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Simulation of water requirements for irrigation of corn on three soils in Iowa

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SIMULATION OF WATER REQUIREMENTS FOR IRRIGATION OF CORN ON THREE SOILS IN IOWA

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Simulation of water requirements for irrigation of corn on three soils in Iowa

by

Zohreh Shahvar

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INTRODUCTION

According to past observation, seasonal water use by corn sometimes exceeds the growing season precipitation in Iowa; the resulting soil moisture stress is a limiting factor in determining the grain yield. Supplemental irrigation may reduce or eliminate soil moisture stress as an important factor influencing corn yield.

To study the problems involved in the use of irrigation water, a detailed understanding of the water balance on agricultural land is required. This balance is only part of the much larger natural system known as the hydrologic cycle. Since the early 1960s, hydrologic modeling has become an accepted branch of scientific hydrology. Most of the early work in hydrologic modeling considered the individual components of the overall hydrologic cycle, such as surface runoff, evapotranspiration, infiltration etc.

Many of the natural phenomena that hydrologists try to model are nonlinear, unsteady and nonuniformly distributed in time and space (Delleur, 1971).

Simplifications and assumptions are required to develop a satisfactory model to simulate various individual processes, and to omit unnecessary details which add to the complication of the program.

A modified version of the Iowa State University Watershed Model by Anderson (1975) will be used to simulate various processes of the hydrologic cycle.

The purpose of this study is to define probabilities of soil moisture shortage under natural conditions, to determine annual water needs and their frequency distribution, and also the most efficient scheduling for irrigation of three selected soils in Iowa, representing sandy to heavy soils.

The procedure used involved the selection of soils and crop type, selection and calibration of a hydrologic model, and finally applying the calibrated model to long-term weather data, to develop the probability function for soil moisture shortage and annual irrigation water requirements.

The selected soils were the Moody silt loam in northwest Iowa, the Chelsea sand in southeast Iowa, and the Albaton clay located in the bottom lands of the Missouri river valley in west central Iowa. The crop was corn with conventional surface planting.

The Anderson (1975) water balance model with its recent modifications was selected for computer simulation. The model was first calibrated under natural conditions. Measured surface runoff at the watershed, and reported soil moisture by Shaw at the Doon station were used to calibrate and verify the model for the Moody silt loam. There were no available measured data for the Chelsea sand or the Albaton clay. Infiltration and soil moisture redistribution processes were modified to increase infiltration rate and retain low soil moisture within the soil profile for the Chelsea sand, and to account for crack development in the heavy Albaton soils under dry conditions.

The calibrated model was then applied to long-term weather data (rainfall records, daily pan evaporation, and spring soil moisture) for each soil, to develop a probability function for moisture shortage for natural conditions.

Soil moisture stress occurrence was simulated by incorporating a subroutine into the program, which uses the procedure developed by Shaw (1974) and calculates a weighted seasonal stress index.

Finally, the model was used to simulate sprinkler irrigation, wherein three situations were considered for each soil; that is, a certain depth of irrigation water was applied when soil moisture in the active root zone fell below 35, 50 and 70% of the available soil moisture in the active root zone.

Non-uniform irrigation application was used on the Chelsea sand, by applying less water early in the growing season, and increasing it as the roots develop during the growing season.

Computer simulation was completed for natural conditions and various irrigation scheduling criteria, to determine probabilities of soil moisture shortage, and annual water needs. Simulation also defined the increase in surface runoff and deep percolation, and decrease in water use efficiency and weighted seasonal stress index, due to irrigation water application.

LITERATURE REVIEW

Estimation of Potential ET by Adjusting Evaporation Pan Data

Evapotranspiration (ET) is the process of changing water located in plants or soil from liquid to vapor, and transporting this vapor upward into the atmosphere. Thus, water and energy must be present in conjunction with a transporting mechanism. Several approaches have been presented in the literature for computing ET.

Tanner (1967) divided the methods of ET measurement into three categories: water balance methods, such as lysimetry and soil water depletion; micrometeorological methods, including the profile, energy balance and combination methods; and empirical methods, which are grouped on the basis of their dependence on radiation, temperature and humidity. By reviewing the empirical methods of ET measurement, he concluded that:

> "Methods such as those of Penman, which are based on the energy balance, appear to be most valuable, and have the widest applicability of all methods. Shallow and sunken pans and methods utilizing radiation are the next best choice. Properly installed pan and radiation methods, when calibrated are much preferred over calibrated and uncalibrated mean temperature methods."

Most of the empirical methods predict potential ET because they were usually developed for irrigated situations. Potential ET occurs when water is readily available and the limiting ET condition is the meteorologic source of energy. Potential ET can be met after irrigation or heavy rains; ponds, very wet soils, and well-watered green vegetation can also meet potential ET rate (Saxton, 1972).

The combination method proposed by Penman (1948) is one of the first and most valuable methods of computing potential ET. To use the Penman method, four variables need to be measured at a single height above the crop: air temperature, air humidity, net radiation and wind velocity. One of the most significant advances toward more direct application of the Penman method came when instrumentation was developed for the direct measurement of net radiation (Fritschen, 1963, 1965).

Tanner and Pelton (1960) compared 48 days of lysimeter data with values calculated by the Penman method for alfalfa-bromegrass cover, and concluded that:

> "A suitable estimate of the energy balance with the Penman approximation is a valuable potential evapotranspiration reference, provided that an appropriate wind function is employed."

Anderson et al. (1978) modified the Penman method to compute potential ET in their water balance model. The difficulty with the use of the Penman method is that the required data are not available for most weather stations in Iowa. Shaw (1963) stated that "Among the methods of computing potential ET, pan evaporation was probably the most available in Iowa, but the Penman equation gives more reliable daily values when data are available." Hellickson (1969) came to a similar conclusion, that "for irrigated plots pan evaporation was somewhat less reliable than net radiation or the Penman potential ET method."

In this study, pan evaporation data were the only data available for computing potential ET. Thus, adjustment is required to convert daily pan data to potential ET. Some of the selected literature which discusses the relation between pan and potential ET calculated by empirical equations is reviewed in this section.

Evaporation pan data may overestimate the amount of evaporation taking place from other surfaces because of heat transfer from the surrounding area into the small pan. The incident radiation on a shallow pan may also result in a different surface temperature than for the deeper pond. Yao (1956) used the data from Albia, south central Iowa, for the period July 20 to October 29, 1956, and related pan evaporation to that from a large pond surface. He also tested the Penman, Blaney-Criddle and Thornthwaite methods of computing potential ET against both pan and pond evaporation.

Daily values for evaporation by the various methods were compared with pan and pond evaporation data, and regression lines were obtained for each month. The reader is referred to the original work for more detail. The variation in daily values might average out over longer periods. The period of observation was divided into seven-day intervals, and the data averaged within the seven-day period. Linear regression lines were then computed for the various empirical methods of computing ET, pan and pond evaporation data, as shown in Table 1, along with the associated correlation coefficients.

The regression line between pond (Y, in) and pan data (X, in), on the basis of seven-day average evaporation was determined as:

$$Y = 0.054 + 0.635\,X$$

where both pan and pond evaporation data are in inches. The value of

Table 1. Relation of potential evapotranspiration values calculated by empirical methods to pan and pond evaporation

	Pan		Pond	
Penman	Y = .076 + .493 X	r = .94	Y = .076 + .771 X	r = .96
Blaney-Criddle	Y = .093 + .476 X	r = .85	Y = .109 + .673 X	r = .76
Thornthwaite	Y = −.020 + .611 X	r = .87	Y = −.001 + .868 X	r = .79

0.054 inches, the point where the regression line intercepts zero pan evaporation, was considered to be an estimate of daily seepage from the pond.

The usefulness of a field pan as a reliable evaporimeter may be questionable due to practical difficulties. Animals may consume or pollute water in open pans; on the other hand, screen covers may alter wind structure over the pan, and increase deposition of foreign matter. Campbell and Phene (1976) evaluated the effect of screening on evaporation, by comparing screened and open pan evaporation calculated by the method of Kohler et al. (1955). They concluded that evaporation from the screend pan averaged 12.8% less than that from an open pan, and the difference in evaporation rate was maximum in the late afternoon, between 4 to 6 p.m. Campbell and Phene (1976) further stated that:

> "A screen placed on the open U.S. Weather Bureau pan prevented water consumption by animals and permitted more accurate

> evaporation measurements. The screened pans not only give greater confidence in pan evaporation readings but the measurements also agreed with potential ET computed from the combination methods of Penman and Van Bavel."

Pan evaporation data are not collected for all weather stations, and winter season evaporation records are generally missing in most parts of the U.S. Kohler et al. (1955) described the development of an empirical relation for estimating pan evaporation from pertinent meteorological factors. They concluded that the results were sufficiently good to instill a high degree of confidence in the accuracy of the relation, except possibly when applied for high elevations. Saxton et al. (1974) derived a regression line for the potential ET calculated by the combination method (Y) and evaporation pan data as:

$$Y = .01 + .83\,X \qquad r = .93$$

They stated that:

> "The close correlation of observed daily pan evaporation amounts with calculated daily potential ET values substantiates the common practice of estimating potential ET by adjusting observed pan evaporation."

Shahghasemi (1980) used the regression line developed by Saxton et al. (1974) to convert pan data to potential ET for use in his computer model.

Um and Maruyama (1980) used the measured evaporation data collected on the Geum river basin in Korea from 1966 to 1972, and calculated the ratios of estimated ET from the water balance method (E_c) to the average pan evaporation data (E_p) and to the calculated ET from the Penman method (E_{pm}) to be 0.43 and 0.52, respectively.

$$\frac{E_c}{E_p} = 0.43 \qquad \frac{E_c}{E_{pm}} = 0.52$$

Thus, the ratio of Penman to pan evaporation would be 0.83 (i.e. $\frac{E_{pm}}{E_p}$ = .83), which is the same as the ratio given by Saxton et al. (1974).

Pan coefficients (the ratios of lake to pan evaporation) have also been used in practice as adjustment factors for pan observations, to give an estimate of potential ET. The most commonly quoted value of pan coefficient is 0.7, and it is considered that this value gives a useful estimate of annual lake evaporation when applied to observed annual pan evaporation. Kohler et al. (1955) found that the use of the customary 0.7 class A pan coefficient, without consideration of advected energy may lead to appreciable error.

Houman (1973) presented data on annual coefficients of lake to class A pan evaporation for various lakes of the world. These coefficients varied significantly in space, in time, and in relation to the particular characteristics of the lake in question. Salton sea lake in California had the lowest pan coefficient of 0.52, and Lake Eucumbene in New South Wales had the highest coefficient of 0.86. Kohler et al. (1959) showed a geographic variation in the annual class A pan coefficient across the continental U.S., ranging from 0.6 to 0.8. The highest value of 0.8 was in the far northeast, with 0.77 along the east coast and 0.79 on the west coast. The higher values for coastal areas are probably related to the higher humidity and lower radiation.

Considerable seasonal variation in pan coefficient has also been reported in the literature. Saxton et al. (1974) presented data on monthly variation of potential ET to pan evaporation for 1969 to 1971, ranging from 0.65 to 0.95. Although the variation was appreciable during the year, the trend was somewhat inconsistent. Yao (1956), in relating pan evaporation data to potential ET calculated by the Penman, Blaney-Criddle and Thornthwaite methods, found various relations for each month. Houman (1973) developed data on the monthly variation of the ratio of lake evaporation to class A pan evaporation, and also the ratio of calculated potential ET from the Penman equation to class A pan evaporation for lakes at various locations. Considering these data, he found that "the variations from month to month are usually great enough to preclude the use of a constant pan coefficient for estimation of potential ET." But since the variations are inconsistent, it is difficult to draw any general conclusions from the given data. The chief factor causing the seasonal variation in pan coefficient is the storage of heat in a large water body, which results in evaporation which is not in phase with solar radiation. Evaporation from pans and tanks is almost completely in phase with radiation, but the phase lag may be several months in the case of very deep and large lakes (Hounam, 1973).

Considering the existing variation among conversion coefficients and equations between potential ET and evaporation pan data, it can be concluded that probably the most reliable relation for estimating potential ET from pan data would be that based on meteorological data taken from stations close to the location of interest.

In this study the required meteorological data for the Penman equation and evaporation pan data were available for the northeast Gingles watershed, west central Iowa, for the years 1967 to 1970. These data were used to develop a relationship predicting potential ET values calculated by the Penman method from evaporation pan data. Various regression lines were determined for the months of June, July and August, as will be discussed in more detail in the potential ET subroutine presentation.

Soil Moisture Stress and its Effect on Crop Yield Reduction

Most of the work dealing with regression models predicting corn yield from weather variables indicates that a multiple regression model with several weather variables, rather than a simple regression line with one weather variable, is required to predict yield adequately (Ewalt et al., 1961; Sanderson, 1954).

Watson (1963) stated that "Yield may be predicted by a simple linear regression model when only one climatic factor, such as rainfall, dominates over all others."

To avoid the confusion resulting from multiple regression analysis of several weather variables, Morris (1972) suggested that simple weather observations could be incorporated into indices which represent the cumulative influences of many weather factors on yield. These indices could be determined by use of simulation models. He further concluded that soil moisture stress indices with excellent results in yield prediction have been obtained in many instances.

Soil moisture stress occurs when soil moisture reserves are low and the plant is using water faster than it can extract it from the soil.

Denmead and Shaw (1960) stated that: "soil moisture stress results from an imbalance between the available water in the soil profile and atmospheric demand for water." Moisture stress will result in many unfertilized ovules which do not develop into mature corn kernels and reduce final grain yield (Mallett, 1972). Mallett's work (1972) also showed that corn yields were reduced linearly as the number of days with moisture stress increased, and under very severe stress there could be considerable yield reduction.

Yield reduction of 3 to 7% per day due to moisture stress imposed at silking has been reported by Claussen and Shaw (1970). Denmead and Shaw (1960) also reported about 51% reduction in yield due to soil moisture stress occurrence in the field.

The periods of tasselling, silking and pollination are very critical stages in the growth of the corn plant, and generally occur in the later part of July (Shaw, 1977). Even small amounts of moisture stress at critical time periods will affect yields. Beer et al. (1967), in a study of irrigated corn in Iowa, concluded that even corn which was irrigated and maintained at a high level of soil moisture content, suffered moisture stress due to high atmospheric demand.

When soil moisture cannot meet the atmospheric demand for water, the plant is considered under stress. Corsi and Shaw (1961) compared four methods of computing soil moisture stress indices to determine the best index for adequate prediction of corn yields in Iowa. They defined four daily soil moisture stress indices as follows:

Index No. 1 - the ratio of plant available moisture in the root zone (PAV) to the atmospheric evaporative demand (TH). This indicates greater stress the lower the index.

Index No. 2 - one minus the ratio of PAV to TH, which shows greater stress at a higher index.

Index No. 3 - one minus the ratio of actual evapotranspiration (ET) to potential evapotranspiration (PET). This index also indicates greater stress at a higher index.

Index No. 4 - this index was calculated as a function of relative water content, percentage of available soil moisture and class A evaporation pan loss. For each day the index can range from zero to one, with the higher values associated with greater stress.

Daily moisture stress indices by each method were summed over a 66-day period (June 27 to August 31), and related to yield data at various locations in Iowa. The analysis showed that index No. 3 had the highest correlation coefficients for 17 of 22 instances, and thus, index No. 3 was selected as the best soil moisture stress index for yield prediction.

Shaw and Felch (1972) used the above selected index and developed 66-day unweighted stress index-yield regression lines for various sites in Iowa. They concluded that all locations could be represented by three regression lines.

The use of 66-day unweighted stress index has not involved weighting according to stages of development. According to Wilson (1968), stress at different stages of development will affect yield differentially.

Shaw (1974) modified the previously defined stress index (No. 3) by assigning weighting factors to various 5-day periods before and after silking date. The seasonal weighted stress index was calculated over an 85-day period, made up of eight 5-day periods before and nine 5-day periods after silking date. To account for the cumulative effects of severe stress, additional weighting factors were applied. Seasonal weighted stress indexes were related to yield for 10 different locations all over Iowa, and resulted in two different stress-yield relationships. Statistical tests showed that they could be combined into one group of seven for high-yielding sites ($r = -0.88$) and one group of three for moderate-yielding sites ($r = -0.83$).

Further modifications were made by Shaw (1978) to account for deep rooting of corn in the years 1976 and 1977. Eighty-five-day weighted stress index is used in this study to predict non-irrigated and irrigated corn yields.

Methods of Soil Moisture Determination

The most common method of determining soil moisture content is the gravimetric method, which has been used in the U.S.A. for more than 80 years. This method involves taking a core sample to a certain depth with an auger, weighing and oven-drying it, and thus determining soil moisture content.

Another widely used method involves utilization of porous blocks, which measure the electrical conductivity and capacitance in soils. Most of these blocks have been calibrated as an index of soil moisture content. Porous blocks have low precision for estimating the water content of the soil.

The neutron moisture meter has been replaced by the gravimetric method and porous blocks since the early 1960s. The error involved in using the neutron probe is smaller than the error involved in gravimetric sampling, however the probe cannot give reliable measurements when used close to the soil surface (less than 18 - 20 cm). Van Bavel (1966) estimated sampling error for the neutron meter to be approximately 0.5% moisture by volume.

Soil Moisture Characteristics

Common understanding of terms describing the status of soil moisture of irrigated fields is required for accurate irrigation scheduling. The following terms are used to describe soil moisture status. The definitions are admittedly simplified descriptions of actual physical conditions; such simplification is necessary for practical use of the concepts.

Bulk density and total porosity

Bulk density is the mass of soil per unit volume of soil, including the soil particle itself and the associated pore space. Bulk density can be used to calculate the actual amount of water held in the soil based on gravimetric data. Zimmerman and Kardos (1961) pointed out that bulk density is not a uniform property of soil; it varies mainly in the vertical direction, but can also vary significantly in the horizontal direction. Shaw et al. (1959) found that the bulk density of glacial till soils in Iowa increased with depth; loess soils did not show such a trend.

Sand, silt and organic matter content are highly related to bulk density in a linear regression, but clay content is not significantly correlated with bulk density.

Bulk density includes the space not occupied by soil, while particle density is determined from soil mass only; hence, it is greater than bulk density.

Total porosity was defined as the part of the bulk volume not occupied by the soil (Vomocil, 1965). Thus, total porosity, T, can be calculated as $T = 100(1 - \frac{\text{bulk density}}{\text{particle density}})$.

Water potential and soil moisture tension

Water potential has been defined by Taylor et al. (1961) as the work needed to remove water from a point in the soil minus the work needed to remove free water from the same point with no soil present. Water potential is expressed in work per unit mass.

Tension and suction are terms often used interchangeably. Matric suction is the amount of suction or negative pressure that would need to be applied to a soil to cause moisture to move out of the soil. Soil moisture tension is the tension that would develop in a column of water to prevent its transfer into or out of the soil. Suction and tension are expressed in units of work per unit volume or pressure. Thus, suction or pressure is applied to the soil and tension is created as the sample approaches equilibrium.

Field capacity

Field capacity is the upper limit of the available water in percent. It is considered to be the amount of water held in soil after gravity water has drained away and the capillary conductivity has become essentially zero (Vehimeyer and Hendrickson, 1931). The American Society of Agronomy defined field capacity as the percentage of water remaining in the soil two or three days after having been saturated and after free drainage has practically ceased.

The most important factors influencing field capacity are: soil texture, structure, and the organic matter content (Carlson and Pierce, 1955). There is no single effect responsible for increasing or decreasing field capacity, but the combination of many factors acting together is the reason for changes in field capacity values. Field capacity is a property of the soil profile as a whole; since a small sample cannot represent the whole soil profile, laboratory determinations of field capacity are rough estimates.

Shaw (1963) used field sampling to measure the field capacity of some Iowa soils. He stated that field capacity varies with the season, probably due to temperature variation.

The 1/3 atmosphere tension has been accepted as a standard for estimating the field capacity conditions of the soil, providing that it has been verified by field determinations. There has been a growing interest in relating field capacity point to the 1/10 atmosphere retention value. Haise et al. (1955), in a detailed study of field capacity at two sites in South Dakota, compared 1/3 and 1/10 atmosphere retention values, and concluded that the moisture content at field capacity is more closely related to the 1/10 atmosphere tension than to the 1/3 atmosphere tension.

However, 1/3 atmosphere is an acceptable and reliable parameter for estimation of field capacity value of the soil until new developments prove otherwise.

Wilting point

Wilting point is the lower limit of available water in percent. It is the soil moisture percentage at which plants wilt and are no longer able to regain turgidity. Black (1965) described wilting point as the water percentage of a soil when plants growing in that soil are first reduced to a wilted condition from which they cannot recover in an approximately saturated atmosphere.

Soil structure, texture, organic matter, conductivity and temperature gradients are the most important factors affecting wilting point. Lund (1959) found that the 15 atmosphere value increased with increasing clay content in a linear fashion.

Wilting point can change in the same soil type if the soil material varies with depth or has variable parent material. Shaw et al. (1959) found variation in wilting point up to 11% in some glacial till soils over a distance of a few feet; loess soils showed less variation.

The 15 atmosphere moisture retention value has been accepted as a standard for estimating permanent wilting point in the laboratory. Haise et al. (1955) found a better approximation of wilting point, especially for medium and coarse textured soil by increasing the moisture tension to 26 atmospheres.

Richards and Weaver (1943) reported wilting point at 15 atmosphere tension or 1.5% above it for 102 of 119 soil samples used in their experiment. They pointed out that the scatter diagram of wilting point versus 15 bar tension followed nearly a 1:1 relationship.

Available water capacity

Available water capacity is the difference in water content between the field capacity and wilting point. Available water content is a very useful soil characteristic in water balance studies. In applying irrigation water, knowing the amount of moisture held by a soil profile can minimize irrigation losses. Once field capacity is attained, any additional moisture is lost through drainage. Israelson (1918) pointed out that no matter how heavily the soil was irrigated above a certain amount, it would drain to that amount after sufficient time, and the excess moisture would be lost through deep percolation.

Peterson et al. (1968), in a study conducted in Pennsylvania, found the lowest values of available water capacity in coarse textured soils, medium values in fine textured soils, and highest values in medium textured soils. Bartelli and Peters (1969) evaluated the relationship between percent moisture at 1/3 and 15 bars, and percent silt and clay content. They concluded that 1/3 bar moisture content versus clay content is a curvilinear relationship. Moisture percentage at 1/3 bar reached a maximum and then leveled off with increasing clay content. Fifteen bar moisture percentage versus clay content was a linear relationship. When clay content increased, the 15 bar moisture percentage increased, and did not level off. As a result, available water content decreased as the percentage of clay content increased.

Salter and Williams (1965) found similar results. They pointed out that as the texture became finer, the water content at 1/3 and 15 bars increased, but not at the same rate. This caused the available water to peak in medium soil textures, and become lower in the finer textures.

Water permeability and conductivity

Soil permeability and conductivity both measure how the soil transmits water through its pore space. Permeability is constant for a soil no matter what fluid passes through it, while conductivity is sensitive to the viscosity and density of the fluid. Conductivity (K) is related to permeability (k), fluid density (p) and viscosity (μ) as $K = k\mu/pg$, where g is acceleration due to gravity (Klute, 1965).

Hydraulic conductivity refers to the conductivity of saturated soil. Measurement of saturated hydraulic conductivity is easier than capillary conductivity, since moisture content is constant. Darcy's law can be used in the laboratory to determine saturated hydraulic conductivity, by maintaining a depth of water over the soil sample and measuring the rate of drainage, length of soil sample and the head of water over the soil sample.

Irrigation Water Application

Introduction

Throughout most humid and subhumid areas of the United States, rainfall shortage during a crop growing season often results in critical soil moisture deficits. Irrigation water is needed to supply adequate moisture during these deficit periods.

The main objective of irrigation projects is to provide a suitable moisture environment in the soil for crop growth, to prevent the occurrence of water stress which will reduce yield to an uneconomical level.

Israelson and Hansen (1962) pointed out that the growth of most crops under irrigation farming is stimulated by moderate quantities of soil moisture and retarded by either excessive or deficient amounts.

Irrigation water requirement

Irrigation water requirement is the quantity of water exclusive of precipitation, required to maintain the desired soil moisture and salinity level during the crop season. Plant water requirement is the total water used in evapotranspiration, whereas irrigation water requirement also includes the water necessary for removing the accumulated salts (leaching). The amount of water required for leaching is directly proportional to evapotranspiration and salt concentration in the irrigation water, and inversely proportional to the salinity tolerance of the crop.

Pair et al. (1975) defined net irrigation requirement as "the moisture that needs to be supplied by irrigation to satisfy the evapotranspiration by crops and that needed for the leaching of salt, which is not provided by stored off-season soil moisture, high groundwater table, and effective rainfall." (Effective rainfall is that part of the total rainfall during the growing season which is available to meet the consumptive water requirements of the crop.)

Net amount of irrigation requirement is a function of the available moisture holding capacity of the soil, the effective root zone depth, and the desired moisture level to be maintained for optimum crop yields and quality.

Irrigation handbooks usually provide values for irrigation water requirements as a function of soil profile and depth of active root zone (Pair et al., 1975; Hansen et al., 1980).

The gross irrigation requirement is the sum of net irrigation requirements and all losses which occur during irrigation, including evaporation, deep percolation, and surface runoff. Gross irrigation depth is approximated either by adding the estimated values of all losses to the net irrigation requirement, or by dividing the net irrigation requirement by the irrigation application efficiency.

Hershfield (1964) performed an analysis to simulate soil moisture conditions for various conditions of crops, soils and climate, to estimate effective rainfall and irrigation water requirements in the United States. He tried to bring together a wide range of information on the relation of rainfall to plant water requirements in the U.S., to furnish information that could be used to determine irrigation water requirements for a specific crop in a given area.

The ideal data for the determination of water requirements would be long records of daily rainfall and the associated intensity, actual amount of water lost by surface runoff and deep percolation, and measurements of evapotranspiration under irrigated conditions. Hershfield used twenty-two widely separated stations with climates varying from humid in the southeast to arid in the southwest. Daily rainfall data for 50 years (1911 - 1960) were taken from U.S. Weather Bureau records. Maximum and minimum daily consumptive use rate and data on the amount of each irrigation were provided by the Soil Conservation Service.

Based on these data, Hershfield (1964) developed two nomographs: one for estimating the effective rainfall during the growing season, and the other for computing the average and 10-year return period amount of irrigation water requirement from the independent parameters of seasonal total rainfall, seasonal consumptive use, and application amount.

Effects of growth stage on irrigation practice

Growth of all plants can be divided into three stages with regard to irrigation practice: vegetative, flowering, and fruiting. During the vegetative stage, consumptive use continues to increase. Flowering occurs near and during the peak of consumptive use. The fruiting stage is accompanied by a decrease in consumptive use until the transpiration essentially ceases during the later part of the formation of dry fruit (Hansen et al., 1980).

The relatively shallow root system during the vegetative stage requires frequent light irrigations. During the flowering stage, where consumptive use is at or near its peak value, ample moisture should be available to the plant. Usually best production is obtained when adequate irrigation is applied during both the vegetative and flowering stages of growth. During the fruiting stage, the root system has extended to its maximum depth, and consumptive use starts to decrease. The last heavy irrigation is usually applied during the wet-fruit stage. Excessive irrigation during the fruiting period can stimulate vegetative growth and reduce fruiting.

Rhodes et al. (1954), in a study of corn production, pointed out that: "There are three stages of corn growth when moisture is critical: the rapid growth period, initial tasselling stage, and silking stage." The tasselling-to-silking stage is critical because formation of grain is initiated in this short time. Lack of soil moisture in this stage will result in incomplete pollination and formation of many poorly filled ears. Severe wilting for two days at the tasselling stage has reduced yields by more than 20%. Corn yield would also be reduced in proportion to the length of time that the plants are without adequate moisture after silking and before maturity (Jamison and Beale, 1958).

Irrigation scheduling

The main factors influencing a farm irrigation schedule are given by Buras et al. (1973) as follows:

1. Consumptive use of the crop.

2. Soil properties, which determine the moisture storage capacity of the root zone.

3. The development of the root system of the crops.

4. Crop tolerance to moisture deficits.

Additional factors which have to be considered for individual farms when planning an irrigation schedule are: irrigation methods and practice, water supply network characteristics, local climatic conditions, and tillage and other farm operations which may affect irrigation timing.

Hansen et al. (1980) also stated that three major considerations influence the time of irrigation and how much water should be applied:

1. Water needs of the crop.
2. Availability of water with which to irrigate.
3. Capacity of root zone to store the water.

Irrigation timing and when to irrigate are common decisions for operation of an irrigation system during the growing season. General procedures used in estimating when to irrigate are soil methods, plant methods, and computer programs for scheduling irrigation. In soil methods, soil augers, probes or core samplers can be used to evaluate the need for irrigation based on soil conditions. Tensiometers and soil moisture blocks are also used extensively in many areas for various crops.

Scheduling irrigation on the basis of plant appearance is also a common method with some crops which show sufficient color change due to soil moisture deficit. Grain crops and some root crops such as sugar beet readily indicate need for water by temporary wilting. However, many crops do not show consistent visual effects of low soil moisture in time to permit using the plant as an indicator. Besides, by the time visual effects are apparent, the yield or quality may already have been adversely affected. It is therefore more essential to base the time of irrigation on observations of moisture content of the soil.

Jensen et al. (1970) also stated that "various alternatives exist for scheduling irrigation. In some areas irrigation application is based on rotation schedules with constant intervals and either constant or variable amounts, regardless of annual climatic variations. Such a system results in low irrigation efficiencies and low yield potentials. Irrigation schedules based on soil and plant characteristics are more efficient. More direct methods of irrigation scheduling require instruments for measuring soil moisture, such as tensiometers and soil moisture blocks. Estimated consumptive use rate coupled with gravimetric determinations provide an excellent basis for predicting irrigation."

The use of computer simulation to predict when and how much to irrigate has been expanded rapidly since the development of a computer program for scheduling irrigation. Jensen (1969) developed a computer program to estimate soil moisture depletion, the number of days before the next irrigation, and the amount of irrigation water applied each time. The major steps involved in his model were the estimation of daily potential evapotranspiration (ET) and a crop coefficent which is primarily a function of the stage of growth, prediction of actual ET based on potential ET, and cumulative soil moisture depletion from cumulative ET and effective rainfall.

Then the number of days before the next irrigation (N) was estimated from $N = \frac{W_o - W_d}{ET}$, where W_o is the maximum allowable soil moisture depletion, W_d is estimated cumulative soil moisture depletion, and ET is the actual ET rate. Total amount of water to be applied per unit area (D) was computed from $D = \frac{W_d}{E}$, where E is the attainable irrigation efficiency.

Jensen at al. (1970) pointed out that "The most important factor affecting irrigation efficiencies and crop yields is scheduling irrigations in time and amount. The importance of irrigation scheduling is magnified when water supply is short and costs are high or when soil conditions exist which restrict water movement or root development." They further stated that "Irrigation scheduling using climate-crop-soil data and computers to facilitate the tedious computations and field observations by experienced personnel is a service that appears to be very attractive to the modern irrigation farm manager."

Crops differ in their tolerance to water stress, and therefore in their tolerance to soil water depletion prior to irrigation. Hagan and Stewart (1972) presented a comprehensive table defining the limits of allowable soil water depletion prior to irrigation of various crops for preventing yield reduction. They also developed a water production function for principle crops, relating yield reduction to water deficits. The production function varies with the type of crop, soil depth and water holding capacity, the evaporative demand of the area in question, and also times and depths of water application.

Most crops should be grown in a soil maintained at an optimal soil moisture level for maximum yield. To keep soil moisture level at an optimal condition requires a continuous supply or frequent irrigation. But the high labor cost encourages people to irrigate with larger volumes and less frequency. This practice increases economic loss due to unfavorable crop conditions. Wu and Liang (1972) developed a simple mathematical model to determine optimal irrigation amount and frequency, based on irrigation cost and consumptive use of crops. Major irrigation costs were considered to be the cost of purchasing and delivering water to the farm and the losses caused by crops grown under unfavorable soil moisture conditions.

Windsor and Chow (1971) proposed a two level optimization approach to determine optimal irrigation policy. In this approach, the multicrop, multisoil, farm irrigation system was broken down into a number of subsystems, each of which was optimized independently before optimization of the entire system.

Dynamic programing was used at the first stage of optimization to determine the optimal irrigation policy, the maximum expected profit, and the expected monthly irrigation labor and water requirements for each crop-soil combination and each level of irrigation development. Linear programing was used at the next level of optimization to determine irrigation system, level of irrigation development, and the crop mix which maximizes the expected farm profit without violating any of the farm resource limitations.

Optimal irrigation policy and optimal farm plans and resource allocation for the selected level of irrigation water supply, production capital, and farm labor were determined.

Irrigation timing can also be determined by use of the neutron probe. Scheduling by neutron probe requires only the identification of the refill point (i.e. the point at which irrigation shall occur), and periodic moisture measurement by neutron probe.

Gear et al. (1977) worked out a simple, accurate technique to schedule irrigation using a neutron meter. Their method improved consistent timing of irrigation, which led to an increase in irrigation efficiency of more than 10%.

The common problem with computer scheduling of irrigation is that irrigation schedules are often based on the previous irrigation depth and amount. This practice assumes that irrigation was complete, that depletion began from field capacity, and that the calculated use rate corresponded with the actual. These three conditions probably never occur.

Correct irrigation scheduling can be programed by incorporating two terms into the irrigation schedule: the amount of water to be removed from the crop root zone, and the rate of such water removal. Thus, the computer should store the value representing total water to be removed from the plant root zone, the amount of water depleted at any given time, and the actual depletion rate (Gear et al., 1977).

Irrigation scheduling on a farm, including planning application time and amounts of water to be applied each time, is a problem of considerable complexity. A computer program adds a great deal of flexibility to the planning and execution of a farm irrigation schedule. By use of a digital computer, the irrigation schedule may be formulated more closely to reality, because it will solve complex computational problems. Buras et al. (1973) developed a computer program for planning and updating irrigation schedules. This program uses the area involved, crop rotation and hydraulic characteristics of the water supply network to provide the irrigation schedule. Planning of irrigation schedules was based on the average monthly climatic data, including soil, climatic, crop, engineering and economic data. All of these data are available in most cases. Least known are the economic data, especially the production function with respect to water for the particular stage of vegetative development of each crop. The main advantage of their program is that it can easily be updated when the information regarding climate, soil conditions, water supply and market conditions departs from that assumed at the planning stage.

Hall and Buras (1961) tried to solve the complex problem of irrigation scheduling analytically, by formulating it as a sequential decision process.

David and Hiler (1970) presented an integrated approach to evaluating irrigation requirements of crops, based on the soil-plant-water and precipitation-water yield-time relationships. They developed a continuous soil moisture accounting model based on daily rainfall and runoff records and periodic soil moisture measurements. The soil moisture accounting model was then used to determine monthly and seasonal irrigation water requirements of cotton and sorghum for 30 years (1938 - 1967). Irrigation water was added every time the available soil moisture fell below 55% of the soil moisture available at field capacity.

The seasonal distribution of irrigation requirements of both crops, based on data for 30 years from the Blackland experimental watershed near Riesel, Texas, was found to be a normal probability distribution.

Dean (1980) also tried to define the probability distribution of seasonal irrigation water requirements. He modified a deterministic hydrologic model to simulate application of supplemental irrigation water. Irrigation water demand for a corn crop grown on Cecil sandy loam soil was simulated using 50 years of synthetically generated precipitation and pan evaporation data. The two management practices used were irrigating when the soil matric potential rose above 0.6 and above 15 bar, respectively. Final model output was daily, monthly and seasonal irrigation water requirements. The probability distribution of the annual irrigation requirement was found to be Log Pearson Type III, which fits both management levels well.

Irrigation efficiency

Usually considerably more water is applied to the soil than it can possibly hold. Water application efficiency measures the efficiency with which the applied water is being stored within the root zone of the soil, where it could be used by the plants. Application efficiency is the ratio of the water stored in the soil root zone during irrigation to the water delivered to the farm.

The most common losses of irrigation water are represented by surface runoff from the farm and deep percolation below the farm root zone soil. Efficiency of irrigation is also affected by depth of water applied in each irrigation. Low efficiencies would result even if water spread uniformly over the land surface.

Keller (1965) compared furrow, border and sprinkler methods of surface irrigation application, based on the achieved irrigation efficiency under each method. He concluded that: "under field conditions sprinkler irrigation efficiencies range from 25 to 40% greater than furrow and border methods."

He further pointed out that water control and management have considerable effects on application efficiency; irrigation efficiency increases as more management factors are built into the system.

Hart et al. (1979), in a study on evaluation of irrigation systems, found that the irrigation performance can be fully described by the fraction of the delivered water absorbed, the fraction of the absorbed water stored in the root zone, the fraction of the infiltrated water which percolates below the root zone, and the fraction of the requirement met. These parameters can be used to evaluate irrigation performance and to define how irrigation can be improved in terms of more uniform irrigation application.

Sprinkler irrigation

Sprinkler irrigation is the method of applying water to the surface of the soil in the form of a spray similar to ordinary rainfall. This method of irrigation was started about 1900. At first, it was a stationary system, but in the 1930s portable sprinkler systems were developed. Since 1950, the development of more efficient sprinklers, lightweight aluminum pipe, and more efficient pumps has increased the number of installations of sprinkler systems rapidly.

The sprinkler system is a network of tubing or pipes with sprinkler heads or nozzles attached for spraying water over the land surface. It consists of a series of laterals connected by valves to the main pipeline, which is connected to the water supply. Sprinkler systems can be permanent, semi-permanent, or portable.

Mechanization of farm operations, together with the shortage of labor for moving portable laterals and sprinklers has resulted in increased use of continuously moving sprinkler systems. In these systems, laterals and sprinklers are connected to the main pipeline, and continuously move when applying water.

The stationary sprinkler systems apply water at a relatively constant rate, while the application rate of a moving system begins at zero, increases to a maximum, and decreases to zero again as it passes over a location.

Center pivot system The circular center pivot system is a continuously moving system which has been used in this study to simulate irrigation application. This system consists of a single sprinkler lateral with one end anchored to a fixed pivot structure, and the other end moving in a circle about the pivot. Water is supplied to the lateral at the pivot point. The lateral is kept in a straight line as it moves around the pivot point by an alignment system that speeds up or reduces the speed of the support unit.

Water application rates along a center pivot lateral are determined by the nozzle sizes, nozzle pressure, sprinkler spacing, length of lateral, and type of sprinkler used. Once these determinations are made, the rate of application is fixed regardless of the rotation speed of a center pivot lateral. The application rate varies from a low value near the pivot to higher values at the outer end.

Design capacity of a center pivot lateral is calculated from the peak water use rate of the main crop, the area irrigated, and the water application efficiency when the system is operating during the period of peak water use.

Sprinkler uniformity and efficiency The effectiveness of a sprinkler system depends upon the uniformity of irrigation water application over the land surface. Thus, sprinklers which distribute water over the land are the most important part of the sprinkler system.

Christiansen (1942) studied the distribution patterns of sprinklers and found that uniformity, speed of rotation, type of geometric pattern, pressure at the nozzle, and spacing distance all influence the uniformity of coverage. He computed a uniformity coefficient (Cu) from:

$$Cu = 1 - \frac{\Sigma x}{mn}$$

where x is the deviation of an individual observation from the mean value m, and n is the number of observations. More uniform application is associated with higher uniformity coefficients.

A system characterized by high water application uniformity and thereby high irrigation efficiencies requires a large capital cost; on the other hand, higher uniformities in irrigation application may increase yield. To optimize such irrigation systems, the relationship among water application uniformity, application efficiency, and operational criteria is required. Wynn (1979) assumed that the sprinkler pattern could be simulated with a normal distribution, and developed an empirical description for sprinkler irrigation uniformity and efficiency.

His model simulated application efficiency, which is a measure of the excess water applied to a field during irrigation, and also the water requirement efficiency, defined as the percentage of the root zone refilled by an irrigation. For most cases application efficiency was predicted with less than 4% error, and water requirement efficiency with less than 2% error.

Hart and Reynolds (1965) also assumed that the distribution of values in an overlapped sprinkler pattern closely approximates the normal distribution. Based on this assumption, they defined parameters representing the interrelatiosnhip between sprinkler water distribution, water lost through deep seepage, water made available to the plant, and water deficits within the areas irrigated by the sprinkler system. They computed a series of representative parameters at various uniformity coefficients (or $s/\bar{x}$ values of the distribution, where s is the standard deviation and $\bar{x}$ is the mean of the distribution), and different fractions of the area adequately irrigated.

Sprinkler irrigation efficiency is also influenced appreciably by losses which take place during irrigation and losses which follow irrigation. The evapotranspiration and drift losses during sprinkler irrigation vary with climatic conditions such as wind velocity and vapor pressure deficit.

Sternberg (1967) analyzed sprinkler irrigation losses, and determined the magnitude of evapotranspiration, evaporation and drift losses which occur during and following irrigation. Tests were conducted for eleven days and six nights; based on these limited tests, he concluded that:

1. Daily evapotranspiration following irrigation is about the same for irrigated and non-irrigated vegetation for either day or night

sprinkling.

2. Under low wind velocities, sprinkler losses were 17 to 22% for daytime and 11 to 16% for nighttime operations.

3. Sprinkler irrigation causes a 5 to 9°F temperature reduction within the sprinkler pattern. Hence, evaporation may be reduced during the sprinkling process.

4. Total losses are probably the same for day and night sprinkling, although the individual components which make up total losses are not necessarily equal.

WATER BALANCE MODEL

Introduction

The present hydrologic model is a modified form of the Iowa State University Watershed Model first presented in 1965 by the Department of Agricultural Engineering. The ISU Watershed Model was originally developed for the flatlands of central Iowa.

The first version of the ISU watershed model developed by Haan and Johnson (1968) considered only the routing of runoff flows through the system of depression and drains. Rainfall excess was used as input data in this version, which was later modified by DeBoer (1969) to use rainfall-time records, and convert them to excess rainfall as needed by the original model.

The second version of the ISU watershed model, developed by DeBoer and Johnson (1971) was designed to predict runoff from single storm events of high total rainfall. In this version, precipitation reaching the soil surface could be stored, infiltrated, evaporated, or allowed to run off. Interception was ignored, since it was insignificant for considering flood-producing events. Holtan's equation, as modified by Huggins and Monke (1968) was used to predict infiltration capacity.

The soil moisture component of the model allowed the root zone to fill to field capacity, and the excess percolated to the water table. Evaporation from the soil surface was considered at a constant rate. Water movement below the water table to tile drains was determined from tile drain flow theory.

In 1975, the third version of the ISU watershed was developed by

Campbell and Johnson. This version was capable of continuous simulation of runoff during the entire season, not only during the flood periods. This modification was performed by using the conceptual model for actual evapotranspiration and soil moisture redistribution developed by Saxton et al. (1974).

The ISU Watershed Model was applicable to the flat land of central Iowa having soils with low infiltration rate, high water table, and high surface storage. It was modified by Anderson et al. (1978) to predict evapotranspiration, soil moisture storage, and runoff volume from deep loess soils of western Iowa, with rolling topography.

Many modifications have been made by Anderson since his disseration (1975), to allow the model to work on more general soil profile conditions for varying soil layers and varying soil moisture characteristics.

Shahghasemi (1980) modified the model by adding an overland flow routing component, to predict the rate of runoff at any time during the rainfall-runoff event.

In the present study, the modified version of Anderson's model will be used to simulate soil moisture stress and water requirements for irrigation of corn on three different soils in Iowa: the Moody silt loam located in the northwest, the Chelsea sand in the southeast, and the Albaton clay of west central Iowa.

Main Program

A general flow chart of the main program is shown in Figure 1; the detailed flow diagram is given in Appendix D. The first function within the program is to initialize model parameters to be used in either the

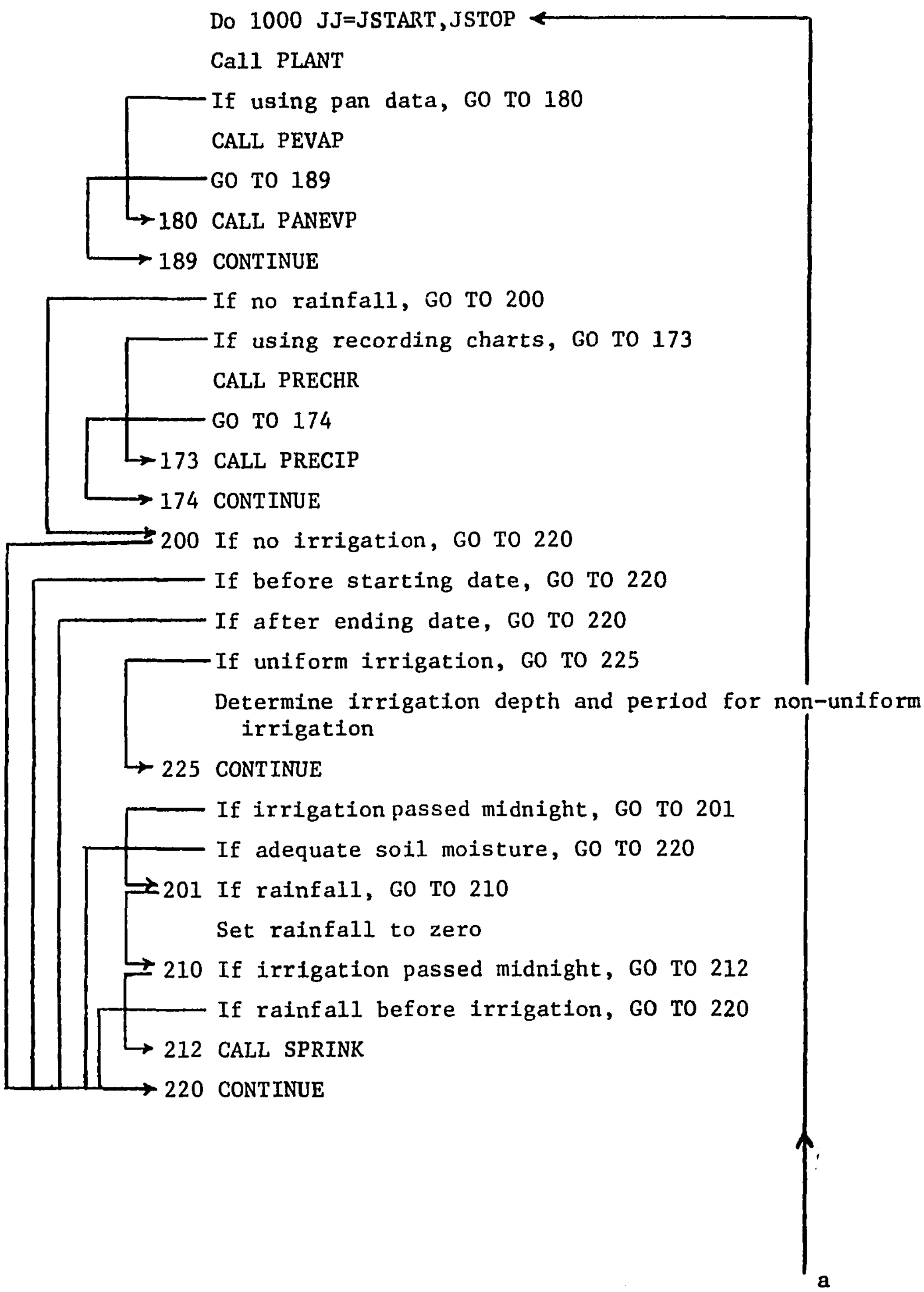
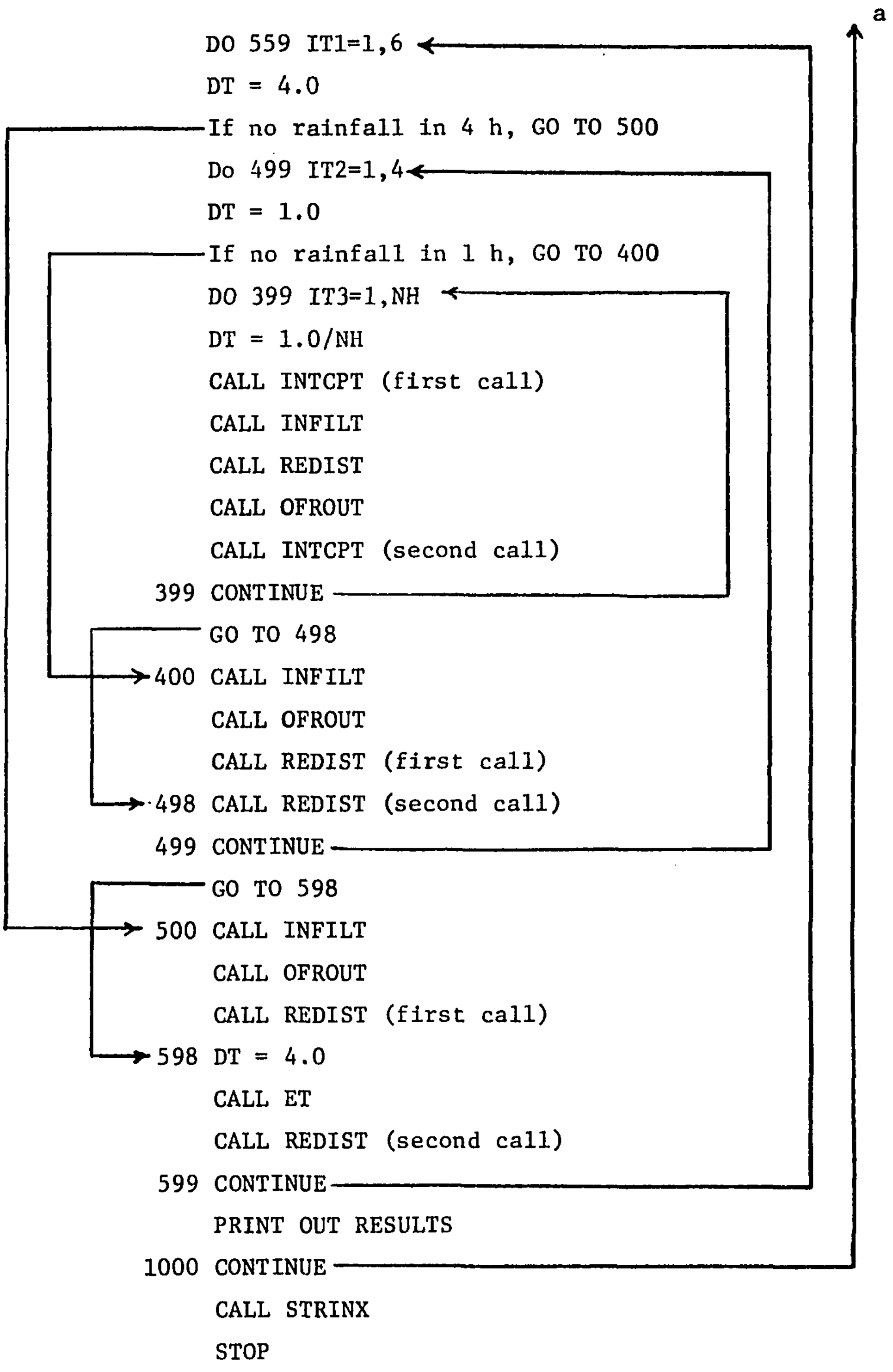


Figure 1. General flow chart of the main program



```
      DO 559 IT1=1,6
      DT = 4.0
      If no rainfall in 4 h, GO TO 500
      Do 499 IT2=1,4
      DT = 1.0
      If no rainfall in 1 h, GO TO 400
      DO 399 IT3=1,NH
      DT = 1.0/NH
      CALL INTCPT (first call)
      CALL INFILT
      CALL REDIST
      CALL OFROUT
      CALL INTCPT (second call)
 399  CONTINUE
      GO TO 498
 400  CALL INFILT
      CALL OFROUT
      CALL REDIST (first call)
 498  CALL REDIST (second call)
 499  CONTINUE
      GO TO 598
 500  CALL INFILT
      CALL OFROUT
      CALL REDIST (first call)
 598  DT = 4.0
      CALL ET
      CALL REDIST (second call)
 599  CONTINUE
      PRINT OUT RESULTS
1000  CONTINUE
      CALL STRINX
      STOP
```

Figure 1. (Continued)

main program or the subroutines. In initializing model parameters, all daily and seasonal totals are set to zero, and the required input data are read into the model.

The program then enters the main iteration loop, which is executed once for each day. Within this loop, first, daily values are set to zero; then the soil moisture at the beginning of each day is set equal to the soil moisture at the end of the previous day, and the soil moisture in the layer below the soil profile is assumed to be equal to the average of the soil moisture in the bottom layer for the past fourteen days, except for the first fourteen days of the run, when the average is taken over the number of days from the starting date. At this point, the plant subroutine is called to update the plant function. The effect of soil moisture and crop growth on the infiltration capacity is considered by adjusting the infiltration equation parameters based on the soil moisture of the top six inches, and the present crop leaf area index at the beginning of the day. Potential evaporation is then determined by calling the associated PE subroutine, according to the available data. If the required data for the Penman equation are available, the average air temperature for the past three days and the weighted average relative humidity are determined and used to call PE subroutine (PEVAP); if only daily pan evaporation data are available, the associated PE subroutine (PANEVP) is called to use pan data to determine potential evaporation.

At this point, a check is made to determine if any rainfall occurred during the day. If so, and depending upon the type of the available rainfall data, either the precipitation subroutine which uses hourly rainfall data (PRECHR), or the precipitation subroutine which uses rainfall data for shorter time increments (PRECIP), will be called to develop rainfall depth, as required in the main program.

If the run is to simulate irrigation for all days between the starting and ending dates of irrigation, the sprinkler irrigation subroutine (SPRINK) will be called whenever the soil moisture is below a previously defined level, unless rainfall occurs on that day before the time planned to begin irrigation. When the planned irrigation period continues after midnight, the irrigation subroutine will be called on the second day without checking the soil moisture.

The program then enters the second iteration loop, which is executed once for each of the six four-hour periods in the day (the longest time increment used in the model for calculations). Within this loop, the model first determines whether there is any rainfall during the four hours. If no rainfall occurred during this period, the program will use the four-hour period, and first calls the infiltration (INFILT) subroutine to take care of delayed plant interception or surface depression storage, then calls the outflow route (OFROUT) subroutine to determine the runoff depth, the soil moisture redistribution (REDIST) subroutine to distribute the infiltration water, the evapotranspiration (ET) subroutine to compute actual evapotranspiration using an energy balance concept, and finally recalls the soil moisture redistribution subroutine.

If rainfall has occurred during the four-hour period, the program enters the third iteration loop, which is executed once for each hour during the four-hour period. Within this loop, a check is again made for the occurrence of rainfall during the hour. For those hours during which rainfall has not occurred, the program will keep the one-hour period, and calls the infiltration, outflow route, and the soil moisture redistribution first and second call. Then the program will test the next hour for rainfall occurrence. When rainfall has occurred within the hour, the program enters a fourth interation loop, which is executed NH times per hour; the value of NH is an input parameter to the model, and determines the shortest period of time used in the model. The sequence of calling operations within this loop is as follows: interception first call, infiltration, soil moisture redistribution first call, outflow route and interception second call. After this loop has been repeated NH times, the program will call the soil moisture redistribution subroutine again (second call), and will return to the beginning of the third loop to test the next hour for rainfall occurrence. When the third loop has been executed four times, the program will call the evapotranspiration and soil moisture redistribution (second call), and will return to the beginning of the second loop to test the next four hours for rainfall occurrence.

After the second iteration loop has been executed six times to complete the day, a check is made to determine whether the stress index calculation is requested. If so, the program determines daily raw stress index, ends the calculations for the day, and prints out the results. Then the program returns to the beginning of the main execution loop for the next day, repeats the same calculations for the whole period of run, and prints out the daily and seasonal summaries of the important parameters, such as rainfall, runoff, deep percolation, actual evapotranspiration, soil moisture storage, irrigation application, and irrigation efficiency. A monthly summary output is printed at the end of each month. A sample of daily output and monthly summary are given in Appendix C.

After the main iteration loop has been executed for all days to complete the period, the seasonal water balance and overall water use efficiency are calculated. Then the stress index (STRINX) subroutine is called to calculate seasonal stress index, if its calculation is included.

The program will then return to the beginning of the run to look for a new set of data to process.

Modifications to the Program

Relating potential evapotranspiration to pan data

Potential evaporation (PET) can be calculated in the model by using either the Penman equation or pan data with appropriate pan coefficients. Shahghasemi (1980) used the regression line developed by Saxton et al. (1974) to convert pan data (PAN) to PET:

$$\text{PET} = 0.01 + 0.83(\text{PAN})$$

where both PET and PAN are in inches.

In the present study, the required data for use in the Penman equation (daily air temperature, relative humidity, wind velocity, and solar radiation) and the daily pan evaporation data on the northeast Gingles watershed, were used to define the best relation between pan data and PET from the Penman approach, as will be explained in more detail in the potential evaporation subroutine.

The regression lines relating PET to daily pan evaporation for the months of June, July and August, were determined to be as follows:

June: $\text{PET} = 0.149 + 0.405(\text{PAN}) \qquad r = 0.75$

July: $PET = 0.140 + 0.497(PAN)$ $r = 0.62$

August: $PET = 0.153 + 0.396(PAN)$ $r = 0.72$

Introducing provisions for use of two precipitation subroutines

Precipitation data are not available for periods less than one hour for most weather stations. A revised precipitation subroutine was developed by Anderson[1], which uses hourly precipitation data in U.S. Weather Bureau format. This subroutine was added to the model, along with the previous precipitation subroutine, which uses rainfall data for short time increments taken from rainfall charts at the breakpoints. Since both subroutines are included in the main program, an input indicator (KPRE) was used to specify the type of available rainfall data, and the associated subroutine to be called to develop rainfall depth as needed in the model.

Simulating crack development in heavy soils

Under dry conditions, cracks develop in heavy soils with high clay content, increasing the infiltration rate and capacity, and thereby decreasing surface runoff. To simulate this phenomenon in applying the model to the heavy soils, appropriate changes were made in the infiltration and soil moisture redistribution subroutines.

The infiltration equation used in the model was Holtan's equation (1961), modified by Huggins and Monke (1968) as:

$$f = f_c + A\left(\frac{S - F}{T}\right)^P$$

---

[1] C. E. Anderson, Department of Agricultural Engineering, Iowa State University, Ames. Unpublished modifications of the original model, 1981.

where f = infiltration capacity during any period, in/h

f_c = wet soil infiltration capacity, in/h

A = maximum potential increase of infiltration capacity above the wet soil value, in/h

S = soil water potential above any impeding strata, in

F = accumulated infiltrated water, in

T = total pore volume above any impeding strata, in^3/in^2

p = steepness of the slope of the infiltration capacity curve at the beginning of the infiltration process

The parameters A and p in the above equation (ASOIL and PSOIL in the computer program) are both a function of the initial soil moisture, and were adjusted based on the soil moisture of the top layer at the beginning of each day.

$$\mathrm{ASOIL} = \mathrm{ASOILM}\ [e^{\mathrm{AM(AMC-FCS)}}]$$

$$\mathrm{PSOIL} = \mathrm{PSFC}\ [\mathrm{AMC/FCP}]^{\mathrm{PM}}$$

where ASOILM = maximum value for parameter ASOIL

AM = an input parameter to be calibrated

AMC = moisture content in the top soil layer at the beginning of the day, percent by volume

FCS = field capacity of the top soil layer, percent by volume

PSFC = PSOIL value for AMC equal to field capacity of top soil layer, percent by volume

FCP = field capacity of top soil layer, percent by volume

PM = exponent on the PSOIL vs. AMC function

In the previous version, the terms FCS and FCP were set equal to the field capacity of the top layer, but in the present version they are part of the input data, and can be adjusted along with the other infiltration equation parameters, to give a better estimate of infiltration capacity for each soil. By decreasing FCS to an assumed moisture level at cracking and increasing ASOILM and AM, the infiltration rate will be increased to account for crack formation, as illustrated in applying the model to the Albaton soil (Figure 7).

Any excess moisture above a certain percentage (PER_1) of saturation was allowed to move to the next lower layer, while flow to each layer was controlled by saturated hydraulic conductivity of that layer. A modification was made for heavy soils in the redistribution subroutine, to allow the excess water to flow downward without any restriction from the saturated hydraulic conductivity of the lower layer, after crack development. The moisture level in each layer at cracking was calculated in the main program as:

TMAC(I) = WP(I) + PAMAC * PLAV(I)

where TMAC = total moisture at cracking, in/layer

WP = soil moisture at wilting point, in/layer

PAMAC = percent available moisture at cracking

PLAV = plant available moisture, in/layer

Note that percent available moisture at cracking is an input parameter, and can be adjusted for each soil. It is high for heavy soils (greater than 50%), and it is very low for sandy soils which never crack (less than 5%).

Determining stages of root development

The roots are gradually developed into the soil layers after planting, and were assumed to reach a depth of five feet by August 1 (Shaw, 1963). The occurrence of soil moisture shortage is more related to the soil moisture in the active root zone than the soil moisture in the entire root zone. Since after rainfall, higher moisture is stored in the upper layers than the lower layers, a soil moisture shortage indicated in the entire root zone may not be present in the active root zone, especially early in the season, when roots are distributed in the upper layers of the soil.

In simulating irrigation, it is also important to check the soil moisture of the active root zone before irrigation, and apply enough water to fill only the active root zone to its field capacity, not the entire root zone.

To take account of this fact, the depth of active root zone was determined as a function of the time of the season; various root depths were used during different stages of root development. The depth of the active root zone with time was determined by using the root extraction schedule for corn given by Shaw (1963), as shown in Table 2.

This modification was made as an optional function of the model, to be changed by the user. An input indicator (KIRD) was read in the model to specify whether the soil moisture in the active or the entire root zone had to be checked against a predetermined moisture level for moisture shortage presence or irrigation application.

Table 2. Root development during the growing season

Dates	Depth to which roots developed by the given date ft
To June 7	0.5
June 8 - June 14	1.0
June 15 - June 27	2.0
June 27 - July 4	2.5
July 5 - July 11	3.0
July 12 - July 18	3.5
July 19 - July 25	4.0
July 25 - August 1	4.5
After August 1	5.0

Simulation of non-uniform irrigation application

Since roots gradually penetrate into the soil layers, it is reasonable to apply enough irrigation water to the active root zone to bring it to field capacity. Filling the entire root zone will decrease the efficiency of irrigation application, especially early in the season, when roots are distributed in the top layers. Therefore, it is more efficient to apply less water early in the season, and increase the application depth according to the stages of root development.

Thus, the model was modified to use non-uniform irrigation. An input indicator (KUIR) was used to specify whether non-uniform irrigation was requested (KUIR = 1). If so, various irrigation depths, application time periods, and associated dates of changing the application depth are read as input data, instead of using one depth and time period for irrigation. The program then changes the application depth during the growing season, according to root development.

Starting and ending dates of irrigation application, number of times to change the application depth, various depths of irrigation application, and the specific dates to change the application depth are all input data which can be adjusted by the user for various plants, soils and weather conditions.

Calculation of seasonal weighted stress index

Determination of the stress index was added to the model as an optional function, by using another input indicator (KSTR) to specify whether the stress index calculation is requested. If so, the daily raw stress index is determined as:

$$RAWSTR(JJ) = 1 - \frac{ADET}{PE} \quad \text{for } PE > 0$$

$$RAWSTR(JJ) = 0 \quad \text{for } PE \leq 0$$

where RAWSTR(JJ) = daily raw stress index for each day

ADET = daily actual evapotranspiration, in

PE = daily potential evaporation, in

The seasonal stress index is calculated for 85 days, made up of eight 5-day periods before the silking date, and nine 5-day periods after the silking date. Various weighting factors are given to each of the 5-day periods, to account for the differential effects on yield due to the stage of development at which stress occurred; see Table 3 (Shaw, 1974).

These and additional weighting factors are applied to the unweighted stress index for the period, to determine seasonal weighted stress index,

Table 3. Weighting factors used to evaluate the effect of stress on corn yield (after Shaw, 1974)

Weighting factor for periods before silking date		Weighting factor for periods after silking date	
period	weighting factor	period	weighting factor
8	0.5	1	2.0
7	0.5	2	1.3
6	1.6	3	1.3
5	1.0	4	1.3
4	1.0	5	1.3
3	1.0	6	1.3
2	1.75	7	1.2
1	2.0	8	1.0
		9	0.5

as will be explained in the stress index subroutine.

Model Subroutines

The major processes involved in the soil-plant-air system to be modeled are precipitation, interception, evapotranspiration, infiltration, soil moisture redistribution, surface runoff and sprinkler irrigation.

The necessary calculations for each process are accomplished by an associated subroutine for a steady-state condition. However, because the soil moisture balance is a dynamic process, the main computer program is designed to call each process in its logical sequence, allow it to operate for an appropriate time period, and update the watershed conditions.

A brief description of the subroutines used in the program is given below. More detailed descriptions of these subroutines are found in Anderson (1975) and Shahghasemi (1980). The flow diagram for all subroutines is shown in Appendix D.

Plant subroutine

The most important components of the hydrologic cycle, infiltration and evapotranspiration, are interrelated through the plant system (Anderson, 1975). The variable used to define crop type is the crop leaf area index (leaf area per unit field area). The plant growth model was originally developed based on the field observations reported by Saxton (1972).

At the beginning of each day, the main program calls the plant subroutine, which uses the day of the year to interpolate the values of crop canopy, root distribution and percent of existing crop canopy actively transpiring. These three factors are of primary importance to the water balance model (Saxton, 1972; Anderson, 1975).

Precipitation subroutine

In the present version of the model, two precipitation subroutines are included:

1. The original precipitation subroutine uses the accumulated rainfall at the breakpoints of a rain gage chart, and the corresponding times as input data, then converts them to rainfall depth increments for the time increments needed by the model. The procedure used in this subroutine allows the use of time increments smaller than those found on the rain gage charts.

2. An hourly precipitation subroutine uses the hourly rainfall data in U.S. Weather Bureau format as input data, and processes the data to

develop rainfall depth as required by the model. With this subroutine, the shortest calculating period in the model is one hour.

In both subroutines, each day is considered from midnight to midnight. Daily rainfall depth, and starting and ending time of the rainfall are determined for each day during which rainfall occurred.

Interception subroutine

The interception subroutine consists of two parts. For each day it is called twice in the main program. The first call divides precipitation into two parts: interception storage and direct precipitation to the soil surface. This division is based on the crop leaf area index (CLAI). In the first entry, storage is allowed to its maximum value (0.03*CLAI), and the remainder is assigned to direct precipitation. During the second entry, drainage occurs from interception storage according to a linear reservoir function. A minimum storage value (0.015*CLAI) is included, below which only evaporation losses may occur.

Potential evaporation subroutine

Potential evaporation (PET) was originally predicted in the model by using the Penman equation (Anderson, 1975). This was revised such that either the Penman equation or daily pan evaporation with pan coefficient could be used to predict PET (Shahghasemi, 1980). Required data for the Penman equation, including maximum and minimum daily air temperatures, maximum and minimum daily relative humidity, daily wind velocity, and daily solar radiation are rarely available for most stations. Daily pan evaporation data are probably the most available data in Iowa, but the Penman equation gives the most reliable results when data are available

(Shaw, 1977).

Since the model was originally developed to predict PET using the Penman equation, it was desirable to define an equation relating pan evaporation to the potential evaporation obtained by using the Penman equation.

There is no unique relation applicable in all cases. Yao (1956) used measured data for Albia in southeast Iowa to relate different methods of determining potential evaporation. He concluded that PET from the Penman equation was related to daily pan evaporation by the following linear regression equation:

$$PET = 0.076 + 0.439 \times PAN$$

where PET = potential evaporation from the Penman equation, in

PAN = daily pan evaporation, in

In this study to define the conversion from pan data to PET from the Penman equation, data from the northeast Gingles watershed were used. The required data for use of the Penman equation, and also daily pan evaporation data were available for the years 1967 through 1970. The first three years were used to derive the conversion equation, and the year 1970 was used to evaluate the validity of the equation.

A linear model, a linear model with no intercept, and a quadratic model were fitted to the data, with the objective that if there were no significant difference between the models, the simplest would be selected. Comparison of the models showed that no significant improvement was achieved by using the quadratic model. Of the two linear models, the one with an intercept produced the smaller error sums of squares; therefore, it was chosen as the best relation to convert pan data to PET using the Penman equation as the criterion.

The three regression lines for the months of June, July and August were determined to be:

June: $PET = 0.149 + 0.405(PAN)$ $r = 0.75$

July: $PET = 0.140 + 0.497(PAN)$ $r = 0.62$

August: $PET = 0.153 + 0.396(PAN)$ $r = 0.72$

To evaluate the validity of the above regression lines, the water balance model was run twice for the year 1970, using the required data for the Penman equation, and pan data with the conversion equations. Potential evaporation and the soil moisture in the top five feet as predicted by the two methods were compared (Figures 2 and 3).

As determined by statistical tests, and shown in the graphs, there was no significant difference between the two methods.

PET is distributed during the day such that 70% of it occurs from 8 a.m. to 4 p.m., and about 20% from 4 p.m. to 8 p.m. The remaining 10% is assigned to the rest of the day (Anderson, 1975).

Evapotranspiration subroutine

The calculation of actual evapotranspiration is based on the method developed by Saxton (1972) and modified by Anderson (1975). PET is the main input to this subroutine, and is used first to evaporate interception storage. The remaining PET is divided between soil evaporation and plant transpiration, depending upon the crop leaf area index. Soil evaporation energy will evaporate surface depression storage and water held in the top six inches, respectively, and the remainder is radiated back, with a

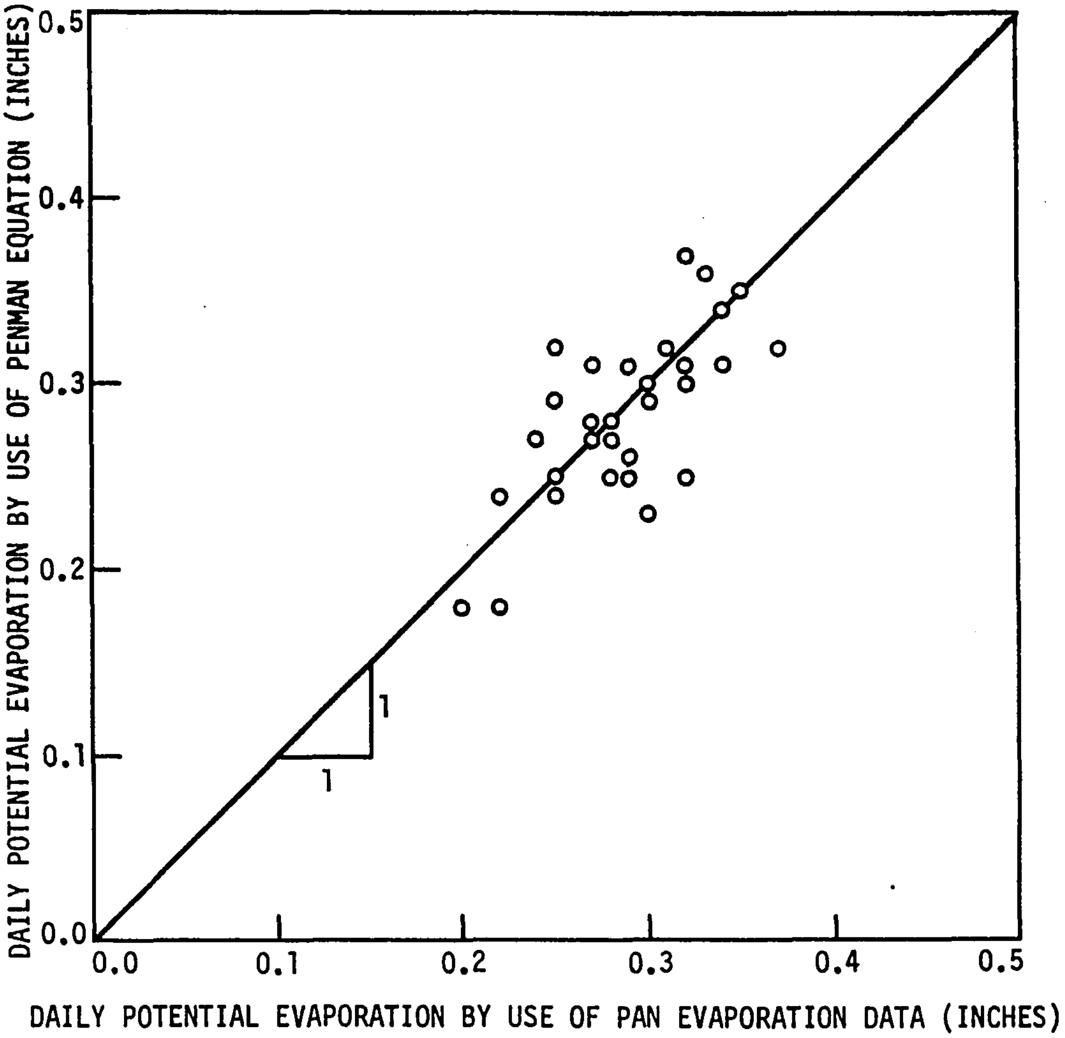


Figure 2. Comparison of the potential evaporation determined by Penman equation and by Pan evaporation data (northeast Gingles watershed, 1970)

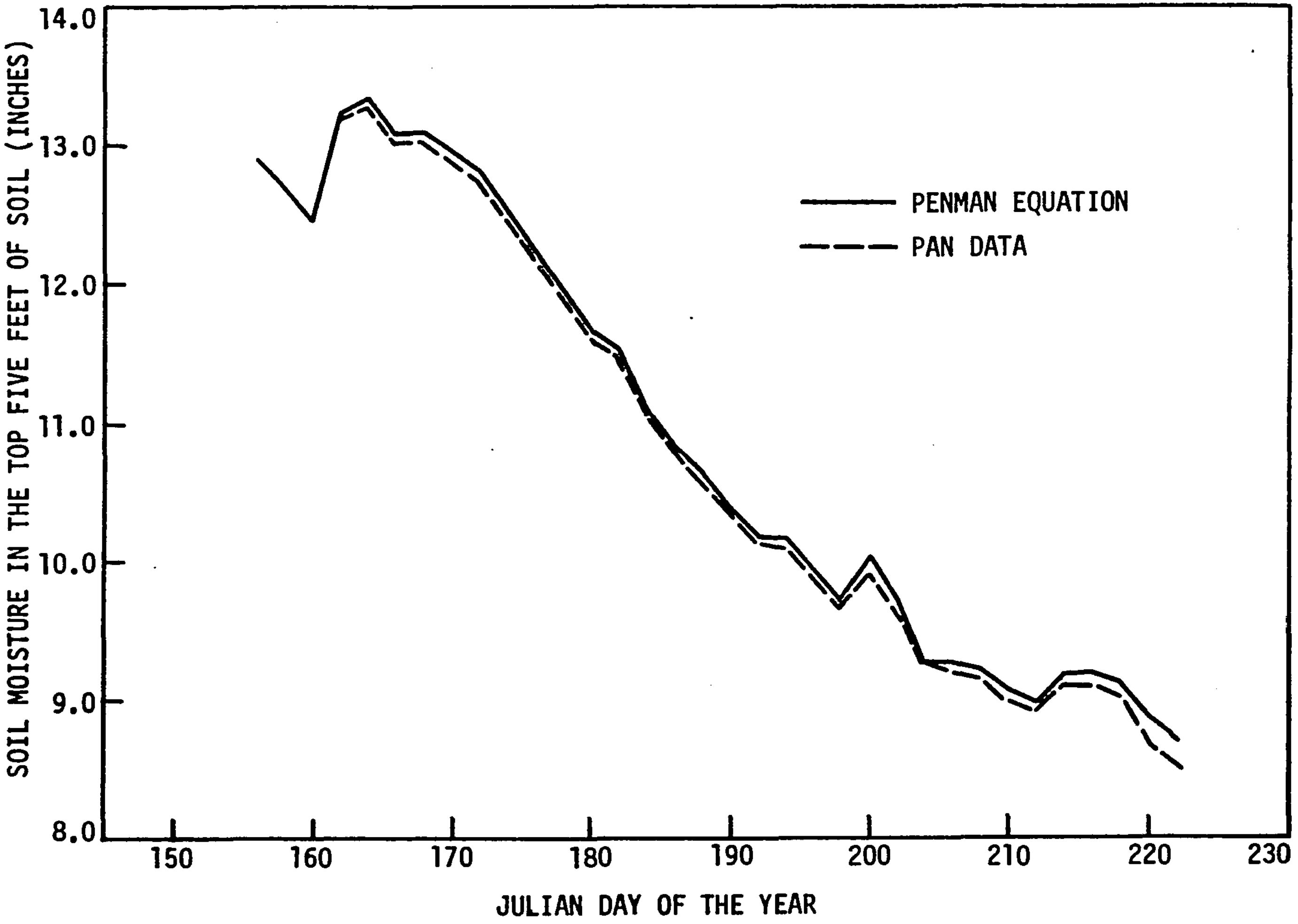


Figure 3. Comparison of the predicted soil moisture in top 5-foot of soil by use of Penman equation and Pan evaporation data, northeast Gingles watershed, 1970

portion added to plant transpiration.

Plant transpiration is adjusted for percent canopy actively transpiring, and is divided among soil layers based on available soil moisture and PET, as described by Anderson (1975). The soil moisture profile for the day is updated by subtracting the actual evapotranspiration from each layer.

Infiltration subroutine

The modified form of Holtan's equation (1961), by Huggins and Monke (1968), was used in the model, and can predict infiltration during periods of intermittent supply, and dry periods. To account for the effect of increasing infiltration capacity with increasing crop cover, and decreasing infiltration rate with increasing rainfall intensity, crop leaf area index and rainfall kinetic energy were used to modify the infiltration equation. Soil moisture in the first layer is used to adjust for soil moisture variation.

Detailed descriptions of the infiltration equation and its modifications are given in Anderson (1975) and Shahghasemi (1980). The reader is referred to those works for more information.

Numerical iteration is used to determine infiltration capacity, which is then compared with water supply rate. The excess supply is passed to the overland flow subroutine for estimation of overland flow during the period.

Soil moisture redistribution subroutine

The soil moisture redistribution subroutine consists of two parts:

1. Distribution of infiltrating water throughout the soil profile.

2. Redistribution of soil moisture according to the potential gradient.

In the first part for the downward movement of water, each layer fills to a certain level of saturation before any infiltrating water drains to the next lower layer. Anderson (1975) used 80 percent of saturation for this value; Shahghasemi (1980) tested other values to determine their effects on the model response, and concluded that 80 percent produced good results for his study. In this study, different values were tested for each soil, with the result that 30 percent for sand, 80 percent for silt loam, and 90 percent for heavy clay gave the most reasonable estimates of model outputs such as soil moisture content, deep percolation, surface runoff and actual evapotranspiration.

The excess water in each layer is then allowed to flow to the next lower layer, where this flow is controlled by the saturated hydraulic conductivity of the lower layer. When the soil moisture of any layer is below the soil moisture at which cracks develop, the saturated hydraulic conductivity no longer controls the flow; that is, all the excess water will flow downward, This modification was made to apply the model to heavy soils with high clay content, where saturated hydraulic conductivity is very low, and cracks develop at moderate to low soil moisture contents. This will increase the infiltration rate, thereby decreasing surface runoff considerably. The infiltrating water passed below the bottom layer of the soil profile is added to the accumulated deep percolation.

For upward movement, any moisture above saturation is re-added to the next higher layer, and then extra moisture from the first layer is added to the surface depression storage.

In the second part, moisture movement is in response to soil-water potential gradients. Moisture tension and the unsaturated hydraulic conductivity of each layer are estimated by a series of equations modified by Anderson based on the concepts of Saxton et al. (1974), Campbell (1974) and Ghosh (1977). These equations are explained in detail by Shahghasemi (1980) in his dissertation.

The one-dimensional Darcy's equation is then used to calculate the flow between two adjacent layers, by using the known gradient and hydraulic conductivity as the average of the unsaturated hydraulic conductivity for the layers. Then the flow between the two layers is checked; whenever it is greater than the average of the saturated hydraulic conductivity of the two layers, the length of the shortest calculating period is decreased to one half of its original value, to increase the model precision.

After determining the flow between the two adjacent layers (positive discharge is downward and negative discharge is upward), the soil moisture content of each layer is updated for each calculating period.

For a second time, the soil moisture of each layer is checked against a certain level of saturation (80%). The excess moisture is allowed to flow to the next lower layer, while controlled by the saturated hydraulic conductivity of the lower layer. The upward movement is treated in the same manner as in the first part.

Finally, the soil moisture of each layer is updated for each period, and becomes a major output of the model for each day.

Overland flow subroutine

The overland flow routing function developed by Crawford and Linsley (1966) in the Stanford Watershed Model is used to simulate the process of overland flow, based on average values of land surface parameters affecting the process.

Average values of lengths, slopes and roughness of overland flow in the Manning and Continuity equations are used in a Stanford Watershed Model component to determine the depth of surface detention, which is then used to calculate rate of overland flow discharge.

Overland flow and infiltration processes occur at the same time; during overland flow, water in the detention storage remains available for infiltration. Surface roughness created by tillage or cultivation reduces the total quantity of runoff by allowing more time for infiltration. Thus, changes in the surface conditions will have significant effects on the overland flow rate and volume. Surface storage and Manning's roughness coefficient are at their maximum values right after tillage before planting, and will gradually decrease during the season, unless cultivation occurs.

The overland flow function developed by Crawford and Linsley (1966) was modified to take into account the changes in surface conditions over time. A detailed description of this subroutine is given by Shahghasemi (1980); the reader is referred to his work for more information.

Sprinkler irrigation subroutine

The sprinkler irrigation subroutine treats the irrigation water as though it were additional rainfall. In the initializing part of the main program associated with this subroutine, the seasonal total values are set to zero, and the required input data are read into the model, including percent available moisture removed at irrigation (PAMRI), gross depth of irrigation application (GDIA) in inches, application time period of irrigation (ATPI) in hours, time planned to begin irrigation (TPBI), hour of the day and Julian days of start and end of irrigation (JDSIR, JDEIR).

The irrigation subroutine determines time to start and end irrigation for each day, and then divides the hours in between into NH increments (1/NH is the shortest time increment used in the program). The irrigation depth for each period (GIDP) is determined as:

$$GIDP = GDIA/ATPI*NH$$

where GIDP = irrigation depth in shortest period of calculation, in/period

GDIA = gross irrigation depth, in

ATPI = application time period of irrigation, h

NH = number of divisions in each hour

For each time period during irrigation, the irrigation depth is added to any natural rainfall increments for that period, and handled by the model in the same manner as natural rainfall.

The irrigation subroutine also determines daily irrigation depth; when irrigation ends before midnight, daily irrigation depth is the same as gross depth of irrigation application. When irrigation continues after midnight, daily irrigation depth is determined by summing the irrigation depth in each period, from the time planned to begin irrigation to midnight for the first day of irrigation, and from midnight to time to end irrigation for the second day of irrigation.

The sprinkler irrigation subroutine is called in the main program to apply irrigation water for days between the starting and ending dates of irrigation, whenever the moisture removed from the active root zone is more than the specified percent of the available moisture, unless rainfall starts before the planned irrigation time. Irrigation application will continue if rainfall begins after irrigation has started.

Stress index subroutine

This subroutine gives weight to the raw stress indices according to the stage of plant development at which stress occurs. The first function within the subroutine sums daily raw stress indices, calculated in the main program, for each 5-day period before and after silking date (eight before, nine after), and then multiplies them by the appropriate weighting factor for the period (Table 3).

To account for the cumulative effects of severe stress, for those periods for which the 5-day unweighted stress index is 4.5 or greater for two or more consecutive periods, an additional weighting factor of 1.5 is applied to the weighted stress index. Another weighting factor of 1.5 is applied to any of the two periods out of one, two or three periods before silking date in which the 5-day unweighted stress index is 3.0 or greater. Note that when the three periods have unweighted stress indices of 3.0 or greater, all of them will be multiplied by 1.5.

The 85-day weighted stress index will be the sum of all the 5-day weighted stress indices for the 17 periods relative to silking (Shaw, 1974). The seasonal stress index weighted in this manner is closely related to yield, as will be discussed later.

DATA AND PROCEDURES

Description of Soils and Required Soil Data

Three soils were selected on which to simulate irrigation for continuous corn cropping in Iowa: Moody silt loam (northwest Iowa), Chelsea sand (southeast Iowa), and Albaton clay (located on the flood plain of the Missouri river in west central Iowa). The following is a description of the general properties of these soils.

Moody silt loam (northwest Iowa)

Moody soils are well-drained, moderately fine textured soils formed in loess on upland and stream branches. These soils are located in Lyon County, and have moderate permeability and high available water capacity.

The soil survey of Lyon County showed that "there is a glacial till at a depth of 42 to 48 inches in many places in the northern part of the Moody association, and the till generally is at a depth of 60 inches in the southern part" (U.S.D.A., Soil Conservation Service, 1978). This finding justifies the use of a very low permeability layer at the bottom of the soil profile, as will be discussed in the model calibration.

The particle size distribution and physical properties of a Moody profile were determined by Castro-Morales (1978), and are summarized in Tables 4 and 5, respectively. The data in Table 5 were used as guides for assigning values to field capacity and wilting point in the model, assuming that the soil moisture at field capacity and wilting point are equivalent to the soil moisture at a tension of 1/3 and 15 bars, respectively. The results of Table 5 are in good agreement with the ranges given in most irrigation handbooks for soils with the same texture as

Table 4. Particle size distribution of the Moody profile, percent Castro-Morales, 1978)

soil depth in	clay <2µ	fine silt 2-20µ	coarse silt 20-50µ	sand >50µ
0-4	33.5	27.0	36.5	3.0
4-9	33.7	28.0	35.1	3.2
9-17	34.1	30.0	32.4	3.5
17-25	31.0	29.0	36.5	3.5
25-36	28.2	26.2	40.3	5.3
36-44	26.5	24.8	41.5	7.2
44-55	23.3	25.2	43.6	7.9
55-64	22.3	27.8	40.5	9.4

Table 5. Physical properties of the Moody profile (Castro-Morales, 1978)

		field capacity percent		wilting point percent		
soil depth ft	bulk density lb/ft^3	by weight	by volume	by weight	by volume	available water capacity in/ft
0-1.0	79.87	31.4	40.2	15.2	19.4	2.49
1.0-2.0	78.62	27.8	35.0	14.6	18.4	1.99
2.0-3.0	80.50	26.0	33.5	13.1	16.9	1.99
3.0-4.0	79.87	25.0	32.0	12.4	15.9	1.99
4.0-5.0	81.12	25.3	32.9	12.5	16.2	1.99

Moody soils.

Saturation moisture was assumed to be equal to the total pore space for a soil with the same texture. The ranges of 47 to 51 percent[1] for saturation moisture, 31 to 41 percent for field capacity, and 15 to 20 percent for wilting point were recommended by Israelson and Hansen (1962) for clay loam which has a texture closest to Moody silt loam, among their categories for soil texture.

The saturated hydraulic conductivity of each layer was assumed to be the same as used by Anderson on loess soils. Low values are assigned to the bottom layer and the layer below the soil profile (54-72 inches) to simulate the presence of glacial till.

On the basis of the above information, the physical properties of the Moody silt loam, including soil moisture content at saturation, field capacity, wilting point and saturated hydraulic conductivity of each layer, as used in the model, are given in Table 6.

Chelsea sand (southeast Iowa)

Chelsea soils are excessively to well-drained soils, formed in coarse sediment on benches along the major rivers, on dominantly wind-deposited sand, and under forest vegetation.

The reason for selection of Chelsea soil was the presence of only a colored surface layer (4 in), underlined with fine sand, sand and loamy sand to a depth of 60 inches. The other sands of the area, including Sparta, Dickinson and Hoopeston, have surface layers of 20, 31 and 50

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[1] All percents represent percent by volume.

Table 6. Soil moisture content at saturation (SAT), field capacity (FC), wilting point (WP), plant available water capacity (PLAV), and saturated hydraulic conductivity (SHC), used in the model for the Moody silt loam on the Doon watershed

soil depth ft	SAT	FC	WP	PLAV in/layer	SHC in/h
	--- percent by volume ----				
0-0.5	51.0	33.0	16.0	1.02	0.14
0.5-1.0	51.0	33.0	16.0	1.02	0.14
1.0-1.5	51.0	33.0	16.0	1.02	0.12
1.5-2.0	51.0	33.0	16.0	1.02	0.12
2.0-2.5	51.0	32.0	15.0	1.02	0.12
2.5-3.0	51.0	32.0	15.0	1.02	0.10
3.0-3.5	51.0	32.0	15.0	1.02	0.10
3.5-4.0	51.0	32.9	15.0	1.02	0.10
4.0-4.5	50.0	31.0	14.0	1.02	0.10
4.5-5.0	50.0	31.0	14.0	1.02	0.001
below 5.0	50.0	31.0	14.0	1.02	0.001

inches, underlined with sand and loamy sand[1].

The available water capacity of Chelsea soils is very low (0.7-1.0 in/ft), and the permeability is high (6-20 in/h), as estimated by the U.S.D.A., Soil Conservation Service (1979).

The ranges of 32 to 42 percent[2] for saturation moisture, 10 to 20

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[1] T. E. Fenton, Department of Agronomy, Iowa State University, Ames. Personal communication, 1981.

[2] All percents represent percent by volume.

percent for field capacity, 3 to 10 percent for wilting point, and 1.0 to 10.0 in/h for permeability were recommended by Israelson and Hansen (1962) for sandy soils. Soil moisture at 1/3 and 15 bar tensions has been measured for various sandy soils in Nebraska.[1]

The physical properties of Chelsea soil, inlcuding the moisture content at saturation, field capacity, and wilting point, and the saturated hydraulic conductivity, were based on the above limited information, and are summarized in Table 7 as used in the model input data.

Albaton clay soil (west central Iowa)

Albaton soils are poorly drained clay soils that formed in river sediment, and occur at low elevations on the bottom lands of the Missouri river valley. These soils have slow to very slow permeability, and the available water capacity is medium to high.

The physical properties of heavy soils, including Albaton and Luton, were measured by the National Soil Service laboratory, U.S.D.A., Soil Conservation Service (1975), using soil samples of Luton and Albaton silty clay taken from Monona County.

Wynne (1976) presented data on particle size distribution of Albaton soil (Table 8). He also measured bulk density and percent moisture under various tensions. The values for 1/3 and 15 bar tension as corrected by Shaw[2] are given in Table 9.

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[1] T. E. Fenton, Department of Agronomy, Iowa State University, Ames. Personal communication, 1981.

[2] R. C. Shaw, Department of Agronomy, Iowa State University, Ames. Personal communication, 1981.

Table 7. Soil moisture content at saturation (SAT), field capacity (FC), wilting point (WP), plant available water capacity (PLAV), and saturated hydraulic conductivity (SHC), as used in the model for Chelsea sandy soil in Lee County

soil depth	SAT	FC	WP	PLAV	SHC
ft	--- percent	by volume	----	in/layer	in/h
0-0.5[a]	44.0	13.0	3.0	0.60	8.67
0.5-1.0	37.0	11.0	5.0	0.36	8.27
1.0-1.5	37.0	11.0	5.0	0.36	8.27
1.5-2.0	37.0	11.0	5.0	0.36	8.27
2.0-2.5	33.0	10.0	4.0	0.36	8.27
2.5-3.0	33.0	10.0	4.0	0.36	7.87
3.0-3.5	30.0	9.0	4.0	0.30	7.87
3.5-4.0	30.0	9.0	4.0	0.30	7.87
4.0-4.5	30.0	9.0	4.0	0.30	7.87
4.5-5.0	30.0	9.0	4.0	0.30	7.87
5.0-6.0	30.0	9.0	4.0	0.60	7.87

[a] The top 4 inches of this layer is the surface layer, with 10 to 15 percent available water capacity, compared to the 6 to 8 percent available water capacity of the other layers.

Table 8. Particle size analysis of Albaton soil (Wynne, 1976)

soil depth ft	percent sand	percent silt	percent clay
0-0.5	0.9	40.5	58.6
1.5-2.5	0.5	30.9	68.6
3.5-4.5	0.2	43.8	56.0

Table 9. Physical properties of Albaton clay profile (Wynne, 1976)

		field capacity percent		wilting point percent	
soil depth ft	bulk density lb/ft^3	by volume	by weight	by volume	by weight
0-0.5	79.24	33.0	42.0	20.2	25.7
0.5-1.5	79.87	32.0	41.0	22.3	28.5
1.5-2.5	84.24	31.85	43.0	22.6	30.5
2.5-3.5	82.37	32.9	43.4	22.8	30.0
3.5-4.5	81.12	33.3	43.3	22.9	29.8

For clay soil, total pore space of 51 to 55 percent, and permeability of 0.02 to 0.2 in/h were recommended by Israelson and Hansen (1962).

Based on the above data, the physical properties of Albaton soil, including moisture content at saturation, field capacity, and wilting point, and the saturated hydraulic conductivity were accepted for use in the simulation model as given in Table 10.

Meteorological Data

Rainfall data

The rainfall data from the Doon station (northwest), Burlington station (southeast), and Sioux City station (west central) were used for Moody silt loam, Chelsea sandy soil, and Albaton clay soil, respectively.

Doon rainfall records were available on rain gage charts, providing data on the distribution of rainfall with time, for the years 1958 through 1979. Rainfall depth at the breakpoints of the recorded rainfall, and the associated times, were used as input to the model, allowing the use of short rainfall increments (5-min) for this station.

Daily rainfall from Shaw's data for the Doon station[1], was used to check the available rainfall data, and provided values for a few missing records in each year (see Table A1). For all these days, a uniform intensity of 0.25 in/h was assumed; for days when the clock failed after providing part of the record, uniform intensity was used to complete the chart.

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[1] R. H. Shaw, unpublished data.

Table 10. Soil moisture content at saturation (SAT), field capacity (FC), wilting point (WP), plant available water capacity (PLAV), and saturated hydraulic conductivity (SHC), as used in the model for Albaton clay soil on the bottom land of the Missouri river, Woodbury County

soil depth	SAT	FC	WP	PLAV	SHC
ft	--- percent by volume ----			in/layer	in/h
0-0.5	55.0	42.0	26.0	0.96	0.20
0.5-1.0	55.0	40.5	29.0	0.69	0.04
1.0-1.5	54.0	40.5	29.0	0.69	0.04
1.5-2.0	54.0	43.0	29.0	0.84	0.04
2.0-2.5	55.0	43.0	29.0	0.84	0.04
2.5-3.0	55.0	43.0	29.0	0.84	0.03
3.0-3.5	54.0	43.0	29.5	0.81	0.03
3.5-4.0	54.0	44.0	29.5	0.87	0.03
4.0-4.5	54.0	44.0	29.0	0.90	0.02
4.5-5.0	55.0	44.0	29.0	0.90	0.001
5.0-6.0	55.0	44.0	29.0	1.80	0.001

There are no published rainfall data for the Doon station; the closest station is Rock Rapids, 10 miles to the north. These data were used to estimate annual rainfall at the Doon station.

For Burlington and Sioux City stations, hourly rainfall data were recorded on tape for the years 1951 through 1978, by the U.S. Weather Bureau. Hourly rainfall data were used for rainfall input data.

Pan evaporation data

Daily pan evaporation data were taken from Shaw's[1] pan evaporation data at the Doon, Burlington and Castana weather stations for Moody silt loam, Chelsea sandy soil, and Albaton clay soil, respectively.

Isoevaporation maps were used to estimate pan evaporation for stations with no pan records, using the measured values for the other stations. An isoevaporation map for June 11, 1969 is given in Figure 4 to illustrate such usage; these maps are available for 1950 through 1980 for all days of the year.

Soil moisture data

Soil moisture data for the Moody silt loam were taken from plant available moisture reported by Shaw et al. (1972) for the Doon station, which were predicted by use of his model, and adjusted to the few measured soil moisture values taken each year. Available soil moisture data are published for the period 1956 to 1970 (Shaw et al., 1972); for the years after 1970, they are assembled in a manuscript by Shaw.[1]

Soil moisture data for April 15 were used as the beginning soil moisture data for the model, and the reported values at the beginning of each month were used for comparison with model prediction. Initial soil moisture data used in the model are given in Table A2, for the years 1958 to 1978.

For Chelsea sand and Albaton clay, no measured soil moisture data

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[1] R. H. Shaw, Department of Agronomy, Iowa State University, Ames. Unpublished data.

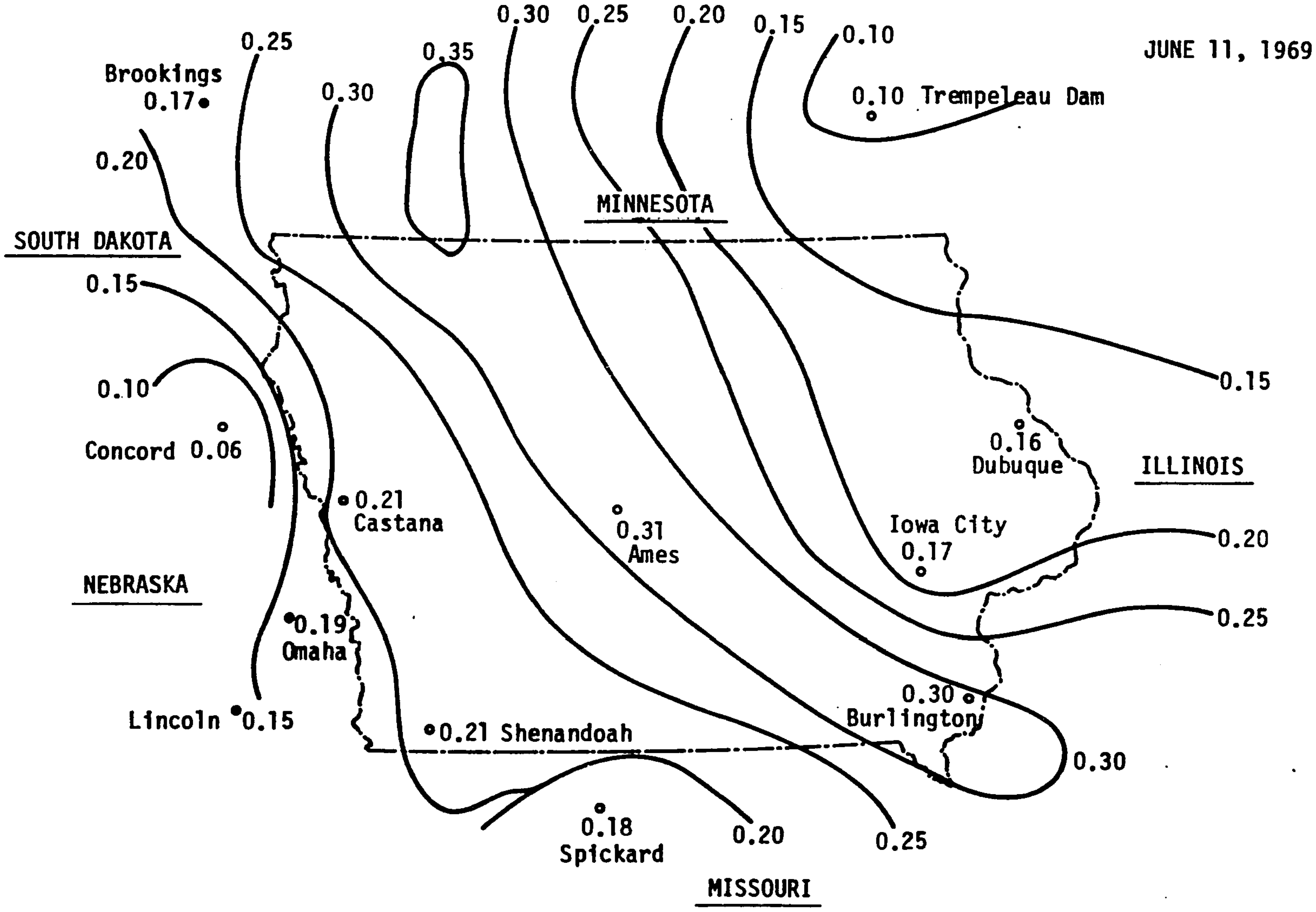

Figure 4. Isoevaporation map for Iowa on June 11, 1969

were available for use as the initial soil moisture for the simulation model. It is assumed that Chelsea sand is at field capacity in early spring (April 15), therefore the initial soil moisture was set to the field capacity of each layer for all years (1951-1978).

Beginning soil moisture data for Albaton soil were estimated using Castana soil moisture data (Shaw et al., 1972). The ratios of initial soil moisture (April 15) to field capacity were determined for each 6-inch layer for the Castana data and the beginning soil moisture for Albaton soil was calculated by multiplying this ratio by the field capacity of the associated layer for the years 1951 to 1978. Total yearly initial soil moistures for each 6-inch layer as used in the model for Albaton clay are given in Table A3.

Runoff data

Measured surface runoff data were available for Doon watershed for the years 1958 to 1978[1]. Surface runoff was measured by use of a 2-ft throat Parshall flume, equipped with a water level gage for recording water depth continuously during the runoff event. The measured surface runoff was used for the calibration of the model in application to the Moody silt loam.

Measured surface runoff data were not available for the Chelsea or Albaton soils. It was assumed that the Chelsea soil, with high permeability, would not produce any surface runoff. Albaton soils are

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[1] D. W. Deboer and H. P. Johnson, Department of Agricultural Engineering, Iowa State University, Ames. Unpublished data.

located in nearly level lands, and are expected to have little runoff, except during wet years and after intense rainfall.

Calibration of the Hydrologic Model

Moody silt loam

The measured data from the Doon watershed were used to calibrate the model in application to Moody silt loam soils.

There were two small watersheds at the experimental farm, north watershed (2.98 acres) and south watershed (2.04 acres). The north watershed, which was contour surface planted, was used in the study. The average slope steepness and slope length of the north wastershed, as obtained from the contour map of the site (Figure 5), were about 2.5 percent and 280 feet, respectively.

Measured depth of surface runoff and the soil moisture values reported by Shaw et al. (1972), were used to calibrate the model for simulation of surface runoff and total moisture stored in the top five feet of the soil. The main objective was to minimize the difference between measured and predicted surface runoff, as well as the difference between soil moisture values reported by Shaw and those predicted by the model.

The available data for all years were used in this calibration, because the objective was to predict changes due to irrigation, rather than the hydrologic response of the watershed under natural conditions.

Most of the years used in the model (1958-1978) produced small depths of surface runoff, and the individual events within each year produced very low surface runoff. Therefore, calibration was made to simulate the annual volume of runoff, rather than the individual storm runoff. For

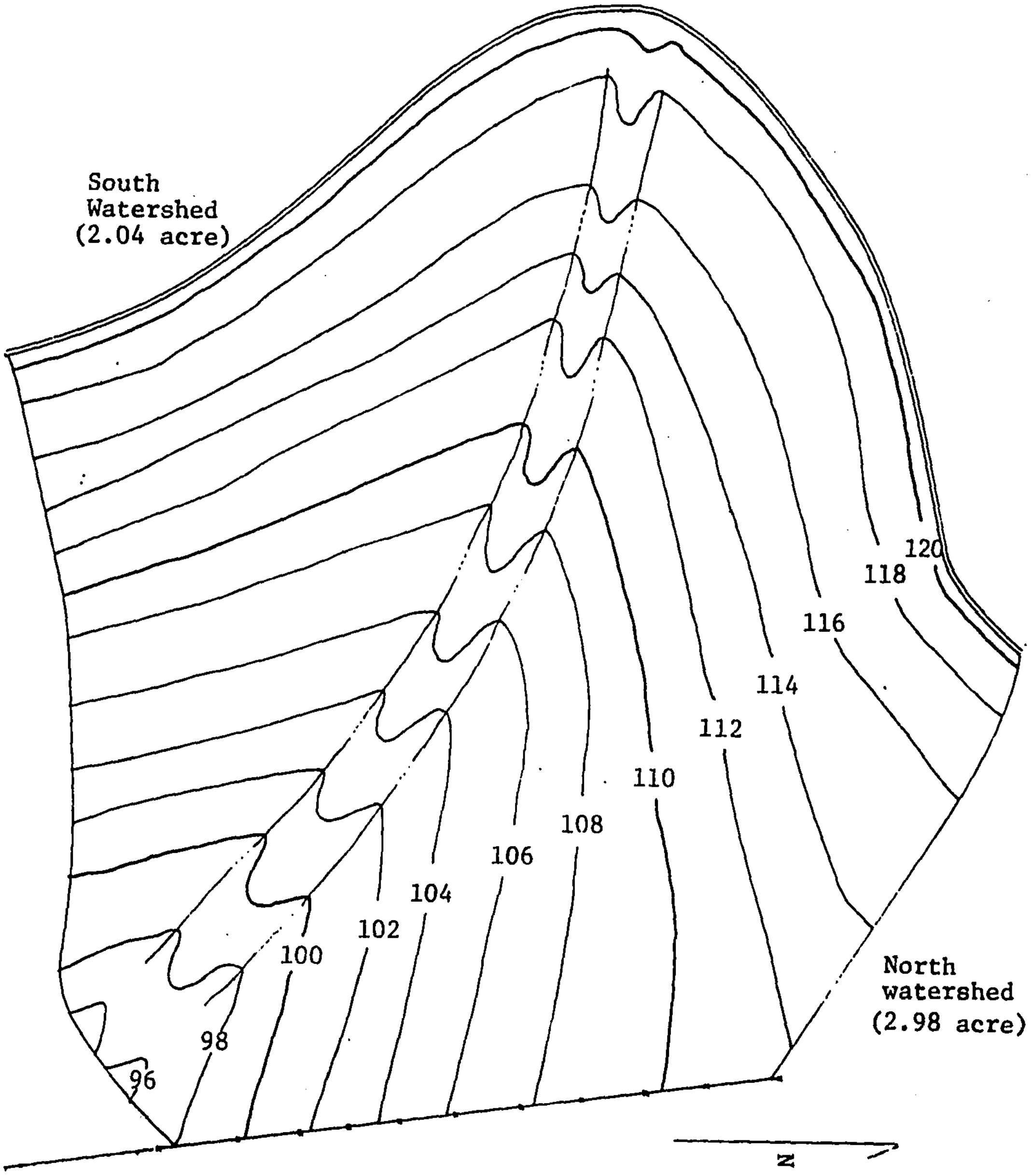

Figure 5. Doon experimental watersheds. Contour interval = 2 ft

most of the years, there were two cultivations after plowing (Table 11), which would partly account for the low surface runoff measured.

The model parameters and other input data were adjusted to improve the predicted values of surface runoff and soil moisture. At first the model was underpredicting soil moisture values, deep percolation was high, and actual evapotranspiration was low. It was then assumed that there was a low permeability layer at the bottom of the root zone, and this assumption improved model predictions by holding more water in the soil profile, consequently decreasing deep percolation and increasing actual evapotranspiration to reasonable values.

The model was then run for all years using the initial soil moisture data (Table A2), associated physical properties of Moody soils (Table 6), Doon rainfall and pan data, and other calibrated input parameters (Table 12).

A comparison of measured and predicted surface runoff for all years is shown in Table 13. Surface runoff predictions for an individual year are predicted well relative to measured values by adjusting model parameters such as land surface parameters, and crop leaf area index distribution, which have a pronounced effect on surface runoff prediction. However, since the objective was to predict changes due to irrigation, uniform parameters were used for all years.

