pond Volume in ha-m (ac-in)	11.66 (1133.98)
Pond Dimensions in meters (ft)	19.5 X 19.5 (65X65)
Direct Receiving Area in ha (ac)	7.6 (18.8)
Minimum Pond Depth in meters (ft)	1.12 (3.73)
Pond Discharges--No. of Years	23
Total No. of Discharges	678
Total Discharge in ha-m (ac-in)	810 (78846.94)

	Plots					
	1	2	3	4	5	6
Crop	C-W-B	C-S	B	P	C	S **
Area in hectares (acres)	34.4 (85)	12.1 (30)	12.1 (30)	76.9 (190)	48.6 (120)	16.2 (40)
Irrigation in cm/yr (in/yr)	11.7 (4.60)	14.1 (5.55)	4.2 (1.65)	0	0	0
Runoff in cm/yr (in/yr)	30.4 (11.98)	33.3 (13.11)	33.3 (13.12)	19.6 (7.73)	28.8 (11.34)	30.8 (12.12)
Percolation in cm/yr (in/yr)	2.7 (1.05)	3.5 (1.39)	3.3 (1.30)	4.0 (1.59)	2.0 (0.80)	3.5 (1.37)
Evapotranspiration in cm/yr (in/yr)	57.0 (22.45)	55.0 (21.76)	47.1 (18.56)	56.6 (22.27)	49.5 (19.48)	46.1 (18.14)
Interception in cm/yr (in/yr)	19.3 (7.61)	19.6 (7.78)	18.2 (7.15)	17.5 (6.88)	17.5 (6.88)	17.5 (6.88)
Change in Soil moisture in cm/yr (in/yr)	-0.13 (-0.05)	-0.13 (-0.05)	-0.13 (-0.05)	-0.10 (-0.03)	-0.13 (-0.05)	-0.15 (-0.06)
No. of Irrigation Days	9.2	11.1	3.3	-	-	-

** C-Corn, W-Wheat, S-Sorghum, B-Soybeans, P-Pasture, F-Fallow

TABLE VIII SUMMARY OF LONG-TERM SIMULATION RESULTS (c)

Station : Fort Scott Simulation Period : 1948-1970
Critical Event : 168 mm (6.6 inches) PAVLU : 0.5
Soil Type : 1
Irrigation Rate : 0 mm (0 inches/day)

Precipitation in mm/yr (in/yr)	977 (38.45)
High	1533 (60.36)
Low	669 (26.35)
Moisture Deficit in mm/yr (in/yr)	174 (6.86)
Lake Evaporation in mm/yr (in/yr)	1151 (45.31)
Maximum Pond Depth in meters (ft)	4.2 (14)
Maximum Pond Volume in ha-m (ac-in)	11.66 (1133.98)
Pond Dimensions in meters (ft)	19.5 X 19.5 (65X65)
Direct Receiving Area in ha (ac)	7.6 (18.8)
Minimum Pond Depth in meters (ft)	
Pond Discharges--No. of Years	23
Total No. of Discharges	776
Total Discharge in ha-m (ac-in)	919 (89394.5)

	Plots					
	1	2	3	4	5	6
Crop	C-W-B	C-S	B	P	C	S **
Area in hectares (acres)	34.4 (85)	12.1 (30)	12.1 (30)	76.9 (190)	48.6 (120)	16.2 (40)
Irrigation in cm/yr (in/yr)	0	0	0	0	0	0
Runoff in cm/yr (in/yr)	27.0 (10.63)	29.6 (11.66)	31.5 (12.41)	19.6 (7.73)	28.8 (11.34)	30.8 (12.12)
Percolation in cm/yr (in/yr)	2.5 (0.98)	3.3 (1.28)	3.1 (1.23)	4.0 (1.59)	2.0 (0.80)	3.5 (1.37)
Evapotranspiration in cm/yr (in/yr)	50.9 (20.02)	47.4 (18.68)	45.7 (17.98)	56.6 (22.27)	49.5 (19.48)	46.1 (18.14)
Interception in cm/yr (in/yr)	17.5 (6.88)	17.5 (6.88)	17.5 (6.88)	17.5 (6.88)	17.5 (6.88)	17.5 (6.88)
Change in Soil moisture in cm/yr (in/yr)	-0.13 (-0.06)	-0.13 (-0.05)	-0.13 (-0.05)	-0.10 (-0.03)	-0.13 (-0.05)	-0.15 (-0.06)
No. of Irrigation Days	0	0	0	-	-	-

** C-Corn, W-Wheat, S-Sorghum, B-Soybeans, P-Pasture, F-Fallow

natural crop growth which requires more water than naturally provided. The character of each component of hydrologic cycle at a location should be examined in order to plan intelligently for the use of the available water.

The long-term average hydrologic budgets for each irrigation rate are tabulated in Table VIII (a-c). Table VIII briefly outlines pond operations, crop, plot hydrology, and precipitation characteristics.

Precipitation

The sub-humid region is normally considered to receive sufficient rainfall resulting from the interaction of warm and cold air masses. The main source of precipitation is affected by the Gulf of Mexico for this region (11).

The annual rainfall totals at Fort Scott ranged from 669 mm (26.35 inches) to 1533 mm (60.36 inches) during the simulation period (1948-1970). As can be seen in Figure 5, the droughts of 1952, 1953, 1963 and 1966 were recorded, and the average annual precipitation was 977 mm (38.45 inches). The annual precipitation data were arrayed and plotted, using normal probability distribution. The ordinate of Figure 6 is the ratio of the observed value divided by the mean value for the simulation period and the abscissa is probability, as defined by the equation m/(n+1), where "m" is the order number or rank of the plotted point with the largest value having m = 1, and "n" is the total number of points in the array (14). The 80 percent chance of rainfall, i.e., once in 5 years, is 762 mm (30 inches) by Figure 6.

Distribution of rainfall through the year favors crop production, with an average of 75 percent of the total annual rainfall occurring

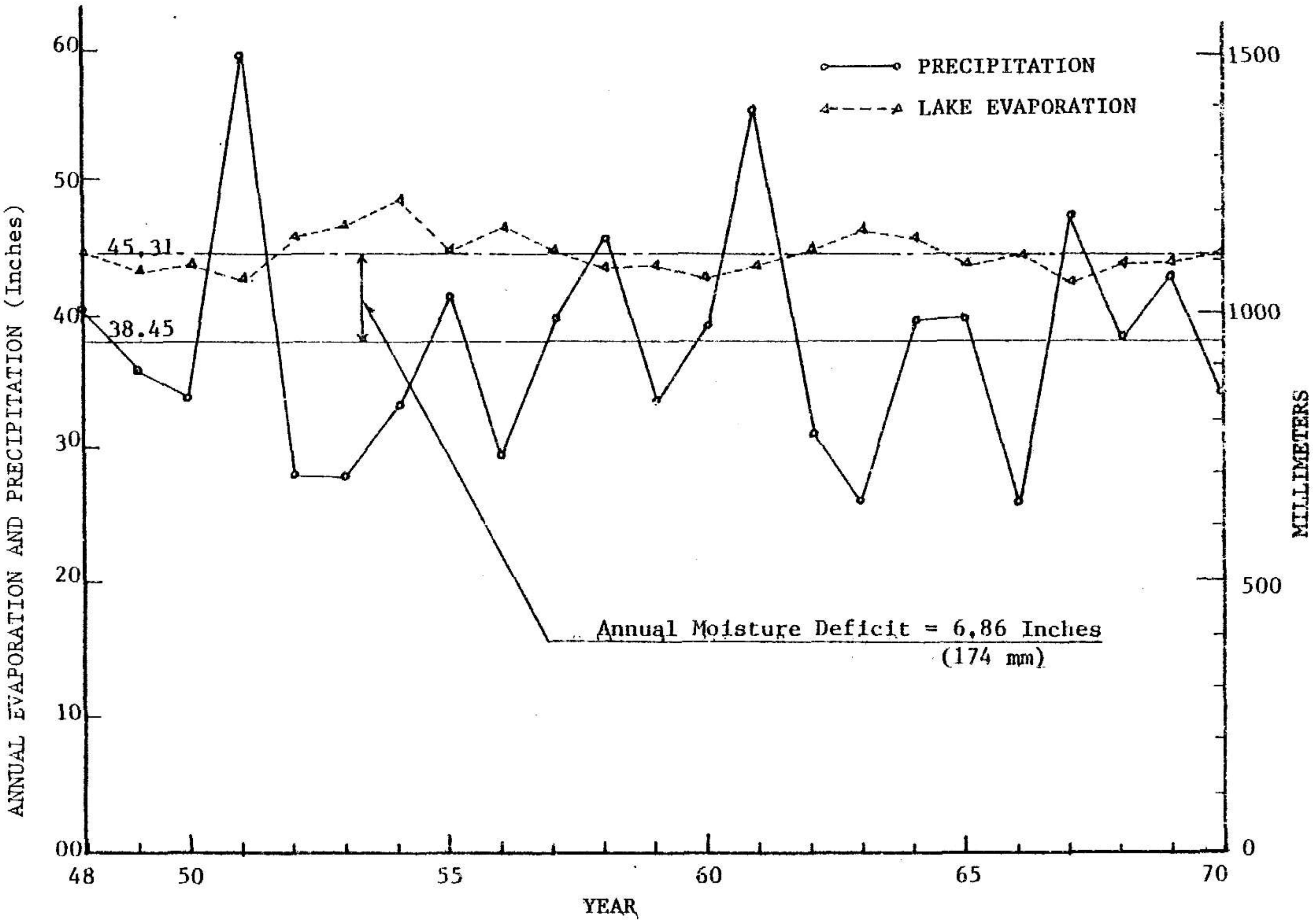


Figure 5. Distribution of Annual Precipitation and Lake Evaporation
(1948-1970)

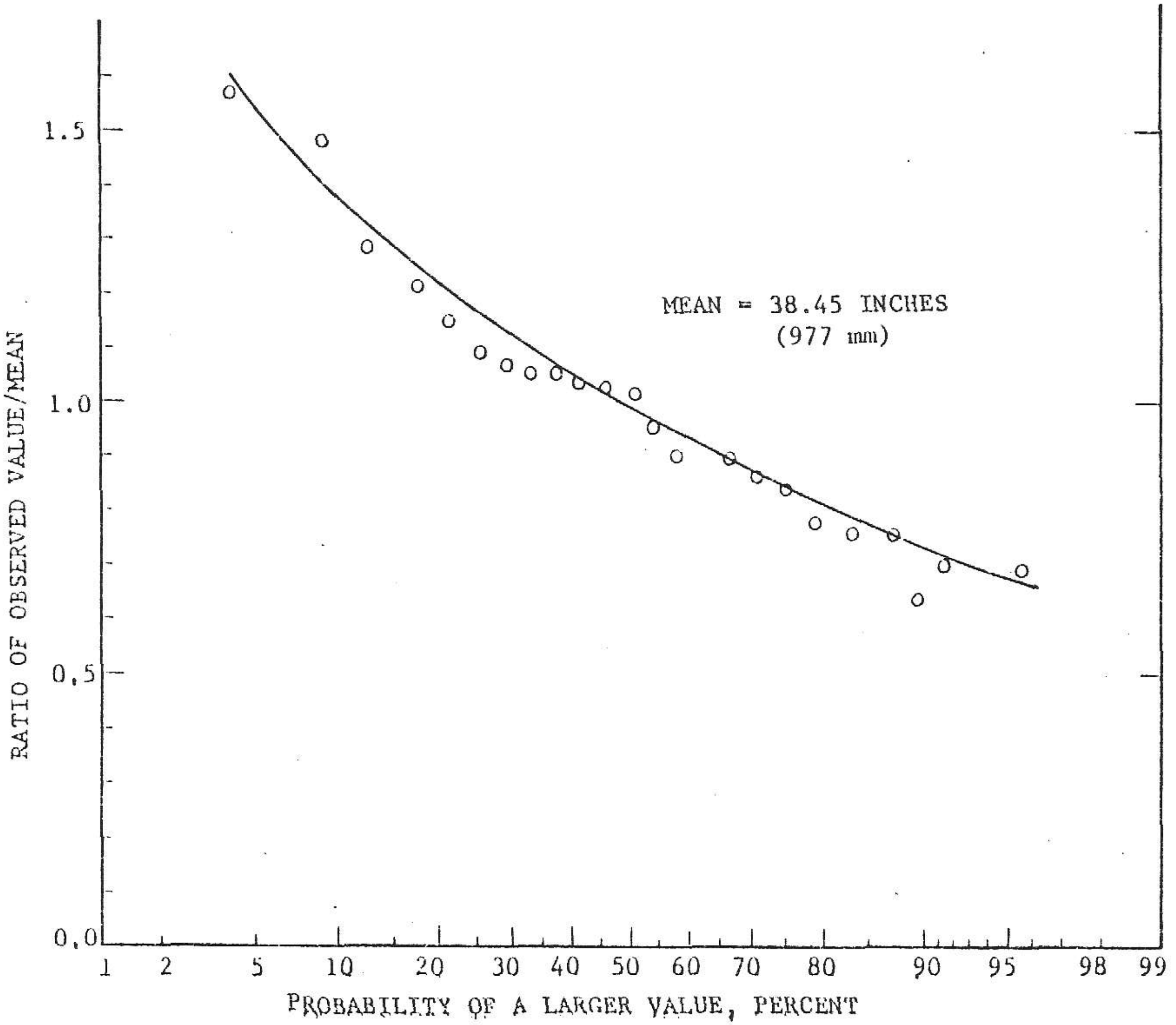


Figure 6. Simulated Annual Precipitation Probabilities(1948-1970)

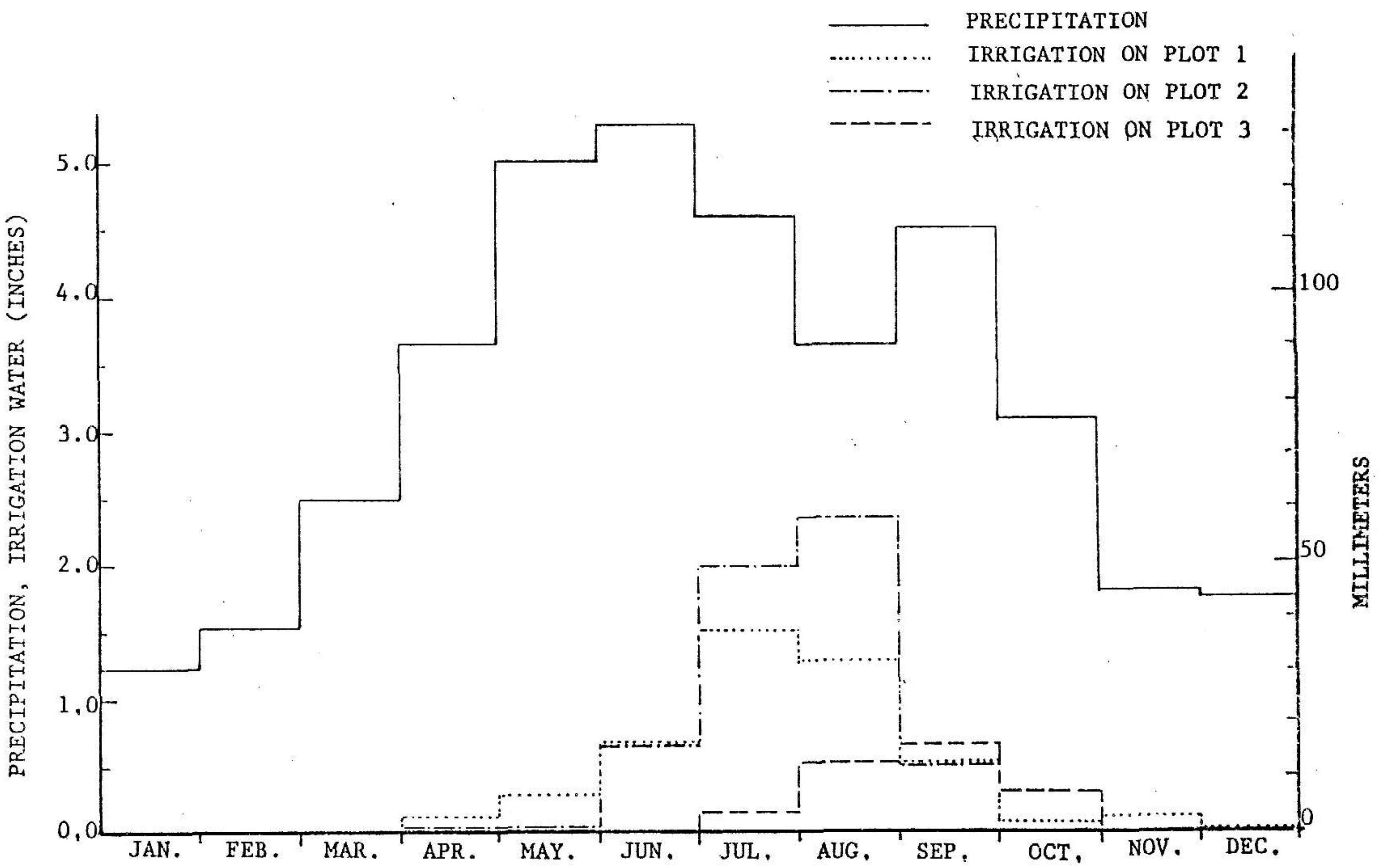


Figure 7. Monthly Distribution of Precipitation and Monthly Average Irrigation Amount at the Irrigation Rate of 0.25 Inches/Day (1948-1970)

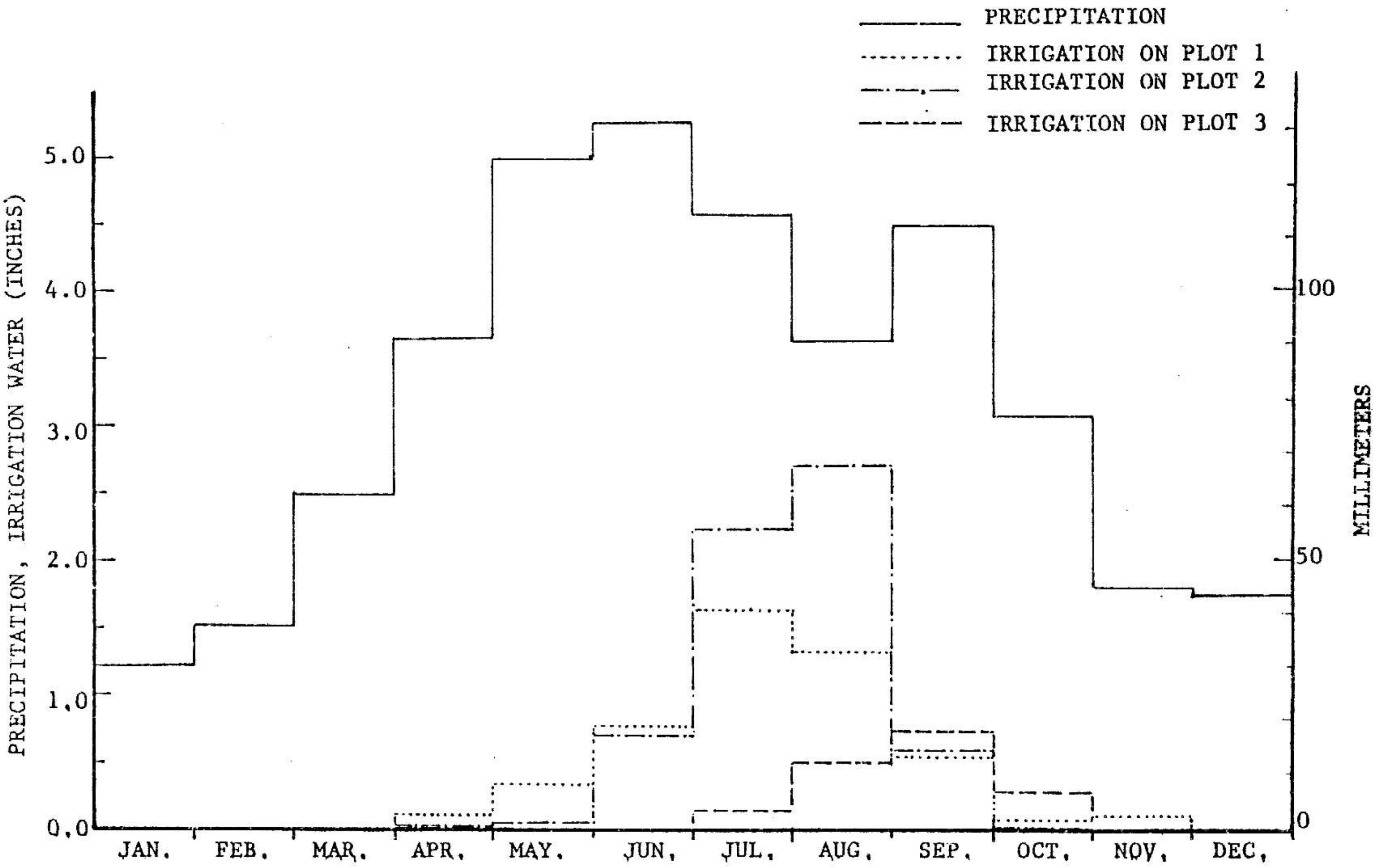


Figure 8. Monthly Distribution of Precipitation and Monthly Average Irrigation Amount at the Irrigation Rate of 0.50 Inches/Day (1948-1970)

in the growing season of April to September. May and June were the months of greatest rain, while a noticeable decrease in the average rainfall occurs in July and to a greater extent in August. An increase occurs again in September, as shown in Figure 7 and Figure 8. The reduction in the amount of rainfall in August may be critical for some crop such as corn.

Runoff

It is evident that more rainfall causes more runoff which can be a major source to fill the reservoir. The response of runoff to annual precipitation is explained in a simple linear regression equation in Figure 9. A map of annual average runoff yield for Kansas was developed by Kansas Water Resources Board (15) based on 1920-1956 records. The runoff by this map is 277 mm (10.9 inches) in the southeast. The average value of 250 mm (9.84 inches) under the condition of dryland cultivation in Figure 9, may reasonably approximate the estimate of 277 mm (10.9 inches). Annual surface runoff amounts were arrayed and plotted by the same method described previously in Figure 10. For a 90 percent probability of occurrence, 50.8 mm (2.0 inches) runoff may be estimated from Figure 11 based on a manual fit of data points.

Much of the runoff occurs in the early spring and the late fall as does precipitation. Figure 11 shows monthly distribution of runoff amount into the pond under consideration of non-irrigation.

Interception

It is difficult to estimate the amount of water intercepted. Lull (16) reported the results of U.S. Department of Agriculture experiments on total interception by various crops. In Missouri,

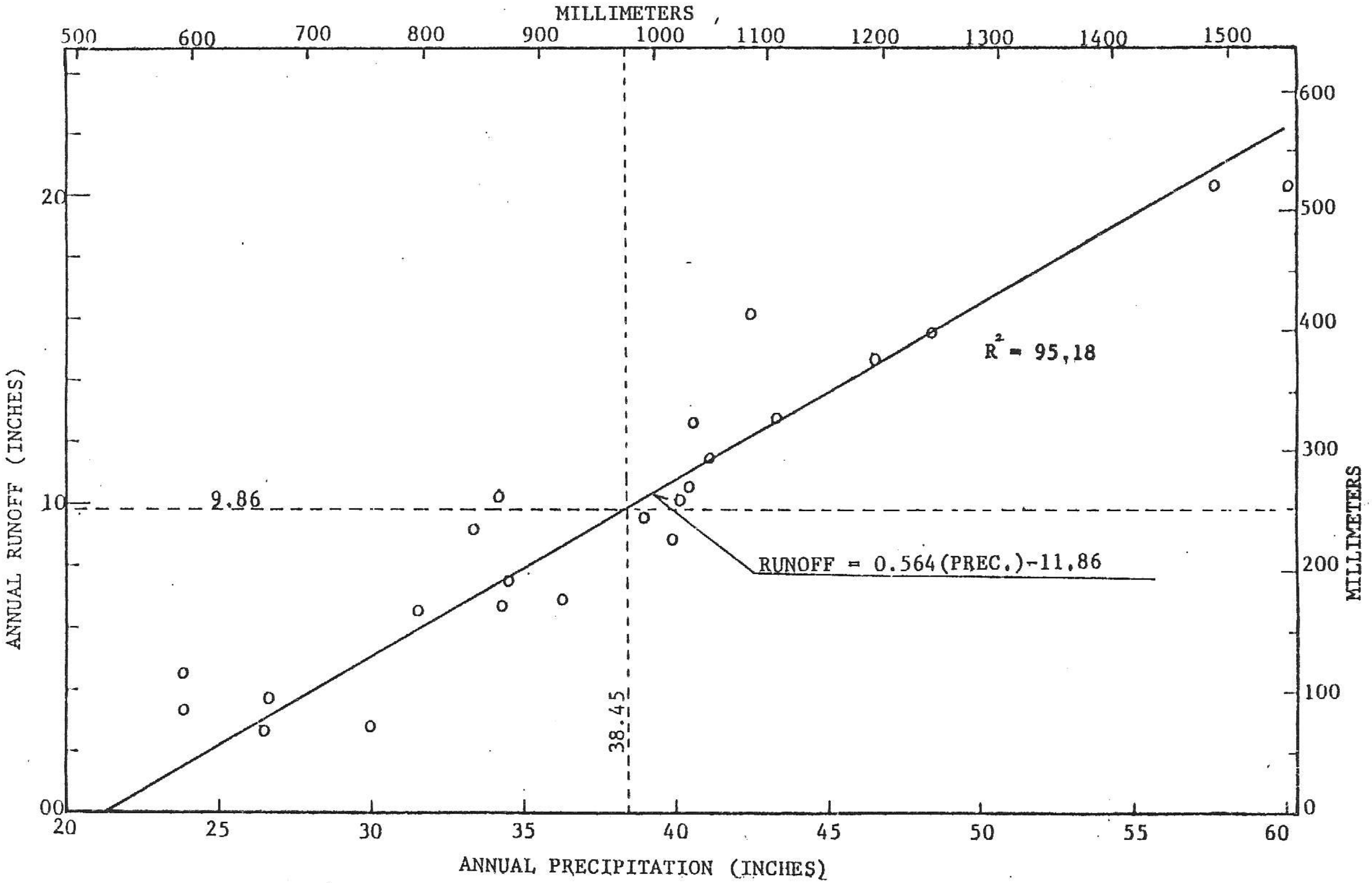


Figure 9. Relationship Between Annual Precipitation and Simulated Annual Average Runoff (1948-1970)

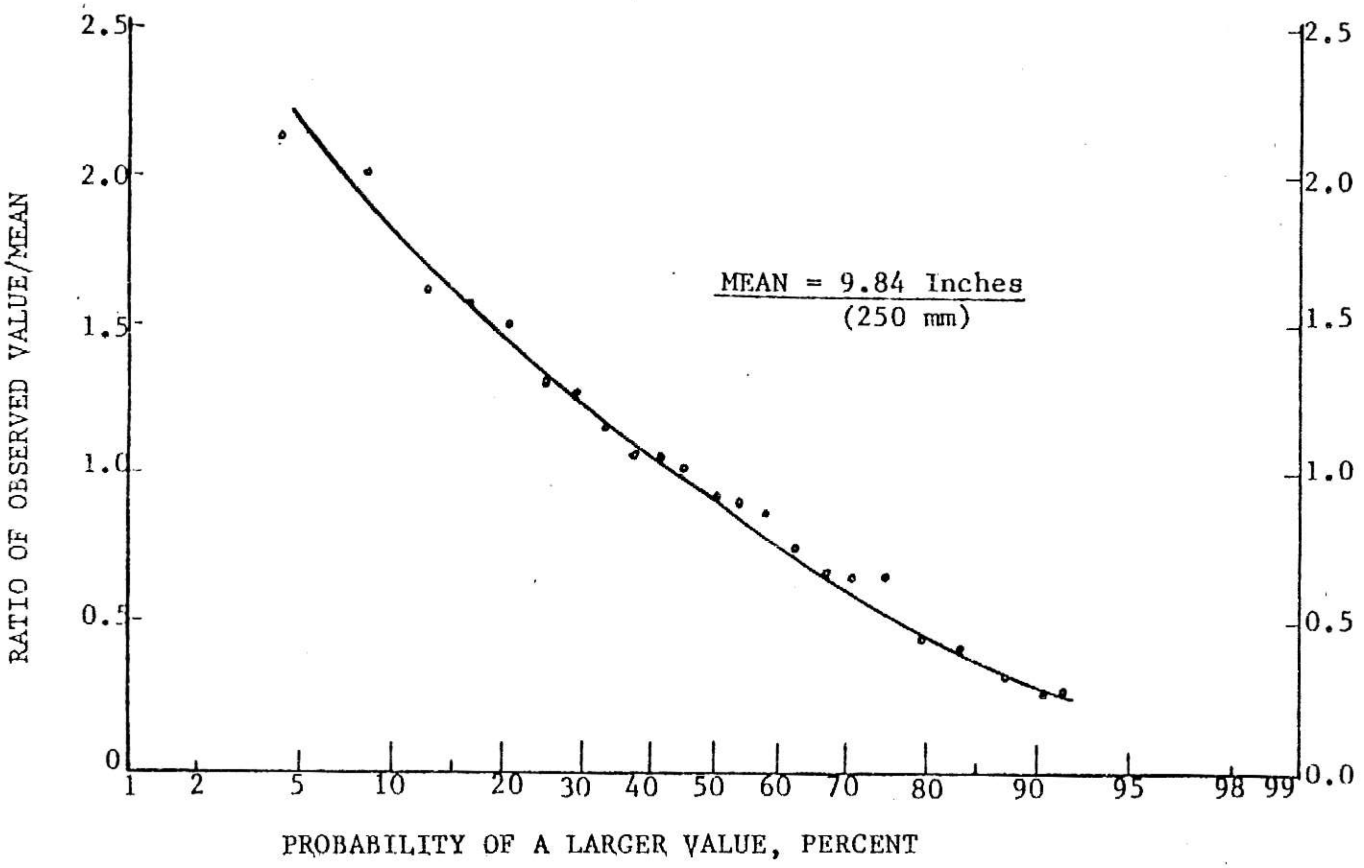


Figure 10. One-Year Simulated Annual Surface Runoff Probabilities (1948-1970)

bluegrass intercepted 17 percent of the rainfall during the month prior to harvest. During the growing season, it was found to intercept 7 to 36 percent and during low vegetation development it was found to intercept 3 to 22 percent for alfalfa, corn, soybean, and oats.