The reported values of soil moisture, in the top five feet at the beginning of each month (Shaw et al., 1972), were compared with the values predicted by the model (Table 14). The regression line between the predicted values (Y) and the values reported by Shaw (X), shown in

Table 11. Date of plowing and cultivation of the north watershed[a]

Year	Plowing data	First cultivation date	Second cultivation date
1962	May 4	June 6	June 19
1963	April 15	June 6	June 17
1964	May 7	June 2	June 25
1965	May 8	June 7	June 15
1966	May 4	June 10	June 24
1967	April 24	June 28	--
1968	April 29	June 6	June 17
1969	May 2	June 20	July 1
1970	May 12	June 8	June 18
1971	April 22	June 14	--
1972	April 20	June 12	June 27
1973	April 25	June 21	--
1974	April 29	June 19	June 28
1975	May 15	June 27	--
1976	May 5	June 15	June 19
1977	--	--	--
1978	May 11	June 5	June 21

[a] D. W. Deboer and H. P. Johnson, Department of Agricultural Engineering, Iowa State University, Ames. Unpublished data.

Table 12. Description of infiltration, soil moisture redistribution and overland flow parameters and calibrated values used in the model for different soils

Parameter name	Parameter description	Calibrated values
FCINF	Wet soil infiltration capacity, in/h	0.14[a]
ASOILM	Maximum value of ASOIL figure 7	7.0[b]
AM	Slope of the curve of ASOIL plotted against the moisture content of the first layer (AMC) on semi-log paper, with ASOIL on log scale	-0.16[c]
PSFC	Value of PSOIL at the field capacity of the surface layer	1.48
PM	Slope of the curve of PSOIL vs. moisture content of the first layer (AMC) on log-log paper	0.199
FCS	Maximum value of AMC for which ASOILM = ASOIL, percent by volume	33.0[d]
FCP	Field capacity of the surface layer, percent by volume	33.0[e]
CE1	Intercept of the line of rainfall energy factor vs. the summation of rainfall kinetic energy on semi-log paper, with rainfall energy factor on log scale	0.125
CE2	Slope of the line of rainfall energy factor vs. the summation of rainfall kinetic energy on semi-log paper, with rainfall energy factor on log scale	1.25
PSIFC	Soil matric potential at field capacity, cm[f]	350.0[g]

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[a] FCINF = 7.0 in/h for sand.

[b] ASOILM = 10.0 in/h for clay.

[c] AM = -0.5 for clay.

[d] FCS = 13% for sand, and 34% for clay.

[e] FCP = 13% for sand, and 42% for clay.

[f] Standard values used in cm in the model.

[g] PSIFC = 330 cm for clay.

Table 12 (continued)

Parameter name	Parameter description	Calibrated values
PSIWP	Soil matric potential at wilting point, cm[f]	15,000
PASMAC	Percent available soil moisture at cracking	5.0[h]
OFMN1	Maximum value of Manning's coefficient	0.12
OFMN2	Minimum value of Manning's coefficient	0.08
TRSTM	Accumulated depth of surface runoff required to remove the puddles created by tillage, in	0.50
PUDDLE1	Maximum depth of water held in puddles immediately after tillage, in	0.50[i]
PUDDLE2	Minimum depth of water held in puddles, in	0.00

[h] PASMAC = 50% for clay.

[i] PUDDLE1 = 1.0 for clay and 0.1 for sand.

Table 13. Accumulated rainfall, measured and predicted surface runoff for the period April 15 to September 1, North Doon watershed

Year	Accumulated rainfall in	Measured runoff in	Predicted runoff in
1958	6.68	0.05	0.00
1959	19.54	2.27	2.34
1960	17.91	0.28	0.27
1961	14.81	0.09	0.00
1962	16.45	0.48	0.08
1963	10.29	0.00	0.00
1964	17.05	0.04	0.50
1965	15.98	0.92	1.70
1966	10.91	0.04	0.00
1967	11.64	1.01	0.95
1968	11.56	0.03	0.00
1969	14.94	0.67	1.90
1970	8.90	0.00	0.00
1971	13.17	0.43	0.76
1972	20.34	1.11	3.40
1973	14.44	0.42	0.90
1974	12.95	0.00	0.00
1975	16.51	0.38	1.10
1976	7.70	0.00	0.00
1977	17.95	1.32	3.30
1978	15.51	0.00	0.41

Table 14. Comparison of the total soil moisture in the top five feet as reported by Shaw, and as predicted by the model, at the beginning of each month, for the years 1958 to 1979, North Doon watershed (moisture expressed in inches)

	April 1	May 1		June 1		July 1		August 1		September 1	
Year	Shaw and Model	Shaw	Model	Shaw	Model	Shaw	Model	Shaw	Model	Shaw	Model
1958	16.6	15.2	16.0	15.9	16.4	14.3	15.3	12.5	12.5	11.5	10.5
1959	11.0	10.5	11.2	14.3	15.9	13.8	15.5	12.3	11.2	12.2	13.1
1960	18.5	18.0	16.6	18.9	17.9	18.6	16.7	14.8	12.9	13.2	14.1
1961	17.8	16.9	16.8	17.8	18.6	16.7	16.8	13.3	12.7	14.2	14.3
1962	16.3	15.7	15.1	16.1	14.4	16.2	15.1	15.5	13.6	13.9	14.1
1963	12.0	11.3	12.5	12.2	13.4	11.2	13.1	11.0	12.3	10.5	11.1
1964	15.3	15.3	15.2	14.9	14.7	14.5	14.4	12.1	12.5	11.8	12.3
1965	16.3	15.8	15.9	17.2	18.7	18.0	17.6	15.0	13.6	13.0	11.5
1966	15.9	15.0	16.7	14.9	16.9	13.9	15.1	14.9	12.2	12.8	13.1
1967	12.0	11.7	12.0	11.9	12.9	15.9	14.4	11.4	10.8	11.3	11.1
1968	9.7	11.5	11.0	11.2	12.7	12.0	13.0	11.2	11.0	10.3	9.7
1969	22.3	19.0	20.6	19.3	20.4	19.5	18.8	16.9	14.9	13.7	12.3
1970	13.3	13.5	14.6	13.2	15.8	11.8	14.9	13.2	11.6	9.9	10.4
1971	14.2	13.7	15.2	13.4	15.5	15.4	17.4	12.1	12.9	10.7	11.0
1972	13.9	15.9	16.8	17.8	18.3	17.3	15.6	16.9	13.6	14.9	11.8
1973	18.5	17.7	15.8	18.9	16.8	16.3	16.7	14.3	15.5	11.9	12.3
1974	15.7	14.9	14.1	15.1	15.5	13.9	14.2	12.0	10.9	12.9	13.4
1975	19.6	19.8	17.7	18.9	15.3	18.4	15.7	14.9	13.7	16.0	14.3
1976	17.7	17.6	17.2	17.4	17.4	14.4	15.2	12.7	12.8	11.3	10.8
1977	15.4	14.5	15.6	15.6	17.0	13.1	13.9	13.1	12.7	14.9	12.5
1978	19.6	19.4	18.0	19.6	17.7	17.3	15.5	16.6	15.7	14.3	14.0
1979	19.8	19.6	19.8	19.3	19.9	18.7	17.7	16.2	14.7	19.6	15.7

Figure 6 was:

$$Y = 3.08 + 0.87\,X \qquad r = 0.86$$

A standard t-test was used to compare the two soil moistures at the beginning of each month. There was no significant difference between the total soil moisture values reported by Shaw and those predicted by the model.

Chelsea sand

To calibrate the model for application to Chelsea sandy soil, no measured data were available for either surface runoff or soil moisture. It was expected that Chelsea sand with high permeability, would produce no runoff, and that water would infiltrate through the profile very rapidly.

It was assumed that the sandy soil was at its field capacity in early spring, thus, the values given for field capacity for Chelsea sand were used as the initial soil moisture.

The associated physical properties of Chelsea soil (Table 6), hourly rainfall data and pan data from the Burlington station, and calibrated values of other parameters (Table 11), were used in the model for all years. No runoff was produced, but soil moisture was higher than the expected values for sandy soil. To overcome this problem in the soil moisture distribution part of the model, it was assumed that each layer filled up to 30% of saturation moisture (compared to 80% of saturation in Moody silt loam), and then the excess water would drain freely to the lower layer. The flow to each layer would not be restricted by the saturated hydraulic conductivity of that layer, because permeability was

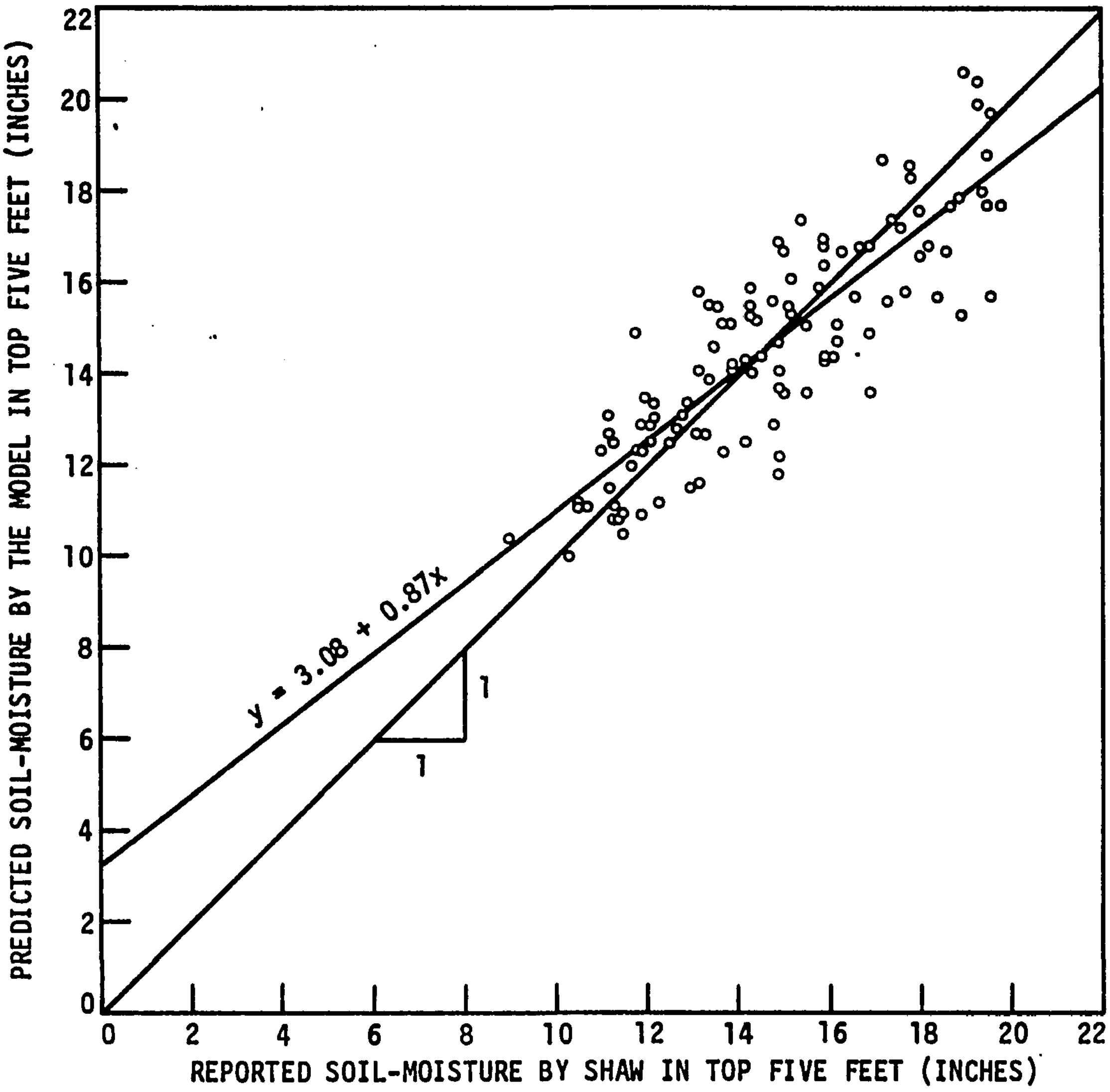

Figure 6. Comparison of measured and predicted soil moisture in the five foot root zone under corn on the North Doon watershed

high for all layers. This assumption modified the model predictions by letting more water pass through the profile, thereby decreasing the soil moisture and increasing deep percolation to an acceptable range.[1]

Albaton clay

Like Chelsea soil, there were no measured data available to calibrate the model for application to Albaton soil. The Albaton soils are located on the bottom lands of the Missouri river valley, which are nearly level; thus low surface runoff is expected, except during high intensity rainfall, or rainfall at a time of high soil moisture.

Under dry conditions, cracks will develop in the surface layers of the Albaton soil, increasing the infiltration rate and capacity. To simulate cracking properties of these soils in the model, the infiltration equation parameters were changed to increase the infiltration to a higher rate (compared to the Moody silt loam) as the moisture content of the top layer decreased (Figure 7). The redistribution subroutine was also modified, such that after crack development, water could flow through the soil profile without being restricted by the very low saturated hydraulic conductivity of the lower layer, as explained in the section on the redistribution subroutine.

The model then used the given physical properties of the Albaton soil (Table 9), calibrated values of other parameters (Table 12),

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[1] H. P. Johnson, C. E. Anderson, and S. W. Melvin. Agricultural Engineering Department, Iowa State University, Ames. Personal communication, 1981.

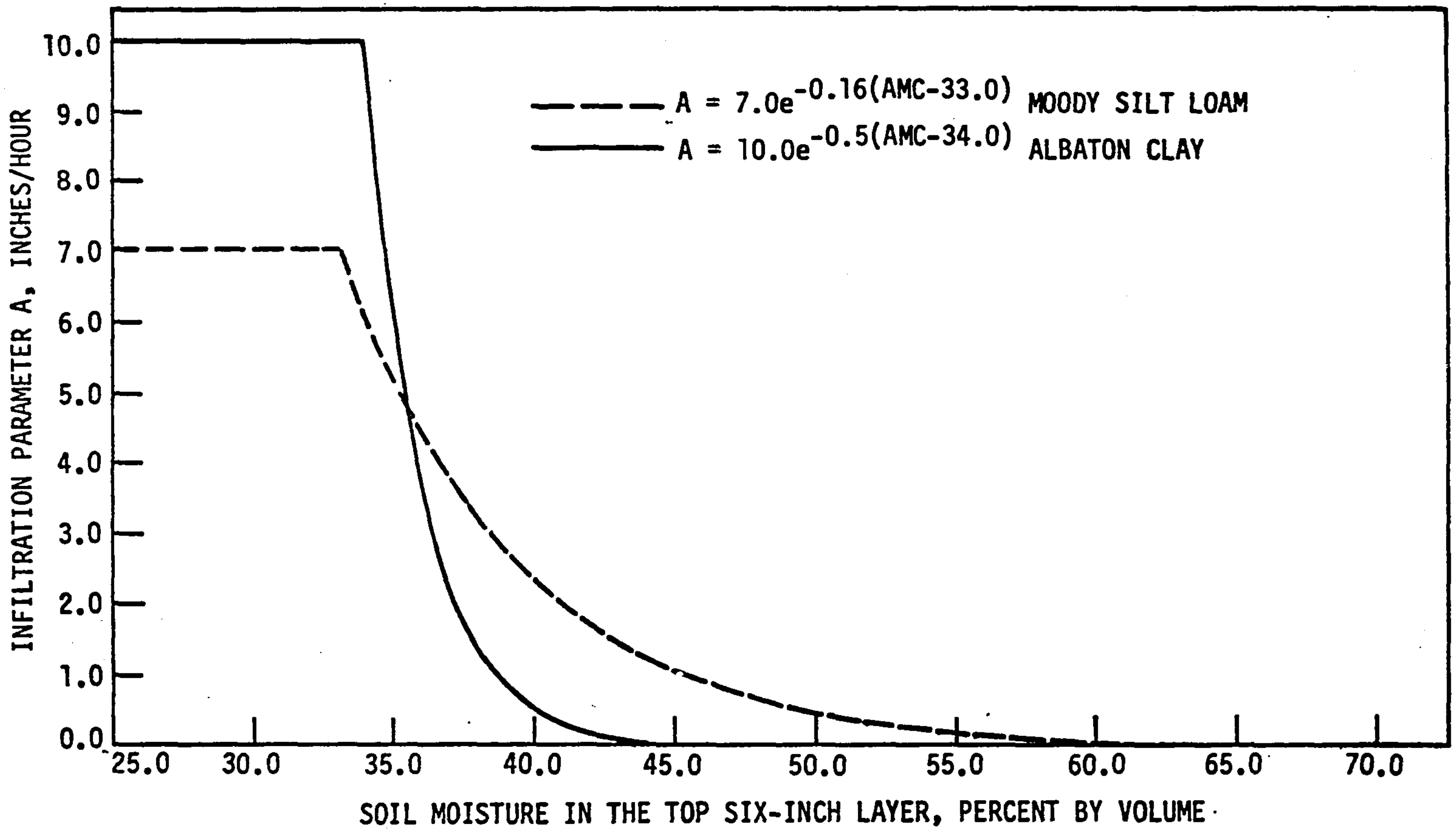

Figure 7. Relationship between the parameter, A, in the infiltration equation and the moisture content of the surface layer after modification for crack development in heavy soils (Albaton Clay).

initial soil moisture as calculated from the Castana soil moisture data (Table A3), Sioux City hourly rainfall data, and Castana pan data for the years 1951 through 1978.

Large amounts of surface runoff were predicted for a few years having high intensity rainfall, and for rainfalls which occurred when the soil moisture content was high. For example, the highest runoff amount (5.48 in) was predicted for the year 1972. In this year, the first rainfall producing runoff was on May 1, when 2.19 inches occurred in 7 hours, and 1.10 inches fell in 2 hours. The soil moisture stored in the top five feet on the previous day was 23.0 inches, and this rain produced 0.97 inches of runoff. On July 17, 5.5 inches of rainfall occurred, of which 4.12 inches fell in 3 hours, and the rest in 7 hours. Soil moisture in the top five feet on July 16 was 19.3 inches, and this rain produced 2.69 inches of runoff according to the model. Similar conditions were present in the years 1961 and 1962, with 4.5 inches of surface runoff. The other years produced low runoff as was expected.

RESULTS AND DISCUSSION

Model Response for Natural Conditions

The hydrologic response of the model was determined under natural conditions for model calibration before applying irrigation water. The results of these runs under natural conditions were also used to determine changes in surface runoff and deep percolation due to irrigation water application.

Three different soils were selected: Moody silt loam with high water-holding capacity (2.0 in/ft), and moderate permeability (0.1-0.15 in/h); Chelsea sand with low available moisture (0.6 in/ft), and very high permeability (6.0-20.0 in/h) throughout the whole profile; and Albaton clay, with moderate water-holding capacity (1.80 in/ft), and very low permeability (0.02-0.04 in/h).

The simulation was performed for the years 1958 to 1979 for Moody silt loam, and for the years 1951 to 1978 for both Chelsea sand and Albaton clay. Rainfall charts from the Doon watershed were used for Moody silt loam, and hourly rainfall data from Burlington and Sioux City stations were utilized for Chelsea sand and Albaton clay. The physical soil properties as required by the model were given in Tables 5, 6 and 9 for Moody silt loam, Chelsea sand and Albaton clay, respectively.

The model was first calibrated for each soil. The main objective was to predict reasonable values for the model outputs, including surface runoff, deep percolation, actual evapotranspiration, and soil moisture profile.

Comparison of the model response to different soils

The model output is summarized in Tables A4 to A6 for Moody silt loam, Chelsea sand and Albaton clay, respectively.

Surface runoff and deep percolation   Moody silt loam and Albaton clay showed low predicted surface runoff for most years, except a few wet years with high intensity rainfalls. Chelsea sand produced no surface runoff even for wet years, because of the high permeability throughout the soil profile. Yearly variation of seasonal rainfall and the generated surface runoff from Moody silt loam and Albaton clay are illustrated in Figure 8. For most of the years, seasonal rainfall and surface runoff for Albaton clay were higher than for Moody silt loam. The higher surface runoff for Albaton clay was the result of higher rainfall and lower permeability than for Moody silt loam.

Figure 9 illustrates the comparison of seasonal deep percolation among the three soils. Chelsea sand produced the highest and Moody silt loam the lowest seasonal deep percolation for most of the years. High deep percolation for sand was the result of high permeability of this soil. Albaton clay produced higher deep percolation than Moody silt loam, which is assumed to be the effect of higher rainfall, flatter slopes, and higher initial soil moisture in the Albaton clay.

Seasonal water use efficiency   Water use efficiency was defined in the program as one minus the ratio of seasonal water loss to the seasonal water supply, where it was assumed that the seasonal water loss was the sum of seasonal surface runoff and deep percolation, and sea-

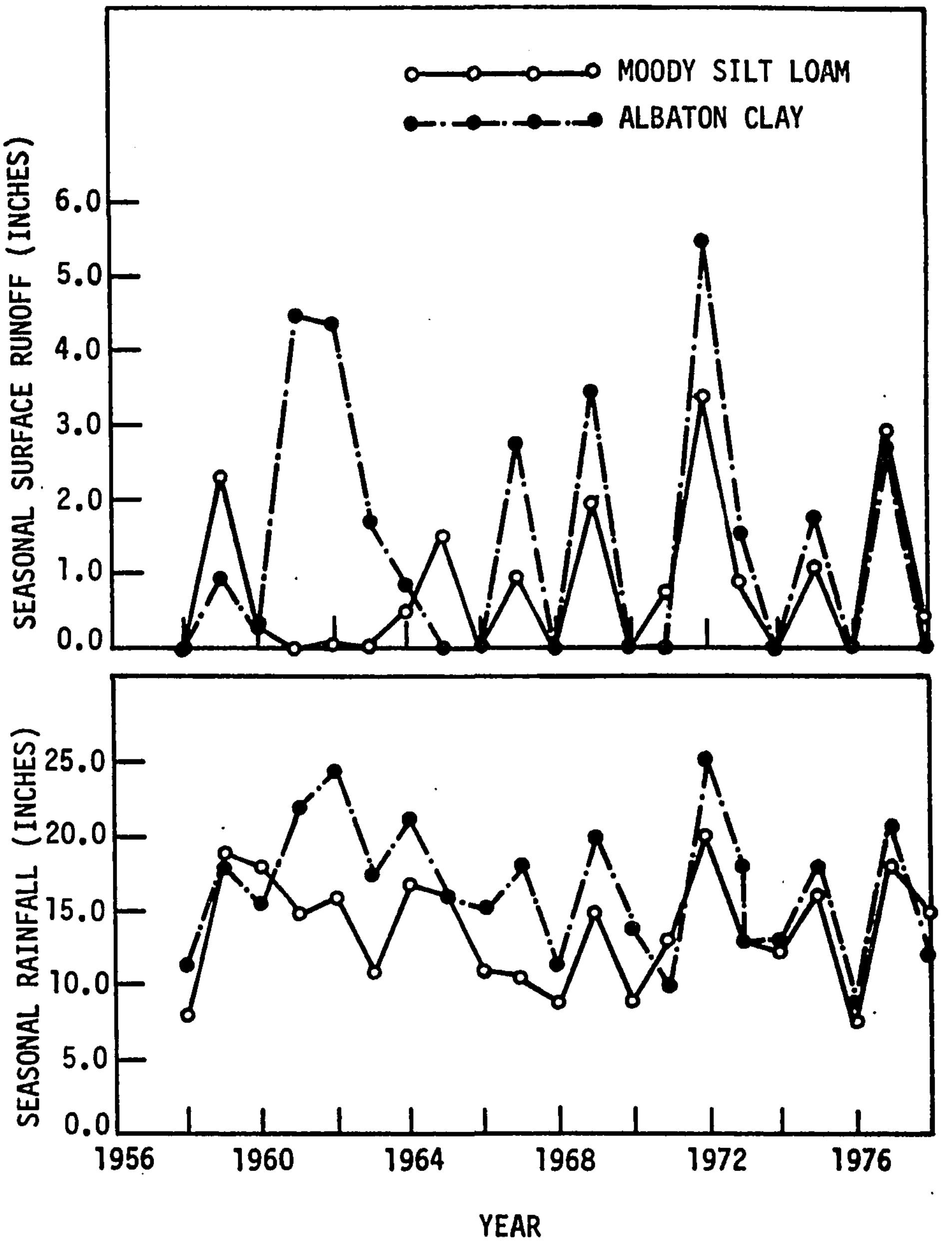

Figure 8. Yearly variation of seasonal rainfall and predicted surface runoff, under natural conditions, for Moody silt loam, northwest Iowa, and Albaton Clay soil, west central Iowa

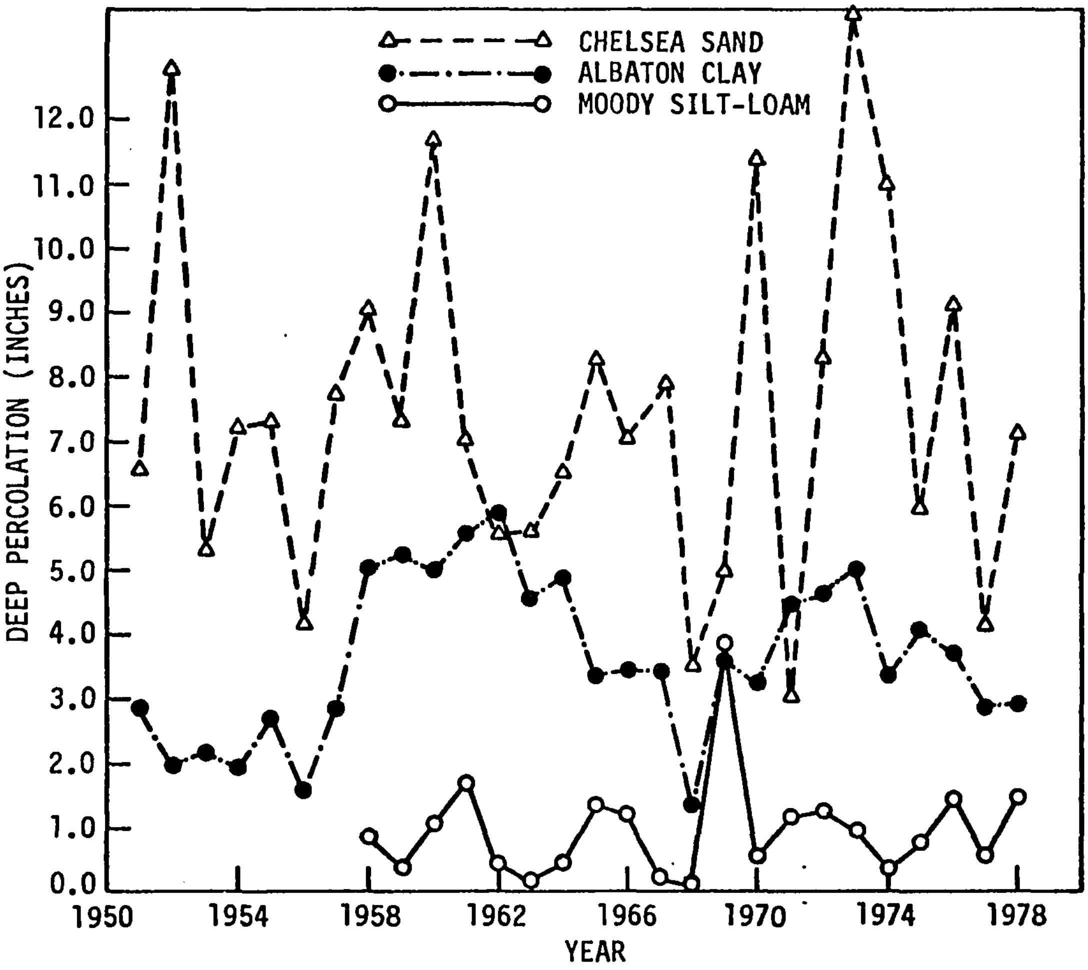

Figure 9. Comparison of seasonal deep percolation under natural conditions, Moody silt-loam (1958-1978), Chelsea sand (1951-1978) and Albaton Clay (1951-1978).

sonal water supply was the sum of seasonal rainfall and total soil moisture depletion (beginning soil moisture minus end of season soil moisture).

The average water use efficiency was 90.0 percent for Moody silt loam, 75.0 percent for Albaton clay, and 64.0 percent for Chelsea sand. For most of the years, Moody silt loam, with the highest available water holding capacity, produced the highest water use efficiency, and Chelsea sand, with the lowest available water holding capacity, resulted in the lowest water use efficiency (Figure 10). High permeability of Chelsea sand caused high deep percolation, and low water use efficiency.

Water use efficiency in dry years was much higher than in wet years for all three soils. Few years indicated less water use efficiency for Albaton clay than for Chelsea sand (Figure 10); these were years with high seasonal rainfall in the west central area (over the Albaton soils), and lower seasonal rainfall in the southeast (over the Chelsea soil).

Frequency distribution of soil moisture shortage

Soil moisture shortage is indicated by the model whenever the soil moisture of the top five feet falls to less than a predetermined percentage of the available soil moisture. This percentage, which is an input parameter was set at 50% for all three soils. Thus, soil moisture shortage was predicted when soil moisture in the active root zone decreased to less than 50% of the available soil moisture in the active root zone.

The length of stress period (total number of days with soil moisture

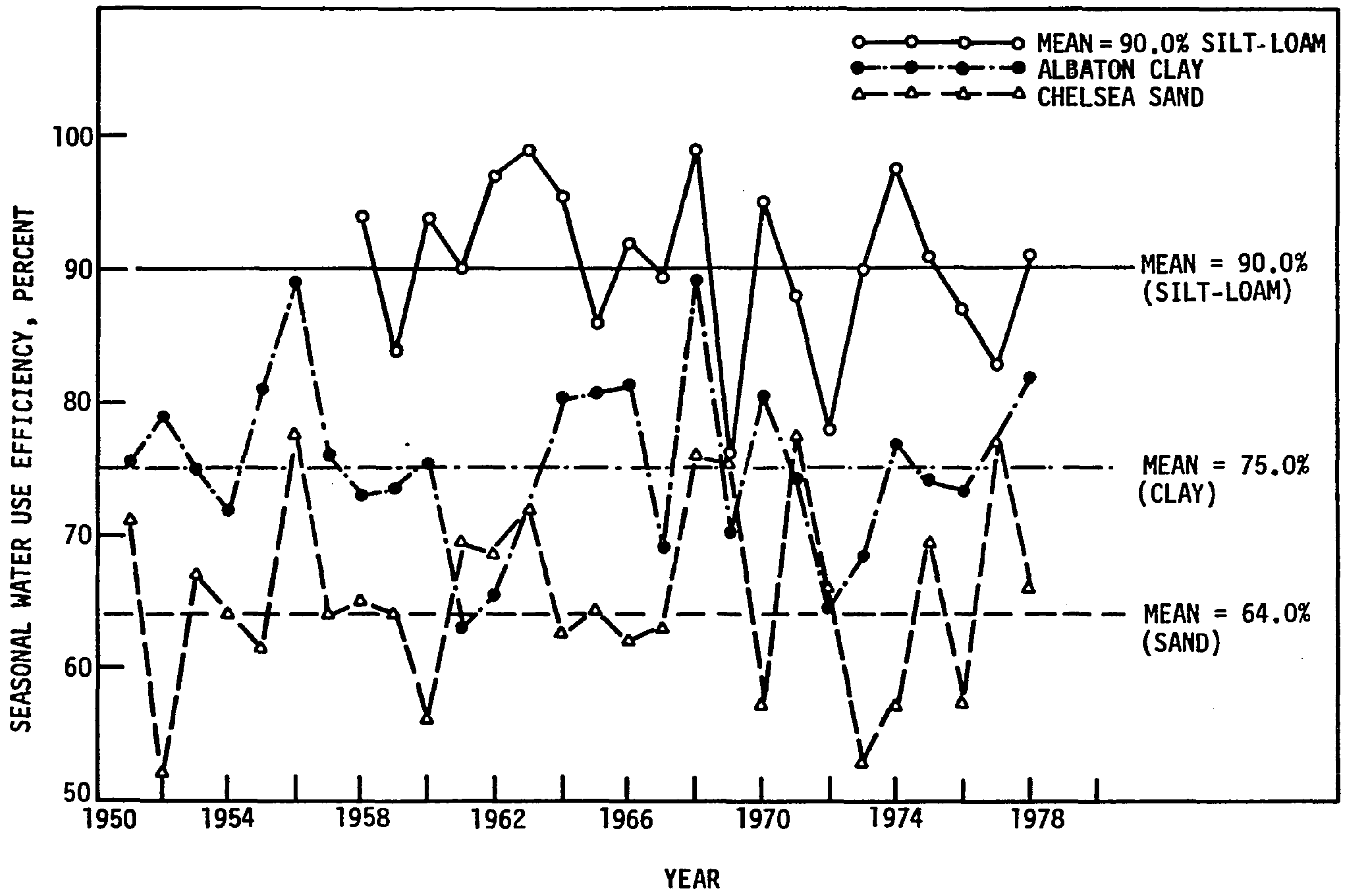

Figure 10. Comparison of the seasonal water use efficiency under natural conditions, Moody silt loam (1958-1978), Chelsea sand (1951-1978) and Albaton Clay (1951-1978)

shortage), and the associated dates for each period, are given in Tables A7 to A9 for Moody silt loam, Chelsea sand and Albaton clay, respectively. Length of stress period was closely related to total moisture supply to the soil (summation of beginning soil moisture and accumulated seasonal rainfall), for all three soils (Figures 11 to 13). Years with long stress period were associated with low soil moisture supply, and vice versa. For example, simulation on Moody silt loam (Figure 11), shows a long stress period with low moisture supply in 1968, and a short stress period, with high moisture supply in 1969.

The probability distribution of soil moisture shortage was determined for each soil. Three different distributions, including Normal, Gamma and Weibull distributions, were tested. The Weibull distribution resulted in the best fit for all three soils.

The probability density function (f(X)) and cumulative distribution function (F(X)) of the Weibull distribution are defined by Haan (1977) as follows:

$$f(X) = \beta X^{\beta-1}\alpha^{-\beta}\exp[-(X/\alpha)^{\beta}]$$

$$F(X) = 1-\exp[-(X/\alpha)^{\beta}]$$

The distribution parameters α and β were estimated by the maximum likelihood procedure. Figures 14 to 16 illustrate the observed frequency of soil moisture shortage and the Weibull distribution fitted to the soil moisture shortage data on Moody silt loam, Chelsea sand and Albaton clay, respectively.

A chi-square test was used to determine how well the observed data approximated a Weibull distribution. Using Chelsea sand data, the

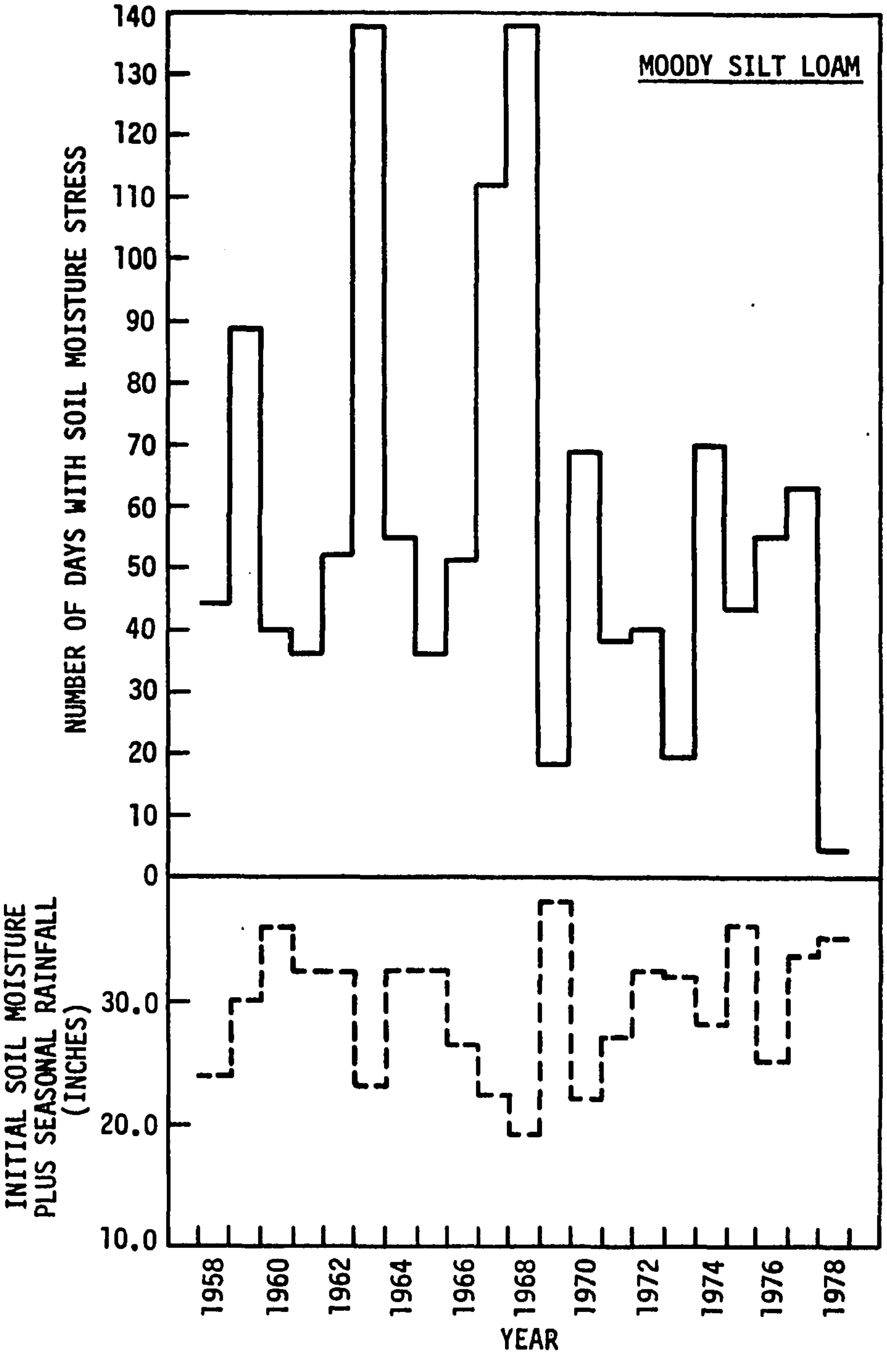

Figure 11. Yearly variation of soil moisture stress period and beginning soil moisture plus seasonal rainfall under natural conditions. Moody silt loam, Doon watershed, northwest Iowa

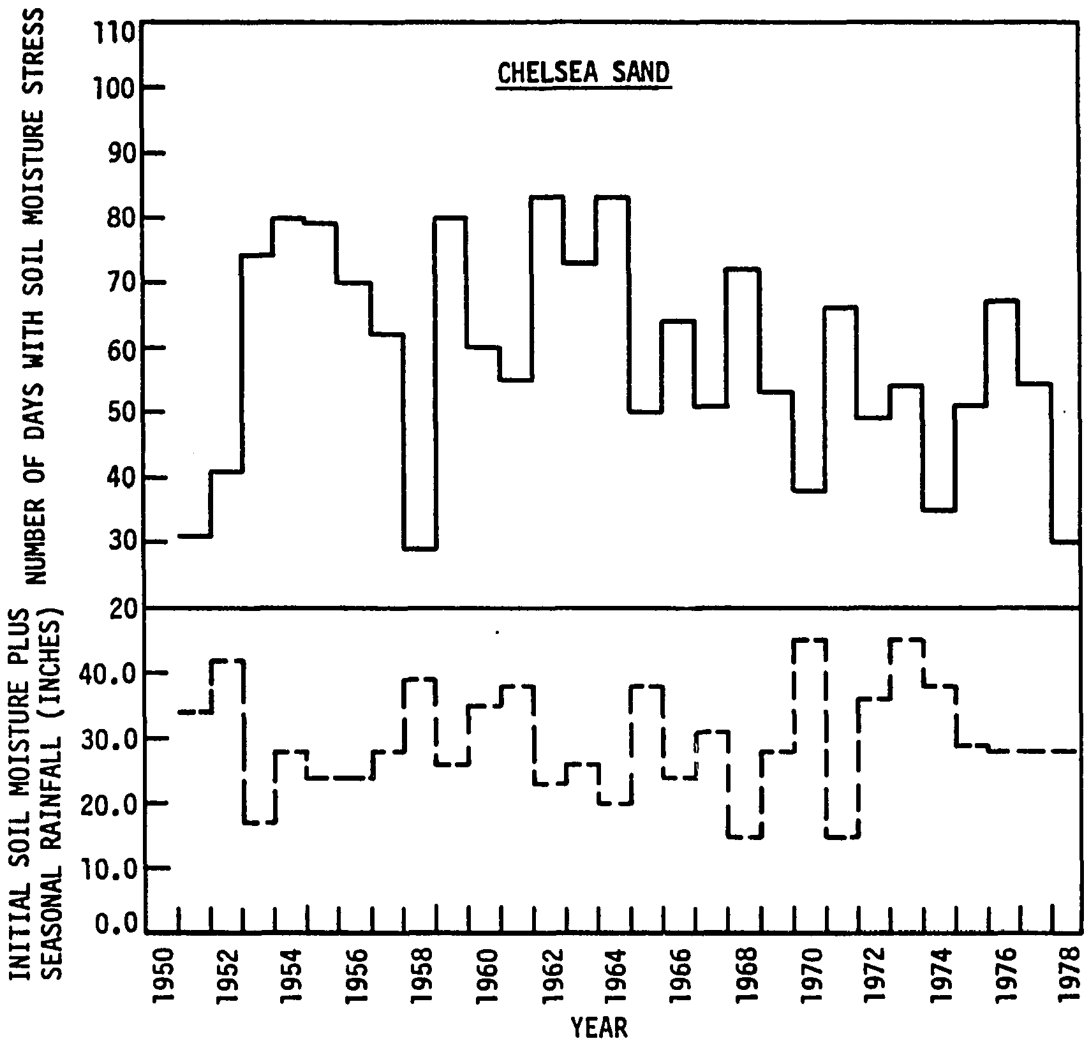

Figure 12. Yearly variation of soil moisture stress period and beginning soil moisture plus seasonal rainfall under natural conditions. Chelsea sand, southeast Iowa.

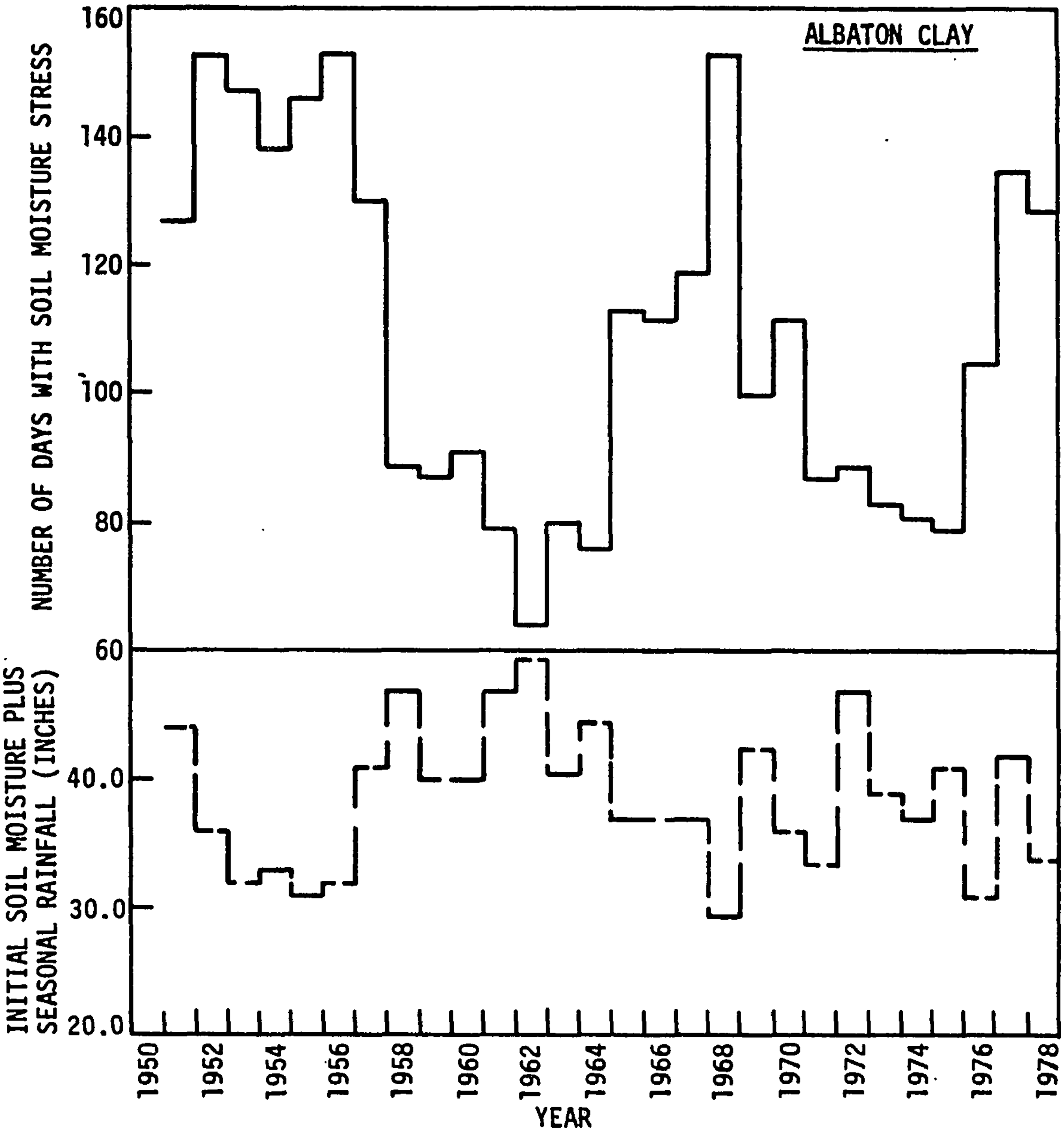

Figure 13. Number of days soil moisture stress occurred in each year, as compared with the summation of seasonal rainfall and beginning soil moisture under natural conditions. Albaton Clay soil, west central Iowa

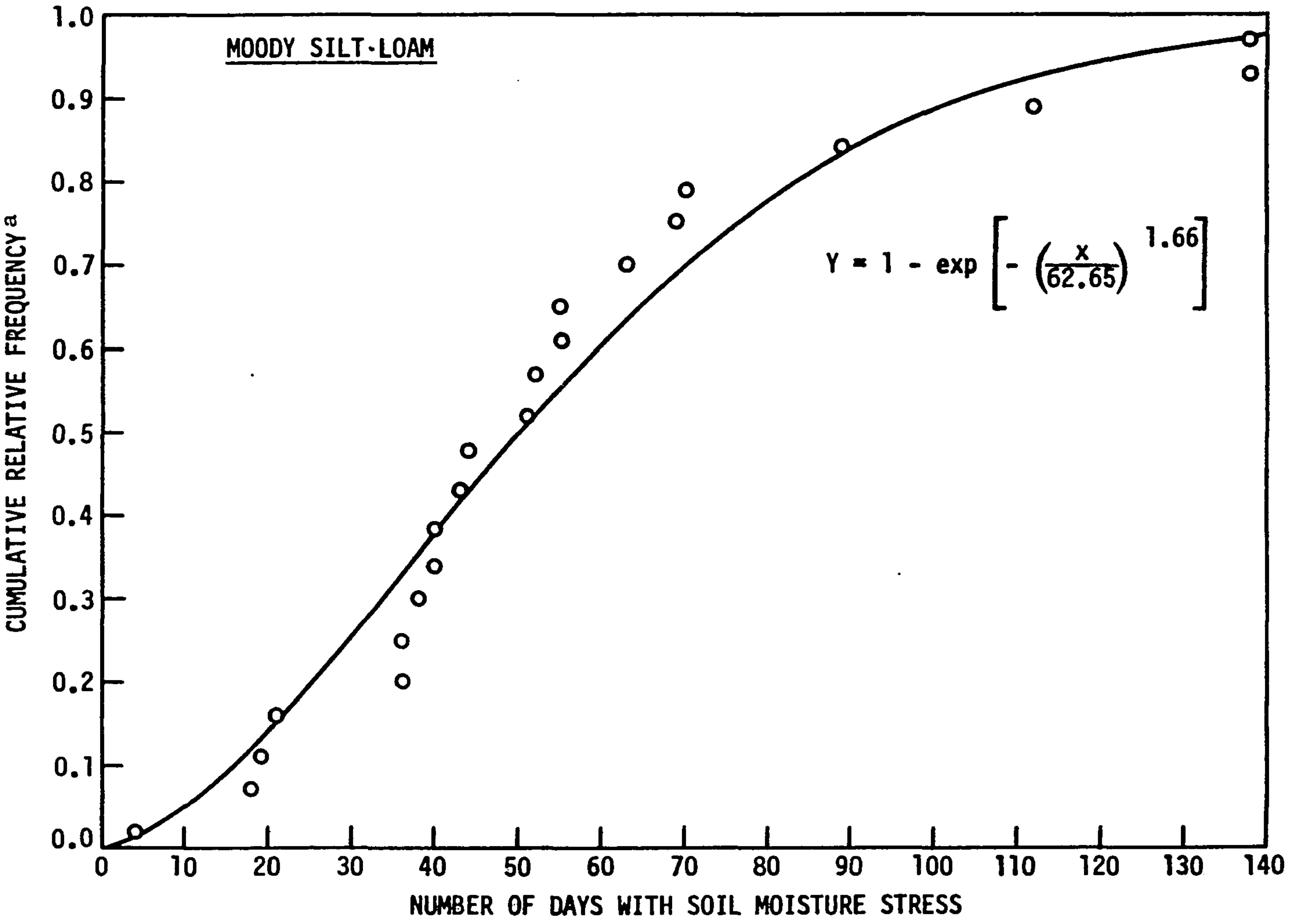

Figure 14. Weibull distribution fitted to the length of soil moisture stress **period for the years 1958-1979. Moody silt·loam, northwest Iowa**

[a] Ordinate shows the probability of less than or equal.

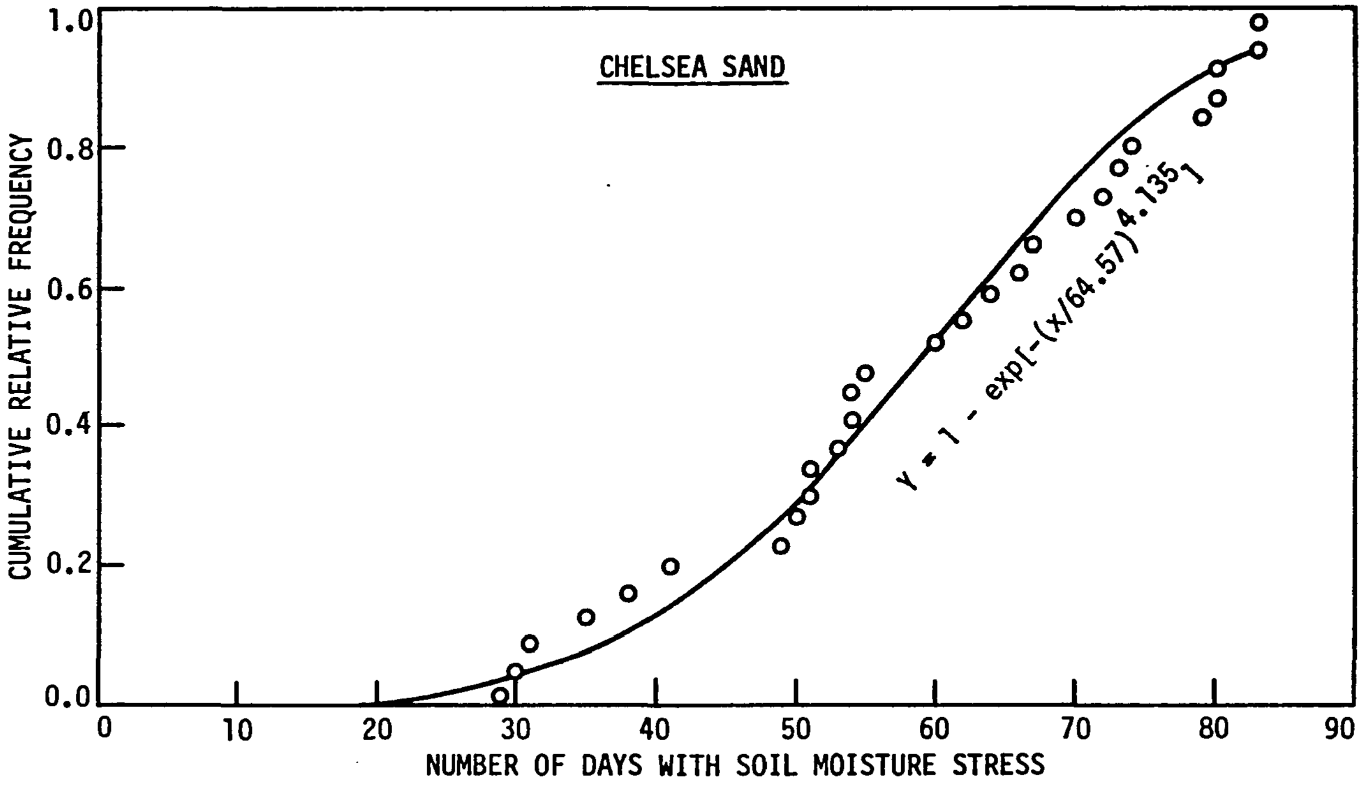

Figure 15. Weibull distribution fitted to the length of moisture stress period for years 1951 through 1958. Chelsea sand, southeast Iowa.

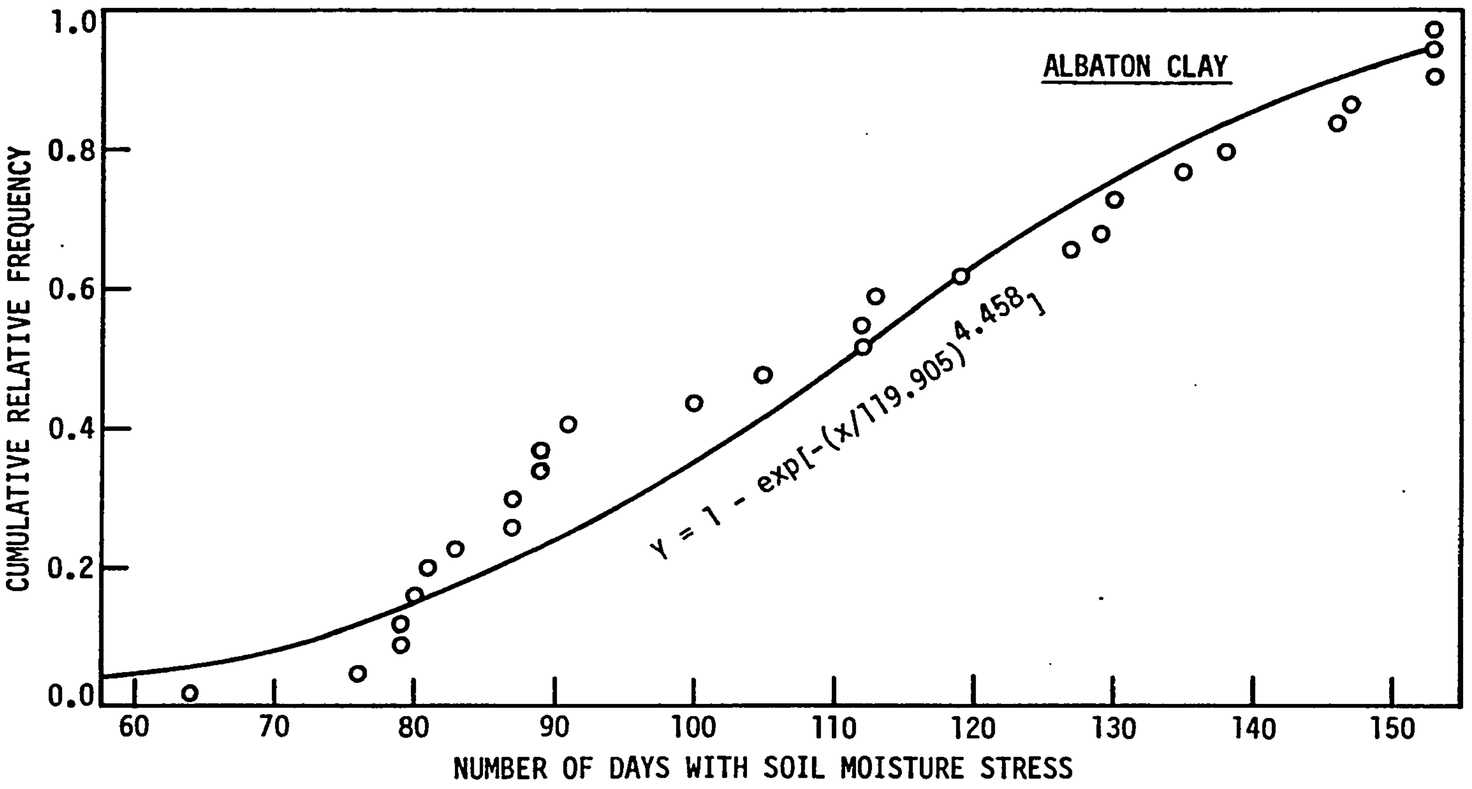

Figure 16. Weibull distribution fitted to the length of moisture stress period for the years 1951 to 1978. Albaton Clay soil, west central Iowa

test criterion (χ^2), defined by $\chi^2 = \Sigma\frac{(\text{observed} - \text{expected})^2}{\text{expected}}$, was calculated as $\chi^2 = 1.0$, with 2.0 (5-2-1) degrees of freedom[1], indicating that there is no significant difference between the observed and expected values of soil moisture shortage occurrence, determined from the Weibull distribution.

Soil moisture stress index

Calculation of weighted stress index A weighted stress index was calculated in the model using the procedure developed by Shaw (1974). A raw stress index for each day was determined as one minus the ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET):

$$\text{Daily raw stress} = 1 - \frac{\text{AET}}{\text{PET}}$$

This relation indicates that days with low soil moisture content, which are not able to meet a high percentage of PET, will have high stress indices, and vice versa. Note that AET is a function of available soil moisture and crop moisture stress, as determined by the effective daily PET. Actual evapotranspiration was calculated in the model based on the work of Shaw (1963). He defined a series of curves to represent low, medium and high PET rates, to estimate AET from PET and available soil moisture.

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[1] The number of degrees of freedom is the number of cells decreased by one and the number of parameters estimated. Two parameters (α and β) were estimated for the Weibull distribution.

Since moisture stress affects yield differentially, depending upon the stage of growth at which stress occurs, silking date was used to give various weights to the raw stress indices, to account for the effect of stage of development. Raw stress indices were summed over five-day periods for eight periods before and nine periods after silking date; various weighting factors were assigned to each period, such that higher weighting factors were given to the periods closer to silking date. Numerical values of the weighting factors are given in Table 3. The seasonal weighted stress index was determined by summing the five-day weighted stress indices for the 17 periods.

The computed values of 85-day weighted stress indices are given in Table 15 for the three soils. For most of the years, Albaton clay had higher weighted stress indices than Moody silt loam; low corn yield obtained in the heavy soil justifies these high values.

Weighted stress index-yield relationship Shaw (1978) used Nicollet silt loam soil moisture characteristics and developed a stress index-yield relationship:

$$Y = 154.25 - 1.89\,X$$

where

Y = corn yield, bu/a

X = 85-day weighted stress index

Among the three soils used in this study, corn yield data were available only for Moody silt loam in the north Doon watershed. Yield data were assembled in an unpublished manuscript by Deboer and Johnson (Agricultural Engineering Department, Iowa State University, Ames).

Table 15. Eighty-five-day weighted stress indices for Moody silt loam, Chelsea sand and Albaton clay

	Eighty-five-day weighted stress index		
Year	Moody silt loam	Chelsea sand	Albaton clay
1951	--	30.5	40.0
1952	--	49.0	45.0
1953	--	68.0	69.0
1954	--	55.5	73.0
1955	--	61.0	64.0
1956	--	45.0	47.5
1957	--	54.0	48.5
1958	50.0	27.0	47.5
1959	48.0	49.0	50.0
1960	38.5	50.0	52.0
1961	40.0	33.0	42.5
1962	35.5	55.0	35.5
1963	51.0	44.0	51.5
1964	39.5	70.0	36.0
1965	38.0	46.0	60.5
1966	51.0	72.0	42.0
1967	76.0	52.0	63.5
1968	72.0	67.5	68.0
1969	26.0	40.0	38.5
1970	56.0	43.0	70.0
1971	44.0	62.0	66.5
1972	31.5	34.0	34.6
1973	33.0	39.5	49.0
1974	59.5	44.5	67.5
1975	45.0	54.5	55.0
1976	57.0	55.5	82.5
1977	34.0	54.0	35.0
1978	28.0	46.0	51.5

Computed values of 85-day weighted stress indices for the years 1958 to 1979 were related to measured yield data (Table 16). The regression line between the corn yield (Y) and 85-day weighted stress index (X) was determined to be:

$$Y = 184.22 - 2.12\,X \qquad r^2 = 0.83$$

where yield is in bu/a (Figure 17).

Estimated corn yields using the above yield-stress index relationship are plotted against measured yield in Figure 18. The yield-stress index relationship is used later to estimate irrigated corn yield and, thereby, yield increase under various irrigation criteria.

Model Response with Irrigation

Estimation of initial soil moisture

It was expected that the initial soil moisture (April 15) used for the runs with no irrigation would be changed after applying irrigation water in the previous year. Thus, a prediction of spring soil moisture with irrigation applied in the previous year was required. To develop an appropriate prediction equation, it was assumed that fall soil moisture and fall-winter rainfall were the most important factors affecting spring soil moisture. Moody silt loam data were used in the analysis, because measured spring soil moisture data were only available for this soil.

Fall soil moisture data were taken as the predicted values of the total soil moisture in the top five feet on September 1 from the runs for which no irrigation water was applied. Fall-winter rainfall data

Table 16. Eighty-five day weighted stress index and yield data from the Doon watershed for the years 1958 through 1979

Year	85-day weighted stress index	Measured yield bu/a
1958	50.32	59.8
1959	48.15	61.0
1960	38.57	96.1
1961	40.06	91.6
1962	35.56	85.6
1963	51.12	97.4
1964	39.61	105.6
1965	37.92	73.7
1966	50.88	86.1
1967	76.30	15.5
1968	72.00	2.9
1969	25.89	139.3
1970	56.28	70.4
1971	43.81	95.3
1972	31.49	114.0
1973	33.37	125.7
1974	59.63	61.1
1975	45.18	96.4
1976	57.44	64.4
1977	33.98	106.0
1978	28.15	114.5
1979	31.31	112.8

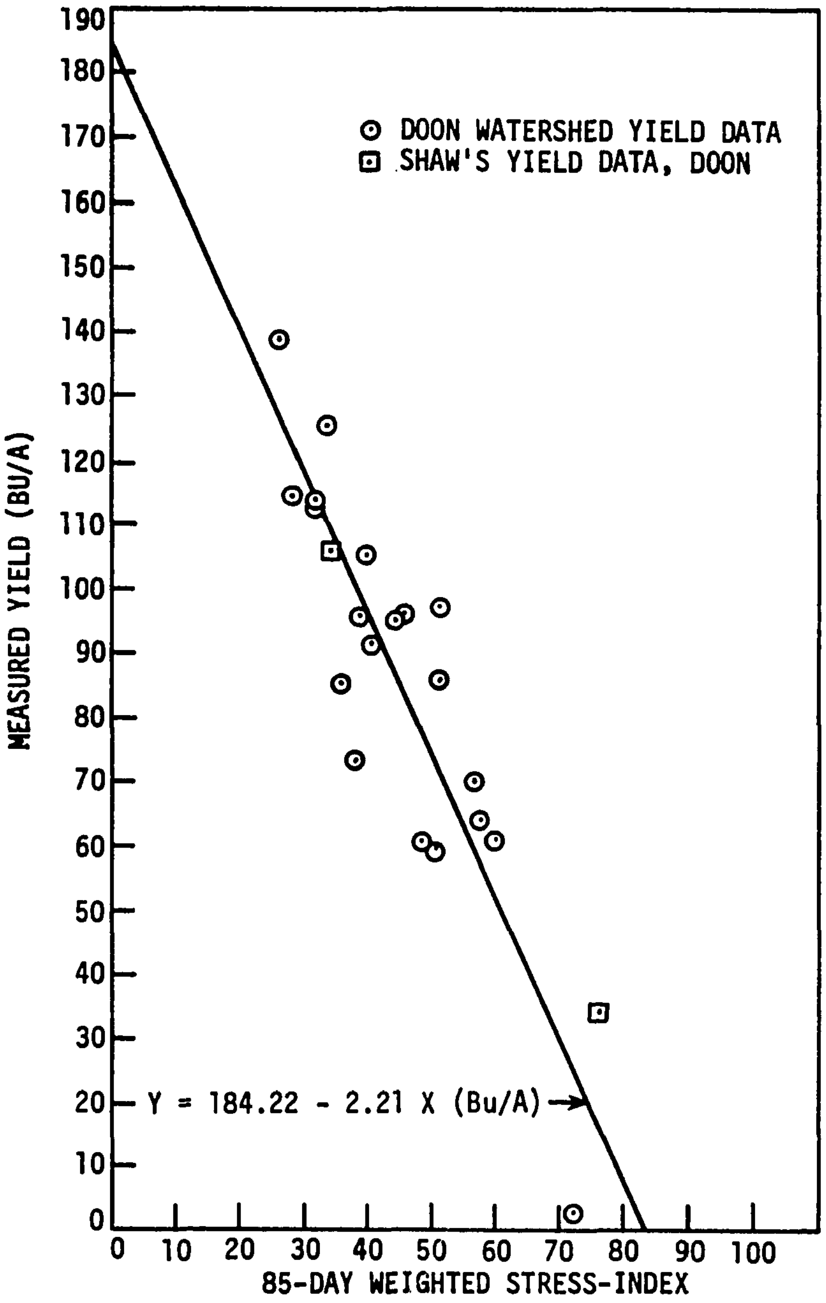

Figure 17. Weighted stress index-yield relationship for silt loam located at North Doon watershed, (1958-1979)

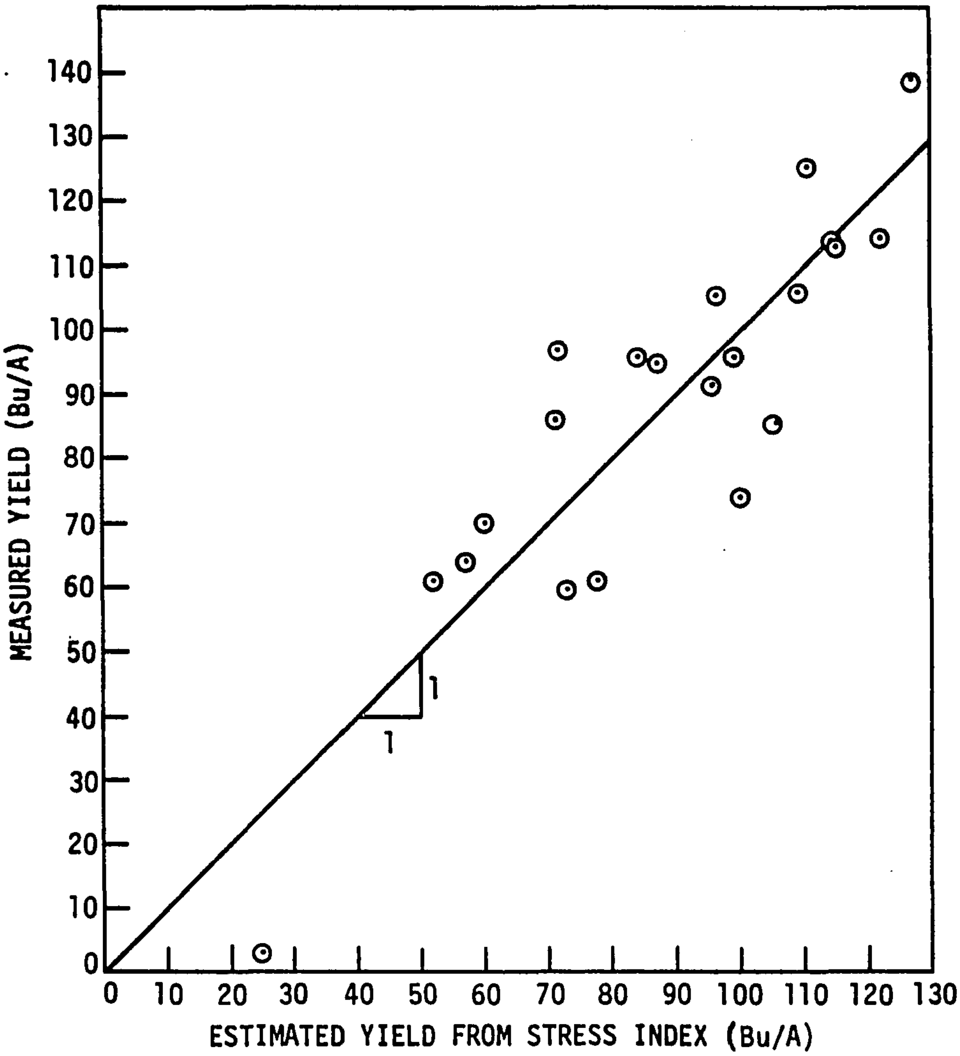

Figure 18. Estimated and measured yield relationship, North Doon watershed 1958 through 1979

(summation of the rainfall from September 1 to April 15) were taken from monthly rainfall records at the Rock Rapids station, since no records were available on winter rainfall at the Doon station; see Table 17.

A correlation analysis among the data given in Table 17 indicated that there was a low correlation between spring and fall soil moisture. Stepwise regression-correlation analysis was used to determine how fall-winter rainfall, fall soil moisture, and their interaction related to spring soil moisture. This analysis showed that only fall-winter rainfall met the 0.05 significance level for entry into the model; that is, spring soil moisture was not closely related to fall soil moisture, as defined, but was related to fall-winter rainfall. Thus, the spring soil moisture used in the runs without irrigation was also used in the program when irrigation water was applied.

Irrigation scheduling criteria

The irrigation part of the model was programmed so that the irrigation water could be applied at any predetermined level of soil moisture content in the active root zone. Gross depth of irrigation and the application time period are both input to the model, and can be adjusted by the user to give an appropriate application rate for each soil. Therefore, irrigation will be initiated at a certain rate whenever the soil moisture in the active root zone falls to less than a given percentage of the available soil moisture (ASM) in the same zone.

Various irrigation scheduling criteria were used for Moody silt loam, Chelsea sand and Albaton clay. The model predicted different amounts of annual irrigation water requirements, and irrigation

Table 17. Fall soil moisture, fall-winter rainfall, and spring soil moisture for the period 1958 through 1979, for Moody silt loam, Doon watershed

	Fall soil moisture Top 5 ft on September 1	Total rainfall September 1 to April 15	Spring soil moisture Top 5 ft on April 15
	inches	inches	inches
58-59	10.55	4.28	11.00
59-60	13.07	12.48	18.50
60-61	14.10	10.90	17.80
61-62	14.30	13.42	16.30
62-63	14.10	4.75	12.00
63-64	11.10	8.92	15.30
64-65	12.30	13.76	16.30
65-66	11.50	11.75	15.90
66-67	13.10	11.88	12.00
67-68	11.10	6.06	9.70
68-69	10.04	19.45	22.30
69-70	12.34	7.46	13.30
70-71	10.44	13.04	14.20
71-72	11.05	9.96	13.00
72-73	11.75	12.70	18.50
73-74	12.35	10.71	15.70
74-75	13.36	7.24	19.60
75-76	14.30	9.97	17.40
76-77	10.76	8.93	15.40
77-78	12.49	15.34	19.60
78-79	14.03	11.17	19.80

frequency under each scheduling criterion for the three soils. Tables A10 to A19 summarize the model output under various scheduling criteria used for Moody silt loam, Chelsea sand and Albaton clay, respectively.

Moody silt loam Irrigation water was applied when needed from April 15 (beginning of the run) and continued to September 1. Four different irrigation scheduling criteria used for this soil were:

1. 2.0 inch application at 35% of ASM in the active root zone.
2. 2.0 inch application at 50% of ASM in the active root zone.
3. 4.0 inch application at 50% of ASM in the active root zone.
4. 2.0 inch application at 70% of ASM in the active root zone.

Moody silt loam has moderate to high available soil moisture (2.0 in/ft) and high field capacity (3.0-4.0 in/ft). Application of 2.0 inch at 70% and 4.0 inch at 50% of ASM filled the top five feet to its field capacity, assuming an irrigation efficiency of 60 to 70%. A 2.0 inch irrigation at 35 and 50% of ASM raised the soil moisture to less than its maximum water holding capacity, increasing water use efficiency by decreasing water losses thorugh deep percolation and surface runoff.

Chelsea sand Chelsea sand has low water holding capacity and very high permeability. It was assumed that in these soils, applying water more frequently at lower application depth would increase application efficiency by decreasing deep percolation.

To account for gradual root development, non-uniform irrigation scheduling was used. In this procedure, irrigation started at a lower depth early in the season, and increased according to root penetration into the soil. Various application depths for different periods of the growing season were determined based on root distribution with time, given by Shaw (1963), and percent available soil moisture at irrigation, as given in Table 18.

Enough irrigation water was added in each period to fill the active root zone to its field capacity. Thus, three different irrigation schedules used for Chelsea sand were:

1. 1.0-3.0 inch at 35% of ASM in the active root zone.
2. 0.75-2.5 inch at 50% of ASM in the active root zone.
3. 0.50-1.5 inch at 70% of ASM in the active root zone.

Irrigation was started on June 1 as needed, and continued to September 1.

Albaton clay Albaton clay soil was irrigated at 50% and 70% of ASM in the active root zone. Soil moisture content was not allowed to fall to less than 50% of the available soil moisture, because of the cracking properties of Albaton clay under dry conditions.

Irrigation was initiated on June 1 as needed, and continued through August 20, with a low rate of about 0.10 in/h.

The three different irrigation schedules used for Albaton clay were:

1. 5.0 inch application at 50% of ASM in the active root zone.
2. 1.5 inch application at 70% of ASM in the active root zone.
3. 3.5 inch application at 70% of ASM in the active root zone.

Assuming an irrigation efficiency of 70 percent, applying 5.0 inch at 50% and 3.5 inch at 70% of ASM fills up the top five feet to its field capacity, whereas 1.5 inch at 70% of ASM can only increase the soil moisture to about 80% of its maximum capacity.

Table 18. Irrigation application depth under various moisture level criteria used for scheduling irrigation on Chelsea sand, southeast Iowa

Date	Depth of active root zone ft	Irrigation amount at given percentage of ASM in the active root zone inches		
		70%	50%	35%
To June 14	1	0.5	0.75	1.0
June 15 - July 11	1 - 3	1.0	1.5	2.0
July 12 - August 1	3 - 5	1.5	2.0	2.5
After August 1	5	1.5	2.5	3.0

Comparison of the model response to various irrigation criteria

Various irrigation scheduling criteria used for each soil required different amounts of annual irrigation water, application frequencies, irrigation efficiencies, increases in surface runoff and deep percolation, and also moisture stress reductions.

Seasonal irrigation water requirement Seasonal irrigation applications were established in the model by adding the amount of water required for each event. Frequency of irrigation application was calculated by dividing the total irrigation requirement by gross depth in each application. For Chelsea sand, with variable application depth during the growing season, an indicator was used in the model to add the number of events per growing season.

Tables 19 to 21 present the number of applications in various years used in the study for Moody silt loam, Albaton clay and Chelsea sand, respectively. Mean, standard deviation of depth, and average number of events per growing season were determined under various irrigation scheduling criteria used for each soil (see Tables 22 to 24).

Comparing the irrigation water requirement with various scheduling criteria, the following results were obtained.

Allowing the soil moisture to decrease to 35% of the available soil moisture (ASM) before applying irrigation water resulted in the lowest annual irrigation water use, with the highest irrigation efficiency. However, this low soil moisture will decrease yield. The initiation of irrigation at 70% of ASM resulted in the highest annual water use, as illustrated in Figures 19 to 21 for Moody silt loam, Chelsea sand, and Albaton clay, respectively.

Applying irrigation water at 50% of ASM, which is the usual procedure, will keep the active root zone above the critical moisture level, thereby decreasing the effect of moisture stress on corn yield. The annual irrigation requirement and application efficiency for irrigation at 50% of ASM were between the other two criteria (i.e. irrigation at 35% and 70% of ASM) for most years (see Figures 19 to 21).

Frequency distribution of irrigation water requirement Frequency distributions of annual irrigation water requirement were determined for each soil, using the yearly irrigation water application values under various irrigation schedules. Cumulative sample frequencies of annual irrigation requirements are illustrated in Figures 22 to 24 for Moody

Table 19. Comparison of the number of irrigation water applications under various irrigation scheduling criteria for Moody silt loam, 1958-1979

Year	Number of 2.0 inch applications at the given percentage of ASM 35%	 50%	 70%	Number of 4.0 inch applications at 50% of the ASM
1958	3	4	7	2
1959	3	4	7	3
1960	1	2	4	2
1961	1	3	4	2
1962	3	4	5	3
1963	3	6	7	3
1964	1	3	5	2
1965	1	3	4	2
1966	2	3	5	2
1967	4	6	8	4
1968	4	6	9	3
1969	1	1	3	1
1970	3	4	7	3
1971	2	3	6	2
1972	2	3	4	2
1973	1	3	6	2
1974	3	5	6	3
1975	2	3	6	2
1976	3	5	7	2
1977	1	3	5	2
1978	0	2	4	1
1979	0	1	3	1

Table 20. Comparison of yearly irrigation frequencies for various irrigation criteria for Albaton clay, 1951-1978

	Irrigation scheduling criteria		
Year	5.0 inch at 50% ASM	1.5 inch at 70% ASM	3.5 inch at 70% ASM
1951	2	7	4
1952	3	9	5
1953	3	11	6
1954	3	10	6
1955	3	12	6
1956	3	10	6
1957	3	10	5
1958	3	8	4
1959	3	9	6
1960	3	10	6
1961	2	8	4
1962	2	6	4
1963	2	8	5
1964	2	7	5
1965	3	10	6
1966	2	8	4
1967	3	9	5
1968	4	11	6
1969	2	8	5
1970	3	10	5
1971	3	10	5
1972	2	8	5
1973	3	9	5
1974	3	9	5
1975	3	9	4
1976	4	12	7
1977	2	8	5
1978	3	9	6

Table 21. Annual irrigation water requirement and frequency of application for various irrigation criteria, Chelsea sand, 1951-1978

	Percentage of ASM before irrigation application					
	35%		50%		70%	
Year	# of events per year	annual depth in	# of events per year	annual depth in	# of events per year	annual depth in
1951	1	3.0	3	7.0	10	13.0
1952	2	5.0	4	8.0	11	13.50
1953	4	10.5	5	12.0	13	17.0
1954	3	7.0	5	11.25	12	14.0
1955	3	7.5	5	12.50	14	18.0
1956	3	7.5	5	9.75	10	12.50
1957	3	8.5	6	12.50	11	14.0
1958	1	3.0	3	6.0	10	12.0
1959	4	9.5	6	11.25	13	17.0
1960	3	8.5	6	14.0	11	15.0
1961	3	8.0	4	8.0	12	14.0
1962	4	10.5	6	12.50	11	15.0
1963	3	7.5	6	11.75	13	15.50
1964	4	10.5	7	13.25	14	17.50
1965	3	7.5	6	12.0	10	13.0
1966	4	10.5	6	13.0	13	17.0
1967	3	7.5	5	10.5	11	14.0
1968	3	8.0	6	12.0	11	14.0
1969	3	8.5	5	11.0	10	12.50
1970	2	4.5	5	8.25	11	13.0
1971	5	12.5	8	15.25	14	17.0
1972	2	5.0	4	8.50	10	12.50
1973	3	8.5	4	7.75	12	14.50
1974	2	5.5	5	10.50	11	14.50
1975	3	7.5	6	11.25	10	12.50
1976	3	8.0	7	12.75	15	18.50
1977	3	7.0	5	9.50	12	14.50
1978	2	5.5	5	10.50	13	16.50

Table 22. Irrigation event statistics for various irrigation scheduling criteria for Moody silt loam, north Doon watershed

Statistic	2.0 inch at 35% ASM	2.0 inch at 50% ASM	2.0 inch at 70% ASM	4.0 inch at 50% ASM
Mean depth applied, inches	4.0	7.0	11.18	8.9
Standard deviation of depth, inches	2.39	2.88	3.25	3.01
Average number of events per season	2.0	3.5	5.6	2.2

Table 23. Irrigation event statistics for various irrigation scheduling criteria for Chelsea sand, southeast Iowa

Statistic	1.0-3.0 inch at 35% ASM	0.75-2.5 inch at 50% ASM	0.5-1.5 inch at 70% ASM
Mean depth applied, inches	7.59	10.80	14.71
Standard deviation of depth, inches	2.28	2.25	1.90
Average number of events per season	2.90	5.40	11.70

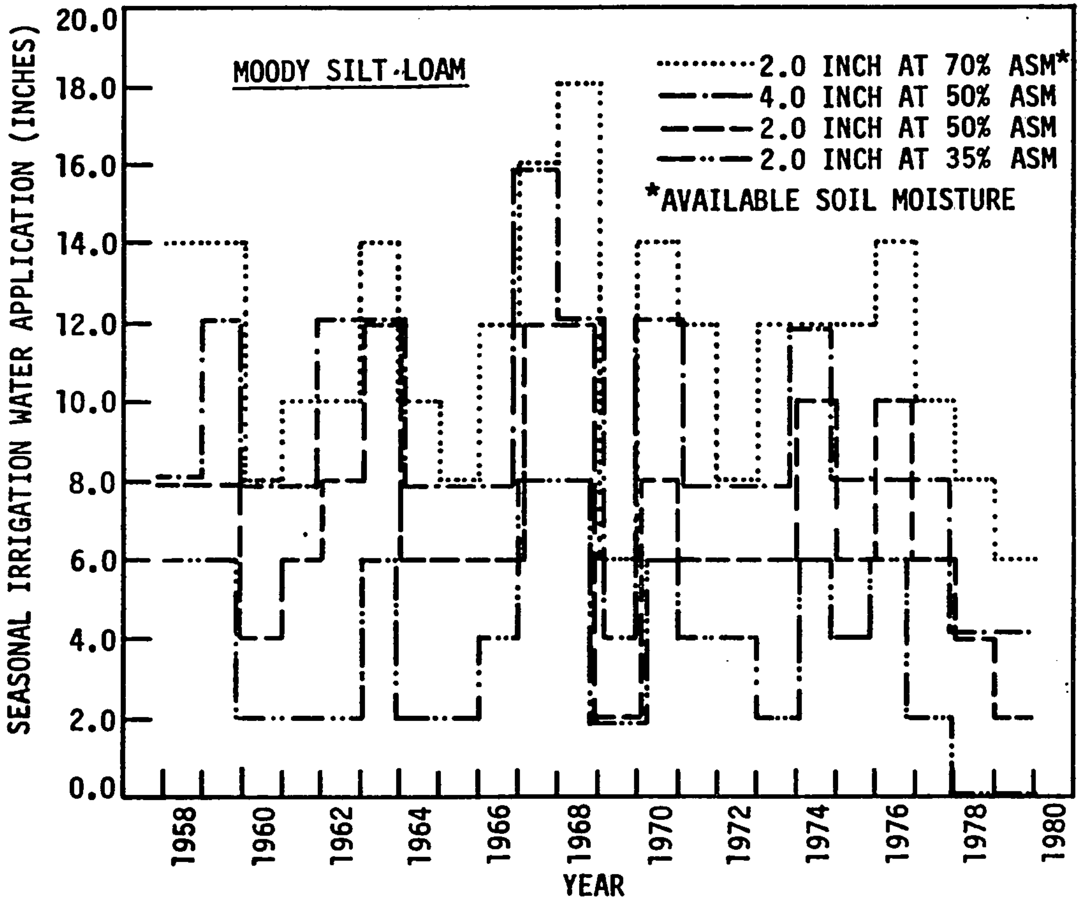

Figure 19. **Comparison of the annual irrigation water requirements for various irrigation scheduling criteria.** Moody silt **loam, Doon watershed, northwest, Iowa**

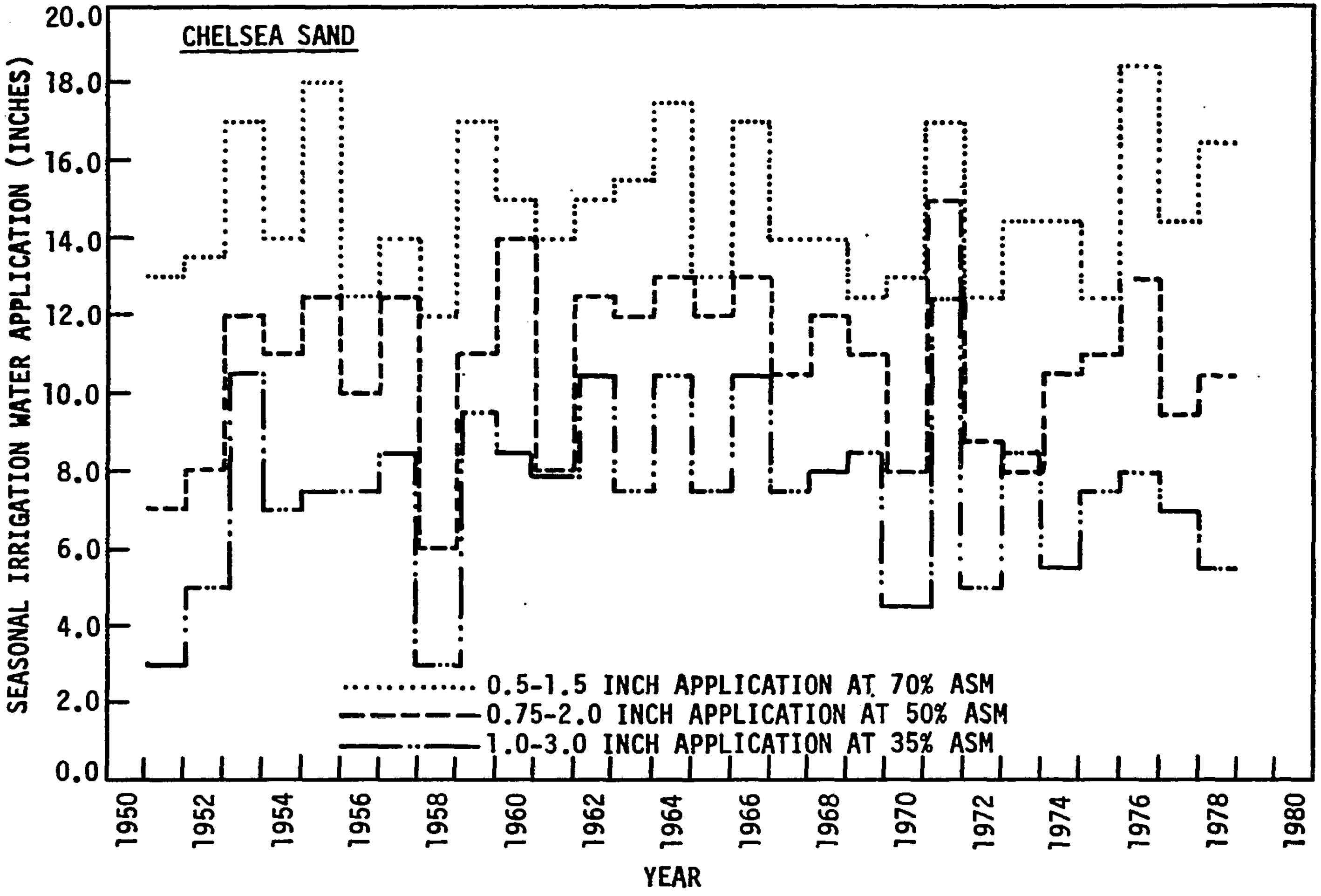

Figure 20. Seasonal total irrigation water requirements for three different irrigation criteria. Chelsea sand, southeast Iowa

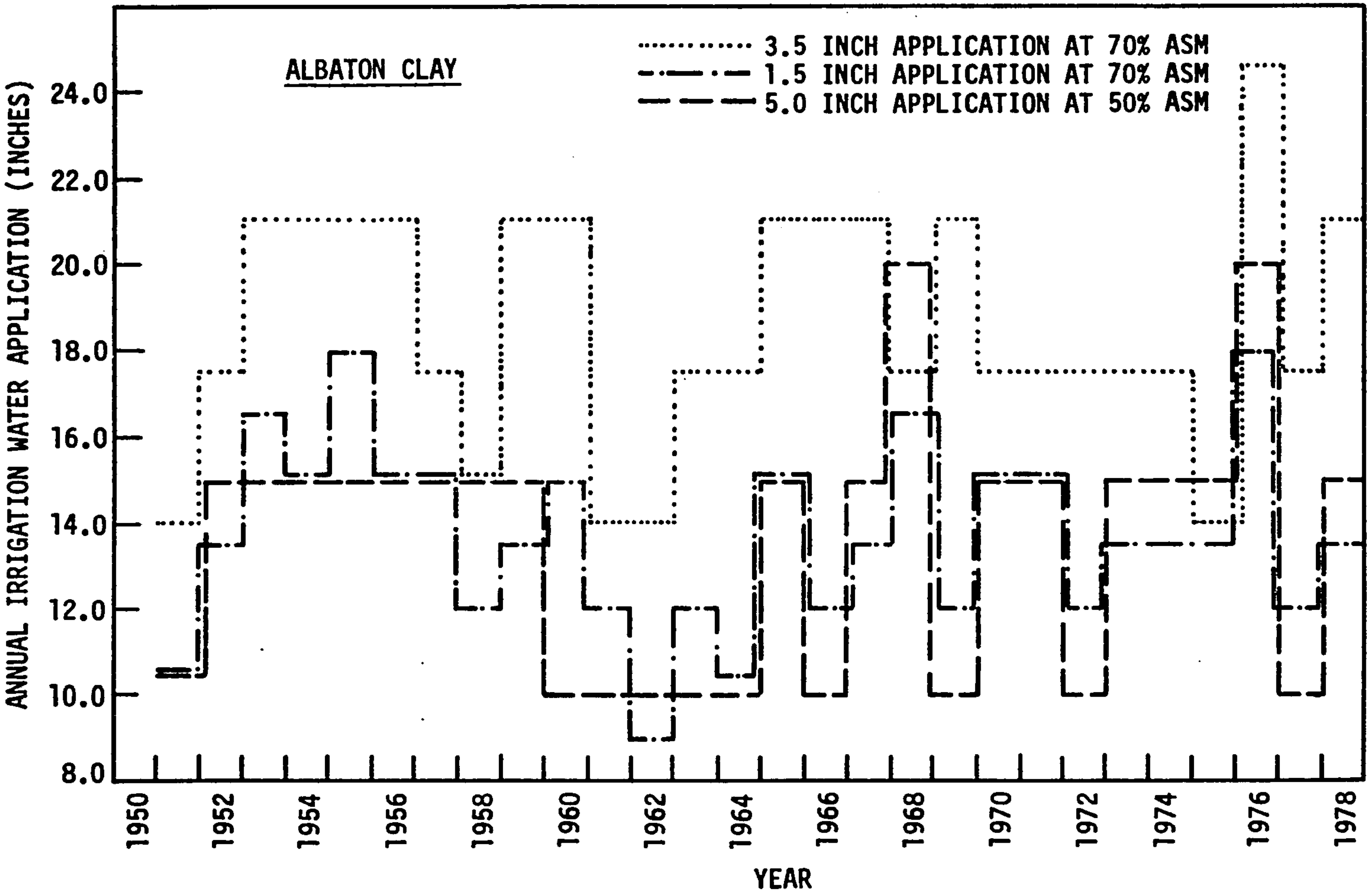

Figure 21. **Comparison of the annual irrigation water application under three different irrigation scheduling criteria. Albaton Clay soil, west central Iowa**

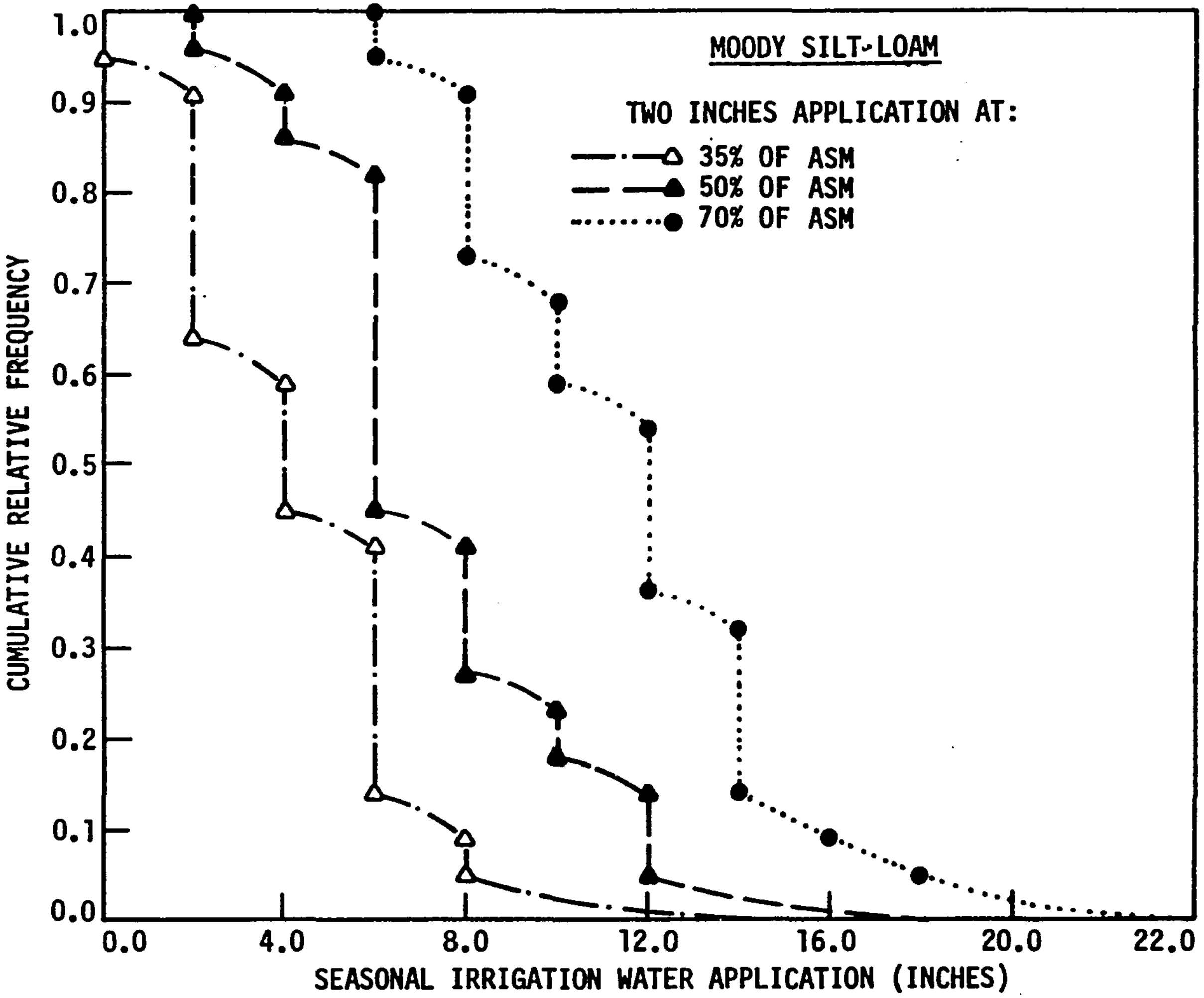

Figure 22. Cumulative sample frequency distribution of annual irrigation water requirements. Moody silt loam, Doon watershed, northwest Iowa

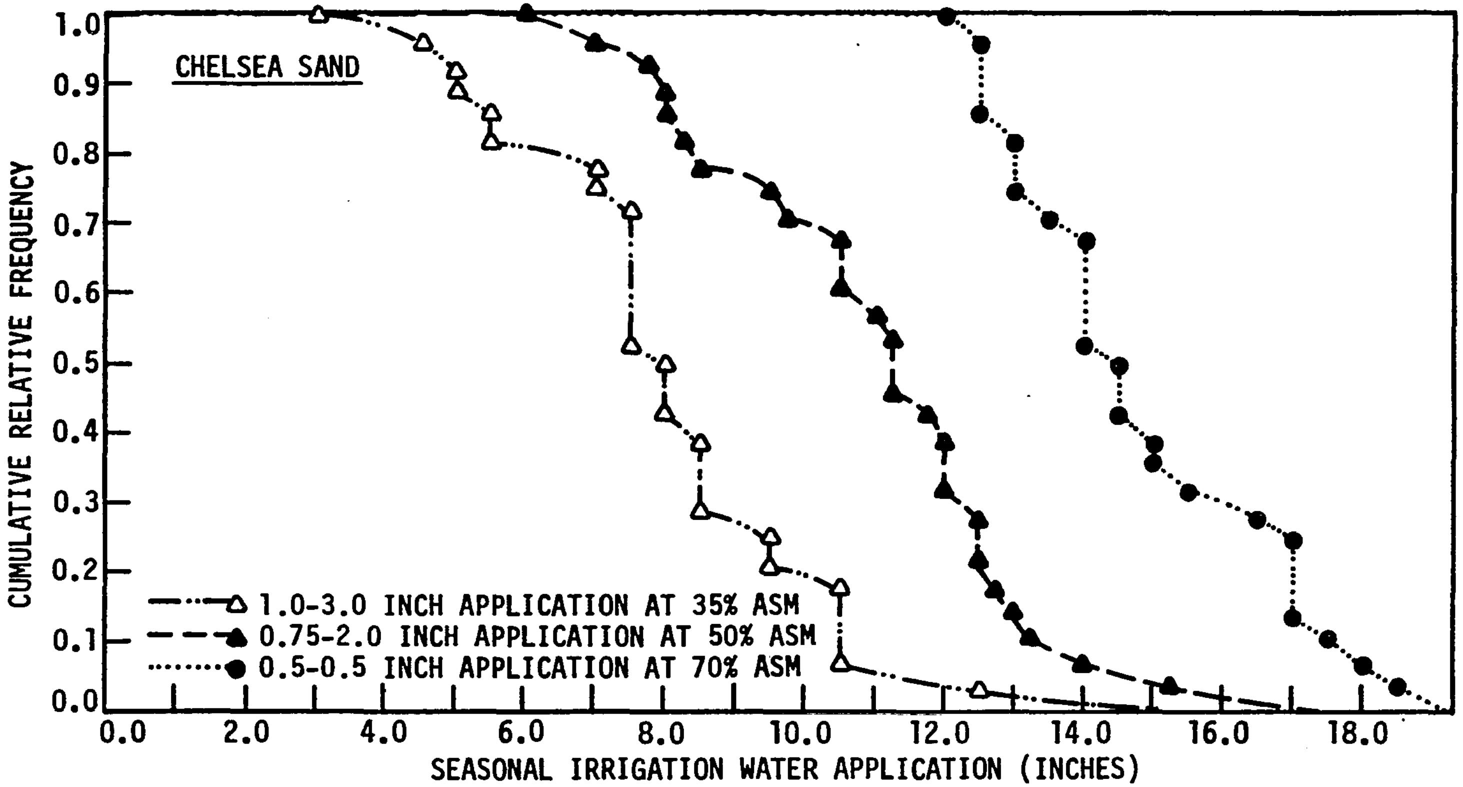

Figure 23. Cumulative sample frequency distribution of annual irrigation water requirements. Chelsea sand, southeast Iowa

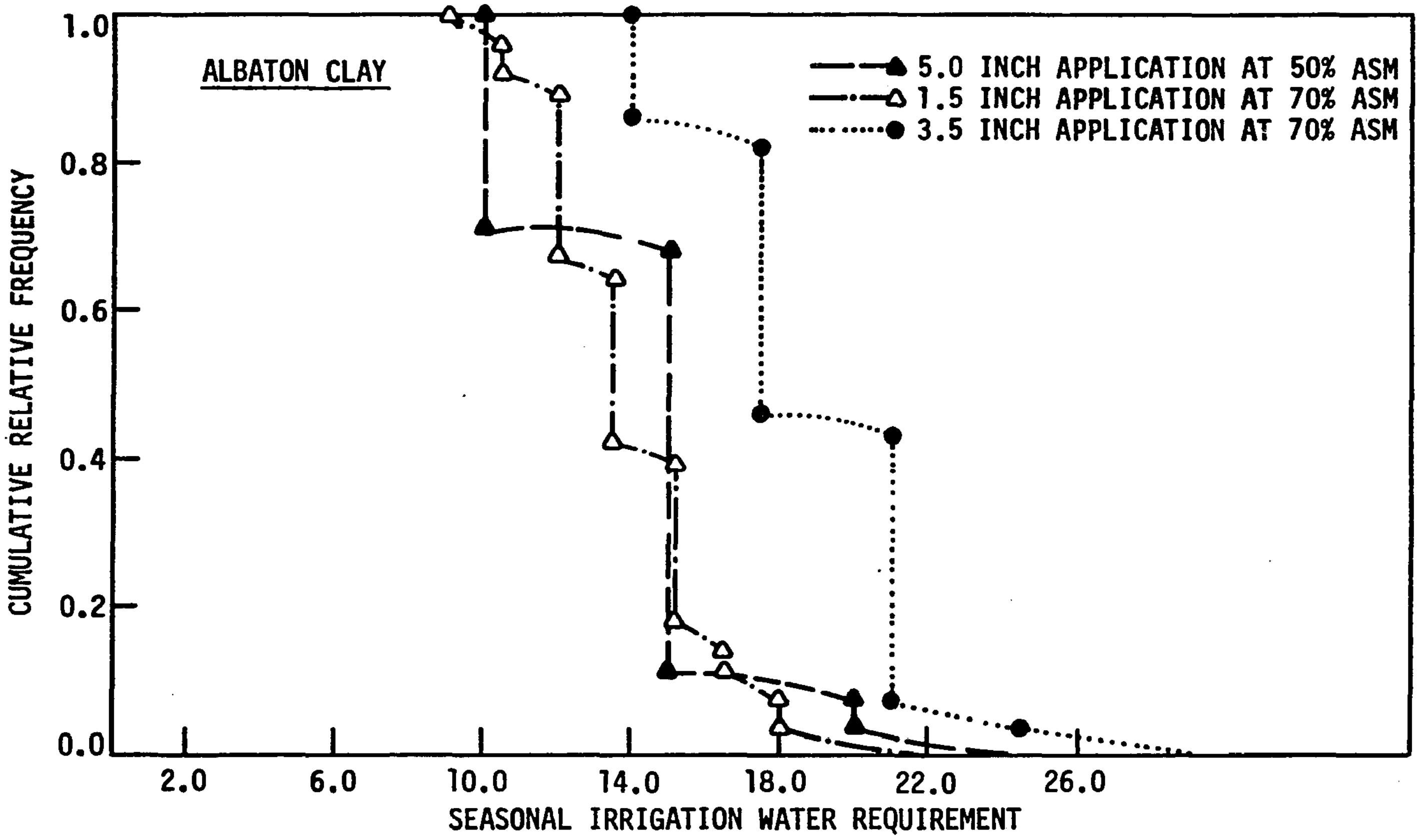

Figure 24. Cumulative sample frequency distribution of annual irrigation water requirements. Albaton Clay soil, west central Iowa

Table 24. Irrigation event statistics for various irrigation scheduling criteria for Albaton clay, west central Iowa

Statistics	5.0 inch at 50% ASM	1.5 inch at 70% ASM	3.5 inch at 70% ASM
Mean depth applied, inches	13.75	13.66	18.13
Standard deviation of depth, in	2.93	2.17	2.87
Average number of events per season	2.75	9.10	5.18

silt loam, Chelsea sand and Albaton clay, respectively.

Monthly irrigation amount and the associated date of individual applications within each month were predicted for the three soils under each irrigation criterion, as given in Table A20 to A29. These data were used to plot the cumulative sample frequency distributions of irrigation water requirements by month (see Figures 25 to 27).