The total annual interception based on long-term simulation was 175 mm (6.88 inches) on an unirrigated area, which would be equivalent to 17.9 percent of the average annaul rainfall of 977 mm (38.45 inches). The suggestion made by Bean (3) to use 2.54 mm (0.1 inch) interception-storage-capacity in the computer program, may therefore be reasonable.

Evapotranspiration

Evapotranspiration (ET) includes bare soil evaporation and transpiration. As shown in Table VIII, long-term average annual ET varies from 461 mm (18.14 inches) to 570 mm (22.45 inches), depending upon the schedule of crop management and the plan of irrigation. These values indicate that approximately one-half of the annual total precipitation is dissipated by ET. The irrigation quantity on irrigation plots causes an increase in ET, as would be anticipated.

Storage Facility

The average monthly runoff volumes from the 166 hectare (410 acre) watershed under natural conditions, are shown in Figure 11. The distribution of runoff throughout the year is very important with regard to the irrigation water supply. The lowest expected runoff is in August during the growing season from April to September. Needless to say, when runoff is low, the irrigation demands are greatest.

The rainfall volumes contributing to the increase of storage volume are greatest in June and lowest in August. The lake evaporation is relatively uniformly distributed from year to year.

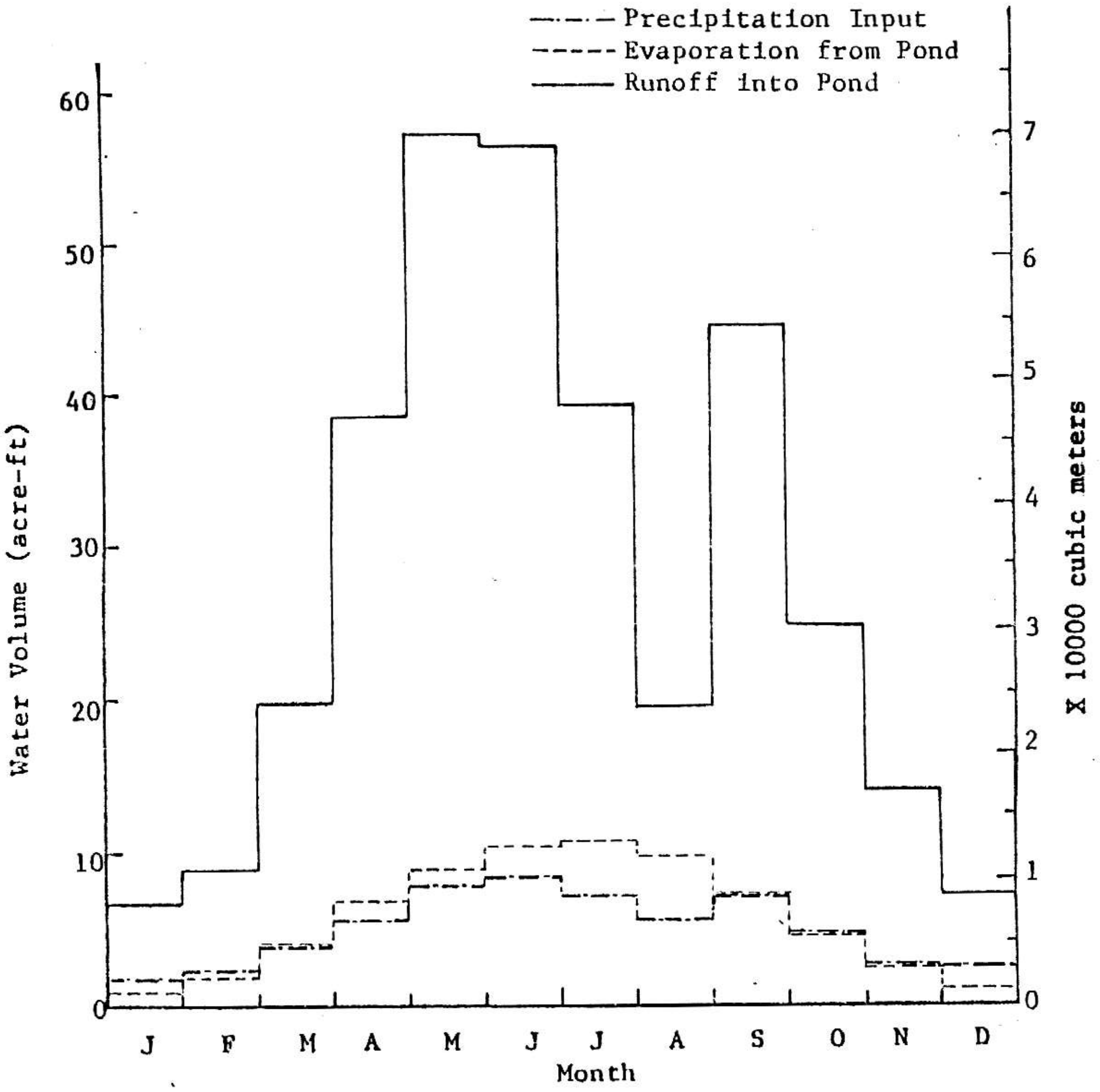


Figure 11. Monthly Distribution of Precipitation, Evaporation, and Runoff to Pond

The average monthly net available water for irrigation shown in Figure 12, was estimated by the summation of expected runoff yield and direct precipitation on the pond and the subtraction of evaporation. The net available water is always positive. The irrigation withdrawals from the reservoir reduce the water available, but the pond was never dry during the simulation period.

In order to impound all of the runoff without overflow for the simulation period would have required a pond of 360 x 360 meter (1200 x 1200 ft.) base dimension with the height of 4.2 meter (14 ft.) and the side slope of 30 to 1, which is a pond volume 9.13 times the actual pond volume. Through the year, the reservoir, however, accumulates the monthly available water to the maximum degree of storage capacity of 11.66 ha-m (94.5 acre-ft.). Thus, there is sufficient water available to irrigate more land.

IRRIGATION NEEDS

The timing of irrigations is determined by the irrigation limitation criteria described in previous chapter. The amount of irrigation applied each time was at two rate levels of 6.35 (0.25) and 12.7 mm/day (0.50 inches/day). For the irrigation rate of 6.35 mm/day (0.25 inches/day), as shown in Table VIII, the water depths irrigated were annually 12.6 cm (4.95 inches) for plot 1 double-cropped rotation management, 16.1 cm (6.32 inches) for plot 2 single-cropped rotation management, and 4.3 cm (1.68 inches) for plot 3 of continuous soybeans. For the 12.7 mm/day (0.50 inches/day), average irrigation amounts were somewhat smaller than for the 6.35 mm/day (0.25 inches/day) rate. It is suggested that seasonal net requirements in Bourbon County are 7.4 cm (2.9) for soybeans, 10.4 cm (4.1) for sorghum, 17.3 cm (6.8 inches) for corn by Kansas Irrigation Guide (8).

The monthly distributions of irrigation amount are presented in Figure 7 and Figure 8, on the basis of various plots. Figure 12 shows the mean monthly overall irrigation water in units of hectare-meter (acre-ft.). These values were modified by considering weighted value of each plot and mean monthly irrigation depths on each plot shown in Figure 7 and Figure 8. From Figure 12, it can be seen that irrigation water for both irrigation rates were mostly needed in July and August. The values in this study are lower than stated requirements, but the differences are not large.

As can be seen in Figure 12, when the available water volume is taken into consideration, August may be a critical month to have a risk not to meet irrigation demand in a certain year. The ultimate purpose of supplemental irrigation is to save crops from disaster of drought and to increase crop yield even with a normal precipitation distribution. The monthly fluctuations of pond depth are presented in Figure 13 showing mean annual depths of 4.16 meters (13.86 ft.) for Zero-rate, 3.8 meters (12.68) for 6.35 mm/day (0.25 inch/day)-rate, and 3.87 meters (12.89) for 12.7 mm/day (0.50 inch/day)-rate. For the latter two irrigation rates, the mean pond depth in August was lowest. The observed pond depths in August were arrayed and plotted by manual fitting of curve, as shown in Figure 14 and in Figure 15, for the 6.35 (0.25) and 12.7 (0.50) rates, respectively.

By the irrigation criteria, when the reservoir storage volume is less than 5 percent of the maximum pond volume, irrigation is not allowed. The maximum pond volume is 11.65 ha-m (94.5 acre-ft.). Its 5 percent

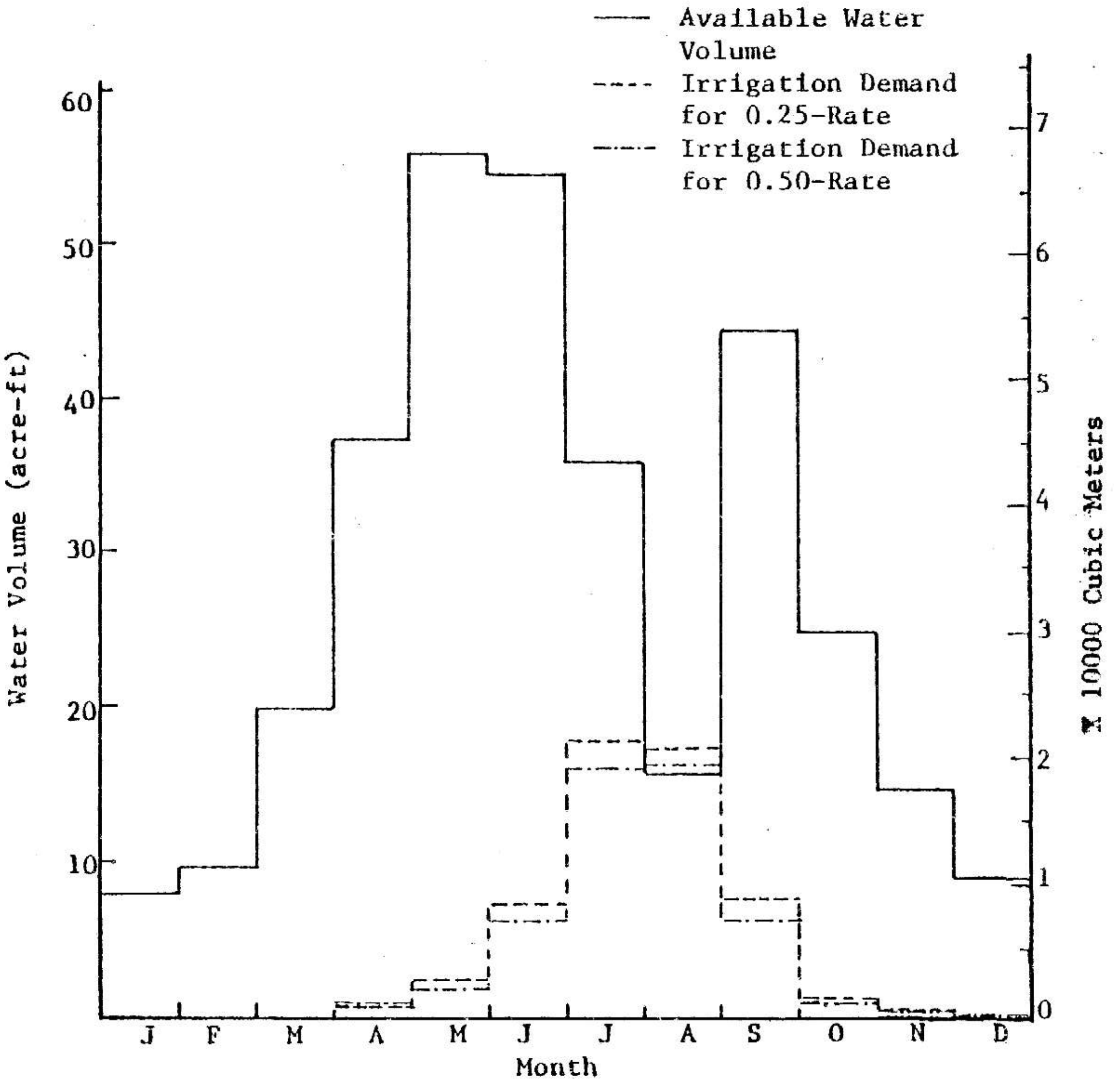


Figure 12. Available Water Volume and Irrigation Demand

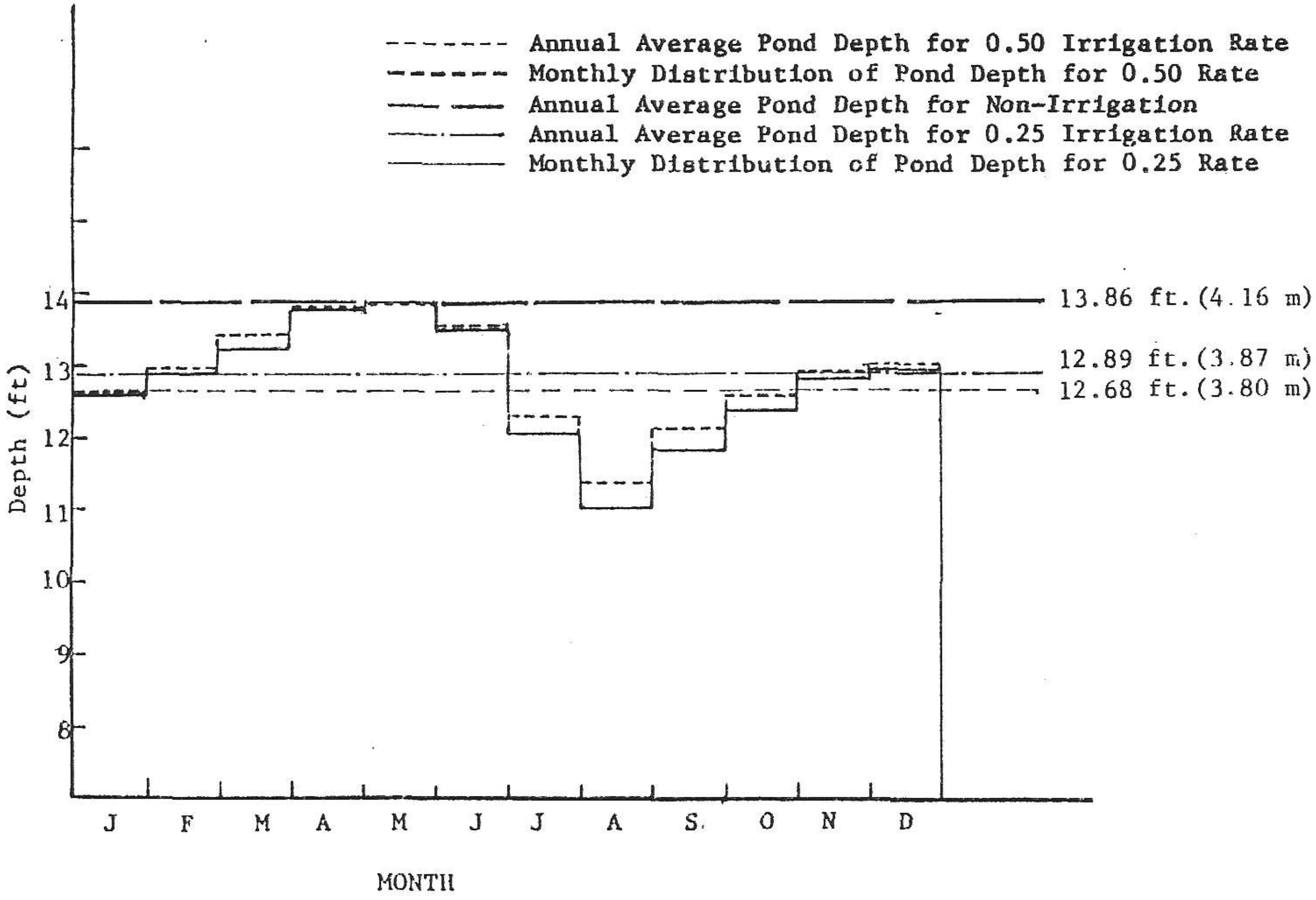


Figure 13. Monthly Distribution of Pond Depth

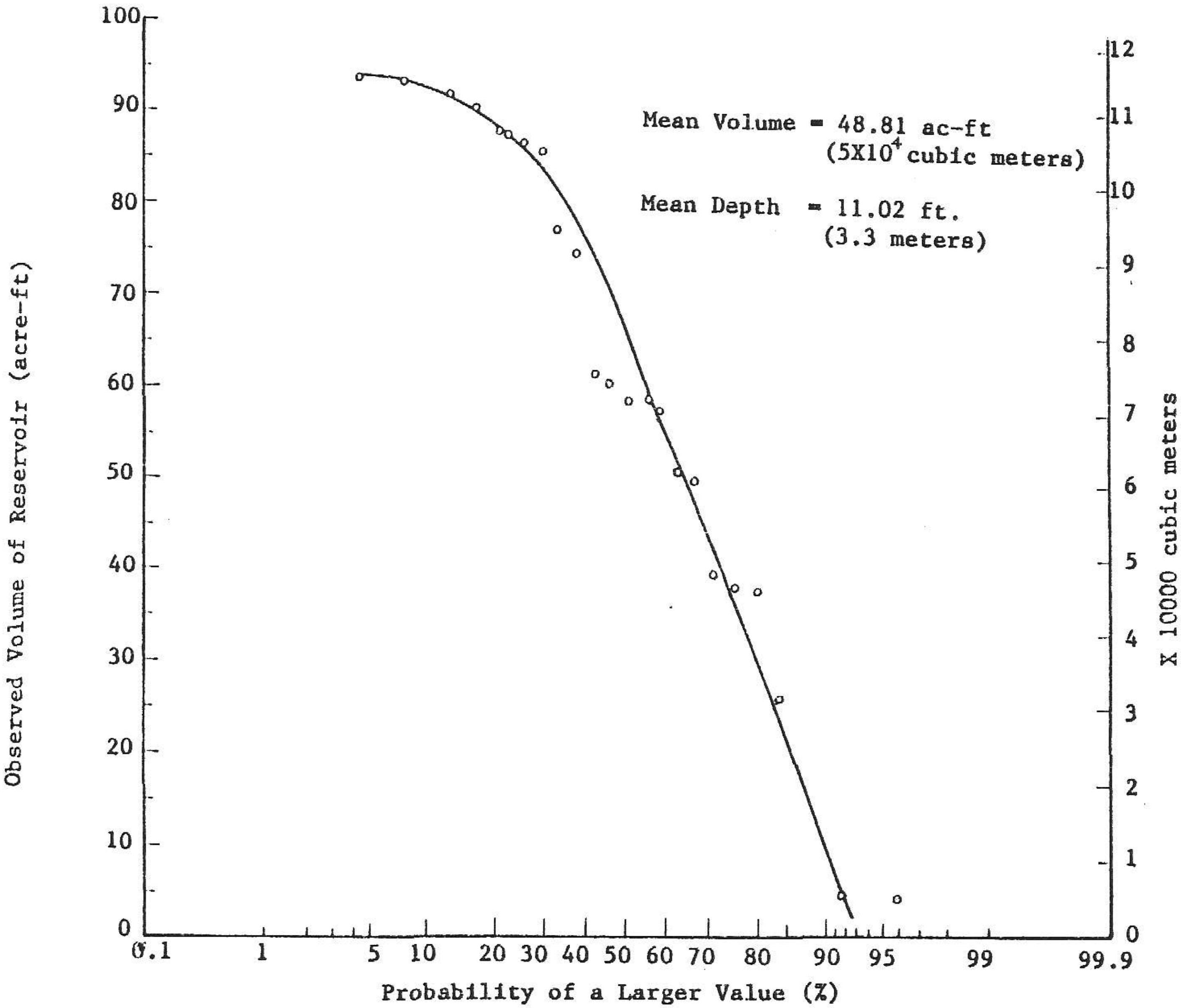


Figure 14. Reservoir Volume Probabilities in August for 0.25 Inches/Day Irrigation Rate (1948-1970)

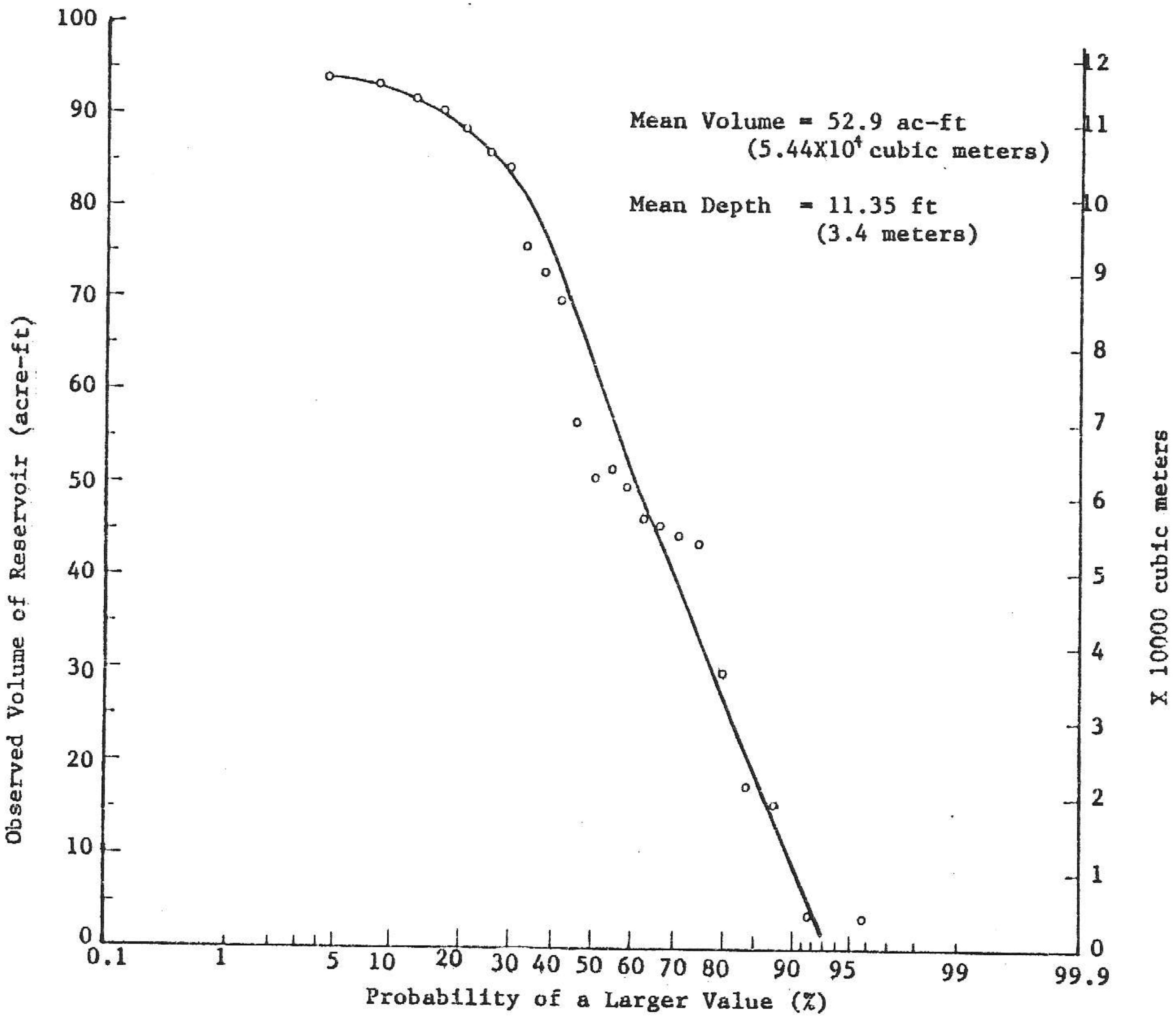


Figure 15. Reservoir Volume Probabilities in August for 0.50 Inches/Day Irrigation Rate (1948-1970)

volume is 0.583 ha-m (4.72 acre-ft.). This volume is equivalent to the pond depth of about 1.35 meters (4.5 ft.). Provided that the pond depth falls below 1.35 meters (4.5 ft.) in a month, there may be a risk not to meet the irrigation demand. It can be seen that the probability not to meet irrigation need in August is abcut 9 percent. The 9 percent risk can also be interpreted as one year out of 11 years. In other words, 58.68 ha (145 acres) could be irrigated at a 9 percent risk by the reservoir volume of 11.66 ha-m (94.5 acre-ft.).

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The aim of this research is to study the feasibility of supplemental irrigation in sub-humid region by developing a general hydrologic crop management model. This purpose was achieved by testing a continuous watershed model. The runoff yield, precipitation to the storage pond, and evaporation were evaluated by this model. In addition, the irrigation demands were also estimated. Hence, the reliability of the pond was predicted. As a result of the model evaluation of Felt's farm,

1. an average of 75 percent of the total annual rainfall occurs in the growing season of April to September, and May and June are the months of greatest rain, while a noticeable decrease occurs in July and to a greater extent in August,
2. the runoff yield is sufficient to fill the storage reservoir so that the reservoir can be kept at the level of 3.80 meter (12.68 ft.) on the average when irrigation is conducted at the rate of 12.7 mm/day (0.5 inches/day),
3. the average annual water volume to be supplemented averages 6.17 to 6.78 ha-m (50 to 55 acre-ft.) for the 58.68-hectare (145-acre) irrigated area, and irrigation occurs mostly in August,
4. although the existing pond facility was never dry during the simulation period, in August it cannot meet the irrigation demand for the 58.68 hectares (145 acres) at the 9 percent probability level,
5. the model for general crop management is an effective tool to simulate various alternative cropping schedule on multiple irrigation plots.

Recommendations

In relation with future research, the following recommendations are made:

1. At a favorable probability level to meet irrigation demands, the optimal area of irrigable land with a specific pond should be studied.

2. Because of the assumption of no seepage loss from the reservoir yield budget, the net available water could be overestimated. Accordingly, a possibility failing to satisfy the water need might be neglected. A study for seepage loss should be conducted.

During the research project period, a crop yield model and an economic model will be developed to determine the feasibility of supplemental irrigation system by examining investment and operating costs, cash return from crop yield, and cash flow over an extended period of time.