Considering the values and distributions of annual and monthly irrigation requirements, the following conclusions were made:

1. Irrigation application at 35% of ASM resulted in two years with no irrigation, and a maximum application of 8.0 inches for Moody silt loam, while in Chelsea sand all years required at least 3.0 inch application, with maximum annual water use of 12.5 inches. In the monthly distribution, only a few years indicated irrigation application in June, most years had at least a 2.0 inch application in July, and all years had 2.0 to 6.0 inch application in August, for both Moody silt loam and

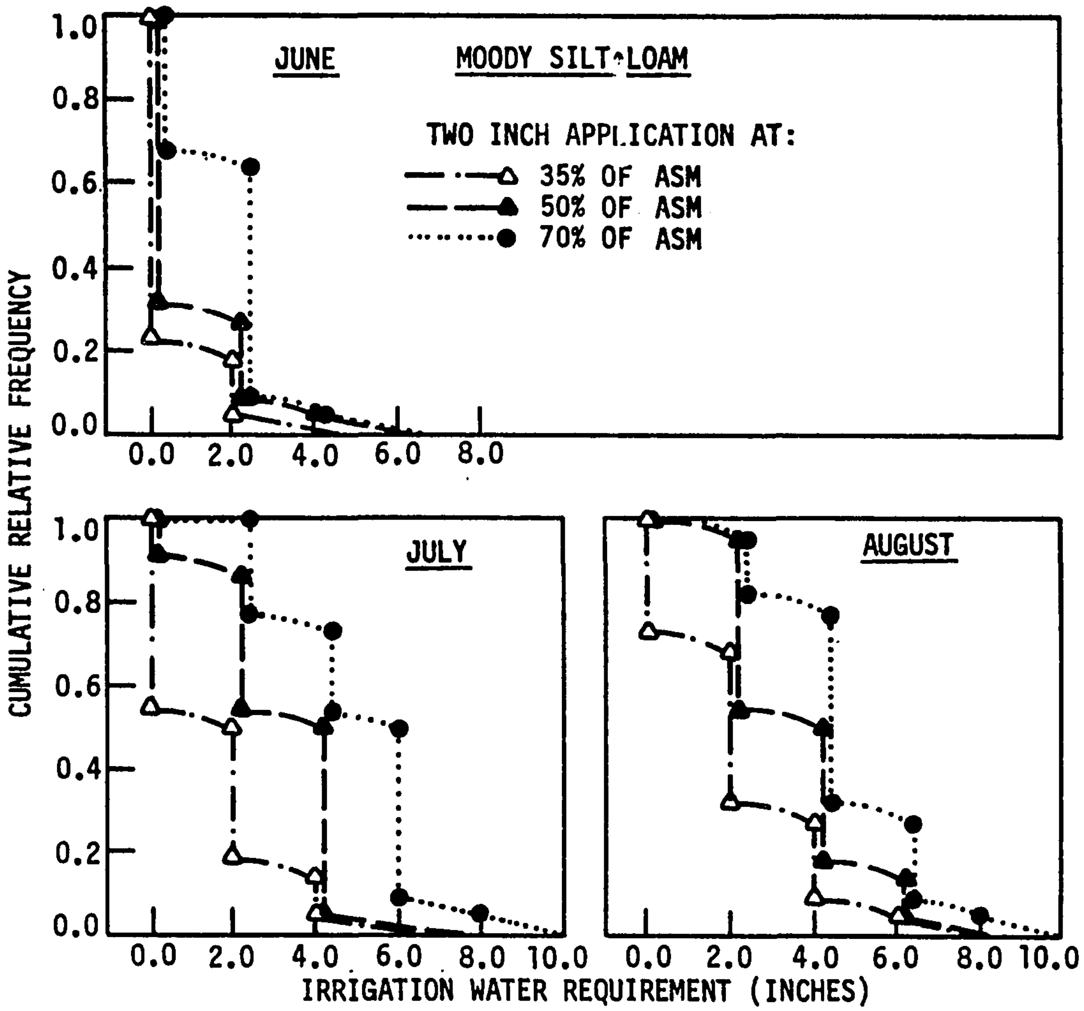

Figure 25. Cumulative sample frequency distribution of monthly irrigation water requirement. Moody silt loam, Doon watershed, northwest Iowa

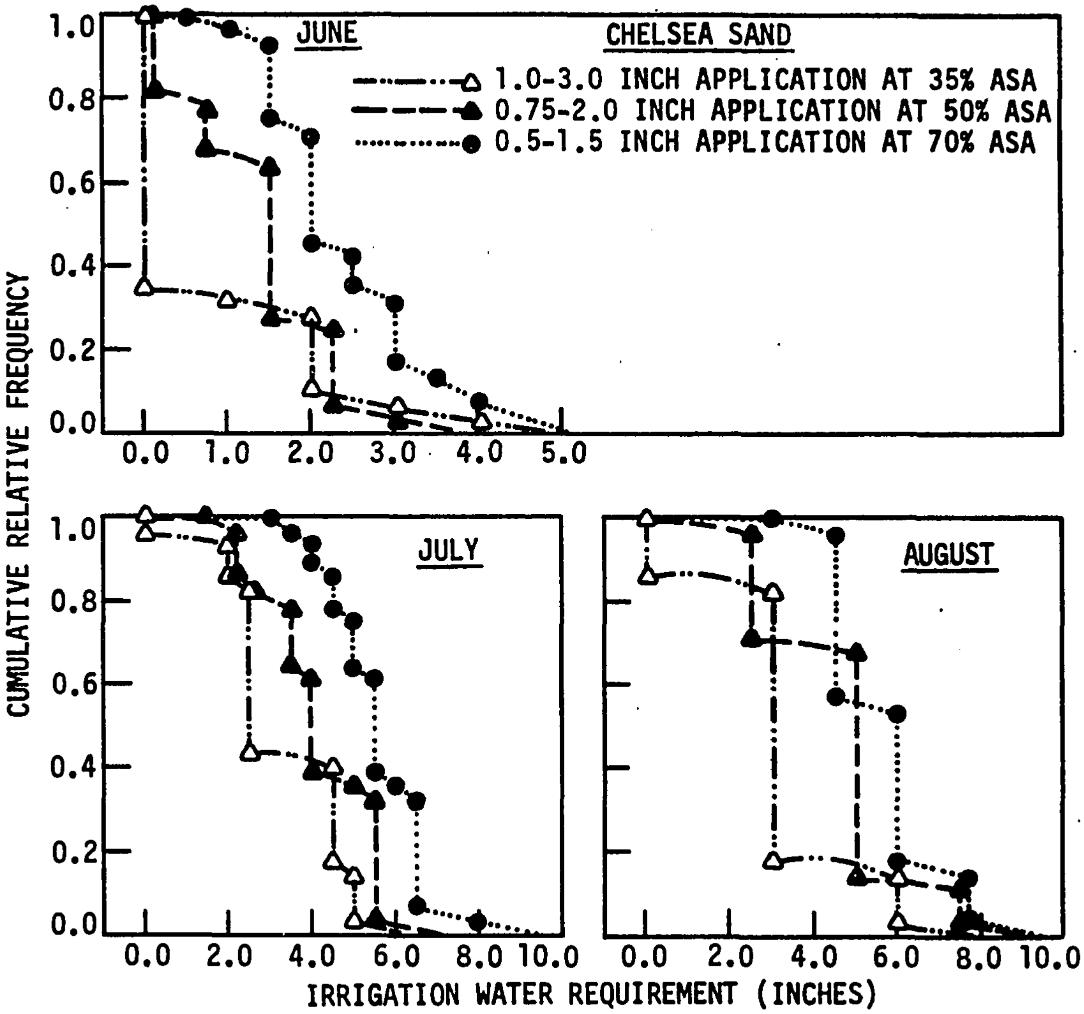

Figure 26. Cumulative sample frequency distribution of monthly irrigation water requirements. Chelsea sand, southeast Iowa

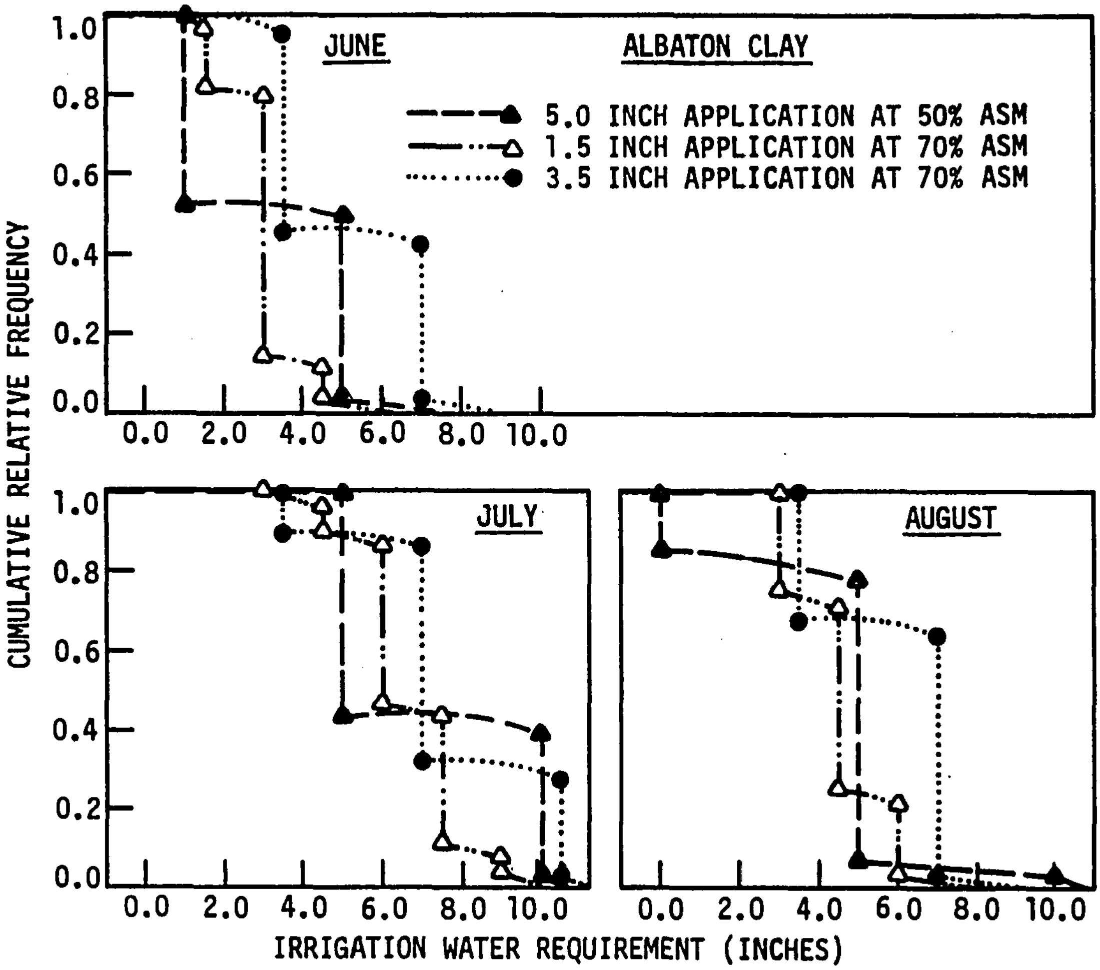

Figure 27. Cumulative sample frequency distribution of monthly irrigation water requirements. Albaton Clay soil, west central Iowa.

Albaton clay.

2. Irrigation application at 50% of ASM resulted in a maximum annual irrigation water use of 12.0, 15.0 and 20.0 inches, and a minimum requirement of 2.0, 6.0 and 10.0 inches for Moody silt loam, Chelsea sand, and Albaton clay, respectively. The monthly distribution indicated that in most years Moody silt loam was not irrigated in June; Chelsea sand had 1.0 to 4.0 inches applied, and Albaton clay was irrigated once (5.0 inch) half the years, and was not irrigated the remaining years. In July, 2.0 to 5.0 inches were applied; 2.0 to 8.0 inches were applied in August to Moody silt loam and Chelsea sand. Albaton clay required 5.0 to 10.0 inches of irrigation water in both July and August.

3. Application at 70% of ASM, which represents a high level of management, indicated a maximum of 18.0 inches of water required for all three soils, except that application of 3.5 inches of water at 70% of ASM for Albaton clay resulted in a maximum requirement of 25.0 inches. The minimum seasonal irrigation water used was 6.0, 12.0, and 9.0 inches, for Moody silt loam, Chelsea sand, and Albaton clay, respectively. The monthly irrigation distribution indicated that for most years Moody silt loam requires at least a 2.0 inch application in June and 2.0 to 8.0 inches in July and August. Chelsea sand and Albaton clay require 1.0 to 4.0 inches of water in June, and 3.0 to 8.0 inches in July and August.

To determine a specific distribution for annual irrigation water requirements, three different distributions - Normal, Gamma and Weibull - were fitted to the annual amount of water used under various irrigation schedules for each soil. The Weibull distribution was selected as the best fit, and the distribution parameters were estimated by using the maximum likelihood procedure. Figures 28 to 30 illustrate the Weibull distribution fitted to the annual irrigation water requirements for various schedules for Moody silt loam, Chelsea sand and Albaton clay, respectively.

Goodness-of-fit for the Weibull distribution was tested using a chi-square test. Chelsea sand data were used in the test, and resulted in the following values for the test criterion (χ^2) for the three irrigation scheduling criteria:

$\chi^2 = 3.65$ for irrigation at 35% of ASM

$\chi^2 = 3.30$ for irrigation at 50% of ASM

$\chi^2 = 5.05$ for irrigation at 70% of ASM

The number of degrees of freedom was two for all soils, indicating no significant difference between observed and expected values of annual irrigation application from the Weibull distribution.

Seasonal surface runoff and deep percolation To determine the increase in surface runoff and deep percolation due to irrigation, seasonal surface runoff and deep percolation were compared under natural conditions and various irrigation scheduling criteria.

Figures 31 and 32 illustrate the comparison of surface runoff for Moody silt loam and Albaton clay, respectively. No surface runoff was generated for Chelsea sand because of its high permeability.

Comparison of surface runoff produced under natural conditions and irrigation application indicated that the increase in surface runoff due to irrigation is greater for wet years than for dry years, which is

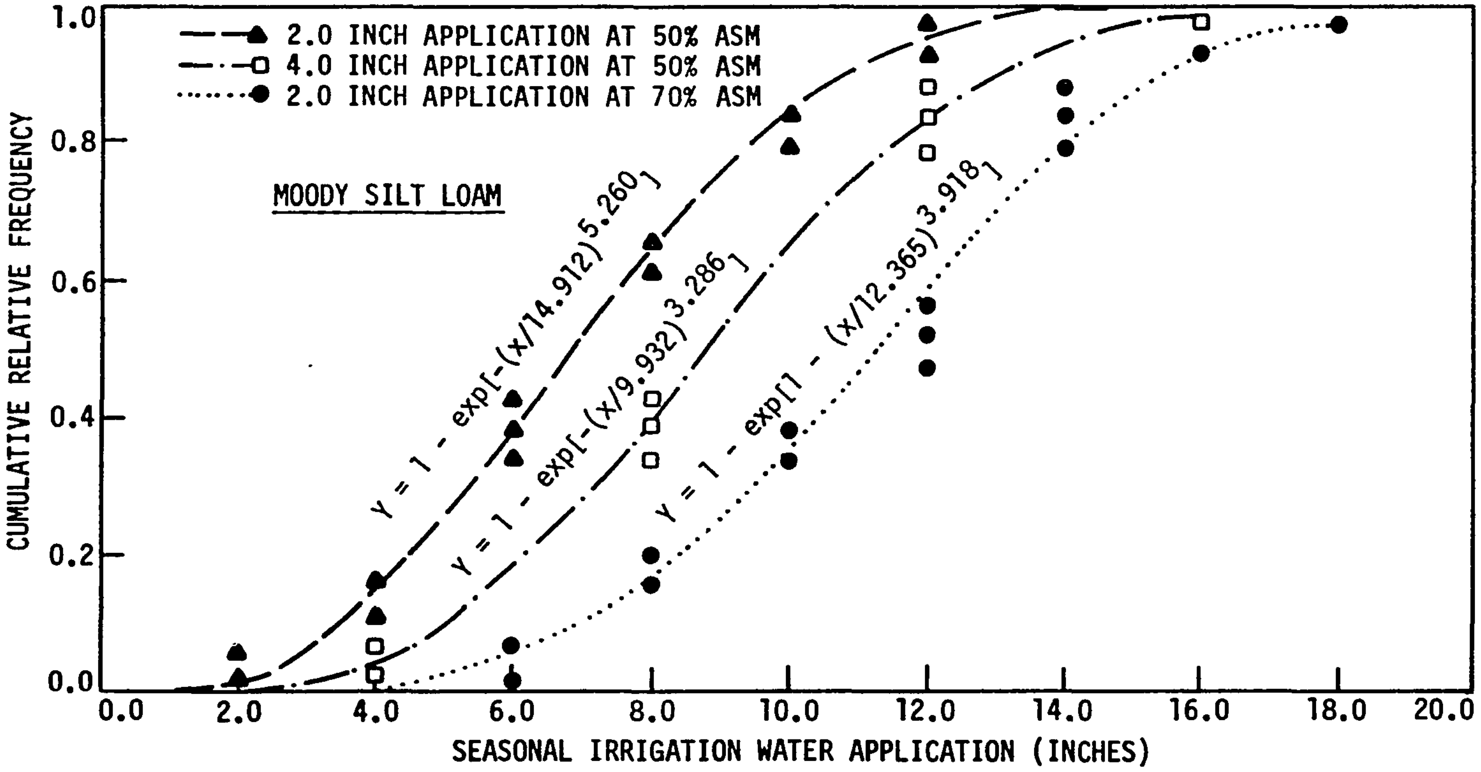

Figure 28. **Weibull distribution fitted to the annual irrigation water requirements. Moody silt loam, Doon watershed, northwest Iowa**

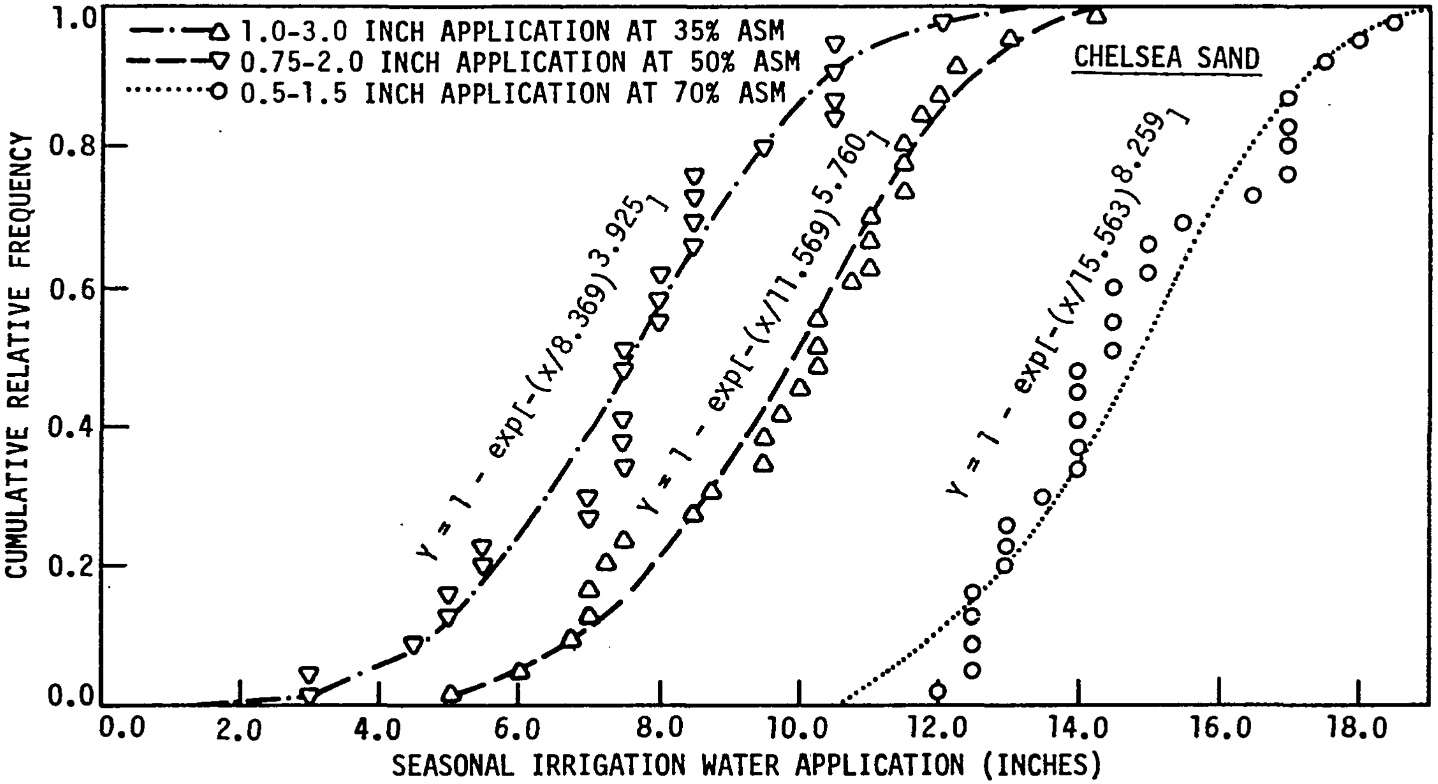

Figure 29. Weibull distribution fitted to the annual irrigation requirements. Chelsea sand, southeast Iowa

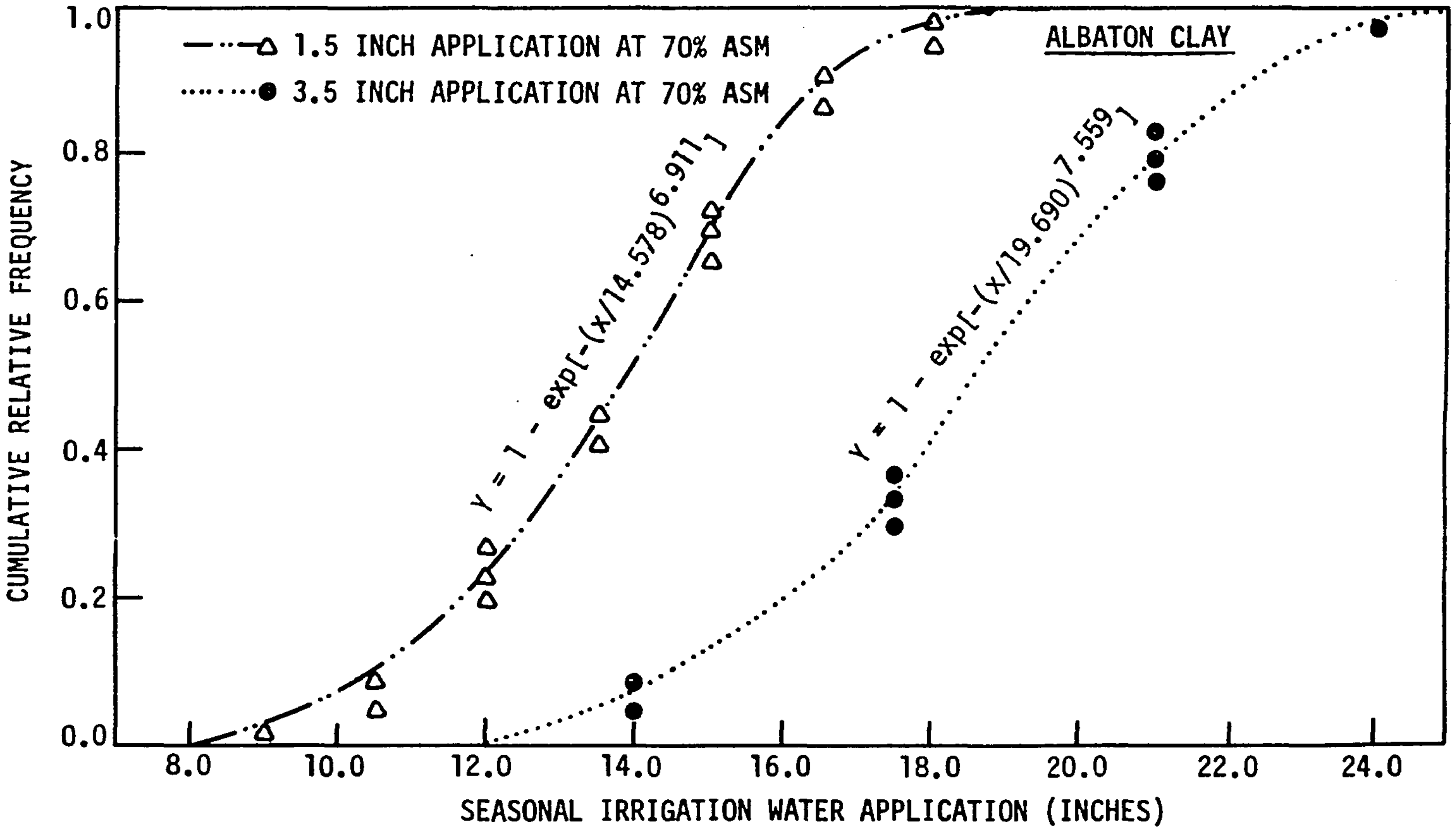

Figure 30. Weibull distribution fitted to the annual irrigation water requirement, Albaton Clay soil, west central Iowa

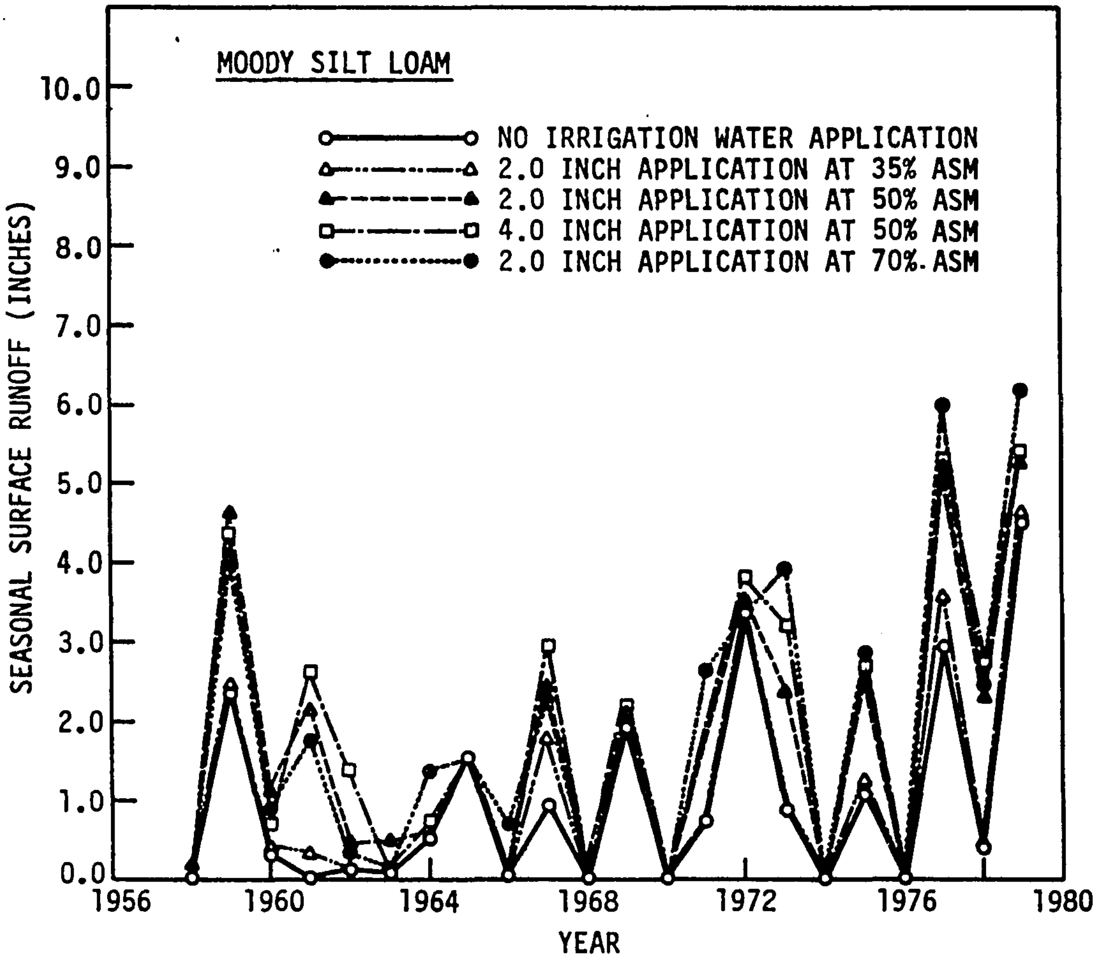

Figure 31. Comparison of the total seasonal surface runoff generated under natural conditions and for irrigation water application at various levels of soil moisture content. Doon watershed, northwest Iowa

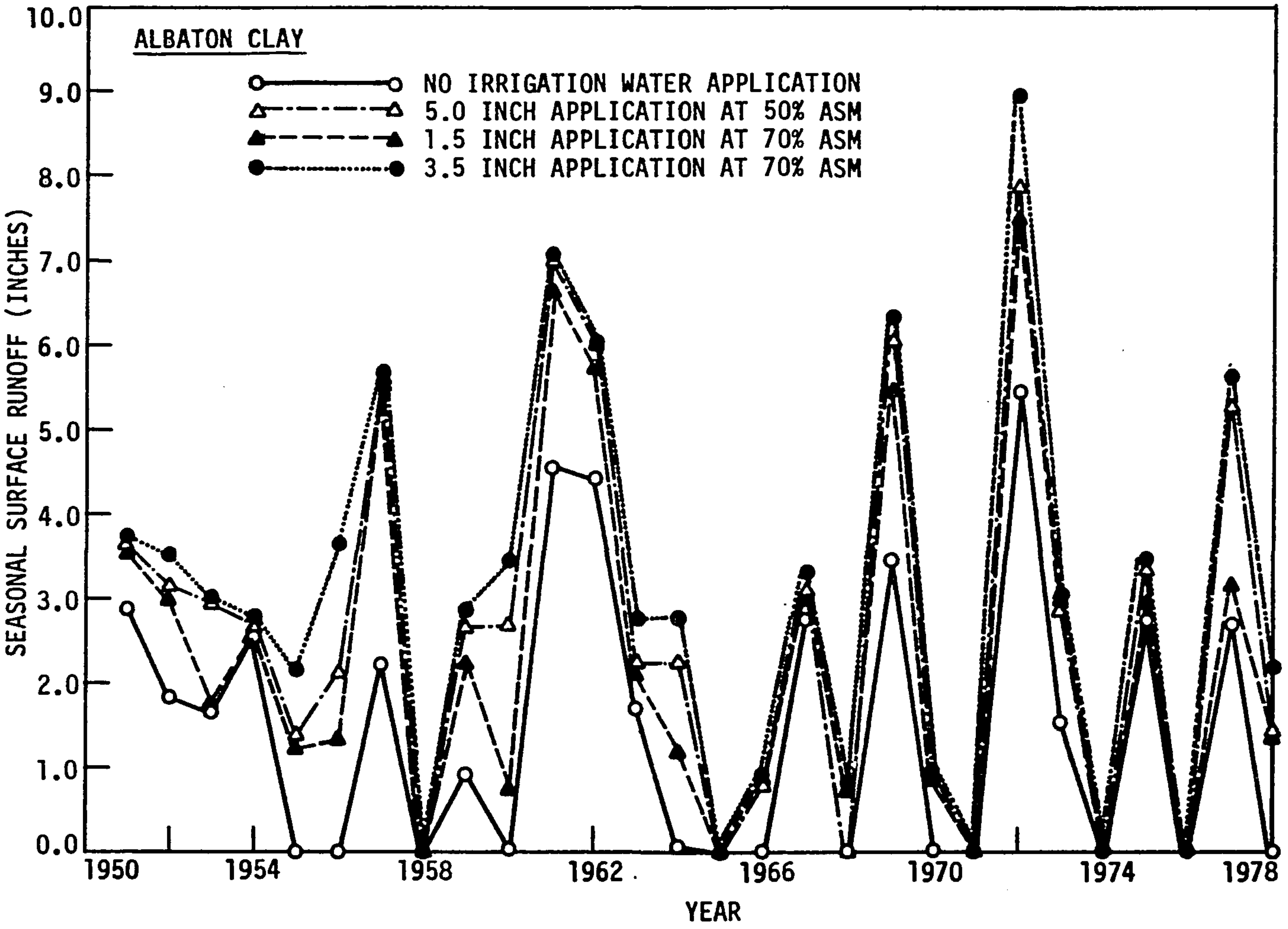

Figure 32. Comparison of seasonal surface runoff under natural conditions and various irrigation scheduling criteria. Albaton Clay soil, west central Iowa.

mostly the result of high intensity rainfalls on wet (irrigated) lands. For both Moody silt loam and Albaton clay, the most surface runoff was generated for irrigation at 70% of ASM; the least surface runoff was associated with irrigation application at 35% of ASM for Moody silt loam and 50% of ASM for Albaton clay.

Comparisons of seasonal deep percolation under natural conditions and various irrigation schedules are shown in Figures 33 to 35 for Moody silt loam, Chelsea sand and Albaton clay, respectively.

Similar to surface runoff, the most deep percolation was generated under irrigation at 70% of ASM for all three soils. Irrigation application at 35% of ASM resulted in the least deep percolation for Moody silt loam and Chelsea sand. The increase in deep percolation due to irrigation for Chelsea sand was higher than for the other two soils, because of the high permeability of this soil. High deep percolation resulted in low irrigation efficiency for most years, especially those which were wet.

<u>Seasonal water use efficiency</u>   Seasonal water use efficiency has been defined as the ratio of seasonal water use (total water supply minus seasonal water loss, where seasonal water loss is assumed to be the sum of total surface runoff and deep percolation) to seasonal water supply, where seasonal water supply is the sum of seasonal rainfall, seasonal soil moisture depletion (initial minus final soil moisture), and seasonal irrigation water application.

Seasonal water use efficiencies were calculated in the program for natural conditions and various irrigation scheduling criteria, to

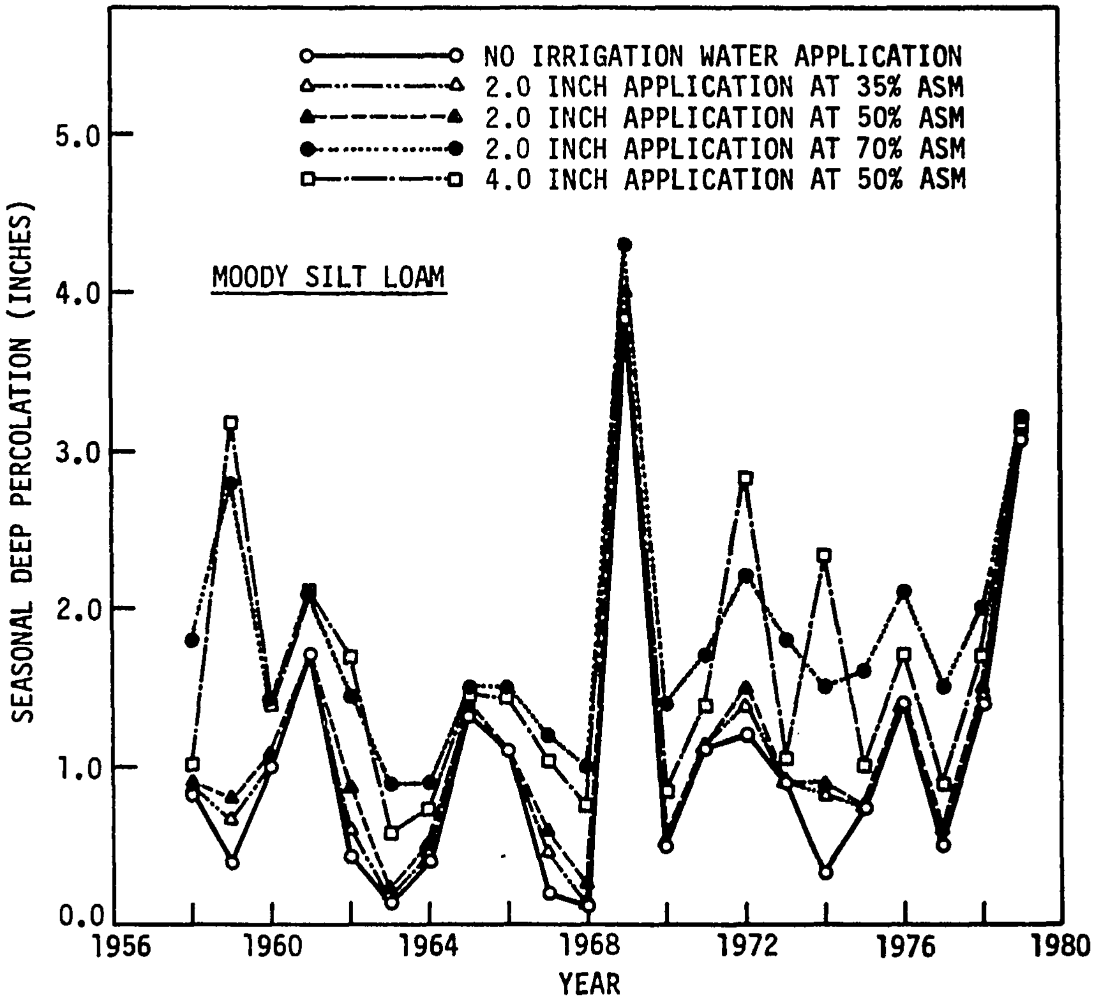

Figure 33. Comparison of seasonal deep percolation under natural conditions and for irrigation water application using various irrigation scheduling criteria. Moody silt-loam, Doon watershed, northwest Iowa

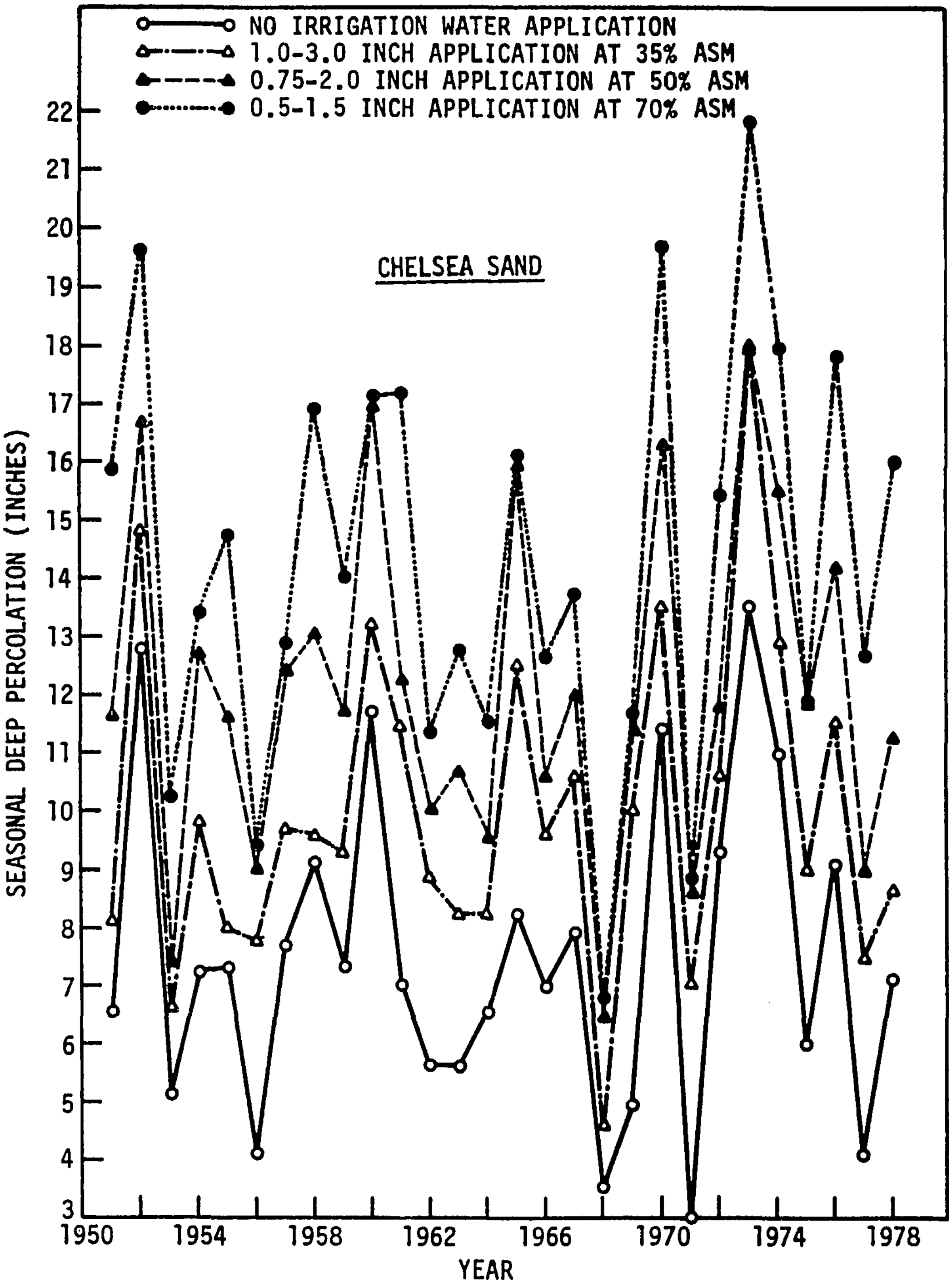

Figure 34. Comparison of seasonal deep percolation under natural conditions and irrigation application at various soil moisture level. Chelsea sand, southeast Iowa.

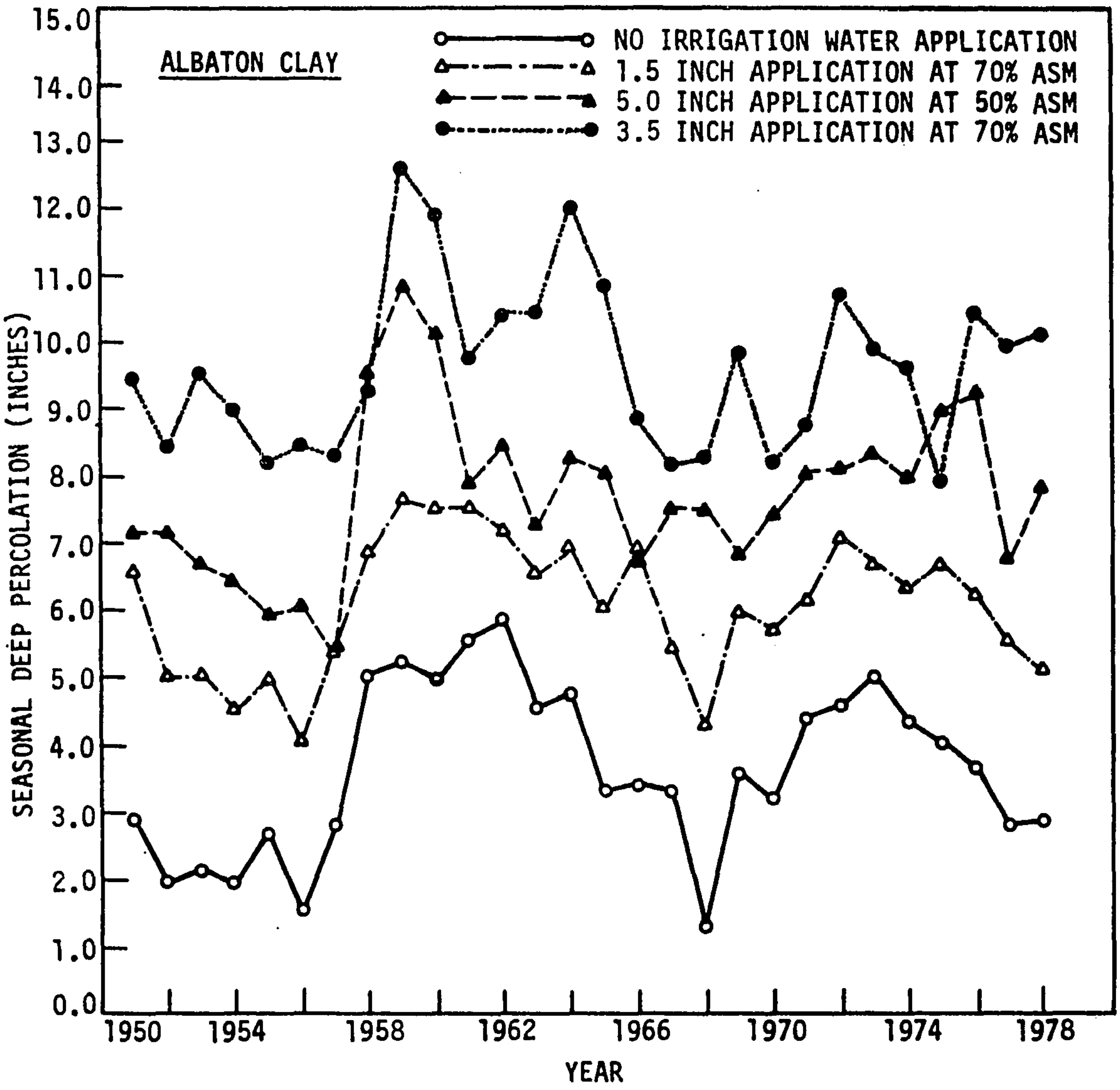

Figure 35. Comparison of seasonal deep percolation for natural conditions and for various irrigation scheduling criteria. Albaton Clay soil, west central Iowa.

determine the decrease in water use efficiency due to irrigation water application. The comparison of these efficiencies is illustrated in Figures 36 to 38 for Moody silt loam, Chelsea sand and Albaton clay, respectively.

For most of the years, the maximum water use efficiencies were obtained under natural conditions, and decreased upon application of irrigation water at 35%, 50% and 70% of ASM, respectively. For a few years, irrigation at 35% of ASM resulted in water use efficiencies higher than under natural conditions.

The variation of initial soil moisture plus seasonal rainfall among the years is shown in Figures 39 to 41 for Moody silt loam, Chelsea sand and Albaton clay, respectively. Comparison of these figures with the associated yearly variation of water use efficiencies indicates that years with high initial soil moisture plus seasonal rainfall have low water use efficiencies; on the other hand, high water use efficiencies correspond with years having low beginning soil moisture plus seasonal rainfall.

Water use efficiency, defined as crop yield per unit water use, was also determined by comparing total water use with the predicted yield. Corn yield increased as soil moisture supply increased either by natural rainfall or irrigation application. The increase in crop yield followed approximately an exponential curve, that is, it leveled off at higher values of moisture supply (Figure 42). The lowest and highest yields were obtained under natural conditions and irrigation at 70% of ASM, where the difference in yield between natural conditions and irrigation

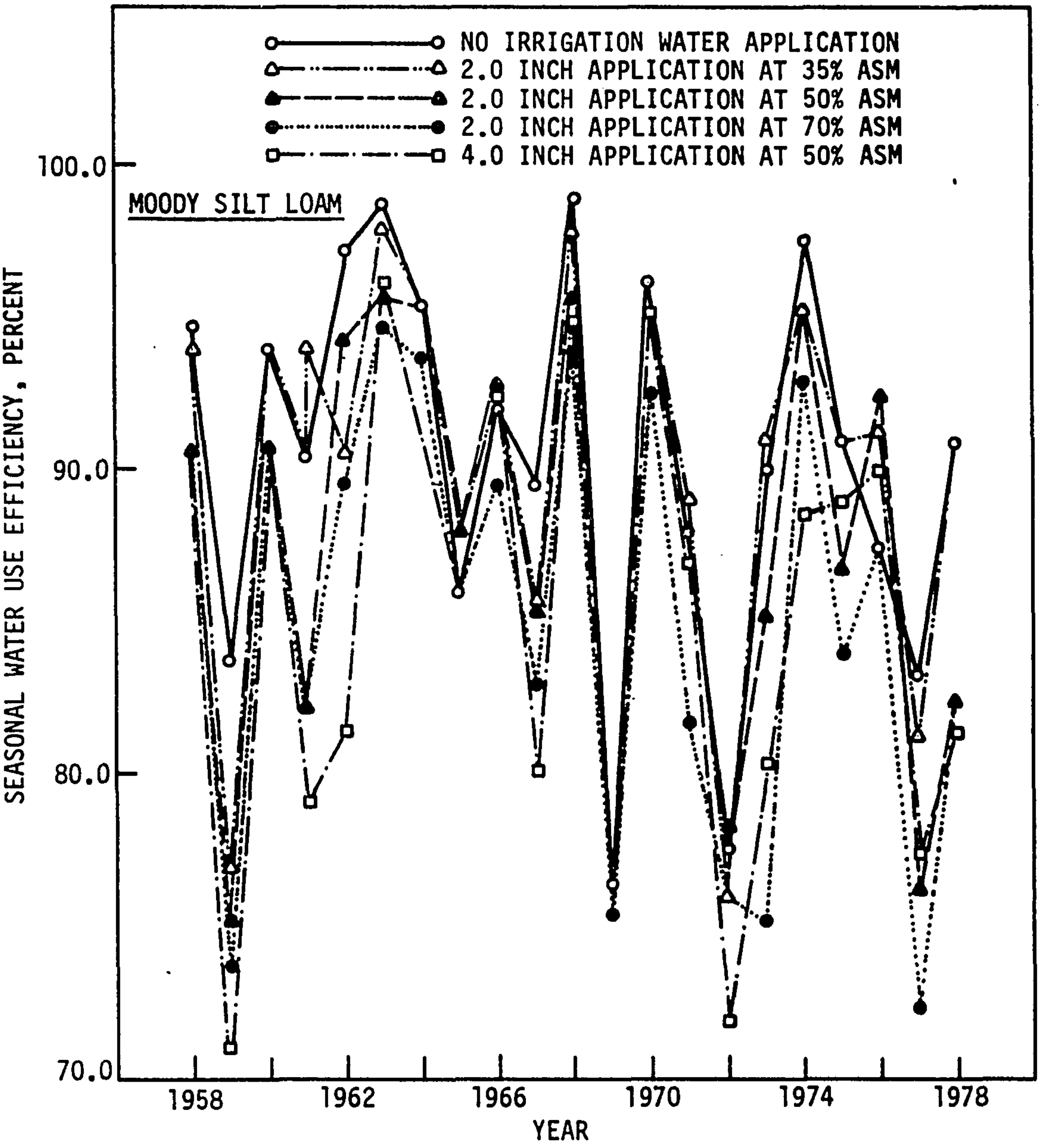

Figure 36. Seasonal water use efficiency for natural conditions and for four different irrigation scheduling criteria. Moody silt loam, Doon watershed, northwest Iowa.

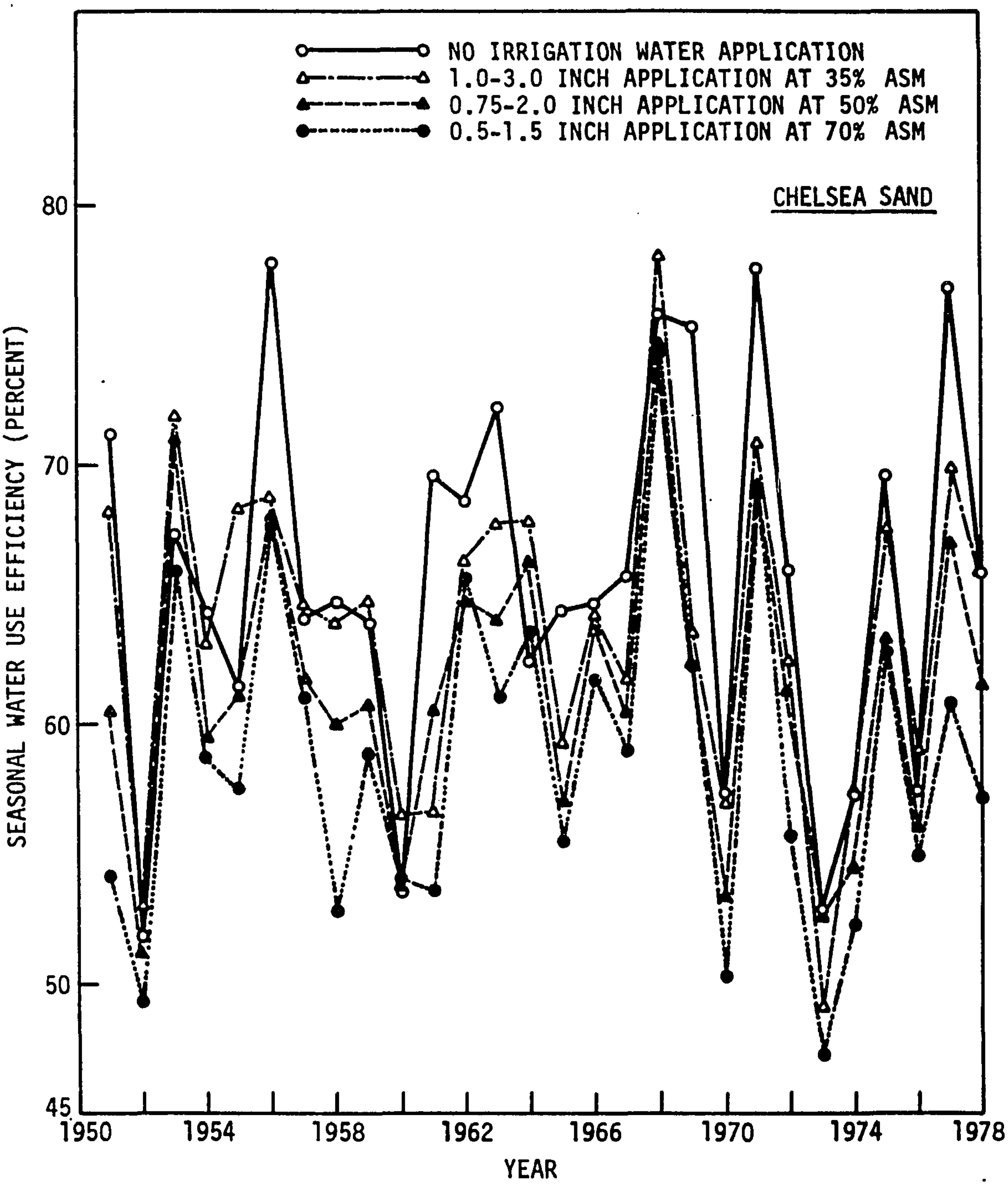

Figure 37. **Seasonal water use efficiency for natural conditions and for irrigation water application at three different soil moisture contents. Chelsea sand, southeast Iowa**

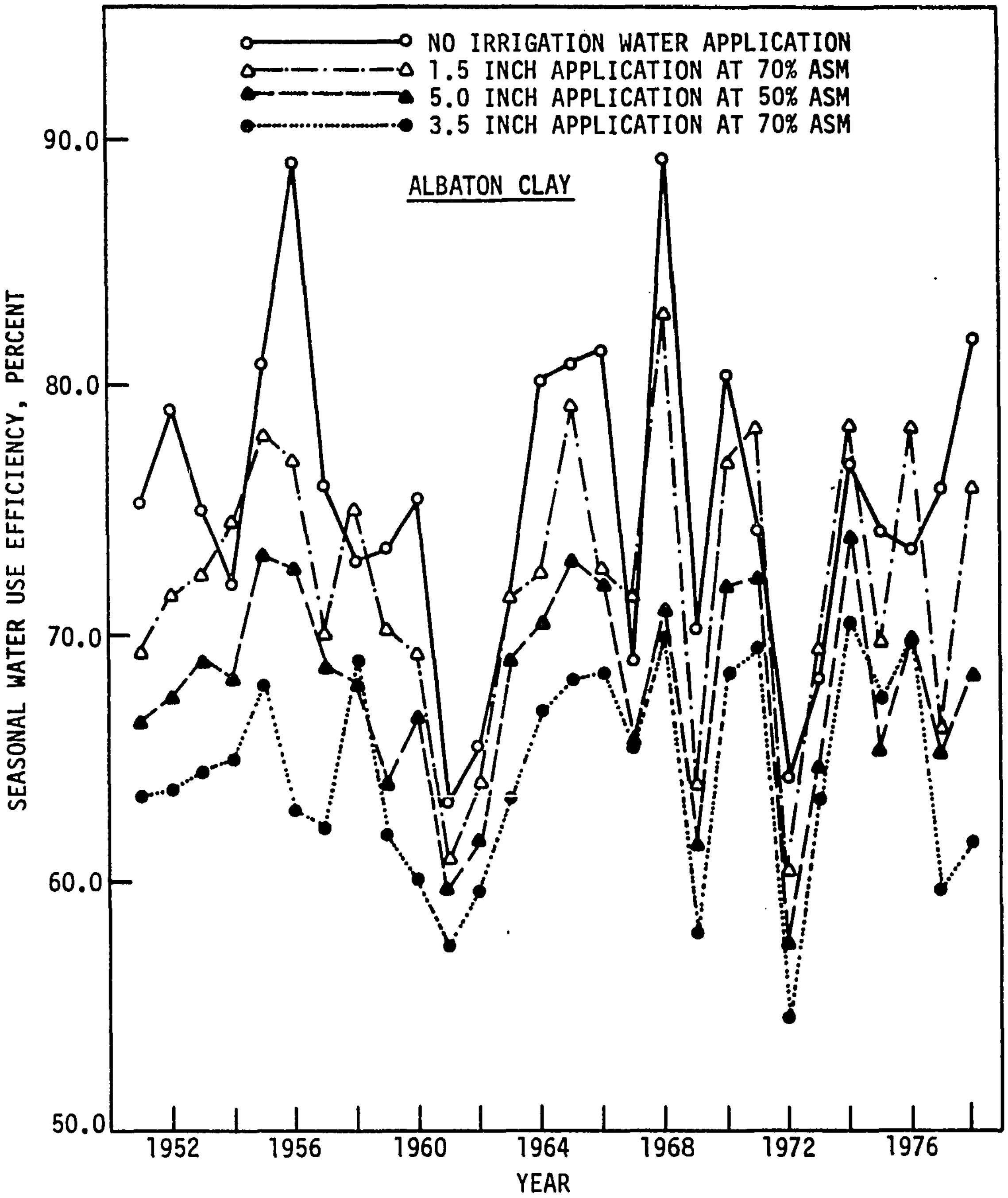

Figure 38. Seasonal water use efficiency for natural conditions and for three different irrigation scheduling criteria. Albaton clay soil, west central Iowa

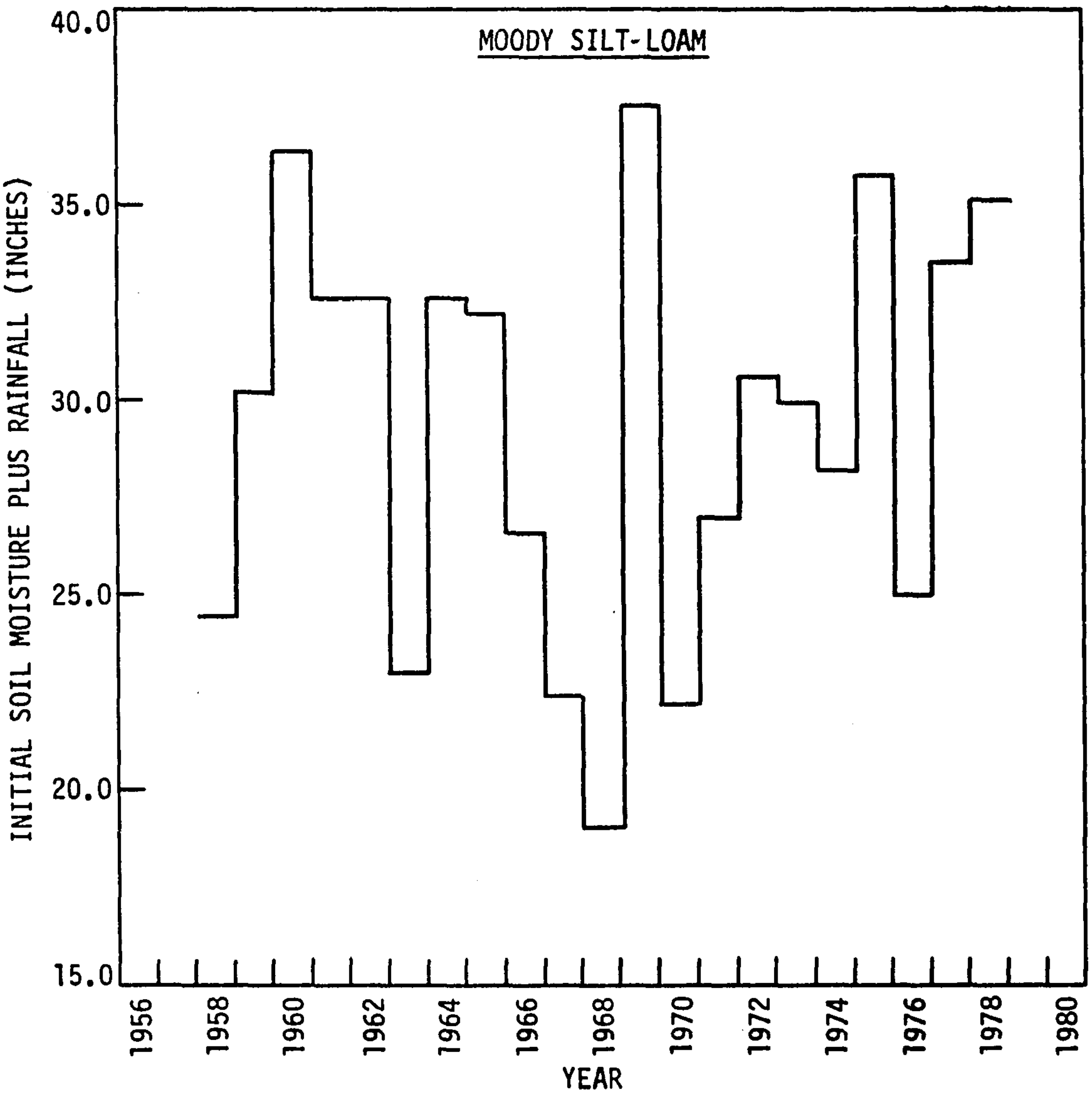

Figure 39. **Variation of initial soil moisture plus seasonal rainfall. Moody silt loam, northwest Iowa.**

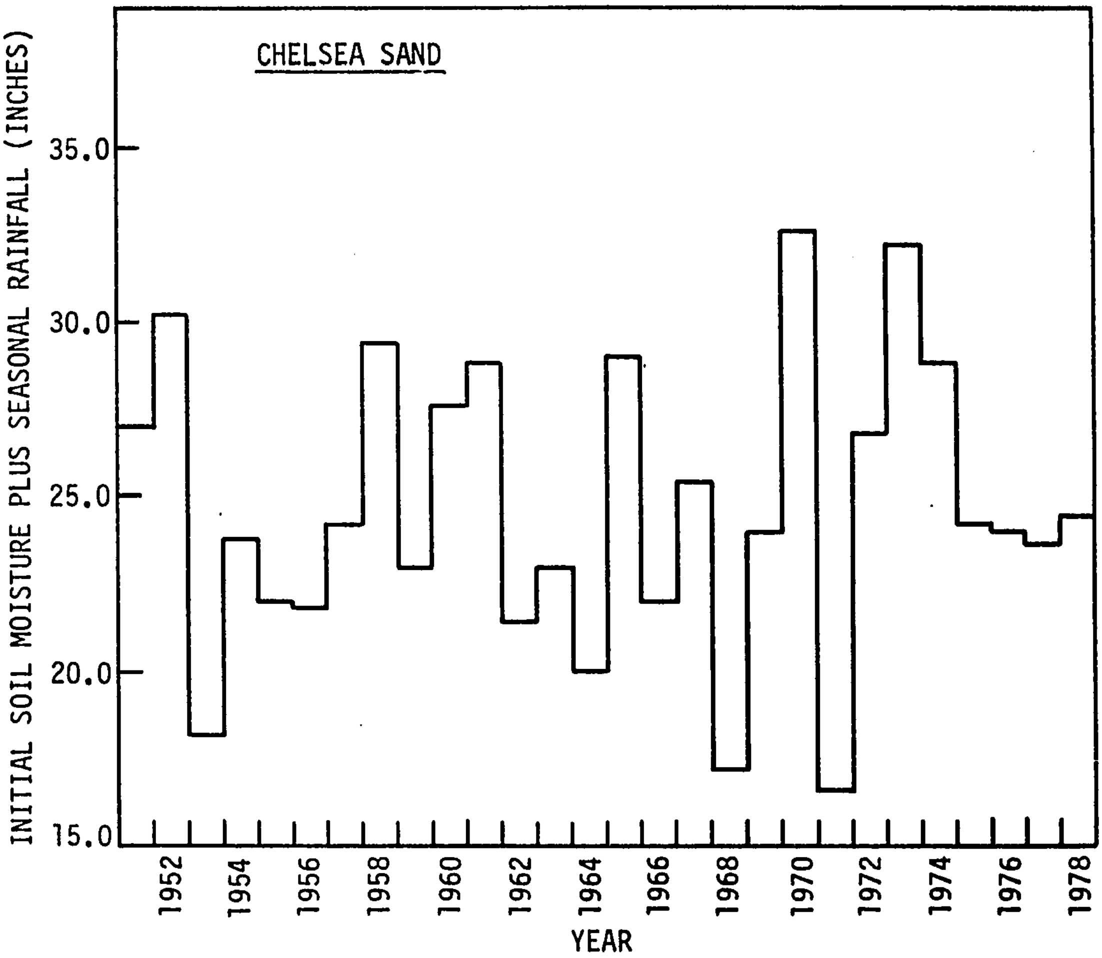

Figure 40. Variation of initial soil moisture plus beginning rainfall. Chelsea sand, southeast Iowa

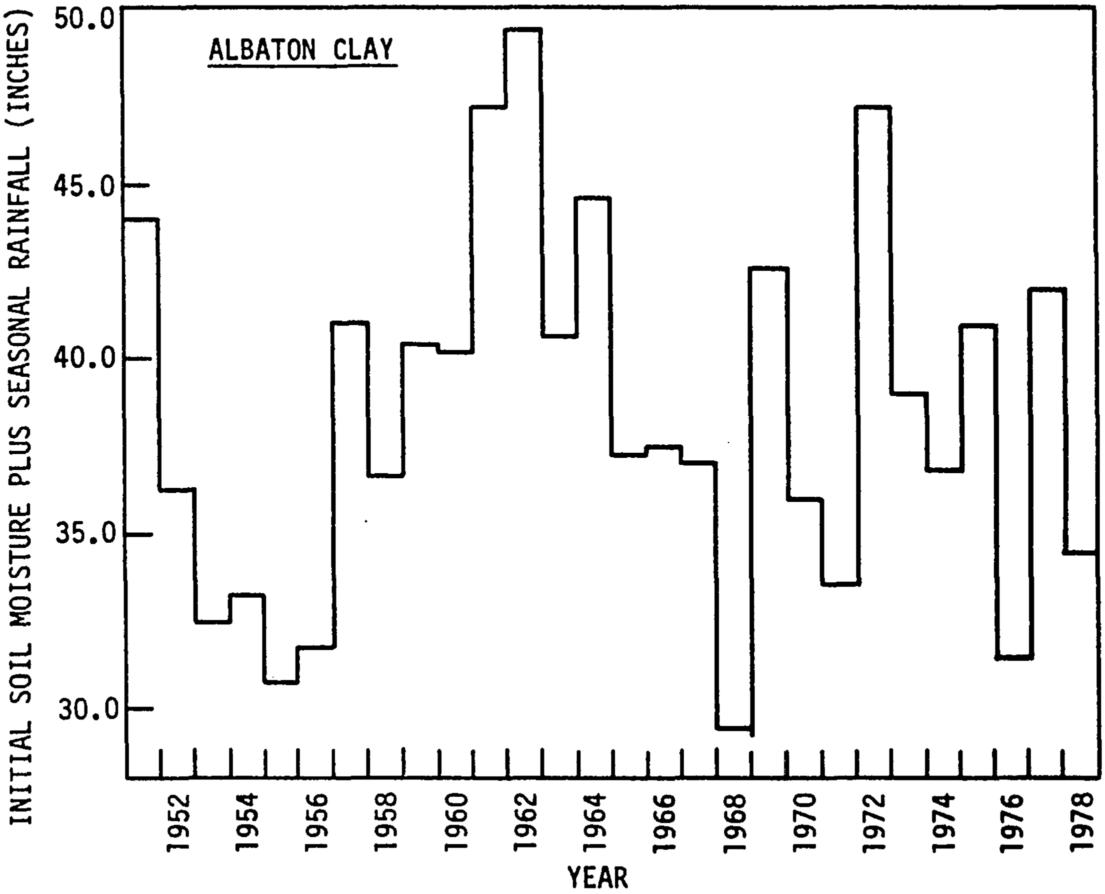

Figure 41. Variation of initial soil moisture plus seasonal rainfall. Albaton Clay, west central Iowa

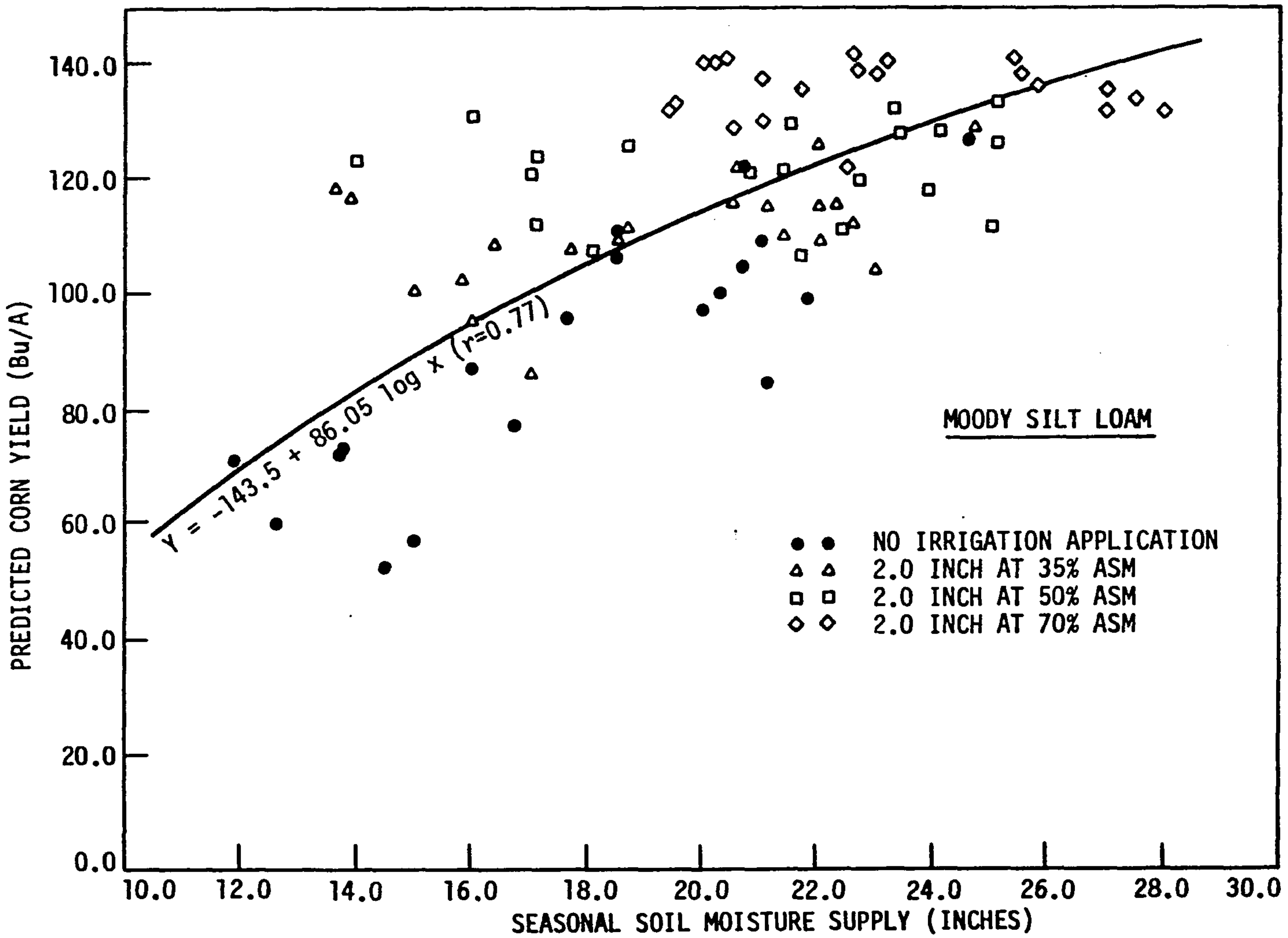

Figure 42. Variation of predicted corn yield with seasonal water supply under natural conditions, and irrigation applications at various levels of soil moisture content. Moody silt loam, northwest Iowa.

even for application at 35% of ASM is much higher than the difference between irrigation at 35% and 70% of ASM.

Predicted yield per unit water use was also determined for natural conditions and various irrigation scheduling criteria. As Figure 43 indicates, the highest water use efficiency (the ratio of crop yield to seasonal water use) was obtained under irrigation at 35% and 50% of ASM. The decrease in water use efficiency with increased moisture supply was also approximated by an exponential distribution, considering the predicted yield under irrigation application (Figure 43).

Weighted stress index   Raw stress index has been defined by Shaw (1974) as one minus the ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET). Appropriate weighting factors were given to the daily raw stress indices to determine the 85-day weighted stress index, as discussed previously.

To determine the decrease in moisture stress due to irrigation, weighted stress indices calculated in the program under natural conditions and various irrigation schedules were compared, as shown in Figures 44 to 46 for Moody silt loam, Chelsea sand and Albaton clay, respectively. The means and standard deviations of weighted stress indices are also given on the corresponding graph for each irrigation criterion.

The comparison of moisture stress indices indicated that for most years weighted stress indices are high for natural conditions, with a wide variation among the years (high standard deviation). Weighted stress indices were lower and much more uniform (low mean and standard

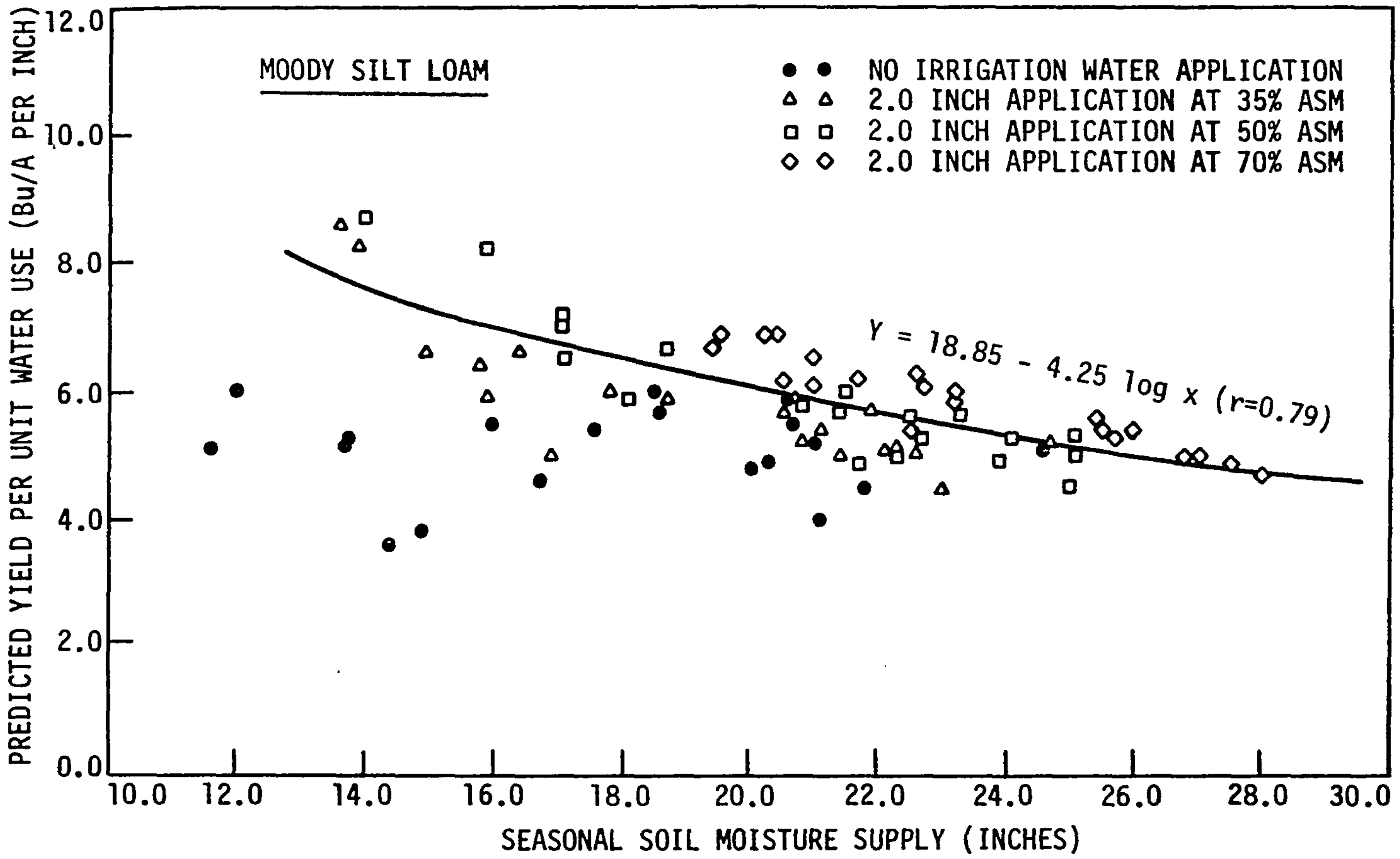

Figure 43. Water use efficiency (yield per unit water use) vs. seasonal water supply under natural conditions and various irrigation criteria. Moody silt loam, northwest Iowa

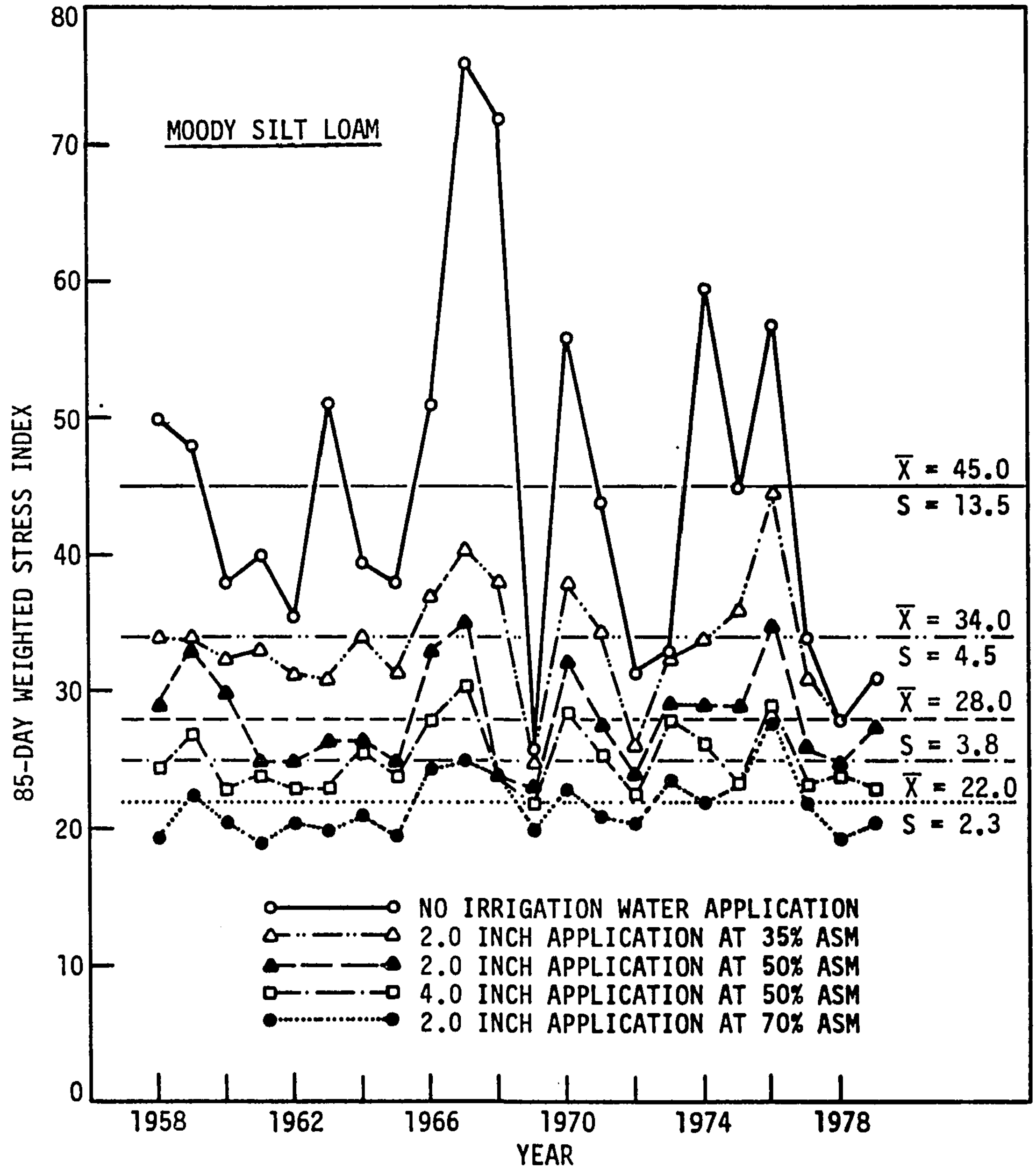

Figure 44. Comparison of the weighted soil moisture stress index for natural conditions and for various irrigation schedules. Moody silt loam, Doon watershed, northwest Iowa

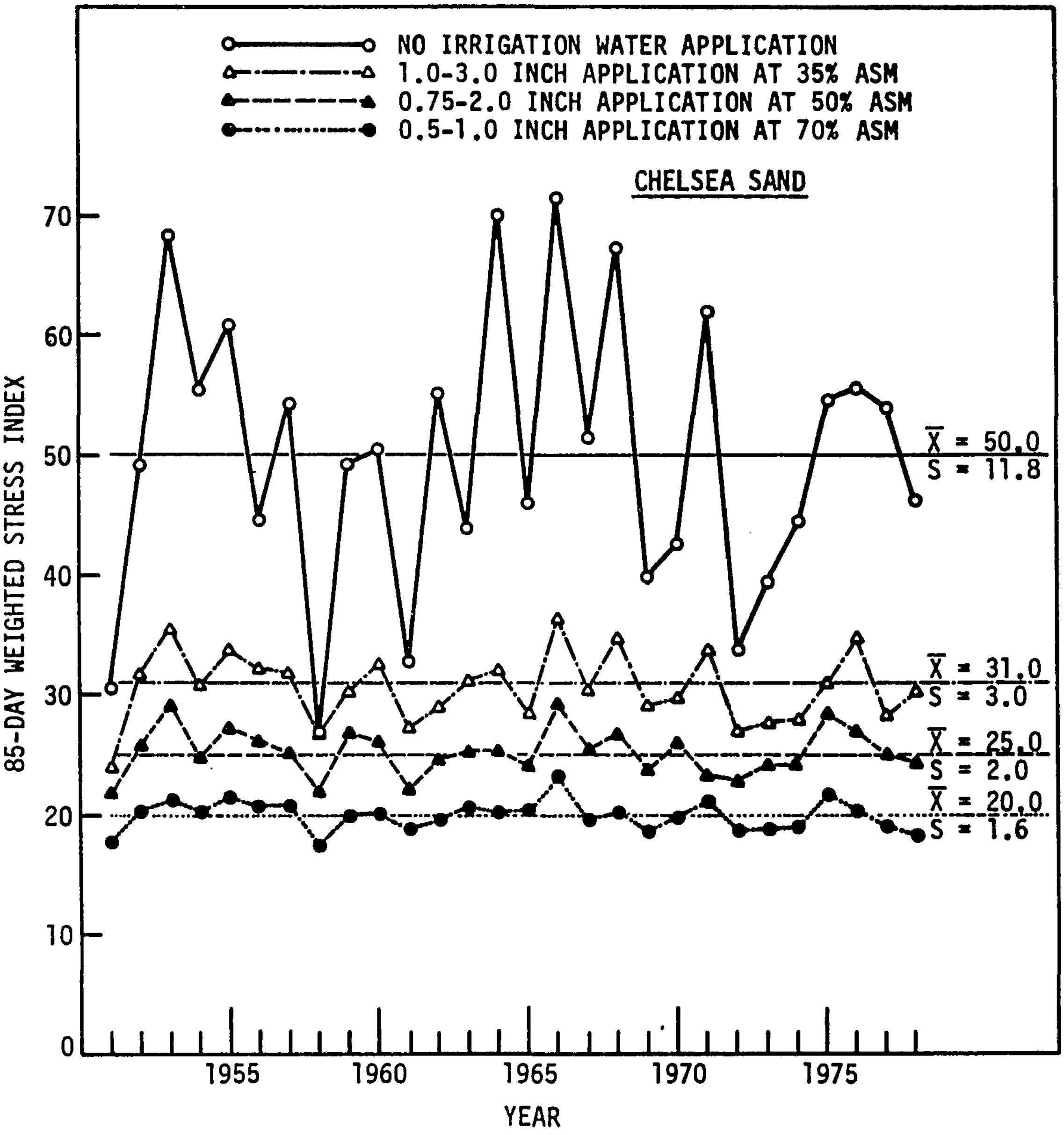

Figure 45. Comparison of soil moisture weighted stress index for natural conditions and various irrigation schedules. Chelsea sand, southeast Iowa

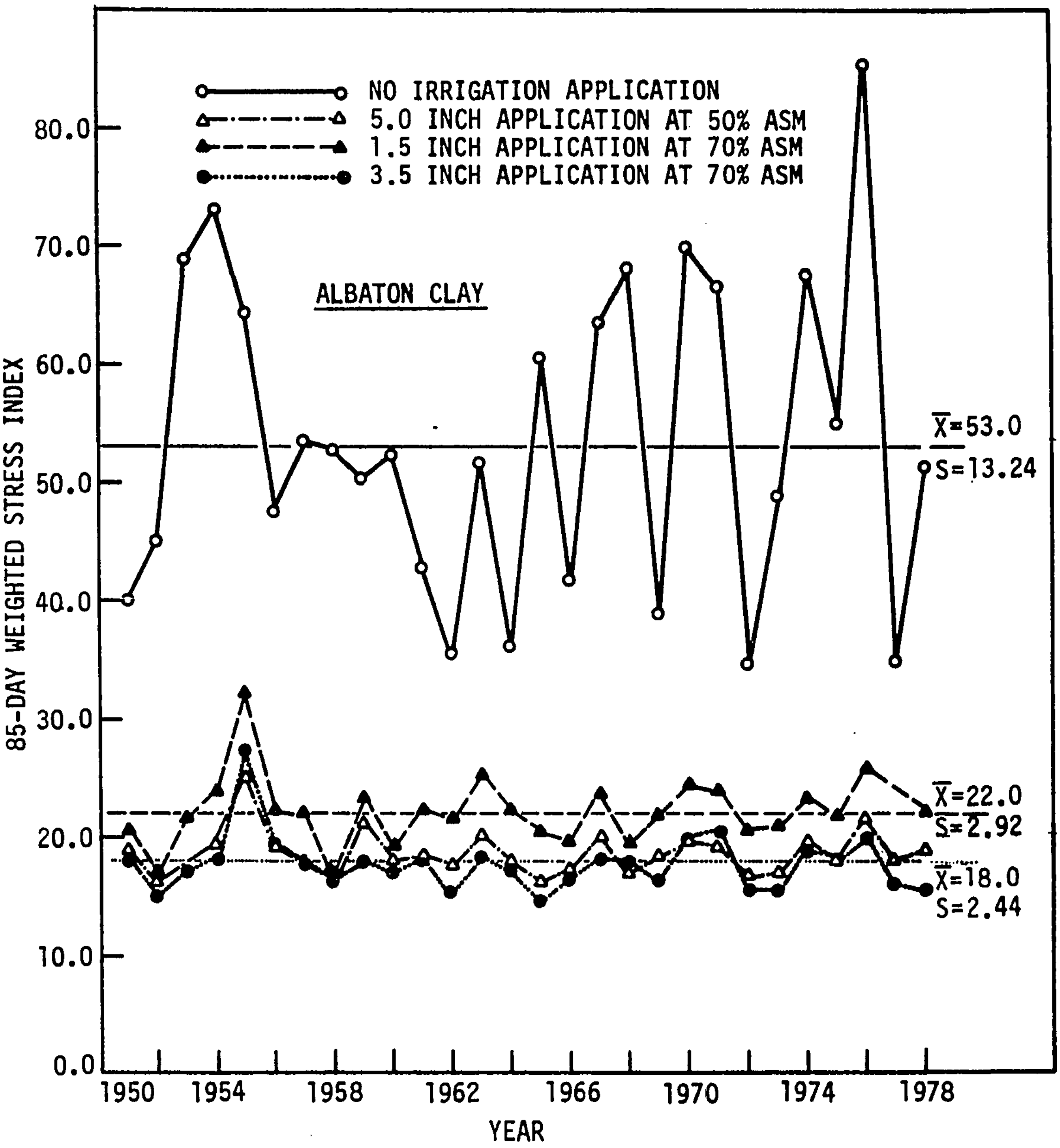

Figure 46. Comparison of 85-day weighted stress indices for natural conditions and for irrigation water application with various irrigation criteria. Albaton Clay soil, west central Iowa

deviation) after application of irrigation water for all three soils (Figures 42 to 44).

Irrigation application at 50% of ASM decreased moisture stress indices considerably, especially during dry years, while irrigation at 70% of ASM did not cause much additional improvement in the weighted stress indices. The highest stress indices were obtained under irrigation at 35% of ASM for Moody silt loam and Chelsea sand.

Moisture stress indices in Albaton clay were higher than in the other two soils for most years. Low corn yields obtained on the heavy soils of the bottom lands of the Missouri river justify the occurrence of high stress indices in this soil.

Predicted corn yield Corn yield data were available only for Moody silt loam (Doon watershed). In the previous section, corn yield data (Y) were related to the predicted values of weighted stress index (X) with the following regression equation:

$$Y = 184.22 - 2.21\,X \qquad r^2 = 0.83$$

where yield is in bu/a.

The computed stress indices under natural conditions and various irrigation criteria were used to predict non-irrigated and irrigated corn yield, thereby determining the yield increase due to irrigation water application.

Comparison of the predicted yield under natural conditions and 2.0 inch irrigation application at 35%, 50% and 70% of ASM (Figure 47), indicated that the variation in non-irrigated corn yield among the years was much higher than the variation in irrigated corn yield. Corn

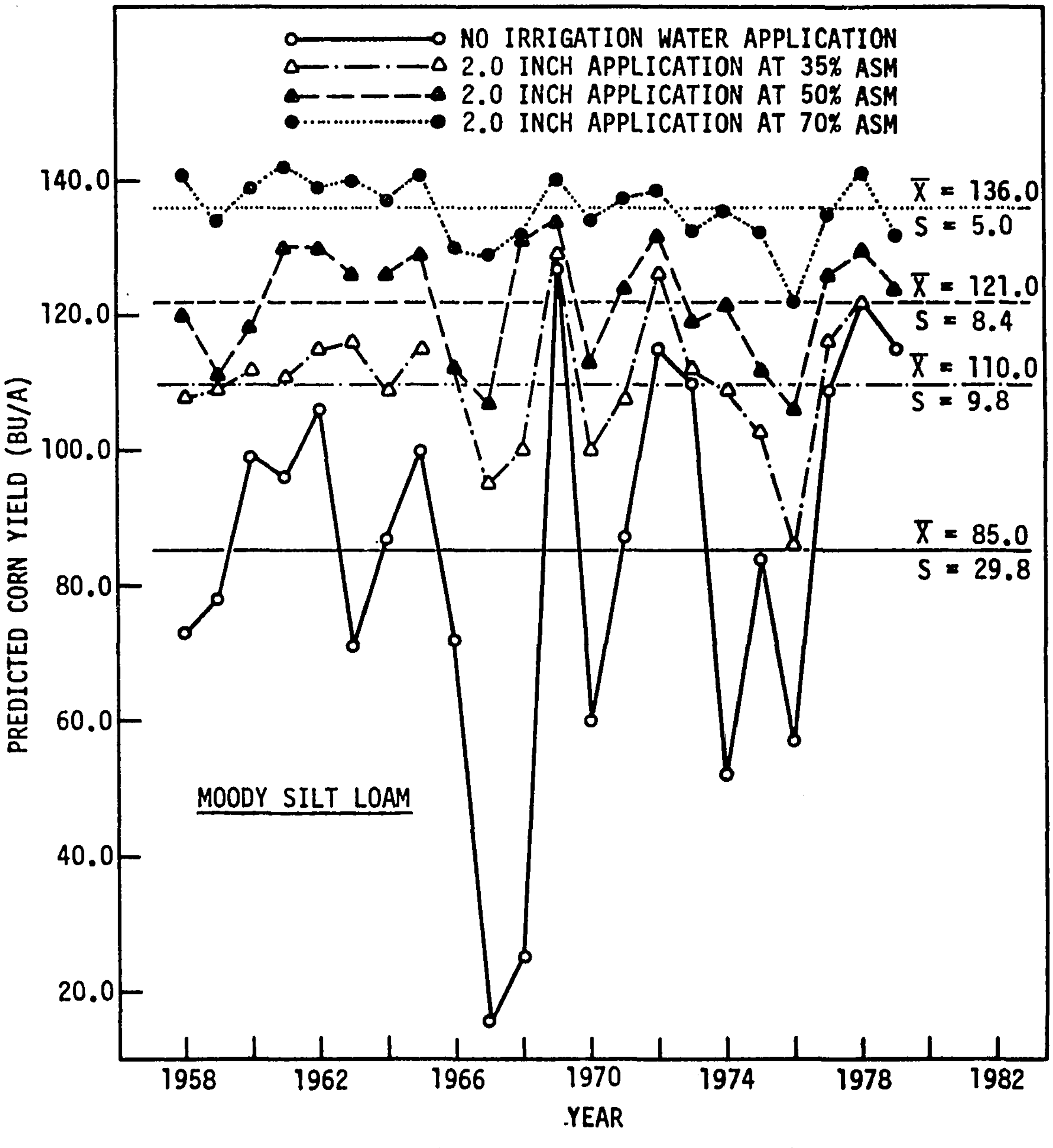

Figure 47. **Predicted corn yield under natural conditions and three different irrigation scheduling criteria. Moody silt loam, Doon watershed, northwest Iowa**

yield increased considerably upon application of irrigation water, while this increase was much more significant for dry years with low yield.

The lowest irrigated corn yield was obtained under irrigation at 35% of ASM. Application of irrigation water at 50% of ASM resulted in higher corn yields, while irrigation at 70% of ASM did not result in much additional increase in corn yield, except for a few dry years.

Sensitivity Analysis of the Model

Sensitivity of the model to some of the major parameters of the overland flow process was discussed by Shahghasemi (1980). In this study, sensitivity of the model to some important soil properties was analyzed. To test the effect of any specified soil property, various runs were made holding all parameters other than the one under study constant at their original values.

Sensitivity of the model was analyzed with respect to soil moisture level at saturation (SAT), field capacity (FC), wilting point (WP), saturated hydraulic conductivity (SHC), and percent saturation moisture at which immediate free drainage to the next lower soil layer occurs (PER_1). The main objective was to evaluate the effect of variation in a given soil property on the response of the model, including seasonal surface runoff, deep percolation, actual evapotranspiration, and accumulated soil moisture in the top five feet of the soil profile.

The year 1967 was selected as an average year for the sensitivity analysis of all three soils used in the study. Albaton clay showed the most, and Chelsea sand the least, significant changes in the response of the model to changes in a given soil property, as will be discussed in the following sections.

Albaton clay

The effects of SAT, FC and WP on the model response were tested by increasing and decreasing these factors by 2.0 to 10.0 percent of their original values. The response of the model showed its highest sensitivity to SAT. As Figure 48 indicates, deep percolation decreased rapidly, and actual evapotranspiration increased, by increasing SAT. Surface runoff decreased sharply by decreasing SAT by 5% or more of its original value. Increase in SAT did not affect end-of-season soil moisture, but 10% decrease in SAT reduced it by 2.0 inches.

The effect of variation in FC (Figure 49) indicates a high increase in deep percolation and a lower decrease in actual evapotranspiration with increasing FC. Surface runoff was reduced sharply by increasing FC by more than 5% of its original value. End-of-season soil moisture was not affected by variation in FC.

Changes in WP did not change surface runoff or actual evapotranspiration appreciably (Figure 50). Deep percolation decreased with increasing WP, but at a slower rate than was caused by changing SAT or FC. End-of-season soil moisture did not change significantly when WP was changed.

SHC was increased and decreased by 50% of its original value; these variations did not affect surface runoff or actual evapotranspiration. Deep percolation increased with increasing SHC (Figure 51). Another run was made using the original values of SHC, but omitting the restricted layer from the bottom of the soil profile; this resulted in a 2.0 inch

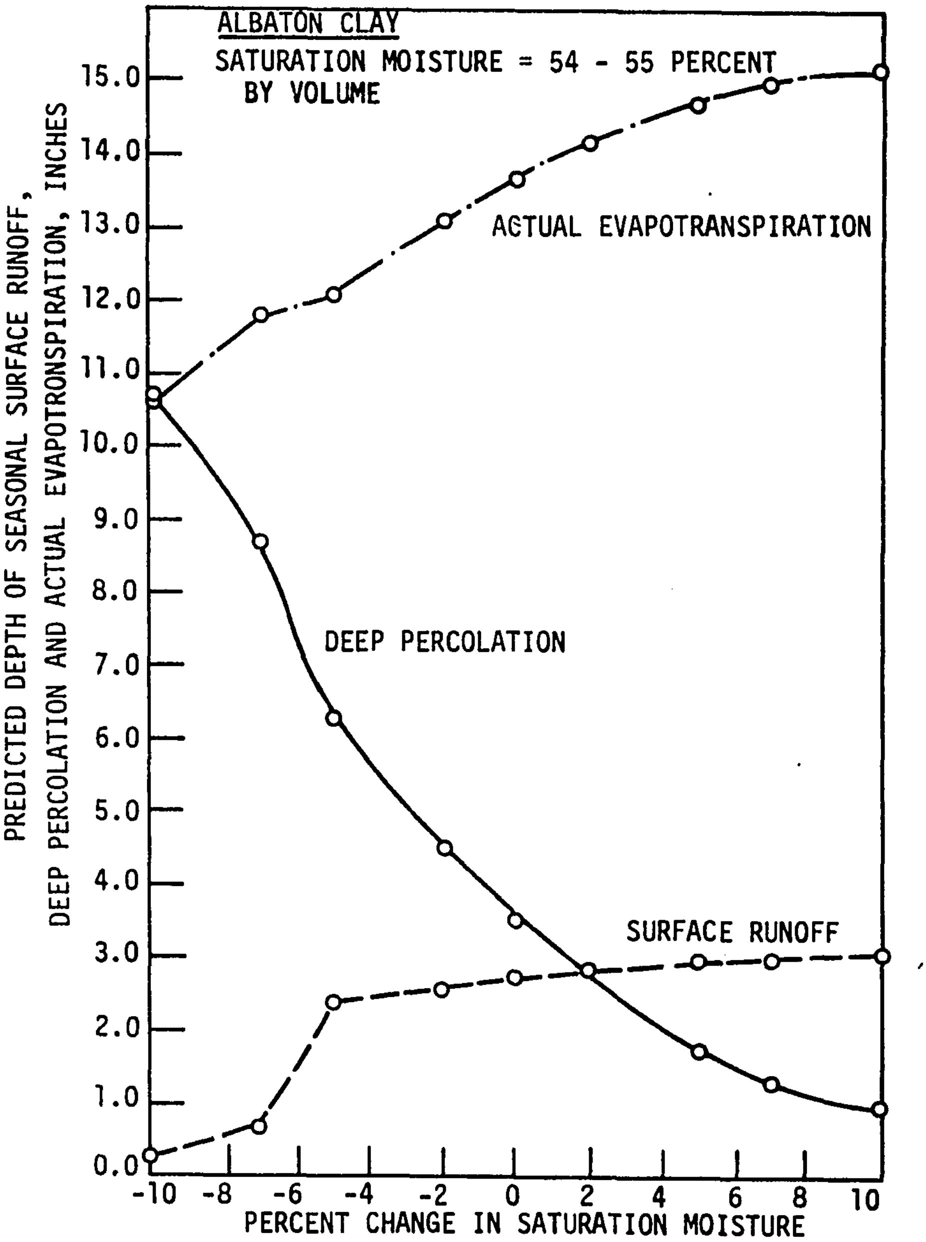

Figure 48. Sensitivity of the model output to changes in saturation moisture, Albaton clay, west central Iowa, 1967

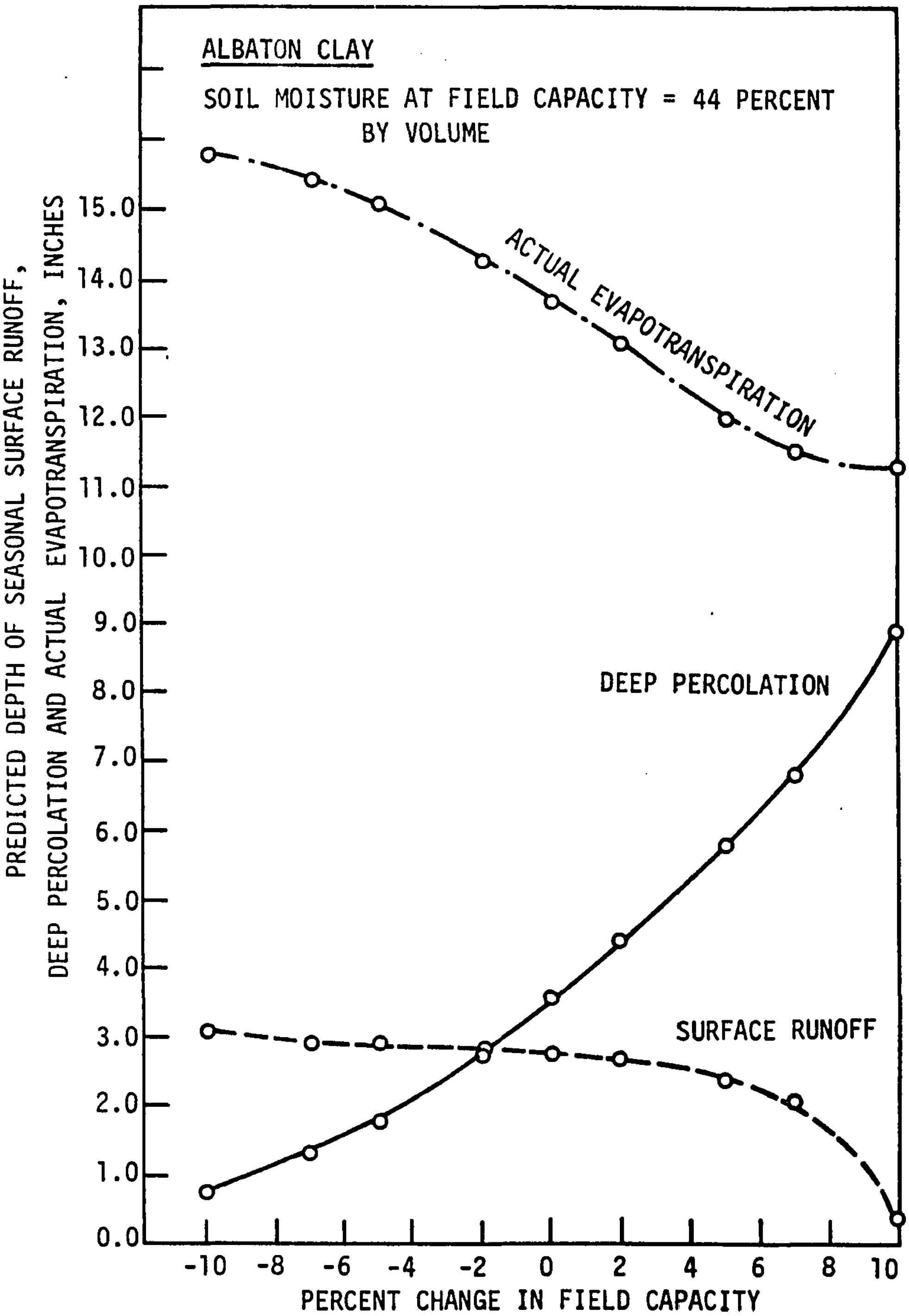

Figure 49. **Sensitivity of the model output to changes in field capacity moisture, Albaton·Clay, west central Iowa, 1967**

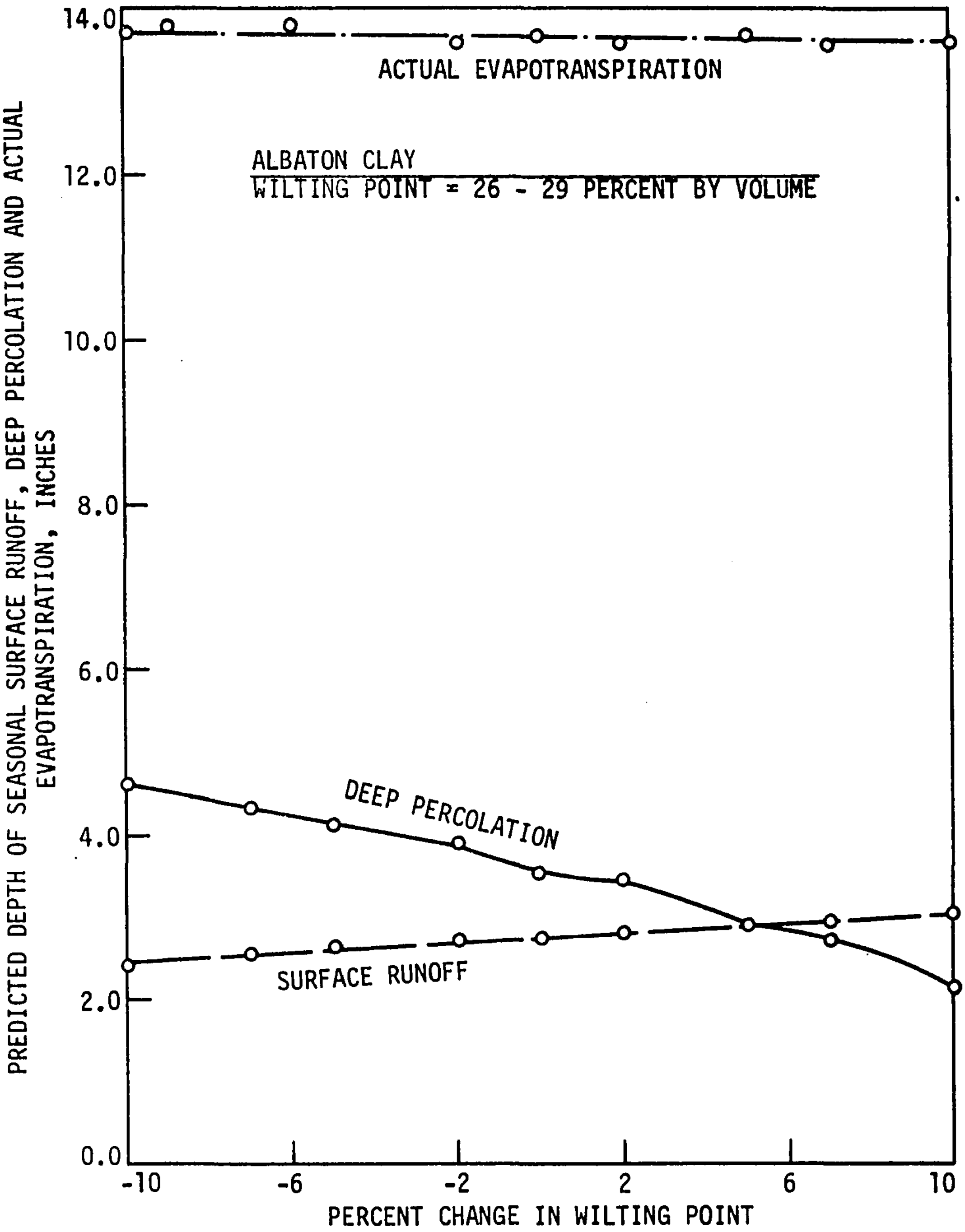

Figure 50. Sensitivity of the model outputs to changes in wilting point moisture. Albaton Clay, west central Iowa, 1967

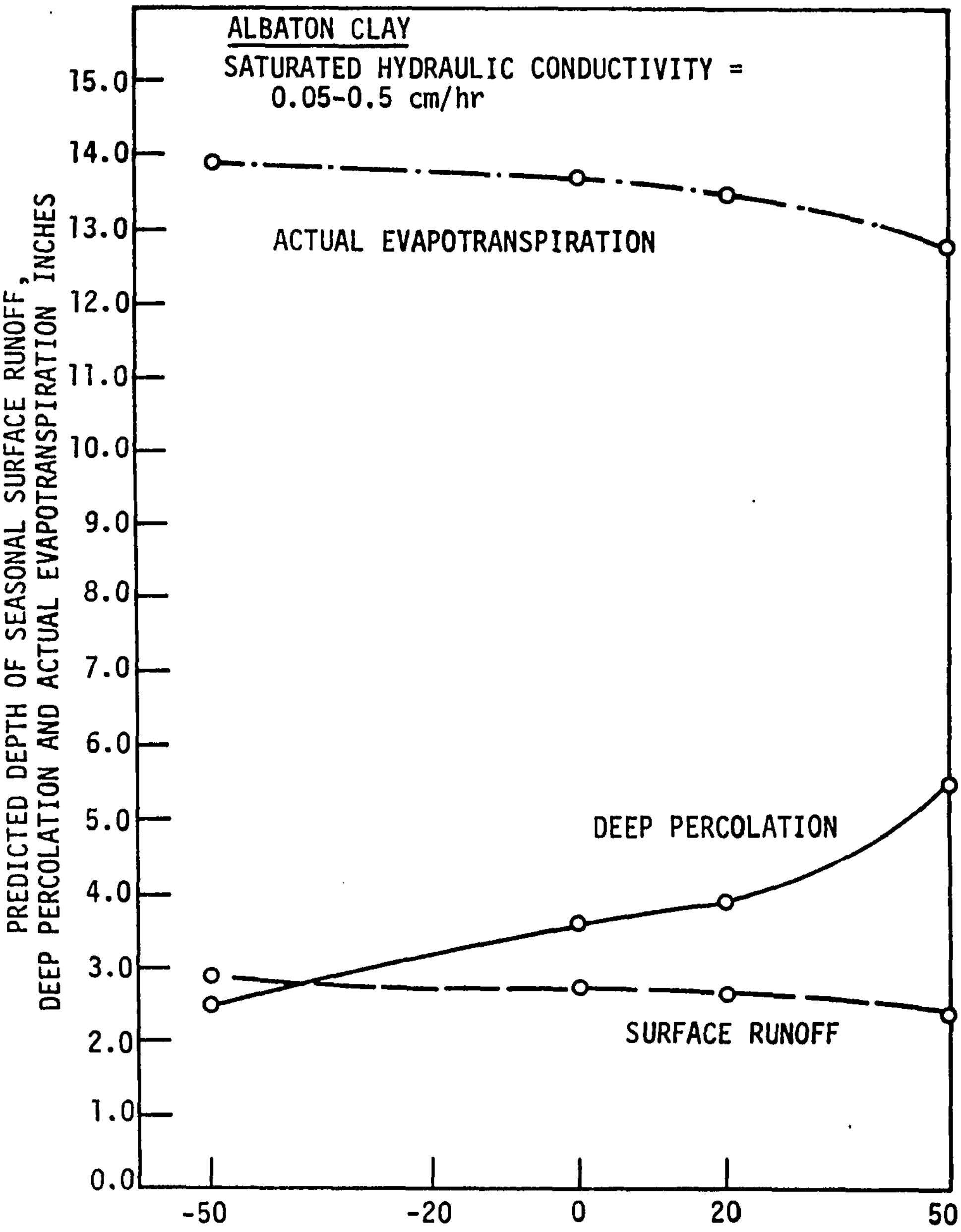

Figure 51. Sensitivity of the model output to changes in saturated hydraulic conductivity, Albaton Clay west central Iowa

increase in deep percolation, but no significant changes in surface runoff or actual evapotranspiration.