NOTATIONS

a = empirical coefficient, which can vary geographically

AET = actual evapotranspiration

AW = available soil moisture (soil moisture content - permanent wilting point)

AWC = available water capacity (field capacity - permanent wilting point)

b = empirical coefficient, which can vary geographically

B_1 = bottom surface area of a storage pond

Bm = area of a plane at h/2 above the bottom

B_2 = top surface area of a storage pond

c = geographic coefficient for Brunt relation in Penman Eq.

c' = hydraulic coefficient

cm = centimeter

CN = runoff curve number

d = geographic coefficient for Brunt relation in Penman Eq.

e = mass transfer coefficient

ES = saturated vapor pressure of a water surface at the Ta

E_S = soil evaporation

h = depth of a pond

ha = hectare

ha-m = hectare-meter, unit of volume

i = hydraulic gradient

IA = initial abstraction

K = crop consumptive use coefficient

K_c = coefficient of crop growth stage

K_t = climatic coefficient for the calculation of crop consumptive use coefficient

m = meter

mm = millimeter

P = precipitation

PET = potential evaporation

PSUNS = percent sunshine

Q = surface runoff

r = reflectance coefficient (albedo)

Ra = solar radiation

RHD = relative humidity

S = potential maximum difference between precipitation and runoff

t = time after the first stage evaporation

T = mean daily air temperature in °K (Kelvin)

Ta = mean daily air temperature in °F (Fahrenheit)

U = upper limit stage two evaporation

V = volume of a pond

WVD = wind velocity

Δh = change in soil water potential over distance ΔZ

ΔZ = change in elevation

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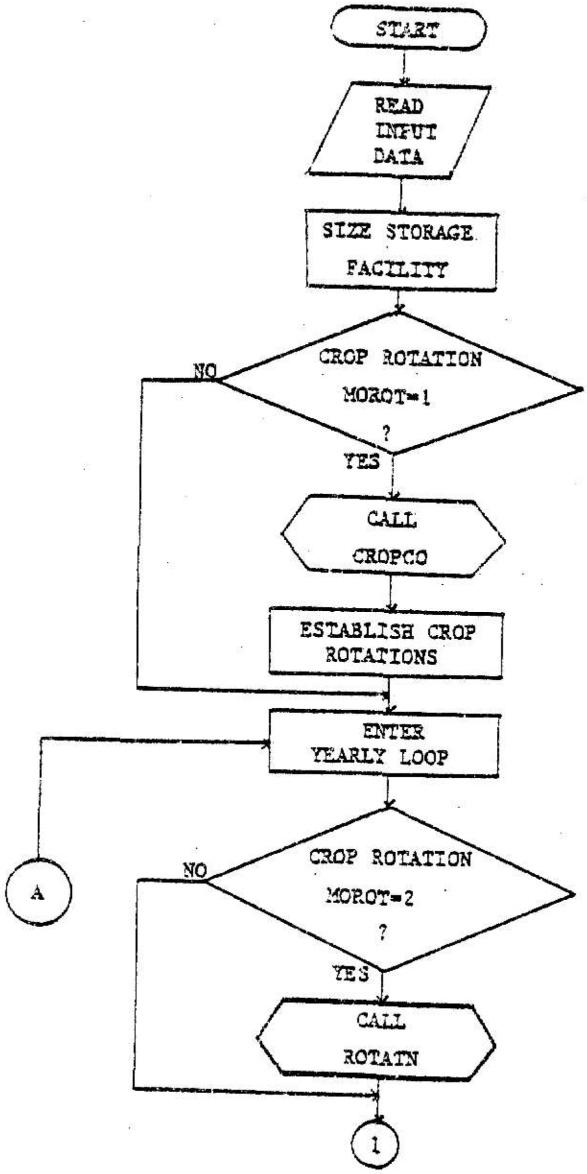
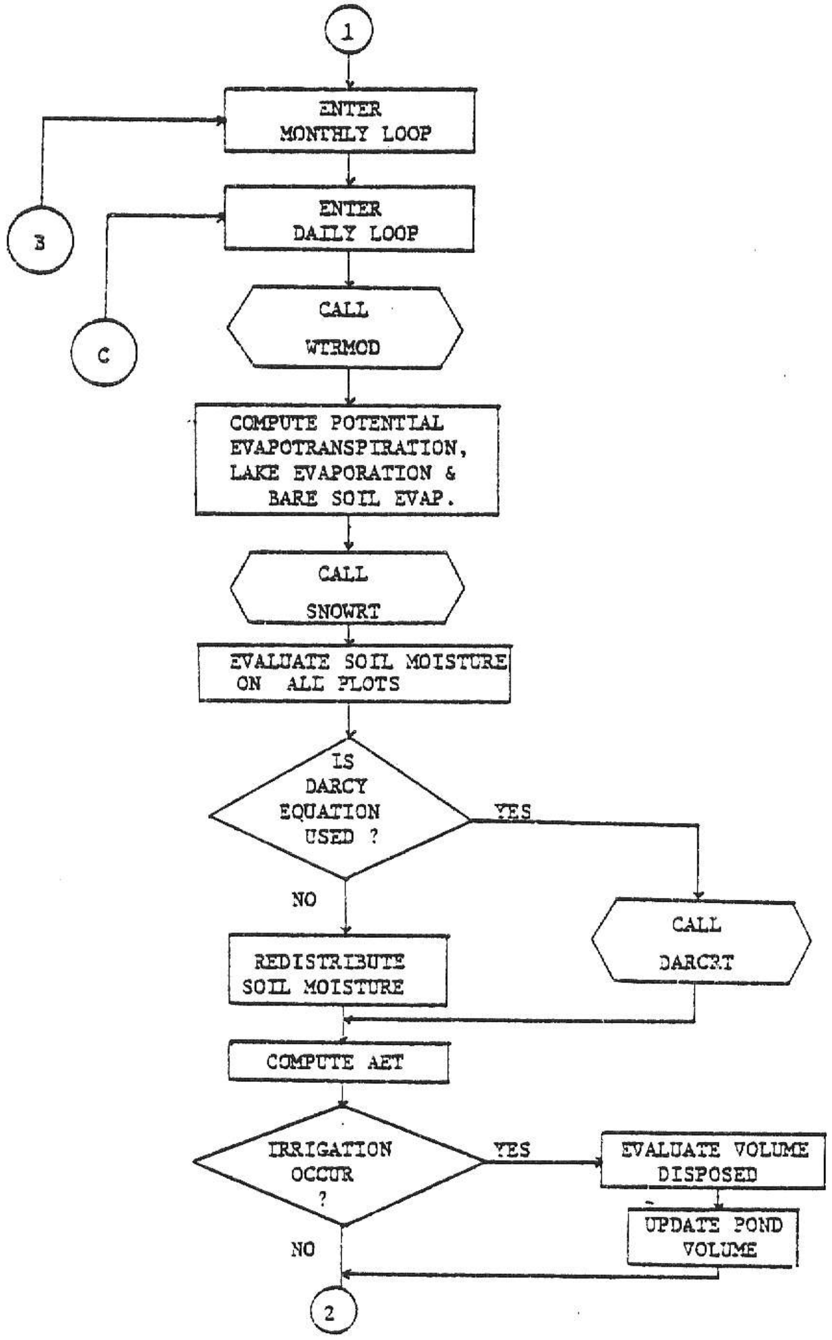
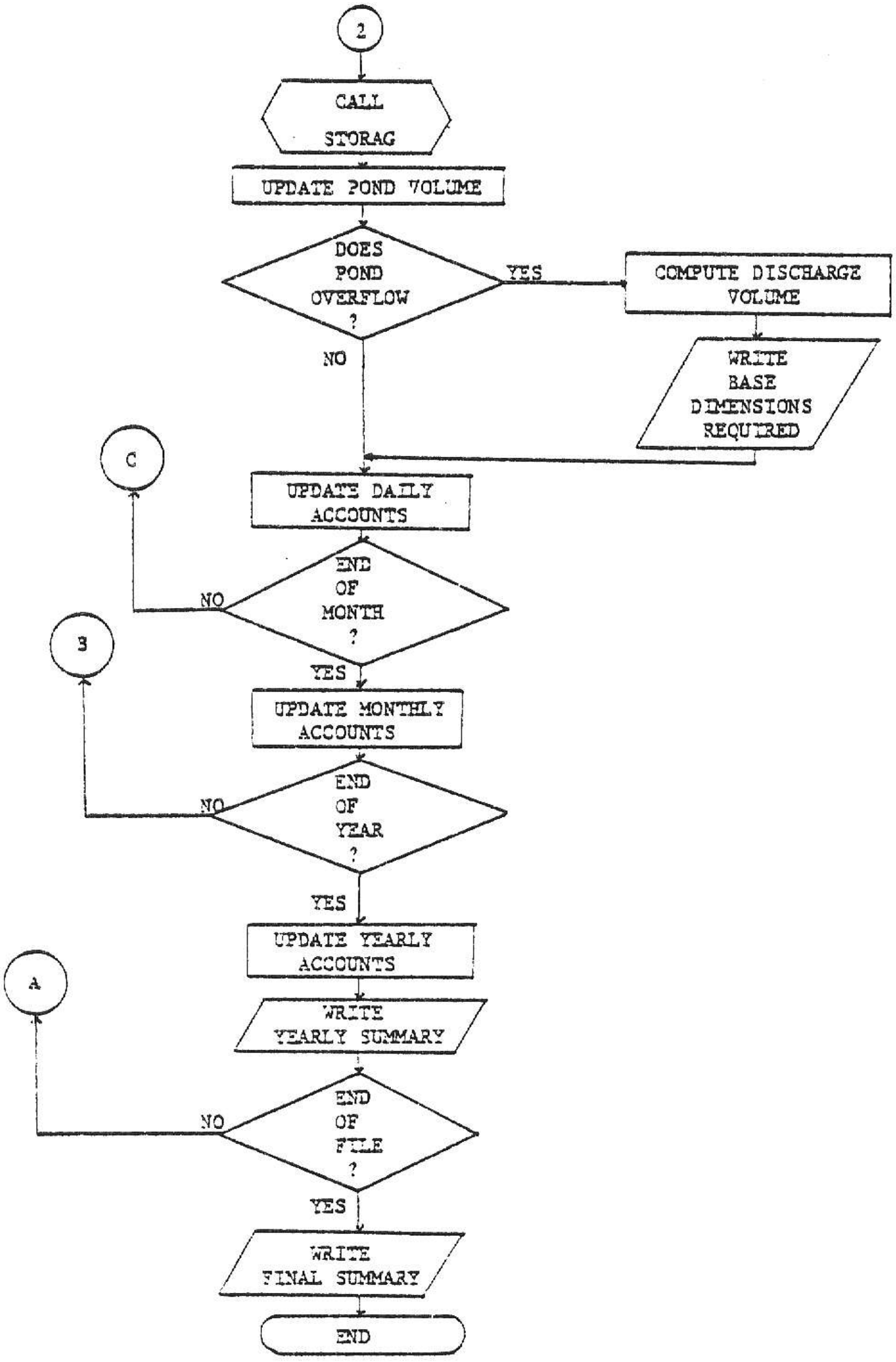
APPENDICES



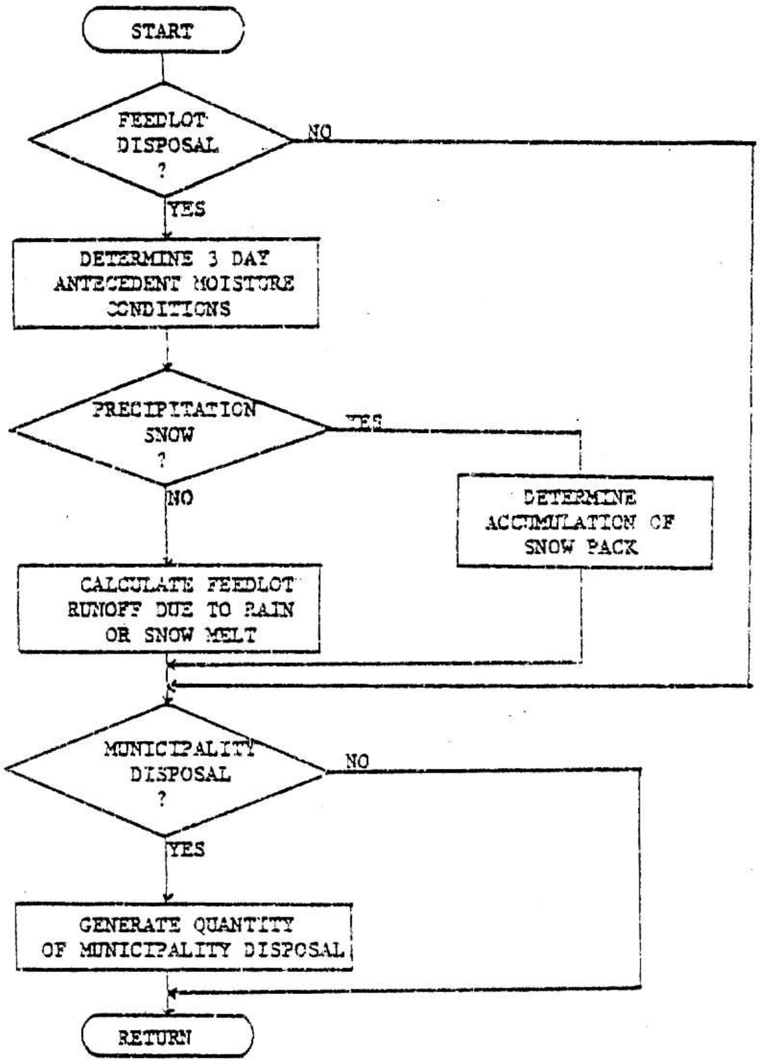
APPENDIX I GENERALIZED FLOW CHART FOR MAIN

*FROM HAYDEN (2)

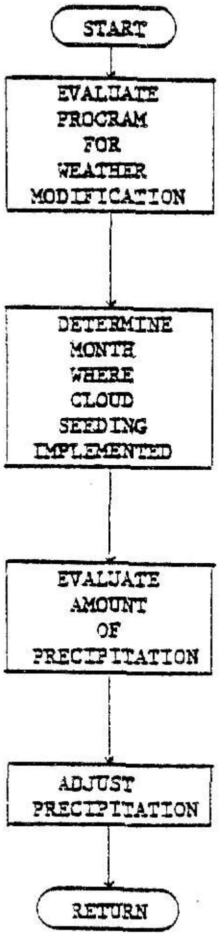

1
ENTER
MONTHLY LOOP
ENTER
DAILY LOOP
B
C
CALL
WTRMOD
COMPUTE POTENTIAL
EVAPOTRANSPIRATION,
LAKE EVAPORATION &
BARE SOIL EVAP.
CALL
SNOWRT
EVALUATE SOIL MOISTURE
ON ALL PLOTS
IS
DARCY
EQUATION
USED ?
YES
NO
CALL
DARCRT
REDISTRIBUTE
SOIL MOISTURE
COMPUTE AET
IRRIGATION
OCCUR
?
YES
NO
EVALUATE VOLUME
DISPOSED
UPDATE POND
VOLUME
2


2
CALL
STORAG
UPDATE POND VOLUME
DOES
POND
OVERFLOW
?
YES
COMPUTE DISCHARGE
VOLUME
WRITE
BASE
DIMENSIONS
REQUIRED
NO
C
UPDATE DAILY
ACCOUNTS
END
OF
MONTH
?
NO
B
YES
UPDATE MONTHLY
ACCOUNTS
END
OF
YEAR
?
NO
YES
UPDATE YEARLY
ACCOUNTS
A
WRITE
YEARLY SUMMARY
END
OF
FILE
?
NO
YES
WRITE
FINAL SUMMARY
END

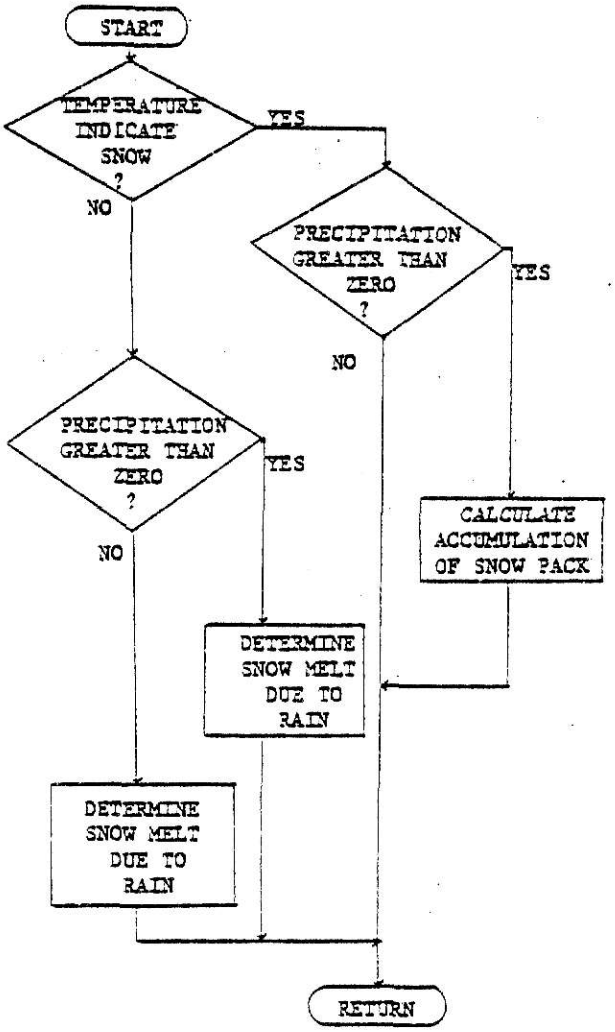
SUBROUTINE STORAC



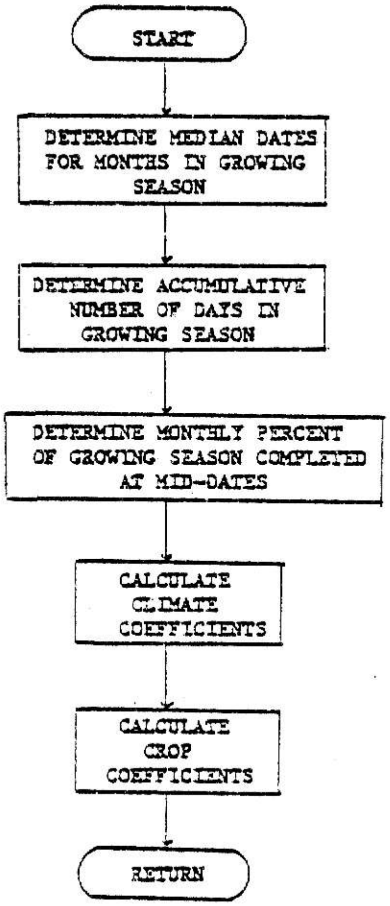
SUBROUTINE WTRMOD



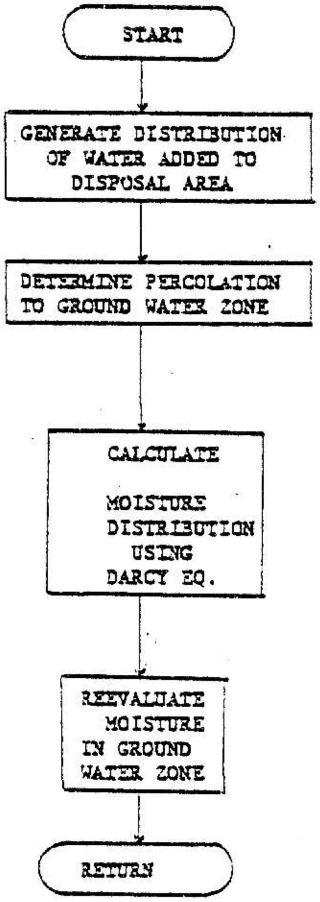
SUBROUTINE SNOWRT



SUBROUTINE CROPCO

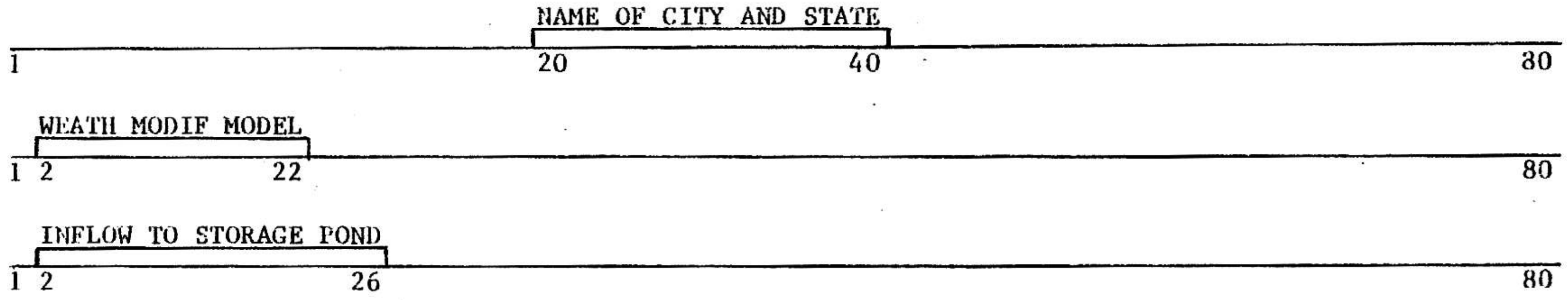


SUBROUTINE DARCRT

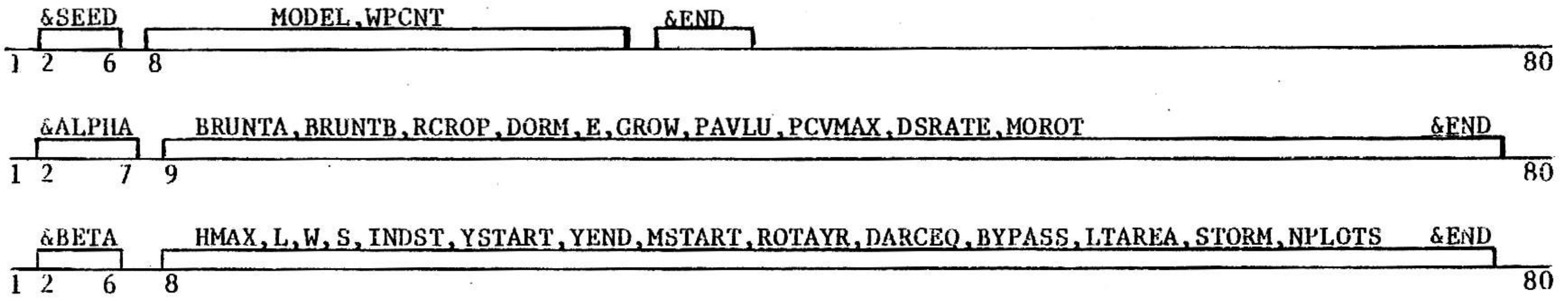


APPENDIX II-(a) GUIDELINE FOR INPUT DATA CARDS (KSUHYDRO)

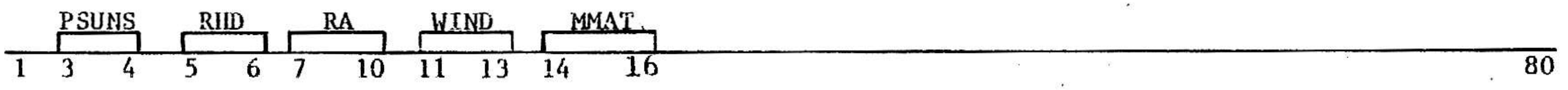
1. Location and Model Identifiers



2. Simulation Model Parameters

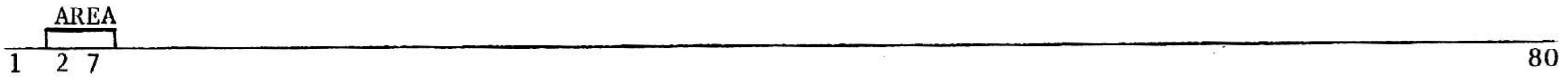


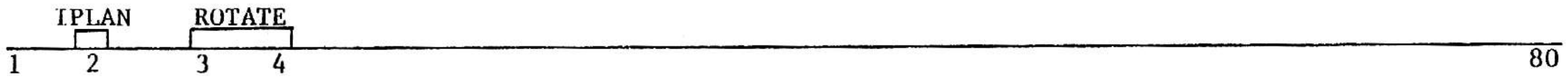
3. Meteorological Data (one card for each month)



4. Disposal Area Data

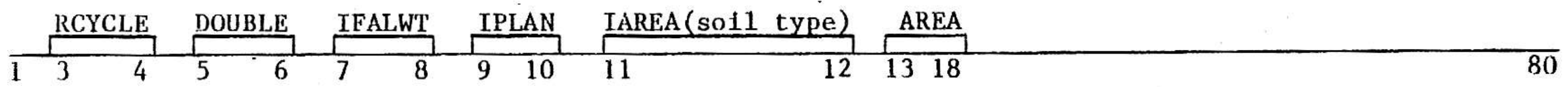
Scheme I (when MOROT=1) (one card for each area)





Scheme II (when MOROT=2)

(1) Crop Rotation Data and Disposal Area Data (one card for each area)



(2) Crop type and Planting and Harvesting Data (Depending on repetition year, select required number of crops and planting and harvesting dates on each plot)

(3) Wheat Crop Data (If double cropping managed, select planting and harvesting dates matching the number of plots double cropping being concerned)

	MGSBW	DGSBW	MGSEW	DGSEW	
1	6 7	8 9	10 11	12 13	80

---

5. Unsaturated Flow Data (one card for each area) Skip,if DARCEQ=2

CONDUZ	CONDLZ	CONDGW	HUZ	HLZ	HGWZ	
1 10	11 20	21 30	31 40	41 50	51 60	80

---

6. Municipal Waste Water Data (one card for each month) Skip, if BYPASS=1 or 2

MUNDIS	
1 10	80

---

7. Magnetic Tape Driver to Control Climatological Data of Daily Rainfall and Max.and Min.Air Temperature for a Specified Weather Station

APPENDIX II-(b) DESCRIPTION OF INPUT DATA

1. Location and model identifiers

2. Simulation model parameters

(1) NAMELIST/SEED

MODEL=1 No Cloud Seeding	WPCNT=1.0
2 B-Zero Modification	1.0
3 Rainfall Increase (%)	any value
4 B-Zero Modified Alteration Scheme	1.0

(2) NAMELIST/ALPHA

DORM : Precipitation routed through SCS Eq. from April through October	Usually 1.0 inch
GROW : Precipitation routed through SCS Eq. from November through March	Usually 1.25 inches
PCVMAX : Level of pond below which irrigation not allowed, expressed as a ratio of max. volume	Usually 0.05
RCROP : Reflectance coeff. (albedo) of crop as a ratio	Usually 0.23
E : Wind coeff. e , in Penman Eq. when calculating potential ET.	Usually 0.75
PAVLU : Percentage (as a ratio) of available soil moisture in upper zone below which irrigation allowed	0.9 : Intensive Irrigation 0.5 : Normal Irrigation 0.0 : No Irrigation
DSRATE : Irrigation disposal rate (inch/day)	
MOROT : Identifier for rotation scheme	1 : Scheme I 2 : Scheme II
BRUNTA, BRUNTB : Coeff. , c and d , respectively, for Brunt relation in Penman Eq.	