One of the other major soil parameters was the variable PER_1, used in the redistribution subroutine, and defined as the percent saturation moisture at which immediate free drainage to the lower soil layer occurs. The original value of PER_1 for Albaton clay was 90%, which was decreased to 50% and increased to 100%. Deep percolation increased, and actual evapotranspiration decreased at a high rate, when PER_1 was decreased below its original value. Changes in PER_1 did not affect surface runoff (Figure 52).

Moody silt loam

Sensitivity of the model response using Moody silt loam was analyzed with respect to the same parameters as for the Albaton clay. SAT and FC were changed by plus and minus 10%, wilting point by plus and minus 20%, and SHC by plus and minus 50% of their original values.

Moody silt loam showed less sensitivity to changes in soil properties than Albaton clay. Figures 53 to 56 illustrate the sensitivity of the model with respect to changes in SAT, FC, WP and SHC, respectively. The results of the analysis indicate that changes in soil properties apparently had no effects on surface runoff, actual evapotranspiration and end-of-season soil moisture. Variation in deep percolation corresponding to each soil property followed the same trends as for Albaton clay soil, but at a lower rate; that is, seasonal deep percolation decreased with increasing SAT and WP, and increased with increasing FC and SHC. Similar to the Albaton clay soil, removing

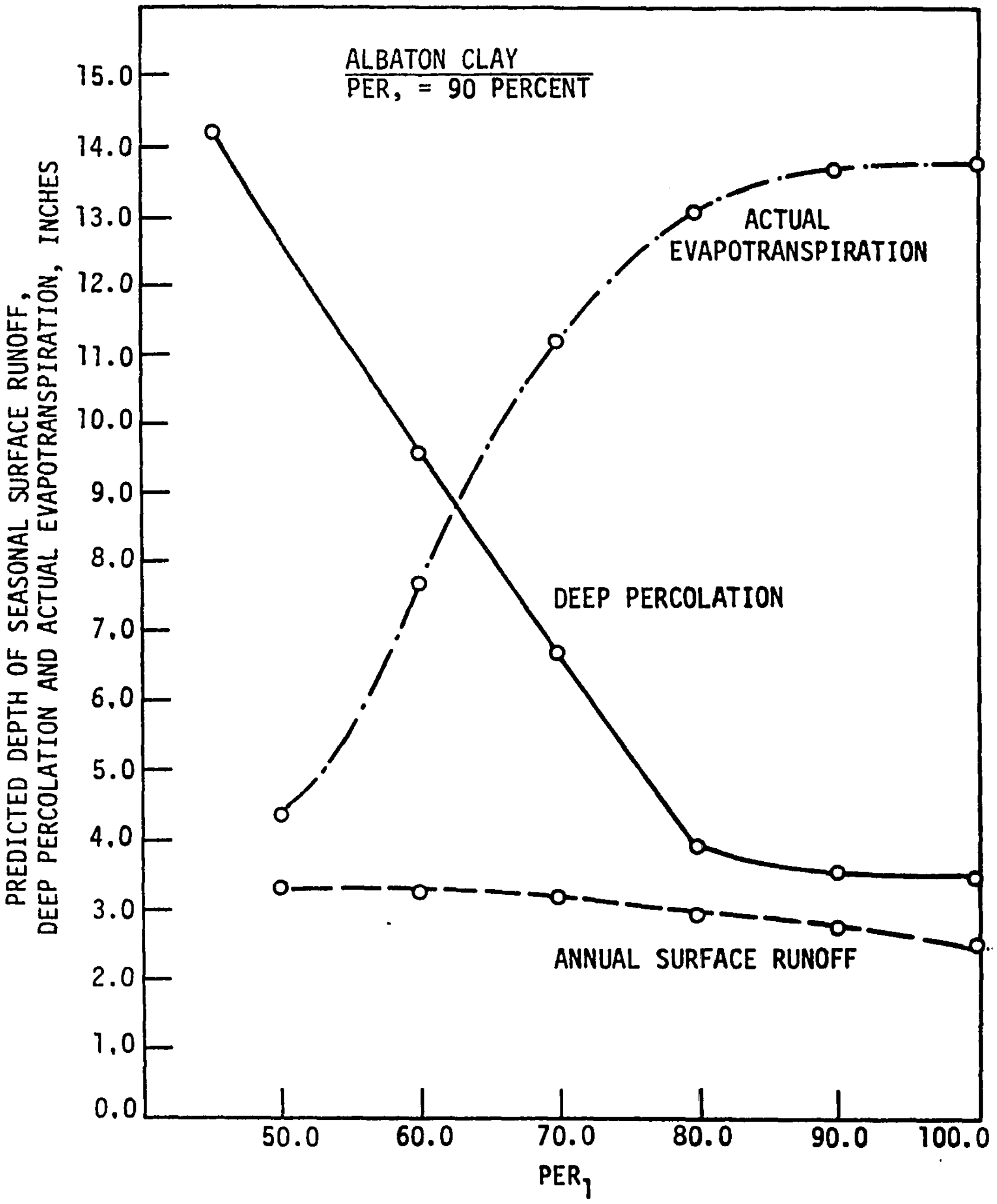

Figure 52. **Sensitivity of the model outputs to percent saturation at which immediate free drainage to lower soil layers occur (PER_1), Albaton·Clay west central Iowa, 1967.**

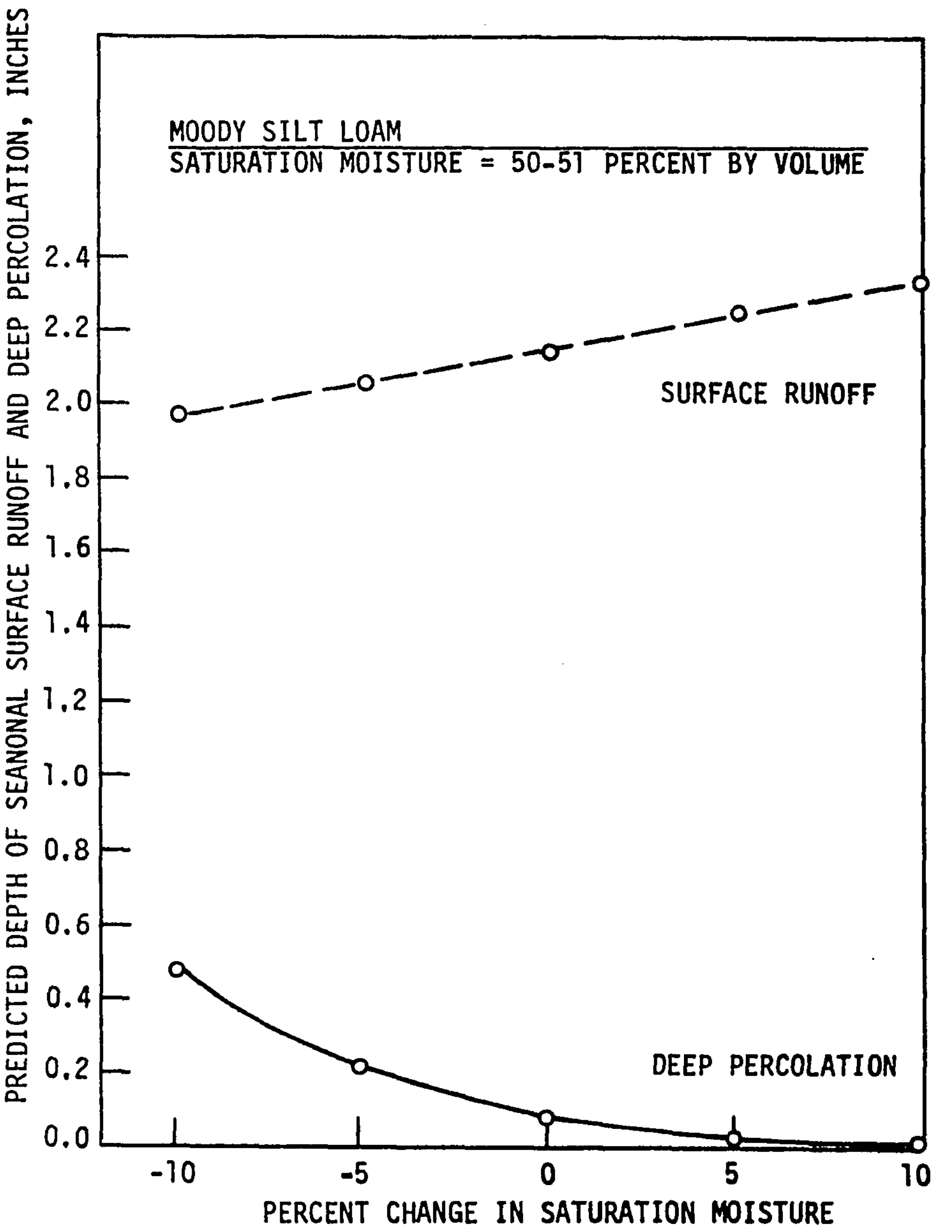

Figure 53. **Sensitivity of the model output to changes in saturation moisture, Moody Silt loam, northwest Iowa, 1967**

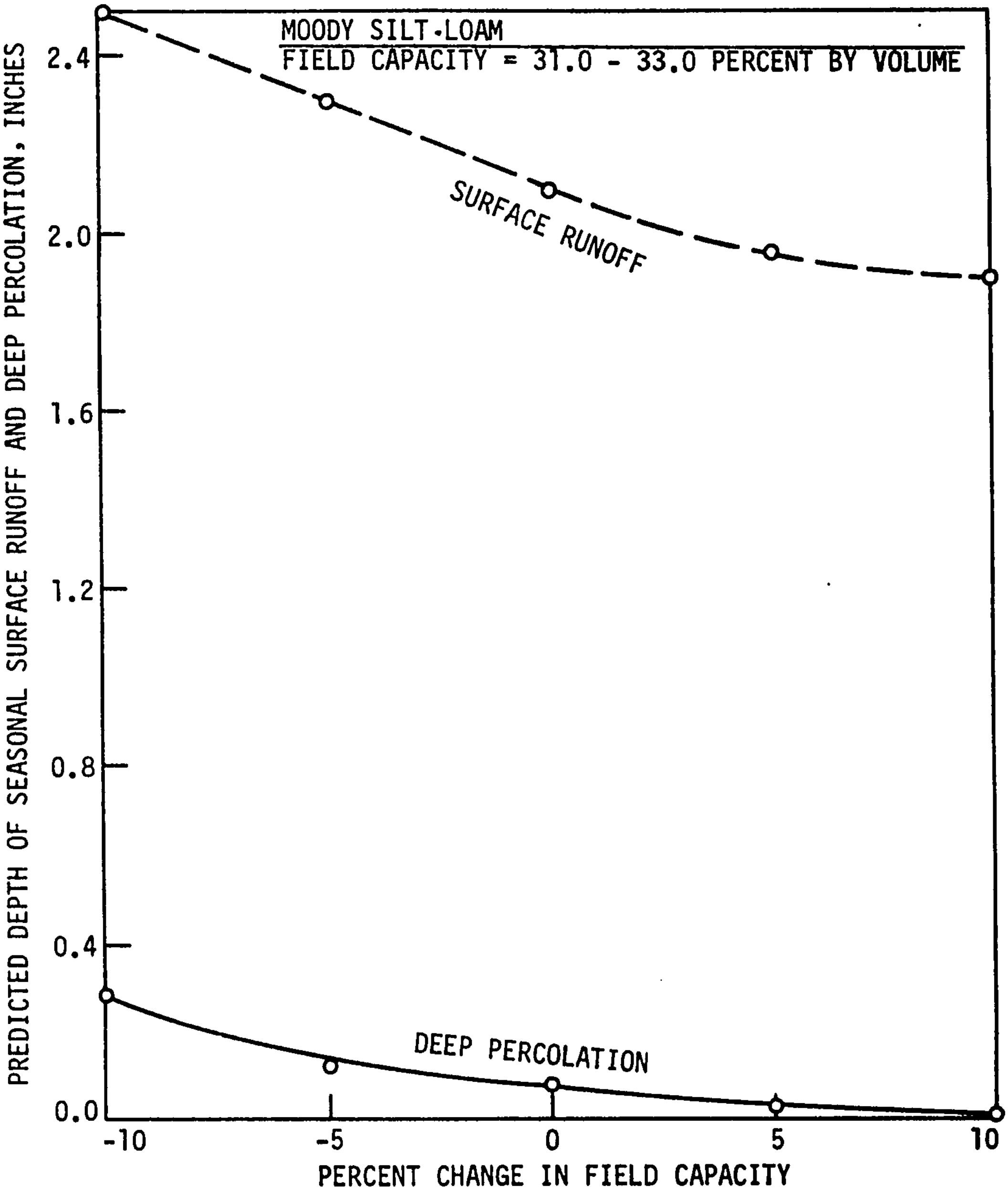

Figure 54. **Sensitivity of the model output to changes in field capacity moisture. Moody silt-loam, northwest Iowa, 1967**

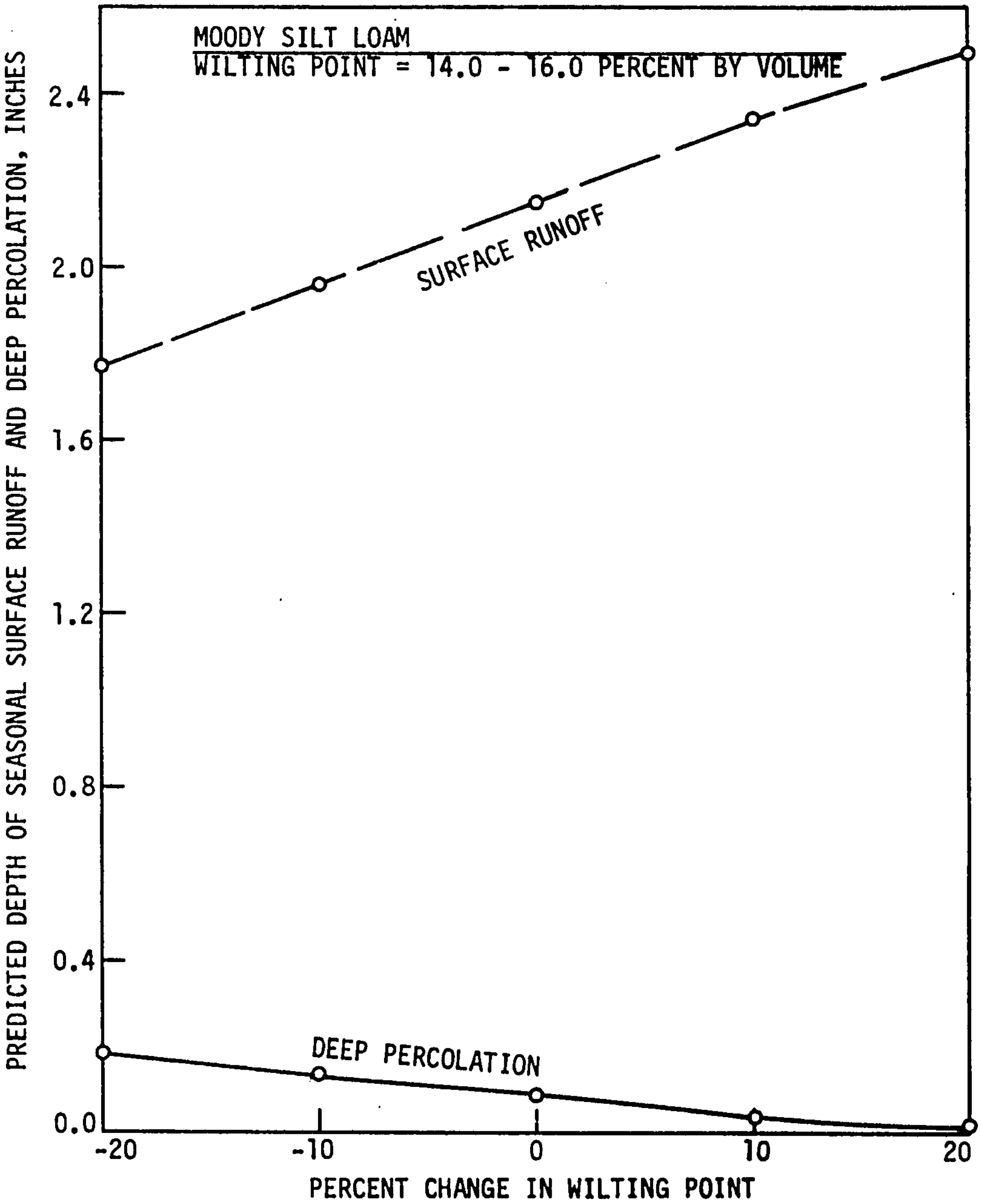

Figure 55. Sensitivity of the model output to changes in wilting point moisture. Moody silt loam, northwest Iowa, 1967

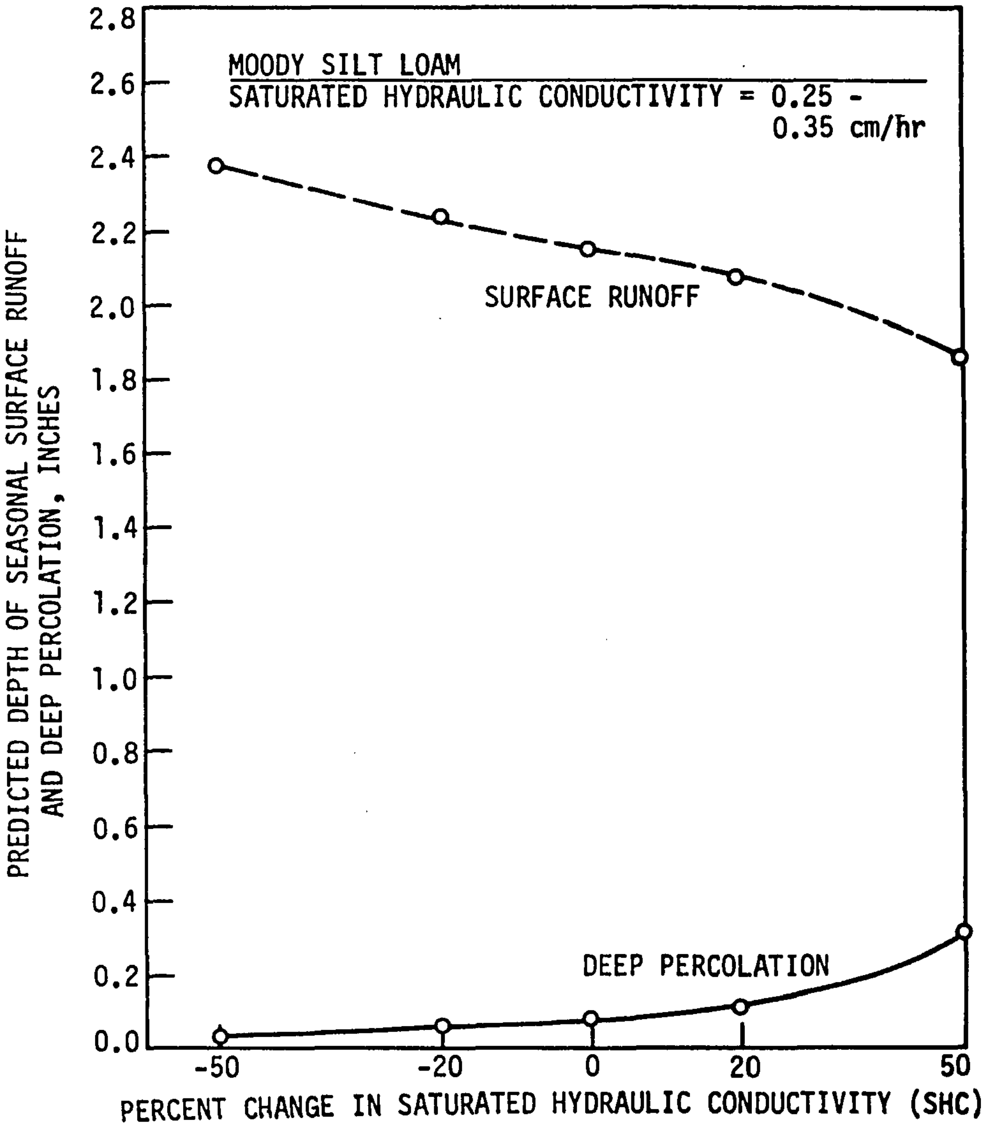

Figure 56. **Sensitivity of the model output to changes in saturated hydraulic conductivity. Moody silt·loam, northwest Iowa, 1967**

the restricted layer from the bottom of the soil profile caused a large increase in deep percolation (from 0.084 to 1.70 inches).

The response of the model using Moody silt loam showed its highest sensitivity to the variable PER_1. Deep percolation increased and actual evapotranspiration decreased at a high rate when PER_1 was decreased below 50%. Surface runoff increased when PER_1 was decreased below its original value (80%), see Figure 57.

Chelsea sand

The response of the model using Chelsea sand resulted in least sensitivity among the three soils used in the program. Thus, only a few runs were made on this soil, and indicated no significant changes in seasonal deep percolation, actual evapotranspiration or end-of-season soil moisture when SAT, SC, WP and SHC were changed.

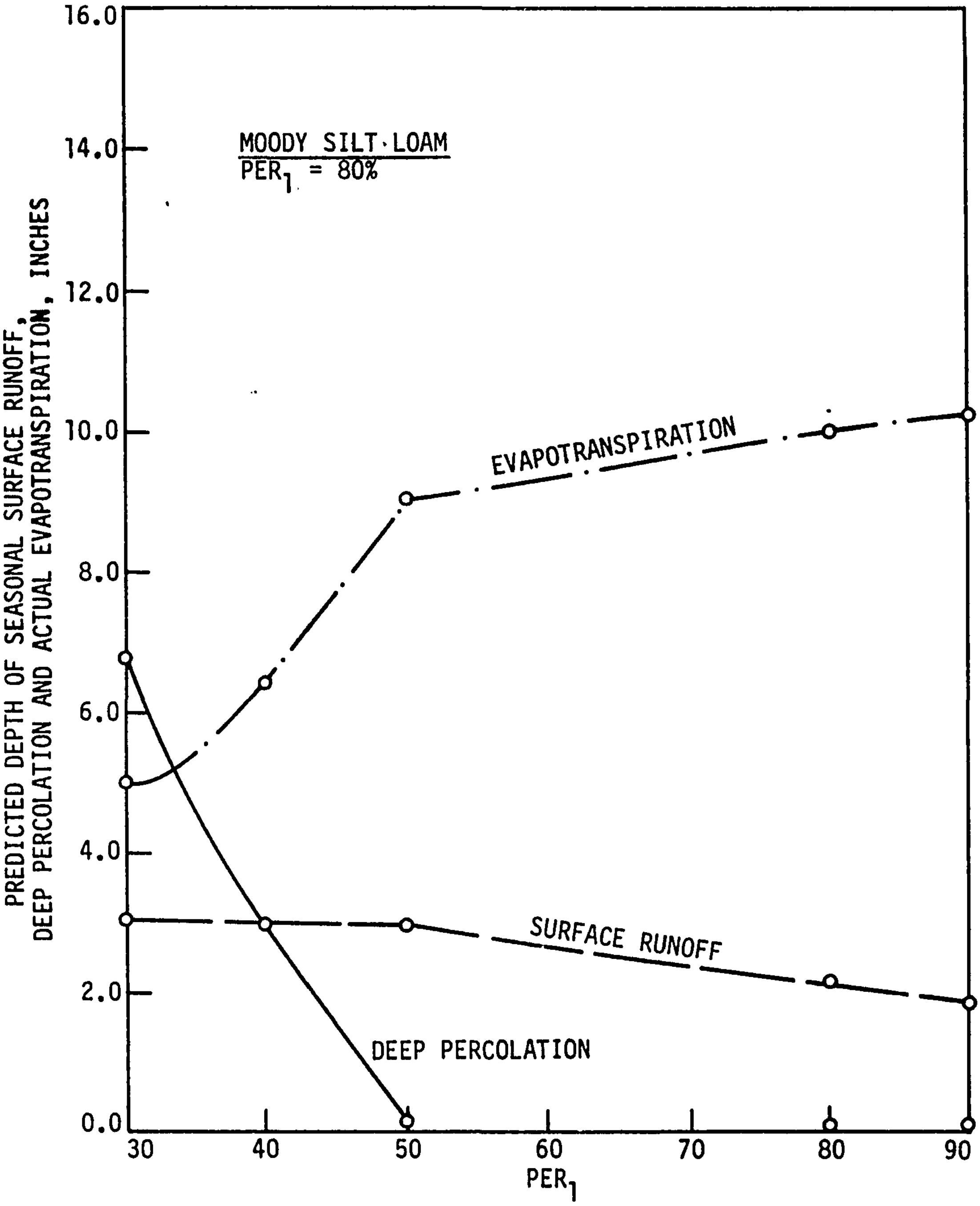

Figure 57. Sensitivity of the model output to percent saturation moisture at which immediate free drainage to lower soil layers occur (PER_1). Moody silt loam, northwest Iowa, 1967

SUMMARY AND CONCLUSIONS

A study of the irrigation potential of corn on three different soils in Iowa was conducted by computer simulation. A water balance model (Anderson, 1975) which uses spring soil moisture, rainfall data from rain gage charts, daily pan evaporation and physical soil properties as input data to estimate moisture balance, was modified for various soils to simulate irrigation application. The model consists of a main program and individual subroutines for the processes of precipitation, interception, evapotranspiration, infiltration, soil moisture redistribution, overland flow, and sprinkler irrigation.

The soils selected for irrigation simulation were: Moody silt loam, with high available soil moisture (2.0 in/ft) and moderate to low permeability (0.1 - 0.14 in/h); Chelsea sand, with low available moisture (0.6 in/ft) and high permeability (6 - 20 in/h); and Albaton clay, with moderate available moisture (1.8 in/ft) and very low permeability (0.02 - 0.04 in/h). Required soil data as needed in the model were determined by use of the recommended ranges in irrigation handbooks for soils with similar texture, and some specific measurements, such as the work by Castro-Morales (1978) on Moody soils, Wynne (1976) on Albaton soils, and Soil Conservation Service data on the physical properties of sandy soils in Nebraska, and Luton and Albaton soils in Monona County, Iowa.

The Moody silt loam site was located in the Doon watershed, northwest Iowa. Rainfall data taken from rain gage charts in the north Doon watershed, Doon daily pan evaporation and reported soil moisture data for the Doon station (Shaw et al., 1972), were used as input data to the model.

Measured depth of surface runoff and the reported values of soil moisture by Shaw et al. (1972), at the beginning of each month, were used to calibrate the model. At first, the model predicted high deep percolation and low soil moisture content. To improve model predictions, it was assumed that there was a low permeability layer at the bottom of the soil profile. The soil survey of Lyon County showed the presence of glacial till at a depth of 42-60 inches in many places in the northern and southern parts of the Moody association, justifying the above assumption.

The Chelsea sand area is located in southeast Iowa. Burlington hourly rainfall and daily pan evaporation data were used as input data for this soil. A revised precipitation subroutine developed by Anderson, which uses hourly rainfall data in U.S. Weather Bureau format, and develops rainfall depth as needed in the model, was added to the program, along with the previous subroutines. An input indicator was used in the main program to specify the type of available rainfall data, and thereby the associated subroutine. Spring soil moisture was assumed to be equal to the field capacity of Chelsea sand. No measured soil moisture or surface runoff data were available for the Chelsea sand to use in calibration.

It was expected that the Chelsea sand, with high permeability, would produce no surface runoff, and retain low moisture in the soil profile. Infiltration equation parameters were changed to increase the infiltration rate. The variable PER_1, defined as percent saturation moisture at which immediate free drainage to the next lower layer occurs, was decreased (from 80% to 30%) for the sandy soil, to hold less moisture within the soil profile.

The Albaton clay is located on the bottom lands of the Missouri river valley, in west central Iowa. Sioux City hourly rainfall and Castana pan evaporation data were used as inputs to the model for this soil. Spring soil moisture was calculated based on the Castana soil moisture values reported by Shaw et al. (1972).

Similar to the Chelsea sand, there were no measured soil moisture or surface runoff data available for the Albaton clay. These soils were located on nearly level lands, thus low surface runoff was expected. In contrast to the Chelsea sand, the heavy soils would retain high moisture within the soil profile. Under dry conditions, cracks will develop in the heavy soils, which increase infiltration rate and capacity, and thereby decrease surface runoff. To simulate this phenomenon, it was assumed that cracks would develop in the soil surface whenever soil moisture content fell to less than 50% of available soil moisture (ASM). Infiltration equation parameters were changed to allow for sudden increases in infiltration rate, and the redistribution subroutine was modified to allow water to flow downward with no restriction from the saturated hydraulic conductivity of the lower layer after crack development in the soil surface. With these modifications, the model predictions for surface runoff, deep percolation, soil moisture content, and actual evapotranspiration were within an acceptable range for heavy soils.

Calculation of weighted seasonal stress index was added to the program, using the procedure developed by Shaw (1974). The daily raw stress index was calculated in the main program as one minus the ratio of actual to potential evapotranspiration. The seasonal stress index was calculated over 85 days made up of eight five-day periods before and nine five-day periods after silking date. The stress index subroutine assigned certain weighting factors to raw stress indices, to account for differential effects on yield due to stages of development at which stress occurred. Higher weighting factors were assigned to the periods closer to silking date.

The effects of irrigation were simulated by incorporating into the program a sprinkler irrigation subroutine, which treated irrigation water as additional rainfall. For each time period during irrigation, the irrigation depth is added to any natural rainfall increments for that period, and handled by the model in the same manner as natural rainfall.

Irrigation water application on the basis of soil moisture content in the total root zone, was modified by replacing depth of active root zone for total depth. Depth of active root zone during different stages of development was determined using Shaw's (1963) root extraction schedule for corn. Thus, irrigation was initiated when the soil moisture in the active root zone fell to a given percentage of the available soil moisture in the active root zone.

Percent available soil moisture at irrigation, gross depth and application time period, and also starting and ending dates of irrigation are inputs to the model, which can be adjusted for various soils and plants.

Non-uniform irrigation application was simulated in the program by applying less water in the early stages of plant development, and increasing the amount according to root growth during the season. Since roots are gradually developing into the soil profile, and early in the season they occupy only the top layers, it was expected that non-uniform irrigation application would increase irrigation efficiency.

Soil moisture, rainfall and pan evaporation data were used in the computer simulation for the period 1958 to 1979 for the Moody silt loam, 1951 to 1978 for the Chelsea sand and Albaton clay. The simulations were made under natural conditions, and for various irrigation scheduling criteria for each soil. A summary of the results obtained in this study follows.

Computer simulation of the three soils under natural conditions gave the following results:

1. The Moody silt loam in northwest Iowa produced low surface runoff (0.0 - 4.5 in), and reasonably low deep percolation (0.0 - 3.0 in). The Chelsea sand in southeast Iowa, with high permeability, produced no surface runoff, and high deep percolation (4.0 - 13.0 in). The Albaton clay generated higher surface runoff (0.0 - 6.0 in) and deep percolation (1.0 - 5.0 in), than the Moody silt loam, as a result of higher seasonal rainfall. The Moody silt loam had the highest seasonal water use efficiency (the ratio of water use to water supply), and the Chelsea sand had the lowest water use efficiency, because of high water loss through deep percolation.

2. The length of stress period was defined as the summation of

consecutive days with soil moisture shortage (i.e. days when soil moisture in the active root zone fell to less than 50% of available soil moisture). It was determined that years with a long stress period were associated with low moisture supply (summation of spring soil moisture and growing season rainfall); on the other hand, years with a short stress period had high moisture supply. Lengths of stress periods in various years were used to define frequency distributions of soil moisture shortage. Three distributions (Gamma, Normal and Weibull) were fitted to stress periods for each soil; the Weibull distribution was selected as the best fit. The parameters of the distribution were estimated using the maximum likelihood procedure. Goodness-of-fit was justified by a chi-square test.

3. Weighted seasonal stress indices calculated in the program for the three soils indicated higher values for the Albaton clay than for the Moody silt loam for most years. The regression line between corn yield and weighted stress index was defined for Moody silt loam, where corn yield data were available, and showed close agreement with the relation developed by Shaw (1978) on Nicollet silt loam.

Computer simulation results under various irrigation scheduling criteria resulted in the following conclusions:

1. In predicting spring soil moisture after applying irrigation water in the previous year, spring soil moisture was related to fall soil moisture and fall-winter rainfall data from the Doon watershed, and was not closely related to fall soil moisture, but was related to fall-winter rainfall. Thus, spring soil moisture as used in the runs

without irrigation was also used in the program for irrigation water application.

2. Four different irrigation scheduling criteria were used for Moody silt loam. Comparison of various irrigation criteria indicated that: application of 2.0 inches at 35% of ASM resulted in lowest annual water requirements (mean depth of 4.0 inches, and maximum depth of 8.0 inches); on the other hand, 2.0 inches at 70% of ASM resulted in the highest annual irrigation water requirements (mean depth of 11.0 inches, and maximum depth of 18.0 inches). A 2.0 inch application at 50% of ASM resulted in an annual water use in between the other two criteria (mean of 7.0 inches, and maximum depth of 12.0 inches). A 4.0 inch application at 50% of ASM resulted in higher annual irrigation water requirements (mean depth of 9.0 inches, and maximum depth of 16.0 inches), than for a 2.0 inch application at 50% of ASM.

3. Non-uniform irrigation application was used for the Chelsea sand at three different soil moisture levels: 35%, 50% and 70% of ASM. A 1.0 - 3.0 inch application at 35% of ASM resulted in the lowest annual water use (mean depth of 7.6 inches, and maximum depth of 12.5 inches), while 0.5 - 1.5 inch applications at 70% of ASM caused the highest annual water use (mean depth of 14.7 inches, and maximum depth of 18.0 inches). Applications of 0.75 - 2.5 inches at 50% of ASM resulted in an annual water use between the other two criteria (mean depth of 10.8 inches, and maximum depth of 15.0 inches).

4. Albaton clay was irrigated at two different soil moisture levels: 50% and 70% of ASM. Because of the cracking properties of the

Albaton clay under dry conditions, soil moisture content was not allowed to fall to less than 50% of ASM. Application of 3.5 inches at 70% of ASM resulted in highest annual irrigation water requirements (mean depth of 18.0 inches, and maximum depth of 24.5 inches). Applying 1.5 inches at 70% of ASM and 5.0 inches at 50% of ASM resulted in the same mean depth of annual irrigation requirements (13.8 inches).

5. To determine frequency distributions of annual irrigation water requirements, different distributions (Normal, Gamma and Weibull) were tested on annual irrigation requirements, and the Weibull distribution was selected as the best fit. Goodness-of-fit for the Weibull distribution was then justified using a chi-square test.

6. The increase in surface runoff and deep percolation, and decrease in seasonal water use efficiency due to irrigation water application, were determined by comparing seasonal surface runoff, deep percolation, and water use efficiencies under natural conditions, and under various irrigation scheduling criteria.

For the Moody silt loam, a 2.0 inch application at 70% and 4.0 inch application at 50% of ASM resulted in the greatest increase in surface runoff and deep percolation, and the greatest decrease in seasonal water use efficiency. An application of 2.0 inches at 35% of ASM produced seasonal surface runoff, deep percolation and water use efficiencies similar to those for natural conditions. The response to a 2.0 inch application at 50% of ASM was between the above two extremes.

The Chelsea sand produced no surface runoff under natural conditions or irrigation water application. High deep percolation was generated under natural conditions, and a considerable increase was obtained due to irrigation application. The greatest increase in deep percolation and the greatest decrease in water use efficiency were obtained under irrigation application at 70% of ASM. The highest water use efficiency was under the application at 35% of ASM, while a few years resulted in water use efficiencies even higher than under natural conditions.

For the Albaton clay soil, the increase in surface runoff due to irrigation was more significant for wet years than for dry years. An application of 3.5 inches at 70% of ASM resulted in highest surface runoff and deep percolation and lowest seasonal water use efficiency. The least increase in surface runoff was for a 5.0 inch application at 50% of ASM. Applying 1.5 inches at 70% of ASM resulted in the least increase in deep percolation, and predicted seasonal water use efficiencies close to natural conditions.

7. Comparisons of seasonal weighted stress indices under natural conditions and various irrigation scheduling criteria, indicated that under natural conditions, weighted stress indices were high with wide variation among the years. Mean ($\bar{x}$) and standard deviation (s) of weighted stress indices were calculated as $\bar{x} = 45.0$ and $s = 13.5$ for the Moody silt loam; $\bar{x} = 50.0$ and $s = 11.8$ for the Chelsea sand; and $\bar{x} = 53.0$ and $s = 13.2$ for the Albaton clay. Considerably lower and more uniform stress indices were obtained after applying irrigation water on each soil. For example, applying irrigation at 50% of ASM reduced the mean and standard deviation to $\bar{x} = 28.0$ and $s = 3.8$ for the Moody

silt loam; $\bar{x} = 25.0$ and $s = 2.0$ for the Chelsea sand; and $\bar{x} = 22.0$ and $s = 3.0$ for the Albaton clay. Irrigation application at 70% of ASM did not improve stress indices significantly, except for a few dry years. Irrigation at 35% of ASM resulted in highest stress indices, but considerably lower than under natural conditions.

8. A stress index-yield relationship developed for the Moody silt loam under natural conditions, was used to predict irrigated corn yield, and thereby, increase in yield due to irrigation application. Comparing non-irrigated and irrigated corn yields at various irrigation schedules, indicated that yield increased considerably after applying irrigation water, while this increase was much more significant for dry years. Average yield under natural conditions was 85.0 bu/a, which increased to 110.0, 121.0 and 136.0 bu/a after irrigation applications at 35%, 50%, and 70% of ASM.

9. Sensitivity of the model was tested with respect to some major soil properties, including saturation moisture (SAT), field capacity (FC), wilting point (WP), saturated hydraulic conductivity (SHC), and percent saturation at which immediate free drainage to the next lower layer occurs (PER_1). The Albaton clay and Chelsea sand showed the most and least sensitivity to changes in soil properties, respectively. Variation of seasonal surface runoff (SRO), deep percolation (deep perco) and actual evapotranspiration (AET) followed the same trends in the Albaton clay and the Moody silt loam, but the rates of change in the Moody silt loam were much lower than in the Albaton clay soil. SAT, FC and WP were changed by plus and minus 10% of their original

values (WP was changed by plus and minus 20% of its original value in Moody silt loam), SHC was changed by plus and minus 50% of its original value, and PER_1 was decreased to 50% and increased to 100%, with the following results.

Deep percolation decreased, while AET and SRO increased with increasing SAT. Increasing FC increased deep percolation, and decreased AET and SRO. Deep percolation decreased and SRO increased with increasing WP, at a rate lower than changing SAT and FC. Increasing SHC, and also removing the restricted layer from the bottom of the soil profile, increased deep percolation. Deep percolation increased and AET decreased with decreasing PER_1.

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APPENDIX A:

SIMULATION RESULTS UNDER NATURAL CONDITIONS AND UNDER IRRIGATION

Table A1. Missing recording rainfall data

		Rainfall with no available charts			
Year	Date gage installed	From April 15 to date gage installed		Clock stopped	
		Date	Inches	Date	Inches
1958	May 31	4/19	0.16	6/22	0.80
		4/24	0.66		
		4/28	0.12		
		5/7	0.26		
		5/17	0.76		
1959	May 2	4/20	0/28		
1960	May 16	4/28	0.48		
		4/29	0.38		
		5/4	0.31		
		5/5	0.87		
1961	May 17	4/23	0.47		
		5/5	0.42		
		5/6	0.42		
		5/7	0.54		
		5/14	0.46		
1962	April 11			4/27	0.55
				4/20	0.24
				5/13	0.16
1963	May 6	4/22	0.28	7/18	0.35
		4/28	0.19	7/19	0.38
		4/29	0.11	8/23	0.38
1964	May 12	4/26	0.31	5/12	1.72
		4/27	0.90		
		4/30	0.28		
		5/3	0.35		
		5/6	0.40		
		5/8	0.57		
1965	May 12	4/17	0.15		
		4/24	0.47		
		4/27	0.17		
1966	April 18			8/12	0.78
				8/15	0.85
1967	April 25			5/10	0.29
				5/29	0.27

Table A1 (continued)

Year	Date gage installed	Rainfall with no available charts			
		From April 15 to date gage installed		Clock stopped	
		Date	Inches	Date	Inches
1968	April 13				
1969	April 14				
1970	April 12			8/2	0.39[a]
				8/15	1.81
1971	April 20				
1972	April 18			4/21	1.79
				4/28	0.25
				6/26	0.27
1973	April 15			7/8	2.3
1974	April 3	6/6	0.93[b]	8/8	3.20[c]
		6/9	0.79	8/17	1.19[c]
		6/22	1.16	8/22	1.65[c]
				8/27	0.43[c]
1975	April 14			4/15	0.35
				8/18	0.44
				8/22	3/25[c]
1976	April 30	4/15	0.54		
		4/23	0.32		
		4/24	0.73		
1977	April 14			5/27	0.78
				7/28	0.35
1978	April 17			4/18	1.58[c]
				4/31	0.51
				6/17	0.36
				8/1	0.68

[a] No charts were available after August 1.

[b] All June charts were missing.

[c] Clock worked for part of the chart.

Table A2. Total soil moisture on April 15, by six-inch increments to five feet (inches), for Moody silt loam on the Doon watershed (Shaw, 1972)

Layer Year	1	2	3	4	5	6	7	8	9	10	Total
1958	2.4	2.4	2.1	2.1	1.45	1.45	1.15	1.15	1.10	1.10	16.40
1959	1.7	1.7	1.2	1.2	0.95	0.95	0.85	0.85	0.80	0.80	11.00
1960	2.4	2.4	2.1	2.1	1.95	1.95	1.50	1.50	1.30	1.30	18.50
1961	2.15	2.15	1.8	1.8	1.70	1.70	1.65	1.65	1.60	1.60	17.80
1962	2.40	2.40	2.1	2.1	1.55	1.55	1.15	1.15	0.95	0.95	16.30
1963	1.85	1.85	1.40	1.40	0.95	0.95	0.90	0.90	0.90	0.90	12.0
1964	2.2	2.3	2.1	2.0	1.6	1.6	0.95	0.95	0.80	0.80	15.30
1965	2.3	2.4	2.1	2.1	1.5	1.4	1.2	1.2	1.1	1.0	16.30
1966	2.15	2.15	1.9	1.9	1.45	1.45	1.35	1.35	1.1	1.1	15.90
1967	1.9	1.9	1.5	1.5	0.95	0.95	0.85	0.85	0.80	0.80	12.0
1968	1.15	1.15	1.1	1.1	0.95	0.95	0.85	0.85	0.80	0.80	9.70
1969	2.40	2.40	2.05	2.05	2.15	2.15	2.20	2.20	2.35	2.35	22.30
1970	2.25	2.25	1.50	1.50	1.0	1.0	0.95	0.95	0.95	0.95	13.30
1971	2.0	2.0	1.80	1.80	1.50	1.50	1.0	1.0	0.80	0.80	14.20
1972	1.70	1.70	1.85	1.85	1.30	1.30	0.85	0.85	0.80	0.80	13.0
1973	2.30	2.30	1.90	1.90	1.75	1.75	1.70	1.70	1.60	1.60	18.50
1974	2.20	2.20	1.95	1.95	1.45	1.45	1.20	1.20	1.05	1.05	15.70
1975	2.45	2.45	1.95	1.95	1.40	1.40	2.0	2.0	2.0	2.0	19.60
1976[a]	2.05	2.05	2.0	2.0	1.75	1.75	1.35	1.35	1.55	1.55	17.40
1977[a]	2.15	2.15	1.95	1.95	1.25	1.25	1.10	1.10	1.25	1.25	15.40
1978[a]	2.30	2.30	2.30	2.30	2.0	2.0	1.70	1.70	1.50	1.50	19.60

[a] For 1976, 1977 and 1978, soil moisture was taken on the following days: 1976 - April 5; 1977 - April 13; 1978 - April 11.

Table A3. Total soil moisture on April 15, by six-inch increments to five feet (inches), for Albaton clay, based on Castana soil moisture data (Shaw, 1972)

Layer Year	1	2	3	4	5	6	7	8	9	10	Total
1951	2.04	2.08	1.81	1.82	1.82	1.82	1.85	1.86	1.83	1.83	18.76
1952	2.04	2.08	1.81	1.82	1.82	1.82	1.85	1.86	1.83	1.83	18.76
1953	2.04	2.08	1.81	1.82	1.82	1.82	1.85	1.86	1.83	1.83	18.76
1954	2.04	2.08	1.81	1.82	1.82	1.82	1.85	1.86	1.83	1.83	18.76
1955	1.94	2.02	2.19	2.29	2.12	2.12	2.05	2.07	2.01	2.01	20.82
1956	1.75	1.88	1.74	1.74	1.74	1.74	1.85	1.86	1.92	1.92	18.14
1957	1.94	2.02	1.98	2.03	1.82	1.82	1.85	1.86	1.83	1.83	18.98
1958	2.23	2.22	2.43	2.58	2.58	2.58	2.58	2.64	2.64	2.64	25.12
1959	2.14	2.15	2.43	2.58	2.58	2.58	2.05	2.07	1.92	1.92	22.42
1960	2.52	2.43	2.43	2.58	2.58	2.58	2.50	2.55	2.28	2.28	24.73
1961	2.42	2.36	2.43	2.58	2.58	2.58	2.58	2.64	2.64	2.64	25.45
1962	2.47	2.40	2.43	2.58	2.58	2.58	2.58	2.64	2.46	2.46	25.18
1963	2.09	2.12	2.43	2.58	2.37	2.37	2.34	2.38	2.37	2.37	23.42
1964	2.42	2.36	2.43	2.58	2.54	2.54	2.05	2.07	2.14	2.14	23.27
1965	2.28	2.26	2.43	2.58	1.99	1.99	1.77	1.77	1.92	1.92	20.91
1966	2.04	2.08	2.29	2.41	2.24	2.24	2.17	2.20	2.19	2.19	22.05
1967	2.18	2.19	1.77	1.78	1.78	1.78	1.85	1.86	1.87	1.87	18.93
1968	1.99	2.05	1.77	1.78	1.74	1.74	1.77	1.77	1.74	1.74	18.09
1969	2.42	2.36	2.46	2.62	2.29	2.29	2.13	2.16	2.10	2.10	22.93
1970	2.52	2.43	2.36	2.50	2.12	2.12	1.93	1.94	1.87	1.87	21.66
1971	2.38	2.33	2.50	2.66	2.33	2.33	2.26	2.29	2.28	2.28	23.64
1972	2.33	2.30	2.33	2.45	2.33	2.33	2.05	2.07	1.83	1.83	21.85
1973	2.52	2.43	2.43	2.58	2.58	2.58	2.58	2.64	2.64	2.64	25.62
1974	2.47	2.40	2.39	2.53	2.33	2.33	2.30	2.34	2.32	2.32	23.73
1975	2.71	2.57	2.33	2.45	2.29	2.29	1.97	1.99	2.05	2.05	22.70
1976	2.62	2.50	2.40	2.54	2.45	2.45	2.01	2.03	1.83	1.83	22.66
1977	2.66	2.53	2.40	2.54	1.95	1.95	1.77	1.77	1.74	1.74	21.05
1978	2.62	2.50	2.36	2.50	2.24	2.24	1.97	1.99	2.01	2.01	22.44
1979	2.62	2.50	2.53	2.71	2.45	2.45	1.97	1.99	1.78	1.78	22.78

Table A4. Summary of the model output for Moody silt loam without applying irrigation water

Year	ISM[a] Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)	Accumulated depth of water subtracted from soil 4/15-9/15 (in.)			ESM[b] Top 5-ft 9/15 (in.)
		Rainfall	SRO[c]	AET[d]	Deep Perc.[e]	
1958	16.4	7.90	0.0	12.90	0.84	10.55
1959	11.0	19.25	2.34	13.34	0.39	13.50
1960	18.5	17.88	0.27	20.24	1.08	14.54
1961	17.8	14.81	0.0	15.0	1.70	14.96
1962	16.3	16.29	0.08	17.66	0.43	14.02
1963	12.0	11.07	0.02	11.82	0.14	11.11
1964	15.3	17.34	0.50	18.49	0.41	12.62
1965	16.3	16.0	1.55	17.32	1.34	11.97
1966	15.9	10.84	0.0	12.55	1.12	13.06
1967	12.0	10.60	0.95	9.70	0.20	11.54
1968	9.7	9.21	0.0	8.89	0.11	9.76
1969	22.3	15.33	1.95	18.34	3.87	12.97
1970	13.3	8.97	0.0	11.01	0.54	10.68
1971	14.20	12.87	0.77	14.10	1.15	11.13
1972	13.0	19.55	3.40	16.03	1.25	11.81
1973	18.5	13.40	0.90	16.42	0.93	13.40
1974	15.7	12.61	0.0	14.09	0.34	13.89
1975	19.6	16.20	1.10	19.26	0.77	14.69
1976	17.4	7.73	0.0	13.48	1.42	10.22

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[a] ISM = Initial soil moisture.

[b] ESM = End of season soil moisture.

[c] SRO = Surface runoff.

[d] AET = Actual evapotranspiration.

[e] Deep perc = Deep percolation.

Table A4. Continued

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)	Accumulated depth of water subtracted from soil 4/15-9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	SRO	AET	Deep Perc.	
1977	15.4	18.09	2.95	17.29	0.55	12.49
1978	19.6	15.68	0.42	19.01	1.46	14.61
1979	19.8	22.87	4.57	16.25	3.08	16.59

Table A5. Summary of the model output for chelsea sand, southeast Iowa, without applying irrigation water

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)	Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
		Rainfall	AET	Deep Perc.	
1951	6.12	21.01	15.97	6.58	4.37
1952	6.12	24.71	13.70	12.79	4.34
1953	6.12	12.18	10.54	5.13	2.63
1954	6.12	17.60	12.99	7.22	3.51
1955	6.12	15.94	11.670	7.33	3.06
1956	6.12	15.75	14.48	4.14	3.25
1957	6.12	18.10	13.69	7.72	2.80
1958	6.12	23.23	16.78	9.09	3.58
1959	6.12	16.85	13.0	7.34	2.63
1960	6.12	21.48	13.44	11.68	2.48
1961	6.12	22.67	16.01	7.02	5.76
1962	6.12	15.36	12.15	5.57	3.76
1963	6.12	16.90	14.48	5.62	2.91
1964	6.12	13.77	10.84	6.54	2.50
1965	6.12	22.85	14.79	8.25	5.88
1966	6.12	15.82	11.41	7.03	3.41
1967	6.12	19.36	13.60	7.92	3.95
1968	6.12	11.12	10.94	3.53	2.69
1969	6.12	17.81	15.0	4.95	3.93
1970	6.12	26.47	15.31	11.40	5.88
1971	6.12	10.55	10.55	3.06	3.06
1972	6.12	21.61	16.01	8.30	3.42
1973	6.12	26.21	15.05	13.53	3.75

Table A5. Continued

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)	Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
		Rainfall	AET	Deep Perc.	
1974	6.12	22.57	14.70	10.99	3.00
1975	6.12	18.15	13.44	5.90	4.93
1976	6.12	17.94	12.30	9.14	2.62
1977	6.12	17.51	13.76	4.15	5.72
1978	6.12	18.35	13.71	7.12	3.63

Table A6. Summary of the model output for Albaton clay, without applying irrigation water

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)	Accumulated depth of water subtracted from soil 4/15-9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	SRO	AET	Deep Perc.	
1951	18.76	25.36	2.88	17.81	2.88	20.46
1952	18.76	17.58	1.84	14.11	1.97	18.42
1953	18.76	13.67	1.68	11.55	2.15	17.06
1954	18.76	14.44	2.53	11.60	1.93	17.14
1955	20.82	9.90	0.0	11.37	2.70	16.65
1956	18.14	13.61	0.0	12.90	1.58	17.27
1957	18.98	22.24	2.24	15.69	2.85	20.09
1958	25.12	11.54	0.0	13.82	5.04	17.80
1959	22.42	18.05	0.93	17.15	5.25	17.14
1960	24.73	15.52	0.034	15.52	5.04	19.66
1961	25.45	21.80	4.57	17.38	5.55	19.74
1962	25.18	24.26	4.44	19.62	5.88	19.50
1963	23.42	17.15	1.70	15.78	4.56	18.53
1964	23.27	21.32	0.084	19.85	4.79	19.86
1965	20.91	16.27	0.0	14.21	3.37	19.60
1966	22.05	16.34	0.0	15.25	3.47	18.67
1967	18.93	18.16	2.76	13.67	3.44	17.22
1968	18.09	11.45	0.0	11.21	1.35	16.98
1969	22.93	19.74	3.43	16.69	3.62	18.93
1970	21.66	14.29	0.0	13.35	3.23	19.36
1971	23.64	9.83	0.0	12.82	4.43	16.22
1972	21.85	25.29	5.48	18.20	4.61	18.85
1973	25.62	13.32	1.55	14.21	5.04	18.14
1974	23.73	13.10	0.0	14.54	4.38	17.90

Table A6. Continued

	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)	Accumulated depth of water subtracted from soil 4/15-9/15 (in.)			ESM Top 5-ft 9/15 (in.)
Year		Rainfall	SRO	AET	Deep Perc.	
1975	22.70	18.26	1.78	16.70	4.09	18.19
1976	22.66	8.86	0.0	10.20	3.70	17.43
1977	21.05	20.85	2.70	17.73	2.88	18.59
1978	22.44	11.88	0.0	12.99	2.91	18.42

Table A7. Initial soil moisture plus growing season rainfall, duration of stress period and the associated dates of moisture shortage occurrence, Moody silt loam, northwest Iowa

Year	Initial soil moisture + growing season rainfall (in.)	Duration of stress period (days)	Dates of soil moisture shortage occurrence
1958	24.30	44	7/19-9/1
1959	30.25	89	4/16-5/19; 7/8-9/1
1960	36.38	40	7/23-9/1
1961	32.61	36	7/17-8/20
1962	32.59	52	5/8-21; 7/25-9/1
1963	23.07	138	4/16-9/1
1964	32.64	55	6/5-6; 6/12-13; 7/3-8; 7/18-9/1
1965	32.30	36	7/27-9/1
1966	26.74	51	7/10-9/1
1967	22.50	112	4/16-6/6; 7/3-9/1
1968	18.91	138	4/16-9/1
1969	37.63	18	8/14-9/1
1970	22.27	69	4/16-5/1; 7/9-9/1
1971	27.07	38	7/25-9/1
1972	32.55	40	4/16-4/20; 7/28-9/1
1973	31.90	19	8/13-9/1
1974	28.31	70	4/30-5/8
1975	35.80	43	7/10-8/21
1976	25.13	55	7/8-9/1
1977	33.49	63	6/30-9/1
1978	35.28	4	7/16-7/20
1979	42.67	21	7/20-21; 7/24-29; 8/4-8; 8/11-16; 8/18

Table A8. Initial soil moisture plus growing season rainfall, duration of stress period and the associated dates of moisture shortage occurrence, Chelsea sand, southeast Iowa

Year	Initial soil moisture + growing season rainfall (in.)	Duration of stress period (days	Dates of soil moisture shortage occurrence
1951	27.13	31	7/14-15; 8/3-24; 9/5-11
1952	30.83	41	7/1-8/10
1953	18.30	74	6/23; 7/3-4; 7/7-9/15
1954	23.72	80	6/12-14; 6/24-28; 7/1-8/25; 8/31-9/15
1955	22.06	79	6/22-23; 6/26-28; 7/4-9/15
1956	21.85	70	6/10-16; 6/29-7/1; 7/15-16; 7/20-9/15
1957	24.22	62	6/24-25; 7/7-7/21; 8/2-9/15
1958	29.35	29	6/26-30; 7/14-18; 7/26-28; 8/28-9/2; 9/6-9/15
1959	22.97	80	6/9-20; 7/10-9/15
1960	27.60	60	7/11-24; 7/27-8/5; 8/11-9/15
1961	28.79	55	6/13-14; 6/17-18; 6/25-29; 7/7-12; 7/16-17; 8/2-9; 8/14-9/12
1962	21.48	83	6/20-30; 7/6-9/15
1963	23.02	73	6/11-18; 6/23-7/3; 7/23-9/15
1964	19.89	83	6/9-10; 6/27-9/15
1965	28.97	50	6/14-19; 6/24-29; 7/8-12; 7/23-8/24
1966	21.94	64	6/29-7/25; 7/29-9/15
1967	25.48	51	7/4-28; 8/6-7; 8/10-9/15

Table A8. Continued

Year	Initial soil moisture + growing season rainfall (in.)	Duration of stress period (days	Dates of soil moisture shortage occurrence
1968	17.24	72	6/23; 7/7-9/15
1969	23.93	53	6/20-21; 7/16; 7/23-8/8; 8/11-19; 8/23-9/15
1970	35.59	38	6/10-13; 6/30-8/3
1971	16.67	66	6/9-7/17; 7/20-9/15
1972	27.73	49	7/4-10; 7/24-8/5; 8/18-9/15
1973	32.33	54	6/11-14; 7/11-20; 7/26; 8/8-9/15
1974	28.69	35	7/1-2; 7/14-9/15
1975	24.27	51	6/11; 7/2-8/13; 8/17-19; 8/23-24; 8/27-28
1976	24.06	67	6/8-9; 6/23-27; 7/6-19; 7/30-8/10; 8/13-9/15
1977	23.63	54	6/20-29; 7/5-8/8; 8/24-27; 8/30-31; 9/9-11
1978	24.47	30	6/13-14; 7/15-20; 7/25-9/15

Table A9. Initial soil moisture plus growing season rainfall, duration of stress period and the associated dates of moisture shortage occurrence, Albaton clay, west central Iowa

Year	Initial soil moisture + growing season rainfall (in.)	Duration of stress period (days)	Dates of soil moisture shortage occurrence
1951	44.12	127	4/16-5/17; 5/25-30; 6/27-9/15
1952	36.34	153	4/16-9/15
1953	32.43	147	4/16-6/16; 6/13-9/15
1954	32.20	138	4/16-6/2; 6/5-19; 6/23-9/15
1955	30.72	146	4/16-27; 5/5-9/15
1956	31.75	153	4/16-9/15
1957	41.13	130	4/16-6/12; 7/6-9/15
1958	36.66	89	6/19-9/15
1959	40.47	87	6/18-29; 7/3-9/15
1960	40.25	91	6/16-9/15
1961	47.25	79	6/29-9/15
1962	49.44	64	7/5-12; 7/22-9/15
1963	40.57	80	6/28-9/15
1964	44.59	76	6/18-21; 6/25-7/4; 7/15-9/15
1965	37.18	113	4/16-5/7; 5/12-13; 6/19-9/15
1966	37.39	112	5/4-6/2; 6/22-23; 6/28-9/15
1967	37.09	119	4/16-5/29; 7/3-9/15
1968	29.54	153	4/16-9/15
1969	42.67	100	6/4-10; 6/15-9/15
1970	35.95	112	4/26-29; 5/5-11; 5/19-28; 6/6-9; 6/20-9/15
1971	33.47	87	6/21-9/15

Table A9. Continued

Year	Initial soil moisture + growing season rainfall (in.)	Duration of stress period (days)	Dates of soil moisture shortage occurrence
1972	47.14	89	6/3-11; 6/22-7/16; 6/23-9/15
1973	38.94	83	6/25-9/15
1974	36.83	81	6/27-9/15
1975	40.96	79	6/29-9/15
1976	31.34	105	5/16-20; 6/8-9/15
1977	41.90	135	4/16-5/27; 5/31-6/25; 7/1-9/15
1978	34.32	129	5/10-9/15

Table A10. Summary of the model output for 2.0 inch irrigation application at 35% available soil moisture, Moody silt loam, 1958 to 1979

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1958	16.40	7.90	6.0	0.0	15.55	0.85	13.89
1959	11.0	19.25	6.0	4.26	16.27	0.66	14.84
1960	18.50	17.88	2.0	0.27	21.02	1.09	15.74
1961	17.80	14.81	2.0	0.35	15.99	1.71	15.90
1962	16.30	16.29	6.0	1.35	16.94	0.61	16.47
1963	12.0	11.07	6.0	0.07	15.63	0.21	15.18
1964	15.30	17.34	2.0	0.50	19.38	0.42	13.81
1965	16.30	16.0	2.0	1.55	18.12	1.34	13.16
1966	15.90	10.84	4.0	0.07	14.60	1.13	14.92
1967	12.0	10.50	8.0	1.79	13.63	0.48	14.56
1968	9.70	9.21	8.0	0.02	13.25	0.19	13.30
1969	22.30	15.33	2.0	1.95	18.43	3.87	14.88
1970	13.30	8.97	6.0	0.0	14.37	0.55	13.31
1971	14.20	12.87	4.0	0.77	15.92	1.16	13.30
1972	13.0	19.55	4.0	3.26	16.39	1.97	14.61
1973	18.50	13.40	2.0	0.90	16.42	0.91	13.40
1974	15.70	12.61	6.0	0.0	17.57	0.89	15.85
1975	19.60	16.20	4.0	1.28	20.84	0.79	16.92
1976	17.40	7.73	6.0	0.0	17.41	1.44	14.26
1977	15.40	18.09	2.0	3.59	17.92	0.56	13.20
1978	19.60	15.68	0.0	0.42	19.01	1.46	14.61
1979	19.80	22.87	0.0	4.60	16.15	3.08	18.84

Table A11. Summary of the model output for 2.0 inch irrigation application at 50% available soil moisture, Moody silt loam, 1958 to 1979

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1958	16.40	7.90	8.0	0.17	16.30	0.83	15.15
1959	11.0	19.25	8.0	4.68	16.64	0.84	15.90
1960	18.50	17.88	4.0	1.13	21.42	1.08	16.49
1961	17.80	19.81	6.0	2.15	16.83	1.68	17.22
1962	16.30	16.29	8.0	0.47	21.16	0.86	17.20
1963	12.0	11.07	12.0	0.57	17.95	0.24	16.32
1964	15.30	17.34	6.0	0.60	21.28	0.49	16.10
1965	16.30	16.0	6.0	1.56	18.92	1.36	14.12
1966	15.90	10.84	6.0	0.19	15.90	1.05	15.59
1967	12.0	10.50	12.0	2.47	14.91	0.62	16.35
1968	9.70	9.21	12.0	0.39	14.99	0.25	14.99
1969	22.30	15.33	2.0	1.96	18.79	3.88	14.52
1970	13.30	8.97	8.0	0.0	15.53	0.50	16.20
1971	14.20	12.87	6.0	0.84	17.22	1.15	15.92
1972	13.0	19.55	6.0	3.58	17.68	1.49	15.29
1973	18.5	13.40	6.0	2.42	17.01	0.93	15.20
1974	15.7	12.61	10.0	0.04	19.72	0.89	17.52
1975	19.6	16.20	6.0	2.55	21.63	0.74	16.86
1976	17.4	7.73	12.0	0.26	20.09	1.36	15.42
1977	15.4	18.09	6.0	5.38	18.90	0.59	14.37
1978	19.6	15.68	4.0	2.31	19.48	1.47	15.96
1979	19.8	22.87	2.0	5.28	17.02	3.06	17.06

Table A12. Summary of the model output for 2.0 inch irrigation application at 70% of available soil moisture, Moody silt loam, 1958-1979

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1958	16.40	7.90	14.0	0.11	18.51	1.81	17.86
1959	11.0	19.25	14.0	4.42	17.98	2.77	16.77
1960	18.50	17.88	8.0	0.90	22.96	1.43	18.83
1961	17.80	14.81	8.0	1.75	18.37	2.13	17.97
1962	16.30	16.29	10.0	0.34	20.82	1.45	19.85
1963	12.0	11.07	14.0	0.16	19.15	0.88	16.84
1964	15.30	17.34	10.0	1.38	22.15	0.87	16.94
1965	16.30	16.0	8.0	1.59	19.97	1.54	17.07
1966	15.90	10.84	12.0	0.67	17.68	1.54	17.67
1967	12.0	10.50	16.0	2.31	16.88	1.18	18.01
1968	9.70	9.21	18.0	0.24	17.90	0.91	17.50
1969	22.30	15.33	6.0	2.04	19.39	4.34	17.56
1970	13.30	8.97	14.0	0.0	17.99	1.44	16.80
1971	14.20	12.87	12.0	2.64	18.87	1.71	18.02
1972	13.0	19.55	8.0	3.37	17.26	2.23	17.34
1973	18.50	13.40	12.0	3.91	18.65	1.85	17.04
1974	15.70	12.61	12.0	0.0	20.17	1.53	18.60
1975	19.60	16.20	12.0	2.87	23.78	1.60	19.77
1976	17.40	7.73	14.0	6.36	21.84	2.13	16.60
1977	15.40	18.09	10.0	5.99	19.14	1.49	16.52
1978	19.50	15.68	8.0	2.39	20.95	1.99	17.92
1979	19.80	22.87	6.0	6.19	18.19	3.20	18.84

Table A13. Summary of the model output for 4.0 inch application at 50% of available soil moisture, Moody silt loam, 1958-1979

	ISM top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
Year		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1958	16.40	7.90	8.0	0.0	16.88	1.02	14.38
1959	11.0	19.25	12.0	4.44	18.33	3.19	16.10
1960	18.50	17.88	8.0	0.69	22.28	1.36	19.79
1961	17.80	14.81	8.0	2.60	17.48	2.12	17.97
1962	16.30	16.29	12.0	1.39	21.24	3.47	18.34
1963	12.0	11.07	12.0	0.18	18.22	0.58	16.01
1964	15.30	17.34	8.0	0.71	20.84	0.74	17.72
1965	16.30	16.0	8.0	1.61	19.30	1.46	17.80
1966	15.90	10.84	8.0	0.0	16.78	1.44	16.22
1967	12.0	10.50	16.0	2.93	16.04	1.05	18.46
1968	9.70	9.21	12.0	0.0	15.69	0.74	14.32
1969	22.30	15.33	4.0	1.96	18.97	3.96	16.28
1970	13.30	8.97	12.0	0.0	16.28	0.81	17.14
1971	14.20	12.87	8.0	0.83	17.52	1.40	15.39
1972	13.0	19.55	8.0	3.85	17.23	2.88	16.29
1973	18.50	13.40	8.0	3.23	17.16	1.05	18.18
1974	15.70	12.61	12.0	0.03	18.49	2.35	19.36
1975	19.60	16.20	8.0	1.74	22.30	1.0	18.80
1976	17.40	7.73	8.0	0.02	19.83	1.72	15.55
1977	15.40	18.09	8.0	4.91	19.65	0.86	15.86
1978	19.60	15.68	4.0	2.75	19.59	1.67	15.45
1979	19.80	22.87	4.0	5.40	17.63	3.26	18.19

Table A14. Summary of the model output for non-uniform (1.0-3.0-in.) irrigation application at 35% available soil moisture, Chelsea sand, 1951-1978

	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)		Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
Year		Rainfall	Irrigation	AET	Deep Perc.	
1951	6.12	21.0	3.0	17.34	8.0	4.67
1952	6.12	24.71	5.0	16.65	14.83	4.34
1953	6.12	12.18	10.5	16.92	6.63	5.24
1954	6.12	17.60	7.0	16.70	9.80	4.21
1955	6.12	15.94	7.5	17.25	8.0	4.31
1956	6.12	15.75	7.5	17.13	7.82	4.42
1957	6.12	18.10	8.5	17.70	9.71	5.31
1958	6.12	23.23	3.0	17.06	9.63	5.76
1959	6.12	16.85	9.5	17.22	9.34	5.91
1960	6.12	21.48	8.5	17.35	13.10	5.57
1961	6.12	22.67	8.0	17.59	13.44	5.76
1962	6.12	15.36	10.5	17.45	8.89	5.64
1963	6.12	16.90	7.3	17.48	8.25	4.79
1964	6.12	13.77	10.5	17.33	8.23	4.82
1965	6.12	22.88	7.5	18.05	12.49	5.88
1966	6.12	15.82	10.5	17.33	9.62	5.48
1967	6.12	19.36	7.50	17.17	10.62	5.18
1968	6.12	11.12	8.0	16.49	4.65	4.03
1969	6.12	17.81	8.50	17.12	9.87	5.38
1970	6.12	26.47	4.5	17.77	13.44	5.88
1971	6.12	10.55	12.5	17.02	7.03	5.12
1972	6.12	21.61	5.0	17.62	10.62	4.48

Table A14. Continued

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)		Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	AET	Deep Perc.	
1973	6.12	26.21	5.0	17.62	10.62	4.48
1974	6.12	22.57	5.5	17.41	12.74	3.84
1975	6.12	18.15	7.5	17.83	9.01	4.93
1976	6.12	17.94	8.0	16.30	11.46	4.30
1977	6.12	17.51	7.0	17.40	7.49	5.73
1978	6.12	18.35	5.5	16.72	8.65	4.60

Table A15. Summary of the model output for non-uniform (0.75-2.5 in.) irrigation application at 50% available soil moisture, Chelsea sands, 1951-1978

	ISM Top 5-ft 4-15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)		Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
Year		Rainfall	Irrigation	AET	Deep Perc.	
1951	6.12	21.0	7.0	17.78	11.67	4.67
1952	6.12	24.71	8.0	17.80	16.68	4.34
1953	6.12	12.18	12.0	18.13	7.36	4.80
1954	6.12	17.60	11.25	17.95	12.74	4.28
1955	6.12	15.94	12.50	18.52	11.60	4.43
1956	6.12	15.75	9.75	18.21	9.04	4.37
1957	6.12	18.10	12.50	19.01	12.40	5.30
1958	6.12	23.23	6.0	17.87	13.06	4.52
1959	6.12	16.85	11.25	18.08	11.72	4.41
1960	6.12	21.48	14.0	18.64	17.04	5.91
1961	6.12	22.67	8.0	18.78	12.25	5.76
1962	6.12	15.36	12.5	18.34	10.0	5.64
1963	6.12	16.90	11.75	18.82	10.65	5.30
1969	6.12	13.77	13.25	18.79	9.52	4.82
1965	6.12	22.85	12.0	19.01	15.97	5.88
1966	6.12	15.82	13.0	18.84	10.56	5.54
1967	6.12	19.36	10.5	18.25	11.93	5.79
1968	6.12	11.12	12.0	17.99	6.48	4.69
1969	6.12	17.81	11.0	18.12	11.37	5.38
1970	6.12	26.47	8.25	18.63	16.33	5.88
1971	6.12	10.55	15.25	18.24	8.56	5.12
1972	6.12	21.61	8.5	18.67	11.83	5.73
1973	6.12	26.21	7.75	18.40	16.43	5.25

Table A15. Continued

Year	ISM Top 5-ft 4-15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)		Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	AET	Deep Perc.	
1974	6.12	22.57	10.5	18.46	15.46	5.27
1975	6.12	18.15	11.25	18.50	12.08	4.93
1976	6.12	17.94	12.75	18.01	14.20	4.60
1977	6.12	17.51	9.50	18.19	8.98	5.96
1978	6.12	18.35	10.50	17.94	11.25	5.77

Table A16. Summary of the model output for non-uniform (0.5-1.5 in.) irrigation application at 70% available soil moisture, Chelsea sand, 1951-1978

	ISM Top 5-ft 4-15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)		Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
Year		Rainfall	Irrigation	AET	Deep Perc.	
1951	6.12	21.0	13.0	18.72	15.89	5.52
1952	6.12	24.71	13.5	19.07	19.63	5.62
1953	6.12	12.18	17.0	19.81	10.24	5.12
1955	6.12	15.94	18.0	19.99	14.76	5.31
1956	6.12	15.75	12.5	19.63	9.40	5.33
1957	6.12	18.10	14.0	20.10	12.86	5.26
1958	6.12	23.23	12.0	19.03	16.92	5.49
1959	6.12	16.85	17.0	20.03	14.04	5.89
1960	6.12	21.48	15.0	20.05	17.12	5.42
1961	6.12	22.67	14.0	19.86	17.17	5.76
1962	6.12	15.36	15.0	19.47	11.37	5.64
1963	6.12	16.90	15.5	19.87	12.75	5.89
1964	6.12	13.77	17.5	20.12	11.53	5.74
1965	6.12	22.88	13.0	19.74	16.10	5.88
1966	6.12	15.82	17.0	20.45	12.65	5.84
1967	6.12	19.36	14.0	19.78	13.75	5.94
1968	6.12	11.12	14.0	19.39	6.78	5.00
1969	6.12	17.81	12.5	19.26	11.73	5.38
1970	6.12	26.47	13.0	19.94	19.77	5.88
1971	6.12	10.55	17.1	19.67	8.88	5.12
1972	6.12	21.61	12.50	19.42	15.42	5.39
1973	6.12	26.21	14.50	19.52	21.81	5.49
1974	6.12	22.57	14.5	19.61	17.97	5.61

Table A16. Continued

Year	ISM Top 5-ft 4-15 (in.)	Accumulated depth of water added to soil 4/15-9/15 (in.)		Accumulated depth of water subtracted from soil 4/15-9/15 (in.)		ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	AET	Deep Perc.	
1975	6.12	18.15	12.5	19.98	11.86	4.93
1976	6.12	17.94	18.5	19.60	17.80	5.16
1977	6.12	17.51	14.50	19.51	12.65	5.96
1978	6.12	18.35	16.50	19.22	15.97	5.77

Table A17. Summary of the model output for 1.5 inch irrigation application at 70% available soil moisture, Albaton clay, 1951-1978

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1951	18.76	25.36	10.50	3.64	23.02	6.56	21.40
1952	18.76	17.58	13.50	3.18	20.62	5.01	21.03
1953	18.76	13.67	16.50	2.95	20.68	5.02	20.28
1954	18.76	14.44	15.0	2.62	21.04	4.53	20.01
1955	20.82	9.9	18.0	1.38	22.56	4.99	19.79
1956	18.14	13.61	15.0	2.11	20.53	4.10	20.01
1957	18.98	22.24	15.0	5.69	22.43	5.50	22.60
1958	25.12	11.54	12.0	0.0	20.50	6.85	21.31
1959	22.42	18.05	13.50	2.65	24.20	7.65	19.46
1960	24.73	15.52	15.0	2.67	22.95	7.51	22.11
1961	25.45	21.80	12.0	6.99	22.66	7.52	22.08
1962	25.18	24.26	9.0	6.02	23.57	7.18	21.65
1963	23.42	17.15	12.0	2.26	22.55	6.55	21.21
1964	23.27	21.32	10.50	2.26	24.24	6.92	21.67
1965	20.91	16.27	15.0	0.0	23.02	6.03	23.12
1966	22.05	15.34	12.0	0.92	20.80	6.93	20.79
1967	18.93	18.16	13.50	3.11	21.68	5.48	20.32
1968	18.09	11.45	16.5	0.07	21.09	4.30	20.58
1969	22.93	19.74	12.0	6.09	21.53	6.03	21.02
1970	21.66	14.29	15.0	0.99	22.47	5.70	21.79
1971	23.64	9.83	15.0	0.0	22.48	6.19	19.80
1972	21.85	25.29	12.0	7.89	23.0	7.08	21.16
1973	25.62	13.32	13.50	2.86	21.73	6.69	21.15

Table A17. Continued

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1974	23.73	13.10	13.50	0.0	23.02	6.32	20.99
1975	22.70	18.26	13.50	3.49	23.45	6.71	20.81
1976	22.66	8.68	18.0	0.0	22.53	6.23	20.57
1977	21.05	20.85	12.0	5.29	22.41	5.58	20.61
1978	22.44	11.88	13.50	1.46	20.72	5.12	20.52

Table A18. Summary of the model output for 3.5 inch irrigation application at 70% available soil moisture, Albaton clay, 1951-1978

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1951	18.76	25.36	14.0	3.71	22.8	9.42	22.19
1952	18.76	17.58	17.50	3.52	21.04	8.41	20.87
1953	18.76	13.67	21.0	3.0	20.69	9.53	20.20
1954	18.76	14.44	21.0	2.67	21.60	8.79	20.94
1955	20.82	9.7	21.0	2.17	21.94	8.21	19.40
1956	18.14	13.61	21.0	3.63	20.63	8.43	20.05
1957	18.98	22.24	17.50	5.41	22.64	8.30	22.37
1958	25.12	11.54	14.0	0.0	20.38	9.29	20.98
1959	22.42	18.05	21.0	2.87	25.26	12.62	20.72
1960	24.73	15.52	21.0	3.48	23.38	11.93	22.46
1961	25.45	21.80	14.0	7.02	22.72	9.78	21.72
1962	25.18	24.26	14.0	5.97	24.09	10.41	22.95
1963	23.42	17.15	17.50	2.75	23.04	10.45	21.82
1964	23.27	21.32	17.50	2.78	24.83	12.08	22.40
1965	20.91	16.27	21.0	0.0	23.43	10.86	23.89
1966	22.05	15.34	14.0	0.80	21.15	8.87	20.57
1967	18.93	18.16	17.50	3.32	22.12	8.16	20.98
1968	18.09	11.45	21.0	0.83	21.09	8.27	20.34
1969	22.93	19.74	17.50	6.34	22.11	9.86	21.75
1970	21.66	14.29	17.50	1.02	22.43	8.19	21.81
1971	23.64	9.83	17.50	0.0	22.27	8.79	19.83
1972	21.85	25.29	17.50	8.92	23.56	10.72	21.44
1973	25.62	13.32	17.50	2.91	22.22	9.91	21.39

Table A18. Continued

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1974	23.73	13.10	17.50	0.0	23.21	9.65	21.96
1975	22.70	18.26	14.0	3.32	23.31	7.92	20.41
1976	22.66	8.68	24.5	0.0	23.74	10.48	21.62
1977	21.05	20.85	17.50	5.64	23.07	9.91	20.77
1978	22.44	11.88	21.0	2.19	22.02	10.12	20.99

Table A19. Summary of the model output for 5.0 inch irrigation application at 50% available soil moisture, Albaton clay, 1951-1978

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1951	18.76	25.36	10.0	3.54	21.33	7.15	22.09
1952	18.76	17.58	15.0	3.01	20.38	7.14	20.81
1953	18.76	13.67	15.0	1.71	19.04	6.84	19.83
1954	18.76	14.44	15.0	2.55	19.35	6.45	19.84
1955	20.82	9.9	15.0	1.22	19.53	5.91	19.05
1956	18.14	13.61	15.0	1.34	19.63	6.08	19.69
1957	18.98	22.24	15.0	5.39	21.01	5.39	21.76
1958	25.12	11.54	15.0	0.0	20.22	9.47	21.97
1959	22.42	18.05	15.0	2.27	22.99	10.81	19.39
1960	24.73	15.52	15.0	0.73	21.56	10.13	22.60
1961	25.45	21.80	10.0	6.76	21.62	7.87	20.97
1962	25.18	24.26	10.0	5.62	22.63	8.45	22.74
1963	23.42	17.15	10.0	2.11	20.89	7.27	20.29
1964	23.27	21.32	10.0	1.20	22.58	8.26	22.54
1965	20.91	16.27	15.0	0.0	21.95	8.08	22.14
1966	22.05	15.34	10.0	0.77	19.46	6.77	20.38
1967	18.93	18.16	15.0	3.43	20.97	7.52	20.16
1968	18.09	11.45	20.0	0.73	19.70	7.50	21.34
1969	22.93	19.74	10.0	5.46	19.58	6.84	20.78
1970	21.66	14.29	15.0	0.89	21.37	7.41	21.28
1971	23.64	9.83	15.0	0.0	21.17	8.07	19.23
1972	21.85	25.29	10.0	7.49	21.17	8.12	20.35
1973	25.62	13.32	15.0	2.93	20.62	8.31	22.08

Table A19. Continued

Year	ISM Top 5-ft 4/15 (in.)	Accumulated depth of water added to soil 4/15 to 9/15 (in.)		Accumulated depth of water subtracted from soil 4/15 to 9/15 (in.)			ESM Top 5-ft 9/15 (in.)
		Rainfall	Irrigation	SRO	AET	Deep Perc.	
1974	23.73	13.10	15.0	0.0	22.06	7.9	21.50
1975	22.70	18.26	15.0	2.97	22.80	9.09	21.09
1976	22.66	8.68	20.0	0.0	21.51	9.29	20.55
1977	21.05	20.85	10.0	4.19	20.70	6.80	20.20
1978	22.44	11.88	15.0	1.40	20.02	7.84	20.05

Table A20. Irrigation amount and application dates for 2.0 inch application at 35% of available soil moisture, Moody silt loam, 1958-1979

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1958	0	--	0	----	6.0	1,13,26
1959	0	--	4.0	17,29	0	--
1960	0	--	0	--	2.0	4
1961	0	--	2.0	31	0	--
1962	0	--	0	--	4.0	9,25
1963	2.0	18	2.0	17	2.0	14
1964	0	--	2.0	30	0	--
1965	0	--	0	--	2.0	13
1966	0	--	2.0	23	2.0	7
1967	2.0	5	4.0	18,31	2.0	15
1968	2.0	22	2.0	17	4.0	7,21
1969	0	--	0	--	2.0	30
1970	0	--	2.0	23	4.0	5,23
1971	0	--	0	--	4.0	4,16
1972	2.0	8	0	--	2.0	30
1973	0	--	0	--	2.0	30
1974	0	--	4.0	18,30	0	--
1975	0	--	2.0	17	2.0	15
1976	0	--	0	--	4.0	11,29
1977	0	--	2.0	21	0	--
1978	0	--	0	--	0	--
1979	0	--	0	--	0	--

Table A21. Irrigation amount and application dates for 2.0 inch application at 50% of available soil moisture, Moody silt loam, 1958-1978

	Irrigation Water Application					
	June		July		August	
Year	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1958	0	--	2.0	20	6.0	3,13,25
1959	0	--	4.0	11,20	2.0	11
1960	0	--	2.0	24	2.0	13
1961	0	--	4.0	11,29	2.0	7
1962	2.0	1	0	--	4.0	7,20
1963	2.0	2	4.0	11,24	4.0	14,30
1964	0	--	4.0	8,29	2.0	17
1965	0	--	2.0	28	4.0	12,27
1966	0	--	4.0	2,22	2.0	4
1967	2.0	6	4.0	11,26	4.0	3,17
1968	2.0	20	2.0	15	6.0	3,18,31
1969	0	--	0	--	2.0	15
1970	0	--	4.0	7,24	4.0	4,20
1971	0	--	2.0	26	4.0	3,14
1972	2.0	8	0	--	4.0	2,24
1973	0	--	2.0	28	4.0	17,30
1974	2.0	7	4.0	15,26	2.0	2
1975	0	--	4.0	9,22	2.0	8
1976	0	--	4.0	3,23	6.0	4,15,30
1977	0	--	4.0	9,23	2.0	5
1978	0	--	2.0	18	2.0	14
1979	0	--	0	--	2.0	15

Table A22. Irrigation amount and application dates for 2.0 inch application at 70% of available soil moisture, Moody silt loam, 1958-1979

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1958	4.0	1,30	2.0	20	8.0	1,9,19,29
1959	0	--	6.0	10,19,28	2.0	31
1960	0	--	4.0	6,23	4.0	1,15
1961	0	--	6.0	1,11,26	2.0	4
1962	0	--	2.0	2	6.0	1,15,25
1963	2.0	16	4.0	9,17	4.0	7,18
1964	2.0	11	6.0	8,21,27	2.0	13
1965	0	--	4.0	17,26	4.0	8,17
1966	2.0	18	6.0	2,13,25	4.0	5,28
1967	0	--	8.0	3,12,20,28	4.0	5,17
1968	2.0	7	6.0	7,14,27	6.0	5,14,26
1969	0	--	2.0	22	4.0	4,25
1970	2.0	26	6.0	12,24,31	4.0	11,24
1971	0	--	4.0	18,26	6.0	2,10,19
1972	2.0	8	2.0	27	4.0	13,24
1973	2.0	18	2.0	2	6.0	3,15,29
1974	2.0	30	6.0	8,16,24	2.0	1
1975	2.0	7	6.0	5,15,23	4.0	8,18
1976	2.0	8	6.0	1,11,24	6.0	6,15,27
1977	2.0	1	4.0	10,21	4.0	3,15
1978	2.0	10	2.0	15	4.0	15,20
1979	0	--	6.0	5,16,28	--	--

Table A23. Irrigation amount and application dates for 4.0 inch application at 50% of available soil moisture, Moody silt loam, 1958-1979

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1958	0	--	4.0	20	4.0	9
1959	0	--	4.0	22	0	--
1960	0	--	4.0	24	4.0	22
1961	0	--	4.0	11	4.0	7
1962	0	--	0	--	4.0	16
1963	0	--	4.0	12	4.0	13
1964	0	--	4.0	8	4.0	15
1965	0	--	4.0	26	4.0	24
1966	0	--	8.0	2,31	0	--
1967	0	--	8.0	11,30	4.0	23
1968	0	--	4.0	11	4.0	7
1969	0	--	0	--	4.0	15
1970	0	--	8.0	7,30	4.0	28
1971	0	--	4.0	26	4.0	13
1972	4.0	8	0	--	4.0	19
1973	0	--	4.0	28	4.0	22
1974	0	--	4.0	15	4.0	5
1975	0	--	4.0	9	4.0	10
1976	0	--	4.0	3	4.0	5
1977	0	--	4.0	6	4.0	6
1978	0	--	4.0	18	0	--
1979	0	--	4.0	16	0	--

Table A24. Irrigation amount and application dates for 1.0-3.0 inch application at 35% available soil moisture, Chelsea sand, 1951-1978

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1951	0	--	0	--	3.0	9
1952	0	--	5.0	12,30	0	--
1953	0	--	4.5	10,25	6.0	10,27
1954	2.0	15	5.0	11,27	0	--
1955	0	--	4.5	9,28	3.0	11
1956	2.0	14	2.5	24	3.0	30
1957	0	--	2.5	11	3.0	10
1958	0	--	0	--	0	--
1959	1.0	13	2.5	15	3.0	22
1960	0	--	2.5	17	3.0	21
1961	0	--	2.0	10	3.0	9
1962	2.0	26	2.5	24	3.0	16
1963	2.0	27	2.5	29	3.0	30
1964	0	--	4.5	4,18	3.0	6
1965	2.0	28	2.5	29	3.0	15
1966	0	--	4.5	3,18	6.0	9,27
1967	0	--	4.5	9,22	3.0	24
1968	0	--	5.0	11,31	3.0	16
1969	0	--	2.5	26	3.0	8
1970	0	--	4.5	8,28	0	--
1971	4	14,28	2.5	27	6.0	12,30
1972	0	--	2.0	9	3.0	24
1973	0	--	2.5	16	3.0	6
1974	0	--	2.5	18	3.0	7

Table A24. Continued

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in)	Dates	Depth (in.)	Dates
1975	0	--	4.5	5,19	3.0	4
1976	0	--	2.0	10	6.0	4,29
1977	2.0	24	5.0	12,26	0	--
1978	0	--	2.5	29	3.0	12

Table A25. Irrigation amount and application dates for 0.75-2.5 inch application at 50% available soil moisture, Chelsea sand, 1951-1978

	Irrigation Water Application					
	June		July		August	
Year	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1951	0	--	2.0	15	5.0	4,14
1952	0	--	5.5	2,13,26	2.5	4
1953	1.5	24	5.5	10,19,29	5.0	10,22
1954	2.25	13,27	4.0	11,10	5.0	3,23
1955	1.5	23	3.5	9,24	7.5	2,13,28
1956	0.75	11	4.0	16,27	5.0	12,24
1957	1.5	25	3.5	8,16	5.0	6,16
1958	1.5	27	2.0	16	2.5	27
1959	2.25	10,21	4.0	11,21	5.0	19,13
1960	0	--	4.0	12,21	7.5	3,7,30
1961	1.5	14	1.5	10	5.0	3,28
1962	1.5	21	3.5	1,21	5.0	1,19
1963	2.25	13,27	2.0	24	5.0	3,17
1964	2.25	10,28	3.5	7,17	5.0	2,12
1965	3.0	15,28	4.0	13,26	5.0	17,5
1966	1.5	30	4.0	19,11	7.5	4,19,31
1967	0	--	5.5	5,14,23	2.5	14
1968	1.5	24	5.5	8,16,30	5.0	11,23
1969	1.5	21	2.5	24	5.0	3,14
1970	0.75	11	5.0	1,10,25	2.5	4
1971	2.25	10,21	5.5	1,18,30	5.0	10,21
1972	0	--	3.5	5,30	2.5	19
1973	0.75	12	2.0	12	5.0	2,27

Table A25. Continued

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1974	0	--	5.5	2,15,26	2.5	9
1975	0.75	12	5.5	3,13,22	5.0	1,11
1976	2.25	9,25	5.5	7,15,31	2.5	19
1977	1.5	21	5.5	8,18,27	0	--
1978	1.5	14	4.0	16,31	2.5	9

Table A26. Irrigation amount and application dates for 0.5-1.5 inch application at 70% available soil moisture, Chelsea sand, 1951-1978

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1951	1.5	7,14	4.0	7,15,21	6.0	1,7,13,24
1952	2.0	8,13,28	5.5	1,11,22,27	4.5	1,7,27
1953	1.5	1,21	8.6	4,10,15,21,26 31	6.0	5,13,19,25
1954	2.0	9,13,24	5.5	6,11,16,24	4.5	2,14,24
1955	2.5	5,18,24	6.5	4,9,14,23,28	7.5	2,0,15,21,28
1956	2.0	6,11,28	4.5	13,22,27	4.5	7,19,26
1957	1.5	6,21	5.0	5,10,14,19	6.0	2,8,14,21
1958	3.0	1,7,21,28	3.0	11,25	4.5	5,21,28
1959	4.0	6,11,15,21,27	5.5	6,12,19,29	4.5	11,19,26
1960	0.5	10	5.5	7,14,19,30	6.0	4,12,18,25
1961	2.5	12,18,26	3.5	5,10,31	4.5	8,16,26
1962	3.0	15,21,26	4.5	11,20,26	6.0	3,15,21,28
1963	4.0	4,10,14,24,30	4.0	10,21,26	6.0	2,11,18,29
1964	3.0	2,10,25,30	5.5	5,11,16,23	7.5	1,7,13,19,31
1965	2.5	13,19,26	6.0	11,19,25,30	4.5	5,13,22
1966	1.5	1,23	6.5	1,9,14,19,24	7.5	1,6,16,23,30
1967	1.0	28	5.0	5,10,15,20	4.5	6,14,25
1968	7.5	8,20	6.5	4,9,14,20,31	6.0	6,19,21,28
1969	1.5	2,19	4.5	15,24,31	4.5	5,14,27
1970	2.0	8,12,27	6.5	2,8,13,22,27	4.5	4,11,28
1971	4.0	7,12,18,24,30	5.5	7,16,23,31	6.0	7,13,19,26
1972	1.0	25	5.0	3,8,24,31	4.5	12,18,25
1973	2.0	9,13,24	6.5	1,8,13,18,28	6.0	3,8,19,29

Table A26. Continued

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1974	2.0	14,27	5.0	2,9,15,23	6.0	3,9,16,29
1975	1.5	7,21	6.5	2,9,15,20,28	4.5	3,9,20
1976	3.0	5,10,20,26	6.5	3,8,12,17,27	7.5	2,9,17,24,31
1977	3.5	5,15,21,27	6.5	5,10,15,21,27	3.0	5,19
1978	2.0	4,11,25	5.5	5,12,18,27	6.0	2,18,14,25

Table A27. Irrigation amount and application dates for 1.5 inch application at 70% of available soil moisture, Albaton clay, 1951-1978

	Irrigation Water Application					
	June		July		August	
Year	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1951	1.5	13	6.0	7,16,22,27	3.0	3,6
1952	3.0	8,17	6.0	5,18,23,27	4.5	2,11,18
1953	3.0	4,19	9.0	1,8,13,19,23, 28	4.5	4,10,19
1954	3.0	13,29	7.5	6,12,16,20,26	4.5	2,5,14
1955	4.5	1,16,29	7.5	6,16,22,27,30	6.0	3,7,13,18
1956	3.0	10,16	6.0	3,10,22,27	6.0	1,5,11,20
1957	3.0	1,12	6.0	6,16,21,28	6.0	1,5,11,17
1958	3.0	17,28	4.5	12,22,29	4.5	5,13,20
1959	3.0	10,23	7.5	7,13,20,26,29	3.0	7,12
1960	3.0	4,19	7.5	4,10,20,24,28	4.5	3,11,17
1961	1.5	25	6.0	3,9,17,24	4.5	3.7,19
1962	1.5	25	3.0	6,24	4.5	2,7,15
1963	3.0	13,30	6.0	9,15,21,28	3.0	3,15
1964	3.0	7,28	4.5	17,21,27	3.0	2,16
1965	3.0	18,27	7.5	4,13,20,25,29	4.5	3,10,15
1966	3.0	1,23	6.0	4,13,20,30	3.0	3,12
1967	0	--	9.0	2,12,17,21,27, 31	4.5	4,12,19
1968	3.0	4,19	7.5	3,10,15,20,26	6.0	1,4,13,19
1969	3.0	5,20	6.0	6,16,24,30	3.0	4,14
1970	3.0	23,30	7.5	7,13,20,24,30	4.5	3,12,17
1971	3.0	17,26	6.0	9,17,21,27	6.0	1,5,11,17
1972	3.0	3,26	4.5	5,12,28	4.5	3,10,16

Table A27. Continued.