Location	BRUNTA	BRUNTB	Location	BRUNTA	BRUNTB
Belleville	0.62	0.039	Hays	0.78	0.035
Colby	0.79	0.035	Horton	0.60	0.040
Dodge City	0.79	0.034	Independence	0.59	0.039
Ellsworth	0.60	0.033	Topeka	0.66	0.041
Garden City	0.80	0.034	Chanute	0.62	0.039
Good Land	0.75	0.036	Ft. Scott	0.64	0.040

(3) NAMELIST/BETA

HMAX : Max. depth of pond (ft)	
W : Base width of pond (ft)	
L : Base length of pond (ft)	
S : Pond side-slope as a ratio of Run/Rise	
INDST : Weather station identifier	
MSTART : Beginning month of simulation	
YSTART : Beginning year of simulation	
YEND : Ending year of simulation	
ROTAYR : Parameter for rotation scheme I	1 : Crop/Fallow 2 : Fallow/Crop
STORM : 25 year-24 hour storm	
LTAREA : Total area of plots (acre)	
NPLOTS : No. of plots in accordance with land use plan	
BYPASS : Source of inflow to the pond	1 : No feedlot and No municipal input 2 : Feedlot and No municipal input 3 : No feedlot and Municipal input 4 : Feedlot and Municipal input

DARCEQ : Moisture redistribution Parameter	1 : Moisture redistribution within the soil profile by Darcy Eq. for one-dimensional flow. 2 : Moisture redistribution by the simplified method

Location	INDST	YSTART	YEND	STORM
Belleville	0682	1949	1973	5.1
Colby	1699	1950	1962	4.5
Dodge City	2164	1949	1973	4.6
Ellisworth	2459	1946	1970	5.4
Garden City	2980	1950	1974	4.5
Goodland	3153	1949	1973	4.3
Hays	3527	1948	1973	4.7
Horton	3810	1946	1970	5.9
Independence	3954	1948	1972	6.7
Topeka	8167	1949	1973	6.1
Chanute	1427	1948	1973	6.7
Ft. Scott	2835	1948	1973	6.6

3. Meteorological Data

PSUNS : Percent sunshine (%)
RHD : relative humidity (%)
WIND : Wind velocity (mph)
RA : Mid-monthly intensity of solar radiation
MMAT : Mean monthly air temperature

4. Disposal Area Data

Scheme I (when MOROT=1)

IAREA(i,j) : Name for crop and soil type

i : Crop type	j : Soil type
1 : wheat 2 : sorghum 3 : corn 4 : soybean 5 : pasture 6 : alfalfa 7 : fallow	One among 12 types of soil classified by SCS

AREA : Area of a plot	
IPLAN : Plan implemented on disposal area	1 : Collect Runoff 2 : Runoff and Irrigation 3 : Irrigation only
ROTATE : Parameter for rotation scheme I	1 : Crop rotation with fallow 2 : Same crop each year
MGSBP,DGSBP,MGSEP,DGSEP : Planting and harvesting dates	

Scheme II (when MOROT=2)

(1) Crop Rotation Data and Disposal Area Data

RCYCLE : Required number of year for sequential crop rotation
- 1 : No crop rotation , i.e.,same crop each year
- 2 : Two-year crop rotation
- Up to seven-year rotation

DOUBLE :
- 1 : Single cropping
- 2 : Double cropping with one fallow term in two years (wheat)

IFALWT :
- 1 : For the first year of simulation period, begins with wheat on a double-cropped area
- 2 : For the first year of simulation period, begins with fallow on a double-cropped area

IPLAN,IAREA,AREA : previously defined

(2) Crop type and planting and harvesting dates

(N number of cards for each area : N= The value of RCYCLE)

NCROP : Name of crop

MGSBP,DGSBP,MGSEP,DGSEP : Plan ing and harvesting dates

(3) Wheat crop data

MGSBW : Month growing season begins, for winter wheat

DGSBW : Day growing season begins, for winter wheat

MGSEW : Month growing season ends , for winter wheat

DGSEW : Day growing season ends , for winter wheat

(Cards for some area which double cropping is considered)

5. Unsaturated flow data

CONDUZ,CONDLZ,CONDGW : Hydraulic conductivity for upper zone, lower zone, and ground water zone, respectively

HUZ,HLZ,HGWZ : Soil water potential

6. Municipal waste water input to the pond

MUNDIS : Municipal disposal (gal/day) - (One card per month)

7. Magnetic tape driver to handle TMAX(ND),TMIN(ND),and PREC(ND) data for a location of simulation analysis

Note :	TMAX	Daily maximum air temperature
	TMIN	Daily minimum air temperature
	PREC	Daily rainfall
	*ND	Number of days in a month

APPENDIX II-(c) EXAMPLE OF INPUT DATA CARD DECK (MOROT=2)

```
        1-10      11-20     21-30     31-40     41-50     51-60     61-70     71-80
     12345678901234567890123456789012345678901234567890123456789012345678901234567890
1.                       FT.SCOTT,KANSAS
      NO MUNICIPAL INPUT
      INFLOW TO STORAGE POND
2.    &SEED MODEL=1,WPCNT=1.0,&END
      &ALPHA BRUNTA=0.64,BRUNTB=0.040,PAVLU=0.5,RCROP=0.23,E=0.75,DSRATE=0.1,
      DORM=1.0,GROW=1.25,PCVMAX=0.05,MOROT=2,&END
      &BETA HMAX=14.0,S=30.0,W=65.0,MSTART=1,YSTART=1948,YEND=1970,INDST=2835,I=65.,
      STORM=6.6,DARCEQ=2,BYPASS=1,LTAREA=0.0,NPLOTS=6,ROTAYR=1,&END
3.   015077 654118314
     025478 877119355
     0356781137135434
     0457791409132551
     0560841592114642
     0665861666110740
     0766871628 93790
     0870871491 94778
     0972861248101698
     106782 973106589
     115780 722117439
     125179 602117347
```

4\. (1)

```
   2 2 2 31   85.0
   2 1 1 21   30.0
   1 1 1 21   30.0
   1 1 1 11  190.0
   1 1 1 11  120.0
   1 1 1 11   40.0
```

(2)

```
  3 410 920
  4 6301030
  3 410 920
  2 6151010
  5 4 11030
  3 410 920
  2 6151010
```

(3)

```
     1010 620
```

7\.

```
//GO FT01F001 DD UNIT=TAPE800,VOL=SER=995401,LABEL=(18,SL),
//     DCB=(DEN=2,LRECL=320,BLKSIZE=320,RECFM=FB),DISP=(NEW,KEEP)
       DSN=FT.SCOTT.KANS.DATA.YR48-73
/*
```

APPENDIX III

NOMENCLATURE OF VARIABLE NAMES USED IN THE COMPUTER PROGRAM

Variables	Definition
AREA	Size of plot (acres)
AVAILL	Percent of available soil moisture remaining in lower zone
AVAILU	Percent of available soil moisture remaining in upper zone
AET	Actual evapotranspiration
AETLZ	Actual evapotranspiration of lower zone
A1	Length times width of pond base
A2	S* (L + W)
A3	(4/3) * S ** 2
A4	2 * A2
A5	4 * S ** 2
ACTIRR	Accumulated total irrigation
ABST	Average daily air temperature in degree Kelvin
APREC	Average annual precipitation
AVGMD	Average annual moisture deficit
ASTAT	Alphanumeric input statistical occurrences of intensity
AREA	Size of plots
AETU	Actual evapotranspiration for the upper zone
AETL	Actual evapotranspiration for the lower zone
AMONTH	Alphanumeric names for months to make table
AVLFCL	Available water capacity for the lower zone
AVLFCU	Available water capacity for the upper zone
AINTER	Average annual disposal area interception
AAETRS	Average annual disposal area evapotranspiration
ACHSOM	Average annual disposal area change in soil moisture
ALPHA	Feedlot parameters in NAMELIST
B2	(W + 2SH) * (L + 2SH)
BYPASS	Establishes feedlot runoff and/or municipal waste as inflow to pond
BRUNTA	Geographical constant for radiation
BRUNTB	Geographical constant for radiation
BETA	Pond and plot parameters in NAMELIST
CROP	Name of crop
CM	Total number of discharges
CTPDAY	Cumulative total of days rainfall occurred
CENT	Average daily air temperature in degrees Centigrade
CCROP	Type of crop on plot
CONTRL	Amount of control to stop pond from overflowing
CNTR	Increment for number of times runoff occurred from plot
CMNEW	Average number of discharges
COUNT	Average number of years having a discharge per year
CONOUZ	Moisture conductivity of the upper zone
CONDLZ	Moisture conductivity of the lower zone
CONDGW	Moisture conductivity of the ground water zone
CTP	Percent of days rainfall exceeded frequency

Variables	Definition
CNS1	Curve numbers of soil type 1 SCS Method
CNS3	Curve numbers of soil type 3 SCS Method
CNS5	Curve numbers of soil type 5 SCS Method
CNS12	Curve numbers of soil type 12 SCS Method
CTPR	Name of month for statistical data
CTRDAY	Number of days runoff occurred from plot during simulation period
C	Degree-day coefficient in °F-day
DGSB	Day growing season begins for crop
DGSE	Day growing season ends for crop
DGSBW	Day growing season begins for wheat
DSRATE	Disposal rate
DOUBLE	Double cropping with wheat and some summer crop reserving fallow term
DGSBP	Day of month crop is planted
DGSEP	Day of month crop harvested
DSCVOL	Discharge volume
DSDAYS	Number of disposal days
DPERC	Amount of percolation out of lower zone
DARCEQ	Integer that determines whether soil is saturated or unsaturated for flow of water through the soil
DSDAY	Cumulative sum of disposal days
DELTA	Slope of saturated vapor pressure-temperature curve
DSAREA	Area of plot on disposal area
DORM	Applies to feedlot runoff
DV	Difference between actual volume and calculated volume of zone
DVDH	Difference between actual and calculated volume with respect to the difference between actual and calculated height of pond
DSCHRG	Amount of water overflowed from pond
DIM	(VC1 - VCB)*12
DSNOW	Change in snow storage
DRY	Lowest annual precipitation
DSCRG	Discharge to plots from pond, also uncontrolled discharge for municipal control
DGSBP	Day of month crop is planted
DGSEP	Day of month crop is harvested
DISVOL	Disposal volume or irrigation volume
DSRNFF	Average annual disposal area runoff
DSPERC	Average annual disposal area percolation
DAYDS	Average annual number of disposal or irrigation days
EPRIM	E prime factor for Penman equation, wind coefficient when calculating lake evaporation
EVAPLK	Cumulative sum of lake evaporation
EXCESS	Runoff and excess water
ES	Daily calculated actual saturated vapor pressure in millibars (mb)
ESA	Daily calculated actual vapor pressure, mb

Variables	Definition
EA	Convective losses, mm H_2O
E	Emissivity
EALAKE	Convective losses for a large body of water
ER	Amount of water that could runoff, unadjusted
EVAP	Average annual lake evaporation
EO	Difference between field capacity and actual soil moisture in upper zone
FREEZE	Sum of three consecutive days average temperature, if less than 64°F, then soil is frozen
FROZE	Condition of moisture in soil
FCGW	Field capacity in the ground water zone
FREQ	Specified amount of rainfall for statistical analysis
FCL	Field capacity of the lower zone
FCU	Field capacity of the upper zone
GAMMA	1 - DELTA, psychrometric constant
GROW	Applies to feedlot runoff
H	Height of water in pond or length of base of pond
HMAX	Maximum depth of pond
HAPRX	Approximate height of surface of pond
HUZ	Soil water potential variable for hydraulic conductivity in upper zone
HLZ	Soil water potential variable for hydraulic conductivity in lower zone
HGW	Soil water potential variable for hydraulic conductivity below lower zone
I	Integer increment for plots
IW	Integer increment for plots
IAREA	Crop name defined monthly, and soil type
IYRCRP	Name of crop defined yearly
IWHT	Temporary storage for wheat or fallow for double cropping
IWI	Temporary storage for wheat or fallow for double cropping
ITEMP	Temporary storage for crop name for data inputs
IFALWT	In first year of simulation, begin with wheat 1 or fallow 2
IPLAN	Irrigation implementation plan
IRRSUM	Cumulative sum of irrigation water applied
IA	Amount of intercepted rain on surface (Initial abstraction)
IDAY	Number of irrigation days
I	Number of individual plot integer increment
II	Number of plot
IDISDA	Number of potential disposal days yearly
INDST	Index of station in question
IPLOT	Number of plot
IRRVOL	Average annual volume of irrigation water, also average annual depth of water applied
INUMI	Number of individual plots plus five
INUM	Number of individual plots plus one
IYRCRP	Name of crop defined yearly

Variables	Definition
IAREA	Crop name defined monthly for subroutine RCTATN
IPLAN	Irrigation plan implementation
INCROP	Temporary storage for type of crop
IAADD	Amount of interception storage for each month
IAET	Initial absolute evaporation
J	Integer increment
JJ	Number of plot
JDISDA	Cumulative number of disposal days
JM	Incremental number of plot
K	Integer increment for rotating crops for each year
KCROP	Crop coefficient
K	Integer increment of plot
KAN	Name of state, Kansas
KI	Incremental number of a plot
KT	Number of plot
KCROP	Crop coefficient from Blaney-Criddle Method
KROP	Alphanumeric name for crop of interest
L	Length of base of storage pond in feet
LTAREA	Feedlot area
LKEVPT	Estimated lake evaporation yearly
LAKEVP	Potential evaporation from lake
MSTART	Number of month program starts
MMM	Required years of rotating crops on an individual plot
MGSB	Month growing season begins for crop
MGSE	Month growing season ends for crop
MGSBW	Month growing season begins for wheat
MGSEW	Month growing season ends for wheat
MMAT	Mean monthly air temperature
MGSBP	Month crop is planted
MGSEP	Month crop is harvested
M	Snowmelt due to atmospheric conditions and rain
MA	Snowmelt due to atmospheric conditions
MR	Snowmelt due to rain
MM	Integer increment
MOROT	Indicates type of rotation model
MAXVOL	Percent of maximum pond volume required yearly
MSTART	Month that program starts in
MONTH	Month of data on tape
MODEL	Denotes type of crop management
MQ	Number of plot
MS	Incremental integer of plot
MP	Incremental integer of a plot
MMAT	Mean monthly air temperature
MUNDIS	Municipal disposal amount on a monthly basis
MGSBP	Month when crop is planted
MGSEP	Month when crop is harvested

Variables	Definition
NPLOTS	Number of plots
NNN	First year of simulation for a single plot
NDIM	Number of days in month
NRCROP	Crop name for data inputs
NPLOTS	Total number of plots
NY	Number of years in loop
NM	Number of month after MSTART to end of year
NDAYS	Number of days in month
ND	Number of days in daily loop
NNN	Number of plot plus one
NCNT	Incremental integer of plot that needs irrigated
NR	Number of years in rotation period
NRCROP	Crop name for data input
NIA	Net intercepted amount for each plot
NRNOF	Monthly amount of direct stored runoff
NOPERC	Amount of deep percolation
NAMES	Alphanumeric input for headings
PLAREA	Area of plot
POT	Potential daily temperature
PEAK	Greatest single discharge in a given time period
PREVDS	Previous disposal carry over
PACK	Amount of snow on ground at end of year
PACKPY	Amount of snow on ground
PDVOL	Pond volume
PERC	Percolation
P1	Previous day's moisture
P2	2 day's previous moisture
P3	3 day's previous moisture
PLOT	Number of plot
PREVYR	Previous year before current year
PSAREA	The direct receiving area of the facility
PLAREA	Area of plot
PAVLU	Percentage of available water field capacity
PET	Calculated potential evapotranspiration
PETBS	Potential evaporation from bare soil
PRECIP	Amoung of rainfall for a single day
PERCL	Water cascaded to lower zone for storage
PCVMAX	Usually five percent of pond volume
PCNTRL	Percent of control to stop pond from overflowing
PCWW	Percent of wastewater controlled
PDACCT	Pond account
PREC	Daily precipitation
PSUNS	Percent amount of sunlight each month
PWPLZ	Permanent wilting point of lower zone
PWPUZ	Permanent wilting point of upper zone
PRECAC	Accumulated precipitation by plot and month
PWG	Permanent wilting point of growing zone

Variables	Definition
RPAVLU	Percentage of available water in soil
RCYCLE	Required years of rotating crops on a plot
RPAVLU	Percent of available moisture capacity in upper zone to start irrigation
ROTAYR	Crop/fallow rotation plan
R	Equals RCROP
RCROP	Shortwave reflectance
RN	Daily calculated net radiation in mm water
RNSOIL	Daily net radiation on soil
RNLAKE	Daily net radiation on lake
RUNMDS	Runoff from disposal area
RAIN	Amount of rain for a single storm
RNOF	Amount of water that could run off, unadjusted
RUNOFF	Feedlot runoff
RANGE	Annual precipitation range for years of study
ROTATE	Crop rotation
RCYCLE	Required years of rotating crops on a plot
RA	Monthly average of solar radiation
RCM	Runoff curve number modified
RCN	Runoff curve number
RHD	Monthly average relative humidity
RUNACO	Accumulated runoff by plot and month
SOIL	Type of soil ***SCS Method***
SMMAXL	0.9 * FCL (SOIL) - SMLZ (JJ), % of maximum available water in lower zone
SMUZPR	Initial amount of soil moisture in the upper zone, 3.25 in.
SMPREV	Soil moisture initially in growing zone
SNOW	Amount of snow covering soil
SNOMLT	Amount of snow melted each day
STRVOL	Cumulative amount of stored runoff
S	Run to rise of side slope
STORM	Size of critical event
STIND	Station index
SNOVAP	Amount of snow melted for a single day
STRNOF	Stored runoff per area of watershed
SI	Maximum potential difference between rainfall and runoff at start of storm
SMMAXU	Present storage available in upper zone
SEVAP	Free surface evaporation of the pond
SMPD	Soil moisture in the upper and lower zone, combined
SM	Soil moisture in the growing zone
SMUZ	Soil moisture in the upper zone
SMLZ	Soil moisture in the lower zone
SMGWZ	Soil moisture in the groundwater zone
SMACCT	Soil moisture account (plot, crop, water, month)
SMASTL	Saturated soil moisture content of lower zone
SMSATU	Saturated soil moisture content of upper zone
SMSATG	Soil moisture at saturation in growing zone
SEED	Weather modification parameters in NAMELIST

Variables	Definition
TPAREA	Total disposal area
TPREC	Total precipitation
TOPERC	Total deep percolation
TRNOF	Total runoff
T1	Previous day's average temperature
T2	Average temperature of two day's prior
THAWED	Sum of three consecutive day's average temperature, if greater than 114, then soil is thawed
T	Days
TAVG	The average daily air temperature degrees Farenheit
TMAX	Highest temperature of the day °F
TMIN	Lowest temperature of the day °F
UZSMCH	Change in upper zone soil moisture
UZEVAP	Upper zone moisture evaporation
U	Upper limit of stage 2 evaporation
VOLDIS	Amount of water disposed
VLOMAX	Maximum volume held by storage facility
VOLIRR	Volume for irrigation
VOLCHG	Amount of change in volume for pond
V	Volume of pond in cubic feet
VC	Calculated volume of pond
VOLMX1	Size of pond to stop overflowing
VCB	2 * S * HMAX
VCC	(4/3) * S ** 2 - (VOLMX1 * 3630/HMAX)
VCD	VCB ** 2 - (4 * VCC)
WASTWW	Cumulative sum of waste water controlled
WET	Highest annual precipitation for years of study
WATER	Daily precipitation
W	Width of base of storage pond in feet
WPCNT	Percent increment
WINDD	Monthly average daily windrun miles per day at 2 mtrs hgt
WIND	Monthly average windrun
YSTART	Starting year of simulation
YEARS	Number of years of simulation
YEND	Last year of simulation
YEAR	Year of data on tape

APPENDIX IV

LISTING OF COMPUTER PROGRAM

```
                 C
                 C
                 C      HYDROLOGICAL WATERSHED MODEL
                 C
                 C      KANSAS STATE UNIVERSITY
                 C
                 C
 0001                   INTEGER CROP,FROZE,SOIL,STIND,T,YEAR,YEARS,YEND,YSTART
 0002                   INTEGER PLOT,PREVYR,BYPASS,NRCPTS,DARCEO,ROTAYR
 0003                   INTEGER DGSB,DGSE,DGSBP(9),DGSEP(9),DAY,ROTATE(9)
 0004                   INTEGER DOUBLE(9),RCYCLE(9),TYRCRP(9),NRCROP(9,50)
 0005                   REAL IA,IAADD,IAET,KCROP,KS,LAKEVP,LKEVPT,LTAREA,L,M,MA,NIA,NOPERC
 0006                   REAL LI,MMAT(12),IRRVOL,IRRSUM,MAXVOL,MR,NRNOF,LZSM,MUNDIS(12)
 0007                   DIMENSION HUZ(9),HLZ(9),HGW(9),EO(9),I(9),SMPD(9),DISVOL(9)
 0008                   DIMENSION SM(9),SMUZ(9),SMLZ(9),SMGWZ(9),FCGW(12),CONDUZ(9)
 0009                   DIMENSION CONDLZ(9),CONDGW(9),CTP(25),ASTAT(25),CIR(25,4)
 0010                   DIMENSION AREA(9),IAREA(9,2),IPLAN(9),INCROP(9),MGSBP(9),MGSEP(9)
 0011                   DIMENSION CNS1(7),CNS3(7),CNS5(7),CNS12(7),FREQ(25),CTPR(25)
 0012                   DIMENSION CTRDAY(4),AETU(9),AETL(9),IAACC(9),IAET(9),NIA(9)
 0013                   DIMENSION AMONTH(13),AVLFCL(12),AVLFCU(12),C(12),FCL(12),FCU(12)
 0014                   DIMENSION KCROP(7,12),NDIM(12),PDACCT(13,11),PREC(31),PSUNS(12)
 0015                   DIMENSION PWPLZ(12),PWPUZ(12),RA(12),RCM(12,7),RCN(12,7),RHD(12)
 0016                   DIMENSION SMACC(13,8,9),SMSATL(12),SMSATU(12),TAVG(31),TMAX(31)
 0017                   DIMENSION TMIN(31),U(12),WIND(12),PRECAC(25,4),RUNACC(25,9)
 0018                   DIMENSION DSRNFF(9),AINTER(9),AAEIRS(9),ACHSOM(9),DSPERC(9)
 0019                   DIMENSION NRNOF(9),NDPERC(9),SMSATG(12),NAMES(6),DAYSDS(9),PWG(12)
 0020                   DIMENSION IFALWT(9)
 0021                   DIMENSION RRIJAN(12),RRIFEB(12),RRIMAR(12),RRIAPR(12),RRIMAY(12),
                      1RRIJUN(12),RRIJUL(12),RRIAUG(12),RRISEP(12),RRIOCT(12),RRINOV(12),
                      2RRIDEC(12)
 0022                   DIMENSION RRI1(9),RRI2(9),RRI3(9),RRI4(9),RRI5(9),RRI6(9),
                      1RRI7(9),RRI8(9),RRI9(9),RRI10(9),RRI11(9),RRI12(9)
 0023                   COMPLEX*16 KROP*16(7)/'WHEAT','SORGHUM','CORN','SOY BEANS',
                      1      'PASTURE','ALFALFA','FALLOW'/
 0024                   DATA CNS1/84.0,86.0,86.0,86.0,80.0,83.0,84.0/
 0025                   DATA CNS3/81.0,82.0,82.0,82.0,74.0,78.0,78.0/
 0026                   DATA CNS5/73.0,75.0,75.0,75.0,61.0,69.0,69.0/
 0027                   DATA CNS12/61.0,65.0,65.0,65.0,39.0,55.0,61.0/
 0028                   DATA NAMES/'IRR.','INT.','RNFF','PERC','AET ',' SM '/
 0029                   DATA AMONTH/'JAN.','FEB.','MAR.','APR.','MAY ','JUNE','JULY',
                      1      'AUG.','SEPT','OCT.','NOV.','DEC.','TOT.'/
 0030                   DATA ASTAT/'>0.0','>0.1','>0.2','>0.3','>0.4','>0.5','>0.6',
                      1      '>0.7','>0.8','>0.9','>1.0','>1.1','>1.2','>1.3','>1.4',
                      2      '>1.5','>1.6','>1.7','>1.8','>1.9','>2.0','>3.0','>4.0',
                      3      '>5.0','>10.'/
 0031                   DATA AVLFCU/2.6,1.5,2.5,2.4,2.5,2.6,2.4,2.4,2.4,2.2,1.5,1.0/
 0032                   DATA AVLFCL/2.7,2.9,5.7,2.5,6.7,4.2,6.6,3.3,5.2,4.1,4.1,2.5/
 0033                   DATA C/0.2,0.2,0.177,0.177,0.177,0.177,0.159,0.159,0.138,0.138,
                      1      0.134,0.131/
 0034                   DATA FCU/4.6,4.4,4.5,4.6,4.5,4.3,4.0,4.0,3.8,3.5,2.3,1.7/
 0035                   DATA FCL/9.4,9.4,14.2,7.0,13.9,9.1,13.7,6.8,9.2,7.0,7.0,4.3/
 0036                   DATA FCGW/7.0,6.9,9.4,5.8,9.2,6.7,8.8,5.4,6.5,5.2,4.6,3.0/
 0037                   DATA PWPUZ/2.0,2.9,2.0,2.2,2.0,1.7,1.6,1.6,1.4,1.3,0.8,0.7/
 0038                   DATA PWPLZ/6.7,6.5,8.5,4.5,7.2,4.9,7.1,3.5,4.0,2.9,2.9,1.8/
 0039                   DATA PWG/4.3,4.7,5.2,3.3,4.6,3.3,4.3,2.6,2.7,2.1,1.8,1.3/
 0040                   DATA SMSATU/5.8,6.2,5.7,5.7,5.7,5.5,5.4,5.4,5.3,5.2,4.8,4.8/
 0041                   DATA SMSATL/11.8,11.5,16.3,8.2,15.8,10.4,15.4,7.7,13.9,13.2,13.2,
                      1      12.9/
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0042              DATA SMSATG/8.8,8.8,11.0,6.9,10.7,8.9,10.4,6.5,9.6,9.2,7.0,8.8/
0043              DATA U/0.47,0.47,0.39,0.39,0.39,0.39,0.35,0.35,0.31,0.31,0.28,
                 1     0.24/
0044              DATA NDIM/31,28,31,30,31,30,31,31,30,31,30,31/
0045              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     1.3,1.4,1.5,1.6,1.7,1.8,1.9,2.0,3.0,4.0,5.0,10.0/
0046              DATA POT,SMMAXL,SMUZPR,SMPREV,EPRIM/37.5,2.2,3.25,12.60,0.5/
0047              DATA AVAILL,AVAILU,CM,DSCVOL,DSDAYS,EVAPLK,H,IRRSUM,
                 1     PEAK,PREVDS,SNOW,TPAREA,TPREC,UZSMCH,WASTWW,WET/16*0.0/
0048              DATA AET,AETLZ,AETUZ,B2,DPERC,EXCESS,IA,M,MA,MR,PACK,PACKPY,PDVOL,
                 1     PERC,PONVOL,P1,P2,P3,SNOMLT,TOPERC,TRNOF,T1,T2/23*0.0/
0049              DATA CTPDAY,WATER,STRVOL,VOLDIS,CROP,IDAY,MM,PLOT,SOIL/4*0.0,5*0/
0050              DATA CTP,CTPR,CTRDAY,CTR/25*0.0,25*0.0,4*0.0,100*0.0/
0051              NAMELIST/ALPHA/BRUNTA,BRUNTB,CROP,DORP,E,GROW,OSRATE,PAVLO,PCVMAX,
                 *RCROP,MOROT
0052              NAMELIST/BETA/NPLOTS,HMAX,INDST,L,LTAREA,PSTART,S,STORM,W,YEND,
                 *YSTART,DARCEQ,ROTAYR,BYPASS
0053              NAMELIST/SEED/MODEL,WPCNT
            C
            C          ***** INPUTS *****
            C
            C***  READ PROGRAM IDENTIFIERS
0054              READ(5,5)  NAME,OF,CITY,AND,STATE
0055            5 FORMAT(20X,5A4)
0056              READ(5,10) WEATH,MODIF,MOD,EL
0057           10 FORMAT(1X,4A4)
0058              READ(5,15) IN,FLOW,TO,STOR,AGE,POND
0059           15 FORMAT(1X,6A4)
            C***  READ WEATHER MODIFICATION, FEEDLOT, POND AND PLOT PARAMETERS
0060              READ(5,SEED)
0061              READ(5,ALPHA)
0062              READ(5,BETA)
0063              PREVYR=YSTART
            C***  READ THE MONTHLY AVERAGE METEOROLOGICAL DATA
0064              READ(5,20) (PSUNS(I),RHD(I),RA(I),WIND(I),MMAT(I),I=1,12)
0065           20 FORMAT(2X,F2.2,F2.0,F4.2,F3.1,F3.1)
            C***  READ INPUTS FOR SOIL TYPE, CROP AND AREA FOR EACH PLOT
            C
            C
            C***  MOROT : INDICATES A SORT OF ROTATION MODEL
            C***  MOROT=1 ; DON'T USE SUBROUTINE ROTAIN
            C***  MOROT=2 : CROP ROTATION SYSTEM WOULD BE ESTABLISHED IN ROTAIN
0066              IF(MOROT.EQ.2) GO TO 41
0067              READ(5,25) ((IAREA(I,J),J=1,2),I=1,NPLOTS)
0068           25 FORMAT(2X,I1,2X,I2)
0069              READ(5,30) (AREA(I),I=1,NPLOTS)
0070           30 FORMAT(1X,F6.0)
            C***  READ INPUTS FOR PLAN IMPLEMENTATION AND CROP ROTATION
0071              READ(5,35) (IPLAN(J),ROTATE(J),J=1,NPLOTS)
0072           35 FORMAT(1X,2I1)
0073              READ(5,40) (MGSBP(I),DGSBP(I),MGSEP(I),DGSEP(I),I=1,NPLOTS)
0074           40 FORMAT(4I3)
0075           41 CONTINUE
            C***  READ INPUTS FOR DARCY'S EQUATION AND MUNICIPAL DISPOSAL
0076              IF(DARCEQ.EQ.1)  READ(5,45)(CONDUZ(I),CONDLZ(I),CONDGW(I),HUZ(I),
                 1HLZ(I),HGW(I),I=1,NPLOTS)
0077           45 FORMAT(3F10.2,3E10.4)
0078              IF(BYPASS.GE.3) READ(5,50)(MUNDIS(I),I=1,12)
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 0079          50 FORMAT(F10.2)
              C
              C***   RUNOFF CURVE NUMBERS FOR SOIL AND CROP TYPES
 0080             DO 55 K=1,7
 0081             RCN(1,K)=CNS1(K)
 0082             RCN(2,K)=CNS1(K)
 0083             RCN(3,K)=CNS3(K)
 0084             RCN(4,K)=CNS3(K)
 0085             RCN(5,K)=CNS5(K)
 0086             RCN(6,K)=CNS5(K)
 0087             RCN(7,K)=CNS5(K)
 0088             RCN(8,K)=CNS5(K)
 0089             RCN(9,K)=CNS5(K)
 0090             RCN(10,K)=CNS5(K)
 0091             RCN(11,K)=CNS5(K)
 0092          55 RCN(12,K)=CNS12(K)
              C***   SIZING POND VOLUME ROUTINE
 0093             A1=L*W
 0094             A2=S*(L+W)
 0095             A3=4./3.*S**2
 0096             A4=2.*A2
 0097             A5=4.*S**2
              C***   VOLMAX IS THE MAXIMUM VOLUME HELD BY THE STORAGE FACILITY
 0098             VOLMAX=(A1*HMAX+A2*HMAX**2+A3*HMAX**3)/3630.
              C***   PSAREA IS THE DIRECT RECEIVING AREA OF THE FACILITY
 0099             PSAREA=((W+2.*S*HMAX)*(L+2.*S*HMAX))/43560.
              C***   CALCULATE THE CROP COEFFICIENTS
 0100             IF(MOROT.EQ.2) GO TO 61
 0101             DO 60 K=1,NPLOTS
 0102             MGSB=MGSBP(K)
 0103             DGSB=DGSBP(K)
 0104             MGSE=MGSEP(K)
 0105             DGSE=DGSEP(K)
 0106             CROP=IAREA(K,1)
 0107             CALL CROPCO(CROP,MGSB,DGSB,MGSE,DGSE,KCROP,NDIM,MMAT)
 0108             INCROP(K)=IAREA(K,1)
 0109          60 CONTINUE
 0110          61 CONTINUE
              C***   INITIALIZE VARIABLES
 0111             DO 70 I=1,25
 0112             DO 65 J=2,9
 0113             IF(J.LE.4) PRECAC(I,J)=0.0
 0114          65 RUNACC(I,J)=0.0
 0115          70 CONTINUE
 0116             DO 75 J=1,12
 0117          75 KCROP(7,J)=0.0
 0118             DO 80  II=1,NPLOTS
 0119             TPAREA=TPAREA+AREA(II)
 0120             I(II)=0.0
 0121             EO(II)=0.0
 0122             IAET(II)=0.0
 0123             IAADD(II)=0.0
 0124             DISVOL(II)=0.0
 0125             DAYSDS(II)=0.0
 0126             DSRNFF(II)=0.0
 0127             AINTER(II)=0.0
 0128             AAETRS(II)=0.0
 0129             ACHSOM(II)=0.0
```

```
FORTRAN IV G LEVEL  21                 MAIN                DATE = 80036          22/25/37                PAGE 0004
0130                DSPERC(II)=0.0
0131                SMLZ(II)=9.35
0132                SMUZ(II)=3.25
0133                SMGWZ(II)=6.30
0134             80 SMPD(II)=SMLZ(II)+SMUZ(II)
0135                YEARS=YEND-YSTART+1
            C
            C***    PRINT INPUT PARAMETERS
0136                WRITE(6,85)  NAME,OF,CITY,AND,STATE,YSTART,YEND,WEATH,MODIF,MOD,EL
                   1,IN,FLOW,IO,STOR,AGE,POND,LTAREA,STORM,L,W,S,HMAX,VOLMAX,PSAREA
0137             85 FORMAT('1',10X//////////10X,'STATION:',3X,5A4,10X,I4,'  TO  ',I4,
                   1////10X,'MODEL:   ',4A4//18X,6A4//10X,'FEEDLOT AREA = ',F6.2,' ACRE
                   2S'////10X,'SIZE OF CRITICAL EVENT:  ',F4.2////10X,'POND VARIABLES:
                   3'//25X,'(A) BASE DIMENSION-- ',F7.2,' FEET BY',F7.2,' FEET'//25X,'
                   4(B) SIDE SLOPE--    RUN:RISE = ',F3.0,' : 1'//25X,'(C) MAXIMUM DEPT
                   5H--  ',F5.2,'  FEET'//25X,'(D) MAXIMUM POND VOLUME--  ',F9.2,' ACR
                   6E-INCHES'//25X,'(E) DIRECT RECEIVING AREA (FOR PRECIPITATION) --
                   7  ',F8.2,' ACRES'////10X,'AREA VARIABLES:')
0138                IF(MOROT.EQ.2) GO TO 135
0139                DO 130 J=1,NPLOTS
0140                PLAREA=AREA(J)
0141                CROP=IAREA(J,1)
0142                SOIL=IAREA(J,2)
0143                RPAVLU=PAVLU
0144                IF(IPLAN(J).EQ.1) PAVLU=0.0
0145                WRITE(6,90)  J,PLAREA,KROP(CROP),SOIL,DSRATE,PAVLU
0146             90 FORMAT(//15X,'PLOT ',I1//25X,'(A) AREA--  ',F6.2,'    ACRES'//25X,'
                   1(B) CROP--   ',2A8//25X,'(C) SOIL TYPE--   ',I3,'  (SCS SOIL TYPE)'/
                   2/25X,'(D) IRRIGATION RATE--   ',F5.2,'  INCHES/DAY '//25X,'(E) IRRI
                   3GATION MANAGEMENT--   IRRIGATION BELOW  ',F5.2,'  FIELD CAPACITY')
0147                IF(IPLAN(J).EQ.1) WRITE(6,95)
0148                IF(IPLAN(J).EQ.2) WRITE(6,100)
0149                IF(IPLAN(J).EQ.3) WRITE(6,110)
0150             95 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF')
0151            100 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF AND IRRIGATION')
0152            110 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   IRRIGATION')
0153                IF(ROTATE(J).EQ.1) WRITE(6,120)
0154            120 FORMAT(/25X,'(G) CROP ROTATION WITH --    FALLOW')
0155                PAVLU=RPAVLU
0156            130 CONTINUE
0157            135 CONTINUE
            C
0158                DO 9000 KK=1,NPLOTS
0159                RRIJAN(KK)=0.
0160                RRIFEB(KK)=0.
0161                RRIMAR(KK)=0.
0162                RRIAPR(KK)=0.
0163                RRIMAY(KK)=0.
0164                RRIJUN(KK)=0.
0165                RRIJUL(KK)=0.
0166                RRIAUG(KK)=0.
0167                RRISEP(KK)=0.
0168                RRIOCT(KK)=0.
0169                RRINOV(KK)=0.
0170           9000 RRIDEC(KK)=0.
            C
            C          ***** ENTER YEARLY LOOP *****
            C
```

```
            DO 980  NY=1,YEARS
      C
            DO 160 I=1,13
            DO 150 J=1,11
            DO 140 K=1,NPLOTS
        140 IF(J.LE.8) SMACCT(I,J,K)=0.0
        150 PDACCT(I,J)=0.0
        160 CONTINUE
      C***  ESTABLISH CROP ROTATIONS
            IF(MOROT.EQ.2) GO TO 195
            DO 170 K=1,NPLOTS
        170 IAREA(K,1)=INCROP(K)
            IF(ROTAYR.EQ.1) GO TO 190
            DO 180 J=1,NPLOTS
            IF(IAREA(J,1).EQ.1) GO TO 180
            IF(ROTATE(J).EQ.2) GO TO 180
            IAREA(J,1)=7
        180 CONTINUE
            ROTAYR=1
            GO TO 200
        190 ROTAYR=2
        195 CONTINUE
      C***  INITIALIZE VARIABLES
        200 IDISDA=0.0
            MAXVOL=0.0
            LKEVPT=0.0
            VOLIRR=0.0
            VOLCHG = 0.0
            IF(NY.GT.1) MSTART=1
            IF(MOROT.EQ.2) GO TO 215
            WRITE(6,210)
        210 FORMAT('1',46X,'***** ANNUAL SUMMARY *****')
        215 CONTINUE
      C
      C
      C        ***** ENTER MONTHLY LOOP *****
      C
            DO 840  NM=MSTART,12
      C
      C***  ESTABLISH CROP ROTATIONS FOR WHEAT
            IF(MOROT.EQ.2) GO TO 235
            DO 230 II=1,NPLOTS
            IF(INCROP(II).NE.1) GO TO 230
            IF(ROTATE(II).EQ.2) GO TO 230
            IF(ROTAYR.EQ.2) GO TO 220
            IF(NM.GT.MGSEP(II)) IAREA(II,1)=7
            GO TO 230
        220 IF(NM.LT.MGSBP(II)) IAREA(II,1)=7
            IF(NM.GE.MGSBP(II)) IAREA(II,1)=INCROP(II)
        230 CONTINUE
            GO TO 240
      C***  CALL SUBROUTINE ROTATN TO ESTABLISH ROTATION SYSTEM FOR MODEL TWO
      C***  CROP MANAGEMENT
      C***
        235 CALL ROTATN (NY,NM,MMAT,NDIM,KCROP,IAREA,NPLOTS,KROP,IPLAN,MSTART,
           1DSRATE,PAVIU,RCYCLE,NRCROP,DOUBLE,IYRCRP,AREA,IFALWT)
      C***  READ MONTHLY METEOROLOGICAL DATA
        240 READ(1,250,END=1520) KAN,STIND,YEAR,MONTH,(PREC(I),I=1,31),
```

```
                 1(TMAX(I).I=1.31).(TMIN(I).I=1.31)
             250 FORMAT(I2.I4.2I2.31F4.2.62F3.0)
                 IF(STIND.NE.INDST) GO TO 240
                 IF(YEAR.LT.YSTART-1900) GO TO 240
                 IF(YEAR.GT.YEND-1900) GO TO 990
                 IF(MONTH.LT.MSTART.AND.YEAR.EQ.YSTART-1900) GO TO 240
                 ACTIRR=0.0
                 DSDAY=0
                 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 800  ND=1.NDAYS
           C
           C***  THE FOLLOWING STATEMENTS CORRECT  FOR MISSING DATA 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 IS THE AVERAGE DAILY AIR TEMPERATURE. DEGREE FAHRENHEIT
                 TAVG(ND)=(TMAX(ND)+TMIN(ND))/2.0-100.0
           C***  SUBROUTINE WTRMD ADJUSTS THE PERCIPITATION RESULTING FROM
           C***  SEEDING CLOUDS
                 CALL WTRMOD(PREC(ND).NM.MODEL.WPCNT)
           C***  THE FOLLOWING CARD EVALUATES WHETHER THE 24 HOUR DESIGN STORM
           C***  HAS BEEN EXCEEDED.
                 IF(PREC(ND).GE.STORM/1.14) WRITE(6.260) NM.ND.YEAR.PREC(ND)
             260 FORMAT(20X.I2.'/'.I2.'/'.I2.'  CRITICAL EVENT EXCEEDED  '.
                1 2X.F10.2.'  INCH STORM  ')
           C
           C
           C     *** CALCULATION OF POTENTIAL EVAPOTRANSPIRATION BY MEANS OF
           C                          PENMAN EQUATION ***
           C
                 R=RCROP
           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, DEGREE KELVIN
                 CENT=(TAVG(ND)-32.0)*100.0/180.0
                 ABST=CENT+273.16
           C***  ES IS THE DAILY CALCULATED SATURATED VAPOR PRESSURE, IN MILLIBARS
                 ES=33.9*((0.00738*CENT+0.8072)**8-0.000019*ABS(1.8*CENT+48)
                1  +0.00136)
                 IF(ES.LE.0.0) ES=0.0
           C***  ESA IS THE DAILY CALCULATED ACTUAL VAPOR PRESSURE, IN MILLIBARS
                 ESA=ES*RHD(NM)/100.0
           C***  RN IS THE CALCULATED DAILY NET RADIATION, IN MM OF WATER
                 RN=(1-R)*RA(NM)*(0.22+0.54*PSUNS(NM))-2.010E-09*ABST**4*
                1(0.98*(1.-BRUNTA-BRUNTB*SQRT(ESA)))*(0.1+0.9*PSUNS(NM))
                 IF(RN.LT.0.0) RN=0.0
           C***  WINDD IS THE MONTHLY AVERAGE WINDRUN, MILES/DAY AT 2 METERS HEIGHT
                 WINDD=(WIND(NM)*24)*0.555
           C***  EA IS THE CONVECTIVE LOSSES, MM WATER
                 EA=0.26*(E+0.01*WINDD)*(ES-ESA)
                 EALAKE=0.26*(EPRIM+0.01*WINDD)*(ES-ESA)
                 IF(TAVG(ND)) 270.270.280
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 0246           270 DELTA=0.0
 0247               GO TO 290
 0248           280 DELTA=0.039*TAVG(ND)**0.673
 0249           290 GAMMA=1-DELTA
                C***  PET IS THE CALCULATED DAILY POTENTIAL EVAPOTRANSPIRATION, INCHES
 0250               PET=((DELTA*RN)+(GAMMA*EA))/25.4
                C
                C***  CALCULATE LAKE AND BARE SOIL EVAPORATION
 0251               RNSOIL=RN*((1.0-0.20)/(1.0-R))
 0252               RNLAKE=RN*((1.0-0.05)/(1.0-R))
 0253               PETBS=((DELTA*RNSOIL)+(GAMMA*EA))/25.4
 0254               LAKEVP=((DELTA*RNLAKE)+(GAMMA*EALAKE))/25.4
 0255               POT=TAVG(ND)
 0256               IF(TAVG(ND).LT.20.0) PET=0.0
 0257               IF(TAVG(ND).LT.20.0) PETBS=0.0
 0258               IF(TAVG(ND).LT.20.0) LAKEVP=0.0
 0259               DO 300 MO=1,NPLOTS
 0260               IAADD(MO)=IAET(MO)-PET
 0261               CCROP=IAREA(MO,1)
 0262               IF(KCROP(CCROP,NM).EQ.0.0) IAADD(MO)=IAET(MO)-PETBS
 0263               IF(IAADD(MO).GT.0.1) IAADD(MO)=0.1
 0264               IF(IAADD(MO).LT.0.0) IAADD(MO)=0.0
 0265           300 CONTINUE
                C***  SUBROUTINE SNOWRT CALCULATES THE MOISTURE ADDED TO THE DISPOSAL
                C***  SITE DUE TO SNOWMELT ON THE AREA
 0266               PRECIP=PREC(ND)
 0267               SNOVAP=0.0
 0268               WATER=PRECIP
 0269               CALL SNOWRT(PRECIP,WATER,PACK,PET,TAVG(ND),SNOVAP)
                C
                C
                C     *** EVALUATION OF SOIL MOISTURE AND CALCULATION
                C                     OF ACTUAL EVAPOTRANSPIRATION ***
                C
 0270               STRVOL=0.0
 0271               RUNMDS=0.0
 0272               JJ=0
 0273               NNN=0
 0274           330 NNN=NNN+1
 0275               IF(NNN.GT.NPLOTS) GO TO 650
 0276               STRNOF =0.0
 0277               JJ=JJ+1
 0278           340 CROP=IAREA(JJ,1)
 0279               SOIL=IAREA(JJ,2)
 0280               DSAREA=AREA(JJ)
 0281               RAIN=WATER+DISVOL(JJ)/DSAREA
 0282               IF(DISVOL(JJ).GT.0.0.AND.PRECIP.LT.0.4) GO TO 410
 0283               IF(RAIN.LE.0.0) GO TO 400
                C***  CALCULATE SURFACE RUNOFF VOLUME BY SCS METHOD
 0284               IF(KCROP(CROP,NM).LE.0.0) GO TO 370
 0285               IF(SMUZ(JJ).LT.(PWPUZ(SOIL)+0.5*AVLFCU(SOIL))) GO TO 350
 0286               IF(SMUZ(JJ).GT.(PWPUZ(SOIL)+0.8*AVLFCU(SOIL))) GO TO 360
 0287               GO TO 380
                C***  MODIFY RUNOFF CURVE NUMBER TO CONDITION I ANTECEDENT MOISTURE
 0288           350 RCM(SOIL,CROP)=RCN(SOIL,CROP)*0.39*EXP(0.009*RCN(SOIL,CROP))
 0289               GO TO 390
                C***  MODIFY RUNOFF CURVE NUMBER TO CONDITION III ANTECEDENT MOISTURE
 0290           360 RCM(SOIL,CROP)=RCN(SOIL,CROP)*1.95*EXP(-0.00663*RCN(SOIL,CROP))
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      GO TO 390
  370 IF(SMUZ(JJ).LT.0.6*FCU(SOIL)) GO TO 350
      IF(SMUZ(JJ).GT.0.9*FCU(SOIL)) GO TO 360
  380 RCM(SOIL,CROP)=RCN(SOIL,CROP)
  390 SI=1000.0/RCM(SOIL,CROP)-10.0
      ER=RAIN-0.2*SI
      IF(ER.LT.0.0) GO TO 410
      RNOF=ER**2/(RAIN+0.8*SI)
      GO TO 420
C***  EVALUATE INTERCEPTION STORAGE
  400 RNOF=0.0
      IA=0.0
      GO TO 430
  410 RNOF=0.0
  420 IA=0.1
      IF(IA.GT.RAIN) IA=RAIN
      IF((IA+IAADD(JJ)).GE.0.1) IA=0.1-IAADD(JJ)
C
C***  EVALUATE INFILTRATION INTO THE UPPER ZONE
  430 PERC=RAIN-RNOF-IA
      UZEVAP=0.0
      IF(DARCEQ.EQ.2) GO TO 435
C***  SUBROUTINE DARCRT EVALUATES THE FLOW WITHIN THE SOIL PROFILE
C***  BY APPLYING THE ONE-DIMENSIONAL DARCY EQUATION
      CALL DARCRT(PERC,FCU(SOIL),SMUZ(JJ),FCL(SOIL),SMLZ(JJ),FCGW(SOIL),
     1SMGWZ(JJ),DPERC,CONDUZ(JJ),CONDLZ(JJ),CONDGW(JJ),HUZ(JJ),HLZ(JJ),H
     2GW(JJ),PWPUZ(SOIL),PWPLZ(SOIL),PWG(SOIL))
      GO TO 450
C***  CALCULATE PRESENT STORAGE AVAILABLE IN UPPER ZONE
  435 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 440
      EXCESS=0.0
      GO TO 450
C***  EVALUATE GRAVITATIONAL WATER IN UPPER ZONE
  440 EXCESS=SMUZ(JJ)-FCU(SOIL)
C
C***  IF THE CROP IS DORMANT OR THE SOIL LIES FALLOW, SOIL
C***  EVAPORATION IS EVALUATED
  450 IF(KCROP(CROP,NM).LE.0.0) GO TO 560
      I(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
      IF(SMUZ(JJ)-(0.3*(AVLFCU(SOIL))+PWPUZ(SOIL))) 460,460,490
C***  CALCUATE AET FROM THE UPPER ZONE WHEN LIMITED BY SOIL MOISTURE
  460 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))) 470,470,480
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      C***   CALCUATE AET FROM THE LOWER ZONE WHEN LIMITED BY SOIL MOISTURE
        470  AETLZ=0.3*AET*(AVAILL/(0.3*AVLFCL(SOIL)))
             GO TO 500
        480  AETLZ=AET-AETUZ
             GO TO 500
      C***   EVALUATE AET FROM BOTH ZONES UNDER WET CONDITIONS
        490  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 470
        500  IF(DARCEQ.EQ.1.0) GO TO 605
             IF(PERC-SMMAXU) 510,520,520
      C
      C***   EVALUATE SOIL MOISTURE
        510  SMUZ(JJ)=SMUZ(JJ)+PERC-AETUZ-EXCESS
             SMLZ(JJ)=SMLZ(JJ)-AETLZ+EXCESS
             GO TO 610
        520  SMUZ(JJ)=SMUZ(JJ)+SMMAXU-EXCESS-AETUZ
        530  SMMAXL=0.9*FCL(SOIL)-SMLZ(JJ)
             IF(PERCL+EXCESS-SMMAXL) 540,540,550
        540  SMLZ(JJ)=SMLZ(JJ)+PERCL-AETLZ+EXCESS
             GO TO 610
        550  SMLZ(JJ)=SMLZ(JJ)+SMMAXL-AETLZ
             DPERC=PERCL+EXCESS-SMMAXL
             GO TO 620
      C***   CALCULATE EVAPORATION FROM BARE SOIL SURFACE(SEVAP) FOR MONTHS OCTOBER
      C***   THROUGH MARCH OR WHEN THE DISPOSAL AREA IS FALLOW
        560  AETUZ=0.0
             AETLZ=0.0
             IF(PACK.GT.0.0) GO TO 590
             IF(SMUZ(JJ).LT.(FCU(SOIL)-U(SOIL))) GC TO 570
             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 580
      C***   CALCULATE STAGE 2 SOIL EVAPORATION
        570  T(JJ)=T(JJ)+1
             UZEVAP=C(SOIL)*(T(JJ)**0.5)-C(SOIL)*((T(JJ)-1)**0.5)
        580  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 600
        590  UZEVAP=0.0
        600  IF(DARCEQ.EQ.1) PERC=0.0
             IF(DARCEQ.EQ.1) EXCESS=0.0
             SMUZ(JJ)=SMUZ(JJ)-UZEVAP+PERC-EXCESS
             IF(SMUZ(JJ).LE.PWPUZ(SOIL)) SMUZ(JJ)=PWPUZ(SOIL)
             IF(DARCEQ.EQ.2) GO TO 530
        605  SMUZ(JJ)=SMUZ(JJ)-AETUZ
             SMLZ(JJ)=SMLZ(JJ)-AETLZ
        610  IF(SMLZ(JJ).LT.PWPLZ(SOIL)) AETLZ=AETLZ-(PWPLZ(SOIL)-SMLZ(JJ))
             IF(SMLZ(JJ).LE.PWPLZ(SOIL)) SMLZ(JJ)=PWPLZ(SCIL)
             IF(DARCEQ.EQ.1) GO TO 620
             DPERC=SMLZ(JJ)-0.9*FCL(SOIL)
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FORTRAN IV G LEVEL  21                  MAIN                DATE = 80036          22/25/37                PAGE 0010

 0381                IF(DPERC.LT.0.0) DPERC=0.0
 0382                IF(SMLZ(JJ).GT.0.9*FCL(SOIL)) SMLZ(JJ)=0.9*FCL(SOIL)
 0383            620 AETUZ=AETUZ+UZEVAP
               C***  SM IS THE SOIL MOISTURE IN THE GROWING ZONE, IN INCHES
 0384                SM(JJ)=SMUZ(JJ)+SMLZ(JJ)
 0385                IAET(JJ)=IA+IAADD(JJ)
 0386                AETU(JJ)=AETUZ
 0387                AETL(JJ)=AETLZ
 0388                NOPERC(JJ)=DPERC
 0389                NIA(JJ)=IA
 0390                NRNOF(JJ)=RNOF
 0391                IF (IPLAN(JJ).LE.2) STRNOF = RNOF
 0392                STRVOL = STRVOL + STRNOF*AREA(JJ)
 0393                GO TO 330
 0394            650 CONTINUE
               C
               C
               C           *** EVALUATION OF VOLUME USED AS IRRIGATION ***
               C
               C***  T1 IS THE PREVIOUS DAY'S AVERAGE TEMPERATURE, IN FAHRENHEIT
               C***  DEGREES. T2 IS THE AVERAGE TEMPERATURE OF THE DAY TWO DAYS
               C***  PRIOR TO TODAY
 0395                VOLDIS=0.0
 0396                JDISDA=0
 0397                NCNT=0
 0398                DO 675 MS=1,NPLOTS
 0399                DISVOL(MS)=0.0
 0400                IF(BYPASS.NE.1) GO TO 655
 0401                MCROP=IAREA(MS,1)
 0402                IF(KCROP(MCROP,NM).EQ.0.) GO TO 660
 0403            655 CONTINUE
 0404                IF(IPLAN(MS).EQ.1) GO TO 660
 0405                THAWED=TAVG(ND)+T1+T2
 0406                FREEZE=TAVG(ND)+T1
 0407                T2=T1
 0408                T1=TAVG(ND)
 0409                IF(FREEZE.LT.64.0) FROZE=1
 0410                IF(THAWED.GT.114.0) FROZE=0
               C***  WHEN FROZE EQUALS 1 THE SOIL IS CONSIDERED TO BE FROZEN IT IS THAWED
               C***  WHEN FROZE EQUALS 0
 0411                IF(FROZE.EQ.1) GO TO 660
               C***  SMUZ IS THE SOIL MOISTURE IN THE TOP 12 INCHES OVER EACH
               C***  PLOT; AVLFCU IS THE AVAILABLE WATER CAPACITY OF THAT SOIL.
               C***  IRRIGATION WILL NOT OCCUR ON DAYS THAT THE SOIL MOISTURE IS AT
               C***  A LEVEL GREATER THAN THAT OF THE PERCENTAGE OF AVAILABLE WATER
               C***  SPECIFIED BY THE VARIABLE PAVLU.
 0412                SOIL=IAREA(MS,2)
 0413                IF(SMUZ(MS).GT.(PAVLU*AVLFCU(SOIL))+PWPUZ(SOIL)) GO TO 660
 0414                JDISDA=JDISDA+1
 0415                NCNT=NCNT+1
 0416                IF(PONVOL.LT.PCVMAX*VOLMAX) GO TO 660
 0417                DISVOL(MS)=DSRATE*AREA(MS)
               C***  IF THE POND VOLUME IS LESS THAN THE VOLUME REQUIRED FOR ONE FULL
               C***  DAY OF IRRIGATION, IT WILL BE ASSUMED THAT NO IRRIGATION WILL OCCUR
               C***  ON THAT DAY.
 0418                PONVOL=PONVOL-DISVOL(MS)
 0419                IF(PONVOL.GT.0.0) GO TO 670
 0420                DISVOL(MS)=DISVOL(MS)+PONVOL
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 0421              PONVOL=0.0
 0422              GO TO 670
 0423          660 DISVOL(MS)=0.0
 0424          670 SMACCT(NM,3,MS)=SMACCT(NM,3,MS)+DISVOL(MS)/AREA(MS)
 0425              VOLDIS=VOLDIS+DISVOL(MS)
 0426              IF(DISVOL(MS).GT.0.0) DAYSDS(MS)=DAYSDS(MS)+1.0
 0427          675 CONTINUE
 0428              IF(NCNT.GT.0) IDISDA=IDISDA+JDISDA/NCNT
             C***  UPDATE DISPOSAL DAY ACCOUNT
 0429              IF(VOLDIS.GT.0.0) DSDAY=DSDAY+1
 0430              IF(BYPASS.NE.1) GO TO 680
 0431              RUNOFF=0.0
 0432              GO TO 730
             C***  SUBROUTINE STORAG CALCULATES ADDITIONAL LOADING TO THE STORAGE
             C***  POND DUE TO FEEDLOT RUNOFF OR MUNICIPALITY DISPOSAL
 0433          680 CALL STORAG(P1,P2,P3,PRECIP,SNOW,FROZE,MONTH,GROW,DORM,RUNOFF,MUND
                  1IS(NM),RUNMDS)
             C
             C
             C      *** CALCULATION OF SURFACE AREA AND DETERMINATION OF SURFACE
             C                   EVAPORATION FROM STORAGE FACILITY ***
             C
             C***  THE FOLLOWING CALCULATION EXPRESSES THE VOLUME OF WATER IN THE
             C***  STORAGE FACILITY IN CUBIC FEET.
 0434          730 IF(PONVOL.LE.0.0) GO TO 750
 0435              V=PONVOL*3630
             C*** THE FOLLOWING CALCULATIONS DETERMINE THE SURFACE AREA OF THE STORAGE
             C***  FACILITY AS A FUNCTION OF STORAGE VOLUME.  AREA IS IN SQUARE FEET
             C***  VOLUME IS IN CUBIC FEET.  THE STORAGE FACILITY IS SHAPED LIKE AN INVERTED
             C***  FRUSTRUM OF A PYRAMID.  INPUT PARAMETERS TO SIZE THE FACILITY ARE LENGTH
             C***  (L) OF THE BASE IN FEET, WIDTH OF THE BASE(W) IN FEET AND SLOPE OF
             C***  THE POND DOES NOT LEAK.  INPUTS TO THE STORAGE WILL BE NATURAL
             C***  INSIDE EMBANKMENTS GIVEN AS A RATIO OF RUN TO RIS(S).  IT IS ASSUMED
             C***  RUNOFF, FEEDLOT RUNOFF, MUNICIPALITY DISPOSAL AND PRECIPITATION.
             C***  LOSSES FROM THE POND INCLUDE EVAPORATION AND DISPOSAL VOLUME.
             C***  B2 IS THE AREA OF THE SURFACE LIQUID IN SQUARE FEET.
 0436              HAPRX=(PONVOL/VOLMAX)*HMAX
 0437          740 VC=A1*HAPRX+A2*HAPRX**2+A3*HAPRX**3
 0438              DV=V-VC
 0439              DVDH=A1+A4*HAPRX+A5*HAPRX**2
 0440              H=HAPRX+DV/DVDH
 0441              IF(ABS(H-HAPRX).LT.0.1) GO TO 750
 0442              HAPRX=H
 0443              GO TO 740
 0444          750 IF (H.GT.HMAX) H=HMAX
 0445              B2=(W+2.*S*H)*(L+2.*S*H)
 0446              IF(FROZE.EQ.1) LAKEVP=0.0
 0447              LKEVPT=LKEVPT+LAKEVP
 0448              SEVAP=B2*(LAKEVP/12)
             C***  SEVAP IS THE VOLUME OF WATER EXTRACTED FROM THE STORAGE FACILITY BY
             C***  FREE SURFACE EVAPORATION.
 0449              IF((SEVAP/3630).GT.PONVOL) SEVAP=PONVOL*3630
 0450              PONVOL=PONVOL-(SEVAP/3630)
 0451              IF(PONVOL.LE.0.0) PONVOL=0.0
             C
             C***  THE VOLUMES OF CALCULATED RUNOFF, FEEDLOT RUNOFF, MUNICIPALITY
             C***  DISPOSAL, AND PRECIPITATION FALLING ON THE FACILITY ARE ADDED
             C***  TO THE VOLUME OF WATER IN THE STORAGE FACILITY (ACRE-IN).
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              PONVOL=PONVOL+(RUNOFF*LTAREA)+(PRECIP*PSAREA)+STRVOL+RUNMOS
        C***  THE VOLUME OF WATER REMAINING AT THE END OF THE DAY IS EXPRESSED
        C***  IN ACRE-IN.
        C
        C***  THE FOLLOWING STATEMENTS DETERMINE WHETHER THE STORAGE FACILITY HAS
        C***  OVERFLOWED AND IF SO, THE QUANTITY DISCHARGED
              DSCHRG=0.0
              IF(PONVOL-VOLMAX)  780,780,760
          760 DSCHRG=PONVOL-VOLMAX
              DSCVOL=DSCVOL+DSCHRG
        C***  VOLUME CALCULATIONS TO INCREASE THE POND SIZE
              CONTRL = 1.0
              PCNTRL = CONTRL*100.0
              VOLCHG = CONTRL*PONVOL-VOLMAX+VOLCHG
              VOLMX1 = VOLMAX+VOLCHG
              VCB = 2.0 * S * HMAX
              VCC = ((4./3.)*S**2) - (VOLMX1*3630./HMAX)
              VCD = VCB**2 - (4.*VCC)
              VC1 = SQRT(VCD)
              DIM = (VC1-VCB)/2.0
              WRITE(6,770) NM,ND,YEAR,DSCHRG,VOLMX1,PCNTRL,DIM
          770 FORMAT(/,1X,I2,'/',I2,'/',I2,' - DISCHARGE OF ',F7.2,' ACRE-IN REQ
             2UIRES VOLUME OF ',F8.2,' ACRE-IN FOR ',F6.2,' % CONTROL WHERE L =
             2W = ',F8.2)
              PONVOL=VOLMAX
              IF(DSCHRG.GE.PEAK) PEAK=DSCHRG
              IF(YEAR.GT.PREVYR.OR.CM.LT.1.0) MM=MM+1
              PREVYR=YEAR
              CM=CM+1.0
          780 CONTINUE
        C
        C***  UPDATE SOIL MOISTURE ACCOUNT FOR EACH PLOT
              DO 785  KI=1,NPLOTS
              SMACCT(NM,2,KI)=SMACCT(NM,2,KI)+PRECIP
              SMACCT(NM,4,KI)=SMACCT(NM,4,KI)+NIA(KI)
              SMACCT(NM,5,KI)=SMACCT(NM,5,KI)+NRNOF(KI)
              SMACCT(NM,6,KI)=SMACCT(NM,6,KI)+NDPERC(KI)
              SMACCT(NM,7,KI)=SMACCT(NM,7,KI)+AETU(KI)+AETL(KI)+SNOVAP
              SMACCT(NM,8,KI)=SMACCT(NM,8,KI)+SM(KI)-SMPD(KI)
          785 SMPD(KI)=SM(KI)
        C
        C***  UPDATE POND ACCOUNT
              ACTIRR=ACTIRR+VOLDIS
              PDACCT(NM,3)=PDACCT(NM,3)+RUNMOS
              PDACCT(NM,4)=PDACCT(NM,4)+RUNOFF*LTAREA
              PDACCT(NM,5)=PDACCT(NM,5)+STRVOL
              PDACCT(NM,8)=PDACCT(NM,8)+SEVAP/3630
              PDACCT(NM,9)=PDACCT(NM,9)+DSCHRG
              PDACCT(NM,10)=PDACCT(NM,10)+(PONVOL-PDVOL)
              IF(ND.EQ.NDAYS) PDACCT(NM,11)=H
              PDVOL=PONVOL
              IF(PONVOL.GT.MAXVOL) MAXVOL=PONVOL