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1973	3.0	9,25	6.0	6,14,23,30	4.5	3,9,17
1974	3.0	20,30	7.5	6,13,17,21,17	3.0	5,16
1975	1.5	30	7.5	6,11,17,22,28	4.5	3,8,15
1976	4.5	6,15,23	7.5	3,8,13,19,23	6.0	1,4,9,15
1977	1.5	7	6.0	4,15,20,28	4.5	3,7,16
1978	4.5	1,10,27	6.0	3,13,17,28	3.0	3,9

Table A28. Irrigation amount and application dates for 3.5 inch application at 70% available soil moisture, Albaton clay, 1951-1978

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1951	3.5	13	7.0	9,23	3.5	3
1952	7.0	8,26	7.0	19,28	3.5	11
1953	7.0	4,22	10.5	7,10,30	3.5	13
1954	3.5	13	10.5	4,15,26	7.0	5,19
1955	7.0	1,27	7.0	9,22	7.0	1,10
1956	7.0	10,25	7.0	10,26	7.0	3,14
1957	3.5	1	7.0	6,20	7.0	1,11
1958	3.5	17	7.0	11,28	3.5	12
1959	7.0	10,26	7.0	12,25	7.0	7,20
1960	7.0	4,26	7.0	11,23	7.0	3.17
1961	3.5	25	7.0	8,24	3.5	7
1962	3.5	25	3.5	23	7.0	6,20
1963	3.5	13	10.5	2,16,28	3.5	15
1964	7.0	7,29	3.5	21	7.0	2,19
1965	3.5	18	10.5	2,16,28	7.0	8,20
1966	3.5	1	7.0	1,17	3.5	2
1967	0	--	10.5	2,16,27	7.0	7,19
1968	7.0	4,22	7.0	9,20	7.0	1,13
1969	3.5	5	7.0	6,21	7.0	3,17
1970	3.5	23	7.0	7,20	7.0	1,13
1971	3.5	17	7.0	9,21	7.0	1,12
1972	7.0	4,29	3.5	16	7.0	2,14
1973	7.0	9,28	3.5	15	7.0	1,12
1974	3.5	20	10.5	4,16,27	3.5	17

Table A28. Continued

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1975	3.5	29	7.0	11,25	3.5	5
1976	7.0	6,20	10.5	5,16,30	7.0	8,20
1977	3.5	7	10.5	5,18,30	3.5	13
1978	7.0	1,13	7.0	2,16	7.0	1,12

Table A29. Irrigation amount and application dates for 5.0 inch application at 50% of available soil moisture, Albaton clay, 1951-1978

Year	Irrigation Water Application					
	June		July		August	
	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1951	0	--	10.0	10,30	0	--
1952	5.0	13	5.0	21	5.0	10
1953	0	--	10.0	4,21	5.0	9
1954	0	--	10.0	4,20	5.0	7
1955	5.0	29	5.0	23	5.0	6
1956	5.0	14	5.0	25	5.0	10
1957	5.0	11	5.0	19	5.0	5
1958	5.0	27	5.0	26	5.0	20
1959	5.0	25	5.0	17	5.0	7
1960	5.0	27	5.0	25	5.0	15
1961	0	--	10.0	1,25	0	--
1962	0	--	5.0	26	5.0	18
1963	0	--	10.0	3,24	0	--
1964	0	--	5.0	21	5.0	20
1965	5.0	24	5.0	16	5.0	3
1966	0	--	10.0	4,30	0	--
1967	0	--	10.0	7,25	5.0	12
1968	5.0	22	5.0	13	10.0	1,20
1969	0	--	5.0	15	5.0	14
1970	5.0	28	5.0	18	5.0	7
1971	5.0	25	5.0	20	5.0	6
1972	0	--	5.0	4	5.0	3
1973	5.0	29	5.0	28	5.0	18

Table A29. Continued

	Irrigation Water Application					
	June		July		August	
Year	Depth (in.)	Dates	Depth (in.)	Dates	Depth (in.)	Dates
1974	0	--	10.0	1,19	5.0	16
1975	0	--	10.0	5,27	5.0	16
1976	5.0	12	10.0	6,23	5.0	10
1977	0	--	5.0	15	5.0	4
1978	5.0	1	10.0	3,29	0	--

APPENDIX B:

COMPUTER PROGRAM

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C*    THIS PROGRAM IS A MODEL OF THE FIELD MOISTURE BALANCE FOR A
C*    HOMOGENEOUS AGRICULTURAL FIELD.  IT IS A MODIFICATION OF THE
C*    PROGRAM DEVELOPED BY C. E. ANDERSON FOR DEEP LOESS SOILS IN
C*    WESTERN IOWA AS DESCRIBED IN TRANS. ASAE, VOL. 21, NO. 2,
C*    PAGES 314 - 320, 1978.
C*    MAJOR REVISIONS HAVE BEEN INCLUDED TO ALLOW THE PROGRAM TO
C*    WORK ON MORE GENERAL SOIL PROFILE CONDITIONS WITH VARYING
C*    SOIL LAYERS WITH VARYING SOIL MOISTURE CHARACTERISTICS AND
C*    THE EXISTANCE OF A WATER TABLE AND POSSIBLE TILE DRAINAGE.
C*    ADDITIONAL MODIFICATIONS HAVE BEEN INCLUDED TO IMPROVE THE
C*    EFFICIENCY OF THE COMPUTER RUNS AND TO CORRECT MINOR ERRORS
C*    IN THE ORIGINAL PROGRAM.
C*    THE OVERLAND FLOW,EROSION AND SEDIMENT TRANSPORT COMPONENTS
C*    WERE ADDED TO THE PROGRAM BY SHAHGHASEMI(1980).
C*    THE HYDROLOGIC MODEL WAS MODIFIED TO SIMULATE IRRIGATION CF
C*    CORN ON THREE DIFFERENT SOILS IN IOWA REPRESENTING SANDY TO
C*    HEAVY SOILS.CALCULATION OF SOIL MOISTURE STRESS INDEX WAS
C*    ADDED TO THE SOIL USING THE PROCEDURE DEVELOPED BY SHAW(1974).
C*    MAJOR MODIFICATIONS WAS MADE TO CONSIDER THE SPESIFIC
C*    PROPERTIES OF EACH SOIL,SUCH AS LOW WATER HOLDING CAPACITY
C*    OF SAND AND CRACK DEVELOPMENT IN HEAVY SOILS UNDER DRY
C*    CONDITIONS.
C*
C*             ZOHREH SHAHVAR
C*             DEPARTMENT OF AGRICULTURAL ENGINEERING
C*             IOWA STATE UNIVERSITY
C*             FALL 1981
C*    ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
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C*    *************  PARAMETER DEFINITION  ************            *
C*                                                                *
C*                                                                *
C*   AAET = ACCUMULATED ACTUAL EVAPOTRANSPIRATION DEPTH (INCHES) SINCE
C*          THE BEGINNING OF THE YEAR, GROWING SEASON, OR OTHER
C*          CALCULATING PERIOD.
C* AAEVAP = ACCUMULATED DIRECT SOIL EVAPORATION (INCHES) FROM THE
C*          SURFACE SOIL LAYER SINCE THE BEGINNING OF THE YEAR OR OTHER
C*          CALCULATING PERIOD.
C*  AAINT = ACCUMULATED EVAPORATION FROM INTERCEPTION STORAGE
C*          SINCE THE BEGINNING OF THIS MODEL RUN. (INCHES)
C* AATRAN = ACCUMULATED ACTUAL TRANSPIRATION (INCHES) SINCE THE
C*          BEGINNING OF THIS MODEL RUN.
C*   ADET = CALCULATED ACTUAL DAILY EVAPOTRANSPIRATION (INCHES)
C*  ADINT = CALCULATED ACTUAL DAILY INTERCEPTION EVAPORATION (INCHES).
C*   ADTF = ACCUMULATED DAILY TILE FLOW IN INCHES
C*  AEARZ = APPLICATION EFFICIENCY OF IRRIGATION BASED ON THE DEPTH
C*          OF ACTIVE ROOT ZONE.(ROOT DEPTH AS A FUNCTION OF THE TIME
C*          OF THE SEASON TAKEN FROM ROOT DISTRIBUTION GIVEN BY SHAW,
C*          1963). I.E. THE RATIO OF THE DEPTH OF WATER STORED IN THE
C*          ACTIVE ROOT ZONE TO THE DEPTH OF WATER APPLIED TO THE SOIL,
C*          IN PERCENT.
C*  AEIRR = APPLICATION EFFICIENCY OF IRRIGATION BASED ON THE
C*          ENTIRE ROOT ZONE DEPTH ,(MAX. DEPTH TO WHICH ROOTS CAN
C*          PENETRATE,5-7 FEET).DEPTH OF WATER STORED IN THE
C*          ENTIRE ROOT ZONE DIVIDED BY THE GROSS DEPTH OF
C*          IRRIGATION APPLICATION IN PERCENT.
C*    AET = CALCULATED TOTAL EVAPOTRANSPIRATION (INCHES) DURING THIS
C*          PERIOD.
C*  AEVAP = CALCULATED DIRECT EVAPORATION FROM THE TOP LAYER OF
C*          SOIL DURING THE PERIOD (INCHES).
C*   AEWP = AIR ENTRY WATER POTENTIAL, CM.
C* AINFIL = INFILTRATION DEPTH TO EACH SOIL LAYER DURING A SINGLE
C*          CALCULATING PERIOD (INCHES) IN SUBROUTINE REDIST.
C*   AINT = CALCULATED EVAPORATION FROM INTERCEPTION STORAGE DURING
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C*          THIS MODEL RUN (INCHES).
C*   ALAI = INPUT VARIABLE NAME FOR CLAI VALUES USED IN PLANT
C* ALBEDO = SURFACE REFLECTIONS OF SHORTWAVE RADIATION.
C*     AM = EXPONENT COEFFICIENT USED IN EQUATION TO CALCULATE ASOIL.
C*          SLOPE OF THE CURVE OF ASOIL VS AMC ON SEMI-LOG PAPER.
C*          WILL BE NEGATIVE.
C*    AMC = SOIL MOISTURE (% BY VOLUME) IN TOP LAYER USED TO CALCULATE
C*          ASOIL AND PSOIL.
C*    ANX = DUMMY VARIABLE NAME USED TO INPUT HOUR ON PRECIP DATA CARDS.
C*   APET = ACCUMULATED POTENTIAL EVAPORATION (INCHES) SINCE THE
C*          BEGINNING OF THE YEAR, GROWING SEASON, OR OTHER CALCULATING
C*          PERIOD.
C*   AREA = AREA OF THE WATERSHED IN SQUARE FEET , THIS VARIABLE IS USED
C*          TO CONVERT RUN OFF DEPTH TO VOLUME.
C*    ARM = ACTIVE ROOT ZONE MOISTURE,INCHES.THE SUMMATION OF
C*          SOIL MOISTURE FOR THE ACTIVE ROOT ZONE.
C* ARMAFC = ACTIVE ROOT ZONE MOISTURE AT FIELD CAPACITY,INCHES.
C*          THE SUMMATION OF SOIL MOISTURE AT FIELD CAPACITY IN
C*          THE ACTIVE ROOT ZONE.
C*  ARMAI = ACTIVE ROOT ZOZE MOISTURE AT IRRIGATION,INCHES.SOIL-
C*          MOISTURE AFTER A GIVEN PERCENTAGE OF THE AVAILABLE
C*          MOISTURE IS REMOVED FROM THE ACTIVE ROOT ZONE.
C* ARMAWP = ACTIVE ROOT ZONE MOISTURE AT WILTING POINT,INCHES.
C*          THE SUMMATION OF SOIL MOISTURE AT WILTING POINT IN
C*          THE ACTIVE ROOT ZONE.
C* ARMSAT = ACTIVE ROOT ZONE MOISTURE AT SATURATION,INCHES.THE
C*          SUMMATION OF SOIL MOISTURE AT SATURATION IN THE
C*          ACTIVE ROOT ZONE.
C* ARZMBI = ACTIVE ROOT ZONE MOISTURE BEFORE IRRIGATION,SUMMATION
C*          OF THE SOIL MOISTURE IN THE ACTIVE ROOT ZONE ON THE
C*          DAY BEFORE IRRIGATION,INCHES.
C*  ASOIL = SOIL PARAMETER IN THE INFILTRATION EQUATION WHICH
C*          REPRESENTS THE MAXIMUM INCREASE IN INFILTRATION CAPACITY
C*          OVER THE WET SOIL RATE.
C* ASOILM = MAXIMUM VALUE FOR ASOIL
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C*    ASTF = ACCUMULATED SEASONAL TILE DRAINAGE FLOW (INCHES)
C*     ATP = APPLICATION TIME PERIOD OF IRRIGATION USED FOR THE
C*           CASE OF NON-UNIFORM IRRIGATION APPLICATION WHEN
C*           IRRIGATION DEPTH CHANGES DURING THE SEASON.VARIOUS
C*           SUBSCRIPTS INDICATING VARIOUS PERIODS WITH DIFFERENT
C*           DEPTH AND TIME OF APPLICATION.
C*    ATPI = APPLICATION TIME PERIOD OF IRRIGATION USED WHEN
C*           IRRIGATION DEPTH IS CONSTANT FOR THE WHOLE SEASON
C*           I.E UNIFORM IRRIGATION.
C*  ATRANS = CALCULATED TRANSPIRATION FROM EACH SOIL LAYER DURING
C*           THE CALCULATING PERIOD. (INCHES)
C*     BAL = DAILY WATER BALANCE , INCHES. THE ALGEBRIC SUMMATION
C*           OF THE DEPTH OF WATER SUPPLY.(DAILY RAINFALL,IRRIGATION
C*           AND SOIL MOISTURE STORAGE),AND DEPTH OF WATER LOSS,
C*           (DAILY SURFACE RUNOFF,ACTUAL EVAPOTRANSPIRATION AND
C*           TILE FLOW).
C*    BALN = SEASONAL WATER BALANCE,INCHES.THE ALGEBRIC SUMMATION
C*           OF THE SEASONAL TOTAL DEPTH OF WATER SUPPLY,(SEASONAL
C*           RAINFALL,SEASONAL SOIL MOISTURE STORAGE AND TOTAL
C*           SEASONAL IRRIGATION APPLICATION),AND TOTAL SEASONAL
C*           DEPTH OF WATER LOSS,(SEASONAL SURFACE RUNOFF,ACTUAL
C*           TOTAL EVAPOTRANSPIRATION AND TOTAL TILE FLOW).
C*     BNX = DUMMY VARIABLE NAME USED TO INPUT MINUTES FOR PRECIP
C*           DATA CARDS.
C*    CARD = COUNTER USED TO DETERMINE THE NUMBER OF CARDS READ FOR
C*           PRECIPITATION DATA ON A PARTICULAR DAY.
C*CE1-CE2 = CONSTANTS USED IN THE MODEL TO CONCIDER THE EFFECT
C*           OF RAINFALL INTENSITY ON INFILTERATION CAPACITY BY
C*           USING RAINFALL KINETIC ENERGY.THESE CONSTANTS HAVE
C*           TO BE DETERMINED OR ESTIMATED BY CALIBRATION.
C*    CLAI = CROP LEAF AREA INDEX.
C*   CLAIX = VALUE OF CLAI USED TO ADJUST ASOIL
C*     CNX = DUMMY VARIABLE NAME USED TO INPUT ACCUMULATED PRECIP.
C*           DATA ON PRECIP. CARDS.
C*    COND = CALCULATED AMOUNT OF SOIL MOISTURE MOVEMENT BETWEEN
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C*           ADJACENT SOIL LAYERS DUE TO POTENTIAL GRADIENTS DURING ANY
C*           ONE CALCULATING PERIOD (INCHES).  A POSITIVE VALUE MEANS
C*           DOWNWARD MOVEMENT AND A NEGATIVE VALUE MEANS UPWARD
C*           MOVEMENT.
C*    DAET = DAILY ACTUAL EVAPOTRANSPIRATION,INCHES.THIS VARIABLE
C*           USED IN PRINTING OUT MONTHLY SUMMARY.
C* DAEVAP = DAILY SOIL EVAPORATION FROM THE SURFACE LAYER,INCHES.
C*  DAQEX = DAILY SUM OF SURFACE RUNOFF,INCHES.
C*    DARZ = DEPTH OF ACTIVE ROOT ZONE IN FEET.THIS DEPTH CHANGES
C*           WITH THE TIME OF THE YEAR ACCORDING TO THE ROOT
C*           DISTRIBUTION GIVEN BY SHAW,1963.
C* DAEVAP = DAILY ACTUAL SOIL EVAPORATION TOTAL (INCHES)
C*  DAQEX = CALCULATED DAILY SUM OF SURFACE RUNOFF (INCHES).
C*    DAYT = DAY OF THE MONTH INPUT VALUE TO SUBROUTINE PRECIP TO
C*           IDENTIFY THE DATE OF A PARTICULAR RAINFALL EVENT.
C* DDELTF = CALCULATED ACTUAL DAILY SUM OF INFILTRATION (INCHES).
C*     DDP = DIRECT PRECIPITATION ON THE SOIL SURFACE DURING A
C*           CALCULATION PERIOD IN INCHES.
C*  DELTF = INFILTRATION DEPTH DURING THE PRESENT CALCULATING PERIOD
C*           (INCHES).
C*  DELTP = TOTAL PRECIPITATION DURING THE PERIOD (INCHES).
C*  DELTQ = INCREMENT OF SURFACE RUNOFF DEPTH WHICH OCCURS DURING A
C*           PARTICULAR CALCULATING PERIOD. (INCHES)
C*     DIA = DAILY DEPTH OF IRRIGATION APPLICATION,INCHES.THIS
C*           DEPTH IS EQUAL TO THE GROSS DEPTH OF APPLICATION
C*           WHEN IRRIGATION TERMINATES BEFORE MIDNIGHT,OTHERWISE
C*           IT IS EQUAL TO THAT PORTION OF THE TOTAL IRRIGATION
C*           DEPTH APPLIED ON EACH DAY.
C*    DINT = DIRECT RAINFALL INTENSITY,INCHES PER HOUR.THE RATIO
C*           OF THE DEPTH OF DIRECT PRECIPITATION TO THE LENGTH OF
C*           THE CALCULATION PERIOD(DT).
C*    DIWA = DAILY IRRIGATION WATER APPLICATION,USED IN THE MONTHLY
C*           SUMMARY CALCULATION.
C*    DLAI = INPUT VARIABLE NAME FOR THE JULIAN DAY NUMBER ASSOCIATED
C*           WITH INPUT CLAI VALUES TO PLANT.  PAIRED WITH ALAI VALUES.
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C*     DOG = SLOPE OF SATURATION VAPOR PRESSURE-TEMPERATURE CURVE
C*           DIVIDED BY THE PSYCHROMETRIC CONSTANT.
C*   DPERC = DAILY DEEP PERCOLATION,INCHES,USED TO PRINTOUT DEPTH
C*           OF DAILY DEEP PERCOLATION IN THE MONTHLY SUMMARY.
C*  DPERCO = CALCULATED ACTUAL DAILY ACCUMULATED DEEP PERCOLATION TO
C*           OR FROM THE SUBSOIL  (INCHES).  A NEGATIVE VALUE
C*           OF DPERCO MEANS MOVEMENT HAS BEEN UPWARD FROM BELOW.
C*   DPINT = INTERCEPTION ON THE PLANT SURFACES DURING THE PRESENT
C*           CALCULATING PERIOD (INCHES).
C*     DRF = DAILY DEPTH OF SURFACE RUNOFF,INCHES,USED FOR MONTHLY
C*           SUMMARY OUTPUT.
C*     DRI = DRAINAGE FROM INTERCEPTION STORAGE (INCHES)
C*  DSOILM = SOIL MOISTURE IN EACH LAYER FOR EACH DAY,INCHES.
C*      DT = LENGTH OF THE CALCULATION PERIOD (HOURS).
C*     DTF = DAILY TILE FLOW (INCHES),USED IN THE OUTPUT OF THE
C*           MONTHLY SUMMARY.
C*      ED = ACTUAL VAPOR PRESSUR IN MILLIBARS.
C*     EQD = EQULLIBRIUM DEPTH.SEE CRAWFORD AND LINSLEY,1966.
C*    EQDF = EQULLIBRIUM DEPTH FACTOR.SEE CRAWFORD AND LINSLEY,1966.
C*    EINT = ESTIMATED VALUE OF THE INTERCEPT TERM IN THE EQUATION
C*           USED TO CONVERT DAILY PAN EVAPORATION TO DAILY
C*           POTENTIAL EVAPORATION,VARIES WITH THE MONTH OF THE
C*           YEAR (0.1-0.15).
C*    EPCM = ESTIMATED VALUE FOR PAN COEFFICIENT FOR EACH MONTH.
C*           THE SLOPE TERM IN THE CONVERSION EQUATION OF PAN
C*           EVAPORATION TO POTENTIAL EVAPORATION,(0.4-0.5).
C*      ES = SATURATION VAPOR PRESSURE AT AIR TEMPERATURE TR IN
C*           MILLIBARS.
C*    ESAT = SATURATION WATER CONTENT IN EACH LAYER EXPRESSED IN INCHES.
C*  ESOILM = ESTIMATED SOIL MOISTURE IN EACH SOIL LAYER FOR EACH
C*           DAY (INCHES).
C*      ET = SUBROUTINE NAME FOR CALCULATING ACTUAL EVAPOTRANSPIRATION
C*  ETRATE = THE RATIO OF ACTUAL TO POTENTIAL TRANSPIRATION. INPUT
C*           VALUES FOR CURVES OF THIS RATIO VS. SOIL MOISTURE AND
C*           ATMOSPHERIC DEMAND.  (CURVES TAKEN FROM DENMEAD AND SHAW).
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C*            RELATED TO SMET AND PAD AND USED IN SUBROUTINE ET.
C* EVAPTR = TOTAL WITHDRAWL BY EVAPORATION AND TRANSPIRATICN FROM
C*          THE TOP TWO FEET OF SOIL DURING A CALCULATING PERICD. (IN.)
C*     F1 = ACCUMULATED INFILTRATICN AT THE START OF A CALCULATING
C*          PERIOD IN SUBROUTINE INFILT (INCHES).
C*     FC = FIELC CAPACITY (PERCENT BY VOLUME) OF EACH SOIL LAYER.
C* FCINFL = WET SOIL INFILTRATICN CAPACITY (IN./HR.)
C*          FOR USE IN THE INFILTRATION SUBROUTINE.
C*    FC2 = FIELD CAPACITY OF THE SURFACE LAYER (% BY VOLUME) FOR USE
C*          IN CALCULATING PSOIL.
C*    FCS = MAXIMUM VALUE OF AMC FCR WHICH ASOIL = ASOILM.  IN THE
C*          CURRENT VERSION OF THE PROGRAM SET AT FC(1).
C*      G = SOIL HEAT FLUX IN LY/DAY ESTIMATED BY THE METHOD OF JENSEN,
C*          WRIGHT AND PRATT.
C*    GDI = GROSS DEPTH OF IRRIGATION (INCHES). THIS VARIABLE IS
C*          USED IN THE NON-UNIFORM IRRIGATICN APPLICATION.
C*          VARIUUS SUBSCRIPTS REFER TO DIFFERENT APPLICATION
C*          DEPTH DURING THE SEASCN.
C*   GDIA = GRCSS DEPTH OF IRRIGATION APPLICATICN (INCHES).THIS
C*          PARAMETER IS USED WHEN THE IRRIGATION DEPTH IS
C*          CONSTANT FOR THE WHCLE SEASON.
C*   GIDP = GROSS IRRIGATICN DEPTH FOR EACH CALCULATION PERIOD.
C*   GINT = FUNCTION NAME FOR THE X-Y PLOT INTERPOLATICN.
C*  GINT2 = FUNCTICN FOR INTERPOLATING ON A FAMILY OF CURVES.
C*    IAP = INDEX TO INDICATE WHETHER THE FIRST OR SECOND CARD OF
C*          RAINFALL DATA IS BEING READ.THIS INDEX IS USED IN
C*          SUBROUTINE PRECHR.
C*   IBIG = INDEX TO INDICATE WHETHER WE ARE READING THE FIRST CARD CF
C*          RAINFALL CATA FOR A GIVEN CAY.
C*   IBIR = INDEX USED IN THE SPRINKLER IRRIGATION (SPRINK) SUBROUTINE
C*          IBIR=0 MEANS THAT SOIL MOISTURE CONTENT IN THE ACTIVE ROCT
C*          ZCNE IS ABOVE THE CRITICAL VALUE FOR IRRIGATION APPLICATION.
C*          IBIR=1 MEANS IRRIGATION APPLICATION TERMINATES BEFCRE
C*          MIDNIGHT.
C*          IBIR=2 MEANS IRRIGATICN APPLICATION CONTINUES AFTER
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C*          MIDNIGHT.
C*       IC = NUMBER OF THE CALCULATING PERIOD DURING A DAY IN WHICH
C*            RAINFALL OCCURS.  THERE WILL BE 24*NH SUCH PERIODS IN A DAY.
C*      ICC = INDICATOR OF LOWER BOUNDRY ON RANGE OF DAILY TIME INCREMENTS
C*            TO BE ADDED TO DETERMINE IF RAINFALL OCCURRED DURING A
C*            PARTICULAR PERIOD.
C*      ICR = UPPER BOUNDRY OF TIME PERIOD RELATED TO ICC.
C*     IERR = INDEX TO INDICATE WHEN SOME ERROR HAS BEEN DETECTED IN DATA
C*            INPUT OR CALCULATED VALUES IN A SUBROUTINE.  IERR = 0 MEANS
C*            ALL IS WELL.  IERR = 1 MEANS AN ERROR IS DETECTED AND
C*            PROGRAM EXECUTION SHOULD BE TERMINATED.
C*       IK = INDEX INDICATOR USED IN THE STRESS INDEX CALCULATION.
C*       IM = INDEX TO INDICATE NUMBER OF 6-INCHES LAYERS TO WHICH
C*            ROOTS PENETRATES DURING VARIOUS TIME OF THE SEASON,
C*            TAKEN FROM ROOT DISTRIBUTION THROUGH OUT THE SEASON
C*            GIVEN BY SHAW,1963.
C*     INCI = INDEX TO INDICATE WHETHER IT IS THE FIRST OR SECOND CALL
C*            OF SUBROUTINE INTCPT DURING THE CALCULATION PERIOD.
C* INFILT = NAME OF SUBROUTINE TO CALCULATE INFILTRATION.
C* INTCPT = SUBROUTINE NAME FOR COMPUTING INTERCEPTION.
C*     IRED = INDEX TO INDICATE WHETHER THIS IS THE FIRST OR SECOND
C*            ENTRY INTO SUBROUTINE REDIST FOR THIS CALCULATING PERIOD.
C*      IRT = JULIAN DAY NUMBER ON WHICH NEW ROOT SYSTEM DISTRIBUTION
C*            BECOMES EFFECTIVE.  INPUT DAY VALUES FOR ROOT SYSTEM
C*            DEVELOPMENT DATA.
C*       JB = JULIAN DAY ASSOCIATED WITH THE INITIAL SOIL MOISTURE
C*            DATA (JSTART-1).
C*    JCULT = JULIAN DAY OF CULTIVATION ,UP TO 20 DAYS CAN BE
C*            SPESIFIED.
C*     JDCH = JULIAN DAY TO CHANGE THE DEPTH OF IRRIGATION APPLICATION.
C*            THIS VARIABLE IS USED FOR NON-UNIFORM IRRIGATION ,EACH
C*            SUBSCRIPTS INDICATES JULIAN DAY FOR EACH CHANGE.THESE
C*            INPUT VARIABELS CAN BE ADJUSTED BY THE USER FOR CROP
C*            SOIL AND WEATHER CONDITIONS ACCORDING TO ROOT GROWTH.
C*    JDEIR = JULIAN DAY OF THE YEAR TO END IRRIGATION.
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C*    JDS = DAY OF SILKING DATE,USED IN STRESS INDEX CALCULATION.
C*  JDSIR = JULIAN DAY OF THE YEAR TO START IRRIGATION.
C*     JF = JUIAIN DAY TO TERMINATE THE RUN.
C*     JI = INDEX NUMBER FOR EACH SOIL LAYER STARTING WITH JI = 1 FOR
C*          THE TOP  SOIL LAYER  AND ENDING WITH JI=JIM FOR THE SUBSOIL.
C*    JIM = NUMBER OF SOIL LAYERS BEING SIMULATED
C*   JIM1 = NUMBER OF SOIL LAYERS ABOVE THE BOTTOM LAYER (= JIM - 1).
C*     JJ = CUMULATIVE NUMBER OF DAYS FROM THE BEGINNING OF THE YEAR.
C*    JJR = JULIAN DAY OF LATEST PRECIP. DATA CARD READ.  USED TO
C*          COMPARE WITH PRESENT DAY NUMBER DURING SIMULATION TO
C*          INITIATE READING AND PROCESSING DATA ON DAYS WHEN
C*          RAINFALL OCCURS.
C*   JJR1 = VALUE OF JJR SAVED TO CHECK DATES ON REMAINING PRECIP.
C*          CARDS READ FOR A GIVEN DAY.
C*     JM = INDEX NUMBER FOR EACH DAY OF THE MONTH,STARTING WITH JM=1
C*          FOR THE FIRST DAY OF THE MONTH AND ENDING WITH JM=31 FOR
C*          THE LAST DAY OF THE MONTH.
C*    JMS = MONTH OF SILKING (JULY OR AUG.) USED IN STRESS INDEX
C*          CALCULATION.
C*   JOUT = JULIAN DAY OF THE YEAR WHEN DETAILED OUTPUT IS REQUESTED.
C*          UP TO 20 DIFFERENT DAYS MAY BE SPECIFIED IN THIS ARRAY.
C*          THESE ARE GENERALLY CHOSEN AS DAYS ON WHICH PRECIP OCCURRED,
C*          OR DAYS ON WHICH SOIL MOISTURE MEASURMENTS WERE TAKEN WHICH
C*          ARE BEING USED FOR COMPARISON WITH MODEL SIMULATION DATA.
C*     JR = INDEX INDICATOR FOR EACH LAYER OF THE SOIL,STARTING WITH
C*          JR=1 FOR THE FIRST LAYER AND ENDING WITH JR=10 FOR THE
C*          10-TH LAYER.
C* JSTART = DAY OF THE YEAR (1 - 365) WHEN THE PROGRAM IS TO BEGIN.
C*  JSTOP = DAY OF THE YEAR WHEN THE PROGRAM IS TO END CALCULATIONS
C*  JTILE = NUMBER OF THE SOIL LAYER IN WHICH TILE IS LOCATED
C*   JUDS = JULIAN DAY OF SILKING DATE,I.E SILKING DATE CONVERTED
C*          TO JULIAN DAY.
C*  JUPSS = JULAIN DAY ASSOCIATED WITH THE PERIODS SURROUNDING
C*          SILKING DATE.SUBSCRIPTS 1 THROUGH 8 REFER TO
C*          8,7,...1 PERIODS BEFORE SILKING AND SUBSCRIPTS 10
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C*           THROUGH 18 REFER TO 1,2,....,9 PERIODS AFTER SILKING
C*            DATE RESPECTIVELY.
C*      JX = LAST LAYER TO WHICH ROOTS PENETRATE BY THE END OF THE
C*           SEASON.
C*     JX1 = ONE LAYER BELOW THE ROOT PENETRATION (JX+1).
C*       K = INDEX INDICATOR FOR THE NUMBER OF TIMES IRRIGATION
C*           DEPTH CHANGES DURING THE SEASON.
C*     KDA = TOTAL ACCUMULATED DAYS IN THE YEAR TO THE BEGINNING OF A
C*           MONTH.
C*   KEVAP = INPUT INDICATOR FOR METHOD OF DETERMINING POTENTIAL ET:
C*           IF KEVAP=0 INPUT IS DATA FOR PENMAN EQUATION.
C*           IF KEVAP=1 INPUT IS PAN EVAPORATION DATA.
C*           NOTE THAT FOR EACH TIME ASSOCIATED SUBROUTINE WILL
C*           BE CALLED TO CALCULATE POTENTIAL ET EITHER FROM PENMAN
C*           EQUATION OR FROM DAILY PAN EVAPORATION.
C*    KIRD = INPUT INDICATOR TO CHECK SOIL MOISTURE FOR IRRIGATION
C*           WATER APPLICATION.
C*           IF KIRD=0 SOIL MOISTURE OF THE ENTIRE ROOT ZONE WILL BE
C*           CHECKED DURING THE WHOLE SEASON.
C*           IF KIRD=1 SOIL MOISTURE OF THE ACTIVE ROOR ZONE WILL BE
C*           CHECKED ACCORDING TO THE TIME OF THE SEASON.
C*    KIRR = INDEX INDICATOR OF IRRIGATION APPLICATION :
C*           IF KIRR=0 IRRIGATION WILL NOT BE SIMULATED IN THE RUN.
C*           IF KIRR=1 IRRIGATION WATER WILL BE APPLIED WHEN IT IS
C*           REQUIRED.
C*   KJ-KL = INDEX INDICATORS FOR THE 5-DAYS PERIODS BEFORE AND
C*           AFTER SILKING DATE ,STARTING WITH 1 FOR ONE PERIOD
C*           BEFORE SILKING AND ENDING WITH 17 FOR 9 PERIODS AFTER
C*           SILKING DATE.
C*    KMOT = INPUT MONTH NUMBER FOR THE DATE OF A PARTICULAR STORM EVENT
C*           TO SUBROUTINE PRECIP.
C*    KPRE = INPUT INDICATOR FOR THE TYPE OF PRECIPITATION DATA :
C*           IF KPRE=0 PRECIPITATION DATA ARE AVAILABLE FOR SHORT
C*           PERIODS OF TIME (LESS THAN AN HOUR).IN THIS CASE THE
C*           RAINFALL DATA ARE TAKEN FROM RAINFALL CHARTS AT
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C*          BREAK PCINTS.
C*          IF KPRE=1 HOURLY PRECIPITATION DATA WILL BE USED WITH
C*          U.S WEATHER BUREAU FORMAT.
C*          NOTE THAT FOR EACH CASE THE ASSOCIATED SUBROUTINE WILL
C*          BE CALLED.
C*   KRHO = INPUT INDICATOR OF RUNOFF HYDROGRAPH REQUIREMENT :
C*          IF KRHO=0 CALCULATION OF RUNOFF HYDROGRAPH IS NOT
C*          REQUESTED.
C*          IF KRHO=1 RJN OFF HYDROGRAPH WII BE DETERMINED FOR
C*          EACH RUNOFF EVENTS.
C*   KSMA = INDICATOR OF SOIL MOISTURE AVAILABILITY FUNCTION USED
C*          IF KSMA = 0 SHAW'S CURVES WILL BE USED.
C*          IF KSMA = 1 ALL MOISTURE WILL BE AVAILABLE ABOVE 50% OF
C*          TOTAL HOLDING CAPACITY BETWEEN FC AND WP, AND A LINEARLY
C*          DECREASING AVAILABILITY WILL BE USED BETWEEN 50% AND THE
C*          WILTING POINT.
C*  KSOIL = INDICATOR OF PRINTING SOIL MOISTURE SUMMARY :
C*          IF KSOIL=0 SOIL MOISTURE SUMMARY IS NOT REQUESTSD.
C*          IF KSOIL=1 SOIL MOISTURE SUMMARY WILL BE PRINTED OUT
C*          FOR EACH LAYER FOR ALL DAYS.
C*   KSTR = INPUT INDICATOR OF STRESS INDEX CALCULATION :
C*          IF KSTR=0 STRESS INDEX WILL NOT BE CALCULATED.
C*          IF KSTR=1 DETERMINATION OF STRESS INDEX IS REQUESTED,
C*          THUS SILKING DATE AND WEIGHT FACTORS HAVE TO BE USED
C*          AS INPUT DATA.
C*   KUIR = INPUT INDICATOR OF UNIFORM IRRIGATION APPLICATION :
C*          IF KUIR=0 DEPTH OF IRRIGATION APPLICATION IS CONSTANT
C*          FOR THE WHOLE SEASON.
C*          IF KUIR=1 VARIOUS DEPTH OF IRRIGATION WATER WILL BE
C*          APPLIED FOR DIFFERENT STAGES OF ROOT GROWTH.
C*     LL = INDEX NUMBER FOR EACH DAY WHEN DETAILED OUTPUT IS
C*          REQUESTED.
C*      M = INDEX NUMBER FOR EACH MONTH STARTING WITH 1 FOR JAN.
C*          AND ENDING WITH 12 FOR DEC.
C*     MD = INDEX FOR EACH DAY OF THE MONTH (1-31),USED IN THE
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C*          MONTHLY SUMMARY OUTPUT.
C*     MTF = INDEX FOR EACH MONTH OF THE YEAR (1-12).
C*      MN = INDEX NUMBER FOR EACH 5 DAYS PERIOD BEFORE AND AFTER
C*           SILKING DATE (1-17)
C*      MC = INDEX FOR EACH MONTH OF THE YEAR (1-12)
C*     MON = DUMMY INPUT VARIABLE NAME FOR MONTH ON PRECIP DATA CARDS
C*   MONTH = ALPHABETIC VARIABLE TO OUTPUT THE MONTH WHEN WRITING OUT
C*           DATES.
C*      NC = NUMBER OF CURVES USED TO DESCRIBE THE ACTUAL ET, POTENTIAL
C*           ET, SOIL MOISTURE RELATIONSHIP (SHAW'S CURVES).
C*     NDA = DUMMY INPUT VARIABLE FOR DAY ON PRECIP DATA CARDS.
C*      NH = NUMBER OF PERIODS INTO WHICH AN HOUR IS DIVIDED FOR
C*           CALCULATING DURING A RAINFALL EVENT.
C*      NI = NUMBER OF TIMES IRRIGATION APPLICATION DEPTH CHANGES
C*           DURING THE SEASON.
C*    NOUT = INDICATOR CALCULATED BY PROGRAM TO PRODUCE DETAILED OUTPUT
C*           ON DAYS WHEN PRECIP OCCURS OR WHEN MEASURED SOIL MOISTURE
C*           DATA IS AVAILABLE FOR COMPARISON.
C*     NPC = NUMBER OF POINTS PER CURVE IN SHAWS RELATIONSHIP.
C*   NRTDS = THE ROOT ACTIVITY IN EACH LAYER EXPRESSED AS A PERCENT OF
C*           THE TOTAL ROOT ACTIVITY IN THE ROOT ZONE.
C*     NYR = DUMMY VARIABLE FOR INPUT OF YEAR ON PRECIP DATA CARDS.
C*    OFMN = ROUGHNESS COEFFICIENT IN MANNING'S EQUATION.
C*   OFMN1 = MAXIMUM ROUGHNESS COEFICIENT IN MANNING'S EQUATION.
C*           VALUE OF OFMN IMMEDIATELY AFTER TILLAGE WHEN TRST=0.
C*   OFMN2 = MINIMUM ROUGHNESS COEFICIENT IN MANNING'S EQUATION.
C*           VALUE OF OFMN WHEN TRST>TRSTM.
C*     OFR = OVERLAND FLOW RUNOFF DEPTH,INCHES.
C*  OFRCFS = OVERLAND FLOW RUNOFF RATE,C.F.S.
C*  OFROUT = SUBROUTINE NAME FOR OVERLAND FLOW.
C*    OFSL = OVERLAND FLOW SLOPE LENGTH,FEET.
C*    OFSS = SLOPE STEEPNESS OF THE SOIL SURFACE ,PERCENT.
C*     PAD = POTENTIAL ATMOSPHERIC DEMAND, INPUT DATA OF VALUES OF
C*           POTENTIAL DAILY EVAPORATION FOR CURVES OF SOIL MOISTURE VS.
C*           THE RATIO OF ACTUAL TO POTENTIAL TRANSPIRATION (AFTER SHAW).
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C*           RELATED TO SMET AND ETRATE AND USED IN SUBROUTINE ET.

C*   PAMAC = PERCENT AVAILABLE MOISTURE AT CRACKING.
C*   PAMRI = PERCENT OF THE AVAILABLE MOISTURE REMOVED AT IRRIGATION.
C*     PAN = DAILY EVAPORATION PAN INPUT DATA (INCHES)
C*  PANEVA = DAILY PANEVAPORATION DEPTH,USED FOR MONTHLY SUMMARY
C*           PRINTOUT.
C*  PANEVP = SUBROUTINE NAME TO CALCULATE POTENTIAL ET FROM DAILY
C*           PAN EVAPORATION DATA.
C*    PAST = NUMBER OF DAYS PAST THE STARTING DATE OF THE RUN.THIS
C*           VARIABLE IS ONLY CALCULATED FOR THE FIRST 14-DAYS OF
C*           THE RUN FOR ESTIMATING SOIL MOISTURE CONTENT IN THE
C*           LAYER BELOW THE SOIL PROFILE AS THE AVERAGE OF THE SOIL-
C*           MOISTURE CONTENT OF THE BOTTOM LAYER FOR THE DAYS PAST
C*           THE STARTING DATE OF THE RUN.
C*    PBAL = THE SUMMATION OF THE TOTAL DAILY SOIL MOISTURE,
C*           INTERCEPTION STORAGE AND THE VOLUME OF DEPRESSION
C*           STORAGE.
C*  PCATRN = THE DECIMAL FRACTION OF THE PLANT CANOPY WHICH IS
C*           ACTIVELY TRANSPIRING AT ANY TIME PERIOD.  USED TO DETERMINE
C*           ACTUAL TRANSPIRATION IN SUBROUTINE ET.  THE VALUE IS
C*           DETERMINED IN SUBROUTINE PLANT.
C*     PCC = PERCENT CANOPY COVER.
C*     PCT = INPUT VALUES OF PERCENT CANOPY ACTIVELY TRANSPIRING
C*           CURVE FOR USE IN PLANT.  PAIRED WITH VALUES OF TJ
C*      PE = POTENTIAL EVAPORATION RATE IN INCHES PER DAY.
C*    PEAI = PRECIPITATION EXCESS AFTER INFILTRATION,INCHES.
C*   PERCO = DEPTH OF WATER PERCOLATING TO OR FROM THE BOTTOM SOIL
C*           LAYER DURING THE CALCULATING PERIOD (INCHES). A NEGATIVE
C*           VALUE INDICATES UPWARD MOVEMENT OF SOIL MOISTURE.
C*    PER1 = PERCENT OF SATURATION MOISTURE AT WHICH IMMEDIATE FREE
C*           DRAINAGE TO LOWER SOIL LAYERS OCCURS DURING WETTING
C*           PERIOD.TAKEN AS 30% FOR SANDY SOIL 80% FOR SILT-LOAM
C*           AND 90% FOR CLAY SOIL.
C*    PER2 = PERCENT OF SATURATION MOISTURE HELD IN THE SOIL DURING
C*           DRYING PERIOD.TAKEN AS 80% FOR SAND AND SILT-LOAM AND
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C*            90% FOR CLAY SOIL.
C*      PET = POTENTIAL EVAPOTRANSPIRATION VALUES IN INCHES FOR EACH
C*            FOUR HOUR PERIOD IN THE DAY.
C*    PEVAP = SUBROUTINE NAME FOR COMPUTING POTENTIAL EVAPORATION.
C*    PIMAX = MAXIMUM POTENTIAL PLANT INTERCEPTION (INCHES).
C*    PIMIN = MINIMUM PLANT INTERCEPTION DEPTH THAT CAN BE REACHED BY
C*            DRAINAGE DOWN THE STEMS AND FALL THROUGH.
C*    PLANT = SUBROUTINE NAME FOR DETERMINING PLANT SYSTEM FUNCTIONS
C*     PLAV = PLANT AVAILABLE SOIL MOISTURE FOR EACH LAYER,INCHES.
C*       PM = SLOPE OF THE PSOIL VS AMC CURVE ON LOG-LOG PAPER.
C*            EXPONENT USED IN EQUATION TO CALCULATE PSOIL.
C*   PRECHR = PRECIPITATION SUBROUTINE WHICH USES HOURLY RAINFALL DATA
C*            WITH U.S WEATHER BUREAU FORMAT.
C*   PRECIP = SUBROUTINE TO CONVERT BREAK-POINT RECORDING RAIN GAUGE
C*            DATA TO EVEN-TIME INTERVAL INCREMENTS FOR USE IN PROGRAM.
C*     PSFC = VALUE OF PSOIL AT THE FIELD CAPACITY OF THE SURFACE LAYER.
C*            USED IN THE EQUATION TO CALCULATE PSOIL.
C*    PSIFC = SOIL METRIC POTENTIAL AT FIELD CAPACITY,CENTIMETER
C*            (300-350 CM).
C*    PSIWP = SOIL METRIC POTENTIAL AT WILTING POINT,CENTIMETER
C*            (15000 CM).
C*   PSILOG = LOG(PSIFC/PSIWP)
C*    PSOIL = SOIL PARAMETER IN THE INFILTRATION EQUATION WHICH
C*            REPRESENTS THE RATE OF DECREASE OF INFILTRATION CAPACITY
C*            WITH INCREASED SOIL MOISTURE.
C*    PUDLE = DEPTH OF SURFACE RUNOFF HELD BY PUDLES AT ANY TIME
C*            DURING RAINFALL RUNOFF EVENTS,INCHES.
C*   PUDLE1 = INITIAL VALUE OF PUDLE.VALUE OF PUDLE IMMEDIATLY AFTER
C*            TILLAGE WHEN TRST=0.
C*   PUDLE2 = FINAL VALUE OF PUDLE.VALUE OF THE PUDLE WHEN TRST
C*            IS GREATER THAN TRSTM.
C*   QEXCES = ACCUMULATED SURFACE RUNOFF DEPTH (INCHES) SINCE THE
C*            BEGINNING OF THIS MODEL RUN.
C*     RAIN = TOTAL RAINFALL FOR THE 24-HR PERIOD ON ONE CALANDAR DAY.
C*            CALCULATED FROM RECORDED PRECIP DATA IN SUBROUTINE PRECIP.
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C* RAWSTR = RAW STRESS INDEX FOR EACH DAY.DEFINED AS ONE MINUS THE
C*          RATIO OF ACTUAL ET TO THE POTENTIAL ET(1-AET/PET).
C*     RB = NET OUTGOING LONGWAVE RADIATION IN LY/ DAY.
C*    RBO = MAXIMUM VALUE OF NET OUTGOING LONGWAVE RADIATION IN LY/DAY.
C* REDIST = SUBROUTINE NAME FOR CALCULATING SOIL MOISTURE MOVEMENT.
C*  RESAT = MOISTURE LEVEL AT WHICH IMMEDIATE FREE DRAINAGE TO LOWER
C*          SOIL LAYERS OCCURS.  TAKEN AS 0.8*SAT.
C*     RH = AVERAGE RELATIVE HUMIDITY FOR THE DAY (PERCENT).
C*  RHMAX = MAXIMUM VALUE OF RELATIVE HUMIDITY RECORDED FOR ANY DAY
C*          (PERCENT).
C*  RHMIN = MINIMUM RECORDED VALUE OF RELATIVE HUMIDITY FOR ANY DAY
C*          (PERCENT).
C*     RN = NET RADIATION IN LY/DAY.
C*     RO = DAILY DEPTH OF SURFACE RUNOFF USED IN MONTHLY SUMMARY
C*          OUTPUT.
C*  ROOTS = INPUT VALUES FOR THE ROOT SYSTEM DEVELOPMENT IN
C*          EACH LAYER (NRTDS) FOR VARIOUS PERIODS OF THE YEAR.
C*          PAIRED WITH VALUES OF IRT.
C*     RS = DAILY SOLAR RADIATION (LANGLEYS).
C*   RSAT = SOIL MOISTURE LEVEL HELD IN EACH SOIL LAYER DURING
C*          DRYING PERIOD.(PER2*SAT).
C* RSMAFC = ROOT SOIL MOISTURE AT FIELD CAPACITY.THE SUMMATION OF
C*          THE SOIL MOISTURE AT FIELD CAPACITY FOR THE ENTIRE
C*          ROOT ZONE.
C*  RSMAI = ROOT SOIL MOISTURE AT IRRIGATION.ROOT ZONE MOISTURE
C*          WHEN A GIVEN PERCENTAGE OF THE AVAILABLE MOISTURE HAS
C*          BEEN REMOVED FROM THE ENTIRE ROOT ZONE.
C* RSMAWP = ROOT SOIL MOISTURE AT WILTING POINT.THE SUMMATION OF
C*          THE SOIL MOISTURE AT WILTING POINT FOR THE ENTIRE ROOT
C*          ZONE,INCHES.
C* RSMSAT = ROOT SOIL MOISTURE AT SATURATION.THE SUMMATION OF THE
C*          SOIL MOISTURE AT SATURATION FOR THE ENTIRE ROOT ZONE,
C*          INCHES.
C*    RSO = MAXIMUM POTENTIAL CLEAR DAY SOLAR RADIATION FOR THE DAY
C*          IN LY.
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C*   RSUM = SUM OF PRECIPITATION OCCURING DURING A PERIOD.  USED TO
C*          DETERMINE WHEN A SHORTER TIME INTERVAL IS REQUIRED IN
C*          SIMULATION.
C*   RZSM = ROOT ZONE SOIL MOISTURE ON A GIVEN DAY,THE SUMMATION OF
C*          THE SOIL MOISTURE FOR THE ENTIRE ROOT ZONE.
C*    SAT = MOISTURE CONTENT OF EACH SOIL LAYER AT SATURATION (PERCENT
C*          BY VOLUME).
C* SDELTF = ACCUMULATED SOIL INFILTRATION DEPTH (INCHES) SINCE THE
C*          BEGINNING OF THE YEAR, GROWING SEASON OR OTHER CALCULATING
C*          PERIOD.
C*  SEARZ = SEASONAL EFFICIENCY OF THE ACTIVE ROOT ZONE,PERCENT.THE
C*          RATIO OF THE TOTAL SEASONAL WATER STORED IN THE ACTIVE
C*          ROOT ZONE TO THE TOTAL SEASONAL IRRIGATION WATER
C*          APPLIED.
C*   SFIA = SEASONAL FREQUENCY OF IRRIGATION APPLICATION.I.E NUMBER
C*          OF TIMES IRRIGATION WATER APPLIED DURING THE GROWING
C*          SEASON.
C*    SHC = SATURATED HYDRAULIC CONDUCTIVITY OF A LAYER,CM/HR.
C*   SIAE = SEASONAL IRRIGATION APPLICATION EFFICIENCY,PERCENT.THE
C*          RATIO OF THE SEASONAL TOTAL WATER STORED IN THE ENTIRE
C*          ROOT ZONE TO THE SEASONAL TOTAL IRRIGATION WATER APPLIED.
C*  SMASM = TOTAL REMAINING UNUSED WATER STORAGE CAPACITY IN THE TOP
C*          4 LAYERS OF SOIL (INCHES).
C*   SMBI = SOIL MOISTURE BEFORE IRRIGATION,INCHES.THE SUMMATION OF
C*          THE SOIL MOISTURE IN THE ENTIRE ROOT ZONE ON THE DAY
C*          PRIOR TO IRRIGATION APPLICATION.
C*   SMET = SOIL MOISTURE VALUE (PERCENT BY VOLUME) EXPRESSED AS A
C*          DECIMAL BETWEEN 0. AND 1. INPUT VALUES FOR RELATIONSHIP
C*          BETWEEN THE RATIO OF ACTUAL TO POTENTIAL TRANSPIRATION, THE
C*          SOIL MOISTURE, AND THE ATMOSPHERIC DEMAND.  RELATED TO PAD
C*          AND ETRATE.  USED IN SUBROUTINE ET.
C* SMHP14 = SOIL MOISTURE HISTORICAL FOR PAST 14 DAYS.FOR EACH DAY
C*          THIS VARIABLE IS EQUAL TO THE SUMMATION OF THE SOIL-
C*          MOISTURE OF THE BOTTOM LAYER FOR FOURTEEN
C*          DAYS PRIOR TO THAT DAY.IT IS USED TO DETERMINE THE
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C*            SOIL MOISTURE OF THE LAYER BELOW THE SOIL PROFILE ON EACH
C*            DAY,AS AN AVERAGE OF THE SOIL MOISTURE OF THE BOTTOM LAYER
C*            FOR THE PAST FOURTEEN DAYS.
C*    SMTC = SLOPE OF THE MOISTURE TENSION CURVE ON LOG-LOG PAPER
C*   SOILM = DAILY SOIL MOISTURE,INCHES.THE SUMMATION OF THE SOIL-
C*            MOISTURE IN THE ENTIRE ROOT ZONE FOR EACH DAY,USED
C*            IN MONTHLY SUMMARY PRINT OUT.
C*  SPERCO = ACCUMULATED DEEP PERCOLATION DEPTH (INCHES) SINCE THE
C*            BEGINNING OF THE YEAR, GROWING SEASON, OR OTHER CALCULATING
C*            PERIOD.
C*  SPRINK = SUBROUTINE NAME FOR SPRINKLER IRRIGATION APPLICATION.
C*    SRKE = SEASONAL RAIN FALL KINETIC ENERGY,JOULES/CM.THE
C*            SUMMATION OF THE RAINFALL KINETIC ENERGY DURING THE
C*            RAINFALL PERIOD FOR THE WHOLE SEASON.
C*    SSRT = SQUARE ROOT OF THE RATIO OF SLOPE STEEPNESS TO SLOPE
C*            LENGTH,(1/FT)**1/2
C*   STIWA = SEASONAL TOTAL IRRIGATION WATER APPLIED,INCHES.THE
C*            SUMMATION OF THE DEPTH OF APPLICATION OVER THE
C*            GROWING SEASON.
C*   STIWS = SEASONAL TOTAL IRRIGATION WATER STORED IN THE ENTIRE
C*            ROOT ZONE,INCHES.
C*     SUM = SUMMATION OF RAW STRESS INDEX FOR EACH 5-DAYS PERIOD
C*            BEFORE AND AFTER SILKING DATE.
C*  SUMLAY = SIMULATED SOIL MOISTURE IN EACH FOOT OF THE TOP 5-FEET.
C*            (INCHES)
C*    SUM5 = TOTAL SIMULATED SOIL MOISTURE (INCHES) IN TOP 5-FEET.
C*    SUM9 = TOTAL SIMULATED SOIL MOISTURE (INCHES) IN TOP 9-FEET.
C*  SUMTRN = CALCULATED ACTUAL DAILY SUM OF TRANSPIRATION FROM ALL
C*            SOIL LAYERS.
C*  SURAIN = SUM OF THE RAINFALL FOR THE SEASON,INCHES.
C*    SWLS = SEASONAL WATER LOSS,INCHES.THE SUMMATION OF SEASONAL
C*            SURFACE RUNOFF,DEEP PERCOLATION AND ACCUMULATED
C*            SEASONAL TILE FLOW.
C*  SWSARZ = SEASONAL WATER STORED IN THE ACTIVE ROOT ZONE,INCHES.
C*    SWSU = SEASONAL WATER SUPPLY,INCHES.THE SUMMATION OF THE
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C*          SEASONAL RAINFALL,TOTAL IRRIGATION WATER APPLICATION
C*          AND SEASONAL SOIL MOISTURE DEPLETION,(THE DIFFERENCE
C*          BETWEEN THE TOTAL INITIAL SOIL MOISTURE AND THE TOTAL
C*          END OF SEASON SOIL MOISTURE).
C*      T = AVERAGE DAILY AIR TEMPERATURE IN DEGREES F.
C*    TBI = TIME TO BEGIN IRRIGATION,HOUR OF THE DAY.
C*    TEI = TIME TO END IRRIGATION,HIUR OF THE DAY.
C*   TENZ = SOIL WATER POTENTIAL IN EACH SOIL LAYER AT THE TIME OF
C*          CALCULATION OF SOIL MOISTURE REDISTRIBUTION (CM, WATER).
C*   TESM = TOTAL END OF SEASON SOIL MOISTURE,THE SUMMATION OF
C*          THE SOIL MOISTURE FOR THE TOTAL WORKING DEPTH OF THE
C*          SOIL ON THE LAST DAY OF THE RUN,INCHES.
C* TESTIN = TOLERANCE FACTOR USED TO TERMINATE THE ITERATIVE PROCEDURE
C*          IN SUBROUTINE INFILT.
C*  THICK = THICKNESS OF A LAYER OF SOIL IN INCHES
C*   TFRC = TILE FLOW RECESSION CONSTANT
C*  TILEQ = TILE OUTFLOW DURING A PERIOD IN INCHES
C*   TIME = HOUR OF BEGINNING OF A CALCULATING PERIOD.
C*          USED TO CHECK FOR INITIATION OF PRECIPITATION.
C*   TISM = TOTAL INITIAL SOIL MOISTURE,INCHES.THE SUMMATION OF
C*          THE SOIL MOISTURE FOR THE TOTAL WORKING DEPTH OF THE
C*          SOIL AT THE BIGINNING OF THE RUN.
C*  TITLE = VARIABLE NAME USED TO INPUT TITLES TO BE PRINTED AT THE
C*          TOP OF OUTPUT DATA.
C*     TJ = JULIAN DAY COORDINATE VECTOR FOR CROP CANOPY ACTIVELY
C*          TRANSPIRING (PCATRN) INPUT DATA. PAIRED WITH VALUES OF
C*          PCT.
C*    TK1 = MINIMUM DAILY AIR TEMPERATURE EXPRESSED AS DEGREES K/100.0.
C*    TK2 = MAXIMUM DAILY AIR TEMPERATURE EXPRESSED AS DEGREES K/100.0.
C*     TM = TIME IN MINUTE ,USED IN THE RUNOFF HYDROGRAPH
C*          CALCULATION.
C*   TMAC = TOTAL MOISTURE AT CRACKING,SOIL MOISTURE IN EACH LAYER
C*          WHEN A GIVEN PERCENTAGE OF THE AVAILABLE SOIL MOISTURE
C*          IS REMOVED FROM THAT LAYER.
C*   TMAX = MAXIMUM DAILY AIR TEMPERATURE IN DEGREES F.
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C*    TMIN = MINIMUM DAILY AIR TEMPERATURE IN DEGREES F.
C*    TOFR = TOTAL OVERLAND FLOW RUNOFF FROM THE BEGINNING OF THE
C*           SEASON,INCHES.
C*  TOTSTR = TOTAL SOIL MOISTURE STORAGE CAPACITY IN THE TOP 4 SOIL
C*           LAYERS (INCHES). SET AT 80% OF SATURATION IN PRESENT PROGRAM
C*   TPAST = AVERAGE AIR TEMPERATURE FOR THE PREVIOUS 3 DAYS IN
C*           DEGREES F.
C*    TPBI = TIME PLANNED TO BEGIN IRRIGATION,HOUR OF THE DAY.
C*   TPINT = TOTAL DEPTH OF WATER IN INTERCEPTION STORAGE AT ANY TIME
C*           (INCHES).
C*      TR = AVERAGE DAILY AIR TEMPERATURE IN DEGREES R.
C*    TRST = VOLUME OF RUNOFF SINCE LAST TILLAGE,INCHES.
C*   TRSTM = MAXIMUM VALUE OF RUNOFF WATER REQUIRED TO REDUCE
C*           PUDLES CREATED BY TILLAGE TO ITS MINIMUM VALUE,
C*           IN INCHES.
C*  TSTART = TIME OF DAY (HOUR) WHEN RAINFALL FIRST OCCURRED.
C*   TSTOP = TIME OF DAY WHEN LAST RAINFALL HAS ENDED (HOUR).
C*  TWLWSR = TOTAL WATER LOSS TO WATER SUPPLY RATIO.(SWLS/SWSU),
C*           IN PERCENT.
C*   TWSTR = TOTAL WEIGHTED STRESS INDEX.THE SUMMATION OF THE
C*           5-DAY RAW STRESS INDEX MULTIPLIED BY THE ASSOCIATED
C*           WEIGHTE FACTOR FOR THAT PERIOD.
C*  TWUEFF = TOTAL OVERALL WATER USE EFFICIENCY,PERCENT(1-TWLWSR).
C*  VOLDPR = DEPTH OF WATER ACTUALLY IN STORAGE IN SURFACE DEPRESSIONS
C*           AT ANY ONE TIME (INCHES).
C*       W = TOTAL DAILY WIND TRAVEL IN MILES IN SUBROUTINE PEVAP.
C*    WIND = INPUT VALUE OF WIND MOVEMENT (MILES PER DAY) FOR EACH DAY.
C*      WP = WILTING POINT OF EACH SOIL LAYER EXPRESSED AS PERCENT
C*           VOLUME.
C*   WSARZ = WATER STORED IN THE ACTIVE ROOT ZONE AFTER EACH
C*           IRRIGATION,INCHES.I.E THE DIFFERENCE IN THE ACTIVE
C*           ROOT ZONE MOISTURE BEFORE AND AFTER IRRIGATION.
C*    WSRZ = WATER STORED IN THE ENTIRE ROOT ZONE AFTER IRRIGATION,
C*           INCHES.THE DIFFERENCE BETWEEN THE ENTIRE ROOT ZONE
C*           SOIL MOISTURE BEFORE AND AFTER IRRIGATION.
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C*    WSTR = WEIGHTED STRESS INDEX FOR EACH 5-DAY PERIOD PRIOR AND
C*           AFTER SILKING DATE,(RAW STRESS INDEX*WEIGHT FACTOR)
C*    WTFS = WEIGHT FACTOR FOR EACH 5-DAY PERIOD.8 PERIODS BEFORE
C*           AND 9 PERIODS AFTER SILKING DATE(0.5-2),GIVEN BY
C*           SHAW,1978.
C*     XDP = HOURLY RAINFALL DEPTH ,INCHES.
C*    YEAR = ALPHANUMERIC VARIABLE NAME USED TO READ IN THE YEAR FOR
C*           PRINTOUT OF DATES.
C*  YEARCK = YEAR CHECK.THIS VARIABLE IS USED TO STOP READING
C*           RAIN FALL DATA FOR A GIVEN YEAR WHEN IT CHANGES TO
C*           THE NEXT YEAR.ALSO TO SEARCH FOR THE CURRENT YEAR ON A
C*           TAPE OF PRECIPITATION DATA.
C*    ZINF = ACCUMULATED INFILTRATION TO EACH SOIL LAYER DURING A DAY
C*           (INCHES).
C*   ZOUTF = ACCUMULATED OUTFLOW FROM EACH SOIL LAYER FOR EACH DAY AS
C*           UNSATURATED WATER MOVEMENT DUE TO MOISTURE POTENTIAL
C*           GRADIENTS.  A NEGATIVE VALUE OF THIS VARIABLE MEANS FLOW
C*           WAS INTO THE LAYER.
C*   ZTRAN = ACCUMULATED DAILY TRANSPIRATION FROM EACH SOIL LAYER
C*           (INCHES).
C*
C*
C*    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
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      COMMON/ABLOCK/DSOILM(15),WP(15),RESAT(15),ESAT(15),RSAT(15),
     1SMET(16),PAD(6),ETRATE(16,6),FC(15),SHC(15),THICK(15),TMAC(15),
     2PLAV(15)
      EXTERNAL GINT2
      INTEGER DAYT,CARD,YEAR,YEARCK,SFIA
      REAL NRTDS(14),ALAI(12),DLAI(12),TJ(12),PCT(12),ESOILM(365,15)
      REAL*8 MONTH(12),COND(14),PERCO,DSOILM
      DIMENSION DRF(31),RO(31),SOILM(31),DAET(31),DPERC(31),
     *            BAL(31),DTF(31),DIWA(31),PANEVA(31)
      DIMENSION MON(13),NDA(13),NYR(13),ANX(13,7),BNX(13,7),
     1          CNX(13,7),DELTP(290),IAP(3),XDP(3,12),
     2          RS(365),TMAX(365),TMIN(365),RHMAX(365),RHMIN(365),
     3          WIND(365),PAN(365),EPCM(12),EINT(12),
     4          JCULT(5),JOUT(20),KDA(13),TITLE(20)
      DIMENSION ROOTS(14,10),IRT(10),RZSM(365),ARM(365),DARZ(365),
     2          ARMAFC(365),ARMAWP(365),ARMSAT(365),ARMAI(365),
     3          SAT(15),AEWP(15),SMTC(15),SUMLAY(5),PET(6),
     4          ZINF(14),ZOUTF(14),ZTRAN(14),ATRANS(14)
      DIMENSION RAWSTR(365),JUPSS(20),WTFC(17),SUM(17),WSTR(17),
     1          GDI(15),ATP(15),JDCH(15)
      EQUIVALENCE (PAN(1),WIND(1))
      DATA  MONTH/'JANUARY ','FEBRUARY','MARCH   ','APRIL   ','MAY     '
     1,'JUNE    ','JULY    ','AUGUST  ','SEPTEMBR','OCTOBER ','NOVEMBER'
     2,'DECEMBER'/
      DATA KDA/0,31,59,90,120,151,181,212,243,273,304,334,365/
    1 FORMAT(5X,15F5.3)
    2 FORMAT(16F5.2)
    3 FORMAT(10X,10F7.3)
    4 FORMAT(I4,2I5)
    7 FORMAT(8F10.3)
    8 FORMAT(1H-//2X,I3,6X,A8,I3,',',I4)
    9 FORMAT(20I4)
   10 FORMAT(I2,1X,I2,15F5.2)
   11 FORMAT(I3,F10.5)
   12 FORMAT(2F10.2)
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19 FORMAT(4X,3I3,7(F3.0,F2.0,F4.2))
20 FORMAT(6X,3I2,I1,12F3.2)
30 FORMAT(20A4)
31 FORMAT(1H1,7X,20A4)
32 FORMAT(11X,'TOTAL PCTENTIAL STORAGE IN THE TOP TWO FEET = ',F5.2,
  1' INCHES'/11X,'RCOTZCNE MOISTURE STORAGE AT DROUGHT STRESS =',
  $F6.2/11X,'RCCTZONE MOISTURE AT FLOOD STRESS =',F6.2)
33 FORMAT(1H ,10X,'METEOROLOGICAL DATA FOR TODAY'/10X,'MAXIMUM AIR TE
  1MP. = ',F5.1,' DEG. F., MIN. = ',F4.1,' DEG. F.'/10X,'DAILY SCLAR
  2RADIATICN = ',F6.1,' LANGLEYS'/10X,'MAXIMUM REL. HUMIDITY =',F5.1,
  3' PCT., MIN. RH.=',F5.1,' PCT.'/10X,'TOTAL DAILY WIND TRAVEL = ',
  4F7.2,' MILES')
34 FORMAT(1H0,20X,'INITIAL SOIL MOISTURE DATA'//1X,'LAYER  THICK   SA
  1T    SHC    AEWP    SMTC      FC      WP     PLAV  RESAT  TMAC  ESCILM'
  2/7X,'INCHES PERCENT CM/HR   CM',12X,'PCT.    PCT.  INCHES INCHES IN
  3CHES INCHES'/14X,'BY VOL.',22X,'BY VCL. BY VCL.'//(2X,I2,3X,F5.2,
  43X,F4.1,2X,F6.3,1X,F7.2,2X,F5.2,1X,F6.2,2X,F6.2,1X,F5.2,2X,F5.2,
  52X,F5.2,2X,F5.2))
35 FORMAT(10X,'PAN EVAPORATION FOR TODAY =',F7.3,' INCHES'/
  $ 9X,'PAN COEFFICIENT =',F7.3/9X,'INTERCEPTION   =',F7.3/)
36 FORMAT(8X,20A4)
37 FORMAT(1H0,5X,'DRAIN TUBE IN LAYER',I3/5X,
  $'TILE FLOW RECESSION CONSTANT =',F7.4/)
38 FORMAT(1H0,3X,'FIELD AREA =',F8.2,' ACRES.  AVERAGE FIELD SLOPE ='
  1,F8.4/4X,'SLOPE LENGTH =',F7.1,' FEET.  SURFACE ROUGHNESS COEFFICI
  2ENT =',2F7.3/4X,'TRSTM = ',F6.3,2X,'SMALLEST TIME INTERVAL USEC =
  31/',I2,'TH  OF AN HOUR')
39 FORMAT(11X,'WET SOIL INFILTRATION CAPACITY = ',F5.3,' IN./HR.')
40 FORMAT(11X,'ASOIL = ',F7.3,5X,'PSOIL = ',F5.3,3X,'AMC = ',F7.3,
  1' PERCENT')
41 FORMAT(1H0,40X,'PAD'/19X,6F8.3/12X,'SMET',23X,'ETRATE')
42 FORMAT(11X,7F8.3)
43 FORMAT(1H0,5X,'SOIL MOISTURE CONSIDERED 100 PERCENT USABLE BETWEEN
  1 100 AND 50 PERCENT OF AVAILABLE,'/
  2 6X,'AND LINEARLY DECREASING USABILITY BETWEEN 50 AND 0 PERCENT'/
```

```
   3 6X,'OF AVAILABLE'/)
44 FORMAT(' ',3X,'SURFACE  STORAGE=',2F7.3)
45 FORMAT(1H-,11X,'CURVE DATA FCR DENMEAD AND SHAW TYPE CURVES')
46 FORMAT(1H0,11X,'DATA FOR INFILTRATION PARAMETERS')
47 FORMAT(1H0,5X,'ASOILM=',F6.3,' AM=',F6.3,' PSFC=',F6.3,' PM=',
  1F6.3/5X,'CE1 = ',F6.3,'  CE2 = ',F6.3,'  FCS= ',F5.2, '  FCP=  ',
  2F5.2/)
48 FORMAT(' ',3X,' SRKE= ',F6.3,'   TRST= ',F6.3/)
49 FORMAT(3X,'PSIFC= ',F6.2,'  PSIWP= ',F8.1)
50 FORMAT(1H0,9X,'TIME    RAINFALL  PRECIP.  SURFACE  OVERLAND',2X,
  1'OVERLAND'/18X,'INTENSITY EXCESS   STORAGE  FLOW      FLCW'/18X,
  2'DURING    AFTER    (INCHES) RUNOFF    RUNOFF'/18X,'PERICD',4X,
  3'INFILT',12X,'(INCHES)   (CFS)'/19X,'IN/HR    (INCHES)'/)
51 FORMAT(10X,2F3.0,2X,F6.3,4X,F7.3,2X,F7.3,2X,F8.3,2X,F8.3,9X,F8.5)
```

```
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*                                                                          *
C*        INITIALIZING PART OF MAIN PROGRAM                                 *
C*                                                                          *
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C
  100 READ(5,30,END=2000)TITLE
      WRITE(6,31)TITLE
      READ(5,30)TITLE
      DO86I=1,365
      DO85J=1,14
   85 ESOILM(I,J)=0.0
C
C*  INITIALIZE PENMAN EQUATION PARAMETERS AND DAILY PAN EVAPORATION.
C
      RS(I)=0.0
      TMAX(I)=0.0
      TMIN(I)=0.0
      RHMAX(I)=0.0
      RHMIN(I)=0.0
      WIND(I)=0.0
      PAN(I)=0.0
      RAWSTR(I)=0.0
      RZSM(I)=0.0
      ARM(I)=0.0
      ARMAFC(I)=0.0
      ARMAWP(I)=0.0
      ARMSAT(I)=0.0
   86 CONTINUE
C
C*  READ A SET OF INPUT INDICATORS TO MAKE THE MODEL'S FUNCTIONS
C*  TO BE OPTIONAL AND ADJUSTABLE BY THE USER.
C
      READ(5,9)NH,KEVAP,KSMA,KRHO,KIRR,KUIR,KSOIL,KSTR,KIRD,KPRE
      READ(5,10)JIM,JX,(THICK(JI),JI=1,JIM)
```

```
      JIM1=JIM-1
      READ(5,4)YEAR,JSTART,JSTOP
      YEARCK=YEAR-1900
C
C*   READ DAYS ON WHICH DETAILED OUTPUT IS REQUESTED.
C
      READ(5,9)JOUT
C
C*   READ DAYS ON WHICH CULTIVATION OCCURRED.
C
      READ(5,9)JCULT
      JJ=JSTART-1
C
C*   READ IN STARTING VALUES FOR SOIL MOISTURE.
C
      READ(5,7)(ESOILM(JJ,JI),JI=1,JIM1)
C
C*   INITIALIZE DAILY VALUES FOR MONTHLY OUTPUT SUMMARY
C
      BALN=0.0
      DO 87 JI=1,JIM1
   87 BALN=BALN+ESOILM(JJ,JI)
      DO 91 I=2,13
      IF(JSTART.GT.KDA(I))GOTO91
      MO=I-1
      GOTO92
   91 CONTINUE
   92 DO 93 JM=1,31
      DRF(JM)=0.0
      RO(JM)=0.0
      SOILM(JM)=0.0
      PANEVA(JM)=0.0
      DAET(JM)=0.0
      DTF(JM)=0.0
      DIWA(JM)=0.0
```

```
      BAL(JM)=0.0
   93 DPERC(JM)=0.0
      SUM9=BALN
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *

C*       INITIALIZING INPUT FOR SUBROUTINE REDIST                 *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
C*  READ VALUES FOR SATURATED HYDRAULIC CONDUCTIVITY IN CM/HR.,
C*  FIELD CAPACITY AND WILTING POINT IN PERCENT BY VOLUME FOR
C*  ALL SOIL LAYERS.
C
      READ(5,2)(SHC(I),I=1,JIM)
      READ(5,2)(FC(I),I=1,JIM)
      READ(5,2)(WP(I),I=1,JIM)
C
C*  READ TILE DEPTH (LAYER NUMBER ON WHICH TILE IS LOCATED),AND
C*  TILE FLOW RECESSION CONSTANT.
C
      READ(5,11)JTILE,TFRC
C
C*  READ SOIL MATRIC POTENTIAL AT FIELD CAPACITY AND WILTING POINT.
C
      READ(5,12)PSIFC,PSIWP
C
C*  READ SOIL MOISTURE CONTENT AT SATURATION PERCENT BY VOLUME
C*  FOR ALL SOIL LAYERS.
C
      READ(5,2)(SAT(I),I=1,JIM)
      READ(5,2)PER1,PER2
C
C*  READ PERCENTAGE OF AVAILABLE SOIL MOISTURE AT WHICH CRACKS
C*  DEVELOPE IN THE SOIL SURFACE.
```

```
      READ(5,2)PAMAC
      PSILOG=-ALOG10(PSIFC/PSIWP)
      DO90I=1,JIM
      PLAV(I)=(FC(I)-WP(I))*THICK(I)/100.0
      TMAC(I)=(WP(I)+PAMAC*(FC(I)-WP(I)))*THICK(I)/100.0
      RESAT(I)=PER1*SAT(I)*THICK(I)/100.0
      RSAT(I)=PER2*SAT(I)*THICK(I)/100.0
      SMTC(I)=PSILOG/ALOG10(FC(I)/WP(I))
      AEWP(I)=PSIFC*(FC(I)/SAT(I))**SMTC(I)
   90 CONTINUE
      DO96JI=1,JIM
   96 ESAT(JI)=SAT(JI)*THICK(JI)*0.01
      ESOILM(JJ,JIM)=ESOILM(JJ,JIM1)
      SMHP14=0.0
      TOTSTR=RESAT(1)+RESAT(2)+RESAT(3)+RESAT(4)
      SMASM=TOTSTR-ESOILM(JJ,1)-ESOILM(JJ,2)-ESOILM(JJ,3)-ESOILM(JJ,4)
      SPERCO=0.0
```

```
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*        INITIALIZING INPUT FOR SUBROUTINE ET                    *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      NC=6
      NPC=16
      DO88I=1,14
   88 ATRANS(I)=0.0
      EVAPTR=0.0
      AAET=0.0
      APET=0.0
      AAEVAP=0.0
      AATRAN=0.0
      AAINT=0.0
      ASTF=0.0
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*        INITIALIZING INPUT TO SUBROUTINE PRECIP                 *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      TSTOP=0.0
      TSTART=0.0
      IERR=0
      IBIG=1
      CARD=1
      SURAIN=0.0
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*   INITIALIZING INPUT TO SUBROUTINE INFILT                      *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
```

```
      READ(5,3)FCINFL,ASOILM,AM,PSFC,PM,CE1,CE2,FCS,FCP
      DELTF=0.0
      SDELTF=0.0
      TESTIN=0.001
      VOLDPR=0.0
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                  *
C*        INITIALIZING INPUT TO SUBROUTINE OFROUT                   *
C*                                                                  *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      PEAI=0.0
      OFR=0.0
      TOFR=0.0
      READ(5,7)OFSS,OFMN1,OFMN2,TRSTM,PUDLE1,PUDLE2,OFSL,AREA
      READ(5,7)SRKE,TRST
      SSRT=SQRT(OFSS)/OFSL
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                  *
C*        INITIALIZING INPUT TO SUBROUTINE INTCPT                   *
C*                                                                  *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      DRI=0.0
      DDP=0.0
      TPINT=0.0
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                  *
C*     INITIALIZING INPUT TO SUBROUTINE PLANT                       *
C*                                                                  *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
```

```
      READ(5,2)ALAI
      READ(5,2)DLAI
      READ(5,2)TJ
      READ(5,2)PCT
      READ(5,9)IRT
      DO105JR=1,10
  105 READ(5,2)(ROOTS(JI,JR),JI=1,JIM1)
      IF(KSTR.EQ.0)GO TO 102
C
C*   ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    **
C*                                                                          *
C*  IF STRESS INDEX IS INCLUDED INITIALIZE ASSOCIATED PARAMETERS.          *
C*                                                                          *
C*   ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    **
C
C*  READ SILKING DATE AND STRESS WEIGHT FACTORS FOR EIGHT 5-DAY
C*  PERIODS BEFORE AND NINE 5-DAY  PERIODS AFTER SILKING DATE.
C
      READ(5,5)JMS,JDS
    5 FORMAT(2I5)
      READ(5,6)(WTFC(MN),MN=1,17)
    6 FORMAT(17F4.2)
      I=JMS
      JUDS=KDA(I)+JDS
      TWSTR=0.0
      DO 104 KJ=1,17
  104 SUM(KJ)=0.0
  102 CONTINUE
      IF(KIRR.EQ.1)GO TO 99
      READ(5,101)PAMRI
  101 FORMAT(F5.3)
C
C*  CALCULATE TOTAL SOIL MOISTURE AT FIELD CAPACITY,WILTING POINT
```

```
C*  AND SATURATION IN THE ENTIRE ROOT ZONE.
C
   99 RSMAFC=0.0
      RSMAWP=0.0
      RSMSAT=0.0
      DO 106 JI=1,JX
      RZSM(JJ)=RZSM(JJ)+ESOILM(JJ,JI)
      RSMSAT=0.9*ESAT(JI)+RSMSAT
      RSMAFC=THICK(JI)*0.01*FC(JI)+RSMAFC
  106 RSMAWP=THICK(JI)*0.01*WP(JI)+RSMAWP
C
C*  ASSUME ACTIVE ROOTS ARE IN THE FIRST TWO LAYERS,(1-FEET),
C*  UNTIL MID-JUNE.
C
      DARZ(JJ)=1.0
      ARM(JJ)=ESOILM(JJ,1)+ESOILM(JJ,2)
      ARMAFC(JJ)=THICK (1)*0.01*(FC(1)+FC(2))
      ARMAWP(JJ)=THICK (1)*0.01*(WP(1)+WP(2))
      ARMSAT(JJ)=0.9*(ESAT(1)+ESAT(2))
      STIWA=0.0
      IF(KIRR.EQ.0)GO TO 108
C
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *
C*                                                                        *
C*   IF IRRIGATION IS INCLUDED INITIALIZE FOR SPRINK                      *
C*                                                                        *
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *
C
      IF(KUIR.EQ.1)GO TO 111
C
C*  IF UNIFORM IRRIGATION IS DESIRED,(KUIR=0),READ ONE IRRIGATION
C*  DEPTH AND APPLICATION TIME PERIOD FOR THE WHOLE SEASON.
C
      READ(5,112)PAMRI,GDIA,ATPI,TPBI,JDSIR,JDEIR
  112 FORMAT(4F10.3,2I5)
```

```
      GO TO 113
  111 READ(5,97)PAMRI,TPBI,JDSIR,JDEIR,NI
C
C*   IF NON-UNIFORM IRRIGATION APPLICTION IS REQUESTED,(KUIR=1),
C*   READ DIFFERENT IRRIGATION DEPTH AND APPLICATION TIME PERIODS
C*   AND THE ASSOCIATED DATES TO CHANGE DEPTH OF APPLICATION.
C
      READ(5,98)(GDI(I),I=1,NI)
      READ(5,98)(ATP(I),I=1,NI)
      READ(5,94)(JDCH(I),I=1,NI)
   94 FORMAT(15I4)
   97 FORMAT(2F5.2,3I5)
   98 FORMAT(15F4.1)
  113 CONTINUE
      SFIA=0
      STIWS=0.0
      SWSARZ=0.0
      SMBI=RZSM(JJ)
      ARZMBI=ARM(JJ)
  108 IBIR=0
      RSMAI=RSMAFC-PAMRI*(RSMAFC-RSMAWP)
      ARMAI(JJ)=ARMAFC(JJ)-PAMRI*(ARMAFC(JJ)-ARMAWP(JJ))
C
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*                                                                          *
C*            READ IN METEOROLOGICAL DATA FOR THE YEAR                      *
C*                                                                          *
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C
      IF(KEVAP.EQ.1)GOTO110
C
C*  IF KEVAP = 1 READ IN PAN DATA.  IF NOT READ PENMAN DATA.
C
      READ(5,3)(TMAX(JJ),JJ=1,365)
      READ(5,3)(TMIN(JJ),JJ=1,365)
```

```
      READ(5,3)(RHMAX(JJ),JJ=1,365)
      READ(5,3)(RHMIN(JJ),JJ=1,365)
      READ(5,3)(RS(JJ),JJ=1,365)
      READ(5,3)(WIND(JJ),JJ=1,365)
C
C*  END PENMAN DATA INPUT  SKIP TO READ PRECIP DATA NEXT.
C
      GO TO 114
C
C*  READ IN PAN DATA AND COEFFICIENTS
C
  110 READ(5,1)(PAN(JJ),JJ=1,365)
      READ(5,2)(EPCM(M),M=1,12)
      READ(5,2)(EINT(M),M=1,12)
C
C*  READ IN FIRST PRECIPITATION DATA CARD
C
  114 IF(KPRE.EQ.0) GO TO 118
C
C*  IF KPRE=0 READ PRECIPITATION DATA FROM CARDS FOR SHORT PERIODS
C*  OF TIME.(LESS THAN AN HOUR).MAKE SURE THAT THE FIRST DATE OF THE
C*  RAINFALL INPUT DATA OCCURS AFTER JSTART,AND AGREES WITH THE DATE
C*  OF THE FIRST NON-ZERO VALUE OF RAIN AFTER JSTART.
C*  IF KPRE=1 READ HOURLY PRECIPITATION DATA FROM DISK WITH U.S
C*  WEATHER BUREAU FORMAT.
  115 READ(11,20)NYR(CARD),MON(CARD),NDA(CARD),IAP(CARD),
     $           (XDP(CARD,N),N=1,12)
      IF(YEARCK.NE.NYR(CARD))GO TO 115
      GO TO 119
  118 READ(5,19)MON(CARD),NDA(CARD),NYR(CARD),(ANX(CARD,N),BNX(CARD,N),
     1 CNX(CARD,N),N=1,7)
  119 I=MON(CARD)
      JJR=KDA(I)+NDA(CARD)
      IF(KPRE.EQ.0)GO TO 124
      IF(JJR.LT.JSTART)GO TO 115
  124 JJR1=0
      JJ=JSTART-1
```

```
C*   ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*                                                                           *
C*           PRINT OUT INPUT PARAMETERS FOR THE MODEL                        *
C*                                                                           *
C*   ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C
      WRITE(6,36)TITLE
      WRITE(6,34)(JI,THICK(JI),SAT(JI),SHC(JI),AEWP(JI),SMTC(JI),FC(JI),
     1WP(JI),PLAV(JI),RESAT(JI),TMAC(JI),ESOILM(JJ,JI),JI=1,JIM)
      WRITE(6,32)TOTSTR,RSMAI,RSMSAT
      WRITE(6,39)FCINFL
      IF(KSMA.EQ.1)GOTO122
      WRITE(6,45)
      WRITE(6,41)PAD
      WRITE(6,606)
      DO120I=1,NPC
      WRITE(6,42)SMET(I),(ETRATE(I,J),J=1,NC)
  120 CONTINUE
      WRITE(6,606)
      GOTO125
  122 WRITE(6,43)
  125 CONTINUE
      WRITE(6,46)
      WRITE(6,47)ASOILM,AM,PSFC,PM,CE1,CE2,FCS,FCP
      WRITE(6,38)AREA,OFSS,OFSL,OFMN1,OFMN2,TRSTM,NH
      WRITE(6,44)PUDLE1,PUDLE2
      WRITE(6,48)SRKE,TRST
      WRITE(6,49)PSIFC,PSIWP
      WRITE(6,53)PAMAC
   53 FORMAT(4X,' PASMAC=   ',F5.2/)
      IF(JTILE.EQ.0)GO TO 126
      WRITE(6,37)JTILE,TFRC
  126 IF(KIRR.EQ.0)GO TO 127
      IF(KUIR.EQ.1)GO TO 116
      WRITE(6,117)PAMRI,GDIA,ATPI,TPBI,JDSIR,JDEIR
```

```
117 FORMAT(3X,'PAMRI= ',F5.2,'   GDIA=  ',F5.2/3X,'ATPI= ',F5.2
   1,'   TPBI= ',F5.2/3X,' JDSTIRR= ',I4,'   JDENIRR=  ',I4)
    GO TO 127
116 WRITE(6,52)PAMRI,TPBI,JDSIR,JDEIR,NI
 52 FORMAT(10X,'PAMRI=',F6.2,'  TPBI= ',F6.2/10X,'JDSIR= ',I5
   1,'  JDEIR=',I5,'  NI=',I3//)
    WRITE(6,54)(GDI (I),ATP (I),JDCH (I),I=1,NI)
 54 FORMAT(10X,'GDIA(IN)    ATPI(HR)    JDCHA(DAY)'//(10X
   1,F6.2,6X,F6.2,6X,I6))
127 DO128JI=1,JIM1
128 DSOILM(JI)=ESOILM(JJ,JI)
```

```
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*           BEGIN MAIN EXECUTION LOOP                            *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
  129 DO1000JJ=JSTART,JSTOP
C
C*  MAJOR CALCULATING DO LOOP NO.1
C*  GO THROUGH THIS LOOP ONCE FOR EACH DAY IN THE SEASON.
C
      RAIN=0.0
      DIA=0.0
      PBAL=SUMS+TPINT+VOLDPR
C
C*  CHECK FOR REQUESTED DAILY OUTPUT DETAIL
C
      NOUT=0
      DO130LL=1,20
      IF(JJ.EQ.JOUT(LL))NOUT=1
  130 CONTINUE
      DO 140 LL=1,5
      IF(JJ.EQ.JCULT(LL))GOTO135
      GOTO140
  135 SRKE=0.0
      TRST=0.0
      GOTO141
  140 CONTINUE
  141 CONTINUE
C
C*  INITIALIZE DAILY SUMMATION VALUES TO ZERO.
C
  145 SUMTRN=0.0
      ADTF=0.0
      ADET=0.0
```

```
      ADINT=0.0
      DDELTF=SDELTF
      DPERCO=SPERCO
      DAQEX=TOFR
      DAEVAP=AAEVAP
      DO150LL=1,JIM1
      ZINF(LL)=0.0
      ZOUTF(LL)=0.0
      ZTRAN(LL)=0.0
  150 CONTINUE
C
C*  SET INITIAL SOIL MOISTURE AT THE BEGINNING OF EACH DAY TO THE VALUE
C*  AT THE END OF THE PREVIOUS DAY.
C
      DO151JI=1,JIM1
  151 ESOILM(JJ,JI)=ESOILM(JJ-1,JI)
      RZSM(JJ)=RZSM(JJ-1)
      ARM(JJ)=ARM(JJ-1)
      ARMAI(JJ)=ARMAI(JJ-1)
C
C*  SET THE SOIL MOISTURE VALUE OF THE LAYER BELOW THE SOIL PROFILE
C*  EQUAL TO THE AVERAGE OF THE SOIL MOISTURE OF THE PREVIOUS LAYER
C*  FOR THE PAST 14 DAYS.
C
      PAST=JJ-JSTART+1
      IF(PAST.LE.14.0)GO TO 152
      SMHP14=SMHP14+ESOILM(JJ,JIM1)-ESOILM(JJ-14,JIM1)
      DSOILM(JIM)=SMHP14/14.0
      GO TO 153
  152 SMHP14=SMHP14+ESOILM(JJ,JIM1)
      DSOILM(JIM)=SMHP14/PAST
  153 CONTINUE
C
C*  UPDATE PLANT SYSTEM FUNCTIONS.
```

```
      CALL PLANT(JJ,NRTDS,PCATRN,CLAI,IRT,ROOTS,ALAI,DLAI,TJ,PCT,JIM1)
C
C*  UPDATE INFILTRATION EQUATION PARAMETERS, ADJUSTING FOR SOIL
C*  MOISTURE CONTENT OF THE TOP SOIL LAYER AND THE CROP LEAF
C*  AREA INDEX AT THE BEGINNING OF THE NEW DAY.
C
      AMC= ESOILM(JJ,1)*100.0/THICK(1)
      IF(CLAI.LE.3.0)GOTO159
      CLAIX=3.0
      GOTO160
  159 CLAIX=CLAI
  160 ASOIL=ASOILM*EXP(AM*(AMC-FCS))
       IF(ASOIL.GT.ASOILM)ASOIL=ASOILM
      ASOIL=ASOIL+0.5*CLAIX
      PSOIL=PSFC*(AMC/FCP)**PM
      DT=4.0
C
C*  DETERMINE MONTH AND DAY FROM JULIAN DAY NUMBER
C
      DO 198 I = 1 , 13
      IF(JJ.GT.KDA(I))GOTO198
      KMOT=I-1
      DAYT=JJ-KDA(I-1)
      GOTO199
  198 CONTINUE
  199 CONTINUE
C
C*  DETERMINE ESTIMATED POTENTIAL EVAPORATION FOR THE DAY FROM
C*  EITHER THE PENMAN EQUATION OR PAN EVAPORATION DATA AS
C*  PROVIDED IN THE INPUT DATA.
C
      IF(KEVAP.EQ.1)GOTO180
      TPAST=(TMAX(JJ-3)+TMAX(JJ-2)+TMAX(JJ-1)+TMIN(JJ-3)+TMIN(JJ-2)
     1+TMIN(JJ-1))/6.0
```

```
C*  MINIMUM RELATIVE HUMIDITY WEIGHTED 3-TIMES IN ESTIMATION THE
C*  AVERAGE RELATIVE HUMIDITY FOR THE DAY.
C
      RH=(RHMAX(JJ)+3.*RHMIN(JJ))*0.25
      CALL PEVAP(JJ,TMAX(JJ),TMIN(JJ),CLAI,RH,RS(JJ),WIND(JJ),TPAST,
     1PE,PET)
      GOTO189
C
C*  IF PAN DATA IS USED CALL DIFFERENT FUNCTION FOR PET
C
 180  CALL PANEVP(PAN,EPCM,EINT,KMOT,JJ,PE,PET)
 189  CONTINUE
      IF(NOUT.NE.1.AND.JJR.NE.JJ)GOTO200
C
C*  IF DETAILED OUTPUT IS REQUESTED FOR THIS DAY, PRINT OUT WEATHER
C*  AND INPUT PARAMETER VALUES NEXT.
C
      WRITE(6,8)JJ,MONTH(KMOT),DAYT,YEAR
      IF(NOUT.NE.1)GO TO 169
      IF(KEVAP.EQ.1)GOTO165
      WRITE(6,33)TMAX(JJ),TMIN(JJ),RS(JJ),RHMAX(JJ),RHMIN(JJ),WIND(JJ)
      GOTO168
 165  WRITE(6,35)PAN(JJ),EPCM(KMOT),EINT(KMOT)
 168  CONTINUE
      WRITE(6,40)ASOIL,PSOIL,AMC
      WRITE(6,612)CLAI,PCATRN,(NRTDS(JI),JI=1,JIM1)
      IF(JJR.NE.JJ)GOTO200
C
C*  IF RAINFALL OCCURS TODAY, NEXT READ THE REMAINING PRECIPITATION
C*  DATA CARDS FOR THIS DAY AND PROCESS THESE DATA FOR USE IN
C*  SUBROUTINE PRECIP.
C
 169  CONTINUE
 170  CARD=CARD+1
      IF(KPRE.EQ.0) GO TO 171
```

```
      READ(11,20,END=190)NYR(CARD),MON(CARD),NDA(CARD),IAP(CARD),
     $                     (XDP(CARD,N),N=1,12)
      GO TO 172
  171 READ(5,19)MON(CARD),NDA(CARD),NYR(CARD),(ANX(CARD,N),BNX(CARD,N),
     1 CNX(CARD,N),N=1,7)
  172 IF(MON(CARD).EQ.MON(1).AND.NDA(CARD).EQ.NDA(1))GOTO170
      IF(KPRE.EQ.0)GO TO 173
      CALL PRECHR(CARD,DELTP,NYR,MON,NDA,IAP,XDP,RAIN,TSTART,TSTOP)
      GO TO 174
  173 CALL        PRECIP(KMOT,DAYT,YEAR,IBIG,NH,DELTP,IERR,TSTART,TSTOP,
     1 MON,NDA,NYR,ANX,BNX,CNX,RAIN)
C
C*  IF AN ERROR WAS DETECTED IN THE SEQUENCE OF INPUT PRECIP DATA
C*  TERMINATE EXECUTION.
C
      IF(IERR.EQ.1)GOTO2000
  174 SURAIN=SURAIN+RAIN
      IF(KRHO.EQ.1)WRITE(6,50)
      JJR1=JJR
      I=MON(CARD)
      IF(I.EQ.0)GOTO190
      IF(KPRE.EQ.0)GO TO 176
      IF(YEARCK.NE.NYR(CARD))GO TO 190
  176 JJR=KDA(I)+NDA(CARD)
      IF(KPRE.EQ.0)GO TO 177
      IF(JJR.GT.JJR1)GOTO200
      WRITE(6,22)
   22 FORMAT('***ERROR IN INPUT PRECIP DATA CARDS DATE***')
       GO TO 2000
  177 IF(JJR.LE.JJR1)GOTO2000
      MON(1)=MON(CARD)
      NDA(1)=NDA(CARD)
      NYR(1)=NYR(CARD)
      DO175N=1,7
      ANX(1,N)=ANX(CARD,N)
```

```
      BNX( 1,N)=BNX(CARD,N)
  175 CNX( 1,N)=CNX(CARD,N)
      CARD=1
      GOTO200
  190 JJR=367
  200 IF(KIRR.EQ.0) GO TO 220
C
C*  IF IRRIGATION IS NOT INCLUDED,(KIRR=0),SKIP THE ASSOCIATED
C*  CALCULATIONS .IF NOT PERFORM THE FOLLOWING REQUIRED CALCULATIONS
C*  FOR THE PERIOD BETWEEN THE STARTING AND ENDING DATES OF
C*  IRRIGATION AS SPECIFIED IN THE INPUT DATA.FOR ALL OTHER DAYS
C*  SKIP THIS PART.
C
      IF(JJ.LT.JDSIR) GO TO 220
      IF(JJ.GT.JDEIR)GO TO 215
      IF(KUIR.EQ.0) GO TO 225
      DO 221 K=1,NI
      IF(JJ.GT.JDCH (K)) GO TO 221
      GDIA=GDI (K)
      ATPI=ATP (K)
      GO TO 225
  221 CONTINUE
  225 GIDP=GDIA/ATPI/NH
      IF(IBIR.GT.2)IBIR=0
      IF(IBIR.EQ.2)GOTO201
      IF(KIRD.EQ.0) GO TO 195
      IF(ARM(JJ).LT.ARMAI(JJ))IBIR=1
      GO TO 196
  195 IF(RZSM(JJ).LT.RSMAI)IBIR=1
  196 IF(IBIR.EQ.0)GOTO220
  201 IF(JJR1.EQ.JJ)GOTO210
      DO202I=1,290
  202 DELTP(I)=0.0
      TSTART=TPBI
      TSTOP=0.0
```

```
  210 IF(IBIR.EQ.2)GOTO212
C
C*   IF RAINFALL STARTED BEFORE THE TIME PLANNED TO BEGIN
C*   IRRIGATION,DO NOT IRRIGATE.BUT IF IT STARTED DURING
C*   IRRIGATION APPLICATION PERIOD, CONTINUE THE APPLICATION.
C
      IF(TSTART.LT.TPBI)GOTO215
  212 CALL SPRINK(IBIR,TPBI,ATPI,GIDP,NH,DELTP,TBI,TEI,DIA)
      IF(TSTART.GT.TBI)TSTART=TBI
      IF(TSTOP.LT.TEI)TSTOP=TEI
      GOTO220
  215 IBIR=0
  220 CONTINUE
C
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*                                                                          *
C*    BEGIN MAJOR CALCULATING LOOP NO. 2                                    *
C*                                                                          *
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C
      DO599IT1=1,6
C
C*     THIS LOOP IS EXECUTED ONCE FOR EACH FOUR HOUR PERIOD DURING
C*  THE DAY.THIS LOOP IS THE LONGEST TIME PERIOD USED FOR
C*  CALCULATIONS IN THE PROGRAM.
C*     IF NO RAINFALL OR IRRIGATION WATER APPLICATION OCCURS FOR
C*  THIS DAY OR DURING THIS FOUR-HOUR PERIOD,GO TO 500 AND MAKE
C*  CALCULATIONS ONLY ON THE FOUR-HOUR TIME INTERVAL.OTHERWISE
C*  ENTER MAJOR DO-LOOP NO.3 AND REDUCE THE TIME INTERVAL TO
C*  ONE HOUR.
C
      IF(JJ.NE.JJR1.AND.IBIR.EQ.0)GOTO500
      TIME=DT*IT1
      IF(TIME.LE.TSTART.OR.TIME.GE.TSTOP+DT)GOTO500
```

```
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                 *
C*     BEGIN MAJOR CALCULATING LOOP NO. 3                          *
C*                                                                 *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      DO499IT2=1,4
C
C*      THIS LOOP IS USED ONLY ON DAYS DURING WHICH RAINFALLS OCCURS.
C*  IN THIS LOOP THE TIME PERIOD IS REDUCED TO ONE HOUR INTERVALS.
C*  THIS TIME INTERVAL WILL BE FURTHER REDUCED IF RAINFALL ACTUALLY
C*  OCCURS DURING THIS HOUR.
C
      DT=1.
      TIME=(IT1-1.)*4.+IT2*1.
C
C*      IF NO RAINFALLS OCCURS DURING THIS HOUR,GO TO 400 AND MAKE ALL
C*  CALCULATIONS USING THIS ONE HOUR TIME INTERVAL.OTHERWISE ENTER
C*  MAJOR DO-LOOP NO.4 AND REDUCE THE TIME INTERVAL TO 1.0/NH HOURS.
C
      IF(TIME.LE.TSTART.OR.TIME.GE.TSTOP+DT)GOTO400
      IC=( TIME-1)*NH
      RSUM=0.0
      ICC=IC+1
      ICR=IC+NH-1
      IF(ICR.LT.ICC)ICR=ICC
      DO 250 IR= ICC,ICR
      RSUM=RSUM+DELTP(IR)
  250 CONTINUE
      IF(RSUM.LE.0.0)GOTO0400
      DT=1./NH
C
C*  IF HYDROGRAPH OUTPUT DETAIL IS NOT WANTED, SKIP TO BEGINNING
C*  OF THE NEXT LOOP.
```

```
      IF(KRHO.EQ.0)GOTO300
      TIME=TIME-1.0
      TM=0.0
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*    BEGIN MAJOR CALCULATING LOOP NO. 4                          *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
  300 DO399IT3=1,NH
C
C*     THIS LOOP USES TIME INTERVALS OF 1.0/NH HOURS TO CALCULATE
C*  INTERCEPTION,INFILTRATION,RUNOFF AND SOIL MOISTURE MOVEMENT
C*  DURING PERIODS OF ACTUAL RAINFALL.
C
      IC=IC+1
      INCI=1
      CALL INTCPT(CLAI,DELTP(IC),DPINT,TPINT,DDP,INCI,DT,DRI)
      CALL INFILT(ASOIL,PSOIL,TOTSTR,FCINFL,SMASM,DT,DDP,IC,
     1DELTF,VOLDPR,DRI,TESTIN,SDELTF,DINT,PEAI,SRKE,CE1,CE2)
      IRED=1
      CALL REDIST(IRED,DELTF,PERCO,SPERCO,JJ,TFRC,ADTF,VOLDPR,DT,COND,
     1ZINF,ZOUTF,TOTSTR,SMASM,SAT,JTILE,JIM,AEWP,SMTC)
      CALL OFROUT(PEAI,VOLDPR,EQD,OFR,TOFR,AREA,DT,OFRCFS,TRST,TRSTM,
     *           CFMN1,OFMN2,SSRT,PUDLE1,PUDLE2)
      TRST=TRST+OFR
      IF(KRHO.EQ.0)GOTO390
      IF(OFR.LE.0.0.AND.DINT.LT.0.1)GO TO 389
      WRITE(6,51)TIME,TM,DINT,PEAI,VOLDPR,OFR,OFRCFS,SRKE
  389 TM=TM+60.0*DT
  390 CALL INTCPT(CLAI,DELTP(IC),DPINT,TPINT,DDP,INCI,DT,DRI)
  399 CONTINUE
```

```
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                  *
C*                END MAJOR CALCULATING LOOP NO. 4                  *
C*                                                                  *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      GOTO498
  400 CONTINUE
      CALL INFILT(ASOIL,PSOIL,TOTSTR,FCINFL,SMASM,DT,DDP,IC,
     1DELTF,VOLDPR,DRI,TESTIN,SDELTF,DINT,PEAI,SRKE,CE1,CE2)
      CALL OFROUT(PEAI,VOLDPR,EQD,OFR,TOFR,AREA,DT,OFRCFS,TRST,TRSTM,
     *            OFMN1,OFMN2,SSRT,PUDLE1,PUDLE2)
      TRST=TRST+OFR
      IRED=1
      CALL REDIST(IRED,DELTF,PERCO,SPERCO,JJ,TFRC,ADTF,VOLDPR,DT,COND,
     1ZINF,ZOUTF,TOTSTR,SMASM,SAT,JTILE,JIM,AEWP,SMTC)
  498 CONTINUE
      CALL REDIST(IRED,DELTF,PERCO,SPERCO,JJ,TFRC,ADTF,VOLDPR,DT,COND,
     1ZINF,ZOUTF,TOTSTR,SMASM,SAT,JTILE,JIM,AEWP,SMTC)
  499 CONTINUE
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                  *
C*                END MAJOR CALCULATING LOOP NO. 3                  *
C*                                                                  *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      GOTO598
  500 CONTINUE
      CALL INFILT(ASOIL,PSOIL,TOTSTR,FCINFL,SMASM,DT,DDP,IC,
     1DELTF,VOLDPR,DRI,TESTIN,SDELTF,DINT,PEAI,SRKE,CE1,CE2)
      CALL OFROUT(PEAI,VOLDPR,EQD,OFR,TOFR,AREA,DT,OFRCFS,TRST,TRSTM,
     *            OFMN1,OFMN2,SSRT,PUDLE1,PUDLE2)
      TRST=TRST+OFR
      IRED=1
      CALL REDIST(IRED,DELTF,PERCO,SPERCO,JJ,TFRC,ADTF,VOLDPR,DT,COND,
```

```
     1ZINF,ZOUTF,TOTSTR,SMASM,SAT,JTILE,JIM,AEWP,SMTC)
  598 DT=4.
      CALL ET(JJ,TPINT,PCATRN,NRTDS,ATRANS,EVAPTR,PET(IT1),AAET,APET,
     1AAEVAP,AAINT,CLAI,NPC,NC,DT,SUMTRN,AINT,AET,VOLDPR,
     2JIM,SAT,SMTC,KSMA,GINT2,AEVAP)
      ADET=ADET+AET
      ADINT=ADINT+AINT
      DO550LL=1,JIM1
      ZTRAN(LL)=ZTRAN(LL)+ATRANS(LL)
  550 CONTINUE
      SMASM=SMASM+EVAPTR
      IRED=2
      CALL REDIST(IRED,DELTF,PERCO,SPERCO,JJ,TFRC,ADTF,VOLDPR,DT,CCND,
     1ZINF,ZOUTF,TOTSTR,SMASM,SAT,JTILE,JIM,AEWP,SMTC)
  599 CONTINUE
      IF(KSTR.EQ.0)GO TO 600
C
C*  IF STRESS INDEX DETERMINATION IS INCLUDED,(KSTR=1),CALCULATE
C*  DAILY RAW STRESS INDEX.IF NOT SKIP THIS CALCULATIONS.
C
      IF(PE.LE.0.0)GO TO 571
  572 RAWSTR(JJ)=1-(ADET/PE)
      GO TO 600
  571 RAWSTR(JJ)=0.0
  600 CONTINUE
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*               END MAJOR CALCULATING LOOP NO. 2                 *
C*               THIS ENDS CALCULATIONS FOR THIS DAY              *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      DDELTF=SDELTF-DDELTF
      DPERCO=SPERCO-DPERCO
```

```
      DAQEX=TOFR-DAQEX
      AATRAN=AATRAN+SUMTRN
      DAEVAP=AAEVAP-DAEVAP
      ASTF = ASTF + ADTF
      DO 618 JI=1,JIM
  618 ESOILM(JJ,JI)=DSOILM(JI)
C
C*  IF DETAILED OUTPUT IS NOT REQUESTED AND NO RAINFALL HAS OCCURRED
C*  FOR THIS DAY,SKIP WRITTING DETAILED INFORMATION FOR THE DAY.
C
      IF(NOUT.NE.1.AND.JJ.NE.JJR1)GOTO699
      WRITE(6,619)SURAIN
  619 FORMAT(10X,'SEASONAL RAIN FALL= ',F7.2)
      IF(KIRR.EQ.0)GO TO 645
      WRITE(6,646)STIWA,SFIA
  646 FORMAT(10X,' SEASONAL IRRIGATION WATER APPLIED= ',F7.2/10X
     1,'  FREQUENCY OF IRRIGATION APPLICATION= ',I7,   ' TIMES')
  645 CONTINUE
      WRITE(6,601)PE,APET
      WRITE(6,608)ADET,AAET
      WRITE(6,610)DPERCO,SPERCO
      WRITE(6,611)CFMN,JJ,DAQEX,TOFR
      WRITE(6,609)DDELTF,SDELTF
      IF(NOUT.NE.1)GO TO 699
C
C*  OUTPUT DETAILS OF DAILY MOISTURE BALANCE CALCULATIONS.
  612 FORMAT(11X     ,'CROP LEAF AREA INDEX (CLAI) = ',G11.3/
     111X,'PERCENT ACTIVE CANOPY (PCATRN) = ',G12.4/11X,'ROOT SYSTEM DIS
     2TRIBUTION'/ 6X,7(2X,F7.1)/ 6X,7(2X,F7.1))
  601 FORMAT(1H0,10X,'TOTAL POTENTIAL EVAPORATION TODAY (PE) =',G13.5,
     1' INCHES'/12X,'ACCUMULATED (APET) = ',G13.5,' INCHES')
      WRITE(6,602)ADINT,AAINT
  602 FORMAT(11X     ,'INTERCEPTION EVAPORATION TODAY (ADINT) = ',G13.5,
     1' INCHES.'/12X,'ACCUMULATED (AAINT) = ',G13.5,' INCHES')
      WRITE(6,603)DAEVAP,AAEVAP
```

```
 603 FORMAT(11X    ,'ACTUAL SOIL EVAPORATION TODAY (DAEVAP) =',G12.4,
     A' INCHES.'/10X,'ACCUMULATED SEASONAL SOIL EVAP.(AAEVAP)=',G12.4,
     B' IN.')
      WRITE(6,607)SUMTRN,AATRAN
 607 FORMAT(11X    ,'TOTAL TRANSPIRATION TODAY (SUMTRN) = ',G13.5,
     1' INCHES'/12X,'ACCUMULATED (AATRAN) = ',G13.5,' INCHES')
 608 FORMAT(11X    ,'TOTAL EVAPOTRANSPIRATION TODAY (ADET) = ',G13.5,
     1' INCHES'/12X,'ACCUMULATED (AAET) = ', G13.5,' INCHES')
 609 FORMAT(1H ,10X,'INFILTRATION TODAY (DDELTF) = ',G13.5,' INCHES'/
     1 12X,'ACCUMULATED (SDELTF) = ',G13.5,' INCHES')
      WRITE(6,613)TPINT
 613 FORMAT(11X,'DEPTH OF WATER ON PLANT SURFACES '/12X,'AT THE END OF
     1THE DAY = ',G13.5,' INCHES')
      WRITE(6,614)VOLOPR
 614 FORMAT(11X,'DEPTH OF WATER IN SURFACE DEPRESSIONS AT '/12X,'THE EN
     1D OF THE DAY = ',G13.5,' INCHES')
 610 FORMAT(11X    ,'DEEP PERCOLATION TODAY (DPERCO) = ',F8.4 ,' INCHES
     1'/12X,'ACCUMULATED FOR THE SEASON (SPERCO) = ',F8.4 ,' INCHES')
 611 FORMAT(4X,F6.3,1X,'RUNOFF FOR DAY ',I3,' =',F6.3 ,' IN.',
     1' SEASON TOTAL =',F6.3 ,' IN.')
      IF(JTILE.NE.0)WRITE(6,615)ADTF,ASTF
 615 FORMAT(5X,'TILE FLOW TODAY =',F8.4,
     $' INCHES.  SEASONAL TOTAL =',F8.4,' INCHES.')
      WRITE(6,604)
 604 FORMAT(1H0,9X,'SOIL MOISTURE   DAILY INFLOW   DAILY OUTFLOW   DAIL
     1Y'/10X,'IN EACH ROOT     TO EACH ZONE   FROM EACH',6X,'TRANSPIRATIO
     2N'/10X,'ZONE AT THE END',16X,'ZONE',11X,'FROM EACH'/10X,'OF THE DA
     3Y',36X,'SOIL ZONE'/15X,'(INCHES)    (INCHES)', 7X ,'(INCHES)
     4(INCHES)')
      WRITE(6,605)(JI,ESOILM(JJ,JI),ZINF(JI),ZOUTF(JI),ZTRAN(JI),
     1JI=1,JIM1)
 605 FORMAT(10X,I2,3X,F8.3,3X,F9.5,6X,F9.5,6X,F9.5)
 699 CONTINUE
C
C*  SET DEPTH OF ACTIVE ROOT ZONE AS A FUNCTION OF THE JULIAN DAY
```

```
C*  OF THE YEAR ,ACCORDING TC ROOT DISTRIBUTION WITH TIME GIVEN
C*  BY SHAW,1963.
C
      IM=10
      IF(JJ.LE.213)IM=9
      IF(JJ.LE.206)IM=8
      IF(JJ.LE.199)IM=7
      IF(JJ.LE.192)IM=6
      IF(JJ.LE.185)IM=5
      IF(JJ.LE.178)IM=4
      IF(JJ.LE.165)IM=2
      DARZ(JJ)=IM*0.5
C
C*  DETERMINE TOTAL SOIL MOISTURE AT FIELD CAPACITY,WILTING POINT
C*  AND SATURATICN OVER THE ACTIVE ROOT ZONE.
C
      ARMAFC(JJ)=0.0
      ARMAWP(JJ)=0.0
      ARMSAT(JJ)=0.0
      DO 131 JI=1,IM
      ARMAFC(JJ)=THICK(JI)*0.01*FC(JI)+ARMAFC(JJ)
      ARMAWP(JJ)=THICK(JI)*0.01*WP(JI)+ARMAWP(JJ)
      ARMSAT(JJ)=0.9*ESAT(JI)+ARMSAT(JJ)
  131 CONTINUE
C
C*  CALCULATE ACTIVE ROOT ZONE MOISTURE AT IRRIGATICN.
C
      ARMAI(JJ)=ARMAFC(JJ)-PAMRI*(ARMAFC(JJ)-ARMAWP(JJ))
C
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*                                                                         *
C*          OUTPUT SOIL MOISTURE SUMMARIES FOR THE DAY                     *
C*                                                                         *
C*  ***    ***    ***    ***    ***    ***    ***    ***    ***    ***    ***
C*  SUM DAILY SOIL MOISTURE OVER THE ENTIRE ROOT ZCNE.
```

```
      RZSM(JJ)=0.0
      DO 700 JI=1,JX
  700 RZSM(JJ)=RZSM(JJ)+ESOILM(JJ,JI)
      SUM9=RZSM(JJ)
C
C*  SUM DAILY SOIL MOISTURE OVER THE ACTIVE ROOT ZONE.
C
      ARM(JJ)=0.0
      DO 703 JI=1,IM
  703 ARM(JJ)=ARM(JJ)+ESOILM(JJ,JI)
      IF(JX.GE.JIM1)GOTO702
      JX1=JX+1
      DO 701 JI=JX1,JIM1
  701 SUM9=SUM9+ESOILM(JJ,JI)
  702 IF(JIM1.LT.10)GOTO710
      DO650LL=1,5
      LX=2*LL
      SUMLAY(LL)=ESOILM(JJ,LX)+ESOILM(JJ,LX-1)
  650 CONTINUE
  710 WRITE(6,620)JJ,MONTH(KMOT),DAYT,YEAR,RZSM(JJ),SUM9,ESOILM(JJ,JIM)
  620 FORMAT(1H0,2X,I3,2X,A8,I3,',',I4,2X,
     $'ROOTZONE MOISTURE =',F6.2,' IN., TOTAL =',F6.2/
     #3X,'SUBSOIL   MOISTURE  =  ',F6.2)
      IF(JIM1.LT.10)GOTO720
      WRITE(6,616)SUMLAY
  616 FORMAT(11X,'TOP 5-FT INCREMENTS',5F7.2)
  720 IF(RZSM(JJ).LT.RSMAI)WRITE(6,630)
  630 FORMAT(5X,'DROUGHT STRESS INDICATED')
      IF(ARM(JJ).GE.ARMAI(JJ))GO TO 634
      WRITE(6,617)DARZ(JJ),ARM(JJ),ARMAFC(JJ),ARMAWP(JJ),ARMAI(JJ)
     #,ARMSAT(JJ)
  617 FORMAT(5X,'DEPTH OF ACTIVE ROOT ZONE= ',F4.2,'FT '/5X
     #,'ACTIVE ROOT ZONE MOISTURE= ',F6.2/5X,'ARMAFC=',F6.2,'   ARMAWP='
     #,F6.2/5X,'ARMAI=',F6.2,'   ARMSAT= ',F6.2)
```

```
      WRITE(6,637)
  637 FORMAT(5X,'DROUGHT STRESS INDICATED IN THE ACTIVE ROOT ZONE')
  634 CONTINUE
      IF(RZSM(JJ).GT.RSMSAT)WRITE(6,631)
  631 FORMAT(5X,'FLOOD STRESS INDICATED')
      IF(ARM(JJ).GT.ARMSAT(JJ))WRITE(6,638)
  638 FORMAT(5X,'  FLOOD STRESS INDICATED IN THE ACTIVE ROOT ZONE')
      IF(KSTR.EQ.0) GO TO 636
      WRITE(6,635)RAWSTR(JJ)
  635 FORMAT(8X,'RAW STRESS INDEX=',F5.3/)
  636 CONTINUE
      IF(DIA.LE.0.0) GO TO 628
      WRITE(6,627)DIA
  627 FORMAT(10X,'DEPTH OF IRRIGATION WATER APPLIED TODAY=',F5.2)
  628 CONTINUE
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                          *
C*  IF IRRIGATION APPLICATION OCCURRED TODAY OUTPUT
C*  RESULTS.                                                *
C*                                                          *
C*   ***   ***   ***   ***   ***   ***   ***   ***   ***   **
C
      IF(KIRR.EQ.0)GO TO 900
C
C*  IF IRRIGATION IS INCLUDED,CALCULATE THE IRRIGATION APPLICATION
C*  EFFICIENCY BASED ON BOTH ACTIVE AND THE ENTIRE ROOT ZONE.
C
      IF(JJ.GT.JDEIR)GO TO 900
      IF(IBIR.EQ.0)GOTO750
      IF(IEIR.EQ.2)GOTO800
      WSRZ=RZSM(JJ)-SMBI+SUMTRN
      AEIRR=WSRZ/GDIA *100.0
      IF(DARZ(JJ).NE.DARZ(JJ-1)) GO TO 639
      WSARZ=ARM(JJ)-ARZMBI+SUMTRN
```

```
      GL TC 642
  639 WSARZ=ARM(JJ)-ESOILM(JJ,IM)-ARZMBI+SUMTRN
  642 AEARZ=WSARZ/GCIA*100.0
      STIWS=STIWS+WSRZ
      STIWA=STIWA+GDIA
      SIAE=STIWS/STIWA*100.0
      SWSARZ=SWSARZ+WSARZ
      SEARZ=SWSARZ/STIWA*100.0
      SFIA=SFIA+1
      WRITE(6,632)GDIA ,AEIRR,STIWA,SIAE,AEARZ,SEARZ
  632 FORMAT(5X,'A',F5.2,' IN. IRRIGATICN WAS APPLIED AT '/9X,
     $'AN APPLICATICN EFFICIENCY OF',F7.2,' PERCENT.'/7X,
     $'TOTAL SEASON IRRIGATION APPLICATION =',F7.2,'INCHES AT',
     $F7.2,' PERCENT EFFICIENCY'/7X,
     3   ' EFFICENCY OF THE ACTIVE ROOT ZONE= ',F6.2,' PERCENT.'/7X,
     4'SEASCNAL EFFICIENCY OF THE ACTIVE ROOT ZONE= ',F6.2,'PERCENT.'/)
      WRITE(6,501)WSRZ,WSARZ,SMBI,ARZMBI,SUMTRN
  501 FORMAT(10X,' WSRZ= ',F6.3,' WSARZ=',F6.3,' SMBI= ',F6.3,' ARZMBI
     1= ',F6.3,' SUMTRN= ',F6.2/)
      IF(RZSM(JJ).LT.RSMAI)WRITE(6,502)
  502 FORMAT(10X,'IRRIGATION APPLICATICN IS NOT SUFFICIENT ')
  750 SMBI=RZSM(JJ)
      ARZMBI=ARM(JJ)
      GOTO900
  800 SMBI=SMBI-SUMTRN
      ARZM3I=ARZMBI-SUMTRN
  900 WRITE(6,606)
  606 FORMAT(10X,'******************************************************
     1********')
C
C* CALCULATION OF MONTHLY SUMMARY OUTPUT.
C
      DC 910 I=2,13
      IF(JJ.GT.KDA(I))GOTO910
      MFT=I-1
```

```
      MD=JJ-KDA(MFT)
      GO TO 915
  910 CONTINUE
  915 IF(MFT.NE.MO)GOTO920
      DRF(MD)=RAIN
      RO(MD)=DAQEX
      SOILM(MD)=RZSM(JJ)
      PANEVA(MD)=PAN(JJ)
      DAET(MD)=ADET
      DPERC(MD)=DPERCO
      DTF(MD)=ADTF
      DIWA(MD)=DIA
      BAL(MD)=PBAL+RAIN+DIA-SUM9-ADET-DPERCO-DAQEX-TPINT-VOLDPR-ADTF
      IF(JJ.NE.JSTOP)GOTO1000
  920 CONTINUE
      IF(KEVAP.EQ.0) GO TO 916
      WRITE(6,625)MCNTH(MO),YEAR
      GO TO 921
  916 WRITE(6,621)MCNTH(MO),YEAR
  921 CONTINUE
      DO 930 JM=1,31
       IF ( SOILM(JM) .EQ. 0.0 ) GO TO 930
      IF(KEVAP.EQ.0) GO TO 917
      WRITE(6,624)JM,PANEVA(JM),DRF(JM),RO(JM),DAET(JM),DPERC(JM),
     1DTF(JM),DIWA(JM),BAL(JM),SOILM(JM)
      GO TO 922
  917 WRITE(6,622)JM,DRF(JM),RO(JM),DAET(JM),DPERC(JM),DTF(JM),
     $DIWA(JM),BAL(JM),SOILM(JM)
  922 CONTINUE
      DTF(JM)=0.0
      DIWA(JM)=0.0
      BAL(JM)=0.0
      DRF(JM)=0.0
      RO(JM)=0.0
      SOILM(JM)=0.0
```

```
      PANEVA(JM)=0.0
      DAET(JM)=0.0
  930 DPERC(JM)=0.0
      MO=MFT
      IF(JJ.EQ.JSTOP)GOTO1000
      GOTO915
  621 FORMAT(1H-,10X,'MONTHLY SUMMARY FOR ',A8,',',I4//
     $1X,'DAY RAINFALL RUNOFF  AET  DPERC TILEFLO IRRIG BALANCE',
     $' SOIL MOISTURE'/)
  625 FORMAT(1H-,10X,'MONTHLY SUMMARY FOR ',A8,',',I4//
     $1X,'DAY PANEVAP RAINFALL RUNOFF  AET  DPERC TILEFLO IRRIG BALANCE'
     $,' SOILMOISTURE'/)
  622 FORMAT(1X,I3,6F7.2,F8.3,F7.2)
  624 FORMAT(1X,I3,7F7.2,F8.3,F7.2)
C
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C*                                                                *
C*                END MAJOR CALCULATING LOOP NO. 1                *
C*                                                                *
C*  ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
 1000 CONTINUE
      BALN=BALN+SURAIN-SUM9-AAET-SPERCO-TOFR-TPINT-VOLDPR+STIWA-ASTF
      WRITE(6,633)BALN
  633 FORMAT(10X,' BALANCE = ',F10.6//)
C
C*  CALCULATION OF OVERALL SEASONAL WATER USE EFFICIENCY.
C
      TISM=0.0
      TESM=0.0
      JB=JSTART-1
      JF=JSTOP
      DO 940 JI=1,JIM1
      TISM=TISM+ESOILM(JB,JI)
      TESM=TESM+ESOILM(JF,JI)
```

```
  940 CONTINUE
      SWLS=TCFR+SPERCO+ASTF
      SWSU=SURAIN+STIWA+TISM-TESM
      TWLWSR=SWLS/SWSU*100.0
      TWUEFF=100.0-TWLWSR
      WRITE(6,945)TWLWSR,TWUEFF
  945 FCRMAT(11X,'SEASCNAL WATER LCSS=',F6.3,' PERCENT'/10X
     1,' SEASCNAL OVERALL WATER USE EFFICIENCY=',F6.3,' PERCENT')
      IF(KSTR.EQ.0)GO TO 1060
      CALL STRINX(JUDS,RAWSTR,WTFC,SUM,WSTR,TWSTR,JUPSS)
      WRITE(6,1053)JMS,JDS,YEAR
 1053 FORMAT('1','SILKING CATE=',I3,'/',I3,'/',I4//)
      WRITE(6,1052)(KJ,SUM(KJ),WTFC(KJ),WSTR(KJ),KJ=1,17)
 1052 FORMAT(     20X,'WEIGHTED STRESS INDEX'//10X,'PERIOD     5-DAY STR.
     1    STR.FAC.     WT.STR.IN'//(13X,I2,6X,F5.3,7X,F6.3,5X,F8.3))
      WRITE(6,1055)TWSTR
 1055 FORMAT(10X,'85-DAY WEIGHTED STRESS INDEX=',F10.4)
 1060 CONTINUE
      IF(KSOIL.EQ.0)GOTO100
C
C*   IF SOIL MOISTURE SUMMARY IS REQUESTED,(KSOIL=1),PRINT OUT
C*   THE SOIL MCISTURE OF EACH LAYER FOR ALL CAYS.IF NOT,(KSOIL=0)
C*   SKIP.
C
      WRITE(6,640)
  640 FORMAT(1H1,30X,'SOIL MOISTURE OUTPUT DETAILS'//30X,'LAYER NUMBER'/
     13X,'JJ      1       2       3       4       5       6       7       8       9      10
     2      11      12      13      14      RZSM(JJ)')
      DO1100JJ=JSTART,JSTOP
      WRITE(6,641)JJ,(ESOILM(JJ,JI),JI=1,JIM1),RZSM(JJ)
  641 FORMAT(2X,I3,2X,15F6.2)
 1100 CONTINUE
      GOTO100
 2000 STOP
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      BLOCK DATA
      COMMON/ABLOCK/DSOILM(15),WP(15),RESAT(15),ESAT(15),RSAT(15),
     1SMET(16),PAD(6),ETRATE(16,6),FC(15),SHC(15),THICK(15),TMAC(15),
     2PLAV(15)
       REAL*8  DSOILM
      DATA SMET/0.0,0.05,0.1,.15,.2,.25,.3,.35,.4,.45,.5,.6,.7,.8,.85,
     A1.0/
      DATA PAD/0.0,0.05,0.15,0.35,0.55,1.1/
      DATA ETRATE/32*1.,.36,.49,.62,.78,.89,.93,.96,.97,.98,.985,.99,
     A.995,4*1.,.14,.18,.23,.30,.39,.52,.65,.76,.84,.91,.94,.98,.985,
     B.995,2*1.,.05,.09,.13,.18,.24,.32,.4,.49,.58,.66,.73,.85,.95,.98,
     C.995,1.,16*0.0/
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE ET (J,TPINT,PCATRN,NRTDS,ATRANS,EVAPTR,PET,AAET,
     1                APET,AAEVAP,AAINT,CLAI,NPC,NC,DT,SUMTRN,AINT,
     2                AET,VOLDPR,JIM,SAT,SMTC,KSMA,GINT2,AEVAP)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                              *
C*     THIS SUBROUTINE USES POTENTIAL EVAPORATION VALUES,       *
C*  ATMOSPHERIC CONDITIONS,PLANT CONDITIONSAND SOIL MOISTURE    *
C*  CONDITIONS TO CALCULATE ACTUAL SOIL EVAPORATION,INTERCEPTION *
C*  EVAPORATION AND TRANSPIRATION FROM EACH SOIL ZONE USING     *
C*  SAXTON'S METHOD.                                            *
C*                                                              *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C
      COMMON/ABLOCK/DSOILM(15),WP(15),RESAT(15),ESAT(15),RSAT(15),
     1SMET(16),PAD(6),ETRATE(16,6),FC(15),SHC(15),THICK(15),PLAV(15),
     2TMAC(15)
      REAL*8 DSOILM
      DIMENSION SAT(15),SMTC(15)
      REAL NRTDS
      DIMENSION NRTDS(14),ATRANS(14)
      JIM1=JIM-1
C
C*  FIRST SUBTRACT EVAPORATION NEEDED TO DRY OFF PLANT SURFACES.
C
      IF(PET.GT.TPINT)GOTO1
      PETC=0.0
      TPINT=TPINT-PET
      GOTO2
    1 PETC=PET-TPINT
      TPINT=0.0
C
C*     NEXT DIVIDE ANY REMAINING ENERGY BETWEEN THE SOIL SURFACE
C*  AND THE PLAT CANOPY BASED ON  CROP LEAF AREA INDEX(CLAI).
C*     THE DIVISION IS BASED ON A FUNCTION BY J.RITCHIE,WHERE THE
```

```
C*  EXPONENT ADJUSTED SLIGHTLY FROM RITCHIE'S EQUATION.
C
    2 CONTINUE
      IF(CLAI.GT.3.0)GOTO10
      CLAIX=CLAI
      GOTO11
   10 CLAIX=3.0
   11 PEVAP=PETC*EXP(-0.4*CLAIX)
      TRANSP=PETC-PEVAP
C
C*     SUBTRACT ENERGY TO EVAPORATE STANDING WATER ON THE SOIL SURFACE
C*  FROM THE ENERGY REACHING THE GROUND.
C
      IF(PEVAP.GT.VOLDPR)GOTO22
      EVAPDP=PEVAP
      VOLDPR=VOLDPR-PEVAP
      PEVAP=0.0
      GOTO23
   22 EVAPDP=VOLDPR
      PEVAP=PEVAP-EVAPDP
      VOLDPR=0.0
   23 CONTINUE
C
C*     CALCULATE SOIL EVAPORATION FROM THE TOP SOIL LAYER.THIS IS A
C*  FUNCTION OF AVAILABLE ENERGY AND AVAILABLE SOIL MOISTURE.
C
      CSMP=DSOILM(1)*100.0/THICK(1)
      SR=CSMP/SAT(1)
      CON=SHC(1)*SR**(1.5*SMTC(1)+3.0)
      IF(SR.GT.0.9)CON=SHC(1)
      CON=CON*0.3937*DT
      IF(CON.GT.PEVAP)GOTO24
      AEVAP=CON
      GOTO25
   24 AEVAP=PEVAP
```

```
   25 IF(AEVAP.GT.DSOILM(1))AEVAP=DSOILM(1)
      UPEVAP=PEVAP-AEVAP
      IF(CLAI.LE.0.0)GOTO3
      IF(CLAI.GT.3.)GOTO4
      PCT=CLAI*33.33
      GOTO5
    3 PCT=0.0
      GOTO5
    4 PCT=100.0
C
C*     ALLOW UPWARD RADIATION OF PART OF ANY EXCESS ENERGY ON THE
C*  SOIL TO REACH THE CROP CANOPY.
C
    5 UPEVAP=UPEVAP*PCT*0.01
      PTRANS=TRANSP+UPEVAP
C
C*     TOTAL POTENTIAL TRANSPIRATION (PPTRAN) = A FUNCTION OF THE
C*  AVAILABLE ENERGY TO THE CANOPY AND THE PERCENT OF CANOPY
C*  ACTIVELY TRANSPIRING (PCATRN) FROM SUBROUTINE PLANT.
C
      PPTRAN=PCATRN*PTRANS
      PAD1=PET*24./DT
      AINT=PET-PETC+EVAPDP
      AET=AEVAP+AINT
C
C*     FOR EACH SOIL LAYER DETERMINE THE POTENTIAL TRANSPIRATION
C*  RATE BASED ON PRESENTED SOIL MOISTURE USING FUNCTIONS AFTER
C*  SHAW'S WORK.
C
      DO6JJ=I,JIM1
      AVSM=(DSOILM(JJ)*100.0/THICK(JJ)-WP(JJ))/(FC(JJ)-WP(JJ))
      IF(AVSM.GT.1.0)AVSM=1.0
      IF(AVSM.LE.0.)AVSM=0.0001
      IF(KSMA.EQ.1)GOTO50
      RETRAT=GINT2(SMET,ETRATE,PAD,PAD1,AVSM,NPC,NC)
```

```
      GOTO55
   50 RETRAT=2.0*AVSM
      IF(RETRAT.GT.1.0)RETRAT=1.0
   55 ATRANS(JJ)=RETRAT*PPTRAN*NRTDS(JJ)*0.01
      IF(ATRANS(JJ).GT.DSOILM(JJ))ATRANS(JJ)=0.5*DSOILM(JJ)
      AET=AET+ATRANS(JJ)
    6 SUMTRN=SUMTRN+ATRANS(JJ)
C
C*     CALCULATE ACCUMULATED VALUES OF EACH TYPE OF ET FOR OUTPUT.
C
      AAET=AAET+AET
      APET=APET+PET
      AAEVAP=AAEVAP+AEVAP +EVAPDP
      AAINT=AAINT+AINT
      EVAPTR=ATRANS(1)+ATRANS(2)+ATRANS(3)+ATRANS(4)+AEVAP
C
C*      CALCULATE NEW SOIL MOISTURE CONTENT FOR EACH SOIL LAYER.
C
      DO7JJ=1,JIM1
    7 DSOILM(JJ)=DSOILM(JJ)-ATRANS(JJ)
      DSOILM(1)=DSOILM(1)-AEVAP
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      FUNCTION GINT(X,Y,N,Z,NS)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***  **
C*
C*     THIS FUNCTION DOES STRAIGHT-LINE INTERPOLATION IN A TABLE    *
C*  OF VALUES OF THE X-Y COORDINATES OF KEY POINTS OF A SINGLE CURVE.
C*  N IS THE NUMBER OF POINTS USED TO DESCRIBE THE CURVE,AND Z IS   *
C*  THE CORRESPONDING VALUE OF Y=GINT.                              *
C*  NS IS THE STATEMENT NUMBER BEING EXECUTED IN CALLING PROGRAM.   *
C*                                                                  *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***
C
      DIMENSION X(N),Y(N)
      DO100I=1,N
      IF(Z.LT.X(1))GOTO160
      IF(Z.GT.X(I))GOTO101
      IF(Z.EQ.X(I))GOTO102
      DX=X(I)-X(I-1)
      DY=Y(I)-Y(I-1)
      IF(DY.EQ.0.0)GOTO102
      GINT=Y(I)-DY/DX*(X(I)-Z)
      GO TO 200
  102 GINT=Y(I)
      GOTO200
  101 IF(I.GE.N)GOTO150
  100 CONTINUE
  150 WRITE(6,10)Z,X(N),NS
   10 FORMAT(3X,'INPUT Z = ',G14.6,' MAXIMUM X = ',G14.6,' IN FUNCTION G
     1INT USING STATEMENT ',I5)
      GOTO190
  160 WRITE(6,20)Z,X(1),NS
   20 FORMAT(3X,'INPUT Z = ',G14.6,',MINIMUM X = ',G14.6,' IN FUNCTION G
     1INT USING STATEMENT ',I5)
  190 STOP
  200 RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      FUNCTION GINT2 (X,Y,Z,U,V,M,N)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                                *
C*      THIS FUNCTION DOES A TWO-WAY STRAIGHT LINE INTERPOLATION  *
C*   ON A FAMILY OF CURVES WHERE Y = A FUNCTION OF X AND Z SUCH   *
C*   THAT Z DESIGNATING A PARTICULAR CURVE FOR WHICH X-Y          *
C*   COORDINATES ARE GIVEN.
C*      U=VALUE OF Z GIVEN FOR THE INTERPOLATION.
C*      V=VALUE OF X GIVEN FOR INTERPOLATION.
C*   WANT TO DETERMINE THE VALUE OF Y CORRESPONDING TO Z=U AND X=V *
C*      N=NUMBER OF CURVES IN THE FAMILY.                         *
C*      M=NUMBER OF POINTS PER CURVE.                             *
C*   SHOULD INCLUDE ONE CURVE FOR Z=0.0 AND ONE FOR Z LARGE ENOUGH *
C*   TO COVER ALL POSSIBLE REASONABLE VALUES OF Z.                *
C*
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
      DIMENSION X(M),Y(M,N),Z(N)
      DO100I=1,N
      IF(U.GT.Z(I))GOTO100
      DO90J=1,M
      IF(V.GT.X(J))GOTO90
      DX=X(J)-X(J-1)
      DY=Y(J,I)-Y(J-1,I)
      YT=Y(J,I)-DY/DX*(X(J)-V)
      DY=Y(J,I-1)-Y(J-1,I-1)
      YB=Y(J,I-1)-DY/DX*(X(J)-V)
      DZ=Z(I)-Z(I-1)
      DY=YT-YB
      GINT2=YT-DY/DZ*(Z(I)-U)
      GOTO200
   90 CONTINUE
  100 CONTINUE
  200 CONTINUE
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE INFILT (AS,PSOIL,TOTSTR,FCINFL,SMASM,DT,DDP,IC,
     1                   DELTF,VOLDPR,DRI,TESTIN,SDELTF,DINT,PEAI,
     2                   SRKE,CE1,CE2)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                               *
C*     THIS SUBROUTINE TAKES RAINFALL THAT REACHES THE GROUND    *
C*  DURING A PERIOD AND ADDS THE STEMFLOW AND DEPRESSION STORAGE *
C*  AND CALCULATES THE RESULTING INFILTRATION DURING THE PERIOD  *
C*  USING HOLTAN'S METHOD AS MODIFIED BY HUGGINS AND MONKE.WITH  *
C*  A CALCULATING PROCEDURE BASED ON THE METHOD DESCRIBED BY     *
C*  HOLTAN,ENGLAND,AND STANHOLTZ IN TRANS.ASAE,1967.WHICH USES   *
C*  BAILEY'S ITERATIVE PROCEDURE AS DESCRIBED IN DEBOER,1969.    *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C
C*     FIRST DETERMINE THE AVAILABLE WATER FOR INFILTRATION AS THE
C*  DIRECT PRECIPITATION,PLANT SURFACE DRAINAGE AND VOLUME OF WATER
C*  STORED IN SURFACE DEPRESSIONS.
C
      DELTP=DDP+DRI
      DINT=DDP/DT
      IF(DINT.LE.0.0)GOTO5
      RKE=DDP*(0.06133+0.02216*ALOG10(DINT))
C
C*  RKE = RAINFALL KINETIC ENERGY DURING THE PERIOD IN JOULES/CM2
C
      IF(RKE.LT.0.0)RKE=0.0
      IF(VOLDPR.GT.0.5)RKE=0.0
      SRKE=SRKE+RKE
C
C*  SRKE = SEASONAL SUM OF RAINFALL KINETIC ENERGY ON THE FIELD.
C
    5 IF(SRKE.LE.0.0)GOTO7
      REF=CE1*SRKE**(-CE2)
C
```

```
C*   REF = RAINFALL ENERGY FACTOR AFFECTING INFILTRATION.
C
      IF(REF.GT.1.0)REF=1.0
      GOTO10
    7 REF=1.0
   10 ASOIL=AS*REF
      F1=TOTSTR-SMASM
      IF(F1.GT.TOTSTR)GOTO30
      F2=F1
      IF(DELTP)15,15,20
   15 IF(VOLDPR)65,65,20
   20 N=0
C
C*      NEXT DETERMINE THE POTENTIAL INFILTRATION DURING THIS PERIOD,
C*   (F2),CONSIDERING THE PREVIOUS MOISTURE CONTENT IN THE TOP TWO
C*   FEET OF SOIL AND THE SOIL PARAMETERS.THIS IS THE MODIFIED HOLTAN
C*   EQUATION AND THE SOLUTION IS AN ITERATIVE PROCEDURE.
C
      F1FCTN=F1/DT+FCINFL+ASOIL/2.*((TOTSTR-F1)/TOTSTR)**PSOIL
      AP2T=ASOIL/2.*PSOIL/TOTSTR
      APT=ASOIL*PSOIL*(PSOIL-1.)/(2.*TOTSTR*TOTSTR)
   25 IF(TOTSTR-F2)30,30,35
   30 F2=F1+FCINFL*DT
      GOTO65
   35 SR=(TOTSTR-F2)/TOTSTR
C
C*      STATEMENT NO.40 IN THIS SUBROUTINE IS THE BASIC EQUATION TO BE
C*   SOLVED FOR THE INFILTRATION RATE.THE OBJECT OF THE ITERATION IS
C*   TO GET THE VARIABLE F2FCTN REASONABLE CLOSE TO 0.0.
C
   40 F2FCTN=F2/DT-ASOIL/2.*SR**PSOIL-FIFCTN
      IF(ABS(F2FCTN)-TESTIN)65,65,45
   45 FPFCTN=1./DT+AP2T*SR**(PSOIL-1.)
      FSFCTN=-APT*SR**(PSOIL-2.)
      F2=F2-F2FCTN/(FPFCTN-F2FCTN*FSFCTN/2./FPFCTN)
```

```
      N=N+1
      IF(N-7)60,60,50
   50 WRITE(6,55)IC
   55 FORMAT(1H0,'ITERATION LIMIT EXCEEDED DURING ',I3,'TH PERIOD')
      GOTO65
   60 GOTO25
C
C*      NEXT DETERMINE THE ACTUAL INFILTRATION DURING THE PERIOD BY
C*   COMPARING THE ACTUAL AVAILABLE SUPPLY WITH THE POTENTIAL
C*   INFILTRATION CALCULATED ABOVE. SUBTRACT THIS FROM THE SUPPLY,ADD
C*   THE EXCESS TO THE VOLUME STORED IN DEPRESSIONS,AND CHECK THIS
C*   AGAINST THE MAXIMUM AVAILABLE DEPRESSION STORAGE (DPSTOR). ANY
C*   EXCESS OVER DPSTOR IS THE RUNOFF (DELTQ) WITH THE REMAINDER IN
C*   DEPRESSION STORAGE (VOLDPR).
C
   65 F3=F2-F1
      F4=DELTP+VOLDPR
      IF(F3-F4)70,75,80
   70 DELTF=F3
      DELTPE=DELTP-DELTF
      GOTO85
   75 DELTF=F3
      DELTPE=-VOLDPR
      GOTO85
   80 DELTF=DELTP+VOLDPR
      DELTPE=DELTP-DELTF
   85 PEAI=VOLDPR+DELTPE
      SMASM=SMASM-DELTF
      SDELTF=SDELTF+DELTF
      DRI=0.0
      DDP=0.0
      RETURN
      END
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
```

```
      SUBROUTINE INTCPT(CLAI,DELTP,DPINT,TPINT,DDP,INCI,DT,DRI)
C
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C*                                                                        *
C*     THIS SUBROUTINE CALCULATES INTERCEPTION ON THE PLAT SURFACE
C*  ROUTES INTERCEPTION WATER TO THE SOIL SURFACE DURING PERIODS *
C*  OF NO RAINFALL.
C*     VOLUME OF WATER AS INPUT TO THE INFILTRATION SUBROUTINE   *
C*  WILL BE DDP PLUS DRI.
C*     VOLUME OF WATER IN INTERCEPTION STORAGE AT ANY ONE TIME   *
C*  AVAILABLE FOR DIRECT EVAPORATION IS TPINT. THIS IS THE VALUE *
C*  WHICH MUST BE PASSED ON TO THE ET SUBROUTINE.
C*                                                                        *
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C
      GO TO (5,30),INCI
C
C*     FIRST ENTRY IS HERE. DIVIDES RAINFALL INTO DIRECT PRECI-
C*  TATION TO THE LAND SURFACE (DDP) AND PRECIPITATION ON TO
C*  LEAF SURFACES (DPINT). THE TOTAL ACCUMULATED DEPTH ON PLANT
C*  SURFACES (TPINT) AT ANY TIME IS NOT ALLOWED TO EXCEED A
C*  MAXIMUM VALUE (PIMAX) WHICH IS DEPENDENT UPON THE CROP LEAF-
C*  AREA INDEX.
C
    5 IF(CLAI.GT. 3.0)GOTO10
      PCC=CLAI*33.33
      GO TO 11
   10 PCC=100.0
   11 DDP=DELTP*(1.0-0.01*PCC)
      PIMAX=0.03*CLAI
      DPINT=DELTP-DDP
      TTPINT = TPINT + DPINT
      IF((PIMAX-TTPINT).GE.0.0)GOTO19
      DPINT = PIMAX-TPINT
      TPINT=PIMAX
```

```
      DDP=DELTP-DPINT
      GOTO20
   19 TPINT=TTPINT
   20 INCI=2
      RETURN
   30 CONTINUE
C
C*      SECOND ENTRY BEGINS HERE. DRAINAGE TO THE GROUND FROM THE
C*  LEAF SURFACE STORAGE (DRI) IS ALLOWED BY AN EXPONENTIA-DECAY
C*  FUNCTION DOWN TO A MINIMUM VALUE (PIMIN) WHICH IS A FUNCTION
C*  OF CROP LEAF AREA INDEX.
C
      PIMIN=0.015*CLAI
      IF(TPINT.LE.PIMIN)GOTO32
      DDRI=TPINT*(1.0-EXP(-1.0*DT))
      IF((TPINT-DDRI).GE.PIMIN)GOTO31
      DRI=DRI+TPINT-PIMIN
      TPINT=PIMIN
      GOTO32
   31 TPINT=TPINT-DDRI
      DRI=DRI+DDRI
   32 INCI=1
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE PEVAP(JJ,TMAX,TMIN,CLAI,RH,RS,W,TPAST,PE,PET)
C
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C*                                                                        *
C*     THIS SUBROUTINE TAKES METEOROLOGICAL DATA AND USES A
C*  MODIFIED PENMAN EMPIRICAL EQUATION WITH A BRUNT EQUATION FOR *
C*  NET RADIATION TO CALCULATE TOTAL DAILY POTENTIAL EVAPORATION *
C*  IN INCHES.THE PROGRAM THEN DIVIDES THIS UP INTO SIX INCREMENT*
C*  FOR THE SIX FOUR-HOUR INCREMENTS OF THE DAY FOR USE IN THE   *
C*  SUBROUTINE ET.THE BASIC METHOD FOR CALCULATING DAILY POTENTIAL
C*  EVAPORATION IS FROM JENSEN'S WORK AS DESCRIBED IN TRANS.ASAE *
C*  AND PROC.ASCE. THE DIVISION OF POTENTIAL OVER THE DAY IS FROM*
C*  VAN BAVEL AS REPORTED IN THE AGRONOMY MONOGRAPH ON IRRIGATION*
C*  OF AGRICULTURAL LANDS.                                       *
C*                                                                        *
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C
      DIMENSION PET(6)
      X=JJ+18.0
C
C*  CALCULATE A MAXIMUM VALUE OF SOLAR RADIATION FOR EACH DAY (RSO).
C
      RSO=547.0+227.0*SIN(0.01721*X-1.5708)
C
C*     THEN CALCULATE THE AVERAGE AIR TEMPERATURE IN DEGREES F.(T)
C*  AND DEGREES R.(TR).NEXT CALCULATE THE SATURATION VAPOR PRESSURE
C*  AT THIS AVERAGE TEMPERATURE (ES) AND THE ACTUAL VAPOR PRESSURE
C*  (ED).
C
      T=(TMAX+TMIN)*0.5
      TR=T+459.69
      B=ALOG(TR)
      BB=54.6329 - 12301.688/TR - 5.16925*B
      ES=68.944*EXP(BB)
      ED=0.01*RH*ES
```

```
      TK2=((TMAX-32.0)/1.8+273.16)*0.01
      TK1=((TMIN-32.0)/1.8+273.16)*0.01
C
C*  CALCULATE MAXIMUM POTENTIAL BACK RADIATION USING A BRUNT EQUATION
      RBO=(0.98-(0.66+0.044*SQRT(ED)))*5.855*(TK2**4-TK1**4)
C*     REDUCE ANY INPUT SOLAR RADIATION VALUES WHICH EXCEED THE
C
C*  CALCULATED MAXIMUM.
C
      IF(RS.GT.RSO) RS=RSO
C*  CALCULATE AN ESTIMATE OF ACTUAL BACK RADIATION FOR THE DAY(RB).
C
      RB=(1.35*RS/RSO-0.35)*RBO
C*  CALCULATE ALBADO USING A MODIFIED RITCHIE'S FUNCTION.
C
      IF(CLAI.GT.4.0)GOTO50
      ALBEDO=0.23-0.0175*CLAI
      GOTO52
   50 IF(TMIN.LT.32.0)GOTO51
      ALBEDO=0.16
      GOTO52
   51 ALBEDO=0.20
C*  CALCULATE ESTIMATED NET RADIATION.
C
   52 RN=(1.0-ALBEDO)*RS-RB
      TC=(T-32.0)/1.8
      DOG=.672+.0428*TC+1.13*10.**(-3.)*TC*TC+1.66*10.**(-5.)
     A*TC*TC*TC+1.7*10.**(-7.)*TC**4.0
C*  CALCULATE ESTIMATED SOIL HEAT FLUX.
C
      G=5.0*(T-TPAST)
C
C*     CALCULATE ESTIMATED POTENTIAL EVAPORATION USING A PENMAN
C*  TYPE EMPIRICAL EQATION.
C
```

```
      PER=(DDG/(DDG+1.0)*(RN-G))*0.000673
      PEW=((1.0/(DDG+1.0))*15.36*(1.0+0.01*W)*(ES-ED))*0.000673
      PE=PER+PEW
C
C*      CALCULATE AN ESTIMATED DISTRIBUTION OF THE POTENTIAL ET FOR
C*    EACH FOUR-HOUR PERIOD OF THE DAY.
C
      PDX=PE/24.
      PET(1)=PDX*0.576
      PET(2)=PDX*1.152
      PET(3)=PDX*6.96
      PET(4)=PDX*9.528
      PET(5)=PDX*4.68
      PET(6)=PDX*1.104
      RETURN
      END
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
```

```
      SUBROUTINE PANEVP(PAN,EPCM,EINT,KMOT,JJ,PE,PET)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***  *
C*                                                                *
C* THIS SUBROUTINE DETERMINES THE POTENTIAL EVAPORATION FROM
C*  DAILY PAN EVAPORATION DATA AND APPROPRIATE PAN COEFFICIENTS   *
C*                                                                *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***  *
C
C*  CONVERTING DAILY PAN EVAPORATION DATA TO POTENTIAL EVAPORATION
C*  THE COEFFICIENTS OF THIS EQUATION ARE BASED ON WEATHER DATA
C*  FROM GINGLES WATERSHED.
C
      DIMENSION PAN(365),EPCM(12),EINT(12),PET(6)
      PE= PAN(JJ)*EPCM(KMOT)+EINT(KMOT)
      PDX=PE/24.0
      PET(1)=PDX*0.576
      PET(2)=PDX*1.152
      PET(3)=PDX*6.96
      PET(4)=PDX*9.528
      PET(5)=PDX*4.68
      PET(6)=PDX*1.104
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***  *
```

```
      SUBROUTINE PLANT(JJ,NRTDS,PCATRN,CLAI,IRT,ROOTS,ALAI,DLAI,
     1                 TJ,PCT,JIM1)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                               *
C*     THIS SUBROUTINE IS A SIMPLE APPROACH TO A PLANT GROWTH    *
C*  MODEL FOR CORN WHICH CALCULATES CROP LEAF AREA INDEX ,ROOT   *
C*  SYSTEM DEVELOPMENT AND PERCENT OF CANOPY ACTIVELY TRANSPIRING*
C*  AS SIMPLE FUNCTIONS OF TIME OF YEAR.LATER VERSIONS HOPE TO   *
C*  EXPAND THESE TO MAKE THEM ALSO BE FUNCTIONS OF AVAILABLE     *
C*  SOLAR RADIATION ,AIR TEMPERATURE ,SOIL TEMPERATURE AND SOIL
C*  MOISTURE CONTENT.
C*                                                               *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C
      REAL NRTDS(14)
      DIMENSION ALAI(12),DLAI(12),ROOTS(14,10),IRT(10),TJ(12),PCT(12)
      DO10J=1,9
      IF(JJ.GT.IRT(J))GOTO10
      DO9I=1,JIM1
    9 NRTDS(I)=ROOTS(I,J-1)
      GOTO13
   10 CONTINUE
   11 DO12I=1,JIM1
   12 NRTDS(I)=ROOTS(I,10)
   13 DJ=JJ
   31 PCATRN=GINT(TJ,PCT,12,DJ,31)
   32 CLAI=GINT(DLAI,ALAI,12,DJ,32)
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE PRECIP(KMOT,DAYT,YEAR,IBIG,NH,DELTP,IERR,TSTART,TSTOP
     1                    ,MON,NDA,NYR,ANX,BNX,CNX,RAIN)
C
C***   ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C*                                                                        *
C*      THIS SUBROUTINE TAKES HOUR AND TOTAL ACCUMULATED                  *
C*    PRECIPITATION DEPTH FROM A RECORDING RAINGAGE AND FIGURES           *
C*    STORM RAINFALL DEPTH INCREMENTS FOR SMALLER UNIFORM INCREMENT*
C*    OF TIME DURING THE DAY. THE FIRST FOUR COLUMNS ON EACH DATA        *
C*    CARD CONTAIN AN IDENTIFYING SYMBOL NAME FOR THE RAINGAGE.          *
C*    THE NEXT THREE COLUMNS CONTAIN THE DAY OF THE MONTHNUMBER.         *
C*    THE NEXT THREE COLUMNS CONTAIN THE YEAR NUMBER SUCH AS 068         *
C*    FOR 1968. THE NEXT FIVE COLUMNS ON THE CARD CONTAIN THE CLOCK*
C*    HOUR IN MILITARY TIME FORMAT FOR THE DATA POINT. IF THIS           *
C*    VALUE IS 9900 THIS INDICATES THAT THIS IS THE FIRST CARD FOR *
C*    A NEW STORM EVENT. THE FOLLOWING FOUR COLUMNS WILL THEN GIVE *
C*    THE TOTAL STORM RAINFALL FOR THIS STORM. SKIP FIVE COLUMNS,  *
C*    THEN THE NEXT FOUR COLUMNS GIVE THE MAXIMUM RECORDED RAINFALL*
C*    DEPTH VALUE FOR THIS GAGE AND THIS STORM. SKIP FIVE MORE           *
C*    COLUMNS AND THE NEXT FOUR COLUMNS GIVE THE ZERO READING. WHEN*
C*    TOTAL STORM RAINFALL DOESN'T AGREE WITH THE MAXIMUM RECORDED *
C*    RAINFALL, THE ZERO READING WILL NOT EQUAL 0.0. THE INFORMATION
C*    ON THIS CARD IS USED TO CORRECT THE RAINFALL DEPTH DATA ON         *
C*    THE REMAINING CARDS FOR THIS STORM.                                 *
C*       ALL OF THE REMAINING CARDS FOR THE SAME STORM HAVE THE          *
C*    FOLLOWING ARRANGEMENT.  THE FIRST THIRTEEN COLUMNS CONTAIN         *
C*    THE SAME IDENTIFICATION AND DATE AS THE FIRST CARD.                *
C*    THEN FOLLOW SEVEN - NINE COLUMN SETS OF DATA. THE FIRST FIVE *
C*    COLUMNS OF ANY SET CONTAIN THE MILITARY TIME FOR THE DATA          *
C*    POINTS. THE FIRST THREE COLUMNS BEING THE HOUR AND THE NEXT        *
C*    TWO BEING THE MINUTES. THE NEXT FOUR COLUMNS OF THE SET            *
C*    CONTAIN THE RECORDED TOTAL STORM RAINFALL TO THAT POINT WITH *
C*    TWO SIGNIFICANT FIGURES TO THE RIGHT OF THE DECIMAL POINT.         *
C*    THESE POINTS ARE CHOSEN TO REPRESENT POINTS OF SIGNIFICANT         *
C*    CHANGE IN RAINFALL INTENSITY DURING THE STORM. IF ADDITIONAL *
```

```
C*   CARDS ARE REQUIRED TO CONTAIN ALL THE POINTS NECESSARY TO       *
C*   DESCRIBE THIS STORM THE FORMAT WILL BE THE SAME AS THIS         *
C*   SECOND CARD STARTING WITH THE GAGE IDENTIFICATION AND DATE.     *
C*   IF THE DATA FOR A STORM ENDS IN THE MIDDLE OF A CARD THE        *
C*   REMAINING COLUMNS ARE LEFT BLANK.                               *
C*   THE LAST CARD IN THE DATA DECK OF PRECIPITATION DATA MUST BE    *
C*   BLANK.                                                          *
C*
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C
       INTEGER CARD,YEAR
      INTEGER DAYI,DAYT
      DIMENSION MON(13),NDA(13),NYR(13),ANX(13,7),BNX(13,7),CNX(13,7)
      DIMENSION A(7),B(7),C(7),DELTP(290),TIME(290),SUMP(290),CLOCK(8),
     1THC(8)
      CARD=0
C
C*     IBIG = 1 MEANS THIS IS THE FIRST TIME TO READ A DATA CARD *
C*   FOR THIS DAY.
C
      IF(IBIG.NE.1)CARD=1
      IF(IBIG.NE.1)GOTO89
      THC(1)=0.0
      CLOCK(1)=0.0
      CLOCK(8)=0.0
      SUMO=0.0
      GOTO90
   89 IF(KMO.NE.KMOT.OR.DAYI.NE.DAYT)GOTO120
      IF(IBIG.NE.2)GOTO90
      IBIG=1
C
C*     NH = NUMBER OF DIVISIONS OF AN HOUR BEING USED.
C
   90 IM=24*NH
      JCM=IM+1
```

```
      TNH=NH
      TIME(1)=0.0
      SUMP(1)=THC(8)
      DELTP(1)=0.0
C
C*     INITIALISE THE VALUES IN THE PROGRAM.
C
      DO95I=2,JCM
      TI=I-1.
      TIME(I)=TI/TNH
      SUMP(I)=0.0
      DELTP(I)=0.0
   95 CONTINUE
      TSTART=0.0
      TSTOP=0.0
      I=1
C
C*     I GREATER THAN IM MEANS THAT WE HAVE REACH THE END OF THE DAY.
C
   99 IF(I.GT.IM)GOTO400
      I=I+1
C
C*     IBIG = 1 OR 2 MEANS EXPECT A NEW DATA CARD.
C*     IBIG = 3 MEANS WE HAVE ALREADY READ A NEW CARD WHICH HASN'T
C*  BEEN PROCESSED.
C*     IBIG = 4 MEANS WE HAVE ONLY PARTIALLY PROCESSED THE LAST
C*  DATA CARD.
C
      GOTO(100,100,200,300),IBIG
  100 CONTINUE
      CARD=CARD+1
      KMC=MON(CARD)
      DAYI=NDA(CARD)
      KYR=NYR(CARD)
      DO98N=1,7
```

```
      A(N)=ANX(CARD,N)
      B(N)=BNX(CARD,N)
   98 C(N)=CNX(CARD,N)
C
C* IF DATA IS CODED FOR GAUGE ERROR OR SNOW, UNCODE DATA
C
      IF(C(1).LT.70.0)GOTO80
      DO60N=1,7
      IF(C(N).GE.70.0)C(N)=C(N)-70.0
      IF(C(N).GE.20.0)C(N)=C(N)-20.0
   60 CONTINUE
      WRITE(6,900)
  900 FORMAT(5X,'RAINGAUGE DATA CODED FOR ERROR OR SNOWFALL.')
   80 CONTINUE
      IF(KMO.NE.KMOT)GOTO101
      IF(DAYT.NE.DAYI)GOTO101
      GOTO102
  101 IF(IBIG.EQ.1)GOTO120
      IF(IBIG.EQ.2)GOTO140
  102 IF(ABS(A(1)-99.0).LT.0.0001)GOTO150
      GOTO200
  120 CONTINUE
      WRITE(6,660)KMCT,DAYT,YEAR,KMO,DAYI,KYR
  660 FORMAT(//'****ERROR****ERROR**DATE CHANGE ON INPUT PRECIPITATION
     UCARD.'/' WORKING DATE WAS ',I3,'/',I3,'/',I4,' AND INPUT CARD DATE
     2 WAS ',I3,'/',I3,'/',I3/)
      IERR=1
      RETURN
C
C*      IF WE REACH 130 WE HAVE CHANGED BOTH DAY AND STORM SINCE
C*  LAST CARD.
C
  130 E=C(3)
      F=C(1)/(C(2)-E)
  132 DO131JC=I,JCM
```

```
      SUMP(JC)=THC(8)+SUMO
  131 CONTINUE
      IBIG=2
      IF(KMO.EQ.0)IBIG=1
      CLOCK(1)=0.0
      THC(1)=0.0
      THC(8)=0.0
      SUMO=0.0
      GOTO600
  140 IF(ABS(A(1)-99.0).LT.0.0001)GOTO130
      IF(KMO.EQ.0)GOTO145
      IBIG=3
      GOTO305
  145 IBIG=1
      GOTO132
C
C*       IF WE REACH 150 WE HAVE CHANGED STORM BUT NOT DAY SINCE
C*  LAST CARD.
C
  150 E=C(3)
      F=C(1)/(C(2)-E)
      SUMP(I)=THC(8)+SUMO
      SUMO=THC(8)
      THC(1)=0.0
      CLOCK(1)=CLOCK(8)
      IF(IBIG.EQ.1)GOTO100
      IBIG=2
      GOTO99
C
C*       READING 200 MEANS THE NEW CARD IS FOR THE SAME DAY AND STORM.
C
  200 DO290N=1,7
      CLOCK(N+1)=A(N)+E(N)/60.
      IF(CLOCK(N+1).EQ.0.0)C(N)=E
      THC(N+1)=(C(N)-E)*F
```

```
  290 CONTINUE
  300 DO302JC=2.8
      IF(CLOCK(JC).LT.0.001)GOTO301
      IF(TIME(I).GT.CLOCK(JC))GOTO302
      IF(TIME(I).EQ.CLOCK(JC))GOTO312
      DX=CLOCK(JC)-CLOCK(JC-1)
      DY=THC(JC)-THC(JC-1)
      SUMP(I)=THC(JC)-DY/DX*(CLOCK(JC)-TIME(I)) +SUMO
  313 IBIG=4
      GOTO99
  312 SUMP(I)=THC(JC)+SUMO
      GOTO313
  301 IBIG=2
      CLOCK(8)=CLOCK(JC-1)
      THC(8)=THC(JC-1)
      GOTO100
  302 CONTINUE
      CLOCK(1)=CLOCK(8)
      THC(1)=THC(8)
      IBIG=2
      GOTO100
C
C*      IF WE REACH 305 WE HAVE CHANGED THE DAY BUT NOT THE STORM.
C
  305 CONTINUE
      IF(I.EQ.JCM)GOTO311
  306  CL = A(1)+B(1)/60.0+24.0
      THC1=(C(1)-E)*F
      DX=CL-CLOCK(8)
      DY=THC1-THC(8)
      DO310JC=I,JCM
      SUMP(JC)=THC1-DY/DX*(CL-TIME(JC))+SUMO
  310 CONTINUE
       GO TO 314
  311 IF(CLOCK(8).NE.24.0)GOTO306
```

```
  314  CLOCK(1)=0.0
       THC(1)=SUMP(JCM)-SUMO
       GOTO600
  400  CONTINUE
       IF(CLOCK(8).EQ.0.0)GOTO450
       GOTO599
  450  CLOCK(8)=24.0
       THC(8)=SUMP(JCM)-SUMO
  599  IBIG=2
       GOTO100
C
C*      WHEN WE REACH 600 WE HAVE COME TO THE END OF A DAY AND ARE
C*   READY TO COMPUTE "DELTP" VALUES AND RETURN TO THE MAIN PROGRAM.
C
  600  CONTINUE
       DO610I=1,IM
       DELTP(I)=SUMP(I+1)-SUMP(I)
  610  CONTINUE
       SUMO=0.0
  680  DO681JC=1,IM
       IF(DELTP(JC).LE.0.0)GOTO681
       TSTART=TIME(JC)
       GOTO682
  681  CONTINUE
  682  CONTINUE
       DO683JC=I,IM
       JCC=JCM-JC
       IF(DELTP(JCC).LE.0.0)GOTO683
       TSTOP=TIME(JCC+1)
       GOTO700
  683  CONTINUE
  700  CONTINUE
       RAIN=0.0
       DO701JI=1,JCM
       RAIN=RAIN+DELTP(JI)
```

```
  701 CONTINUE
      WRITE(6,13)RAIN
   13 FORMAT(11X,'TOTAL RAINFALL TODAY = ',F8.3,' INCHES')
      WRITE(6,9)TSTART,TSTOP
    9 FORMAT(10X,'RAINFALL STARTED AT',G12.4,'HOURS AND ENDED AT',
     1G12.4,'HOURS')
      RETURN
      END
C***  ***  ***  ***  ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE PRECHR(KCARD,DELTP,NYR,MON,NDA,IAP,XDP,RAIN,
     1                   TSTART,TSTOP)
      DIMENSION DELTP(290),NYR(3),MON(3),NDA(3),IAP(3),XDP(3,12)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                               *
C*      THIS REVISED SUBROUTINE IS USED TO INPUT HOURLY RAINFALL *
C*   DATA FROM THE U.S.WEATHER BUREAU FORMAT AND PROCESS IT      *
C*   FOR USE IN THE MODEL                                        *
C*
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C
      DO 10 I=1,24
   10 DELTP(I)=0.0
      IF(IAP(1).EQ.2)GOTO40
C*  FIRST CARD IS A MORNING CARD
      DO 20 I=1,12
   20 DELTP(I)=XDP(1,I)
      KCARD=2
      IF(MON(2).NE.MON(1).OR.NDA(2).NE.NDA(1))GOTO60
      IF(IAP(2).EQ.1)GOTO60
C*  SECOND CARD IS AN AFTERNOON CARD
      DO 30 I=13,24
      KI=I-12
   30 DELTP(I)=XDP(2,KI)
      KCARD=3
      GO TO 60
   40 DO 50 I=13,24
C*  FIRST CARD IS AN AFTERNOON CARD
      KI=I-12
   50 DELTP(I)=XDP(1,KI)
      KCARD=2
C*  NOW TRANSFER NEXT RAIN DAY DATA TO FIRST CARD
   60 NYR(1)=NYR(KCARD)
      MON(1)=MON(KCARD)
```

```
      NDA(1)=NDA(KCARD)
      IAP(1)=IAP(KCARD)
      DO 70 N=1,12
   70 XDP(1,N)=XDP(KCARD,N)
      RAIN=0.0
      TSTART=0.0
      DO 80 I=1,24
      RAIN=RAIN+DELTP(I)
      IF(RAIN.LE.0.0)TSTART=I
      IF(DELTP(I).GT.0.0)TSTOP=I+1
   80 CONTINUE
      WRITE(6,81)RAIN
   81 FORMAT(11X,'TOTAL RAINFALL TODAY = ',F8.3,' INCHES')
      WRITE(6,82)TSTART,TSTOP
   82 FORMAT(10X,'RAINFALL STARTED AT',F7.2,' HOURS AND ENDED AT',
     $ F7.2,' HOURS')
      KCARD=1
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE REDIST (IRED,DELTF,PERCO,SPERCO,J,TFRC,ADTF,VOLDPR,
     1                   DT,COND,ZINF,ZOUTF,TOTSTR,SMASM,SAT,
     2                   JTILE,JIM,AEWP,SMTC)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                               *
C*      THIS SUBROUTINE DOES THE INITIAL DISTRIBUTION OF THE     *
C*   INFILTRATING WATER TO THE VARIOUS SOIL LAYERS,AND THEN      *
C*   DETERMINE SOIL MOISTURE REDISTRIBUTION BY BOTH GRAVITY AND  *
C*   MOISTURE TENSION GRADIENTS BETWEEN THE ADJACENT SOIL LAYERS *
C*   AND TO THE UNDERLYING SOIL. THE SOIL IS DIVIDED INTO SIX-INCH*
C*   LAYERS FOR THE FIRST FIVE FEET OF THE PROFILE AND ONE-FEET  *
C*   LAYERS FOR THE NEXT FOUR FEET.THE TENTH FOOT LAYER IS ASSUMED*
C*   TO REPRESENT ALL SOIL BELLOW THAT DEPTH,AND THE MOISTURE    *
C*   LEVEL OF THIS LAYER IS TAKEN AS THE AVERAGE OF THE SOIL     *
C*   MOISTURE OF THE PREVIOUS LAYER FOR THE PAST FOURTEEN DAYS.  *
C*   MOISTURE IS ALLOWED TO MOVE FREELY UNDER TENSION GRADIENTS  *
C*   BOTH INTO AND OUT OF THIS LOWEST LAYER RELATIVE TO THE NEXT *
C*   HIGHER LAYER.                                               *
C*      THE PRESENT VERSION OF THIS SUBROUTINE AS MODIFIED BY    *
C*   C.E ANDERSON IS CAPABLE OF HANDLING DIFFERENT SOIL MOISTURE *
C*   CHARACTERISTICS IN EACH LAYER AND ALLOWES THE BUILDUP OF A  *
C*   WATER TABLE AND DISCHARGE OF WATER THROUGH A TILE DRAIN.    *
C*   THE WATER CHARACTERISTIC FUNCTION IS TAKEN AS A STRAIGHT    *
C*   LINE ON A LOG-LOG PLOT FOR ALL MOISTURE LEVELS BELOW 90% OF *
C*   SATURATION THE SAME IS TRUE OF THE UNSATURATED HYDRAULIC    *
C*   CONDUCTIVITY FUNCTION SEE ARTICLE BY G. S. CAMPBELL IN      *
C*   SOIL SCIENCE 117(6):311-314,JUNE 1 AND ALSO ARTICLE BY      *
C*    R.K.GHOSH IN SOIL SCIENCE 124(2):122-124,1977              *
C*                                                               *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C
      COMMON/ABLOCK/DSOILM(15),WP(15),RESAT(15),ESAT(15),RSAT(15),
     1 SMET(16),PAD(6),ETRATE(16,6),FC(15),SHC(15),THICK(15),TMAC(15),
     2PLAV(15)
```

```
      DIMENSION COND(14),ZINF(14),ZOUTF(14),AINFIL(15),
     1 TENZ(15),SAT(15),AEWP(15),SMTC(15),UHC(15)
         REAL*8 DSOILM,AINFIL,COND,ZPERC,EXT,EXTRA,PERCO,EXTA
      JIM1=JIM-1
      PERCO=0.0
      TILEQ=0.0
C
C*      FIRST ENTRY STARTS HERE.DURING THE DOWNWARD MOVEMENT OF WATER
C*    EACH LAYER FILLS UP TO A CERTAIN LEVEL OF SATURATION DEPENDING
C*    UPON THE SOIL TYPE.IN THIS STUDY 30% HAVE BEEN USED FOR SAND,80%
C*    FOR SILT-LOAM AND 90% FOR HEAVY SOILS.
C*    THE EXCESS WATER IS ALLOWED TO FLOW TO THE NEXT LOWER LAYER,WHILE
C*    THE SATURATED HYDRAULIC CONDUCTIVITY (SHC) OF THE LOWER LAYER
C*    CONTROLS THE FLOW TO EACH LAYER.
C
      DO2KZZ=1,JIM
    2 AINFIL(KZZ)=0.0
      GOTO(3,45),IRED
    3 AINFIL(1)=DELTF
      JI=1
      JIM1=JIM-1
      IF(DELTF.EQ.0.0)GOTO40
      DO5JI=1,JIM1
      K3=JI
      DSOILM(JI)=DSOILM(JI)+AINFIL(JI)
      IF(DSOILM(JI).LE.RESAT(JI))GOTO10
      AINFIL(JI+1)=DSOILM(JI)-RESAT(JI)
C
C*      IF SOIL MOISTURE LEVEL IN ANY LAYER IS BELOW THE MOISTURE CONTENT
C*    AT WHICH CRACKS DEVELOPE,THE SHC WILL NO LONGER CONTROLS THE FLOW
C*    BETWEEN THE TWO ADJACENT LAYERS.
C
      IF(DSOILM(JI+1).LE.TMAC(JI)) GO TO 5
      EXT=SHC(JI+1)*DT*0.3937
      IF(EXT.LT.AINFIL(JI+1))AINFIL(JI+1)=EXT
```

```
    5 DSOILM(JI)=DSOILM(JI)-AINFIL(JI+1)
C
C*      INFILTRATING WATER PASSES BELOW THE BOTTOM LAYER OF THE SOIL
C*   PROFILE IS ADDED TO THE ACCUMULATED DEEP PERCOLATION.
C
   10 PERCO=AINFIL(JIM)
C
C*      IN THE UPWARD MOVEMENT OF WATER FIRST ANY MOISTURE ABOVE
C*   SATURATION IS RE ADDED TO THE NEXT HIGHER LAYER.AND THEN THE EXTRA
C*   MOISTURE FROM THE FIRST LAYER IS ADDED TO THE SURFACE DEPRESSION
C*   STORAGE.
C
   15 EXTRA=DSOILM(KB)-ESAT(KB)
      IF(EXTRA.GT.0.0)GOTO20
      KB=KB-1
      IF(KB.EQ.0)GOTO35
      GOTO15
   20 DSOILM(KB)=ESAT(KB)
   25 KB=KB-1
      IF(KB.EQ.0)GOTO30
      DSOILM(KB)=DSOILM(KB)+EXTRA
      GOTO15
   30 VOLDPR=VOLDPR+EXTRA
   35 SMASM=TOTSTR-DSOILM(1)-DSOILM(2)-DSOILM(3)-DSOILM(4)
      DELTF=0.0
       SPERCO=SPERCO+PERCO
      DO 36 LL = 1,JIM1
   36 ZINF(LL)=ZINF(LL)+AINFIL(LL)
   40 IRED=2
      GO TO 160
C
C*   SECOND ENTRY STARTS HERE.
C
   45 CONTINUE
      JI=1
```

```
      JIM1=JIM - 1
      DO50KZZ=1,14
      COND(KZZ)=0.0
   50 CONTINUE
C
C*      TO INCREASE THE MODEL PRECISION THE LENGTH OF THE SHORTEST TIME
C*   INCREMENT (DTU)IS REDUCED TO HALF OF ITS ORIGINAL VALUE WHENEVER
C*   THE FLOW BETWEEN THE TWO ADJACENT LAYER IS GREATER THAN THE AVERAGE
C*   OF THE SHC OF THE TWO LAYER.
C
      N=1
      DTU=DT
      GO TO 60
   55 DTU=DTU*0.5
      N=N*2
C
C*      IN THE SECOND ENTRY FIRST THE SOIL MOISTURE CONTENT(PERCENT-
C*   SATURATION) FOR EACH SOIL LAYER IS CALCULATED.THEN THE CAPILARY
C*   POTENTIAL (TENZ) AND UNSATURATED HYDRAULIC CONDUCTIVITY (UHC) AT
C*   THIS MOISTURE CONTENT FOR EACH LAYER IS DETERMINED BY USING THE
C*   FOLLOWING EQUATIONS AS MODIFIED BY ANDERSON BASED ON THE CONCEPT
C*   BY SAXTON (1974), CAMPBELL (1974)AND GHOSH (1977).
C
   60 DO 110 I=1,N
      DO 75 JI = 1,JIM
      CSMP=DSOILM(JI)/THICK(JI)*100.0
      SR=CSMP/SAT(JI)
      IF(SR.GT.0.9)GO TO 65
      TENZ(JI)=AEWP(JI)*SR**(-SMTC(JI))
      UHC(JI)=SHC(JI)*SR**(1.5*SMTC(JI)+3.0)
      GO TO 75
   65 IF(SR.GT.1.0)GOTO70
      TENZ(JI)=(10.0*SR-9.0)*AEWP(JI)*0.9**(-SMTC(JI))
      UHC(JI)=SHC(JI)
      GO TO 75
```

```
   70 TENZ(JI)=0.0
      UHC(JI)=SHC(JI)
   75 CONTINUE
      DO 80 JI = 1,JIM1
      TH2=THICK(JI)+THICK(JI+1)
      THM=TH2*1.27
C
C* TH2 = TOTAL THICKNESS OF ANY TWO ADJACENT LAYERS (INCHES)
C* THM = DISTANCE BETWEEN MIDPOINTS OF ANY TWO ADJACENT LAYERS (CM)
C*     NEXT IT DETERMINES TOTAL POTENTIAL GRADIENT BETWEEN THE TWO
C*  ADJACENT LAYERS (GRAD) , CAPILARY CONDUCTIVITY (CON) AND THE FLOW
C*  BETWEEN THE TWO ADJACENT LAYERS (COND) BY USING THE ONE DIMENSIONAL
C*  DARCY'S EQUATION.
C
      GRAD=(TENZ(JI+1)-TENZ(JI)+THM)/THM
      CON=(UHC(JI)+UHC(JI+1))*0.5
      TEST=(SHC(JI)+SHC(JI+1))*0.4
      COND(JI)=CCN*GRAD*DTU*0.3937
      IF(DABS(COND(JI)).GT.TEST) CC TO 55
   80 CCNTINUE
      JIM2=JIM-2
C
C*     THE MAXIMUM FLCW FROM EACH LAYER IS NOT ALLOWED TO BE MORE THAN
C*  50% OF THE SOIL MOISTURE CONTENT OF THAT LAYER.
C
      DO95JI=I,JIM2
      IF(COND(JI).LT.0.0)GOTO85
      CONMAX=DSOILM(JI)*0.5
      IF(COND(JI).GT.CONMAX)COND(JI)=CONMAX
      GOTO90
   85 CONMAX=DSOILM(JI+1)*(-0.5)
      IF(COND(JI).LT.CONMAX)COND(JI)=CONMAX
C
C*     THE SOIL MOISTURE CONTENT OF EACH LAYER IS UPDATED BASED ON THE
C*  CALCULATED FLOW BETWEEN EACH TWO ADJACENT LAYER.
```

```
   90 DSOILM(JI)=DSOILM(JI)-COND(JI)
      DSOILM(JI+1)=DSOILM(JI+1)+COND(JI)
   95 CONTINUE
      IF(COND(JIM1).LT.0.0)GOTO100
      CONMAX=DSOILM(JIM1)*0.5
      IF(COND(JIM1).GT.CONMAX)COND(JIM1)=CONMAX
  100 DSOILM(JIM1)=DSOILM(JIM1)-COND(JIM1)
C
C*      ANY FLOW PASSED THE BOTTOM LAYER IS ADDED TO THE ACCUMULATED
C*   DEPTH OF DEEP PERCOLATION.
C
      PERCO=PERCO+COND(JIM1)
      ZPERC=0.0
C
C*      SOIL MOISTURE OF EACH LAYER IS CHECKED FOR THE SECOND TIME
C*   AGAINST A CERTAIN LEVEL OF SATURATION (80% WERE USED HERE) AND
C*   ANY EXCESS MOISTURE IS ALLOWED TO FLOW TO THE NEXT LOWER LAYER
C*   WHILE THIS FLOW IS CONTROLED BY SHC OF THE LOWER LAYER.
C
      DO105JI=1,JIM1
       IF(RSAT(JI).GE.DSOILM(JI)) GO TO 105
      ZPERC=SHC(JI+1)*DTU*0.3937
      EXTA=DSOILM(JI)-RSAT(JI)
      IF(ZPERC.GT.EXTA)ZPERC=EXTA
      DSOILM(JI)=DSOILM(JI)-ZPERC
      IF(JI.EQ.JIM1)GOTO104
      DSOILM(JI+1)=DSOILM(JI+1)+ZPERC
      AINFIL(JI+1)=AINFIL(JI+1)+ZPERC
      GOTO105
  104 PERCO=PERCO+ZPERC
  105 CONTINUE
  110 CONTINUE
      IF(ZPERC.EQ.0.0)GOTO140
```

```
C*     SIMILAR TO THE FIRST ENTRY, IN THE UPWARD MOVEMENT ANY MOISTURE
C*  ABOVE SATURATION IS RE-ADDED TO THE NEXT HIGHER LAYER.
C
      KB=JIM1
  115 EXTRA=DSOILM(KB)-ESAT(KB)
      IF(EXTRA.GT.0.0)GOTO120
      KB=KB-1
      IF(KB.EQ.0)GOTO140
      GOTO115
  120 DSOILM(KB)=ESAT(KB)
      IF(KB.EQ.JTILE)GOTO130
  125 KB=KB-1
      IF(KB.EQ.0)GOTO135
C
C*  UP DATING THE SOIL MOISTURE CONTENT OF ALL LAYERS.
C
      DSOILM(KB)=DSOILM(KB)+EXTRA
      GOTO115
C
C*  CALCULATING TILE FLOW VOLUME USING TILE FLOW RECESSION CONSTANT.
C
  130 TILEQ=EXTRA*(-ALOG(TFRC**(DT/24.0)))
      EXTRA=EXTRA-TILEQ
      IF(EXTRA.GT.0.0)GOTO125
      TILEQ=TILEQ+EXTRA
      EXTRA=0.0
      KB=KB-1
      IF(KB.EQ.0)GOTO140
      GOTO115
  135 VOLDPR=VOLDPR+EXTRA
  140 SPERCO=SPERCO+PERCO
      ADTF=ADTF+TILEQ
      SMASM=TOTSTR-DSOILM(1)-DSOILM(2)-DSOILM(3)-DSOILM(4)
      DO145LL=1,JIM1
       ZINF(LL)=ZINF(LL)+AINFIL(LL)
```

```
      ZOUTF(LL)=ZOUTF(LL)+COND(LL)
  145 CCNTINUE
  160 RETURN
      END
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
```

```
      SUBROUTINE OFROUT (PEAI,VOLDPR,EQD,OFR,TOFR,AREA,DT,OFRCFS,
     1                   TRST,TRSTM,OFMN1,OFMN2,SSRT,PUDLE1,PUDLE2)
C
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C*                                                                        *
C*      THIS SUBROUTINE USES THE OVERLAND FLOW ROUTING FUNCTION           *
C*   AS DEVELOPED BY CRAWFORD AND LINSLEY IN THE STANFORD                 *
C*   WATERSHED MODEL (TP-39) TO ESTIMATE THE PROCESS OF OVERLAND          *
C*   FLOW,BASED ON THE AVERAGE VALUES OF LAND SURFACE PARAMETERS          *
C*   AFFECTING THE PROCESS.                                               *
C*                                                                        *
C***    ***    ***    ***    ***    ***    ***    ***    ***    ***    *** *
C
      QR=TRST/TRSTM
      OFMN=OFMN1-QR*(OFMN1-OFMN2)
      IF(OFMN.LT.OFMN2)OFMN=OFMN2
      OFRF=1020.0*SSRT/OFMN
      EQDF=0.00982*(OFMN/SSRT)**0.6
      PUDLE=PUDLE1-0.80*(QR*(PUDLE1-PUDLE2))
      IF(PUDLE.LT.PUDLE2)PUDLE=PUDLE2
      OFR=0.0
      OFRCFS=0.0
      SWS=VOLDPR+PEAI-PUDLE
      IF(SWS.LE.0.001)GOTO12
      IF((PEAI-VOLDPR).GT.0.0)GOTO10
      EQD=0.5*SWS
      GOTO11
   10 EQD=EQDF*((PEAI-VOLDPR)**0.6)
   11 IF(SWS.GT.(2.0*EQD))EQD=0.5*SWS
      OFR =( DT ) *OFRF*((SWS*0.5)**1.67)*((1.0+0.6*(SWS/(2.0*EQD))
     $ **3.0)**1.67)
      IF(OFR.GT.(0.75*PEAI)) OFR = 0.75*PEAI
      OFRCFS=1.0083*AREA*OFR/DT
   12 TOFR=TOFR+OFR
      VOLDPR=PEAI-OFR
      RETURN
      END
```

```
      SUBROUTINE SPRINK(IBIR,TPBI,ATPI,GIDP,NH,DELTP,TBI,TEI,DIA)
C
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                              *
C*      THIS SUBROUTINE TREATS IRRIGATION WATER AS ADDITIONAL   *
C*   RAINFALL . IT DETERMINES TIME TO START AND END IRRIGATION FOR*
C*   EACH DAY AND DIVIDES THE HOUR IN BETWEEN INTO NH INCREMENTS *
C*   FOR EACH TIME PERICD IRRIGATION DEPTH IS ADDED TO ANY NATURAL*
C*   RAINFALL INCREMENTS FOR THAT PERIOD AND HANDLED BY THE MODEL *
C*   IN THE SAME MANNER AS NATURAL RAINFALL.
C*      GROSS DEPTH AND APPLICATION TIME PERICD OF IRRIGATION,   *
C*   PERCENT MOISTURE REMOVED AT IRRIGATION.STARTING AND ENDING  *
C*   DATES OF APPLICATION AND HOUR OF THE DAY TO BEGIN IRRIGATICN *
C*   ARE INPUT DATA TO THIS SUBROUTINE.
C*                                                              *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C
      DIMENSICN DELTP(290)
      IF(IBIR.EQ.2)GOTC80
C
C*   DETERMINE THE TIME TO START (TBI) AND TIME TO END (TEI) IRRIGATICN
C
      TBI=TPBI
      ICB=TBI*NH+1
      TEI=TBI+ATPI
C
C*       CHECK IF IRRIGATION APPLICATION CONTINUES AFTER MIDNIGHT.IF
C*   SO SET THE MIDNIGHT TO BE TIME TO END IRRIGATION IN THE FIRST DAY
C*   AND ALSO TIME TO START IRRIGATION IN THE SECOND DAY.
C
   70 IF(TEI.LE.24.0)GOTC85
      EXTIME=TEI-24.0
      TEI=24.0
      TBIT=0.0
      IBIR=2
```

```
      GOTO90
C
C*  DETERMINE THE TIME TO END IRRIGATION IN THE SECOND DAY.
C
   80 TEI=EXTIME
      TBI=TBIT
      ICB=TBI*NH+1
      GOTO70
   85 IBIR=3
   90 ICE=TEI*NH
      DO100I=ICB,ICE
C
C*  CALCULATE DAILY DEPTH OF IRRIGATION WATER APPLICATION.
C
      DIA=DIA+GIDP
C
C*      ADD THE IRRIGATION DEPTH DURING EACH TIME INCREMENT TO THE DEPTH
C*  OF ANY NATURAL RAINFALL IN THE SAME PERIOD OF TIME.
C
  100 DELTP(I)=DELTP(I)+GIDP
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
      SUBROUTINE STRINX(JUDS,RAWSTR,WTFC,SUM,WSTR,TWSTR,JUPSS)
C
C***   ***   ***  ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                              *
C*     THIS SUBROUTINE CALCULATES THE WEIGHTED STRESS INDEXS FOR*
C*  85 DAYS MADE UP OF EIGHT 5-DAY PERIODS BEFORE SILKING AND   *
C*  NINE 5-DAY PERIODS AFTER SILKING.                           *
C*  THE CALCULATIONS ARE BASED ON THE PROCEDURE DEVELOPED BY    *
C*  SHAW (1974) AS DESCRIBED IN ISU JOURNAL OF RESEARCH,VOL.49  *
C*  NOVEMBER 1974.                                              *
C*     DAILY RAW STRESS INDEXES CALCULATED IN THE MAIN PROGRAM, *
C*  SILKING DATE AND 17 WEIGHT FACTORS ASSOCIATED WITH THE      *
C*  8-PERIODS BEFORE AND 9-PERIODS AFTER SILKING DATE ARE INPUT *
C*  DATA TO THIS SUBROUTINE.                                    *
C*                                                              *
C***   ***   ***  ***   ***   ***   ***   ***   ***   ***   *** *
C
      DIMENSION RAWSTR(365),WTFC(17),SUM(17),WSTR(17),JUPSS(20)
C
C*  FIRST DAILY RAW STRESS INDEXES ARE SUMMED OVER EACH 5-DAY
C*  PERIOD.
C
      DO 10 I=1,18
   10 JUPSS(I)=JUDS-45+5*I
      M=JUPSS(1)
      N=JUPSS(18)-1
      DO 20 JJ=M,N
      DO 30 I=1,17
      IF(JJ.LT.JUPSS(I+1))GO TO 35
      GO TO 30
   35 SUM(I)=SUM(I)+RAWSTR(JJ)
      GO TO 20
   30 CONTINUE
   20 CONTINUE
      IK=0
```

```
C
C*  THEN THE 5-DAY STRESS INDEXES ARE MULTIPLIED BY THE ASSOCIATED
C*  WEIGHT FACTOR FOR EACH PERIOD.
C
      DO41 KL=1,17
      WSTR(KL)=SUM(KL)*WTFC(KL)
C
C*  AN ADDITIONAL WEIGHTING FACTOR OF 1.5 IS APPLIED TO THE PERIODS
C*  WHOSE UNWEIGHTED STRESS INDEX IS 4.5 OR GREATER FOR AT LEAST TWO
C*  CONSECUTIVE PERIODS.
C
      IF(KL.EQ.1)GO TO 41
      IF(SUM(KL).GE.4.50) GO TO 42
      IK=0
      GO TO 41
   42 IF(SUM(KL-1).GE.4.50)GO TO 43
      GO TO 41
   43 IF(IK.NE.1)GO TO 44
      WSTR(KL)=WSTR(KL)*1.5
      IK=1
      GO TO 41
   44 WSTR(KL-1)=WSTR(KL-1)*1.5
      WSTR(KL)=WSTR(KL)*1.5
      IK=1
   41 CONTINUE
C
C*  ANOTHER WEIGHTING FACTOR OF 1.5 IS APPLIED TO THE TWO OF THE
C* THREE PERIODS( ONE,TWO AND THREE BEFORE SILKING) WITH THE
C*  UNWEIGHTED STRESS INDEX OF THREE OR GREATER.
C
      KC=0
      DO 70 K=6,8
   70 IF(SUM(K).GE.3.0)KC=KC+1
      IF(KC.LT.2)GO TO 80
      DO 75 K=6,8
```

```
   75 IF(SUM(K).GE.3.0) WSTR(K)=WSTR(K)*1.5
   80 CONTINUE
C
C*  SEASONAL STRESS INDEX IS THEN THE SUM OF ALL WEIGHTED STRESS
C*  INDEXES FOR ALL 17 PERIODS.
C
      DO 90 I=1,17
   90 TWSTR=TWSTR+WSTR(I)
      RETURN
      END
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
```

```
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
C*                                                                *
C*             LIST OF INPUT DATA CARDS                           *
C*                                                                *
C***   ***   ***   ***   ***   ***   ***   ***   ***   ***   *** *
ALBATON SOIL ON THE BOTTOM LAND OF THE MISSOURI RIVER VALLEY.1951.DATA
TRIAL RUN WITH (2.IN)IRR. AT 70% OF THE AVAILABLE MOISTURE
   1    1    0    0    0    0    0    0    0    1
11 10 6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0 12.0 12.0 12.0 12.0 12.0
1953  142  144
 258
 115
  0.60       0.63       1.0        0.62       0.72       0.85       0.84       0.92
  0.84       0.79       1.53
0.50 0.10 0.10 0.09 0.09 0.08 0.08 0.08 0.05 .001 .001
43.0 43.5 43.5 48.0 50.0 49.0 49.0 45.0 44.0 43.0 39.0
28.0 32.0 32.0 32.5 34.0 33.5 33.5 35.0 33.0 32.5 27.0
000  0.001
  330.0    15000.0
48.5 49.0 49.0 54.0 56.0 54.5 54.5 50.5 50.5 49.0 49.0
0.80 0.30
0.50
           0.15   7.0    -0.16  1.48   0.199  0.125  1.25   43.0   43.5
 0.005     0.12      0.080     0.50      1.0       0.00      1000.0    1.00
  0.0       0.0
 0.00 0.00 0.15 1.00 4.00 5.00 5.00 4.10 0.00 0.00 0.00 0.00 0.00 0.00
 1.00 130. 150. 180. 210. 230. 250. 280. 320. 365. 305. 365.               17.
 0.0  120. 121. 182. 192. 204. 212. 222. 242. 273. 305. 365.               18.
 0.0  0.0  1.0  1.0  1.0  1.0  1.0  0.87 0.61 0.2  0.0  0.0                19.
   1 130 158 165 178 185 192 199 206 213                                   20.
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00     21.
100.0 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00     22.
 50.0 50.0 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00     23.
 40.0 27.0 18.0 13.0 2.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00     24.
 35.0 26.0 17.0 10.0 6.00 4.00 2.00 00.0 00.0 00.0 00.0 00.0 0.00 0.00     25.
```

```
 34.0 25.0 16.0 9.00 7.00 5.00 3.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00     26.
 33.0 25.0 12.0 8.00 6.00 5.00 4.00 4.00 2.00 1.00 0.00 0.00 0.00 0.00     27.
 32.0 25.0 10.0 7.00 5.00 5.00 4.00 4.00 4.00 4.00 0.00 0.00 0.00 0.00     28.
 31.0 25.0 8.00 8.00 5.00 5.00 5.00 5.00 5.00 5.00 0.00 0.00 0.00 0.00     29.
 30.0 25.0 8.00 7.00 5.00 5.00 5.00 5.00 5.00 5.00 0.00 0.00 0.00 0.00     30.
0.50
51 1 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
51 2 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
51 3 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
51 4 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
51 5 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
51 6 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
51 7 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0100.0100.0100.2200.040
51 8 0.1800.1200.1600.0900.0200.0100.0800.0500.0500.0500.1000.2000.2000.1700.110
51 9 0.0600.2400.2500.1800.1600.1100.1800.2700.0000.1700.2200.2600.2600.0500.150
5110 0.1000.0700.1900.0700.2200.1300.2300.3000.2900.1100.3300.2600.1600.2700.160
5111 0.1000.0400.0400.0400.0700.0600.0800.1300.0400.2100.2000.2100.2300.2300.150
5112 0.1400.1300.2300.1800.2300.1900.0900.0800.1200.2200.2300.2900.2200.2200.130
5113 0.1600.2000.0300.2500.2800.1300.0800.1800.2200.2100.0400.0700.0700.1200.320
5114 0.1600.2600.4200.1100.2700.3200.2700.2400.2600.3300.2700.2500.2600.2600.180
5115 0.3100.1900.2300.2800.1400.2300.2100.2900.2900.2600.2000.2100.1900.1500.200
5116 0.2900.1600.0900.1100.1100.1200.1800.1700.1200.1700.0500.1000.2300.3500.200
5117 0.0600.2500.1400.0700.0400.0500.0400.0600.1500.1600.1300.1200.1900.1200.250
5118 0.1200.1700.1700.0800.0900.2000.1800.1700.1100.0600.0300.0800.0300.1100.180
5119 0.1000.0400.0600.1100.1800.1300.1900.0500.0000.0800.0900.0400.1600.0700.190
5120 0.1200.1500.1500.1600.0300.0100.0400.0100.0000.0500.0400.0500.1100.0800.050
5121 0.0400.0500.0900.0300.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
5122 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
5123 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
5124 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
5125 0.0000.0000.0000.0000.000
 .405 .405 .405 .405 .405 .405 .497 .396 .396 .405 .405 .405
 .149 .149 .149 .149 .149 .149 .140 .153 .153 .153 .153 .153
//GO.FT11F001  DD  DSN=Z.I4323.BURL(YR1953),DISP=SHR,LABEL=(,,,IN)
```

APPENDIX C:

SAMPLE OUTPUT FROM THE COMPUTER PROGRAM

```
        3.5 IN. APPLICATION AT 70% AVAILABLE SOIL MOISTURE.
        ALBATON SOIL ON THE BOTTOM LAND OF MISSOURI RIVER VALLEY.1967 DATA

                         INITIAL SOIL MOISTURE DATA

LAYER THICK  SAT      SHC    AEWP    SMTC      FC      WP     PLAV   RESAT   TMAC   ESOILM
      INCHES PERCENT CM/HR    CM               PCT.    PCT.   IN      IN      IN      IN
             BY VOL.                          BY VOL. BY VOL.
  1    6.0   55.0    0.900   38.59    7.96   42.00   26.00   0.96    2.97    2.04    2.18
  2    6.0   55.0    0.100    9.99   11.43   40.50   29.00   0.69    2.97    2.08    2.19
  3    6.0   54.0    0.100   12.33   11.43   40.50   29.00   0.69    2.92    2.08    1.77
  4    6.0   54.0    0.090   36.31    9.69   43.00   29.00   0.84    2.92    2.16    1.78
  5    6.0   55.0    0.090   30.39    9.69   43.00   29.00   0.84    2.97    2.16    1.78
  6    6.0   55.0    0.080   30.39    9.69   43.00   29.00   0.84    2.97    2.16    1.78
  7    6.0   54.0    0.080   32.85   10.13   43.00   29.50   0.81    2.92    2.17    1.85
  8    6.0   54.0    0.080   46.71    9.55   44.00   29.50   0.87    2.92    2.20    1.86
  9    6.0   54.0    0.050   50.61    9.16   44.00   29.00   0.90    2.92    2.19    1.87
 10    6.0   55.0    0.001   42.78    9.16   44.00   29.00   0.90    2.97    2.19    1.87
 11   12.0   55.0    0.001   42.78    9.16   44.00   29.00   1.80    5.94    4.38    1.87
          TOTAL POTENTIAL STORAGE IN THE TOP TWO FEET = 11.77 INCHES
          ROOTZONE MOISTURE STORAGE AT DROUGHT STRESS = 23.12
          ROOTZONE MOISTURE AT FLOOD STRESS = 29.43
          WET SOIL INFILTRATION CAPACITY = 0.150 IN./HR.
         **************************************************************
```

```
  CURVE DATA FOR DENMEAD AND SHAW TYPE CURVES
                              PAD
            0.0     0.050   0.150   0.350   0.550   1.100
  SMET                       ETRATE
*************************************************************
    0.0     1.000   1.000   0.360   0.140   0.050   0.0
    0.050   1.000   1.000   0.490   0.180   0.090   0.0
    0.100   1.000   1.000   0.620   0.230   0.130   0.0
    0.150   1.000   1.000   0.780   0.300   0.180   0.0
    0.200   1.000   1.000   0.890   0.390   0.240   0.0
    0.250   1.000   1.000   0.930   0.520   0.320   0.0
    0.300   1.000   1.000   0.960   0.650   0.400   0.0
    0.350   1.000   1.000   0.970   0.760   0.490   0.0
    0.400   1.000   1.000   0.980   0.840   0.580   0.0
    0.450   1.000   1.000   0.985   0.910   0.660   0.0
    0.500   1.000   1.000   0.990   0.940   0.730   0.0
    0.600   1.000   1.000   0.995   0.980   0.850   0.0
    0.700   1.000   1.000   1.000   0.985   0.950   0.0
    0.800   1.000   1.000   1.000   0.995   0.980   0.0
    0.850   1.000   1.000   1.000   1.000   0.995   0.0
    1.000   1.000   1.000   1.000   1.000   1.000   0.0
*************************************************************
```

```
          DATA FOR  INFILTRATION PARAMETERS

    ASOILM=10.000 AN=-0.500 PSFC= 1.480 PW= 0.199
   CE1 =  0.125  CE2 =  1.250  FCS= 34.00  FCP=  42.00
******************************************************************

         DATA FOR OVERLAND FLOW ROUTING PARAMETERS

 FIELD AREA =     1.00 ACRES.  AVERAGE FIELD SLOPE =  0.0050
 SLOPE LENGTH =  500.0 FEET.  SURFACE ROUGHNESS COEFFICIENT =  0.120  0.080
 TRSTM =  0.500  SMALLEST TIME INTERVAL USED = 1/ ITH  OF AN HOUR
 SURFACE  STORAGE=  1.000  0.0
  SRKE=  0.0      TRST=  0.0
PSIFC= 330.00  PSIWP=  15000.0
  PASMAC=   0.50
******************************************************************


        DATA FOR IRRIGATION APPLICATION PARAMETERS

PAWRI=  0.30   GDIA=   3.50
ATPI= 35.00   TPBI=  6.00
 JDSTIRR=  152   JDENIRR=   232
 *****************************************************************
```

```
          MONTHLY SUMMARY FOR JULY     ,1967
DAY PANEVAP RAINFALL RUNOFF  AET   DPERC TILEFLO IRRIG BALANCE  SOILMOISTURE
  1   0.33    0.0     0.0    0.29   0.07   0.0    0.0   -0.000   25.33
  2   0.30    0.0     0.0    0.27   0.08   0.0    0.0   -0.000   24.99
  3   0.23    0.0     0.0    0.23   0.09   0.0    0.0    0.000   24.67
  4   0.22    0.0     0.0    0.21   0.10   0.0    0.0   -0.000   24.35
  5   0.26    0.0     0.0    0.21   0.11   0.0    0.0   -0.000   24.03
  6   0.24    0.0     0.0    0.21   0.11   0.0    0.0   -0.000   23.71
  7   0.31    0.0     0.0    0.22   0.11   0.0    0.0    0.000   23.38
  8   0.12    0.41    0.01   0.18   0.14   0.0    0.0   -0.000   23.46
  9   0.19    1.51    1.10   0.21   0.12   0.0    0.0    0.000   23.53
 10   0.27    0.0     0.0    0.24   0.09   0.0    0.0   -0.000   23.21
 11   0.27    0.0     0.0    0.24   0.08   0.0    0.0    0.000   22.89
 12   0.26    0.0     0.0    0.26   0.14   0.0    1.80   0.034   24.24
 13   0.32    0.0     0.0    0.28   0.12   0.0    1.70  -0.034   25.59
 14   0.22    0.0     0.0    0.24   0.06   0.0    0.0   -0.000   25.28
 15   0.21    0.0     0.0    0.24   0.07   0.0    0.0   -0.000   24.98
 16   0.23    0.0     0.0    0.25   0.09   0.0    0.0   -0.000   24.64
 17   0.23    0.0     0.0    0.24   0.09   0.0    0.0    0.000   24.31
 18   0.26    0.0     0.0    0.25   0.10   0.0    0.0    0.000   23.97
 19   0.16    0.0     0.0    0.21   0.10   0.0    0.0    0.000   23.66
 20   0.30    0.0     0.0    0.25   0.09   0.0    0.0   -0.000   23.31
 21   0.16    0.05    0.0    0.21   0.12   0.0    0.0   -0.000   23.03
 22   0.35    0.0     0.0    0.29   0.15   0.0    1.80   0.049   24.31
 23   0.31    0.05    0.0    0.28   0.14   0.0    1.70  -0.049   25.72
 24   0.23    0.0     0.0    0.24   0.07   0.0    0.0    0.000   25.41
 25   0.20    0.0     0.0    0.23   0.08   0.0    0.0    0.000   25.10
 26   0.20    0.0     0.0    0.23   0.09   0.0    0.0   -0.000   24.78
 27   0.24    0.0     0.0    0.24   0.09   0.0    0.0    0.000   24.44
 28   0.27    0.0     0.0    0.25   0.10   0.0    0.0   -0.000   24.10
 29   0.29    0.0     0.0    0.25   0.10   0.0    0.0    0.000   23.75
 30   0.25    0.0     0.0    0.24   0.09   0.0    0.0    0.000   23.42
 31   0.38    0.0     0.0    0.26   0.09   0.0    0.0   -0.000   23.08
 ***********************************************************************
```

```
     DETAILED INFORMATION FOR THE LAST DAY OF RUN

258       SEPTEMBER 15,1967
         PAN EVAPORATION FOR TODAY =  0.150 INCHES
        PAN COEFFICIENT =  0.396
        INTERCEPTION   =  0.153
          ASOIL =   6.908     PSOIL = 1.429   AMC =  35.229 PERCENT
          CROP LEAF AREA INDEX (CLAI) =    4.76
          PERCENT ACTIVE CANOPY (PCATRN) =   0.3984
          ROOT SYSTEM DISTRIBUTION
          30.0     25.0     8.0      7.0      5.0      5.0      5.0
           5.0      5.0     5.0
         SEASONAL RAIN FALL=   18.16
          SEASONAL IRRIGATION WATER APPLIED=   21.00
           FREQUENCY OF IRRIGATION APPLICATION=        6 TIMES
          TOTAL POTENTIAL EVAPORATION TODAY (PE) =  0.21240     INCHES
           ACCUMULATED (APET) =    37.210     INCHES
          TOTAL EVAPOTRANSPIRATION TODAY (ADET) =   0.74910E-01 INCHES
           ACCUMULATED (AAET) =    22.778     INCHES
          DEEP PERCOLATION TODAY (DPERCO) =   0.0327 INCHES
           ACCUMULATED FOR THE SEASON (SPERCO) =  11.4260 INCHES
   0.0    RUNOFF FOR DAY 258 = 0.0   IN.. SEASON TOTAL = 3.251 IN.
          INFILTRATION TODAY (DDELTF) =   0.0         INCHES
           ACCUMULATED (SDELTF) =    33.102     INCHES
          INTERCEPTION EVAPORATION TODAY (ADINT) =   0.0         INCHES.
           ACCUMULATED (AAINT) =    2.8058     INCHES
          ACTUAL SOIL EVAPORATION TODAY (DAEVAP) =  0.5635E-02 INCHES.
         ACCUMULATED SEASONAL SOIL EVAP.(AAEVAP)=   8.533     IN.
          TOTAL TRANSPIRATION TODAY (SUMTRN) =   0.69272E-01 INCHES
           ACCUMULATED (AATRAN) =    11.530     INCHES
          DEPTH OF WATER ON PLANT SURFACES
           AT THE END OF THE DAY =   0.0         INCHES
          DEPTH OF WATER IN SURFACE DEPRESSIONS AT
           THE END OF THE DAY =   0.0         INCHES
```

```
          SOIL MOISTURE    DAILY INFLOW    DAILY OUTFLOW   DAILY
          IN EACH ROOT     TO EACH ZONE    FROM EACH      TRANSPIRATION
          ZONE AT THE END                  ZONE           FROM EACH
          OF THE DAY                                      SOIL ZONE
               (INCHES)    (INCHES)        (INCHES)       (INCHES)
           1        2.084    0.0             0.00020        0.02269
           2        2.130    0.0             0.00042        0.01914
           3        2.100    0.0             0.00024        0.00590
           4        2.165    0.0             0.00040        0.00511
           5        2.157    0.0             0.00090        0.00363
           6        2.130    0.0             0.00152        0.00353
           7        2.098    0.0             0.00212        0.00327
           8        2.058    0.0             0.00276        0.00285
           9        1.952    0.0             0.00341        0.00216
          10        1.759    0.0             0.00408        0.00099
258  SEPTEMBR 15,1967  ROOTZONE MOISTURE = 20.63 IN., TOTAL = 20.63
SUBSOIL    MOISTURE  =     1.82
        TOP 5-FT INCREMENTS   4.21   4.27   4.29   4.16   3.71
  DROUGHT STRESS INDICATED
  DEPTH OF ACTIVE ROOT ZONE= 5.00FT
  ACTIVE ROOT ZONE MOISTURE=  20.63
  ARMAFC= 25.62   ARMAWP= 17.28
  ARMAI= 23.12   ARMSAT=  29.43
  DROUGHT STRESS INDICATED IN THE ACTIVE ROOT ZONE
     RAW STRESS INDEX=0.647
          ****************************************************************
```

```
     CALCULATION OF 85-DAY WEIGHTED STRESS INDEX

SILKING DATE=  8/ 11/1967

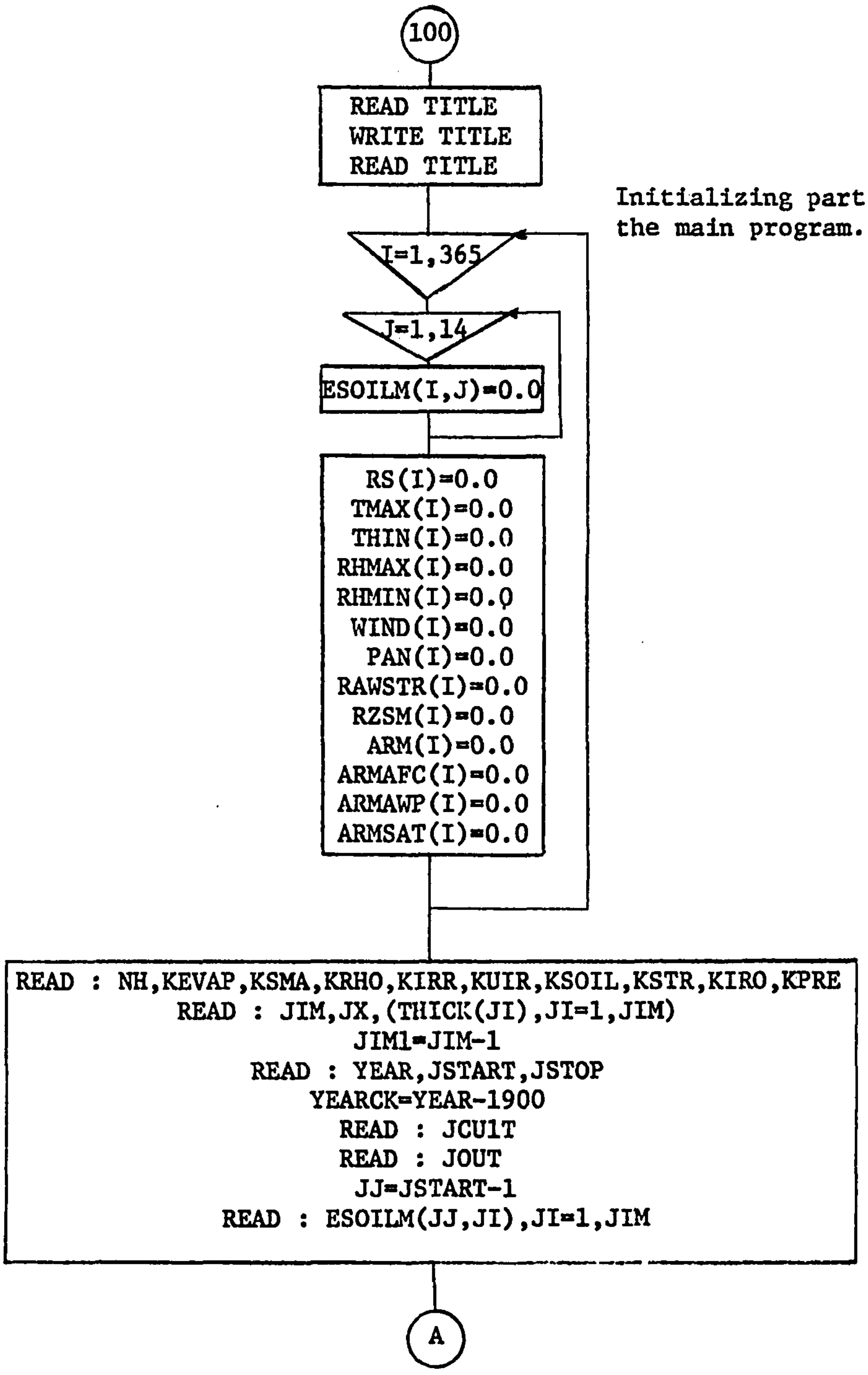
                         WEIGHTED STRESS INDEX
            PERIOD     5-DAY STR.       STR.FAC.     WT.STR.IN
                 1       0.737           2.000         1.474
                 2       0.681           1.750         1.191
                 3       0.176           1.000         0.176
                 4       0.295           1.000         0.295
                 5       0.246           1.000         0.246
                 6       0.585           1.000         0.585
                 7       0.257           0.500         0.128
                 8       0.466           0.500         0.233
                 9       0.696           2.000         1.391
                10       0.856           1.300         1.112
                11       1.569           1.300         2.040
                12       1.867           1.300         2.427
                13       2.250           1.300         2.925
                14       2.917           1.300         3.792
                15       2.607           1.200         3.128
                16       0.647           1.000         0.647
                17       0.0             0.500         0.0
            85-DAY WEIGHTED STRESS INDEX=   21.7920
       *****************************************************************
```

```
                              SOIL MOISTURE OUTPUT DETAILS
                             LAYER NUMBER
 JJ       1      2      3      4      5      6      7      8      9      10     11     12
106     2.14   2.16   1.83   1.78   1.78   1.78   1.85   1.86   1.86   1.82  18.87
107     2.12   2.14   1.87   1.79   1.78   1.79   1.85   1.87   1.86   1.78  18.82
108     2.10   2.13   1.89   1.79   1.78   1.79   1.85   1.87   1.85   1.75  18.79
109     2.13   2.14   1.90   1.80   1.78   1.79   1.85   1.86   1.84   1.73  18.82
110     2.16   2.17   1.93   1.81   1.79   1.79   1.84   1.86   1.83   1.71  18.89
111     2.14   2.16   1.94   1.82   1.79   1.79   1.84   1.86   1.82   1.69  18.86
112     2.12   2.15   1.95   1.83   1.79   1.80   1.84   1.86   1.81   1.68  18.83
113     2.11   2.14   1.95   1.84   1.80   1.80   1.84   1.85   1.80   1.67  18.80
114     2.09   2.13   1.96   1.84   1.80   1.80   1.84   1.85   1.80   1.66  18.78
115     2.48   2.38   1.98   1.86   1.81   1.80   1.84   1.84   1.79   1.65  19.43
116     2.42   2.36   2.08   1.88   1.82   1.80   1.84   1.84   1.78   1.64  19.45
117     2.36   2.32   2.10   1.90   1.82   1.80   1.84   1.84   1.77   1.63  19.40
118     2.33   2.30   2.10   1.92   1.83   1.81   1.84   1.83   1.77   1.63  19.35
119     2.30   2.28   2.10   1.94   1.85   1.81   1.84   1.83   1.76   1.62  19.31
120     2.27   2.26   2.09   1.95   1.86   1.81   1.83   1.83   1.76   1.62  19.28
121     2.25   2.24   2.09   1.96   1.87   1.82   1.83   1.82   1.75   1.61  19.25
122     2.23   2.23   2.08   1.97   1.88   1.82   1.83   1.82   1.75   1.60  19.22
123     2.21   2.22   2.08   1.98   1.89   1.83   1.83   1.82   1.75   1.60  19.19
124     2.20   2.21   2.07   1.98   1.90   1.83   1.83   1.82   1.74   1.59  19.17
125     2.21   2.21   2.07   1.99   1.91   1.84   1.83   1.81   1.74   1.59  19.18
126     2.19   2.20   2.06   1.99   1.91   1.84   1.83   1.81   1.73   1.58  19.16
127     2.18   2.19   2.06   1.99   1.92   1.85   1.83   1.81   1.73   1.58  19.14
128     2.16   2.19   2.06   2.00   1.92   1.85   1.83   1.81   1.72   1.57  19.11
129     2.19   2.19   2.05   2.00   1.93   1.86   1.83   1.80   1.72   1.57  19.14
130     2.42   2.36   2.08   2.00   1.94   1.86   1.84   1.80   1.71   1.56  19.57
131     2.38   2.33   2.11   2.01   1.94   1.87   1.84   1.80   1.71   1.56  19.54
132     2.35   2.31   2.12   2.03   1.95   1.87   1.84   1.80   1.71   1.55  19.53
133     2.31   2.29   2.12   2.04   1.96   1.88   1.84   1.80   1.71   1.55  19.48
134     2.28   2.27   2.12   2.04   1.96   1.88   1.84   1.79   1.70   1.54  19.45
135     2.26   2.25   2.12   2.05   1.97   1.88   1.84   1.79   1.70   1.54  19.41
136     2.24   2.24   2.11   2.05   1.98   1.89   1.84   1.79   1.70   1.54  19.38
137     2.22   2.22   2.10   2.06   1.98   1.89   1.84   1.79   1.70   1.54  19.34
```

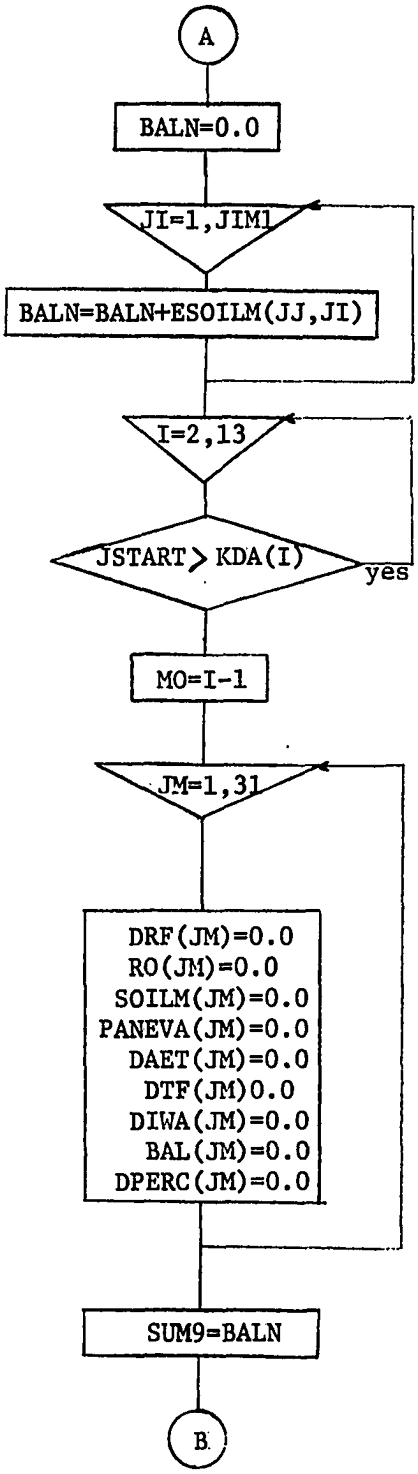
APPENDIX D:

DETAILED FLOW DIAGRAM OF COMPUTER PROGRAM

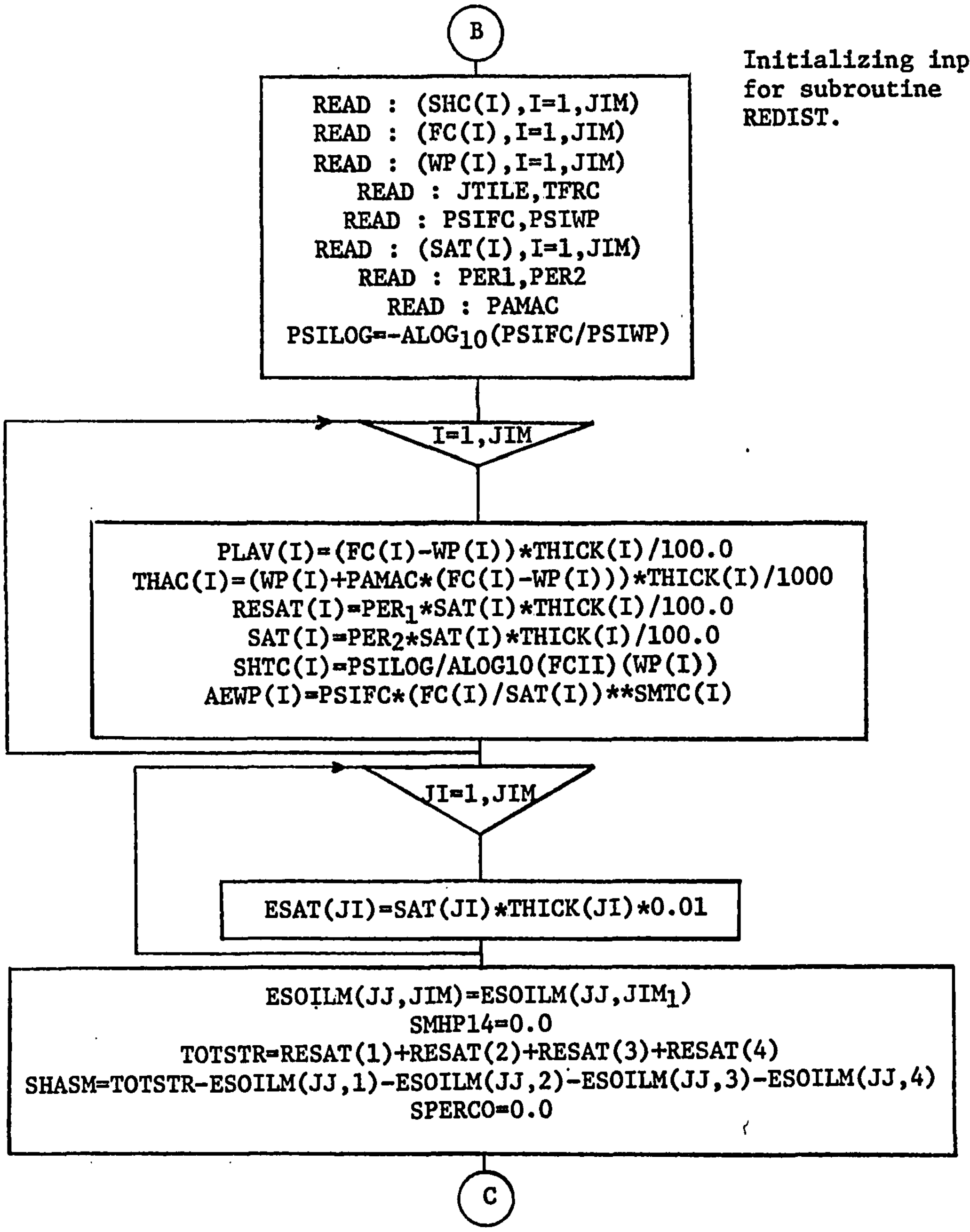
Main Program



Initializing part of
the main program.



Initialize daily values for monthly summary output.



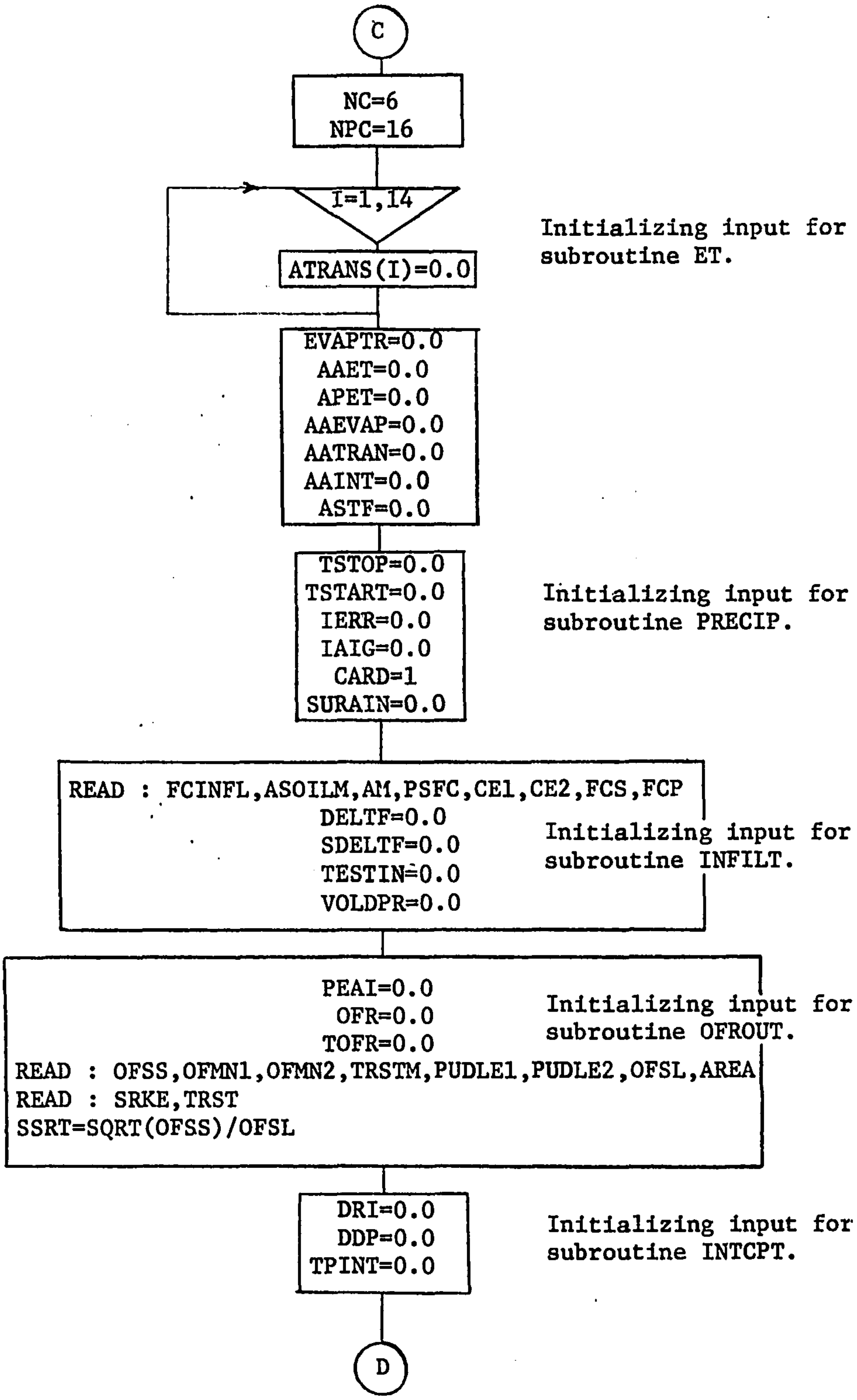
Initializing input for subroutine REDIST.