        C
        C***  STATISTICAL PRECIPITATION AND RUNOFF FREQUENCY DATA
              IF(PREC(ND).GT.0.0) CTPDAY = CTPDAY+1.0
              IPLOT=NPLOTS
              IF(NPLOTS.GT.4) NPLOTS=4
              DO 795 II=1,25
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      IF(PREC(ND).GT.FREQ(II))CTP(II)=CTP(II)+1.0
      CNTR=0.0
      DO 790 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
  790 IF(NRNOF(KI).GT.FREQ(II)) CTR(II,KI)=CTR(II,KI)+1.0
  795 IF(PREC(ND).GT.FREQ(II).AND.CNTR.EQ.1.0) CTPR(II)=CTPR(II)+1.0
      NPLOTS=IPLOT
  800 CONTINUE
C
C
C        ***** EXIT DAILY LOOP *****
C
C***  UPDATE ACCOUNTS
      PDACCT(NM,1)=AMONTH(NM)
      PDACCT(NM,2)=SMACCT(NM,2,1)*PSAREA
      PDACCT(NM,6)=DSDAY
      PDACCT(NM,7)=ACTIRR
      DO 810  J=2,10
  810 PDACCT(13,J)=PDACCT(13,J)+PDACCT(NM,J)
      DO 830  MP=1,NPLOTS
      DO 820  J=2,8
  820 SMACCT(13,J,MP)=SMACCT(13,J,MP)+SMACCT(NM,J,MP)
      SMACCT(NM,1,MP)=AMONTH(NM)
  830 SMACCT(13,1,MP)=AMONTH(13)
      PDACCT(13,1)=AMONTH(13)
      VOLIRR=VOLIRR+ACTIRR
  840 CONTINUE
C
C
C        ***** EXIT MONTHLY LOOP *****
C
      DSNOW=PACK-PACKPY
      PACKPY=PACK
      PCWW=((PDACCT(13,2)+PDACCT(13,3)+PDACCT(13,4)+PDACCT(13,5)-PDACCT(
     113,9))/(PDACCT(13,2)+PDACCT(13,3)+PDACCT(13,4)+PDACCT(13,5)))*100.
      WASTWW=WASTWW+PCWW
      PDACCT(13,11)=PDACCT(12,11)
      DO 850  KT=1,NPLOTS
      DSRNFF(KT)=DSRNFF(KT)+SMACCT(13,5,KT)
      AINTER(KT)=AINTER(KT)+SMACCT(13,4,KT)
      AAETRS(KT)=AAETRS(KT)+SMACCT(13,7,KT)
      ACHSUM(KT)=ACHSUM(KT)+SMACCT(13,8,KT)
  850 DSPERC(KT)=DSPERC(KT)+SMACCT(13,6,KT)
      IRRSUM=IRRSUM+VOLIRR
      TPREC=TPREC+SMACCT(13,2,1)
      IF((YEAR+1900).EQ.YSTART) DRY=SMACCT(13,2,1)
      IF(SMACCT(13,2,1).GE.WET) WET=SMACCT(13,2,1)
      IF(SMACCT(13,2,1).LE.DRY) DRY=SMACCT(13,2,1)
C
C***  PRINT POND ACCOUNT
      WRITE(6,860) YEAR
  860 FORMAT('0',27X,'       WATER ACCOUNT FOR STORAGE FACILITY (IN ACRE-
     1INCHES)          - 19',I2//9X,'-----------------------------------
     2-----------------------------------------------------------------
     3---------------'/28X,'INFLOWS',40X,'OUTFLOWS'/12X,'--------------
     4---------------------',17X,'-------------------------------------
     5-----'/3X,'MONTH',4X,'PRECIP.   MUNICIPAL    FEEDLOT   RUNOFF',4X,'
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     6IRR. DAYS',4X,'DISPOSAL VOL.   SURFACE EVAP.   DISCHARGE',4X,'VOL.
     7 CHANGE    HEIGHT')
      WRITE(6,870)  ((PUACCT(I,K),K=1,11),I=1,13)
  870 FORMAT(4X,A4,F10.1,F12.1,2F10.1,F10.0,F16.1,F17.1,F13.1,F15.1,F10.
     12)
C
C***  PRINT SOIL MOISTURE ACCOUNTS
      DO 910  JM=1,NPLOTS
      IF(MOROT.EQ.1) CROP=IAREA(JM,1)
      IF(MOROT.EQ.2) CROP=IYRCRP(JM)
      SOIL=IAREA(JM,2)
      WRITE(6,880)  JM,KRCP(CROP),SOIL,AREA(JM)
  880 FORMAT(////,60X,'PLOT NO.',I3,////,25X,'CROP--',2A8,5X,'SOIL TYPE-
     1-',I3,5X,'DISPOSAL AREA--',F6.2,' ACRES')
      IF(MOROT.EQ.2.AND.DOUBLE(JM).EQ.2) WRITE(6,5680)
 5680 FORMAT(' ',30X,'DOUBLE CROPPING WITH WHEAT')
C
C
      WRITE(6,890)  YEAR
  890 FORMAT('0',35X,'WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 19',
     1I2/10X,'-----------------------------------------------------------
     2-----------------------------------------------------------'/32X,
     3 'INPUTS',38X,'OUTPUTS'/21X,'---------------------------',3X,    '
     4-------------------------------------------------------'/9X,'MONTH',
     57X,'PRECIPITATION',4X,'IRRIGATION',3X,'INTERCEPTION',2X,'SURFACE R
     6UNOFF',3X,'PERCOLATION',8X,'AET',8X,'CHANGE IN SM')
      WRITE(6,900)  ((SMACCT(I,K,JM),K=1,8),I=1,13)
  900 FORMAT(10X,A4,7F15.2)
  910 CONTINUE
      WRITE(6,920)  PCWW
  920 FORMAT('0',10X,'PERCENT OF WASTEWATER CONTROLLED=',F10.2)
      WRITE (6,930)  IDISDA
  930 FORMAT('0',10X,'POTENTIAL DISPOSAL DAYS=',I4)
      WRITE(6,940)  PACK,DSNOW
  940 FORMAT('0',10X,'PACK ON DECEMBER 31 =',F5.2,15X,
     1'CHANGE IN SNOW STORAGE=',F5.2)
      WRITE(6,950)
  950 FORMAT('0',10X,'INPUTS-OUTPUTS-CHANGE IN SNOW STORAGE=CHANGE IN
     1SOIL MOISTURE')
      MAXVOL=MAXVOL*100.0/VOLMAX
      WRITE(6,960)  MAXVOL
  960 FORMAT('0',10X,'PERCENT OF MAXIMUM POND VOLUME REQUIRED =',F7.2)
      EVAPLK=EVAPLK+LKEVPI
      WRITE(6,970)  LKEVPI
  970 FORMAT('0',10X,'ESTIMATED LAKE EVAPORATION, INCHES =',F6.2)
      DO 7000 KK=1,NPLOTS
      IF(IPLAN(KK).EQ.1.OR.DSRATE.EQ.0.) GO TO 7000
      RRIJAN(KK)=RRIJAN(KK)+SMACCT(1,3,KK)
      RRIFEB(KK)=RRIFEB(KK)+SMACCT(2,3,KK)
      RRIMAR(KK)=RRIMAR(KK)+SMACCT(3,3,KK)
      RRIAPR(KK)=RRIAPR(KK)+SMACCT(4,3,KK)
      RRIMAY(KK)=RRIMAY(KK)+SMACCT(5,3,KK)
      RRIJUN(KK)=RRIJUN(KK)+SMACCT(6,3,KK)
      RRIJUL(KK)=RRIJUL(KK)+SMACCT(7,3,KK)
      RRIAUG(KK)=RRIAUG(KK)+SMACCT(8,3,KK)
      RRISEP(KK)=RRISEP(KK)+SMACCT(9,3,KK)
      RRIOCT(KK)=RRIOCT(KK)+SMACCT(10,3,KK)
      RRINOV(KK)=RRINOV(KK)+SMACCT(11,3,KK)
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0579          7000 RRIDEC(KK)=RRIDEC(KK)+SMACCT(12,3,KK)
0580           980 CONTINUE
              C
              C
              C        ***** EXIT YEARLY LOOP *****
              C
0581           990 CONTINUE
0582          1520 CONTINUE
              C***     CALCULATE AVERAGE ANNUAL VALUES
0583               EVAP=EVAPLK/YEARS
0584               CMNEW=CM
0585               IF(MM.EQ.0)   MM=1
0586               COUNT=CM/MM
0587               IF(COUNT.EQ.0.0) MM=0
0588               IF(CM.EQ.0.0) CM=YEARS
0589               DSCRG=DSCVOL/CM
0590               CM=CMNEW
0591               CONTRL=WASTHW/YEARS
0592               IRRVOL=IRRSUM/YEARS
0593               APREC=TPREC/YEARS
0594               RANGE=WET-DRY
0595               AVGMD=EVAP-APREC
0596               DO 1000  J=1,NPLOTS
0597               DSPERC(J)=DSPERC(J)/YEARS
0598               DSRNFF(J)=DSRNFF(J)/YEARS
0599               ACHSUM(J)=ACHSUM(J)/YEARS
0600               AINTER(J)=AINTER(J)/YEARS
0601               AAETRS(J)=AAETRS(J)/YEARS
0602          1000 DAYSDS(J)=DAYSDS(J)/YEARS
0603               IF(NPLOTS.GT.4) NPLOTS=4
0604               DO 1020  J=1,25
0605               PRECAC(J,3)=CTP(J)
0606               IF(CTPDAY.GT.0.0) CTP(J)=CTP(J)/CTPDAY*100.0
0607               PRECAC(J,1)=ASTAT(J)
0608               PRECAC(J,2)=CTP(J)
0609               PRECAC(J,4)=CTPR(J)
0610               DO 1010  I=1,NPLOTS
0611               INUM1=5+I
0612               RUNACC(J,INUM1)=CTR(J,I)
0613               IF(CTRDAY(I).GT.0.0) CTR(J,I)=CTR(J,I)/CTRDAY(I)*100.0
0614               INUM=I+1
0615          1010 RUNACC(J,INUM)=CTR(J,I)
0616          1020 RUNACC(J,1)=ASTAT(J)
0617               NPLOTS=IPLOT
              C
              C***     PRINT INPUT PARAMETERS
0618               WRITE(6,85)  NAME,OF,CITY,AND,STATE,YSTART,YEND,WEATH,MODIF,MOD,EL
                  1,IN,FLOW,TO,STOR,AGE,POND,LTAREA,STORM,L,W,S,HMAX,VOLMAX,PSAREA
0619               IF(MOROT.EQ.2) GO TO 1085
0620               DO 1080  J=1,NPLOTS
0621               CROP=INCROP(J)
0622               PLAREA=AREA(J)
0623               SOIL=IAREA(J,2)
0624               RPAVLU=PAVLU
0625               IF(IPLAN(J).EQ.1) PAVLU=0.0
0626               WRITE(6,1030)J,PLAREA,KROP(CROP),SOIL,OSRATE,PAVLU
0627          1030 FORMAT(//15X,'PLOT ',I1//25X,'(A) AREA--  ',F6.2,'   ACRES'//25X,'
                  1(B) CROP--  ',2A8//25X,'(C) SOIL TYPE--  ',I3,'  (SCS SOIL TYPE)'/
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     2/25X,'(D) IRRIGATION RATE--  ',F5.2,'  INCHES/DAY '//25X,'(E) IRRI
     3GATION MANAGEMENT--   IRRIGATION BELOW  ',F5.2,'  FIELD CAPACITY')
      IF(IPLAN(J).EQ.1) WRITE(6,1040)
      IF(IPLAN(J).EQ.2) WRITE(6,1050)
      IF(IPLAN(J).EQ.3) WRITE(6,1060)
 1040 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF')
 1050 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF AND IRRIGATION')
 1060 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   IRRIGATICN')
      IF(ROTATE(J).EQ.1) WRITE(6,1070)
 1070 FORMAT(/25X,'(G) CROP ROTATION WITH --   FALLCW')
      PAVLU=RPAVLU
 1080 CONTINUE
      GO TO 1095
 1085 CONTINUE
      DO 5330 J=1,NPLOTS
      PLAREA=AREA(J)
      SOIL=IAREA(J,2)
      RPAVLU=PAVLU
      IF(IPLAN(J).EQ.1) PAVLU=0.0
      NR=RCYCLE(J)
      WRITE(6,5260) J,PLAREA
 5260 FORMAT(//15X,'PLOT ',I1//25X,'(A) AREA--  ',F6.2,'   ACRES')
      IF(NR.EQ.1) WRITE(6,5261) KROP(NRCROP(J,1))
      IF(NR.EQ.2) WRITE(6,5262) (KRCP(NRCROP(J,K)),K=1,2)
      IF(NR.EQ.3) WRITE(6,5263) (KROP(NRCROP(J,K)),K=1,3)
      IF(NR.EQ.4) WRITE(6,5264) (KRCP(NRCROP(J,K)),K=1,4)
      IF(NR.EQ.5) WRITE(6,5265) (KROP(NRCROP(J,K)),K=1,5)
      IF(NR.EQ.6) WRITE(6,5266) (KRCP(NRCROP(J,K)),K=1,6)
      IF(NR.EQ.7) WRITE(6,5267) (KROP(NRCROP(J,K)),K=1,7)
 5261 FORMAT(/25X,'(B) CROP--  ',2A8)
 5262 FORMAT(/25X,'(B) CROP--  ',4A8)
 5263 FORMAT(/25X,'(B) CROP--  ',6A8)
 5264 FORMAT(/25X,'(B) CROP--  ',8A8)
 5265 FORMAT(/25X,'(B) CROP--  ',10A8)
 5266 FORMAT(/25X,'(B) CROP--  ',12A8)
 5267 FORMAT(/25X,'(B) CROP--  ',14A8)
      WRITE(6,5268) SOIL,USRATE,PAVLU
 5268 FORMAT(/25X,'(C) SOIL TYPE--  ',I3,'  (SCS SOIL TYPE)'//25X,'(D) I
     1RRIGATION RATE--  ',F5.2,'  INCHES/DAY '//25X,'(E) IRRIGATION MANA
     2GEMENT--   IRRIGATION BELOW  ',F5.2,'  FIELD CAPACITY')
      IF(IPLAN(J).EQ.1) WRITE(6,5270)
      IF(IPLAN(J).EQ.2) WRITE(6,5280)
      IF(IPLAN(J).EQ.3) WRITE(6,5290)
 5270 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF')
 5280 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF AND IRRIGATION')
      IF(RCYCLE(J).EQ.1) WRITE(6,5300)
 5300 FORMAT(/25X,'(G) CROP MANAGEMENT--   NO CROP ROTATION')
 5290 FORMAT(/25X,'(F) PLAN IMPLEMENTED--   IRRIGATICN')
      IF(RCYCLE(J).GE.2) WRITE(6,5310) NR
 5310 FORMAT(/25X,'(G) CROP MANAGEMENT--   CROP ROTATION WITH ** ',I1,'
     1YEAR REPETITION')
      IF(DOUBLE(J).EQ.1) WRITE(6,5325)
      IF(DOUBLE(J).EQ.2) WRITE(6,5320)
 5320 FORMAT(/25X,'(H) DOUBLE CROPPING MANAGEMENT WITH WINTER WHEAT BETW
     1EEN CROPS MENTIONED IN PART (B)')
 5325 FORMAT(/25X,'(H) SINGLE CROPPING MANAGEMENT')
      PAVLU=RPAVLU
 5330 CONTINUE
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0680          1095 CONTINUE
              C
              C***   PRINT FINAL SUMMARY
0681                 WRITE(6,1090)
0682           1090 FORMAT(////,47X,'***** FINAL SUMMARY *****')
0683                 WRITE(6,1100)
0684           1100 FORMAT('0',10X,'METEOROLOGICAL SUMMARY')
0685                 WRITE(6,1110) EVAP
0686           1110 FORMAT('0',25X,'AVERAGE ANNUAL LAKE EVAPORATION=',F6.2,' INCHES')
0687                 WRITE(6,1120) APREC
0688           1120 FORMAT('0',25X,'AVERAGE ANNUAL PRECIPITATION=',F6.2,' INCHES')
0689                 WRITE(6,1130) RANGE,DRY,WET
0690           1130 FORMAT('0',25X,'PRECIPITATION RANGE=',F6.2,' INCHES   (FROM A LOW
                   1OF',F6.2,' INCHES  TO A HIGH OF ',F6.2,' INCHES)')
0691                 WRITE(6,1140) AVGMD
0692           1140 FORMAT('0',25X,'AVERAGE ANNUAL MOISTURE DEFICIT=',F6.2,' INCHES')
0693                 WRITE(6,1150)
0694           1150 FORMAT('0',10X,'SUMMARY OF POND OPERATIONS')
0695                 WRITE(6,1160) MM
0696           1160 FORMAT('0',25X,'NO. OF YEARS HAVING A DISCHARGE=',I6)
0697                 WRITE(6,1170) COUNT
0698           1170 FORMAT('0',25X,'AVERAGE NO. OF DISCHARGES / YEAR HAVING A DISCHARG
                   1E=',F6.2)
0699                 WRITE(6,1180) DSCRG
0700           1180 FORMAT('0',25X,'AVERAGE DISCHARGE=',F6.2,1X,'ACRE-INCHES')
0701                 WRITE(6,1190) CONTRL
0702           1190 FORMAT('0',25X,'AVERAGE PERCENT OF DISCHARGE CONTROLLED BY EVAPORA
                   1TION AND IRRIGATION=',F6.2)
0703                 WRITE(6,1200) DSCVOL
0704           1200 FORMAT('0',25X,'TOTAL DISCHARGE VOLUME=',F9.2,' ACRE-INCHES')
0705                 WRITE(6,1210) CM
0706           1210 FORMAT('0',25X,'TOTAL NO. OF DISCHARGES=',F4.0)
0707                 WRITE(6,1220) PEAK
0708           1220 FORMAT('0',25X,'MAXIMUM DISCHARGE=',F6.2,' ACRE-INCHES')
0709                 WRITE(6,1230) IRRVOL
0710           1230 FORMAT('0',25X,'AVERAGE ANNUAL VOLUME OF IRRIGATED WATER TO THE FI
                   1ELD=',F8.2,' ACRE-INCHES')
0711                 WRITE(6,1240)
0712           1240 FORMAT('0',10X,'SUMMARY OF DISPOSAL PLOTS')
0713                 DO 1320 J=1,NPLOTS
0714                 WRITE(6,1250) J
0715           1250 FORMAT('0',15X,'PLOT ',I1)
0716                 WRITE(6,1260) DSRNFF(J)
0717           1260 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA RUNOFF=',F6.2,' INCHE
                   1S')
0718                 WRITE(6,1270) DSPERC(J)
0719           1270 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=',F6.2,'
                   1INCHES')
0720                 WRITE(6,1280) DAYSDS(J)
0721           1280 FORMAT('0',25X,'AVERAGE ANNUAL NO. OF DISPOSAL DAYS=',F6.1)
0722                 WRITE(6,1290) AINTER(J)
0723           1290 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION=',F6.2,'
                   1 INCHES')
0724                 WRITE(6,1300) AAETRS(J)
0725           1300 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION=',
                   1F6.2,' INCHES')
0726                 WRITE(6,1310) ACHSCM(J)
0727           1310 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTU
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     1RE=',F6.2,' INCHES')
1320 CONTINUE
     WRITE(6,1330)
1330 FORMAT('0',10X,'SUMMARY OF STATISTICAL DATA')
     WRITE(6,1340)
1340 FORMAT('0',41X,'PRECIPITATION FREQUENCY DATA',//27X,'INTENSITY',5X
    1,'FREQUENCY',5X,'FREQUENCY',5X,'RUNOFF FREQ.',/29X,'(IN.)',10X,'(%
    2)',9X,'(DAYS)',10X,'(DAYS)',/)
     WRITE(6,1350)((PRECAC(I,J),J=1,4),I=1,25)
1350 FORMAT(29X,A4,3F15.2)
     WRITE(6,1360)
1360 FORMAT('0',///60X,'RUNOFF FREQUENCY DATA',//27X,'INTENSITY',15X,'F
    1REQUENCY (%)',26X,'FREQUENCY (DAYS)',/29X,'(IN.)',7X,'PLOT 1   PLO
    3T 2   PLOT 3   PLOT 4',8X,'PLOT 1   PLOT 2   PLOT 3   PLOT 4',/)
     WRITE(6,1370)((RUNACC(I,J),J=1,9),I=1,25)
1370 FORMAT(29X,A4,5X,4F9.2,4X,4F9.2)
     DO 8000 I=1,NPLOTS
     IF(IPLAN(I).EQ.1.OR.DSRATE.EQ.0.) GO TO 8000
     RRI1(I)=RRIJAN(I)/YEARS
     RRI2(I)=RRIFEB(I)/YEARS
     RRI3(I)=RRIMAR(I)/YEARS
     RRI4(I)=RRIAPR(I)/YEARS
     RRI5(I)=RRIMAY(I)/YEARS
     RRI6(I)=RRIJUN(I)/YEARS
     RRI7(I)=RRIJUL(I)/YEARS
     RRI8(I)=RRIAUG(I)/YEARS
     RRI9(I)=RRISEP(I)/YEARS
     RRI10(I)=RRIOCT(I)/YEARS
     RRI11(I)=RRINOV(I)/YEARS
     RRI12(I)=RRIDEC(I)/YEARS
8000 CONTINUE
     WRITE(6,1380)
1380 FORMAT('0',10X,'SUMMARY OF MONTHLY DISTRIBUTION OF IRRIGATION (INC
    1HES)')
     WRITE(6,1390)
1390 FORMAT(10X,'-----------------------------------------------------------
    1----------------------------------------------------')
     WRITE(6,1400) (AMONTH(I),I=1,12)
1400 FORMAT(10X,12(6X,A4))
     DO 1420 K=1,NPLOTS
     IF(IPLAN(K).EQ.1.OR.DSRATE.EQ.0.) GO TO 1420
     WRITE(6,1410) K,RRI1(K),RRI2(K),RRI3(K),RRI4(K),RRI5(K),RRI6(K),
    1RRI7(K),RRI8(K),RRI9(K),RRI10(K),RRI11(K),RRI12(K)
1410 FORMAT(8X,'PLOT=',I1,11(F6.2,4X),F6.2)
1420 CONTINUE
     STOP
     END
```

```
 0001                   SUBROUTINE CROPCO (CROP,MGSB,DGSB,MGSE,DGSE,KCROP,NDIM,MMAT)
                  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 THECHNICAL 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 ADAPTATION 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.
 0002                   INTEGER CROP,DGSB,DGSE
 0003                   INTEGER NDIM(12),SHIFT
 0004                   REAL MID(12),DBMD(12),ACC(12),PCGS(12)
 0005                   REAL MMAT(12),KT(12),KCROP(7,12),PCGS1(12)
 0006                   DO 65 M=1,12
 0007                   MID(M)=0.0
 0008                   ACC(M)=0.0
 0009                   DBMD(M)=0.0
 0010                   PCGS(M)=0.0
 0011                65 CONTINUE
                  C***  MGSB= MONTH GROWING SEASON BEGINS EXPRESSED NUMERICALLY IE 1-12
                  C***  DGSB= DAY GROWING SEASON BEGINS EXPRESSED NUMERICALLY
                  C***  MGSE= MONTH GROWING SEASON ENDS EXPRESSED NUMERICALLY IE 1-12
                  C***  DGSF= DAY GROWING SEASON ENDS EXPRESSED NUMERICALLY
                  C***  MID=MEDIAN DATES OF THE MONTHS IN THE GROWING SEASON
                  C***  DBMD= DAYS BETWEEN MID DATES
                  C***  ACC= ACCUMULATIVE DAYS IN GROWING SEASON
                  C***  PCGS= PERCENT OF GROWING SEASCN REACHED AT MID DATES
                  C***  MMAT=MEAN MONTHLY AVERAGE TEMPERATURES
                  C***  MGSB1=TEMPORARY STORAGE FOR MGSB
                  C***  MGSE1=TEMPORARY STORAGE FOR MGSE
                  C***  PCGS1=TEMPORARY STORAGE FOR PCGS
 0012                   MGSB1=MGSB
 0013                   MGSE1=MGSE
 0014                   IF(MGSB.GT.MGSE) GO TO 10
 0015                   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*******************************M*************************************
                  C***                                                              ***
                  C***                                                              ***
                  C***                                                              ***
                  C***  *** CAUTION TO USE- ***  THIS ROUTINE WILL NOT WORK IF THE  ***
                  C***  GROWING SEASON EXCEEDS ONE YEAR.                            ***
                  C***                                                              ***
                  C***                                                              ***
                  C***                                                              ***
                  C***                                                              ***
                  C***                                                              ***
```

```
              C*********************************************************************
              C*********************************************************************
              C*********************************************************************
 0016              10 SHIFT=13-MGSB
 0017                 MGSE=MGSE+SHIFT
 0018                 MGSB=1
 0019              20 NPLUS=MGSB+1
 0020                 NMINUS=MGSE-1
 0021                 MID(MGSB)=((NDIM(MGSB)-DGSB)/2.)+DGSB
 0022                 DO 30 N=NPLUS,NMINUS
 0023              30 MID(N)=NDIM(N)/2.0
 0024                 MID(MGSE)=DGSE/2.0
 0025                 DBMD(MGSB)=MID(MGSB)-DGSB
 0026                 DO 40 N=NPLUS,NMINUS
 0027              40 DBMD(N)=NDIM(N-1)-MID(N-1)+MID(N)
 0028                 DBMD(MGSE)=NDIM(MGSE-1)-MID(MGSE-1)+DGSE
 0029                 ACC(MGSB)=DBMD(MGSB)
 0030                 DO 50 N=NPLUS,MGSE
 0031              50 ACC(N)=ACC(N-1)+DBMD(N)
 0032                 ACC(MGSE)=ACC(MGSE)-MID(MGS E)
 0033                 DO 60 N=MGSB,MGSE
 0034              60 PCGS(N)=(ACC(N)*100.)/(ACC(MGSE)+MID(MGSE))
 0035                 IF(MGSB1.LE.MGSE1) GO TO 100
 0036                 DO 80 N=1,12
 0037                 NN=N-SHIFT
 0038                 IF(NN.LE.0) NN=NN+12
 0039                 IF(NN.GT.MGSE1.AND.NN.LT.MGSB1) GO TO 70
 0040                 PCGS1(NN)=PCGS(N)
 0041                 GO TO 80
 0042              70 PCGS1(NN)=0.0
 0043              80 CONTINUE
 0044                 DO 90 N=1,12
 0045              90 PCGS(N)=PCGS1(N)
 0046             100 MGSB=MGSB1
 0047                 MGSE=MGSE1
 0048                 DO 110 J=1,12
              C***    KT IS A CLIMATIC COEFFICIENT APPLIED TO THE CRCP GROWTH
              C***    COEFFICIENT.  IT IS CALCULATED BY THE FOLLOWING ECUATION:
 0049                 KT(J)=.0173*MMAT(J)-.314
 0050                 IF(MMAT(J).LT.36.) KT(J)=.3
 0051             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
 0052                 GO TO (120,130,140,150,160,180,200),CROP
 0053             120 XBAR=50.
 0054                 A=1.39093399                                                   WHEAT
 0055                 B=-0.00368378                                                  WHEAT
 0056                 C=-0.00004976                                                  WHEAT
 0057                 D=-0.00000233                                                  WHEAT
 0058                 E=-0.00000004                                                  WHEAT
 0059                 GO TO 210
 0060             130 XBAR=50.
 0061                 A=1.05528355                                                   SORGHUM
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0062                B=0.00198600                                                                SORGHUM
0063                C=-0.00051577                                                               SORGHUM
0064                D=0.00000045                                                                SORGHUM
0065                E=0.00000011                                                                SORGHUM
0066                GO TO 210
0067            140 XBAR=50.
0068                A=1.02805328                                                                   CORN
0069                B=0.00880046                                                                   CORN
0070                C=-0.00031919                                                                  CORN
0071                D=-0.00000194                                                                  CORN
0072                E=0.00000007                                                                   CORN
0073                GO TO 210
0074            150 XBAR=50.
0075                A=0.74790430                                                               SOYBEANS
0076                B=0.01474796                                                               SOYBEANS
0077                C=-0.00013486                                                              SOYBEANS
0078                D=-0.00000443                                                              SOYBEANS
0079                E=0.                                                                       SOYBEANS
0080                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.
0081            160 KCROP(5,1)=0.49
0082                KCROP(5,2)=0.57                                                             PASTURE
0083                KCROP(5,3)=0.73                                                             PASTURE
0084                KCROP(5,4)=0.85                                                             PASTURE
0085                KCROP(5,5)=0.90                                                             PASTURE
0086                KCROP(5,6)=0.92                                                             PASTURE
0087                KCROP(5,7)=0.92                                                             PASTURE
0088                KCROP(5,8)=0.91                                                             PASTURE
0089                KCROP(5,9)=0.87                                                             PASTURE
0090                KCROP(5,10)=0.79                                                            PASTURE
0091                KCROP(5,11)=0.67                                                            PASTURE
0092                KCROP(5,12)=0.55                                                            PASTURE
0093                DO 170 J=1,12
0094                KCROP(5,J)=KCROP(5,J)*KT(J)                                                 PASTURE
0095                IF(PCGS(J).LE.0.0) KCROP(5,J)=0.0                                           PASTURE
0096            170 CONTINUE
0097                GO TO 230
0098            180 KCROP(6,1)=0.63
0099                KCROP(6,2)=0.73                                                             ALFALFA
0100                KCROP(6,3)=0.86                                                             ALFALFA
0101                KCROP(6,4)=0.99                                                             ALFALFA
0102                KCROP(6,5)=1.08                                                             ALFALFA
0103                KCROP(6,6)=1.13                                                             ALFALFA
0104                KCROP(6,7)=1.11                                                             ALFALFA
0105                KCROP(6,8)=1.06                                                             ALFALFA
0106                KCROP(6,9)=0.99                                                             ALFALFA
0107                KCROP(6,10)=0.91                                                            ALFALFA
0108                KCROP(6,11)=0.78                                                            ALFALFA
0109                KCROP(6,12)=0.64                                                            ALFALFA
0110                DO 190 J=1,12
0111                KCROP(6,J)=KCROP(6,J)*KT(J)                                                 ALFALFA
0112            190 IF(PCGS(J).LE.0.0) KCROP(6,J)=0.0
0113                GO TO 230
0114            200 XBAR=0.
0115                A=0.                                                                         FALLOW
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FORTRAN IV G LEVEL  21              CROPCO            DATE = 80036         22/25/37              PAGE 0004

0116                B=0.                                                                 FALLOW
0117                C=0.                                                                 FALLOW
0118                D=0.                                                                 FALLOW
0119                E=0.                                                                 FALLOW
0120            210 DO 220 J=1,12
0121                Z=PCGS(J)-XBAR
0122                KCROP(CROP,J)=(A+B*Z+C*Z**2+D*Z**3+E*Z**4)*KT(J)
0123                IF (PCGS(J).LE.0.0) KCROP(CROP,J)=0.0
0124            220 CONTINUE
0125            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.
0126                KCROP(CROP,MGSB)=KCROP(CROP,MGSB)*(NDIM(MGSB)-DGSB+1)/NDIM(MGSB)
0127                KCROP(CROP,MGSE)=KCROP(CROP,MGSE)*DGSE/NDIM(MGSE)
0128                RETURN
0129                END
```

```
0001                 SUBROUTINE ROTATN (NY,NM,MMAT,NDIM,KCROP,IAREA,NPLOTS,KROP,IPLAN,
                    1MSTART,DSRATE,PAVLU,RCYCLE,NRCROP,DOUBLE,IYRCRP,AREA,IFALWT)
0002                 INTEGER DGSB,DGSE,DGSBW,DGSEW,SOIL
0003                 INTEGER RCYCLE(9),DOUBLE(9),CROP,DGSBP(9,9),DGSEP(9,9)
0004                 REAL MMAT(12),KCROP(7,12),AREA(9)
0005                 DIMENSION MGSBP(9,9),MGSEP(9,9),NDIM(12),IAREA(9,2),IYRCRP(9)
0006                 DIMENSION IWHT(9,50),IWT(9,50),ITEMP(9,9,50),NRCROP(9,50),IFALWT(9
                    1),IPLAN(9)
0007                 COMPLEX*16 KROP*16(7)
              C***   SUBROUTINE ROTATN IS USED TO DETERMINE CROPPING MANAGEMENT.
              C***   ONE: FOR SINGLE-CROPPING. A SAME SORT OF CROP MAY BE ASSIGNED TO
              C***        A SPECIFIC FARM PLOT CONTINUOUSLY THROUGH SIMULATION PERIOD,
              C***        OR A CERTAIN SET OF DIFFERENT CROPS WITH A SPECIFIED ROTATING
              C***        CYCLE UP TO SEVEN-YEAR TERM OR MORE CAN BE MANAGED ON A PLOT.
              C***   TWO: FOR DOUBLE-CROPPING, THREE CROPS IN TWO YEARS CAN BE GROWN
              C***        ON A PLOT.COMBINING WITH WINTER WHEAT: EX;WHEAT-CORN-FALLOW-
              C***        SORGHUM,OR FALLOW-SOY BEAN-WHEAT-SORGHUM,ETC.
              C***   PARTICULARLY, IT IS POSSIBLE TO GROW ONE CROP FOR EACH YEAR FOR
              C***        THE FIRST THREE YEARS AND THEN THE OTHER CROP FOR THE NEXT TWO YEARS.
              C***   NRCROP= CROP NAME FOR DATA INPUTS
              C***   IYRCRP= NAME OF CROP DEFINED YEARLY
              C***   IAREA(I,1)= CROP NAME DEFINED MONTHLY FOR SUBROUTINE ROTATN
              C***   DGSBW= DAY GROWING SEASON BEGINS FOR WHEAT
              C***   DGSEW= DAY GROWING SEASON ENDS FOR WHEAT
              C***   RCYCLE= REQUIRED YEARS OF ROTATING CROPS ON A PLOT
              C***   DOUBLE= DOUBLE CROPPING WITH WHEAT AND SOME CROP,RESERVING FALLOW
              C***   TERM
              C***   IWHT= TEMPORARY STORAGE FOR WHEAT OR FALLOW FOR DOUBLE CROPPING
              C***   IWT = TEMPORARY STORAGE FOR WHEAT OR FALLOW FOR DOUBLE CROPPING
              C***   IFALWT= IN THE FIRST YEAR OF SIMULATION. BEGIN WITH WHEAT?
              C***          OR FALLOW ?
0008                 IF(NM.GT.MSTART.OR.NY.GT.1) GO TO 110
              C***   CAUTION::: IN ADDITION TO CROP TYPES,DOUBLE CROPPING,OR NOT
              C***   AND ROTATION CYCLE, USERS MUST INPUT SOIL TYPE,IRRIGATION
              C***   MANAGEMENT,AND AREA OF EACH PLOT
0009                 READ(5,10) (RCYCLE(I),DOUBLE(I),IFALWT(I),IPLAN(I),IAREA(I,2),AREA
                    1(I),I=1,NPLOTS)
0010              10 FORMAT(2X,5I2,F6.1)
              C***   READ TYPES OF CROP,PLANTING AND HARVESTING DATE
0011                 DO 40 J=1,NPLOTS
0012                 MMM=RCYCLE(J)
0013                 DO 30 K=1,MMM
              C***   READ PLANTING AND HARVESTING DATES
0014                 READ(5,20) NRCROP(J,K),MGSBP(J,K),DGSBP(J,K),MGSEP(J,K),DGSEP(J,K)
0015              20 FORMAT(2X,I1,4I2)
0016              30 CONTINUE
0017              40 CONTINUE
              C***   CALCULATE CROP COEFFICIENTS
0018                 IF(NY.GT.1.OR.NM.GT.MSTART) GO TO 90
0019                 DO 80 K=1,NPLOTS
0020                 MMM=RCYCLE(K)
0021                 DO 70 J=1,MMM
0022                 MGSB=MGSBP(K,J)
0023                 DGSB=DGSBP(K,J)
0024                 MGSE=MGSEP(K,J)
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FORTRAN IV G LEVEL  21                 ROTATN              DATE = 80036            22/25/37                PAGE 0002

0025                 DGSE=DGSEP(K,J)
0026                 CROP=NRCROP(K,J)
0027                 CALL CROPCO(CROP,MGSB,DGSB,MGSE,DGSE,KCROP,NDIM,MMAT)
0028              70 CONTINUE
0029              80 CONTINUE
0030              90 CONTINUE
            C***     CALCULATE CROP COEFFICIENT FOR WHEAT OF DOUBLE CROPPING
            C***     READ PLANTING AND HARVESTING DATES FOR WHEAT SHOULD BE READ
            C***     ACCORDING TO THE PLAN OF DOUBLE CROPPING IF ANY.  I.E. IF TWO PLOTS
            C***     CONSIDERED TO BE DOUBLE CROPPED, TWO CARDS OF SAME DATA SHOULD BE
            C***     INPUT
0031                 DO 100 IW=1,NPLOTS
0032                 IF(DOUBLE(IW).NE.2) GO TO 100
0033                 READ(5,35) MGSBW,DGSBW,MGSEW,DGSEW
0034              35 FORMAT(5X,4I2)
0035                 MGSB=MGSBW
0036                 DGSB=DGSBW
0037                 MGSE=MGSEW
0038                 DGSE=DGSEW
0039                 CROP=1
0040                 CALL CROPCO(CROP,MGSB,DGSB,MGSE,DGSE,KCROP,NDIM,MMAT)
0041             100 CONTINUE
0042             110 CONTINUE
            C***
            C*** ESTABLISH CROP ROTATION SYSTEM FOR MODEL TWO
            C***
0043                 DO 250 I=1,NPLOTS
0044                 MMM=RCYCLE(I)
            C***     SINGLE CROPPING EACH YEAR
0045                 DO 240 J=1,MMM
0046                 IF(NY.GE.MMM+1) GO TO 120
0047                 ITEMP(I,MMM,NY)=NRCROP(I,NY)
0048                 GO TO 130
0049             120 ITEMP(I,MMM,NY)=ITEMP(I,MMM,NY-MMM)
0050                 GO TO 130
0051             130 IF(DOUBLE(I).NE.2) GO TO 230
            C***     DOUBLE CROPPING
0052                 NNN=IFALWT(I)
0053                 GO TO (150,190),NNN
            C***     BEGINNING WITH WHEAT
0054             150 IF(NY.EQ.1) GO TO 160
0055                 IF(NY.EQ.2) GO TO 170
0056                 IF (NY.GE.3) GO TO 180
0057             160 IWHT(I,NY)=1
0058                 IWT(I,NY)=7
0059                 GO TO 220
0060             170 IWHT(I,NY)=7
0061                 IWT(I,NY)=1
0062                 GO TO 220
0063             180 IWHT(I,NY)=IWHT(I,NY-2)
0064                 IWT(I,NY)=IWT(I,NY-2)
0065                 GO TO 220
            C***     BEGINNING WITH FALLOW
0066             190 IF(NY.EQ.1) GO TO 200
0067                 IF(NY.EQ.2) GO TO 210
0068                 IF(NY.GE.3) GO TO 215
0069             200 IWHT(I,NY)=7
0070                 IWT(I,NY)=1
```