```
B
READ : (SHC(I),I=1,JIM)
READ : (FC(I),I=1,JIM)
READ : (WP(I),I=1,JIM)
READ : JTILE,TFRC
READ : PSIFC,PSIWP
READ : (SAT(I),I=1,JIM)
READ : PER1,PER2
READ : PAMAC
PSILOG=-ALOG10(PSIFC/PSIWP)

I=1,JIM
    PLAV(I)=(FC(I)-WP(I))*THICK(I)/100.0
    THAC(I)=(WP(I)+PAMAC*(FC(I)-WP(I)))*THICK(I)/1000
    RESAT(I)=PER1*SAT(I)*THICK(I)/100.0
    SAT(I)=PER2*SAT(I)*THICK(I)/100.0
    SHTC(I)=PSILOG/ALOG10(FCII)(WP(I))
    AEWP(I)=PSIFC*(FC(I)/SAT(I))**SMTC(I)

JI=1,JIM
    ESAT(JI)=SAT(JI)*THICK(JI)*0.01

ESOILM(JJ,JIM)=ESOILM(JJ,JIM1)
SMHP14=0.0
TOTSTR=RESAT(1)+RESAT(2)+RESAT(3)+RESAT(4)
SHASM=TOTSTR-ESOILM(JJ,1)-ESOILM(JJ,2)-ESOILM(JJ,3)-ESOILM(JJ,4)
SPERCO=0.0
C
```



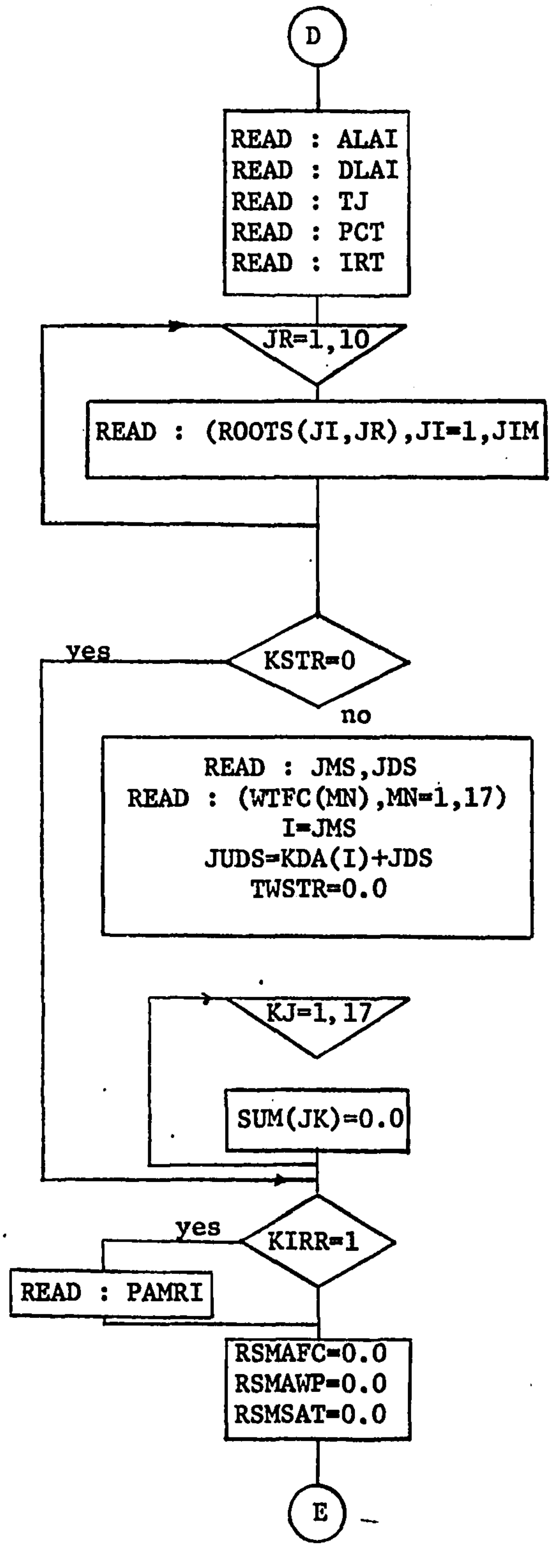
Initializing input for subroutine ET.

Initializing input for subroutine PRECIP.

Initializing input for subroutine INFILT.

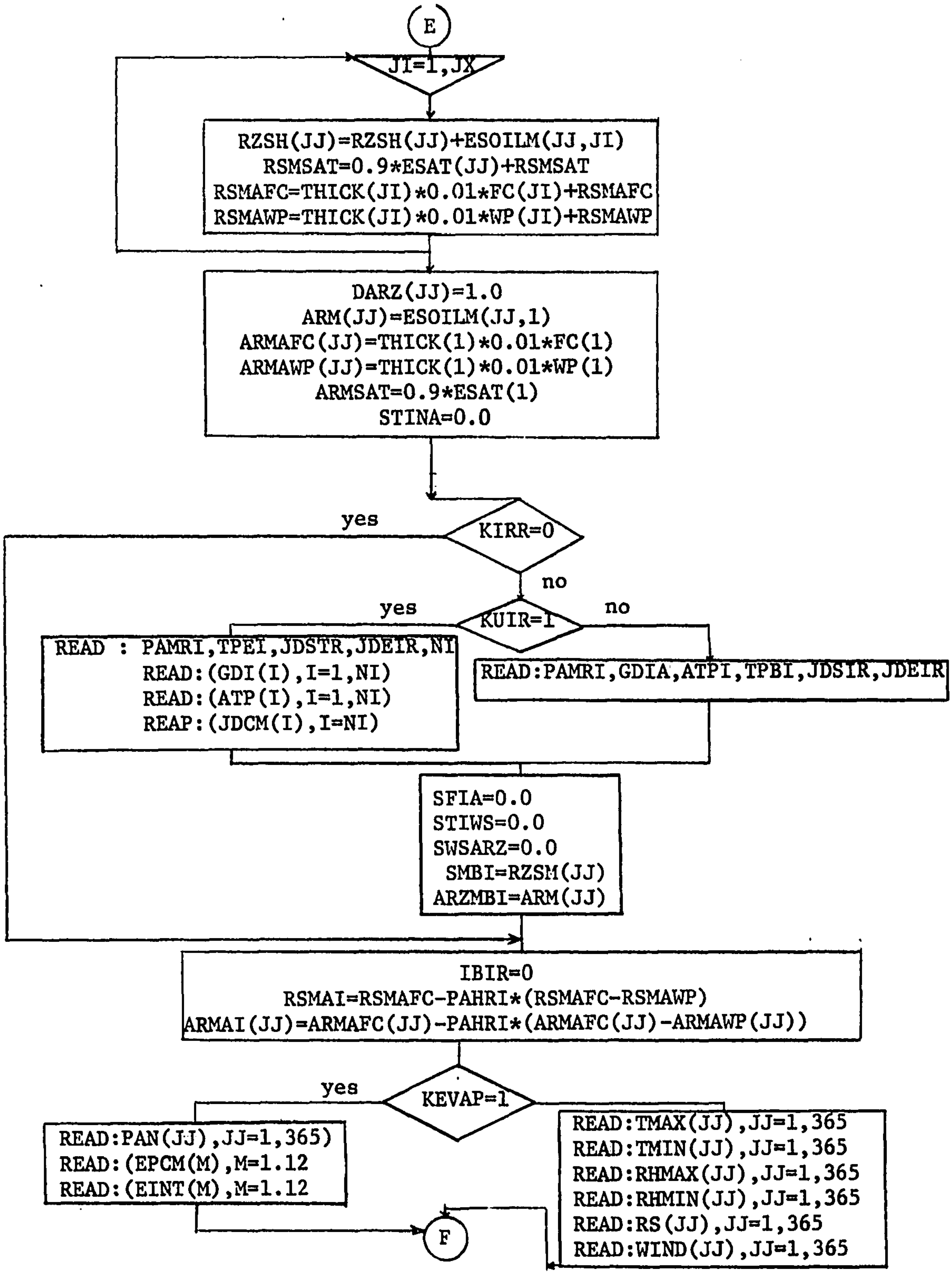
Initializing input for subroutine OFROUT.

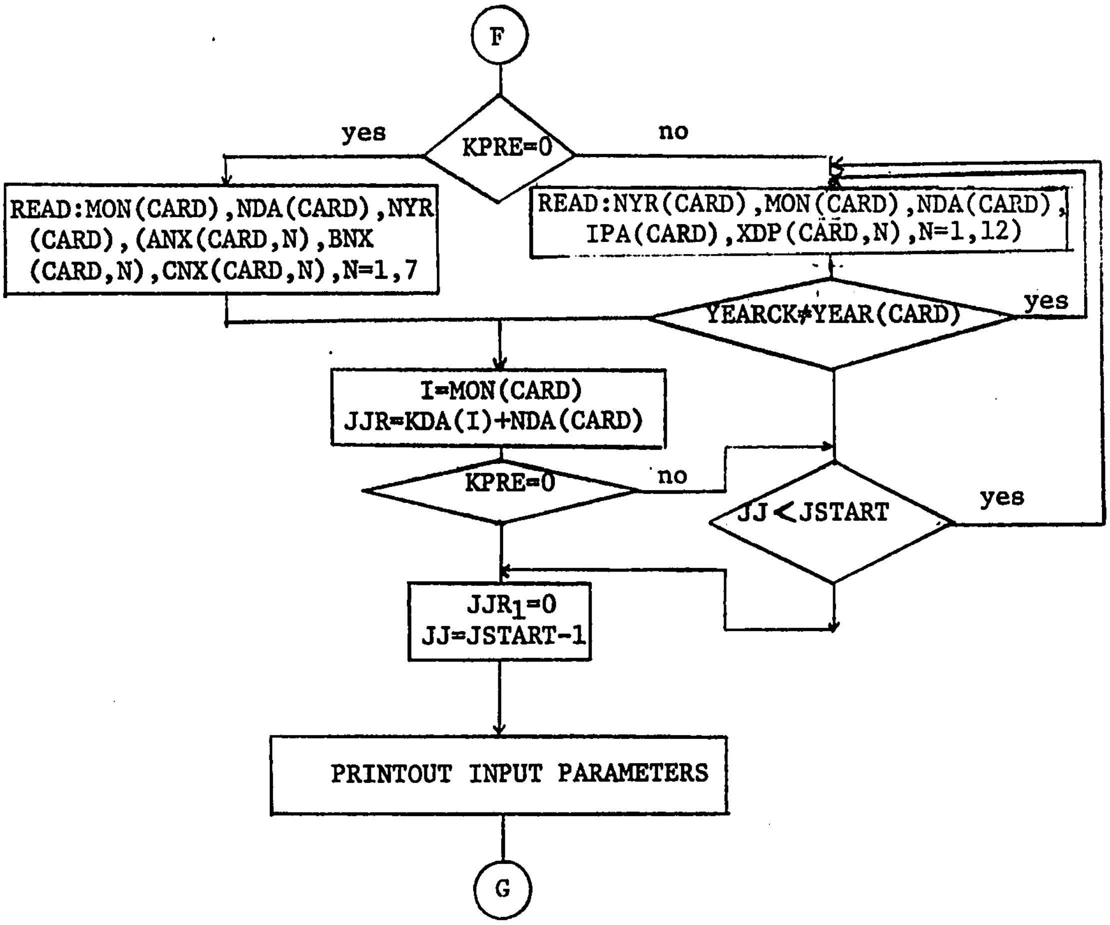
Initializing input for subroutine INTCPT.



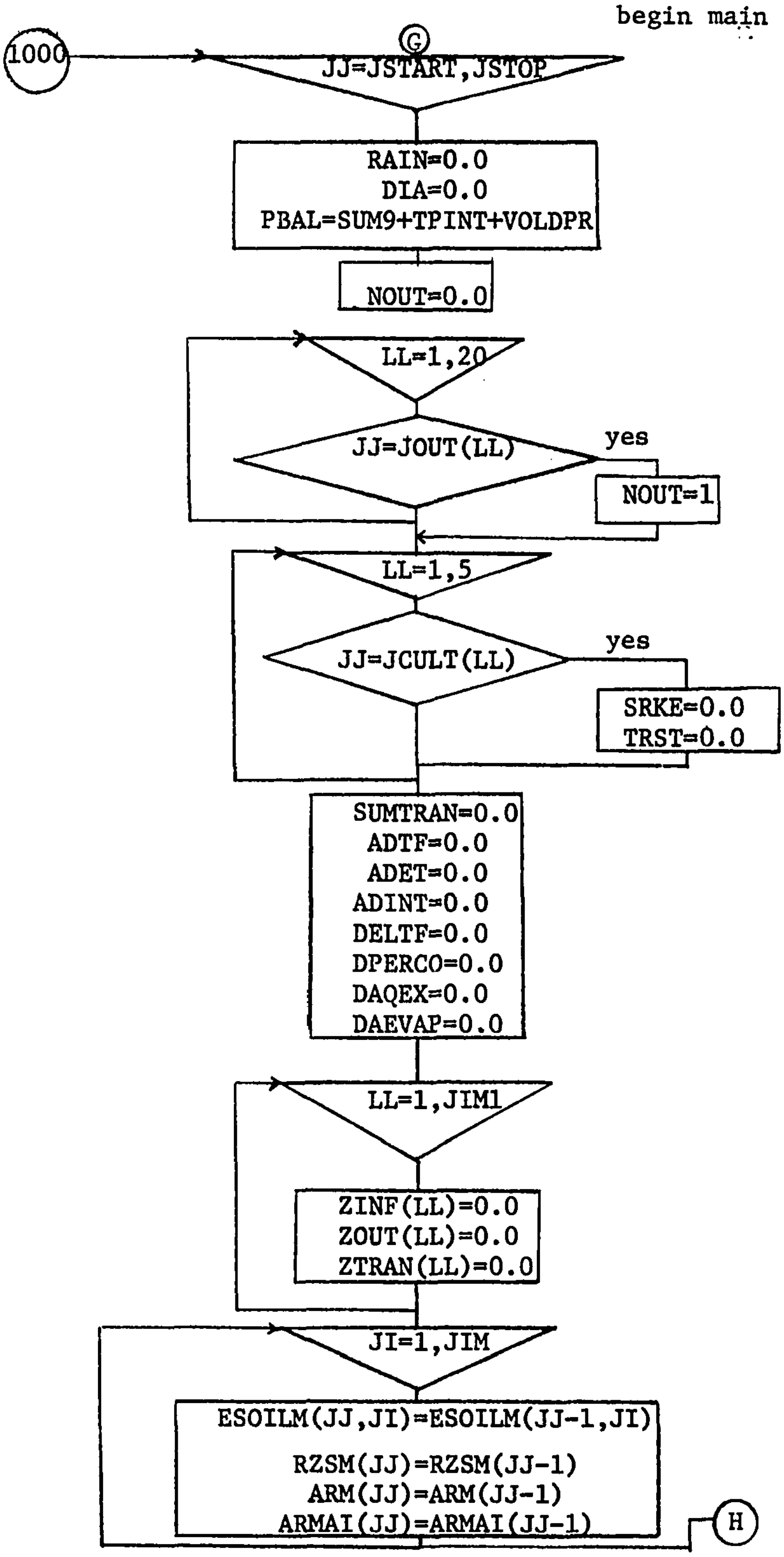
Initializing input for subroutine PLANT.

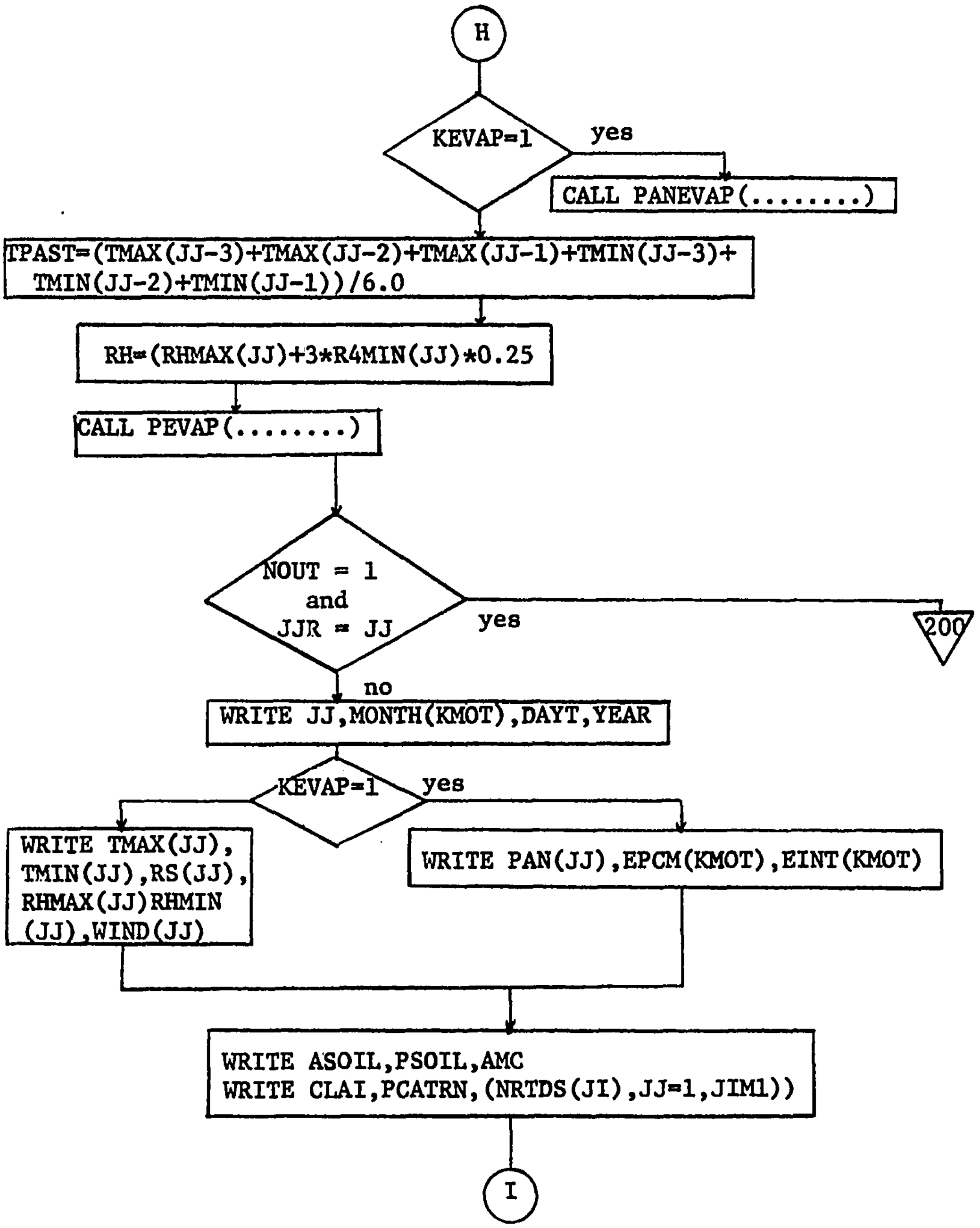
Initializing input for subroutine STRINX (only if stress index is included).

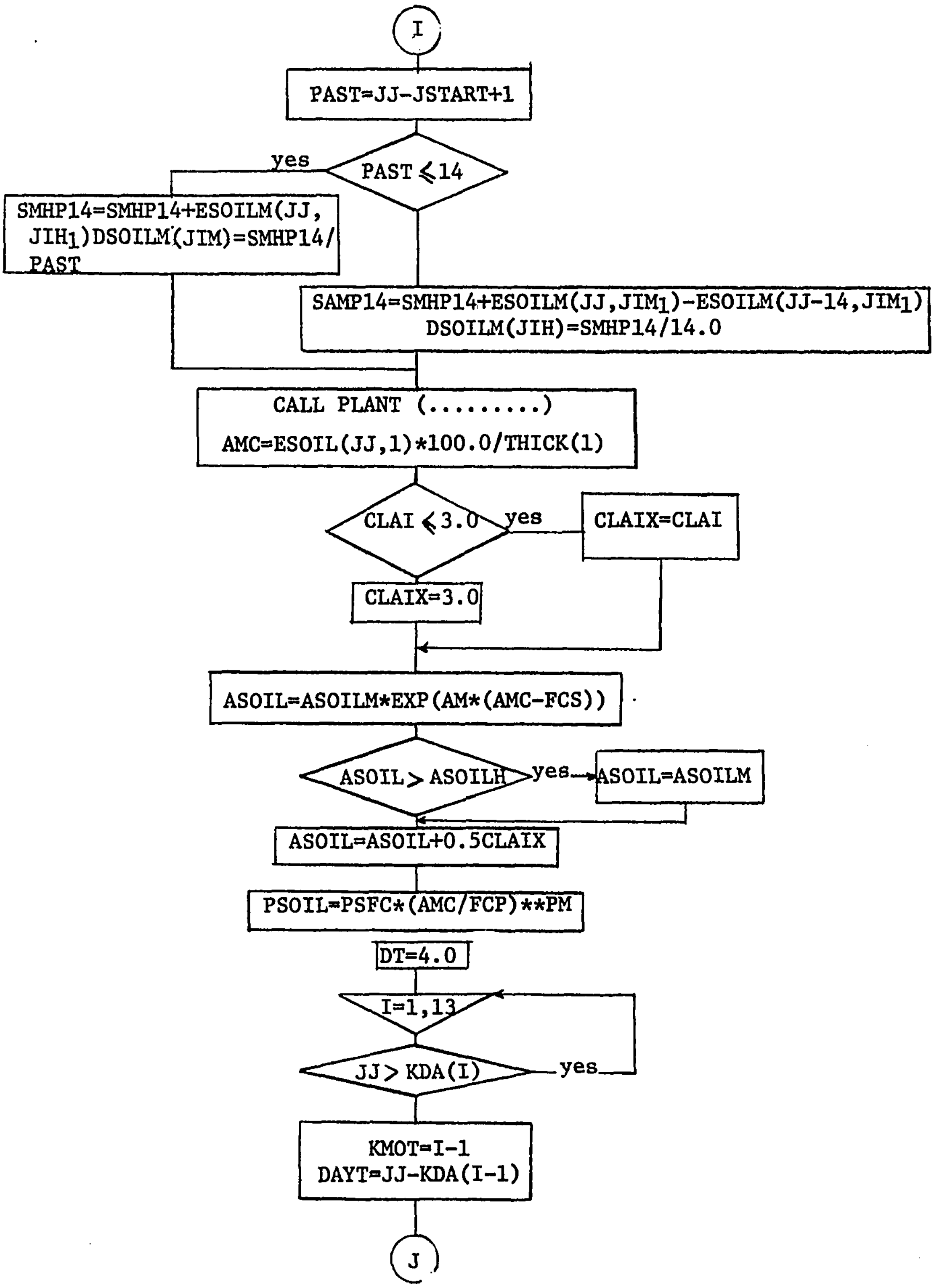

E
JI=1,JX
RZSH(JJ)=RZSH(JJ)+ESOILM(JJ,JI)
RSMSAT=0.9*ESAT(JJ)+RSMSAT
RSMAFC=THICK(JI)*0.01*FC(JI)+RSMAFC
RSMAWP=THICK(JI)*0.01*WP(JI)+RSMAWP
DARZ(JJ)=1.0
ARM(JJ)=ESOILM(JJ,1)
ARMAFC(JJ)=THICK(1)*0.01*FC(1)
ARMAWP(JJ)=THICK(1)*0.01*WP(1)
ARMSAT=0.9*ESAT(1)
STINA=0.0
yes
KIRR=0
no
yes
KUIR=1
no
READ : PAMRI,TPEI,JDSTR,JDEIR,NI
READ:(GDI(I),I=1,NI)
READ:(ATP(I),I=1,NI)
REAP:(JDCM(I),I=NI)
READ:PAMRI,GDIA,ATPI,TPBI,JDSIR,JDEIR
SFIA=0.0
STIWS=0.0
SWSARZ=0.0
SMBI=RZSM(JJ)
ARZMBI=ARM(JJ)
IBIR=0
RSMAI=RSMAFC-PAHRI*(RSMAFC-RSMAWP)
ARMAI(JJ)=ARMAFC(JJ)-PAHRI*(ARMAFC(JJ)-ARMAWP(JJ))
yes
KEVAP=1
READ:PAN(JJ),JJ=1,365)
READ:(EPCM(M),M=1.12
READ:(EINT(M),M=1.12
READ:TMAX(JJ),JJ=1,365
READ:TMIN(JJ),JJ=1,365
READ:RHMAX(JJ),JJ=1,365
READ:RHMIN(JJ),JJ=1,365
READ:RS(JJ),JJ=1,365
READ:WIND(JJ),JJ=1,365
F

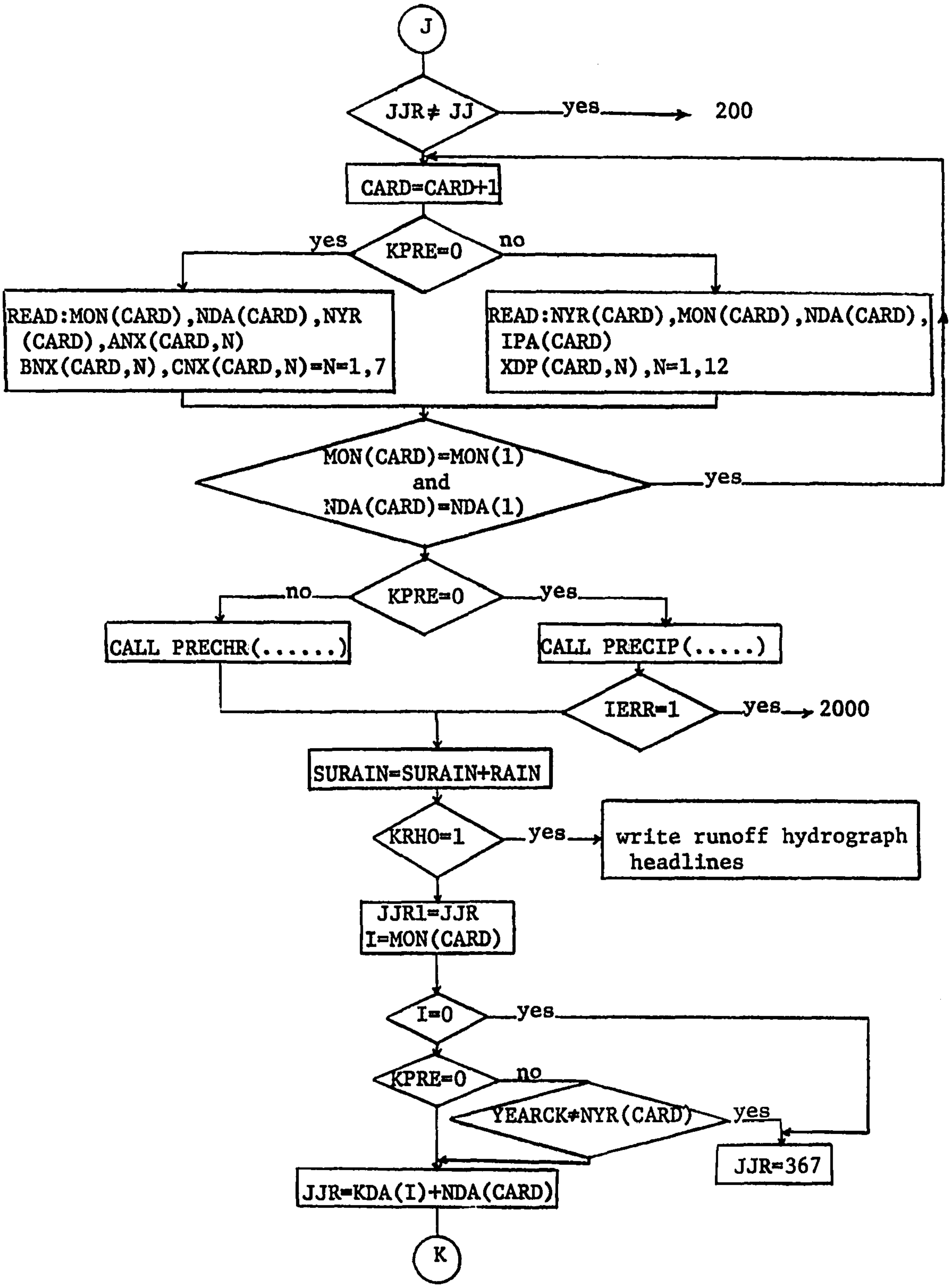

F
KPRE=0
yes
no
READ:MON(CARD),NDA(CARD),NYR(CARD),(ANX(CARD,N),BNX(CARD,N),CNX(CARD,N),N=1,7
READ:NYR(CARD),MON(CARD),NDA(CARD),IPA(CARD),XDP(CARD,N),N=1,12)
YEARCK≠YEAR(CARD)
yes
I=MON(CARD)
JJR=KDA(I)+NDA(CARD)
KPRE=0
no
JJ<JSTART
yes
JJR1=0
JJ=JSTART-1
PRINTOUT INPUT PARAMETERS
G

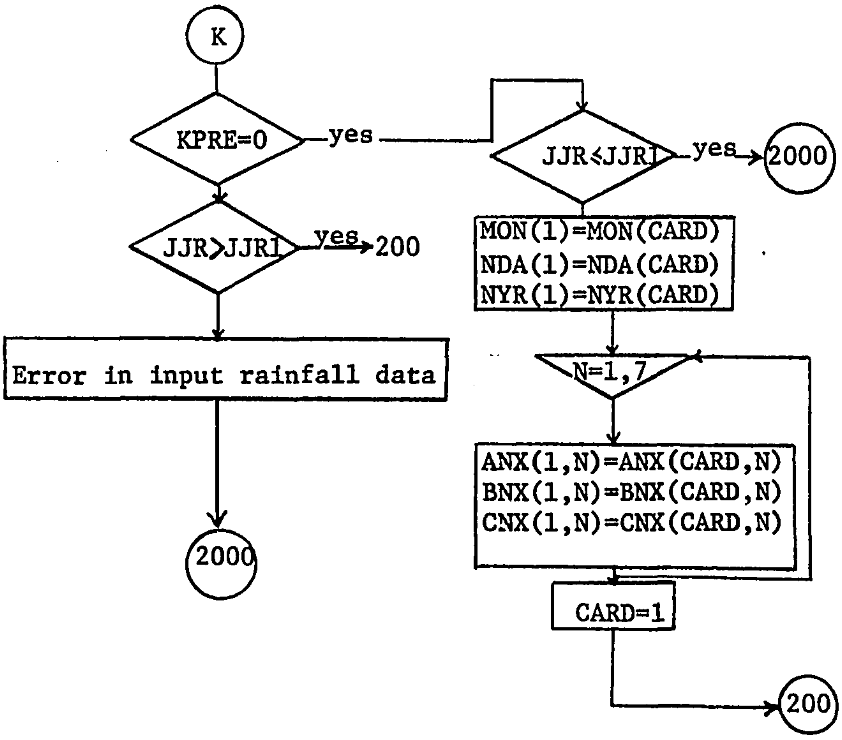
begin main execution loop

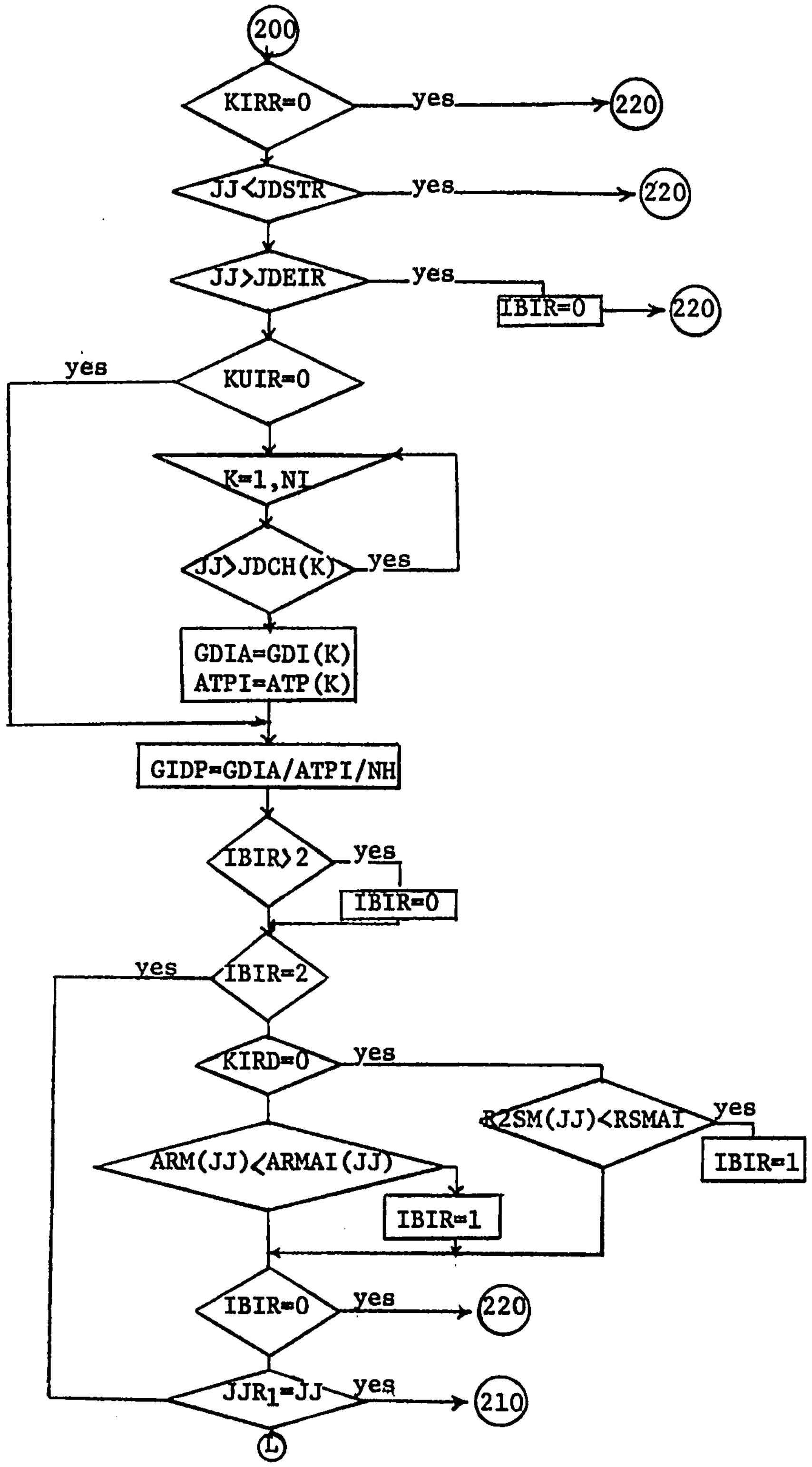


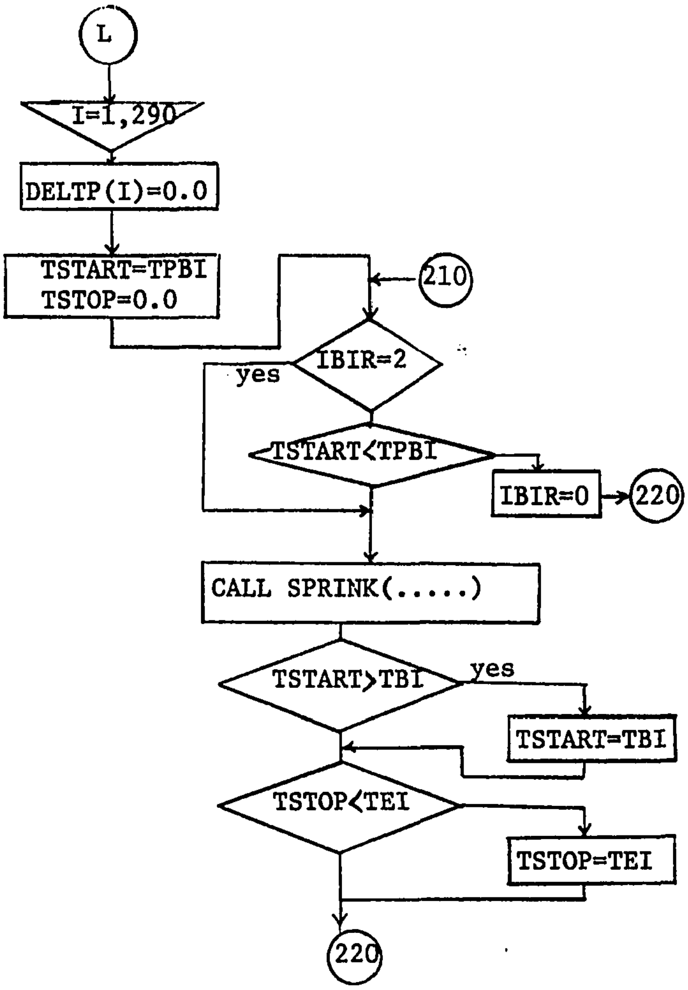

H
KEVAP=1
yes
CALL PANEVAP(........)
TPAST=(TMAX(JJ-3)+TMAX(JJ-2)+TMAX(JJ-1)+TMIN(JJ-3)+ TMIN(JJ-2)+TMIN(JJ-1))/6.0
RH=(RHMAX(JJ)+3*R4MIN(JJ)*0.25
CALL PEVAP(........)
NOUT = 1 and JJR = JJ
yes
200
no
WRITE JJ,MONTH(KMOT),DAYT,YEAR
KEVAP=1
yes
WRITE TMAX(JJ), TMIN(JJ),RS(JJ), RHMAX(JJ)RHMIN (JJ),WIND(JJ)
WRITE PAN(JJ),EPCM(KMOT),EINT(KMOT)
WRITE ASOIL,PSOIL,AMC
WRITE CLAI,PCATRN,(NRTDS(JI),JJ=1,JIM1))
I

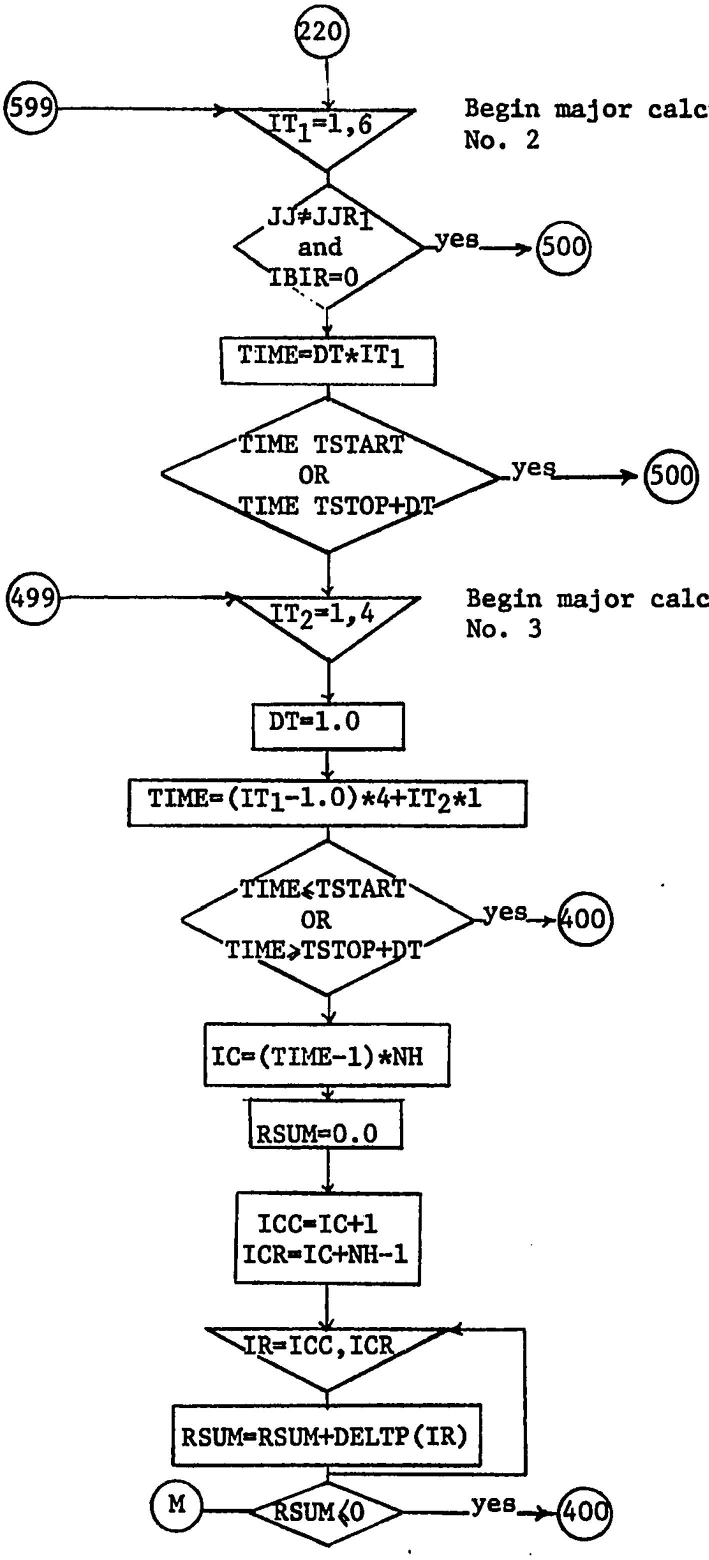

I
PAST=JJ-JSTART+1
PAST ≤14
yes
SMHP14=SMHP14+ESOILM(JJ, JIH1)DSOILM(JIM)=SMHP14/ PAST
SAMP14=SMHP14+ESOILM(JJ,JIM1)-ESOILM(JJ-14,JIM1)
DSOILM(JIH)=SMHP14/14.0
CALL PLANT (.........)
AMC=ESOIL(JJ,1)*100.0/THICK(1)
CLAI ≤3.0
yes
CLAIX=CLAI
CLAIX=3.0
ASOIL=ASOILM*EXP(AM*(AMC-FCS))
ASOIL > ASOILH
yes
ASOIL=ASOILM
ASOIL=ASOIL+0.5CLAIX
PSOIL=PSFC*(AMC/FCP)**PM
DT=4.0
I=1,13
JJ > KDA(I)
yes
KMOT=I-1
DAYT=JJ-KDA(I-1)
J


J
JJR≠ JJ
yes
200
CARD=CARD+1
yes
KPRE=0
no
READ:MON(CARD),NDA(CARD),NYR (CARD),ANX(CARD,N) BNX(CARD,N),CNX(CARD,N)=N=1,7
READ:NYR(CARD),MON(CARD),NDA(CARD), IPA(CARD) XDP(CARD,N),N=1,12
MON(CARD)=MON(1) and NDA(CARD)=NDA(1)
yes
no
KPRE=0
yes
CALL PRECHR(......)
CALL PRECIP(.....)
IERR=1
yes
2000
SURAIN=SURAIN+RAIN
KRHO=1
yes
write runoff hydrograph headlines
JJR1=JJR
I=MON(CARD)
I=0
yes
KPRE=0
no
YEARCK≠NYR(CARD)
yes
JJR=367
JJR=KDA(I)+NDA(CARD)
K


K
KPRE=0
yes
JJR>JJR1
yes
200
Error in input rainfall data
2000
JJR<JJR1
yes
2000
MON(1)=MON(CARD)
NDA(1)=NDA(CARD)
NYR(1)=NYR(CARD)
N=1,7
ANX(1,N)=ANX(CARD,N)
BNX(1,N)=BNX(CARD,N)
CNX(1,N)=CNX(CARD,N)
CARD=1
200

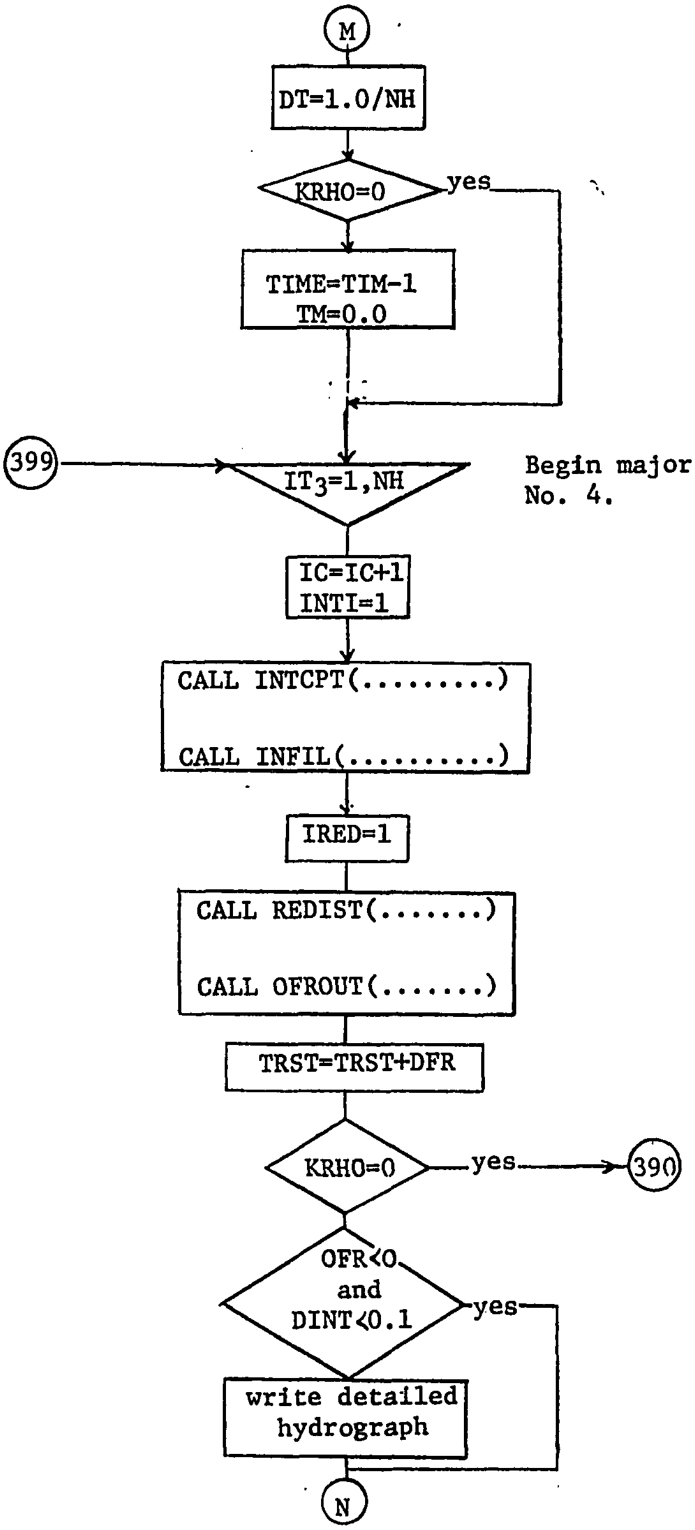

200
KIRR=0
yes
220
JJ<JDSTR
yes
220
JJ>JDEIR
yes
IBIR=0
220
KUIR=0
yes
K=1,NI
JJ>JDCH(K)
yes
GDIA=GDI(K)
ATPI=ATP(K)
GIDP=GDIA/ATPI/NH
IBIR>2
yes
IBIR=0
IBIR=2
yes
KIRD=0
yes
R2SM(JJ)<RSMAI
yes
IBIR=1
ARM(JJ)<ARMAI(JJ)
IBIR=1
IBIR=0
yes
220
JJR1=JJ
yes
210
L


L
I=1,290
DELTP(I)=0.0
TSTART=TPBI
TSTOP=0.0
210
IBIR=2
yes
TSTART<TPBI
IBIR=0
220
CALL SPRINK(.....)
TSTART>TBI
yes
TSTART=TBI
TSTOP<TEI
TSTOP=TEI
220

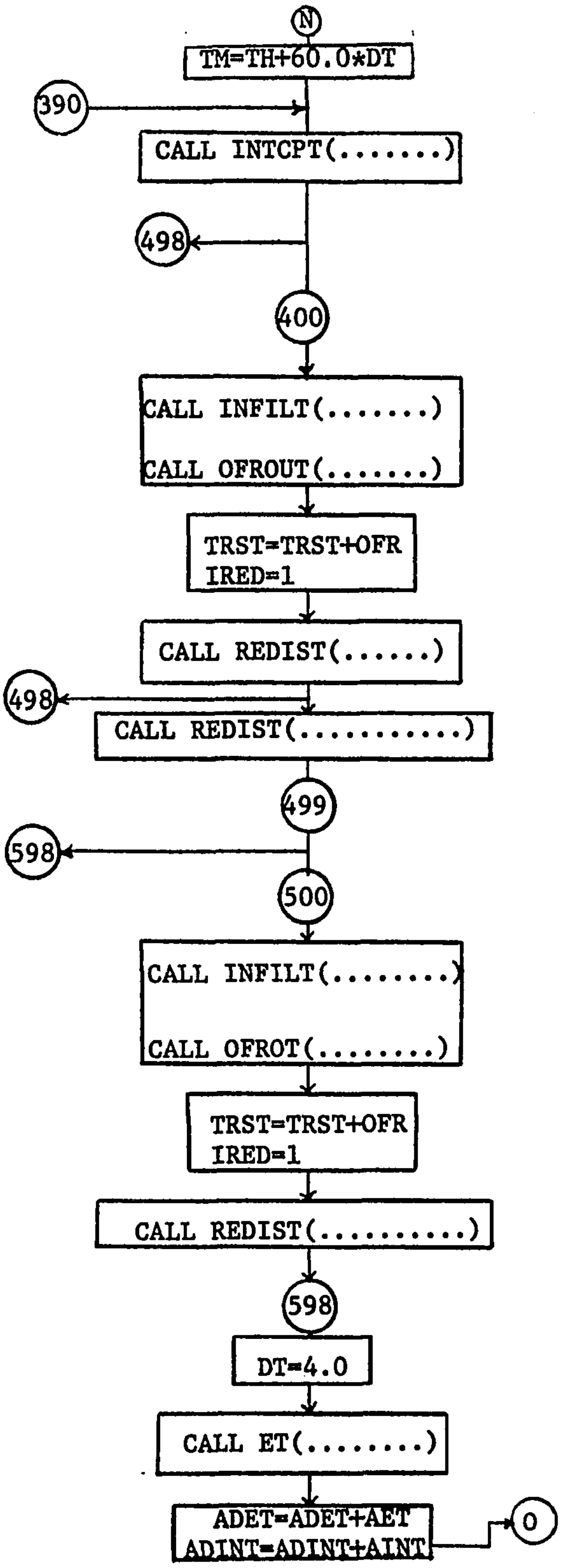


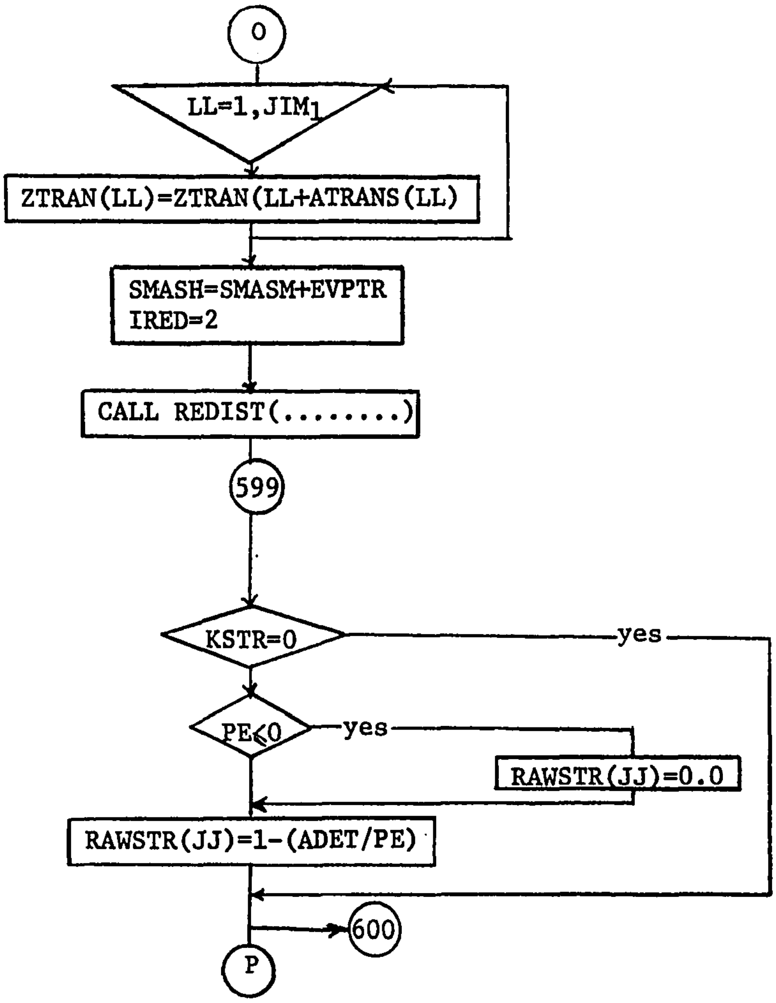
Begin major calculating loop No. 2

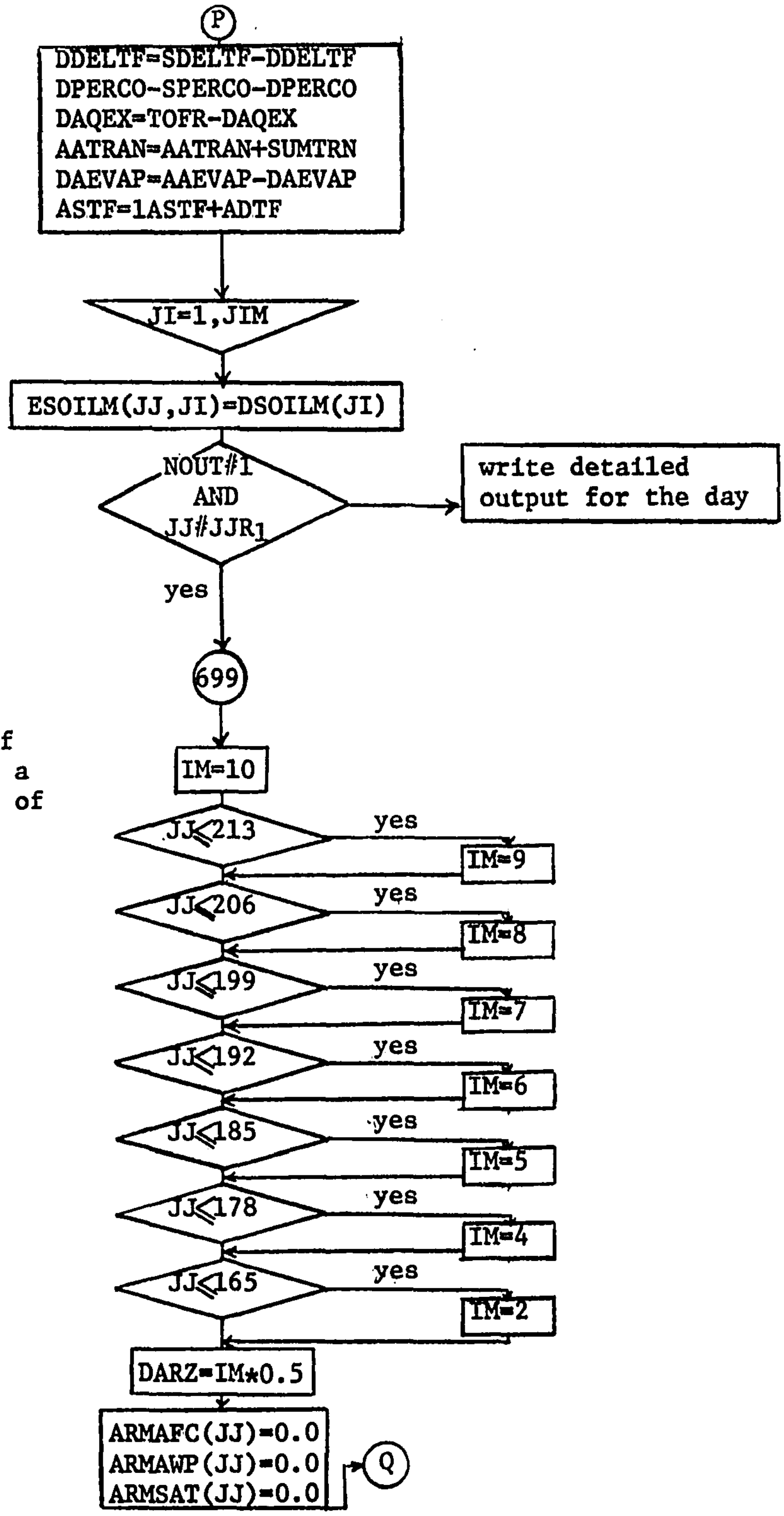
Begin major calculating loop No. 3



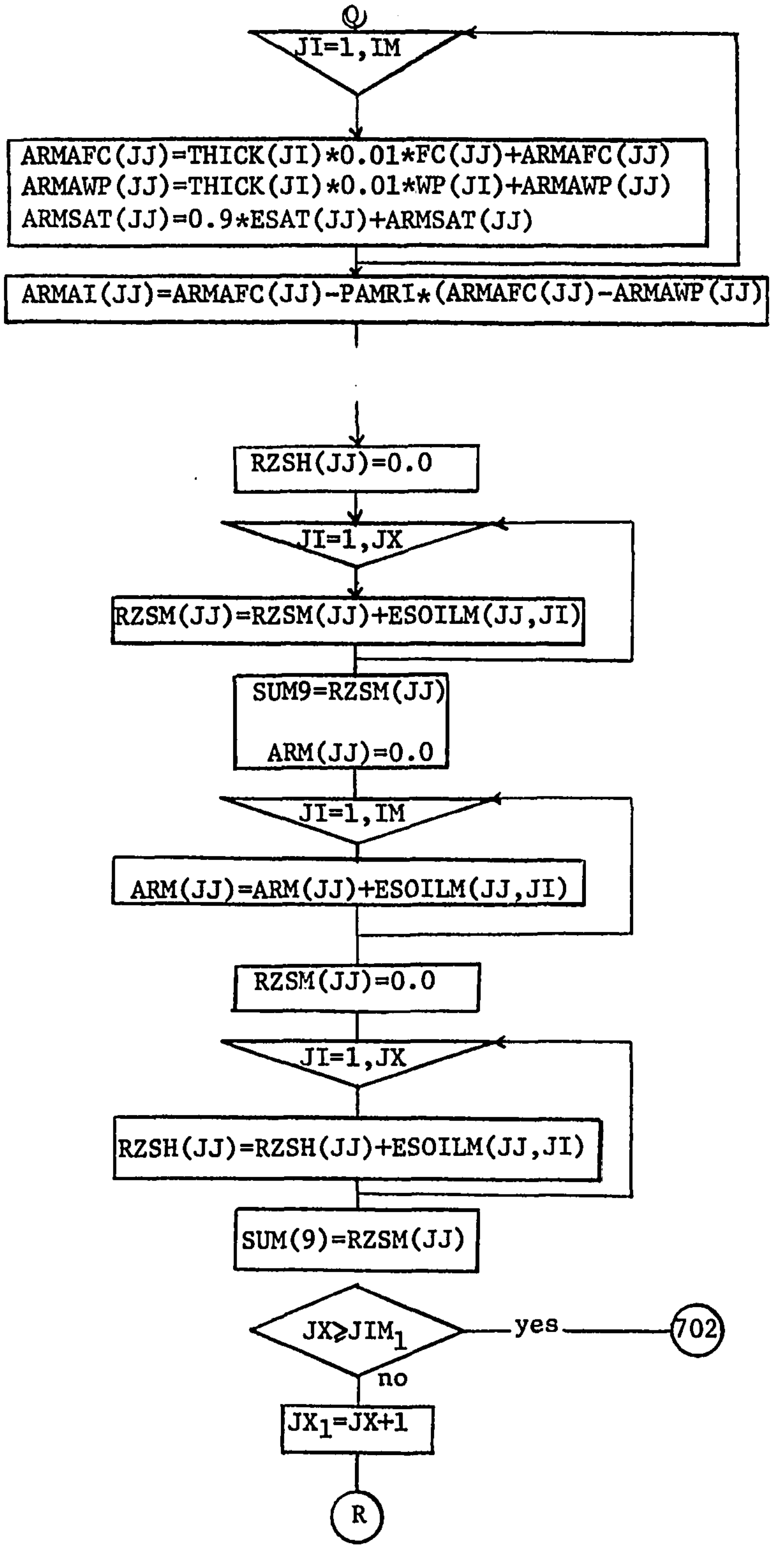
Begin major calculating loop No. 4.

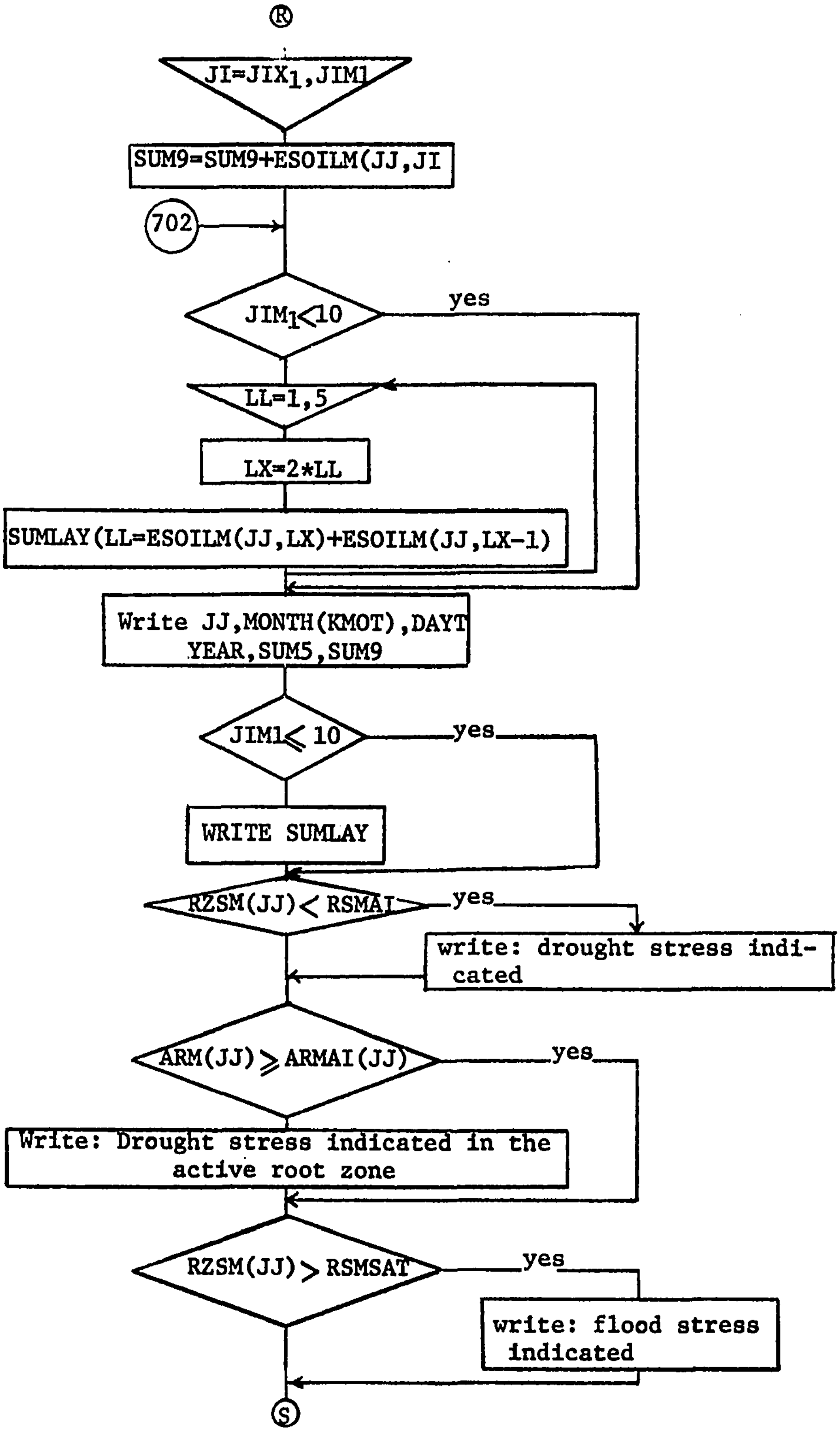

N
TM=TH+60.0*DT
390
CALL INTCPT(.......)
498
400
CALL INFILT(.......)
CALL OFROUT(.......)
TRST=TRST+OFR
IRED=1
CALL REDIST(......)
498
CALL REDIST(...........)
499
598
500
CALL INFILT(........)
CALL OFROT(........)
TRST=TRST+OFR
IRED=1
CALL REDIST(..........)
598
DT=4.0
CALL ET(........)
ADET=ADET+AET
ADINT=ADINT+AINT
O

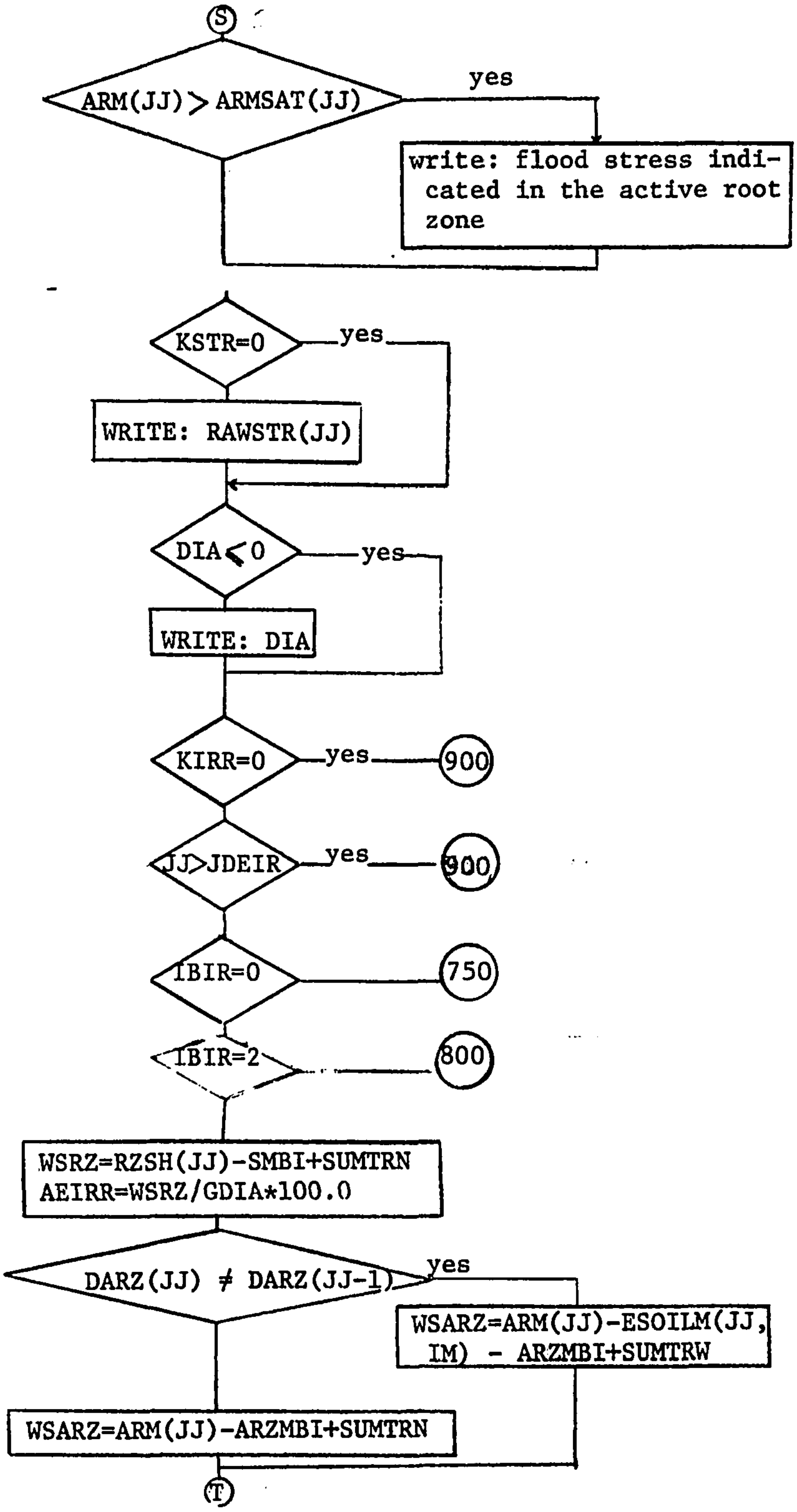

O
LL=1,JIM1
ZTRAN(LL)=ZTRAN(LL+ATRANS(LL)
SMASH=SMASM+EVPTR
IRED=2
CALL REDIST(........)
599
KSTR=0
yes
PE<0
yes
RAWSTR(JJ)=0.0
RAWSTR(JJ)=1-(ADET/PE)
600
P

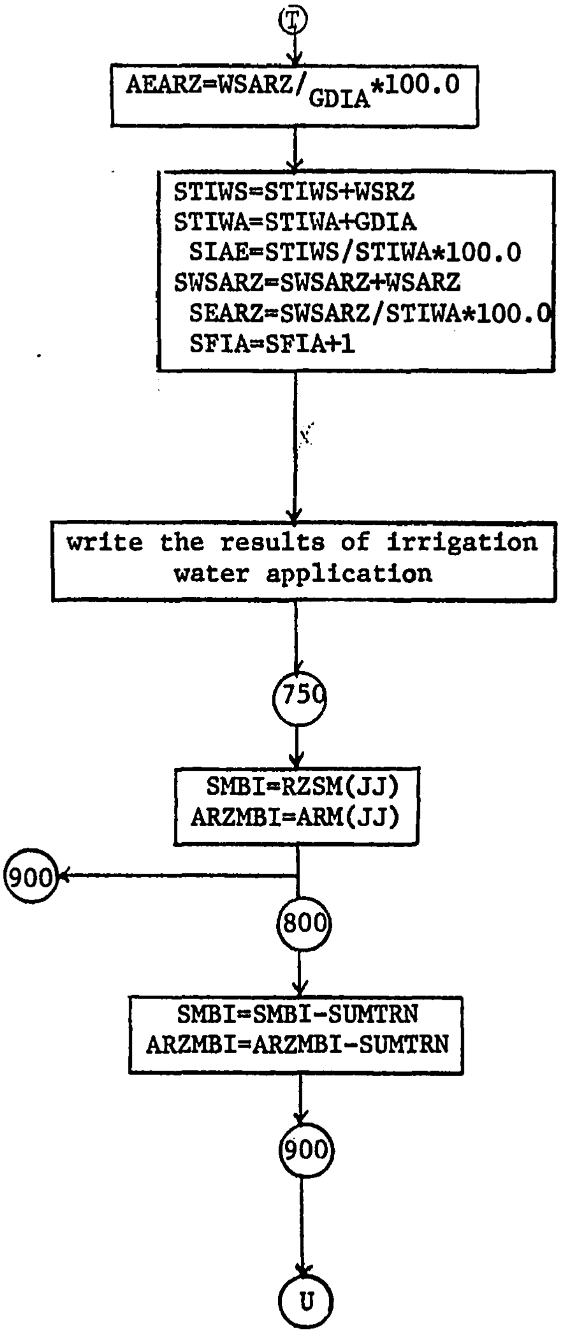


Determining depth of active root zone as a junction of the day of the year.

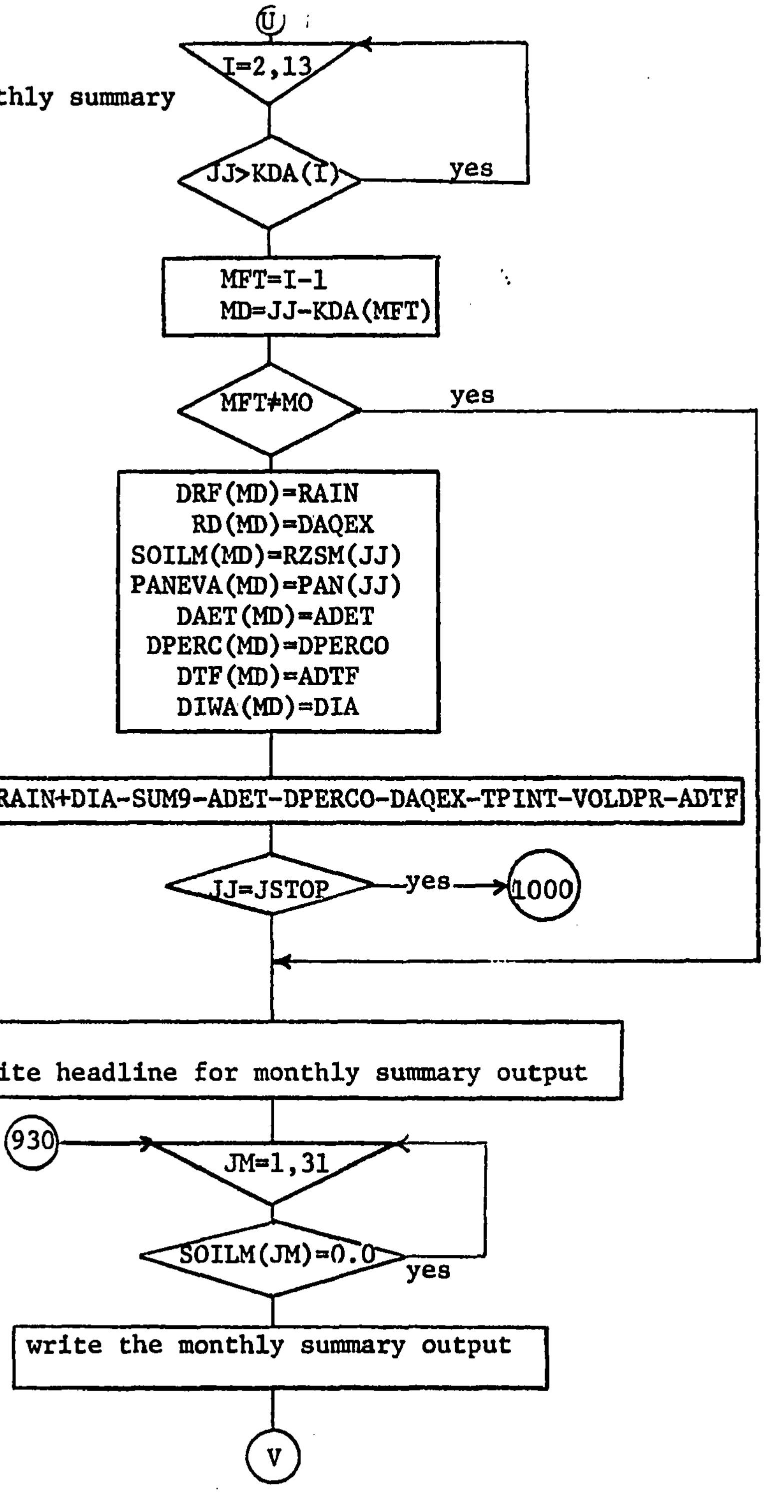

Q
JI=1,IM
ARMAFC(JJ)=THICK(JI)*0.01*FC(JJ)+ARMAFC(JJ)
ARMAWP(JJ)=THICK(JI)*0.01*WP(JI)+ARMAWP(JJ)
ARMSAT(JJ)=0.9*ESAT(JJ)+ARMSAT(JJ)
ARMAI(JJ)=ARMAFC(JJ)-PAMRI*(ARMAFC(JJ)-ARMAWP(JJ)
RZSH(JJ)=0.0
JI=1,JX
RZSM(JJ)=RZSM(JJ)+ESOILM(JJ,JI)
SUM9=RZSM(JJ)
ARM(JJ)=0.0
JI=1,IM
ARM(JJ)=ARM(JJ)+ESOILM(JJ,JI)
RZSM(JJ)=0.0
JI=1,JX
RZSH(JJ)=RZSH(JJ)+ESOILM(JJ,JI)
SUM(9)=RZSM(JJ)
JX≥JIM1
yes
702
no
JX1=JX+1
R

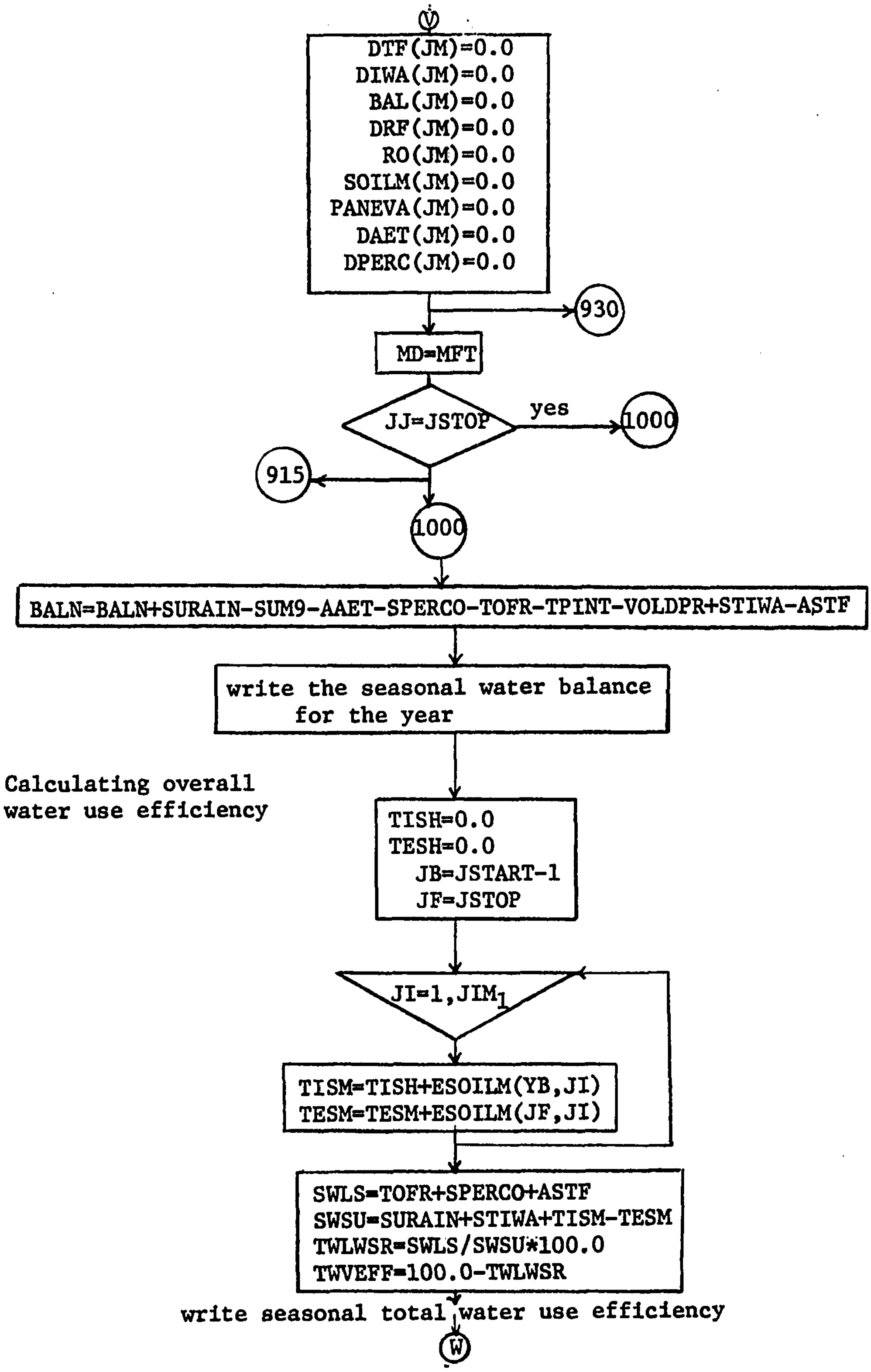

R
JI=JIX1,JIM1
SUM9=SUM9+ESOILM(JJ,JI
702
JIM1<10
yes
LL=1,5
LX=2*LL
SUMLAY(LL=ESOILM(JJ,LX)+ESOILM(JJ,LX-1)
Write JJ,MONTH(KMOT),DAYT YEAR,SUM5,SUM9
JIM1≤ 10
yes
WRITE SUMLAY
RZSM(JJ)< RSMAI
yes
write: drought stress indicated
ARM(JJ)≥ARMAI(JJ)
yes
Write: Drought stress indicated in the active root zone
RZSM(JJ)> RSMSAT
yes
write: flood stress indicated
S

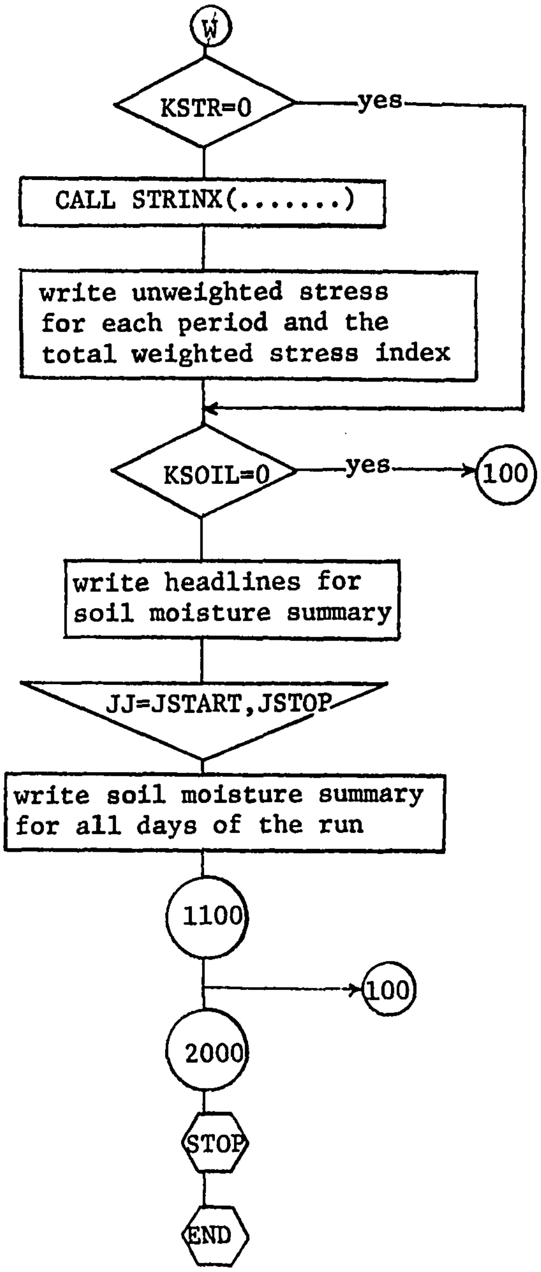

S
ARM(JJ) > ARMSAT(JJ)
yes
write: flood stress indicated in the active root zone
KSTR=0
yes
WRITE: RAWSTR(JJ)
DIA < 0
yes
WRITE: DIA
KIRR=0
yes
900
JJ>JDEIR
yes
900
IBIR=0
750
IBIR=2
800
WSRZ=RZSH(JJ)-SMBI+SUMTRN
AEIRR=WSRZ/GDIA*100.0
DARZ(JJ) ≠ DARZ(JJ-1)
yes
WSARZ=ARM(JJ)-ESOILM(JJ, IM) - ARZMBI+SUMTRW
WSARZ=ARM(JJ)-ARZMBI+SUMTRN
T

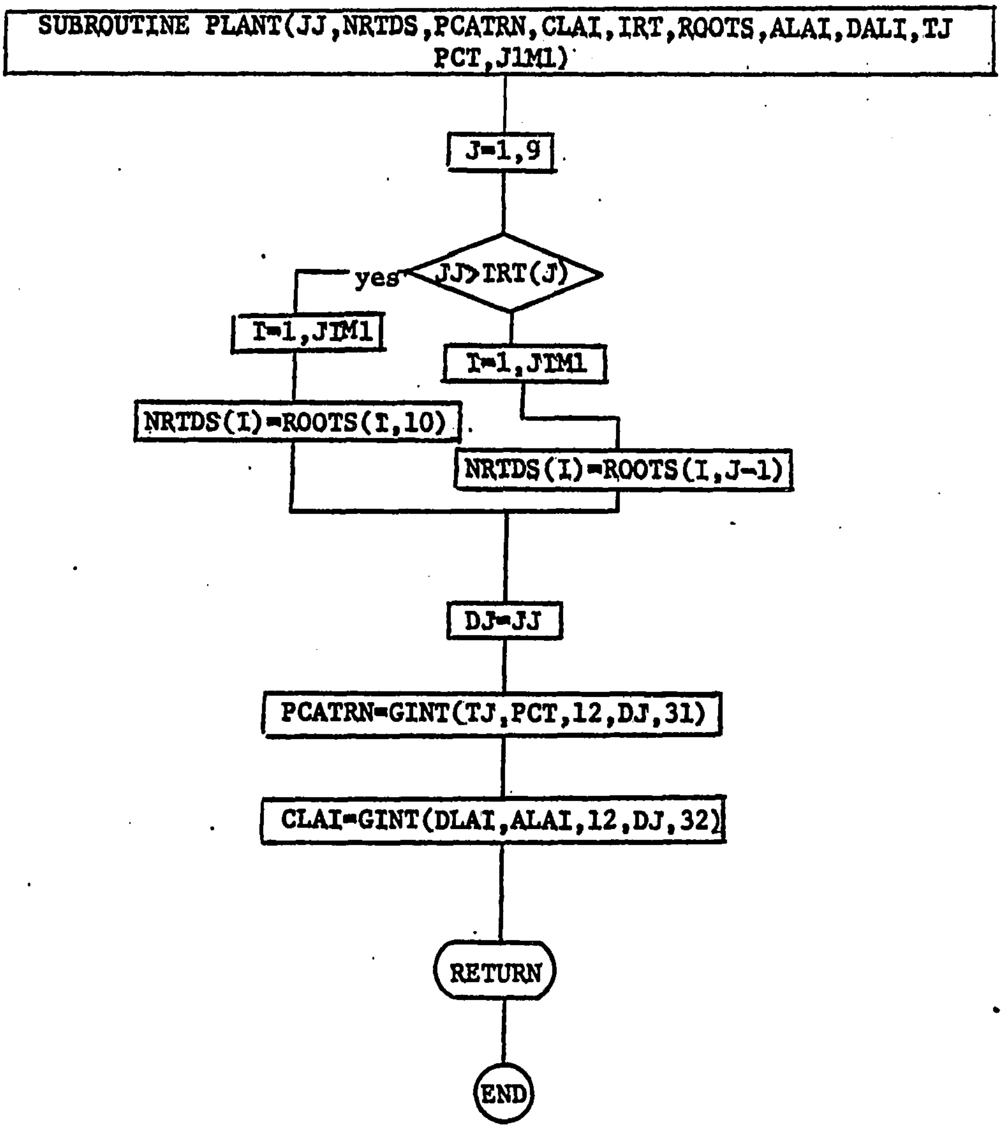

T
AEARZ=WSARZ/GDIA*100.0
STIWS=STIWS+WSRZ
STIWA=STIWA+GDIA
SIAE=STIWS/STIWA*100.0
SWSARZ=SWSARZ+WSARZ
SEARZ=SWSARZ/STIWA*100.0
SFIA=SFIA+1
write the results of irrigation water application
750
SMBI=RZSM(JJ)
ARZMBI=ARM(JJ)
900
800
SMBI=SMBI-SUMTRN
ARZMBI=ARZMBI-SUMTRN
900
U

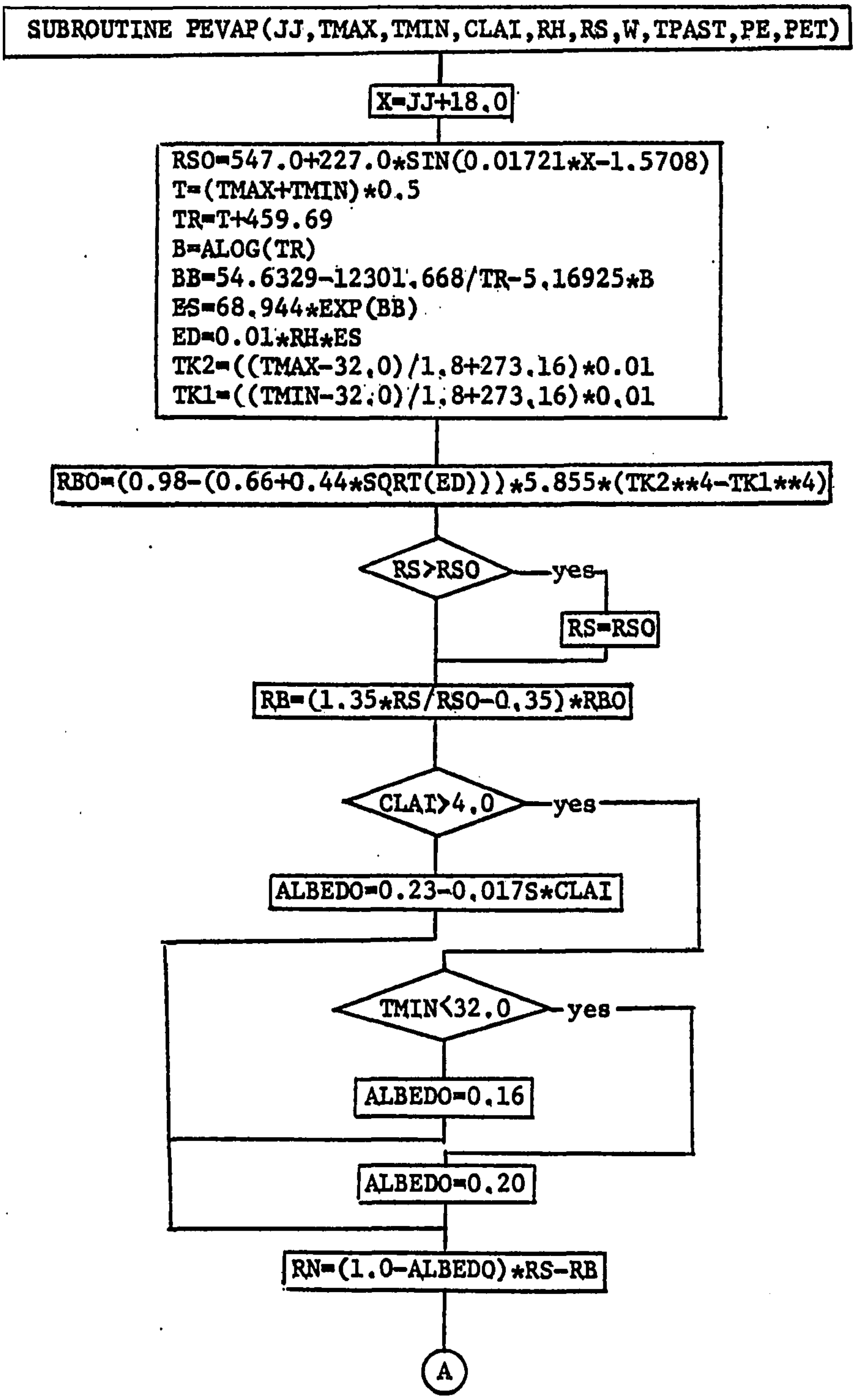
Determining monthly summary output.



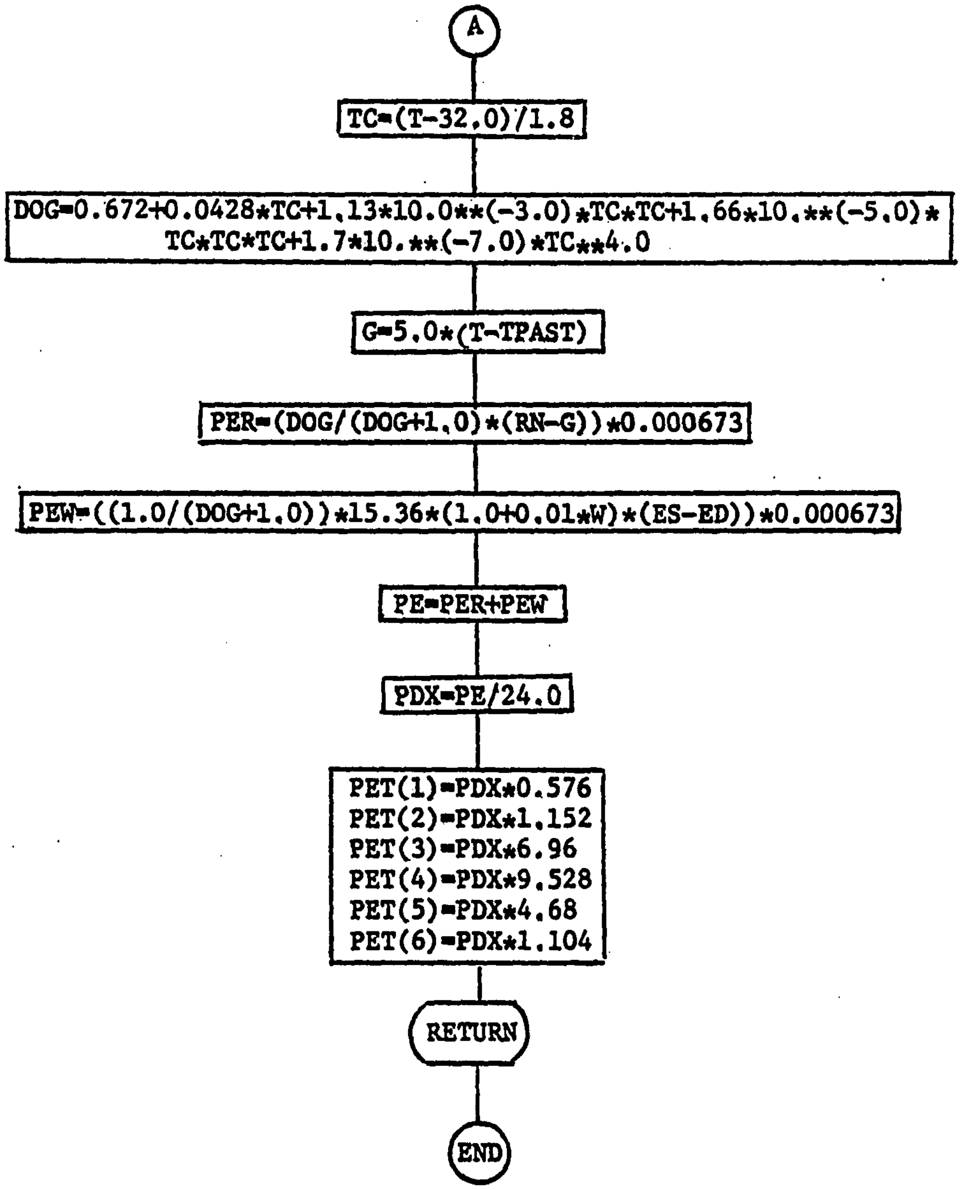

Calculating overall water use efficiency


W
KSTR=0
yes
CALL STRINX(.......)
write unweighted stress for each period and the total weighted stress index
KSOIL=0
yes
100
write headlines for soil moisture summary
JJ=JSTART,JSTOP
write soil moisture summary for all days of the run
1100
100
2000
STOP
END

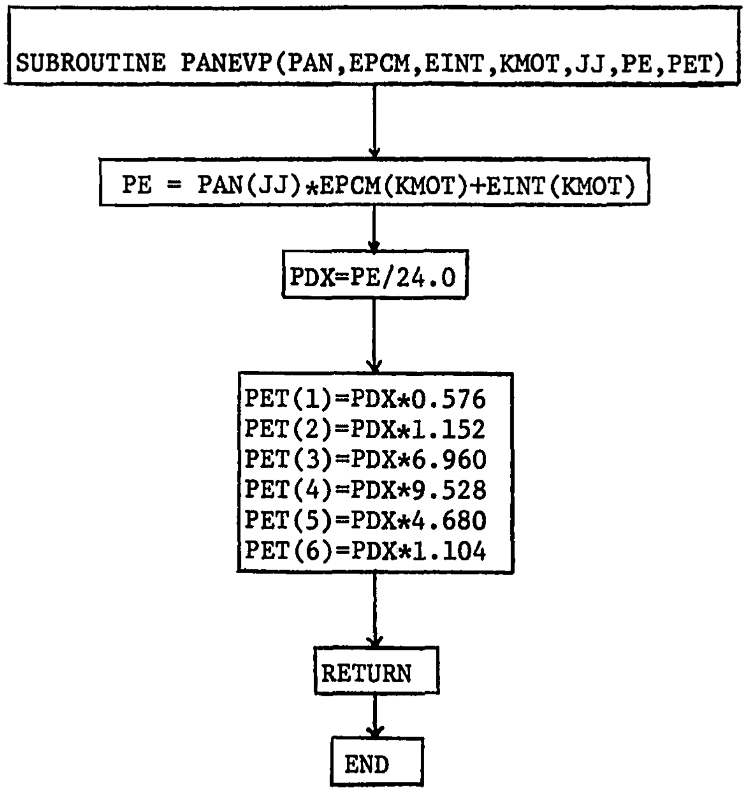

SUBROUTINE PLANT(JJ,NRTDS,PCATRN,CLAI,IRT,ROOTS,ALAI,DALI,TJ PCT,J1M1)
J=1,9
JJ>IRT(J)
yes
I=1,J1M1
I=1,J1M1
NRTDS(I)=ROOTS(I,10)
NRTDS(I)=ROOTS(I,J-1)
DJ=JJ
PCATRN=GINT(TJ,PCT,12,DJ,31)
CLAI=GINT(DLAI,ALAI,12,DJ,32)
RETURN
END

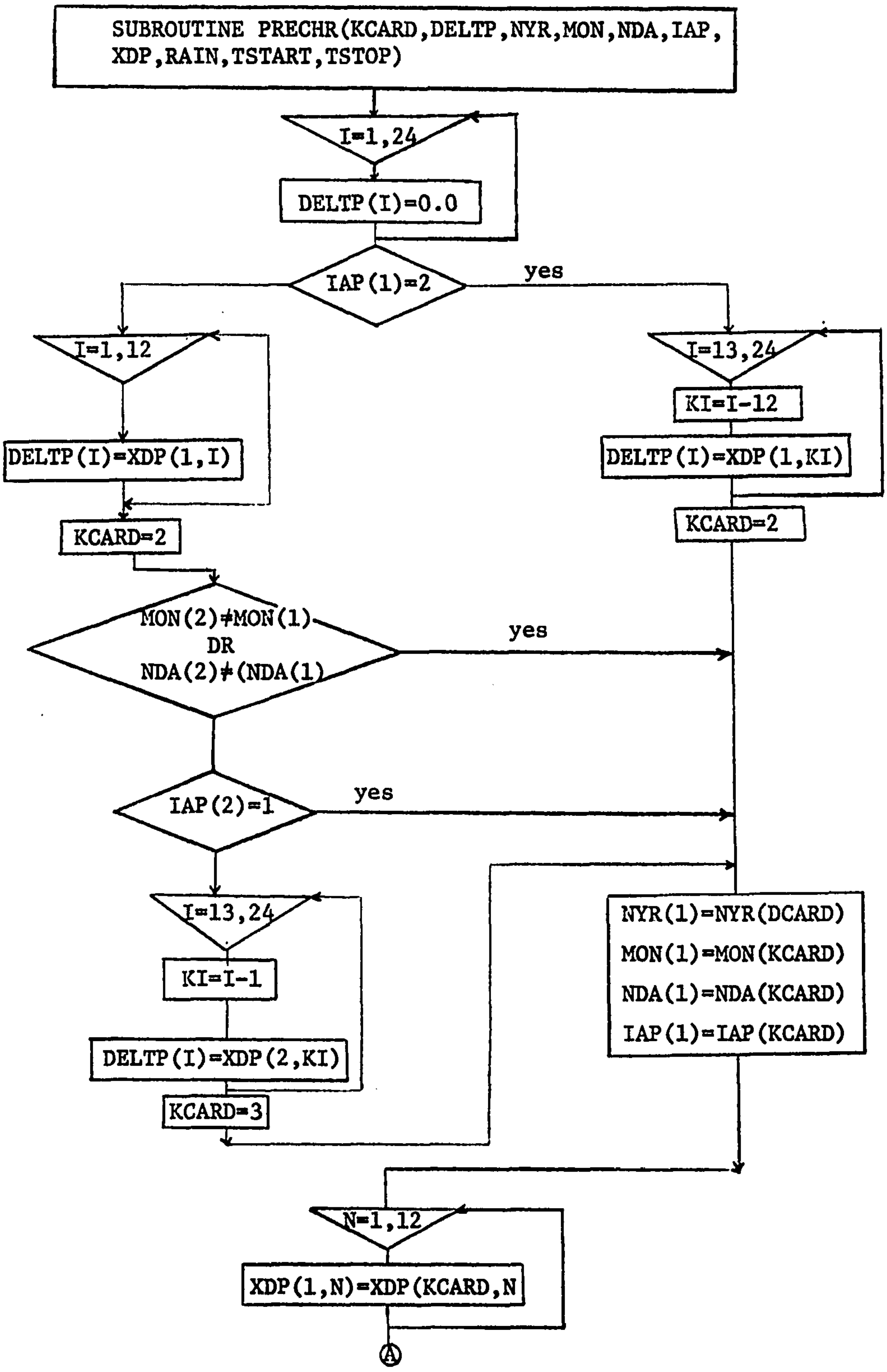


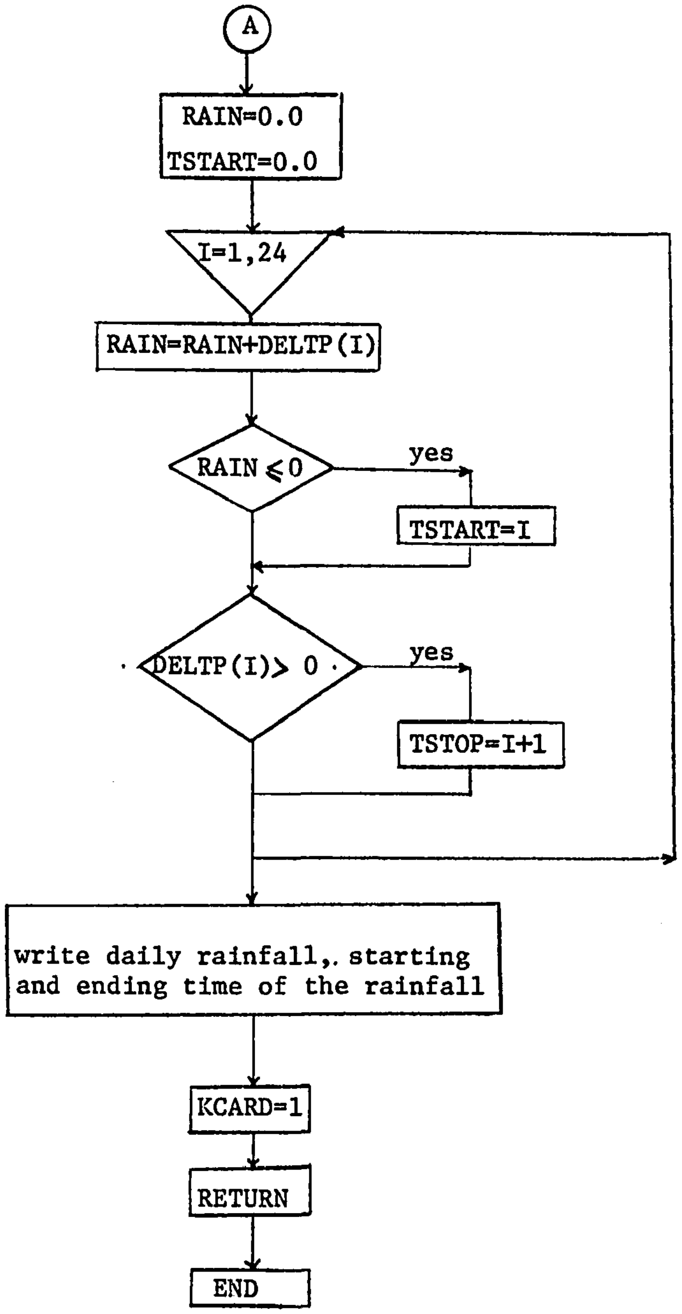
```
SUBROUTINE PEVAP(JJ,TMAX,TMIN,CLAI,RH,RS,W,TPAST,PE,PET)
X=JJ+18.0
RSO=547.0+227.0*SIN(0.01721*X-1.5708)
T=(TMAX+TMIN)*0.5
TR=T+459.69
B=ALOG(TR)
BB=54.6329-12301.668/TR-5.16925*B
ES=68.944*EXP(BB)
ED=0.01*RH*ES
TK2=((TMAX-32.0)/1.8+273.16)*0.01
TK1=((TMIN-32.0)/1.8+273.16)*0.01
RBO=(0.98-(0.66+0.44*SQRT(ED)))*5.855*(TK2**4-TK1**4)
RS>RSO
RS=RSO
RB=(1.35*RS/RSO-0.35)*RBO
CLAI>4.0
ALBEDO=0.23-0.017S*CLAI
TMIN<32.0
ALBEDO=0.16
ALBEDO=0.20
RN=(1.0-ALBEDO)*RS-RB
```

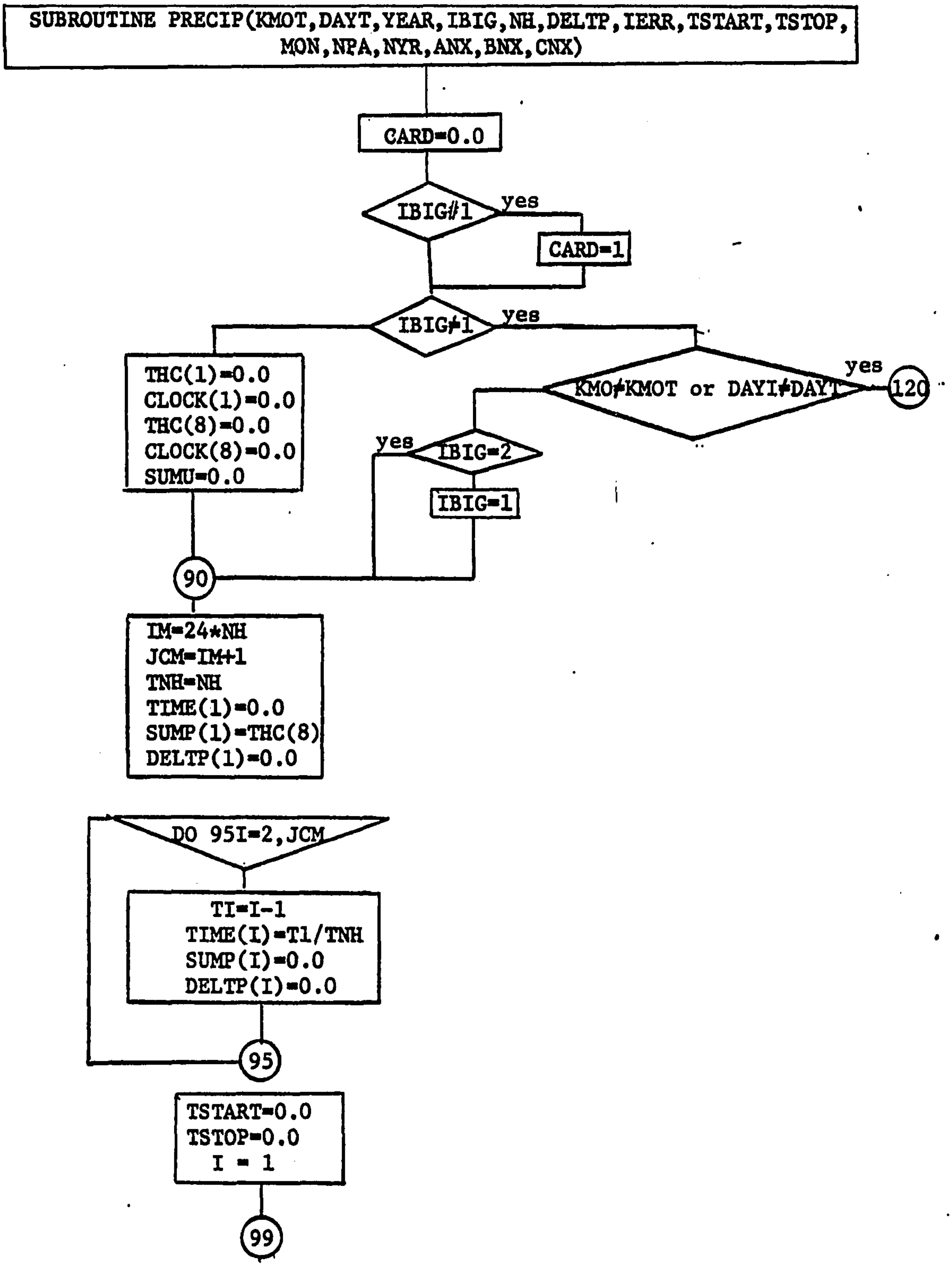


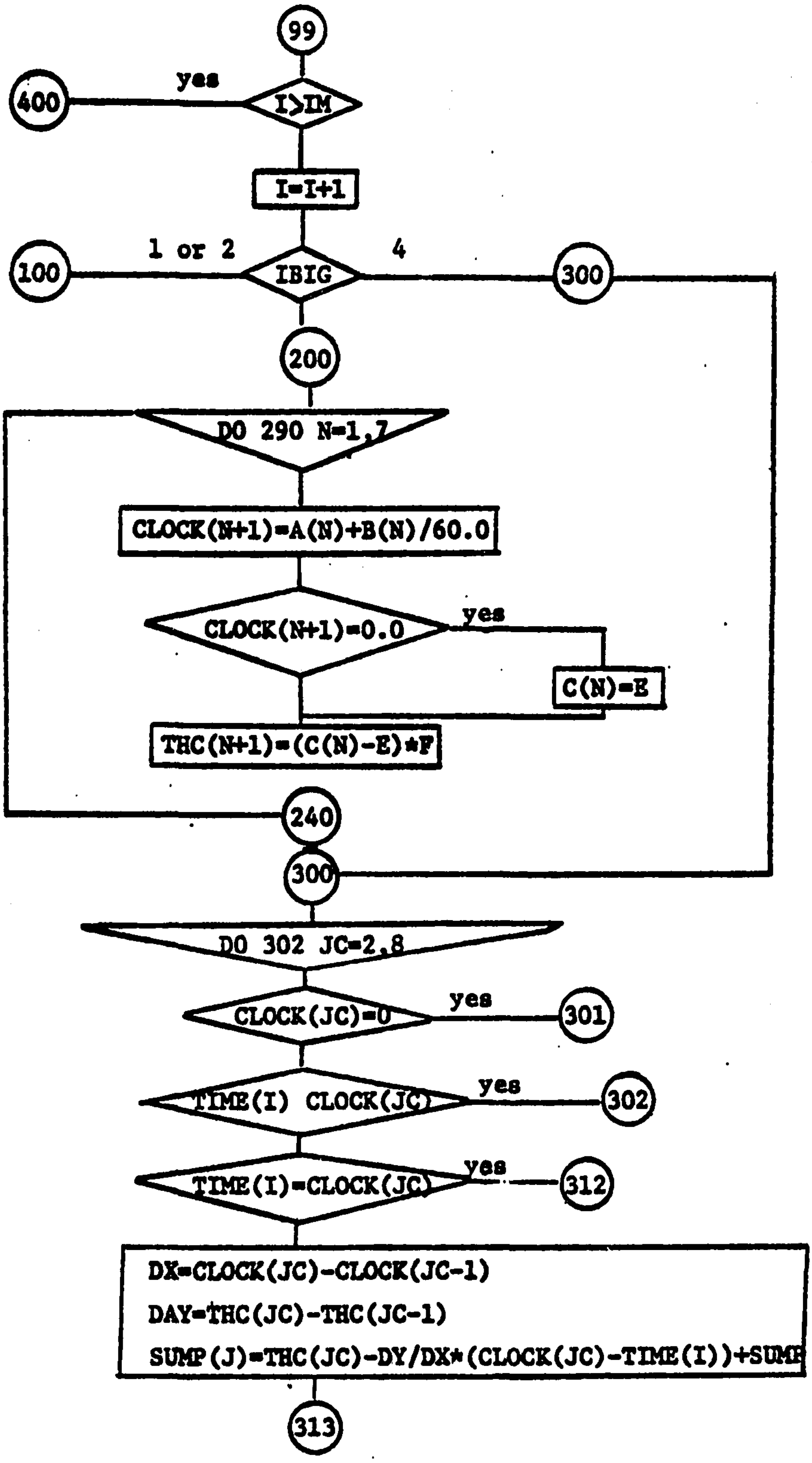
```
TC=(T-32.0)/1.8
DOG=0.672+0.0428*TC+1.13*10.0**(-3.0)*TC*TC+1.66*10.**(-5.0)*
        TC*TC*TC+1.7*10.**(-7.0)*TC**4.0
G=5.0*(T-TPAST)
PER=(DOG/(DOG+1.0)*(RN-G))*0.000673
PEW=((1.0/(DOG+1.0))*15.36*(1.0+0.01*W)*(ES-ED))*0.000673
PE=PER+PEW
PDX=PE/24.0
PET(1)=PDX*0.576
PET(2)=PDX*1.152
PET(3)=PDX*6.96
PET(4)=PDX*9.528
PET(5)=PDX*4.68
PET(6)=PDX*1.104
```

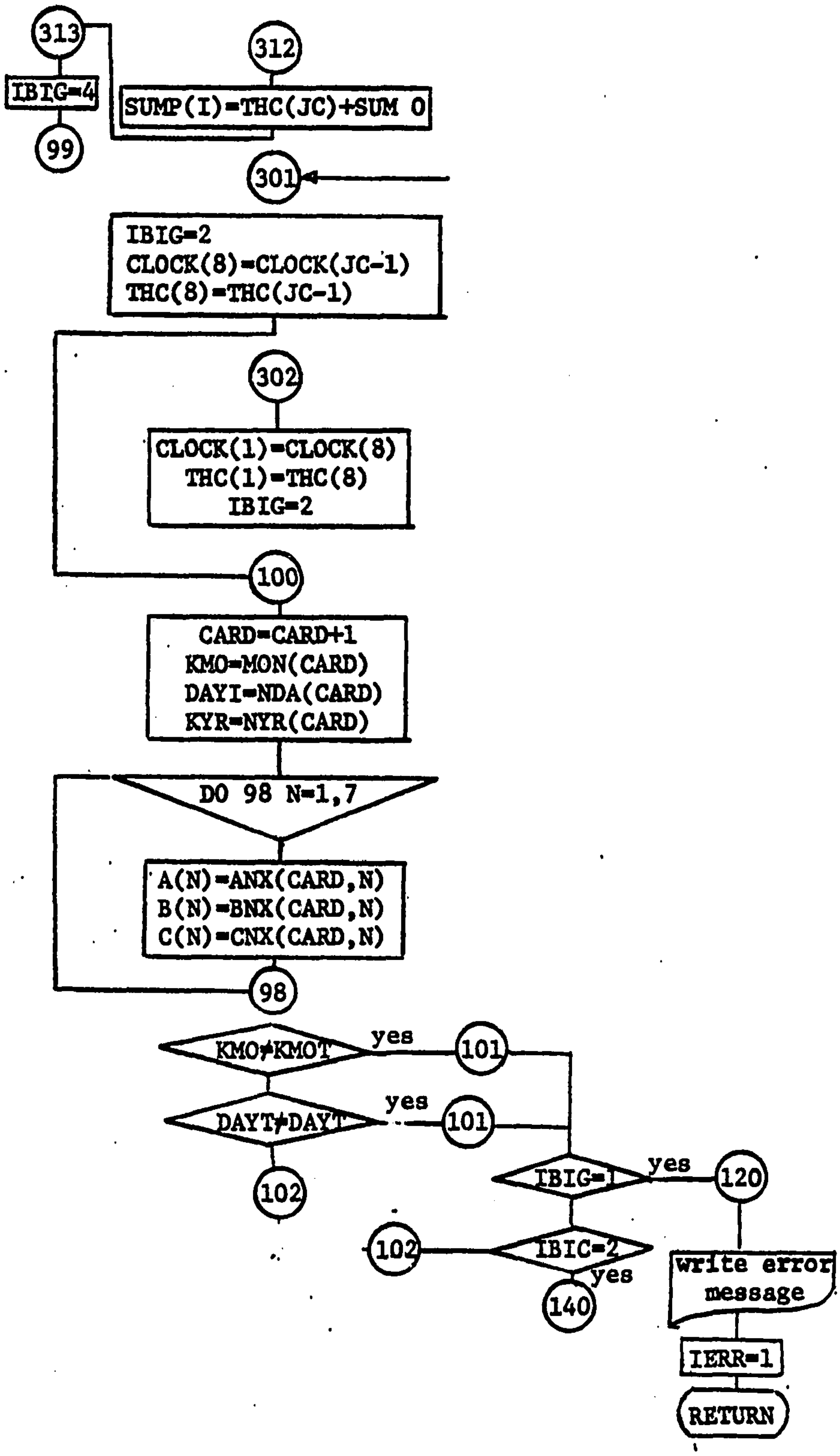

SUBROUTINE PANEVP(PAN,EPCM,EINT,KMOT,JJ,PE,PET)
PE = PAN(JJ)*EPCM(KMOT)+EINT(KMOT)
PDX=PE/24.0
PET(1)=PDX*0.576
PET(2)=PDX*1.152
PET(3)=PDX*6.960
PET(4)=PDX*9.528
PET(5)=PDX*4.680
PET(6)=PDX*1.104
RETURN
END

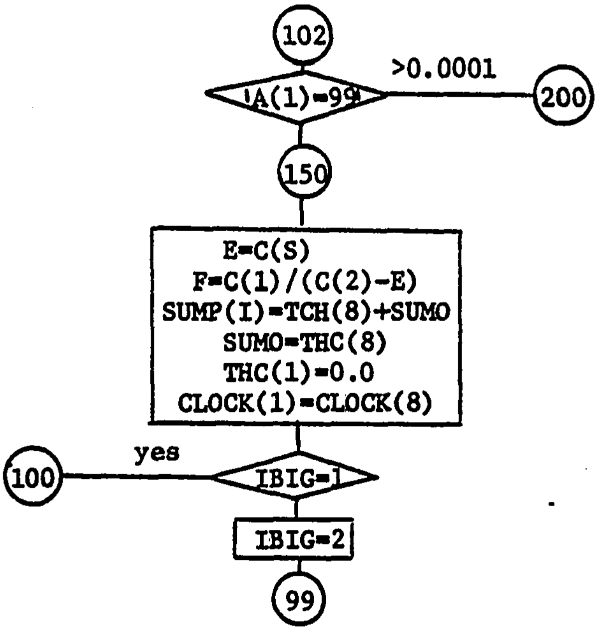

SUBROUTINE PRECHR(KCARD,DELTP,NYR,MON,NDA,IAP,
XDP,RAIN,TSTART,TSTOP)
I=1,24
DELTP(I)=0.0
IAP(1)=2
yes
I=1,12
DELTP(I)=XDP(1,I)
KCARD=2
I=13,24
KI=I-12
DELTP(I)=XDP(1,KI)
KCARD=2
MON(2)≠MON(1)
DR
NDA(2)≠(NDA(1)
yes
IAP(2)=1
yes
I=13,24
KI=I-1
DELTP(I)=XDP(2,KI)
KCARD=3
NYR(1)=NYR(DCARD)
MON(1)=MON(KCARD)
NDA(1)=NDA(KCARD)
IAP(1)=IAP(KCARD)
N=1,12
XDP(1,N)=XDP(KCARD,N
Ⓐ

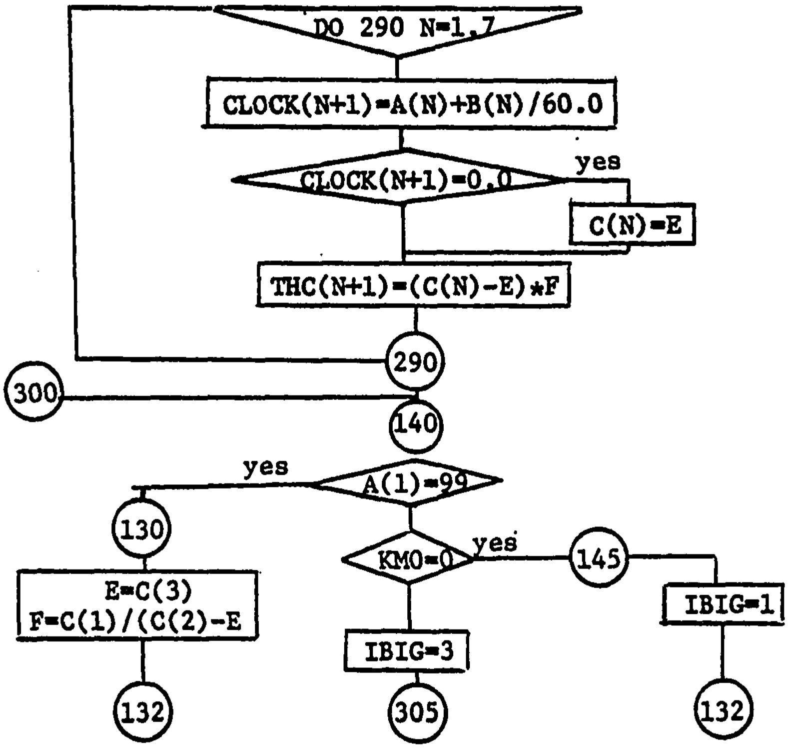

A
RAIN=0.0
TSTART=0.0
I=1,24
RAIN=RAIN+DELTP(I)
RAIN ≤ 0
yes
TSTART=I
DELTP(I) > 0
yes
TSTOP=I+1
write daily rainfall, starting and ending time of the rainfall
KCARD=1
RETURN
END

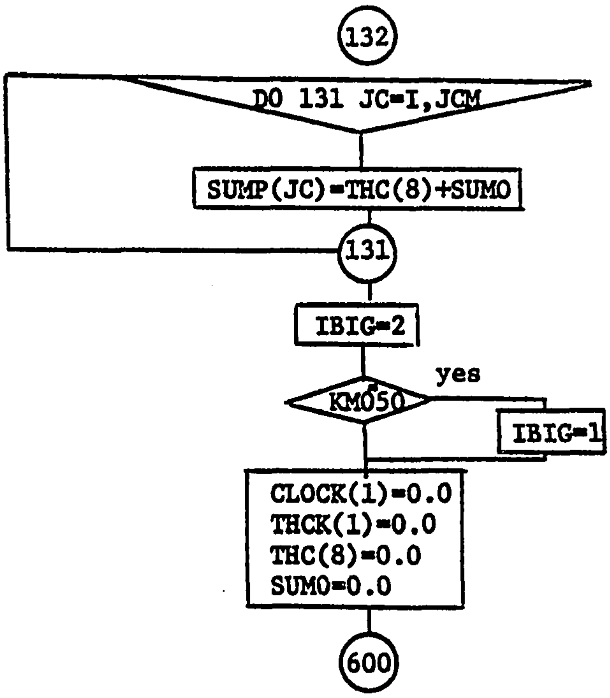

SUBROUTINE PRECIP(KMOT,DAYT,YEAR,IBIG,NH,DELTP,IERR,TSTART,TSTOP, MON,NPA,NYR,ANX,BNX,CNX)
CARD=0.0
IBIG≠1
yes
CARD=1
IBIG≠1
yes
THC(1)=0.0
CLOCK(1)=0.0
THC(8)=0.0
CLOCK(8)=0.0
SUMU=0.0
KMO≠KMOT or DAYI≠DAYT
yes
120
yes
IBIG=2
IBIG=1
90
IM=24*NH
JCM=IM+1
TNH=NH
TIME(1)=0.0
SUMP(1)=THC(8)
DELTP(1)=0.0
DO 95I=2,JCM
TI=I-1
TIME(I)=T1/TNH
SUMP(I)=0.0
DELTP(I)=0.0
95
TSTART=0.0
TSTOP=0.0
I = 1
99

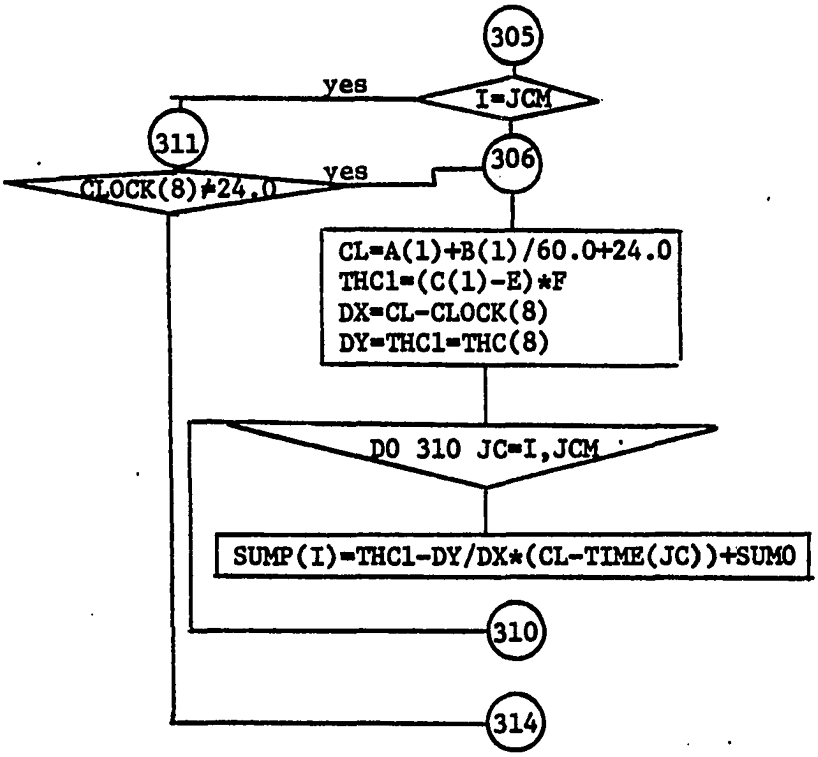

99
yes
400
I>IM
I=I+1
1 or 2
4
100
IBIG
300
200
DO 290 N=1,7
CLOCK(N+1)=A(N)+B(N)/60.0
CLOCK(N+1)=0.0
yes
C(N)=E
THC(N+1)=(C(N)-E)*F
240
300
DO 302 JC=2,8
CLOCK(JC)=0
yes
301
TIME(I) CLOCK(JC)
yes
302
TIME(I)=CLOCK(JC)
yes
312
DX=CLOCK(JC)-CLOCK(JC-1)
DAY=THC(JC)-THC(JC-1)
SUMP(J)=THC(JC)-DY/DX*(CLOCK(JC)-TIME(I))+SUMP
313

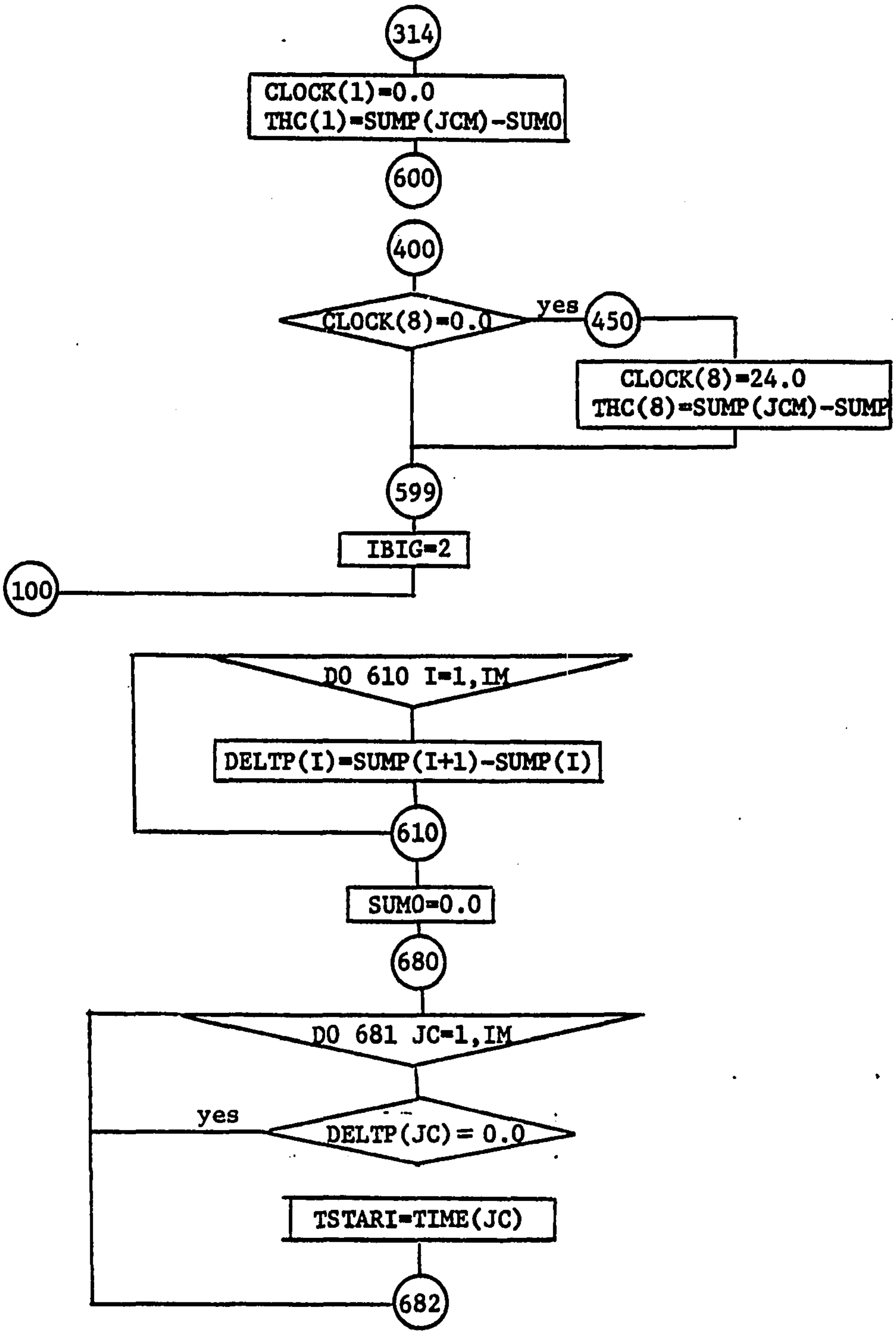

313
IBIG=4
99
312
SUMP(I)=THC(JC)+SUM 0
301
IBIG=2
CLOCK(8)=CLOCK(JC-1)
THC(8)=THC(JC-1)
302
CLOCK(1)=CLOCK(8)
THC(1)=THC(8)
IBIG=2
100
CARD=CARD+1
KMO=MON(CARD)
DAYI=NDA(CARD)
KYR=NYR(CARD)
DO 98 N=1,7
A(N)=ANX(CARD,N)
B(N)=BNX(CARD,N)
C(N)=CNX(CARD,N)
98
KMO≠KMOT
yes
101
DAYT≠DAYT
yes
101
102
IBIG=1
yes
120
write error message
IERR=1
RETURN
102
IBIC=2
yes
140

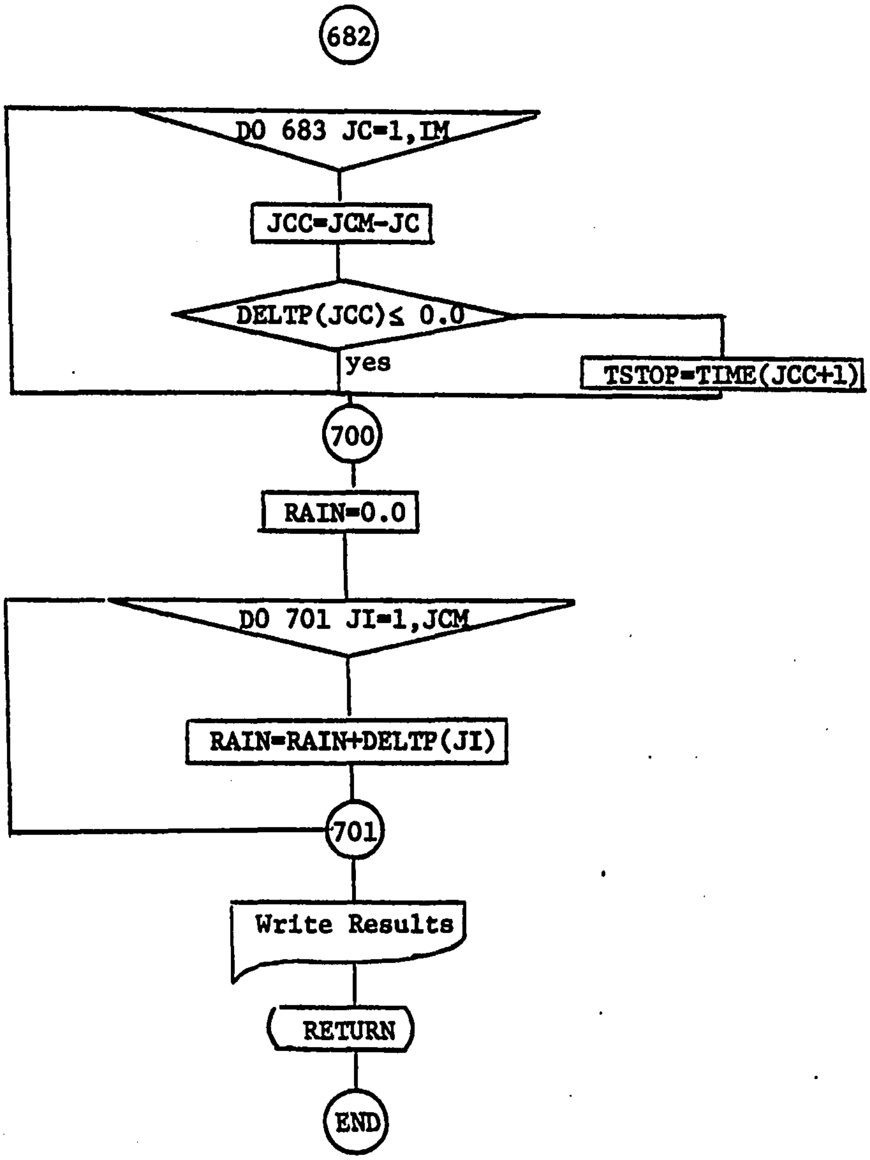

102
'A(1)=99'
>0.0001
200
150
E=C(S)
F=C(1)/(C(2)-E)
SUMP(I)=TCH(8)+SUMO
SUMO=THC(8)
THC(1)=0.0
CLOCK(1)=CLOCK(8)
yes
100
IBIG=1
IBIG=2
99

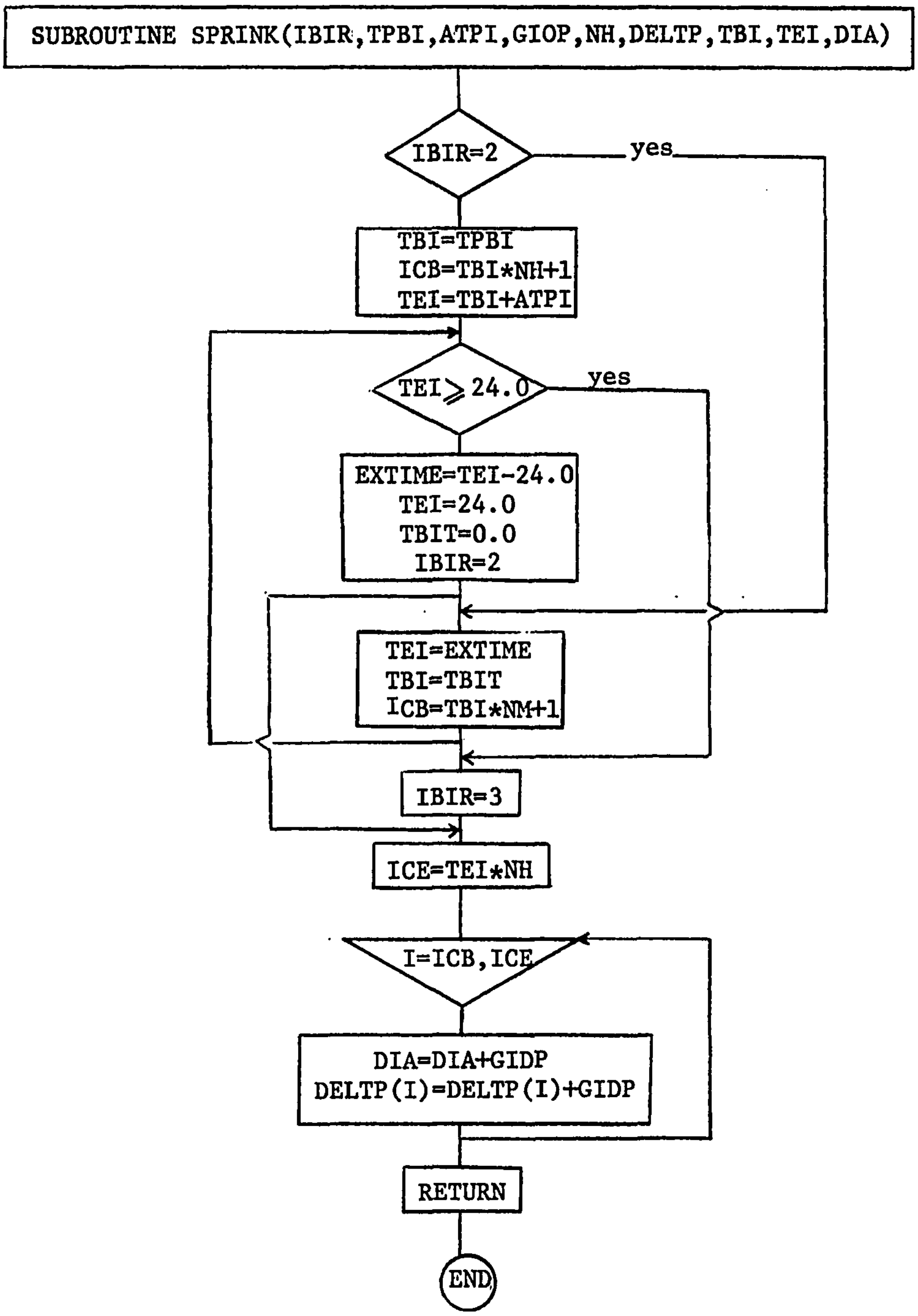

DO 290 N=1,7
CLOCK(N+1)=A(N)+B(N)/60.0
CLOCK(N+1)=0.0
yes
C(N)=E
THC(N+1)=(C(N)-E)*F
290
300
140
yes
A(1)=99
130
E=C(3)
F=C(1)/(C(2)-E
132
KMO=0
yes
145
IBIG=1
IBIG=3
305
132

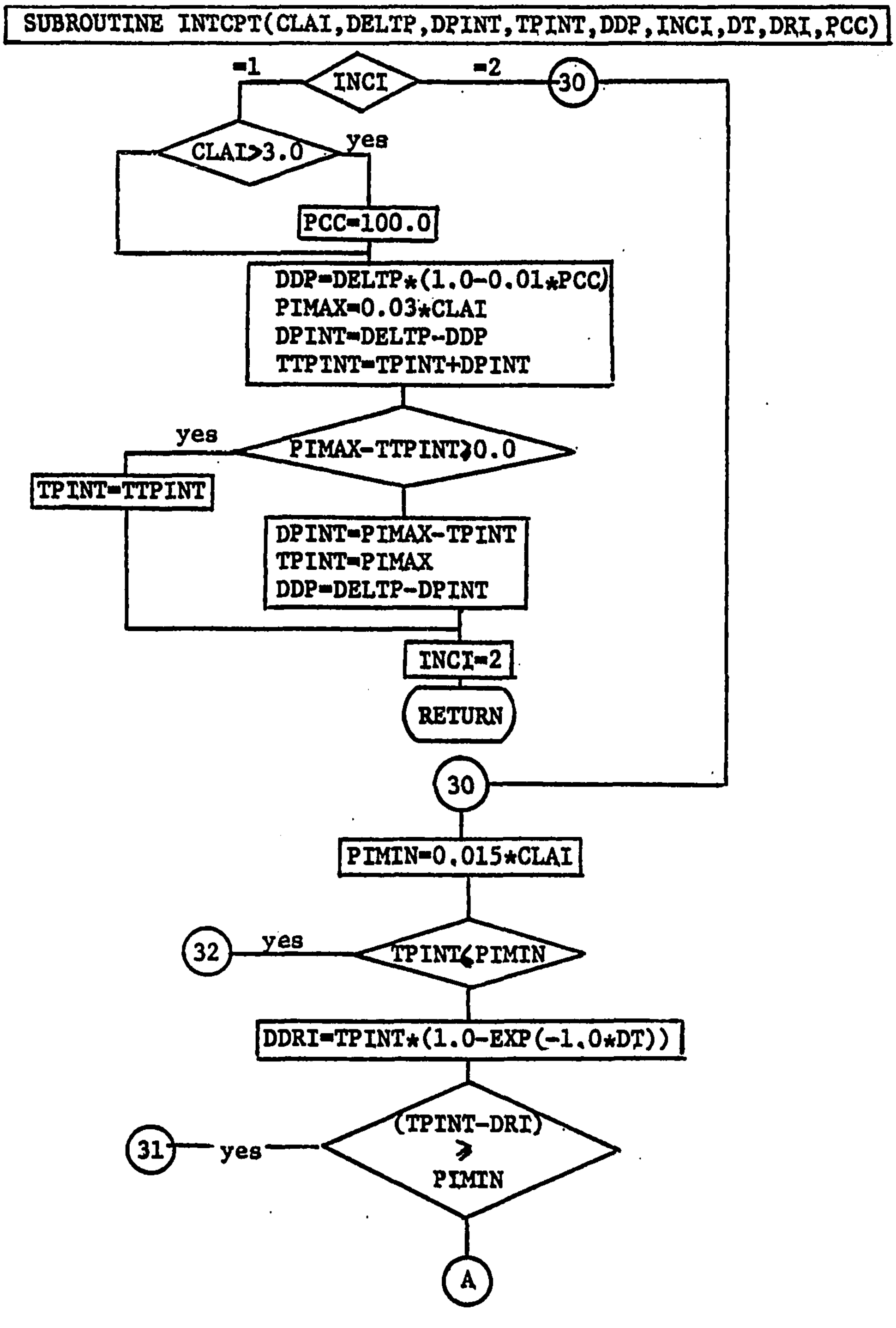

132
DO 131 JC=I,JCM
SUMP(JC)=THC(8)+SUMO
131
IBIG=2
KM050
yes
IBIG=1
CLOCK(1)=0.0
THCK(1)=0.0
THC(8)=0.0
SUMO=0.0
600

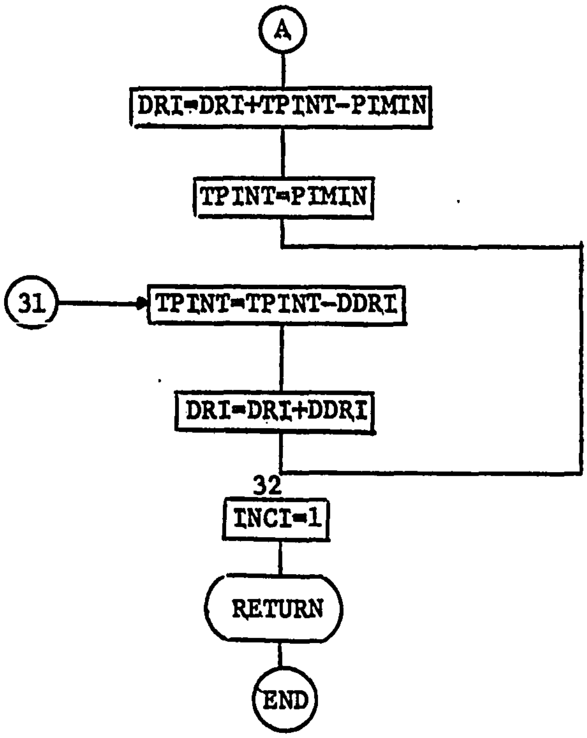

305
yes
I=JCM
311
306
CLOCK(8)≠24.0
yes
CL=A(1)+B(1)/60.0+24.0
THC1=(C(1)-E)*F
DX=CL-CLOCK(8)
DY=THC1=THC(8)
DO 310 JC=I,JCM
SUMP(I)=THC1-DY/DX*(CL-TIME(JC))+SUMO
310
314

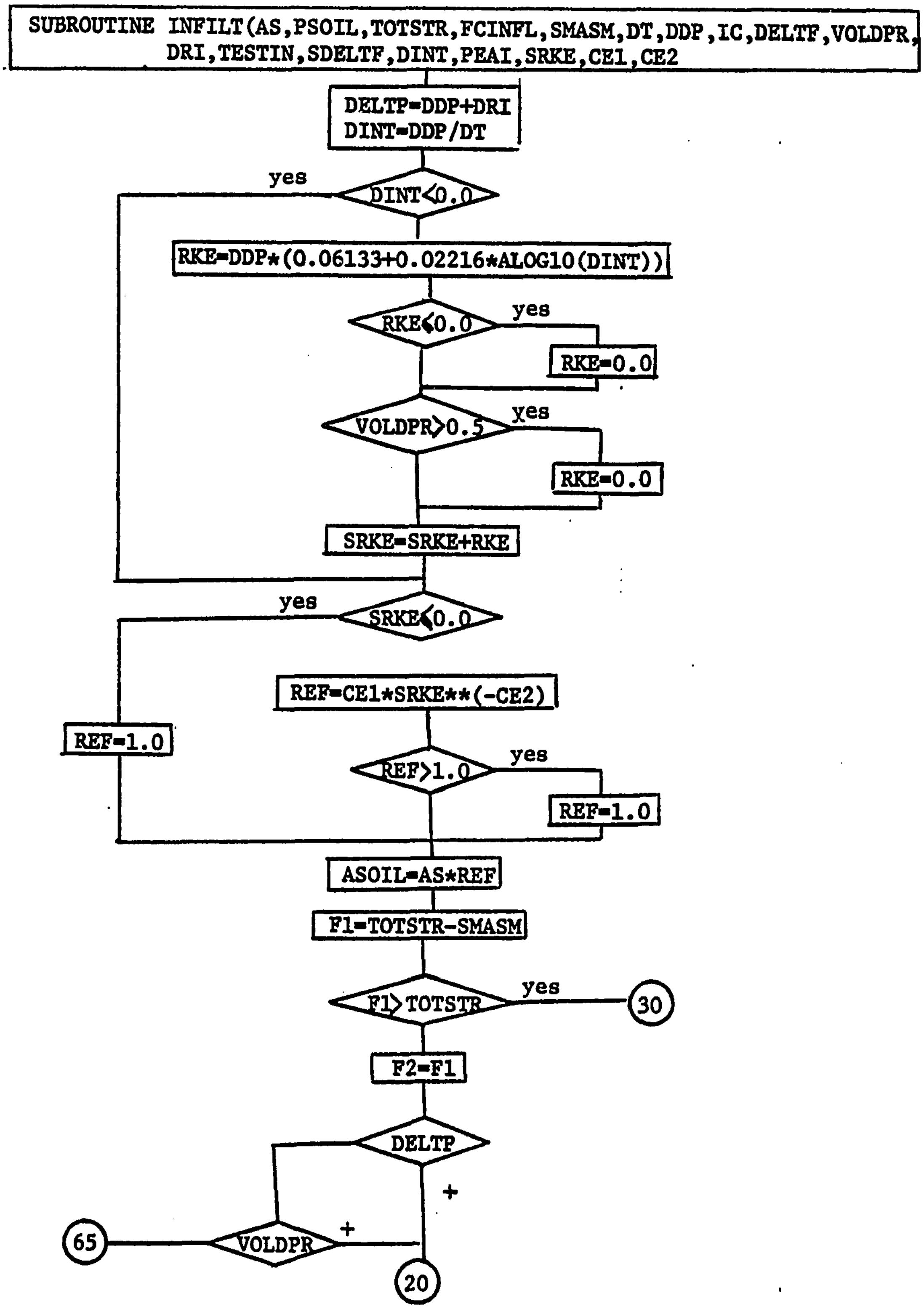

314
CLOCK(1)=0.0
THC(1)=SUMP(JCM)-SUMO
600
400
CLOCK(8)=0.0
yes
450
CLOCK(8)=24.0
THC(8)=SUMP(JCM)-SUMP
599
IBIG=2
100
DO 610 I=1,IM
DELTP(I)=SUMP(I+1)-SUMP(I)
610
SUMO=0.0
680
DO 681 JC=1,IM
yes
DELTP(JC) = 0.0
TSTARI=TIME(JC)
682

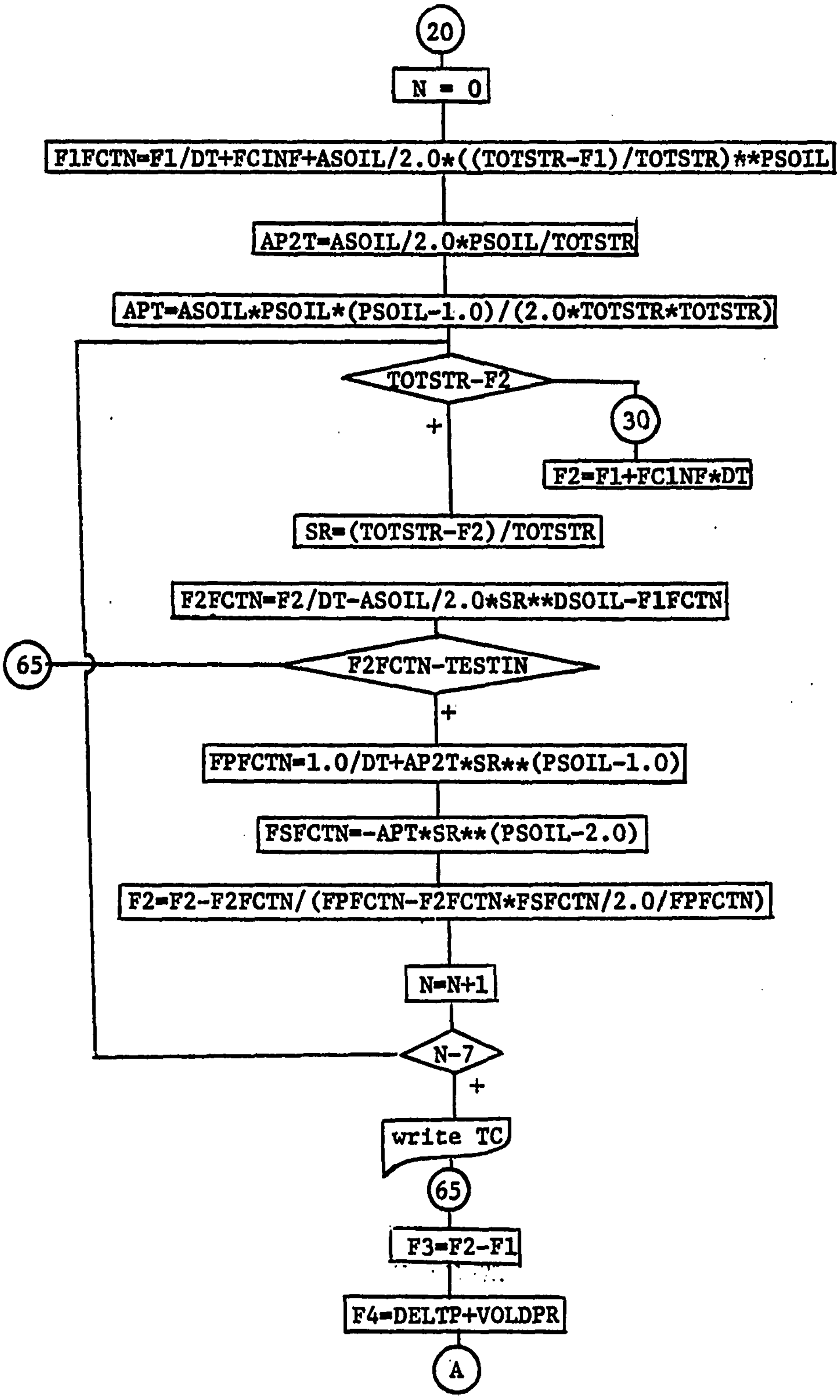

682
DO 683 JC=1,IM
JCC=JCM-JC
DELTP(JCC)≤ 0.0
yes
TSTOP=TIME(JCC+1)
700
RAIN=0.0
DO 701 JI=1,JCM
RAIN=RAIN+DELTP(JI)
701
Write Results
RETURN
END

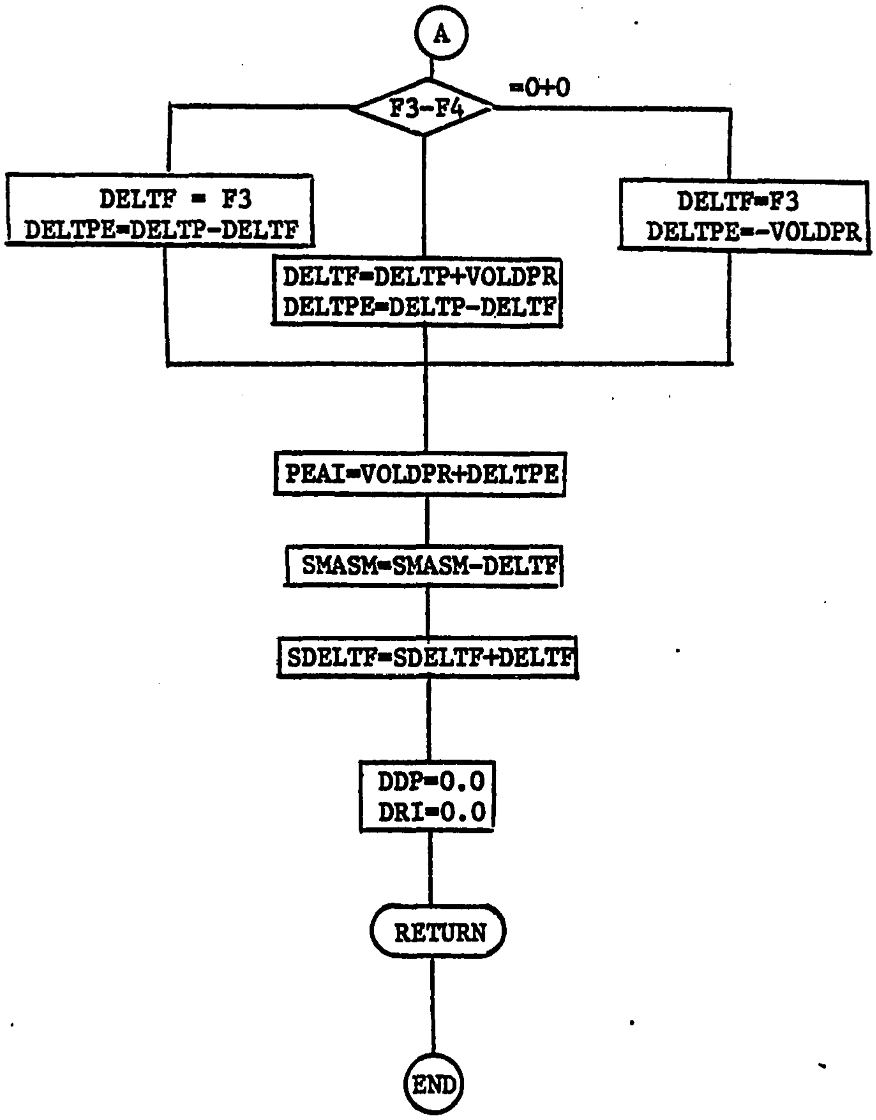

SUBROUTINE SPRINK(IBIR,TPBI,ATPI,GIOP,NH,DELTP,TBI,TEI,DIA)
IBIR=2
yes
TBI=TPBI
ICB=TBI*NH+1
TEI=TBI+ATPI
TEI≥24.0
yes
EXTIME=TEI-24.0
TEI=24.0
TBIT=0.0
IBIR=2
TEI=EXTIME
TBI=TBIT
ICB=TBI*NM+1
IBIR=3
ICE=TEI*NH
I=ICB,ICE
DIA=DIA+GIDP
DELTP(I)=DELTP(I)+GIDP
RETURN
END

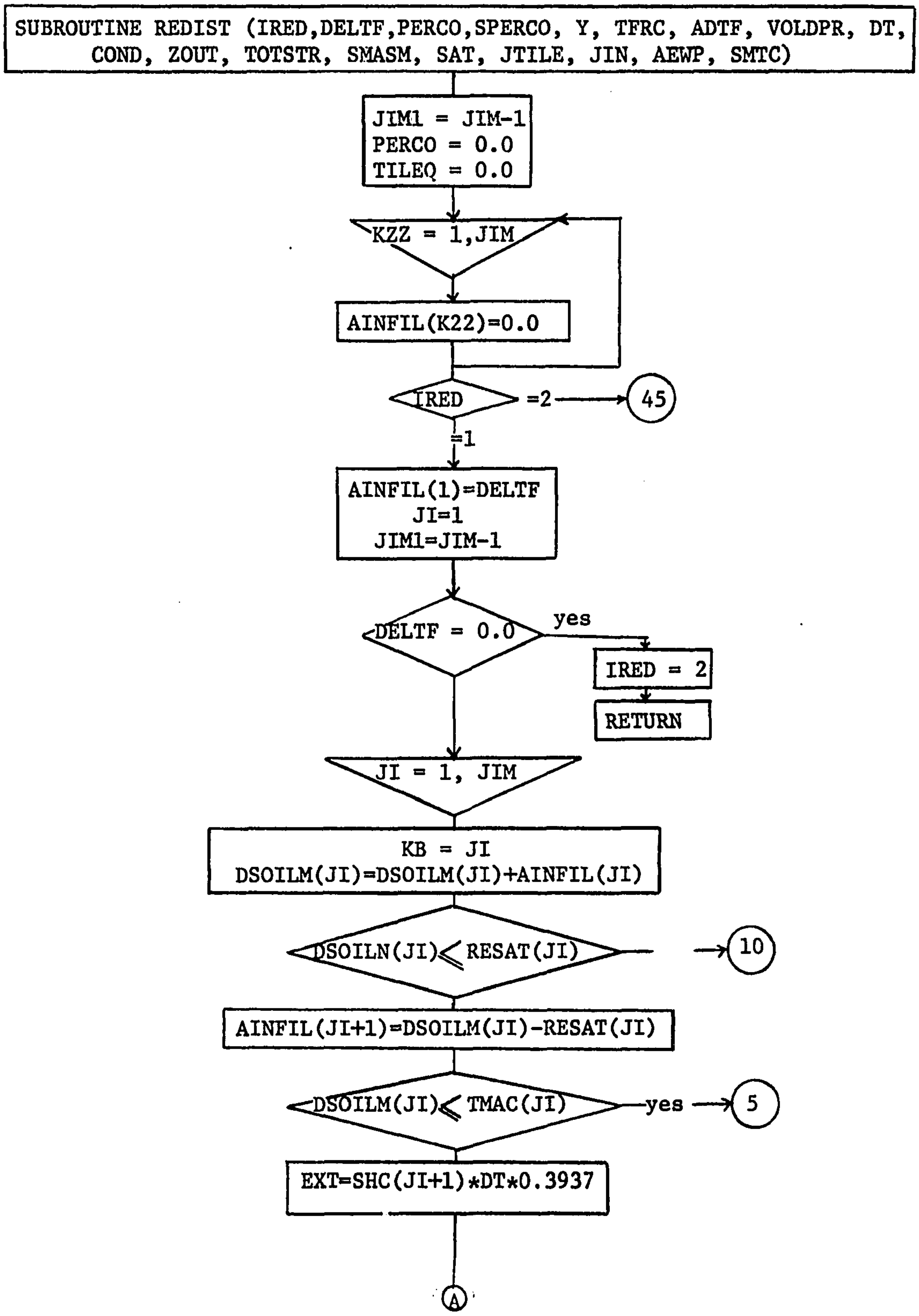

SUBROUTINE INTCPT(CLAI,DELTP,DPINT,TPINT,DDP,INCI,DT,DRI,PCC)
=1
INCI
=2
30
CLAI>3.0
yes
PCC=100.0
DDP=DELTP*(1.0-0.01*PCC)
PIMAX=0.03*CLAI
DPINT=DELTP-DDP
TTPINT=TPINT+DPINT
yes
PIMAX-TTPINT≥0.0
TPINT=TTPINT
DPINT=PIMAX-TPINT
TPINT=PIMAX
DDP=DELTP-DPINT
INCI=2
RETURN
30
PIMIN=0.015*CLAI
32
yes
TPINT≤PIMIN
DDRI=TPINT*(1.0-EXP(-1.0*DT))
31
yes
(TPINT-DRI)
≥
PIMIN
A

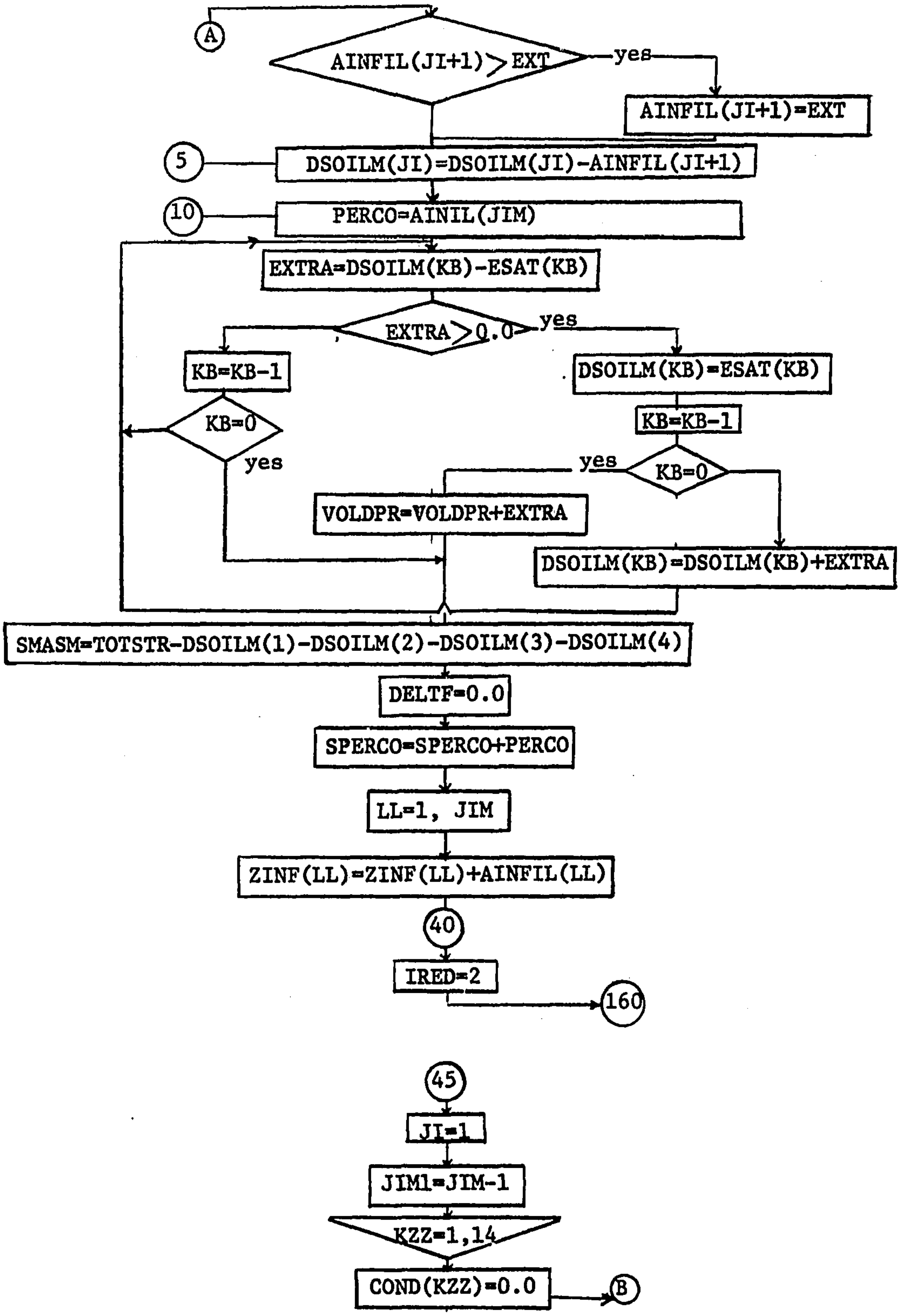

A
DRI=DRI+TPINT-PIMIN
TPINT=PIMIN
31
TPINT=TPINT-DDRI
DRI=DRI+DDRI
32
INCI=1
RETURN
END

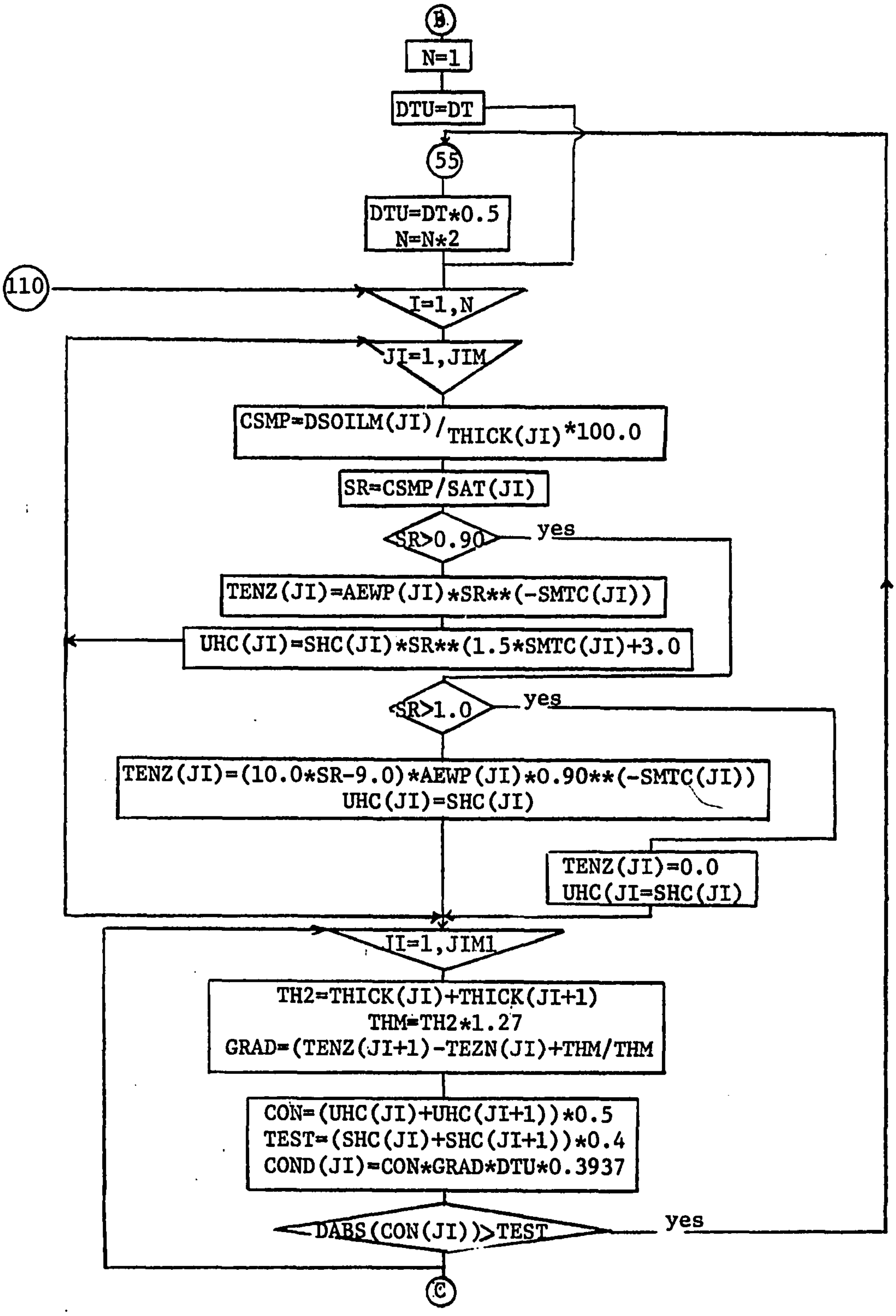

SUBROUTINE INFILT(AS,PSOIL,TOTSTR,FCINFL,SMASM,DT,DDP,IC,DELTF,VOLDPR,
DRI,TESTIN,SDELTF,DINT,PEAI,SRKE,CE1,CE2
DELTP=DDP+DRI
DINT=DDP/DT
yes
DINT<0.0
RKE=DDP*(0.06133+0.02216*ALOG10(DINT))
RKE<0.0
yes
RKE=0.0
VOLDPR>0.5
yes
RKE=0.0
SRKE=SRKE+RKE
yes
SRKE<0.0
REF=CE1*SRKE**(-CE2)
REF=1.0
REF>1.0
yes
REF=1.0
ASOIL=AS*REF
F1=TOTSTR-SMASM
F1>TOTSTR
yes
30
F2=F1
DELTP
+
65
VOLDPR
+
20

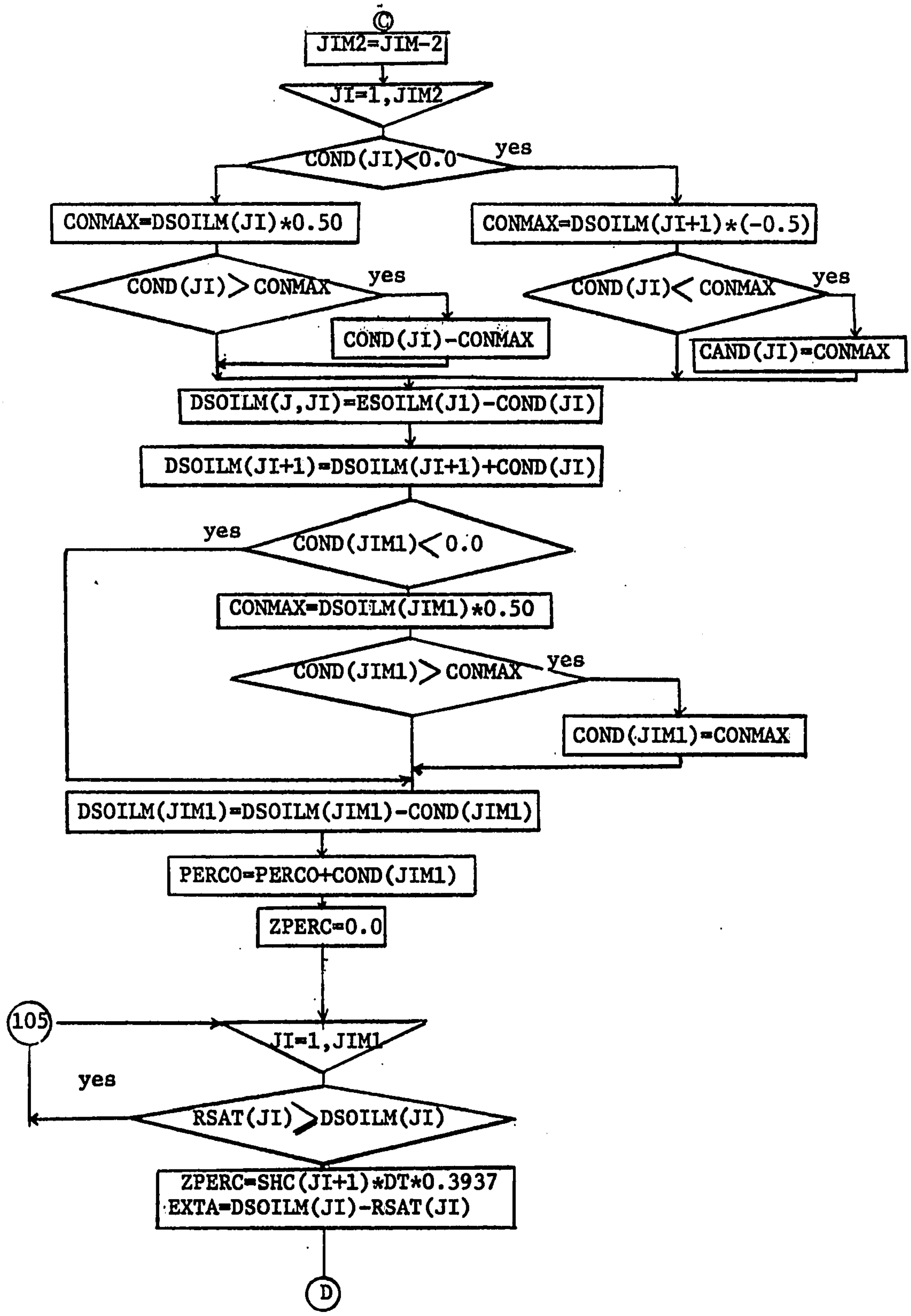

20
N = 0
F1FCTN=F1/DT+FCINF+ASOIL/2.0*((TOTSTR-F1)/TOTSTR)**PSOIL
AP2T=ASOIL/2.0*PSOIL/TOTSTR
APT=ASOIL*PSOIL*(PSOIL-1.0)/(2.0*TOTSTR*TOTSTR)
TOTSTR-F2
+
30
F2=F1+FC1NF*DT
SR=(TOTSTR-F2)/TOTSTR
F2FCTN=F2/DT-ASOIL/2.0*SR**DSOIL-F1FCTN
65
F2FCTN-TESTIN
+
FPFCTN=1.0/DT+AP2T*SR**(PSOIL-1.0)
FSFCTN=-APT*SR**(PSOIL-2.0)
F2=F2-F2FCTN/(FPFCTN-F2FCTN*FSFCTN/2.0/FPFCTN)
N=N+1
N-7
+
write TC
65
F3=F2-F1
F4=DELTP+VOLDPR
A

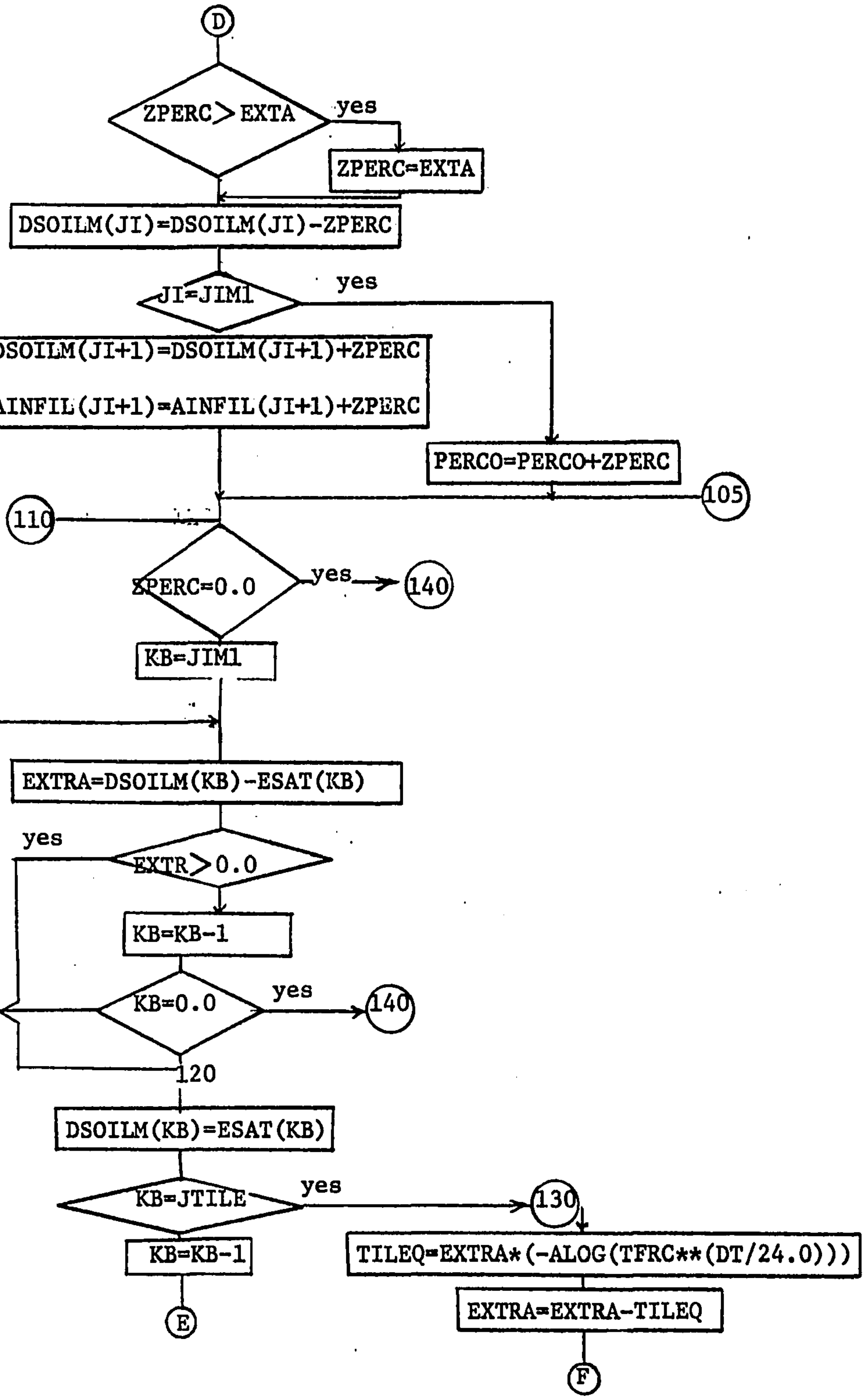

A
F3-F4
=0+0
DELTF = F3
DELTPE=DELTP-DELTF
DELTF=DELTP+VOLDPR
DELTPE=DELTP-DELTF
DELTF=F3
DELTPE=-VOLDPR
PEAI=VOLDPR+DELTPE
SMASM=SMASM-DELTF
SDELTF=SDELTF+DELTF
DDP=0.0
DRI=0.0
RETURN
END

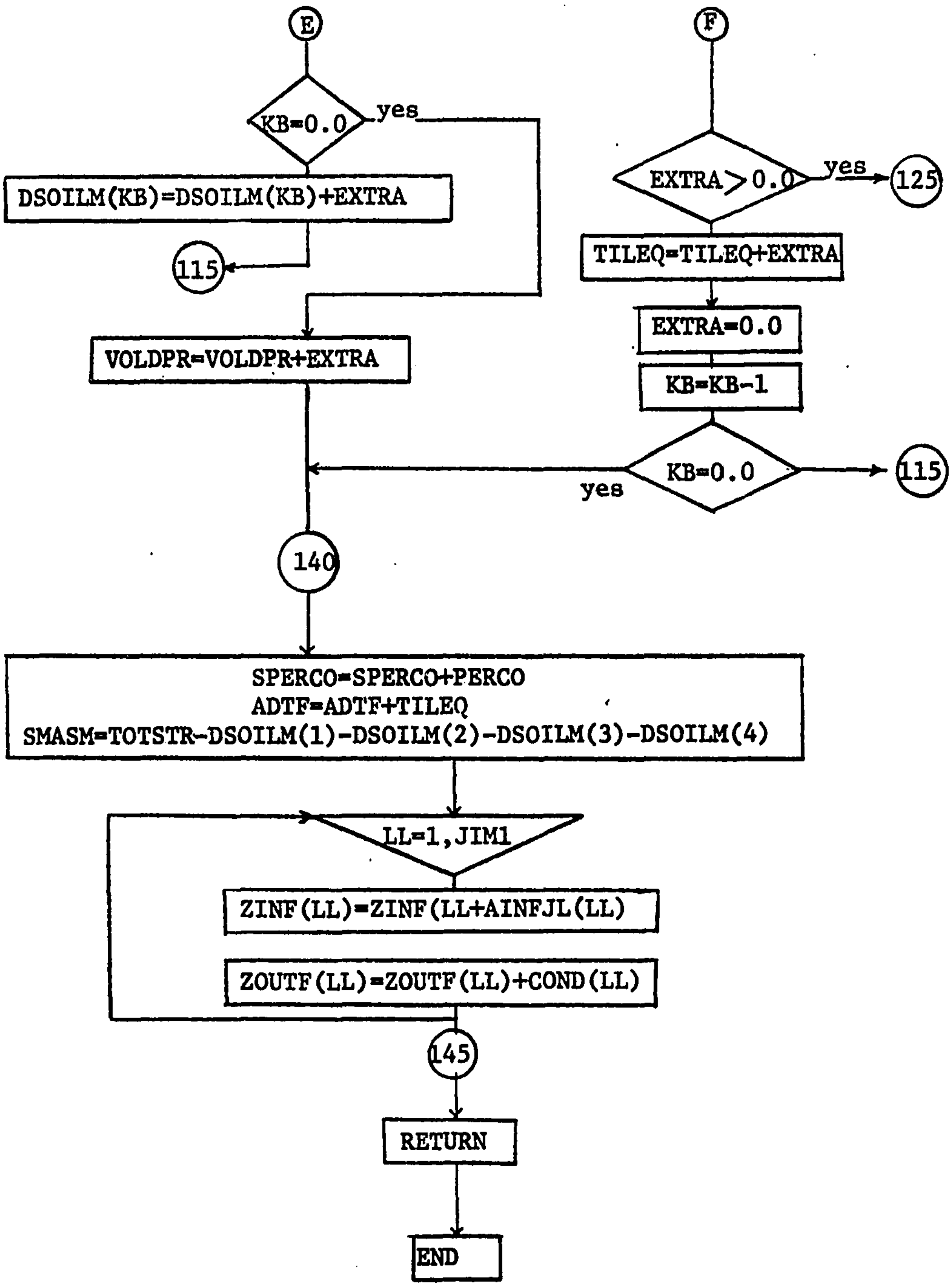

SUBROUTINE REDIST (IRED,DELTF,PERCO,SPERCO, Y, TFRC, ADTF, VOLDPR, DT, COND, ZOUT, TOTSTR, SMASM, SAT, JTILE, JIN, AEWP, SMTC)
JIM1 = JIM-1
PERCO = 0.0
TILEQ = 0.0
KZZ = 1,JIM
AINFIL(K22)=0.0
IRED
=2
45
=1
AINFIL(1)=DELTF
JI=1
JIM1=JIM-1
DELTF = 0.0
yes
IRED = 2
RETURN
JI = 1, JIM
KB = JI
DSOILM(JI)=DSOILM(JI)+AINFIL(JI)
DSOILN(JI)≤RESAT(JI)
10
AINFIL(JI+1)=DSOILM(JI)-RESAT(JI)
DSOILM(JI)≤TMAC(JI)
yes
5
EXT=SHC(JI+1)*DT*0.3937
A

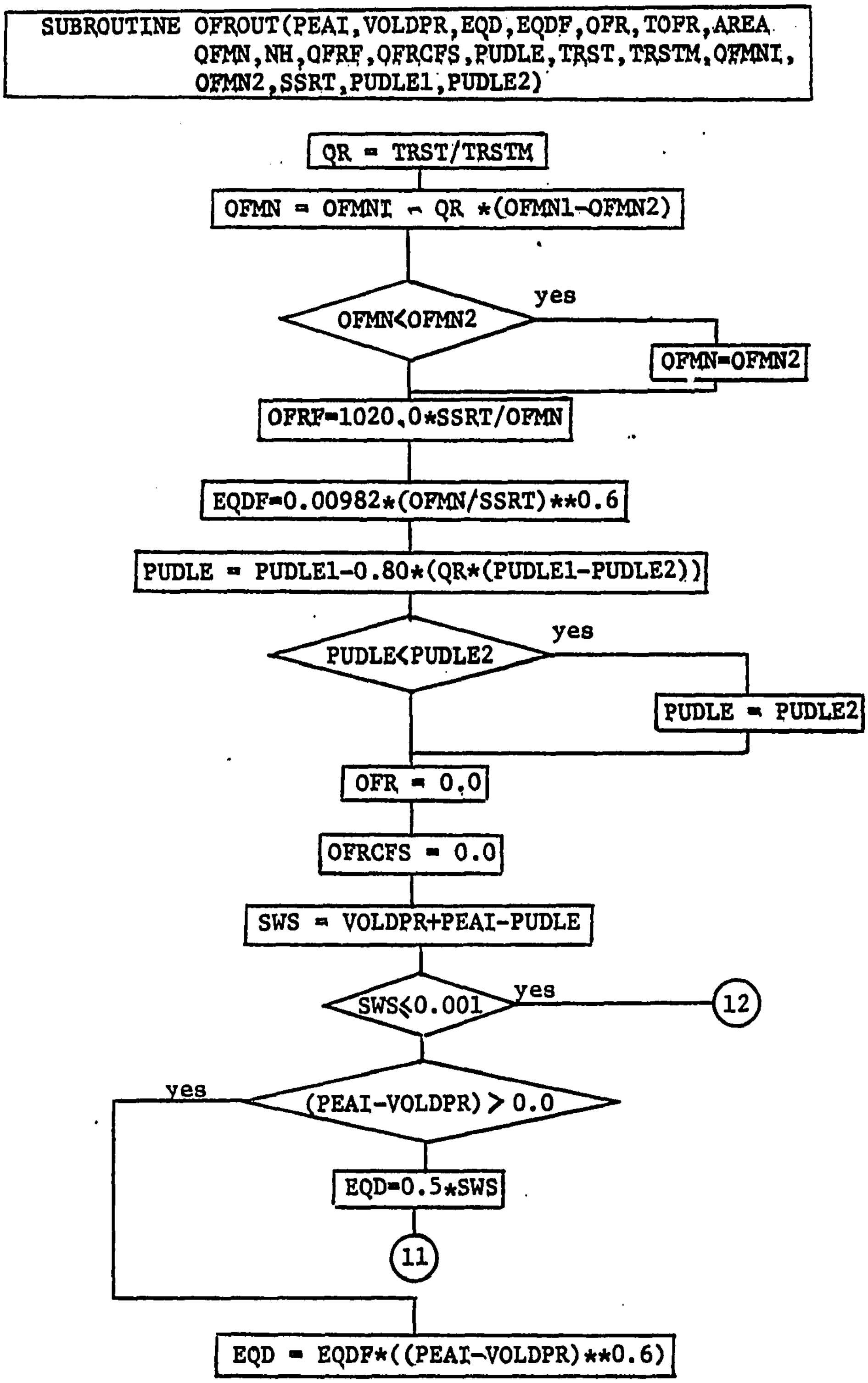

A
AINFIL(JI+1) > EXT
yes
AINFIL(JI+1)=EXT
5
DSOILM(JI)=DSOILM(JI)-AINFIL(JI+1)
10
PERCO=AINIL(JIM)
EXTRA=DSOILM(KB)-ESAT(KB)
EXTRA > 0.0
yes
KB=KB-1
DSOILM(KB)=ESAT(KB)
KB=0
yes
KB=KB-1
yes
KB=0
VOLDPR=VOLDPR+EXTRA
DSOILM(KB)=DSOILM(KB)+EXTRA
SMASM=TOTSTR-DSOILM(1)-DSOILM(2)-DSOILM(3)-DSOILM(4)
DELTF=0.0
SPERCO=SPERCO+PERCO
LL=1, JIM
ZINF(LL)=ZINF(LL)+AINFIL(LL)
40
IRED=2
160
45
JI=1
JIM1=JIM-1
KZZ=1,14
COND(KZZ)=0.0
B

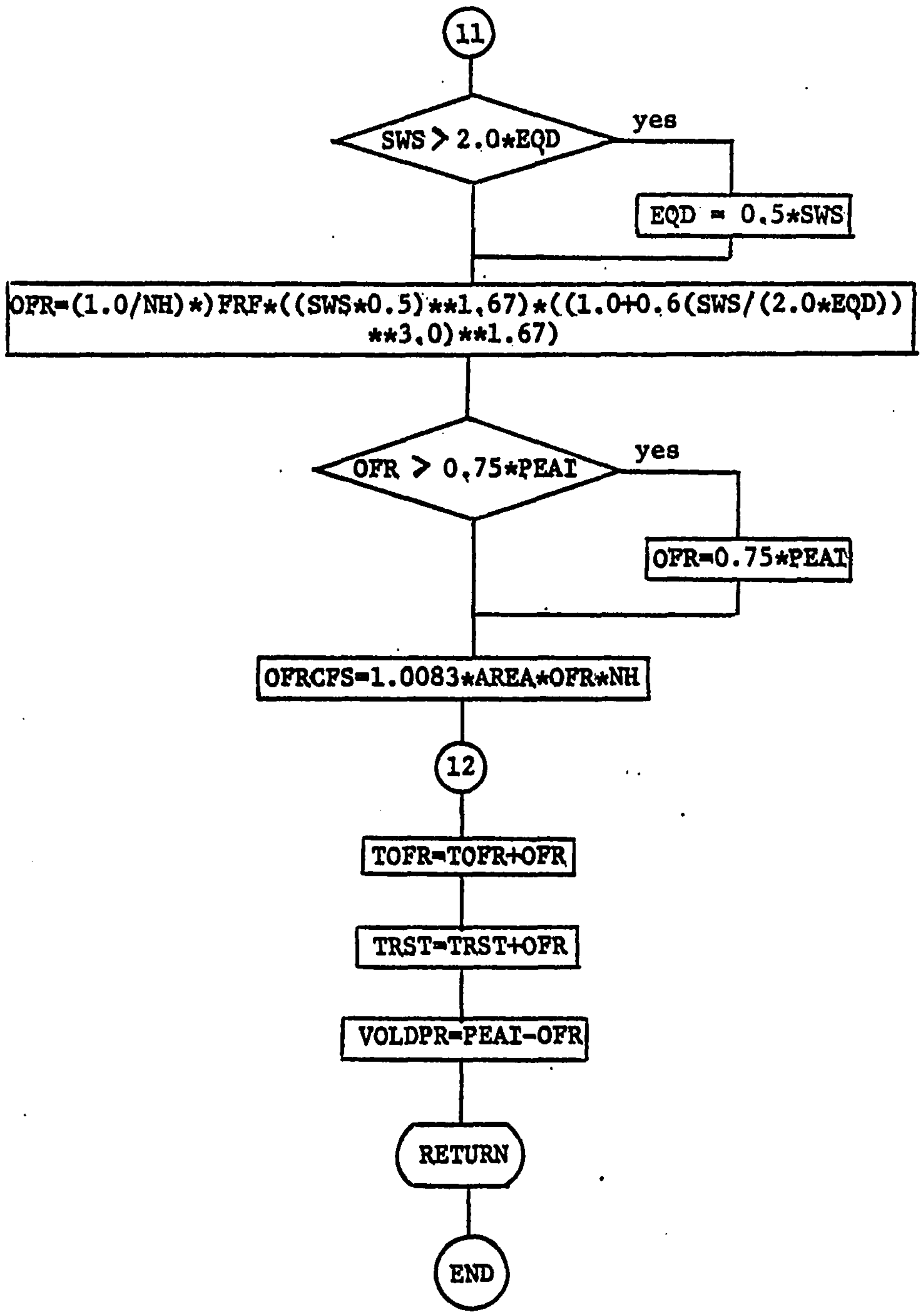

B
N=1
DTU=DT
55
DTU=DT*0.5
N=N*2
110
I=1,N
JI=1,JIM
CSMP=DSOILM(JI)/THICK(JI)*100.0
SR=CSMP/SAT(JI)
SR>0.90
yes
TENZ(JI)=AEWP(JI)*SR**(-SMTC(JI))
UHC(JI)=SHC(JI)*SR**(1.5*SMTC(JI)+3.0
SR>1.0
yes
TENZ(JI)=(10.0*SR-9.0)*AEWP(JI)*0.90**(-SMTC(JI))
UHC(JI)=SHC(JI)
TENZ(JI)=0.0
UHC(JI=SHC(JI)
JI=1,JIM1
TH2=THICK(JI)+THICK(JI+1)
THM=TH2*1.27
GRAD=(TENZ(JI+1)-TEZN(JI)+THM/THM
CON=(UHC(JI)+UHC(JI+1))*0.5
TEST=(SHC(JI)+SHC(JI+1))*0.4
COND(JI)=CON*GRAD*DTU*0.3937
DABS(CON(JI))>TEST
yes
C

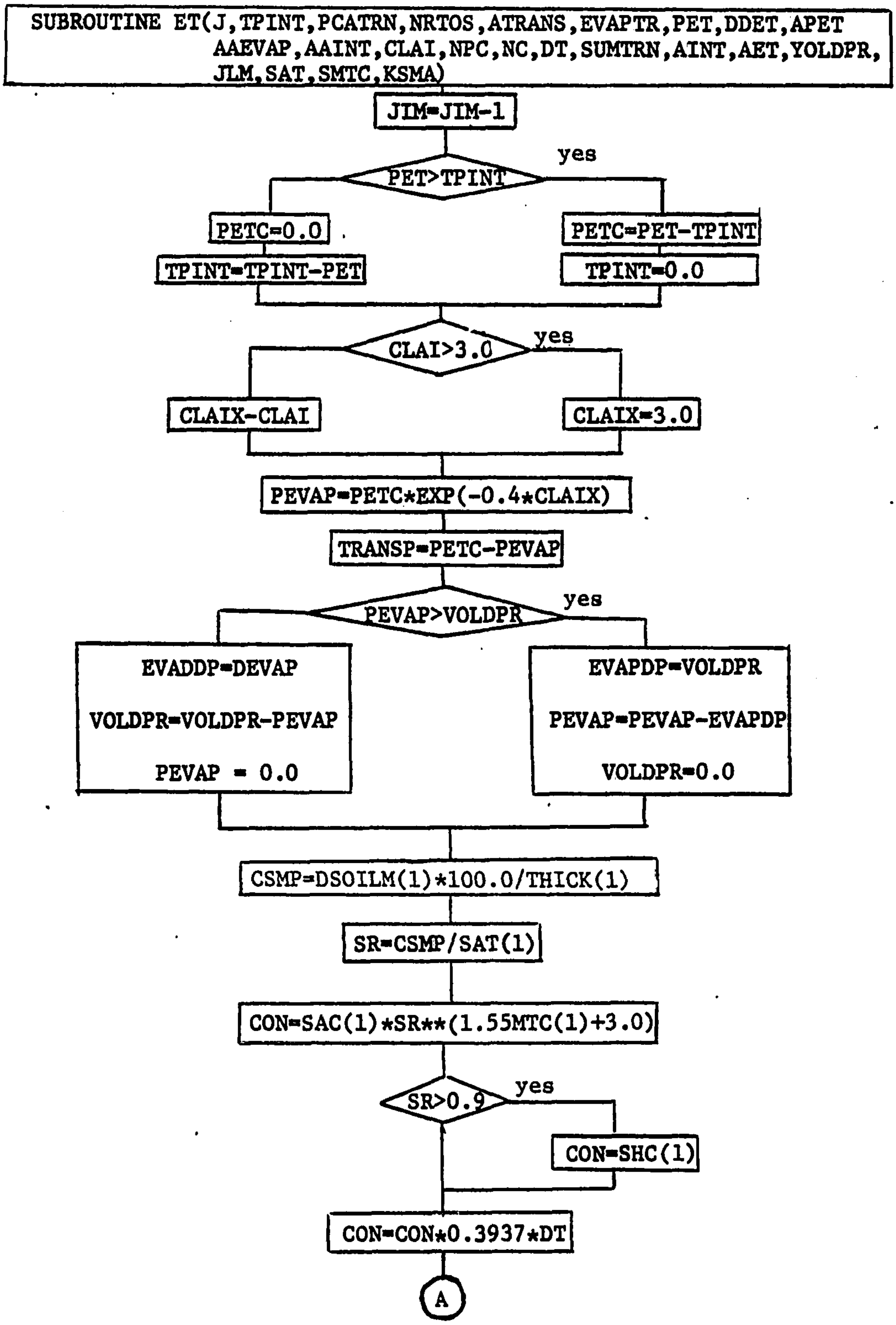

C
JIM2=JIM-2
JI=1,JIM2
COND(JI)<0.0
yes
CONMAX=DSOILM(JI)*0.50
CONMAX=DSOILM(JI+1)*(-0.5)
COND(JI)>CONMAX
yes
COND(JI)-CONMAX
COND(JI)< CONMAX
yes
CAND(JI)=CONMAX
DSOILM(J,JI)=ESOILM(J1)-COND(JI)
DSOILM(JI+1)=DSOILM(JI+1)+COND(JI)
yes
COND(JIM1)< 0.0
CONMAX=DSOILM(JIM1)*0.50
COND(JIM1)> CONMAX
yes
COND(JIM1)=CONMAX
DSOILM(JIM1)=DSOILM(JIM1)-COND(JIM1)
PERCO=PERCO+COND(JIM1)
ZPERC=0.0
105
JI=1,JIM1
yes
RSAT(JI)>DSOILM(JI)
ZPERC=SHC(JI+1)*DT*0.3937
EXTA=DSOILM(JI)-RSAT(JI)
D

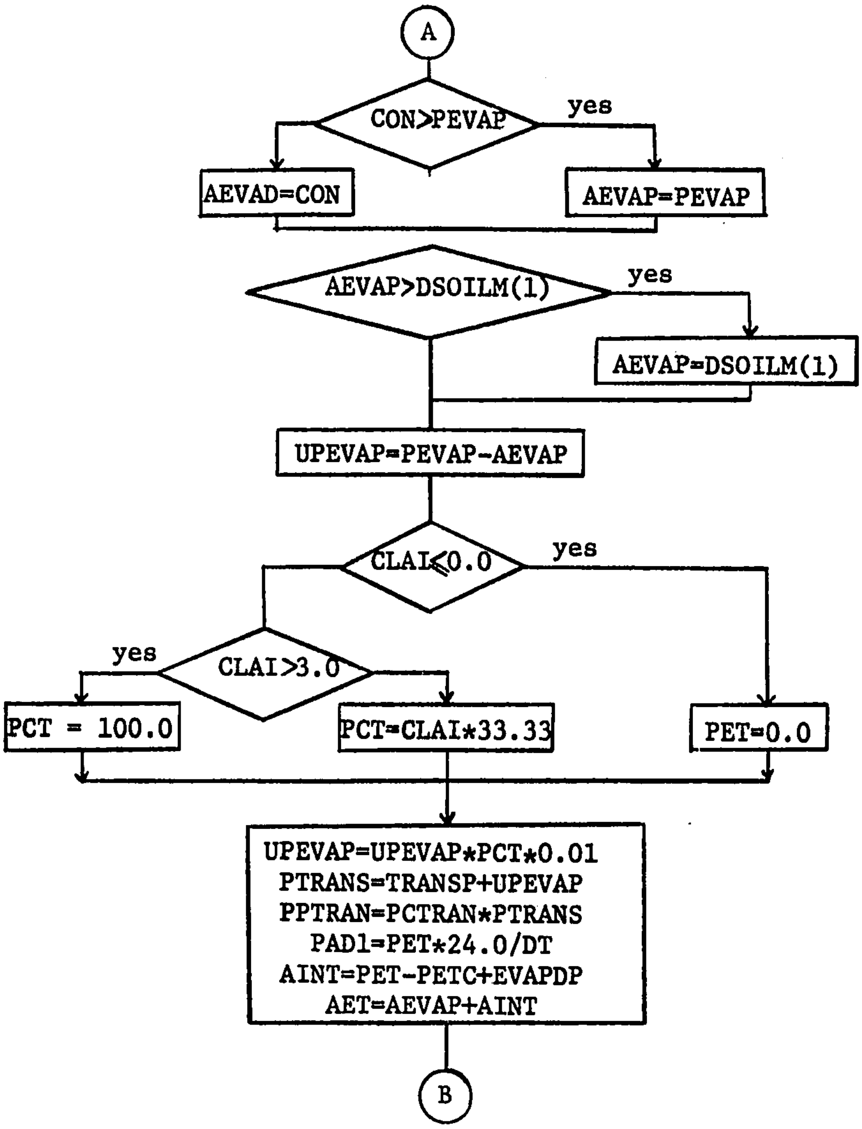

D
ZPERC>EXTA
yes
ZPERC=EXTA
DSOILM(JI)=DSOILM(JI)-ZPERC
JI=JIM1
yes
DSOILM(JI+1)=DSOILM(JI+1)+ZPERC
AINFIL(JI+1)=AINFIL(JI+1)+ZPERC
PERCO=PERCO+ZPERC
105
110
ZPERC=0.0
yes
140
KB=JIM1
EXTRA=DSOILM(KB)-ESAT(KB)
yes
EXTR>0.0
KB=KB-1
KB=0.0
yes
140
120
DSOILM(KB)=ESAT(KB)
KB=JTILE
yes
130
KB=KB-1
E
TILEQ=EXTRA*(-ALOG(TFRC**(DT/24.0)))
EXTRA=EXTRA-TILEQ
F

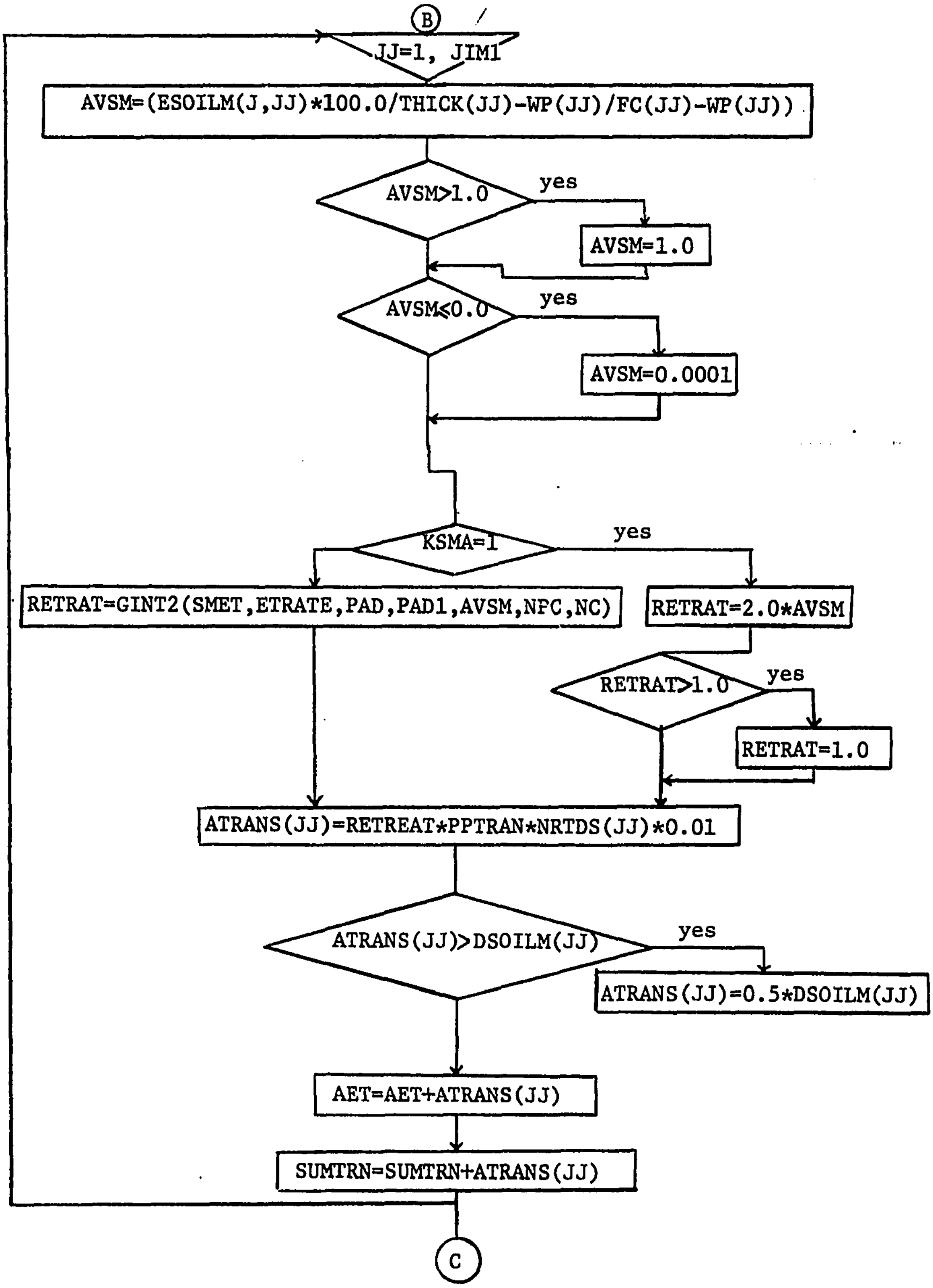

E
KB=0.0
yes
DSOILM(KB)=DSOILM(KB)+EXTRA
115
VOLDPR=VOLDPR+EXTRA
F
EXTRA > 0.0
yes
125
TILEQ=TILEQ+EXTRA
EXTRA=0.0
KB=KB-1
KB=0.0
yes
115
140
SPERCO=SPERCO+PERCO
ADTF=ADTF+TILEQ
SMASM=TOTSTR-DSOILM(1)-DSOILM(2)-DSOILM(3)-DSOILM(4)
LL=1,JIM1
ZINF(LL)=ZINF(LL+AINFJL(LL)
ZOUTF(LL)=ZOUTF(LL)+COND(LL)
145
RETURN
END

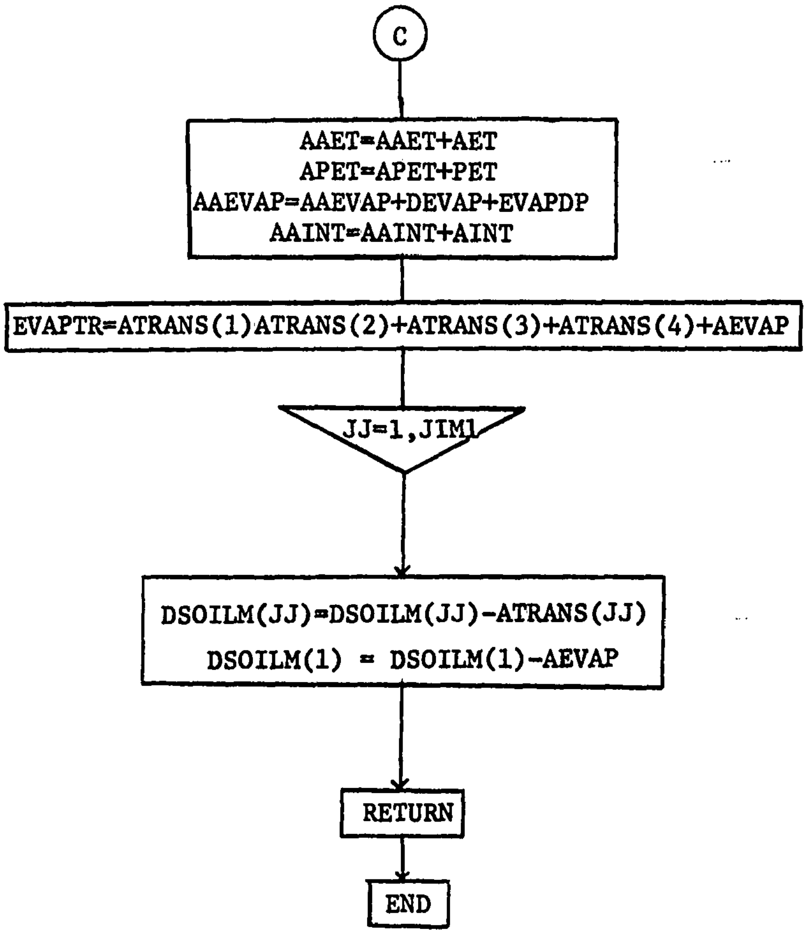

SUBROUTINE OFROUT(PEAI,VOLDPR,EQD,EQDF,OFR,TOFR,AREA
OFMN,NH,OFRF,OFRCFS,PUDLE,TRST,TRSTM,OFMN1,
OFMN2,SSRT,PUDLE1,PUDLE2)
QR = TRST/TRSTM
OFMN = OFMN1 - QR *(OFMN1-OFMN2)
OFMN<OFMN2
yes
OFMN=OFMN2
OFRF=1020.0*SSRT/OFMN
EQDF=0.00982*(OFMN/SSRT)**0.6
PUDLE = PUDLE1-0.80*(QR*(PUDLE1-PUDLE2))
PUDLE<PUDLE2
yes
PUDLE = PUDLE2
OFR = 0.0
OFRCFS = 0.0
SWS = VOLDPR+PEAI-PUDLE
SWS≤0.001
yes
12
(PEAI-VOLDPR) > 0.0
yes
EQD=0.5*SWS
11
EQD = EQDF*((PEAI-VOLDPR)**0.6)

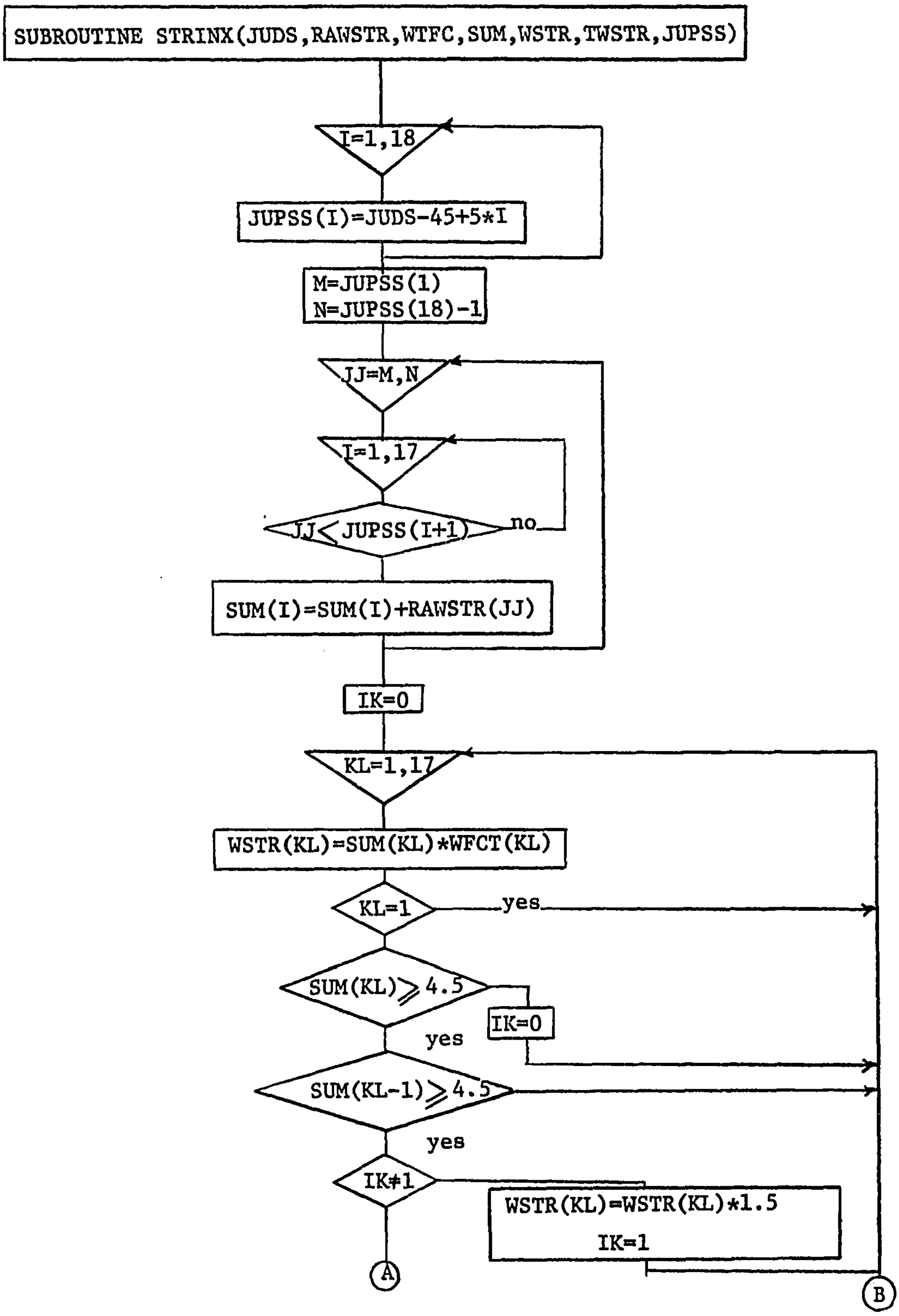

11
SWS > 2.0*EQD
yes
EQD = 0.5*SWS
OFR=(1.0/NH)*)FRF*((SWS*0.5)**1.67)*((1.0+0.6(SWS/(2.0*EQD))
3.0)1.67)
OFR > 0.75*PEAT
yes
OFR=0.75*PEAT
OFRCFS=1.0083*AREA*OFR*NH
12
TOFR=TOFR+OFR
TRST=TRST+OFR
VOLDPR=PEAT-OFR
RETURN
END

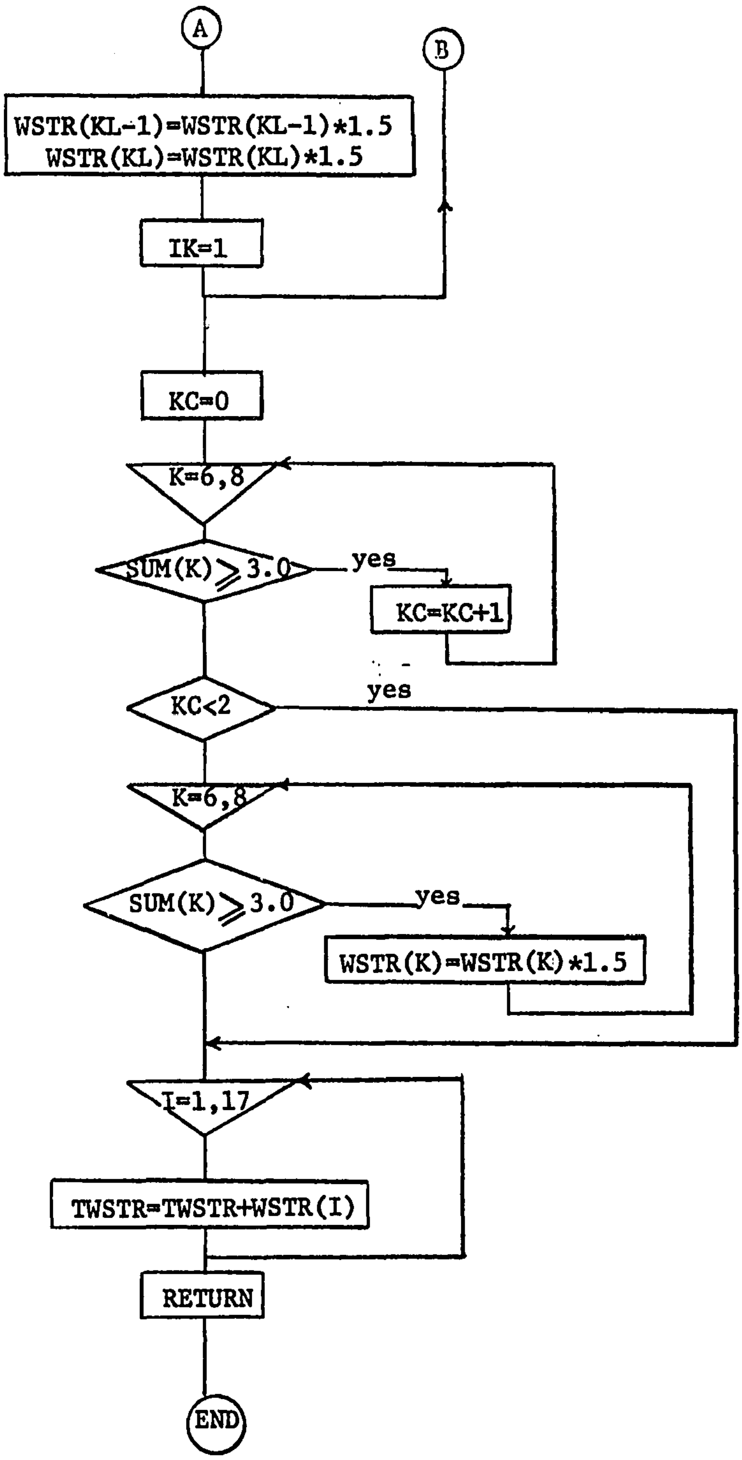

SUBROUTINE ET(J,TPINT,PCATRN,NRTOS,ATRANS,EVAPTR,PET,DDET,APET
AAEVAP,AAINT,CLAI,NPC,NC,DT,SUMTRN,AINT,AET,YOLDPR,
JLM,SAT,SMTC,KSMA)
JIM=JIM-1
PET>TPINT
yes
PETC=0.0
TPINT=TPINT-PET
PETC=PET-TPINT
TPINT=0.0
CLAI>3.0
yes
CLAIX-CLAI
CLAIX=3.0
PEVAP=PETC*EXP(-0.4*CLAIX)
TRANSP=PETC-PEVAP
PEVAP>VOLDPR
yes
EVADDP=DEVAP
VOLDPR=VOLDPR-PEVAP
PEVAP = 0.0
EVAPDP=VOLDPR
PEVAP=PEVAP-EVAPDP
VOLDPR=0.0
CSMP=DSOILM(1)*100.0/THICK(1)
SR=CSMP/SAT(1)
CON=SAC(1)*SR**(1.55MTC(1)+3.0)
SR>0.9
yes
CON=SHC(1)
CON=CON*0.3937*DT
A


A
CON>PEVAP
yes
AEVAD=CON
AEVAP=PEVAP
AEVAP>DSOILM(1)
yes
AEVAP=DSOILM(1)
UPEVAP=PEVAP-AEVAP
CLAI≤0.0
yes
yes
CLAI>3.0
PCT = 100.0
PCT=CLAI*33.33
PET=0.0
UPEVAP=UPEVAP*PCT*0.01
PTRANS=TRANSP+UPEVAP
PPTRAN=PCTRAN*PTRANS
PAD1=PET*24.0/DT
AINT=PET-PETC+EVAPDP
AET=AEVAP+AINT
B


B
JJ=1, JIM1
AVSM=(ESOILM(J,JJ)*100.0/THICK(JJ)-WP(JJ)/FC(JJ)-WP(JJ))
AVSM>1.0
yes
AVSM=1.0
AVSM≤0.0
yes
AVSM=0.0001
KSMA=1
yes
RETRAT=GINT2(SMET,ETRATE,PAD,PAD1,AVSM,NFC,NC)
RETRAT=2.0*AVSM
RETRAT>1.0
yes
RETRAT=1.0
ATRANS(JJ)=RETREAT*PPTRAN*NRTDS(JJ)*0.01
ATRANS(JJ)>DSOILM(JJ)
yes
ATRANS(JJ)=0.5*DSOILM(JJ)
AET=AET+ATRANS(JJ)
SUMTRN=SUMTRN+ATRANS(JJ)
C


C
AAET=AAET+AET
APET=APET+PET
AAEVAP=AAEVAP+DEVAP+EVAPDP
AAINT=AAINT+AINT
EVAPTR=ATRANS(1)ATRANS(2)+ATRANS(3)+ATRANS(4)+AEVAP
JJ=1,JIM1
DSOILM(JJ)=DSOILM(JJ)-ATRANS(JJ)
DSOILM(1) = DSOILM(1)-AEVAP
RETURN
END


SUBROUTINE STRINX(JUDS,RAWSTR,WTFC,SUM,WSTR,TWSTR,JUPSS)
I=1,18
JUPSS(I)=JUDS-45+5*I
M=JUPSS(1)
N=JUPSS(18)-1
JJ=M,N
I=1,17
JJ< JUPSS(I+1)
no
SUM(I)=SUM(I)+RAWSTR(JJ)
IK=0
KL=1,17
WSTR(KL)=SUM(KL)*WFCT(KL)
KL=1
yes
SUM(KL)≥4.5
IK=0
yes
SUM(KL-1)≥4.5
yes
IK≠1
WSTR(KL)=WSTR(KL)*1.5
IK=1
A
B


A
B
WSTR(KL-1)=WSTR(KL-1)*1.5
WSTR(KL)=WSTR(KL)*1.5
IK=1
KC=0
K=6,8
SUM(K)≥3.0
yes
KC=KC+1
KC<2
yes
K=6,8
SUM(K)≥3.0
yes
WSTR(K)=WSTR(K)*1.5
I=1,17
TWSTR=TWSTR+WSTR(I)
RETURN
END