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              GO TO 220
        210   IWHT(I,NY)=1
              IWT(I,NY)=7
              GO TO 220
        215   IWHT(I,NY)=IWHT(I,NY-2)
              IWT(I,NY)=IWT(I,NY-2)
              GO TO 220
        220   CONTINUE
              IF(NM.LT.MGSBP(I,J)) IAREA(I,1)=IWHT(I,NY)
              IF(NM.GT.MGSEP(I,J)) IAREA(I,1)=IWT(I,NY)
              IF(NM.GE.MGSBP(I,J).AND.NM.LE.MGSEP(I,J)) GO TO 230
              GO TO 240
        230   IYRCRP(I)=ITEMP(I,MMM,NY)
              IAREA(I,1)=IYRCRP(I)
        240   CONTINUE
        250   CONTINUE
      C
      C***    PRINT DISPOSAL AREA VARIABLES
      C
              IF(NM.GT.MSTART.OR.NY.GT.1) GO TO 340
              DO 330 J=1,NPLOTS
              PLAREA=AREA(J)
              SOIL=IAREA(J,2)
              RPAVLU=PAVLU
              IF(IPLAN(J).EQ.1) PAVLU=0.0
              NR=KCYCLE(J)
              WRITE(6,260) J,PLAREA
        260   FORMAT(//15X,'PLOT ',I1//25X,'(A) AREA--   ',F6.2,'   ACRES')
              IF(NR.EQ.1) WRITE(6,261) KROP(NRCROP(J,1))
              IF(NR.EQ.2) WRITE(6,262) (KROP(NRCROP(J,K)),K=1,2)
              IF(NR.EQ.3) WRITE(6,263) (KROP(NRCROP(J,K)),K=1,3)
              IF(NR.EQ.4) WRITE(6,264) (KROP(NRCROP(J,K)),K=1,4)
              IF(NR.EQ.5) WRITE(6,265) (KROP(NRCROP(J,K)),K=1,5)
              IF(NR.EQ.6) WRITE(6,266) (KROP(NRCROP(J,K)),K=1,6)
              IF(NR.EQ.7) WRITE(6,267) (KROP(NRCROP(J,K)),K=1,7)
        261   FORMAT(/25X,'(B) CROP--   ',2A8)
        262   FORMAT(/25X,'(B) CROP--   ',4A8)
        263   FORMAT(/25X,'(B) CROP--   ',6A8)
        264   FORMAT(/25X,'(B) CROP--   ',8A8)
        265   FORMAT(/25X,'(B) CROP--   ',10A8)
        266   FORMAT(/25X,'(B) CROP--   ',12A8)
        267   FORMAT(/25X,'(B) CROP--   ',14A8)
              WRITE(6,268) SOIL,DSRATE,PAVLU
        268   FORMAT(/25X,'(C) SOIL TYPE--   ',I3,'   (SCS SOIL TYPE)'//25X,'(D) I
             1RRIGATION RATE--   ',F5.2,'  INCHES/DAY '//25X,'(E) IRRIGATION MANA
             2GEMENT--   IRRIGATION BELOW   ',F5.2,'  FILED CAPACITY')
              IF(IPLAN(J).EQ.1) WRITE(6,270)
              IF(IPLAN(J).EQ.2) WRITE(6,280)
              IF(IPLAN(J).EQ.3) WRITE(6,290)
        270   FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF')
        280   FORMAT(/25X,'(F) PLAN IMPLEMENTED--   RUNOFF AND IRRIGATION')
        290   FORMAT(/25X,'(F) PLAN IMPLEMENTED--   IRRIGATION')
              IF(KCYCLE(J).EQ.1) WRITE(6,300)
        300   FORMAT(/25X,'(G) CROP MANAGEMENT--   NO CROP ROTATION')
              IF(KCYCLE(J).GE.2) WRITE(6,310) NR
        310   FORMAT(/25X,'(G) CROP MANAGEMENT--   CROP ROTATION WITH ** ',I1,'
             1YEAR REPETITION')
              IF(DOUBLE(J).EQ.1) WRITE(6,325)
```

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0123                IF(DOUBLE(J).EQ.2) WRITE(6.320)
0124            320 FORMAT(/25X,'(H) DOUBLE CROPPING MANAGEMENT WITH WINTER WHEAT BETW
               1EEN CROPS MENTIONED IN PART (B)')
0125                IF(DOUBLE(J).EQ.2.AND.IFALWT(J).EQ.1) WRITE(6,360)
0126                IF(DOUBLE(J).EQ.2.AND.IFALWT(J).EQ.2) WRITE(6,370)
0127            370 FORMAT(/25X,'(I) SEQUENCE OF DOUBLE-CROPPING ; FALLOW--SUMMER CROP
               1--WINTER WHEAT--SUMMER CROP--AGAIN FALLOW')
0128            360 FORMAT(/25X,'(I) SEQUENCE OF DOUBLE-CROPPING ; WINTER WHEAT--SUMME
               1R CROP--FALLOW--SUMMER CROP--AGAIN WHEAT')
0129            325 FORMAT(/25X,'(H) SINGLE CROPPING MANAGEMENT')
0130                PAVLU=RPAVLU
0131            330 CONTINUE
0132            340 CONTINUE
0133                IF(NM.EQ.MSTART) WRITE(6.350)
0134            350 FORMAT('1',46X,'**** ANNUAL SUMMARY ****')
0135                RETURN
0136                END
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```
FORTRAN IV G LEVEL  21                 SNOWRT              DATE = 80036          22/25/37              PAGE 0001

 0001                 SUBROUTINE SNOWRT(PRECIP,WATER,PACK,PET,TEMPAV,SNOVAP)
              C
              C       *** CALCULATION OF MOISTURE ADDED TO DISPCSAL AREA DUE TO
              C                        SNOWMELT ON THE AREA ***
              C
 0002                 REAL M,MA,MR
 0003                 M=0.0
 0004                 IF(PACK.GT.0.1) SNOVAP=PET
 0005                 PACK=PACK-SNOVAP
 0006                 IF(SNOVAP.GT.0.0) PET=0.0
 0007                 IF(TEMPAV-32.) 10,10,20
 0008              10 IF(PRECIP) 70,70,30
 0009              20 IF(PACK) 90,90,40
 0010              30 PACK=PACK+PRECIP
 0011                 WATER=0.0
 0012                 GO TO 90
              C***    MA IS SNOWMELT DUE TO ATMOSPHERIC CONDITIONS
 0013              40 MA=0.05*(TEMPAV-34.)
 0014                 IF(MA.LT.0.0) MA=0.0
 0015                 IF(PACK-MA) 60,60,50
              C***    MR IS SNOWMELT DUE TO RAIN
 0016              50 MR=(PRECIP*(TEMPAV-32.))/144
 0017                 M=MR+MA
 0018                 IF(PACK-M) 60,70,70
 0019              60 M=PACK
 0020                 PACK=0.0
 0021                 GO TO 80
 0022              70 PACK=PACK-M
 0023              80 WATER=M+PRECIP
 0024              90 RETURN
 0025                 END
```

```
 0001             SUBROUTINE DARCRI(PERC,FCU,SMUZ,FCL,SMLZ,FCGW,SMGWZ,DPERC,CONDUZ,C
                 1ONDLZ,CONDGW,HUZ,HLZ,HGW,PWU,PWL,PWG)
 0002             DIMENSION H(3),HI(3),SMD(3),WF(3),COND(3),DEP(3),Q(2)
 0003             DATA DEP,RCHGS,EXCESS,RCHGR/30.48,91.44,60.96,3*0.0/
            C
            C***  DISTRIBUTION OF WATER ADDED TO EACH PLOT
            C
 0004             EXCESS=0.0
 0005             IF(PERC.LE.0.0) GO TO 10
 0006             SMAVUZ=FCU-SMUZ
 0007             IF(SMAVUZ.LT.0.0) SMAVUZ=0.0
 0008             EXCESS=PERC-SMAVUZ
 0009             IF(EXCESS.LT.0.0) EXCESS=0.0
 0010             SMUZ=SMUZ+PERC-EXCESS
 0011             SMAVLZ=FCL-SMLZ
 0012             IF(SMAVLZ.LT.0.0) SMAVLZ=0.0
 0013             EXTRA=EXCESS
 0014             EXCESS=EXCESS-SMAVLZ
 0015             IF(EXCESS.LT.0.0) EXCESS=0.0
 0016             SMLZ=SMLZ+EXTRA-EXCESS
 0017             SMAVGW=FCGW-SMGW
 0018             IF(SMAVGW.LT.0.0) SMAVGW=0.0
 0019             EXTRA=EXCESS
 0020             EXCESS=EXCESS-SMAVGW
 0021             IF(EXCESS.LT.0.0) EXCESS=0.0
 0022             SMGWZ=SMGWZ+EXTRA-EXCESS
 0023             RCHGR=EXTRA-EXCESS
 0024             IF(RCHGR.LT.0.0) RCHGR=0.0
            C
            C***  MOISTURE REDISTRIBUTION USING THE ONE-DIMENSIONAL DARCY EQUATION
            C***  FOR UNSATURATED FLOW
            C
 0025          10 LCOUNT=1
 0026             DTIME=0.1667
 0027             IF(PERC.LE.0.0) DTIME=1.0
 0028             IF(PERC.LE.0.0) LCOUNT=6
 0029             DPERC=EXCESS
 0030             WF(1)=PWU/12.
 0031             WF(2)=PWL/36.
 0032             WF(3)=PWG/24.
 0033             SMD(1)=SMUZ/12.
 0034             SMD(2)=SMLZ/36.
 0035             SMD(3)=SMGWZ/24.
 0036             DO 20 K=1,3
 0037          20 IF(SMD(K).GT.1.0) SMD(K)=1.
            C
            C***  CALCULATE SOIL MOISTURE TENSION IN CM
 0038             HI(1)=SMD(1)-HUZ
 0039             HI(2)=SMD(2)-HLZ
 0040             HI(3)=SMD(3)-HGW
 0041             DO 30 K=1,3
 0042             H(K)=EXP(HI(K))
 0043             IF(H(K).GT.1500.) H(K)=1500.
 0044             IF(H(K).LT.0.0) H(K)=0.0
 0045             XXX=SMD(K)-WF(K)
 0046             IF(XXX.LT.0.01) SMD(K)=WF(K)+0.01
            C
            C***  CALCULATE UNSATURATED HYDRAULIC CONDUCTIVITY IN CM PER DAY
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FORTRAN IV G LEVEL  21                    DARCRT             DATE = 80036        22/25/37              PAGE 0002

 0047             IF(K.EQ.1) COND(K)=CONDUZ*(EXP(72.039*SMD(K)))/(SMD(K)-WF(K))
 0048             IF(K.EQ.2) COND(K)=CONDLZ*(EXP(75.595*SMD(K)))/(SMD(K)-WF(K))
 0049             IF(K.EQ.3) COND(K)=CONDGW*(EXP(70.588*SMD(K)))/(SMD(K)-WF(K))
 0050             IF(COND(K).GT.10.0) COND(K)=10.0
 0051          30 IF(COND(K).LT.1.0E-07) COND(K)=1.0E-07
           C
           C***   CALCULATE MOISTURE FLOW, IN INCHES
 0052          40 DO 50 K=1,2
 0053             Q(K)=(COND(K)+COND(K+1))/2*DTIME*(H(K+1)-H(K)+DEP(K))/DEP(K)
 0054          50 Q(K)=Q(K)/2.54
 0055             SMUZ=SMUZ-Q(1)
 0056             SMLZ=SMLZ+Q(1)
 0057             SMLZ=SMLZ-Q(2)
 0058             SMGWZ=SMLZ+Q(2)
 0059             RCHGS=RCHGS+Q(2)
 0060             LCOUNT=LCOUNT+1
 0061             IF(LCOUNT.LE.6) GO TO 40
 0062             OPERC=OPERC+RCHGS+RCHGR
 0063             RETURN
 0064             END
```

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FORTRAN IV G LEVEL  21                  STORAG              DATE = 80036          22/25/37                PAGE 0001

 0001              SUBROUTINE STORAG(P1,P2,P3,PRECIP,SNOW,FRCZE,MONTH,GROW,DORM,RUNOF
                  1F,WWINPT,RUNOFT)
             C
             C
             C                   *** CALCULATION OF FEEDLOT RUNOFF ***
             C
 0002              IF(BYPASS.EQ.3) GO TO 60
             C***  CALCULATE 3 DAY ANTECEDENT MOISTURE
 0003              AM=P1+P2+P3
 0004              P1=P2
 0005              P2=P3
 0006              P3=PRECIP
 0007              IF (SNOW.GT.0.0.AND.FRUZE.EC.0) GO TO 10
 0008              IF(PRECIP.LE.0.0) GO TO 50
 0009              IF (FRUZE.EQ.1) GO TO 40
 0010              IF(AM.LE.0.5.AND.PRECIP.LE.0.5) GO TO 50
             C***  CALCULATE FEEDLOT RUNOFF USING 3 DAY ANTECEDENT MOISTURE CONDITIONS
             C***  MODIFICATION OF THE SCS METHOD
 0011           10 AM1=AM+PRECIP
 0012              PRESIP=PRECIP+SNOW
 0013              RC=97.0
 0014              IF(MONTH.LT.4.OR.MONTH.GT.10) GO TO 20
 0015              IF(AM.LT.0.75) RC=91.0
 0016              IF(AM1.GT.GROW.AND.PRECIP.GT.GROW) PRESIP=GROW
 0017              GO TO 30
 0018           20 IF(AM.LT.0.50) RC=91.0
 0019              IF (SNOW.GT.0.0) RC=97.0
 0020              IF(AM1.GT.DORM.AND.PRECIP.GT.DORM) PRESIP=DORM
 0021           30 CS=1000.0/RC-10.0
 0022              RUNOFF=(PRESIP-0.2*CS)**2/(PRESIP+0.8*CS)
 0023              RUNOFF=RUNOFF+PRECIP-PRESIP+SNOW
 0024              SNOW=0.0
 0025              IF(RUNOFF.GT.0.06) RUNOFF=RUNOFF-0.06
 0026              IF(PRESIP-0.2*CS.LT.0.0) GO TO 50
 0027              GO TO 60
 0028           40 SNOW=SNOW+PRECIP
 0029           50 RUNOFF=0.0
 0030              IF(BYPASS.EQ.2) GO TO 70
 0031           60 RUNOFT=WWINPT/(3630*7.48)
 0032           70 RETURN
 0033              END
```

```
      SUBROUTINE WTRMOD(PRECIP,MONTH,MODEL,WPCNT)
C
C***  SUBROUTINE WTRMOD ADJUSTS THE PRECIPITATION RESULTING FROM
C***  SEEDING CLOUDS
C
C***  NO PRECIPITATION MODIFICATION
C***  MODEL 2:  INCREASE PRECIPITATION DURING MARCH THROUGH SEPTEMBER BY
C***            THE FOLLOWING PERCENTAGES - 75% FOR RAINFALLS < 0.10 IN.
C***            30% FOR RAINFALLS < 0.50 IN. 10% FOR RAINFALLS < 1.0 IN.
C***            -10% FOR RAINFALLS > 1.0 IN
C***  MODEL 3:  INCREASE ALL RAINFALLS DURING EVERY MONTH BY A SPECIFIED
C***            PERCENTAGE, WPCENT
C***  MODEL 4:  INCREASE PRECIPITATION DURING MARCH THROUGH SEPTEMBER BY
C***            THE FOLLOWING PERCENTAGES - 75% FOR RAINFALLS < 0.10 IN.
C***            30% FOR RAINFALLS < 0.50 IN. 10% FOR RAINFALLS < 1.0 IN.
C***            NO ADJUSTMENT FOR RAINFALLS > 1.0 IN
C
      IF(MODEL.EQ.1) GO TO 40
      IF(MONTH.LT.3) GO TO 10
      IF(MONTH.GT.9) GO TO 10
      ADJ=1.75
      IF(PRECIP.GT.0.10) ADJ=1.30
      IF(PRECIP.GT.0.50) ADJ=1.10
      IF(MODEL.EQ.4) GO TO 20
      IF(PRECIP.GT.1.0) ADJ=0.90
      GO TO 30
   10 ADJ=1.0
      IF(MODEL.EQ.3) ADJ=WPCNT
      GO TO 30
   20 IF(PRECIP.GT.1.0) ADJ=1.0
   30 PRECIP=PRECIP*ADJ
   40 RETURN
      END
```

```
STATION:   FT.SCOTT.KANSAS                  1948  TO  1970

MODEL:  NO MUNICIPAL INP
        INFLOW TO STORAGE POND
        FEEDLOT AREA =    0.0  ACRES

SIZE OF CRITICAL EVENT:  6.60

POND VARIABLES:
              (A) BASE DIMENSION--   65.00 FEET BY  65.00 FEET
              (B) SIDE SLOPE--   RUN:RISE = 30. : 1
              (C) MAXIMUM DEPTH--  14.00  FEET
              (D) MAXIMUM POND VOLUME--    1133.98 ACRE-INCHES
              (E) DIRECT RECEIVING AREA (FOR PRECIPITATION) --       18.80 ACRES

AREA VARIABLES:

     PLOT 1
              (A) AREA--   85.00   ACRES
              (B) CROP--  CORN             SOY BEANS
              (C) SOIL TYPE--    1  (SCS SOIL TYPE)
              (D) IRRIGATION RATE--   0.10  INCHES/DAY
              (E) IRRIGATION MANAGEMENT--   IRRIGATION BELOW   0.50  FIELD CAPACITY
              (F) PLAN IMPLEMENTED--   IRRIGATION
              (G) CROP MANAGEMENT--   CROP ROTATION WITH ** 2 YEAR REPETITION
              (H) DOUBLE CROPPING MANAGEMENT WITH WINTER WHEAT BETWEEN CROPS MENTIONED IN PART (B)
              (I) SEQUENCE OF DOUBLE-CROPPING : FALLOW--SUMMER CROP--WINTER WHEAT--SUMMER CROP--AGAIN FALLOW
```

```
PLOT 2
          (A) AREA--    30.00    ACRES
          (B) CROP--   CORN               SORGHUM
          (C) SOIL TYPE--     1  (SCS SOIL TYPE)
          (D) IRRIGATION RATE--    0.10   INCHES/DAY
          (E) IRRIGATION MANAGEMENT--    IRRIGATION BELOW    0.50  FIELD CAPACITY
          (F) PLAN IMPLEMENTED--    RUNOFF ANC IRRIGATICN
          (G) CROP MANAGEMENT--    CROP ROTATION WITH ** 2 YEAR REPETITION

          (H) SINGLE CROPPING MANAGEMENT

PLOT 3
          (A) AREA--    30.00    ACRES
          (B) CROP--   SOY BEANS
          (C) SOIL TYPE--     1  (SCS SOIL TYPE)
          (D) IRRIGATION RATE--    0.10   INCHES/CAY
          (E) IRRIGATION MANAGEMENT--    IRRIGATION BELOW    0.50  FIELD CAPACITY
          (F) PLAN IMPLEMENTED--    RUNOFF AND IRRIGATICN
          (G) CROP MANAGEMENT--    NO CROP ROTATICN
          (H) SINGLE CROPPING MANAGEMENT

PLOT 4
          (A) AREA--  190.00    ACRES
          (B) CROP--   PASTURE
          (C) SOIL TYPE--     1  (SCS SOIL TYPE)
          (D) IRRIGATION RATE--    0.10   INCHES/CAY
          (E) IRRIGATION MANAGEMENT--    IRRIGATION BELOW    0.0    FIELD CAPACITY
          (F) PLAN IMPLEMENTED--    RUNOFF
          (G) CROP MANAGEMENT--    NO CROP ROTATION
          (H) SINGLE CROPPING MANAGEMENT
```

```
PLOT 5
        (A) AREA--  120.00   ACRES
        (B) CROP--  CORN
        (C) SOIL TYPE--    1  (SCS SOIL TYPE)
        (D) IRRIGATION RATE--   0.10  INCHES/DAY
        (E) IRRIGATION MANAGEMENT--   IRRIGATION BELOW   0.0   FIELD CAPACITY
        (F) PLAN IMPLEMENTED--   RUNOFF
        (G) CROP MANAGEMENT--   NO CROP ROTATION
        (H) SINGLE CROPPING MANAGEMENT

PLOT 6
        (A) AREA--   40.00   ACRES
        (B) CROP--  SORGHUM
        (C) SOIL TYPE--    1  (SCS SOIL TYPE)
        (D) IRRIGATION RATE--   0.10  INCHES/DAY
        (E) IRRIGATION MANAGEMENT--   IRRIGATION BELOW   0.0   FIELD CAPACITY
        (F) PLAN IMPLEMENTED--   RUNOFF
        (G) CROP MANAGEMENT--   NO CROP ROTATION
        (H) SINGLE CROPPING MANAGEMENT
```

```
                                   **** ANNUAL SUMMARY ****
1/ 5/63 - DISCHARGE OF   33.25 ACRE-IN REQUIRES VOLUME OF  1167.23 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   271.26
1/20/63 - DISCHARGE OF    2.65 ACRE-IN REQUIRES VOLUME OF  1169.88 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   271.76
1/23/63 - DISCHARGE OF    2.82 ACRE-IN REQUIRES VOLUME OF  1172.70 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   272.29
1/26/63 - DISCHARGE OF    0.94 ACRE-IN REQUIRES VOLUME OF  1173.64 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   272.47
2/ 4/63 - DISCHARGE OF   20.66 ACRE-IN REQUIRES VOLUME OF  1194.30 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   276.32
3/ 5/63 - DISCHARGE OF   95.92 ACRE-IN REQUIRES VOLUME OF  1290.23 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   293.96
3/ 9/63 - DISCHARGE OF   84.28 ACRE-IN REQUIRES VOLUME OF  1374.51 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   309.10
3/11/63 - DISCHARGE OF    8.39 ACRE-IN REQUIRES VOLUME OF  1382.89 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   310.59
8/13/63 - DISCHARGE OF  682.22 ACRE-IN REQUIRES VOLUME OF  2065.11 ACRE-IN FOR 100.00 % CONTROL WHERE L = W =   423.00
                             WATER ACCOUNT FOR STORAGE FACILITY (IN ACRE-INCHES)          - 1963

          --------------------------------------------------------------------------------------------------------------
                              INFLOWS                                                  OUTFLOWS
          ------------------------------------------------         -------------------------------------------
MONTH     PRECIP.    MUNICIPAL     FEEDLOT     RUNOFF     IRR. DAYS    DISPOSAL VOL.   SURFACE EVAP.   DISCHARGE       VOL. CHANGE    HEIGHT
 JAN.       25.6         0.0          0.0        27.2         0.            0.0             0.0          39.7              5.1       14.00
 FEB.        0.4         0.0          0.0        20.7         0.            0.0             8.1          20.7             -7.8       13.57
 MAR.       51.5         0.0          0.0       171.6         0.            0.0            60.8         188.6            -26.3       13.86
 APR.       14.1         0.0          0.0         0.0        22.          187.0            82.2           0.0           -255.1       12.60
 MAY        76.5         0.0          0.0       210.0        25.          212.5            83.2           0.0             -9.2       12.56
 JUNE       60.4         0.0          0.0        99.6         0.            0.0           110.8           0.0             49.2       12.82
 JULY       65.1         0.0          0.0       122.0        10.           30.0           121.4           0.0             35.7       13.01
 AUG.      112.2         0.0          0.0       869.3        18.           54.0           119.1         682.2            126.2       13.62
 SEPT       26.7         0.0          0.0         0.0        30.          320.0            80.0           0.0           -373.3       11.61
 OCT.       12.2         0.0          0.0         0.0        31.          449.5            35.3           0.0           -472.6        7.40
 NOV.       44.7         0.0          0.0         7.6         0.            0.0            10.0           0.0             42.4        7.95
 DEC.       10.2         0.0          0.0         0.0         0.            0.0             3.7           0.0              6.5        8.03
 TOT.      499.6         0.0          0.0      1527.9       136.         1253.0           722.5         931.1           -879.2        8.03


                                                        PLOT NO.  1


                         CROP--SOY BEANS              SOIL TYPE--  1       DISPOSAL AREA-- 85.00 ACRES
                              DOUBLE CROPPING WITH WHEAT

                                   WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1963
            ----------------------------------------------------------------------------------------------------------
                            INPUTS                                        OUTPUTS
                    -----------------------------      ------------------------------------------------
MONTH        PRECIPITATION     IRRIGATION      INTERCEPTION . SURFACE RUNOFF    PERCOLATION       AET           CHANGE IN SM
 JAN.             1.36             0.0              0.10            0.32             0.0           0.26              0.18
 FEB.             0.02             0.0              0.18            0.05             0.0           0.52             -0.73
 MAR.             2.74             0.0              0.71            0.88             0.0           1.42             -0.27
 APR.             0.75             2.20             2.20            0.0              0.0           2.74             -2.09
 MAY              4.07             2.50             2.70            0.50             0.0           2.26              1.21
 JUNE             3.21             0.0              0.69            0.64             0.0           2.18             -0.30
 JULY             3.46             0.0              0.30            0.90             0.0           1.13              1.12
 AUG.             5.97             0.0              0.50            3.63             0.0           2.82             -0.98
 SEPT             1.42             2.00             2.10            0.0              0.0           2.53             -1.31
 OCT.             0.65             3.10             3.03            0.0              0.0           0.57              0.15
 NOV.             2.38             0.0              0.52            0.08             0.0           0.52              1.37
 DEC.             0.54             0.0              0.12            0.0              0.0           0.25              0.17
 TOT.            26.57             9.80            13.15            7.01             0.0          17.19             -0.99
```

```
                                          PLOT NO.  2

            CROP--SORGHUM              SOIL TYPE--  1      DISPOSAL AREA-- 30.00 ACRES

                          WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1963
--------------------------------------------------------------------------------------------------------
                      INPUTS                                          OUTPUTS
            ---------------------------------     ------------------------------------------------------
MONTH       PRECIPITATION     IRRIGATION     INTERCEPTION  SURFACE RUNOFF   PERCULATION        AET          CHANGE IN SM
 JAN.           1.36             0.0             0.10           0.10            0.0            0.27             0.39
 FEB.           0.02             0.0             0.18           0.07            0.0            0.78            -0.51
 MAR.           2.74             0.0             0.71           0.54            0.0            1.51            -0.03
 APR.           0.75             0.0             0.32           0.00            0.0            0.64            -0.21
 MAY            4.07             0.0             0.76           1.31            0.0            0.97             1.03
 JUNE           3.21             0.0             0.69           0.84            0.30           1.08             0.29
 JULY           3.46             1.00            1.20           0.97            0.0            4.52            -2.23
 AUG.           5.97             1.80            1.90           2.42            0.0            4.60            -1.24
 SEPT           1.42             3.00            3.00           0.0             0.0            1.66            -0.24
 OCT.           0.65             3.10            3.03           0.0             0.0            0.15             0.57
 NOV.           2.38             0.0             0.52           0.11            0.0            0.60             1.25
 DEC.           0.54             0.0             0.12           0.0             0.0            0.41             0.01
 TOT.          26.57             8.90           12.53           6.38            0.30          17.18            -0.42


                                          PLOT NO.  3

            CROP--SOY BEANS            SOIL TYPE--  1      DISPOSAL AREA-- 30.00 ACRES

                          WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1963
--------------------------------------------------------------------------------------------------------
                      INPUTS                                          OUTPUTS
            ---------------------------------     ------------------------------------------------------
MONTH       PRECIPITATION     IRRIGATION     INTERCEPTION  SURFACE RUNOFF   PERCULATION        AET          CHANGE IN SM
 JAN.           1.36             0.0             0.10           0.10            0.0            0.27             0.39
 FEB.           0.02             0.0             0.18           0.07            0.0            0.81            -0.54
 MAR.           2.74             0.0             0.71           0.54            0.0            1.52            -0.03
 APR.           0.75             0.0             0.32           0.00            0.0            0.64            -0.21
 MAY            4.07             0.0             0.76           1.31            0.0            0.97             1.03
 JUNE           3.21             0.0             0.69           0.64            0.0            2.26            -0.39
 JULY           3.46             0.0             0.30           0.90            0.0            1.57             0.69
 AUG.           5.97             0.0             0.50           3.63            0.0            3.27            -1.44
 SEPT           1.42             2.00            2.10           0.0             0.0            2.71            -1.49
 OCT.           0.65             3.10            3.03           0.0             0.0            0.60             0.12
 NOV.           2.38             0.0             0.52           0.11            0.0            0.52             1.33
 DEC.           0.54             0.0             0.12           0.0             0.0            0.25             0.17
 TOT.          26.57             5.10            9.33           7.32            0.0           15.39            -0.37
```

```
                                        PLOT NO.  4

            CROP--PASTURE               SOIL TYPE--  1      DISPOSAL AREA--190.00 ACRES
                              WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1963
------------------------------------------------------------------------------------------------------
                   INPUTS                                   OUTPUTS
         ---------------------------   ------------------------------------------------------
MONTH    PRECIPITATION   IRRIGATION    INTERCEPTION  SURFACE RUNOFF   PERCOLATION        AET          CHANGE IN SM
 JAN.        1.36           0.0            0.10           0.03            0.0           0.31              0.42
 FEB.        0.02           0.0            0.18           0.03            0.0           0.81             -0.50
 MAR.        2.74           0.0            0.71           0.28            0.22          1.54             -0.01
 APR.        0.75           0.0            0.32           0.0             0.0           2.28             -1.85
 MAY         4.07           0.0            0.76           0.04            0.0           2.34              0.92
 JUNE        3.21           0.0            0.69           0.02            0.0           3.90             -1.40
 JULY        3.46           0.0            0.30           0.03            0.0           2.94              0.19
 AUG.        5.97           0.0            0.50           1.65            0.0           4.05             -0.23
 SEPT        1.42           0.0            0.50           0.0             0.0           1.64             -0.72
 OCT.        0.65           0.0            0.28           0.0             0.0           0.33              0.04
 NOV.        2.38           0.0            0.46           0.0             0.0           0.52              1.40
 DEC.        0.54           0.0            0.12           0.0             0.0           0.25              0.17
 TOT.       26.57           0.0            4.93           2.07            0.22         20.91             -1.56

                                        PLOT NO.  5

            CROP--CORN                  SOIL TYPE--  1      DISPOSAL AREA--120.00 ACRES
                              WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1963
------------------------------------------------------------------------------------------------------
                   INPUTS                                   OUTPUTS
         ---------------------------   ------------------------------------------------------
MONTH    PRECIPITATION   IRRIGATION    INTERCEPTION  SURFACE RUNOFF   PERCOLATION        AET          CHANGE IN SM
 JAN.        1.36           0.0            0.10           0.10            0.0           0.27              0.39
 FEB.        0.02           0.0            0.18           0.07            0.0           0.78             -0.51
 MAR.        2.74           0.0            0.71           0.54            0.0           1.51             -0.03
 APR.        0.75           0.0            0.32           0.0             0.0           0.85             -0.42
 MAY         4.07           0.0            0.76           0.59            0.0           2.35              0.37
 JUNE        3.21           0.0            0.69           0.15            0.0           4.10             -1.74
 JULY        3.46           0.0            0.30           0.19            0.0           3.03             -0.06
 AUG.        5.97           0.0            0.50           2.34            0.0           3.64             -0.50
 SEPT        1.42           0.0            0.50           0.0             0.0           1.12             -0.20
 OCT.        0.65           0.0            0.28           0.0             0.0           0.54             -0.17
 NOV.        2.38           0.0            0.46           0.00            0.0           0.33              1.58
 DEC.        0.54           0.0            0.12           0.0             0.0           0.20              0.21
 TOT.       26.57           0.0            4.93           3.98            0.0          16.72             -1.06
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                                        PLOT NC.  6

              CROP--SORGHUM              SOIL TYPE--  1      DISPOSAL AREA-- 40.00 ACRES

                           WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1963
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                        INPUTS                                   OUTPUTS
             ------------------------------   ----------------------------------------------------
MONTH        PRECIPITATION    IRRIGATION    INTERCEPTION  SURFACE RUNOFF  PERCULATION      AET        CHANGE IN SM
 JAN.             1.36           0.0             0.10          0.10           0.0          0.30           0.36
 FEB.             0.02           0.0             0.18          0.07           0.0          0.81          -0.54
 MAR.             2.74           0.0             0.71          0.54           0.0          1.55          -0.06
 APR.             0.75           0.0             0.32          0.00           0.0          0.64          -0.21
 MAY              4.07           0.0             0.76          1.31           0.0          0.97           1.03
 JUNE             3.21           0.0             0.69          0.84           0.07         1.08           0.53
 JULY             3.46           0.0             0.30          0.94           0.0          4.52          -2.30
 AUG.             5.97           0.0             0.50          2.34           0.0          4.40          -1.27
 SEPT             1.42           0.0             0.50          0.0            0.0          1.22          -0.30
 OCT.             0.65           0.0             0.28          0.0            0.0          0.11           0.26
 NOV.             2.38           0.0             0.46          0.00           0.0          0.67           1.24
 DEC.             0.54           0.0             0.12          0.0            0.0          0.25           0.17
 TOT.            26.57           0.0             4.93          6.15           0.07        16.51          -1.10
   PERCENT OF WASTEWATER CONTROLLED=      54.07

   POTENTIAL DISPOSAL DAYS= 136

   PACK ON DECEMBER 31 = 0.0                 CHANGE IN SNOW STORAGE= 0.0

   INPUTS-OUTPUTS-CHANGE IN SNOW STORAGE=CHANGE IN    SCIL MOISTURE

   PERCENT OF MAXIMUM POND VOLUME REQUIRED = 100.00

   ESTIMATED LAKE EVAPORATION, INCHES = 47.03
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                                 ***** FINAL SUMMARY *****
METEOROLOGICAL SUMMARY
               AVERAGE ANNUAL LAKE EVAPORATION= 45.31 INCHES
               AVERAGE ANNUAL PRECIPITATION= 38.45 INCHES
               PRECIPITATION RANGE= 34.01 INCHES   (FROM A LOW OF 26.35 INCHES  TO A HIGH OF  60.36 INCHES)
               AVERAGE ANNUAL MOISTURE DEFICIT=  6.86 INCHES
SUMMARY OF POND OPERATIONS
               NO. OF YEARS HAVING A DISCHARGE=    23
               AVERAGE NO. OF DISCHARGES / YEAR HAVING A DISCHARGE= 29.04
               AVERAGE DISCHARGE=115.75 ACRE-INCHES
               AVERAGE PERCENT OF DISCHARGE CONTROLLED BY EVAPORATION AND IRRIGATION= 36.71
               TOTAL DISCHARGE VOLUME= 77320.19 ACRE-INCHES
               TOTAL NO. OF DISCHARGES=668.
               MAXIMUM DISCHARGE=****** ACRE-INCHES
               AVERAGE ANNUAL VOLUME OF IRRIGATED WATER TO THE FIELD=  625.30 ACRE-INCHES
SUMMARY OF DISPOSAL PLOTS
    PLOT 1
               AVERAGE ANNUAL DISPOSAL AREA RUNOFF= 11.01 INCHES
               AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=  1.03 INCHES
               AVERAGE ANNUAL NO. OF DISPOSAL DAYS=  46.2
               AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION= 10.49 INCHES
               AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION= 20.60 INCHES
               AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTURE= -0.06 INCHES
    PLOT 2
               AVERAGE ANNUAL DISPOSAL AREA RUNOFF= 11.98 INCHES
               AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=  1.33 INCHES
               AVERAGE ANNUAL NO. OF DISPOSAL DAYS=  53.7
               AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION= 11.21 INCHES
               AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION= 19.34 INCHES
               AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTURE= -0.05 INCHES
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PLOT 3
          AVERAGE ANNUAL DISPOSAL AREA RUNOFF= 12.68 INCHES
          AVERAGE ANNUAL DISPOSAL AREA PERCULATION=  1.29 INCHES
          AVERAGE ANNUAL NO. OF DISPOSAL DAYS=  24.0
          AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION=  8.86 INCHES
          AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION= 18.06 INCHES
          AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTURE= -0.04 INCHES
PLOT 4
          AVERAGE ANNUAL DISPOSAL AREA RUNOFF=  7.73 INCHES
          AVERAGE ANNUAL DISPOSAL AREA PERCULATION=  1.59 INCHES
          AVERAGE ANNUAL NO. OF DISPOSAL DAYS=   0.0
          AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION=  6.88 INCHES
          AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION= 22.27 INCHES
          AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTURE= -0.03 INCHES
PLOT 5
          AVERAGE ANNUAL DISPOSAL AREA RUNOFF= 11.34 INCHES
          AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=  0.80 INCHES
          AVERAGE ANNUAL NO. OF DISPOSAL DAYS=   0.0
          AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION=  6.88 INCHES
          AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION= 19.48 INCHES
          AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTURE= -0.05 INCHES
PLOT 6
          AVERAGE ANNUAL DISPOSAL AREA RUNOFF= 12.12 INCHES
          AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=  1.37 INCHES
          AVERAGE ANNUAL NO. OF DISPOSAL DAYS=   0.0
          AVERAGE ANNUAL DISPOSAL AREA INTERCEPTION=  6.88 INCHES
          AVERAGE ANNUAL DISPOSAL AREA EVAPOTRANSPIRATION= 18.14 INCHES
          AVERAGE ANNUAL DISPOSAL AREA CHANGE IN SOIL MOISTURE= -0.06 INCHES
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SUMMARY OF STATISTICAL DATA

                    PRECIPITATION FREQUENCY DATA

          INTENSITY     FREQUENCY      FREQUENCY      RUNOFF FREQ.
            (IN.)          (%)          (DAYS)          (DAYS)

            >0.0         100.00        1970.00         1074.00
            >0.1          71.27        1404.00         1065.00
            >0.2          54.01        1064.00          874.00
            >0.3          42.99         847.00          758.00
            >0.4          34.72         684.00          624.00
            >0.5          29.29         577.00          539.00
            >0.6          23.05         454.00          432.00
            >0.7          19.59         386.00          368.00
            >0.8          16.55         326.00          312.00
            >0.9          14.57         287.00          274.00
            >1.0          12.28         242.00          231.00
            >1.1          10.46         206.00          197.00
            >1.2           9.19         181.00          175.00
            >1.3           7.97         157.00          151.00
            >1.4           7.16         141.00          136.00
            >1.5           6.29         124.00          119.00
            >1.6           5.23         103.00           98.00
            >1.7           4.26          84.00           82.00
            >1.8           3.81          75.00           73.00
            >1.9           2.99          55.00           57.00
            >2.0           2.54          50.00           50.00
            >3.0           0.56          11.00           11.00
            >4.0           0.20           4.00            4.00
            >5.0           0.10           2.00            2.00
            >10.           0.0            0.0             0.0
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                                        RUNOFF FREQUENCY DATA
      INTENSITY                 FREQUENCY (%)                                    FREQUENCY (DAYS)
        (IN.)         PLOT 1    PLOT 2    PLOT 3    PLOT 4          PLOT 1    PLOT 2    PLOT 3    PLOT 4

         >0.0         100.00    100.00    100.00    100.00          997.00   1045.00   1091.00    759.00
         >0.1          45.45     46.03     45.83     41.50          454.00    481.00    500.00    315.00
         >0.2          32.03     32.82     33.09     30.43          320.00    343.00    361.00    231.00
         >0.3          25.23     24.59     25.21     23.72          252.00    257.00    275.00    180.00
         >0.4          20.52     20.57     21.45     18.45          205.00    215.00    234.00    140.00
         >0.5          16.22     17.51     17.87     13.97          162.00    183.00    195.00    106.00
         >0.6          12.41     13.68     13.93     11.07          124.00    143.00    152.00     84.00
         >0.7          10.01     11.39     11.73      9.35          100.00    119.00    128.00     71.00
         >0.8           7.91      9.19      9.17      8.04           79.00     96.00    100.00     61.00
         >0.9           6.51      7.75      7.70      6.19           65.00     81.00     84.00     47.00
         >1.0           5.71      6.51      6.69      5.27           57.00     68.00     73.00     40.00
         >1.1           5.01      5.45      5.68      4.48           50.00     57.00     62.00     34.00
         >1.2           4.30      4.50      4.67      3.82           43.00     47.00     51.00     29.00
         >1.3           3.60      3.83      4.12      3.16           36.00     40.00     45.00     24.00
         >1.4           3.20      3.25      3.57      2.77           32.00     34.00     39.00     21.00
         >1.5           2.30      2.68      2.93      2.37           23.00     28.00     32.00     18.00
         >1.6           2.00      2.30      2.29      2.37           20.00     24.00     25.00     18.00
         >1.7           1.40      1.72      1.47      2.11           14.00     18.00     16.00     16.00
         >1.8           1.30      1.63      1.37      1.84           13.00     17.00     15.00     14.00
         >1.9           1.30      1.63      1.28      1.71           13.00     17.00     14.00     13.00
         >2.0           1.30      1.53      1.28      1.19           13.00     16.00     14.00      9.00
         >3.0           0.40      0.38      0.46      0.13            4.00      4.00      5.00      1.00
         >4.0           0.10      0.10      0.09      0.13            1.00      1.00      1.00      1.00
         >5.0           0.0       0.0       0.0       0.0             0.0       0.0       0.0       0.0
         >10.           0.0       0.0       0.0       0.0             0.0       0.0       0.0       0.0
  SUMMARY OF MONTHLY DISTRIBUTION OF IRRIGATION (INCHES)
-------------------------------------------------------------------------------------------------------------------
         JAN.      FEB.      MAR.      APR.      MAY       JUNE      JULY      AUG.      SEPT      OCT.      NOV.      DEC.
PLOT=1   0.0       0.0       0.0       0.10      0.34      0.43      1.04      1.35      0.97      0.25      0.11      0.32
PLOT=2   0.0       0.0       0.0       0.01      0.06      0.43      1.42      2.07      1.17      0.20      0.0       0.0
PLOT=3   0.0       0.0       0.0       0.0       0.0       0.0       0.28      0.63      0.79      0.70      0.0       0.0
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DEVELOPMENT OF SUPPLEMENTAL IRRIGATION SYSTEM MODEL FOR A FARM IN SOUTHEASTERN KANSAS

by

JONG SEONG IM

B.S., Seoul National University, 1974

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

ABSTRACT

Supplemental irrigation has been increasingly popular in the eastern half of the United States. In an area where a crop can be grown by natural rainfall alone, but additional water produces improved yields, irrigation is defined as supplemental.

The aim of this research is to study the feasibility of supplemental irrigation in subhumid regions by developing a general hydrologic crop management model. This purpose can be achieved by testing a continuous watershed hydrologic model, which can estimate the effect of each hydrologic component on a specified site. The actual site used to test the model is owned by Ronnie Felt, located near Uniontown, Kansas, in Bourbon County. The Felt site consists of a 11.66×10^4 m^3 (94.5 ac-ft) storage pond, and a 166 ha (410 acres) watershed, of which 57 ha (145 acres) are irrigated with three center pivot sprinklers. To examine the performance of a pond water supply for irrigation, meteorological data (1948-1970) and various geographic input variables were used in the simulation. The variability of surface runoff in response to precipitation, and irrigation demand are important factors to analyze the reliability of a pond. A general method of crop management system is capable of simulating any typical cropping schedule for Southeastern Kansas.

According to this simulation, the annual irrigation demand was estimated to be about 110 mm (4.3 inches) on the average. The precipitation produces sufficient runoff to the pond for use as supplemental irrigation water. The storage pond can meet the irrigation needs at the probability level of 91 percent.