DEVELOPING AN IRRIGATION SCHEDULING METHODOLOGY

by

Robert B. Hulsman
Principal Investigator
Agricultural Engineering Department

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ABSTRACT

This irrigation scheduling model uses a meteorologically-based equation to predict crop water use. The equation combines an energy balance function with an aerodynamic function, and utilizes pertinent meteorological variables in its derivation. Irrigation scheduling is based upon a water budget that maintains a predetermined soil moisture range within the crop root zone. A precise water balance bookkeeping system monitors soil water inputs and outputs. Irrigation scheduling is accomplished by evaluating present soil moisture conditions relative to a 7 - day prediction of crop water use. The model has been tested against previously determined values of evapotranspiration for corn and winter wheat. Results of these comparisons are within 0.4 percent for corn and 4.6 percent for winter wheat.

Keywords: computer models, irrigation programs, scheduling, water

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INTRODUCTION

The timely application of precise amounts of water, which assures adequate soil moisture is available for crop consumptive use without excessive runoff, deep percolation or conveyance losses, must be the goal of all irrigators. There are many methods available to the farmer to schedule irrigation applications. They range from the simple feel-and-appearance method to sophisticated irrigation scheduling techniques using micro-computers. The feel-and-appearance method is based on the farmer's ability to judge soil type and water content by feeling a sample of soil (Soil Conservation Service 1964).

Other techniques include measuring crop canopy temperatures with infrared thermometers, or checking the soil moisture status by measuring plant water potential using a pressure bomb (Hatfield 1981). Rhoades et al. (1981) discussed irrigation scheduling and soil moisture control through the use of salinity probes to measure bulk soil electric conductivity within the root zone. Changes in soil electric conductivity in the upper 15 to 30 cm are related to changes in soil water content. Irrigation is needed when the conductivity reaches a threshold value. Gary (1981) installed three to four gypsum blocks in series, in a silt soil, at a depth of 15 cm. The devices were connected so any changes in the resistance of the blocks could be transmitted to a microprocessor. Gypsum blocks could be used to schedule irrigations if the resistance recording device was calibrated to read soil moisture potential. Automatically controlled sprinkler irrigation systems have been tested using such sensors (Shull et al. 1980).

Tensiometers are often used to measure soil water potential and can be used to schedule irrigations without reference to soil water content (Haise et al. 1967). Usually an automatically operated switch, activated by a tripping device attached to the tensiometer dial, sends a signal to the irrigation system when an irrigation is needed or when an irrigation is complete. The tensiometer dial is equipped with limiting devices that can be set manually to maximum and minimum values of soil water potential, reflecting irrigation start and stop conditions. In actual practice, the tensiometer is most frequently used in coarse- to medium-textured soils, and resistance blocks in medium- to fine-textured soils. Resistance readings for given soil water contents will be lower in salt-affected soils than in those soils of low salt content (Haise et al. 1967).

Other soil moisture instruments have been used to monitor the distribution and quantity of moisture in the soil. A graphic display of neutron probe measurements was employed by Gear et al. (1977). His method required only the identification of a soil moisture refill point and neutron measurements of water content with time on a graph for each field. When the soil moisture content reached the refill point on the graph, an irrigation was called for. The amount of applied irrigation water was equal to the amount indicated on the graph.

Soil moisture information is needed to irrigate using all of the above mentioned methods, which means the irrigator must have the measuring equipment or use the services of someone who does. The washtub method, developed to be used in the field by the farmer with little more than a $10 capital investment, was introduced by Westesen (1981). This method uses a No. 1 washtub calibrated to provide the user with an estimate of crop water use. A daily log was maintained of evaporation from the pan. When a predetermined depletion was noted, the sprinkler system was activated and remained on until the water level in the pan was again at the prescribed level. This level corresponded to field capacity for that particular soil.

The concept of an irrigation scheduling service was first introduced by Jensen (1969). He developed an irrigation scheduling model that estimated crop water use using meteorological data and a water-balance checkbook method of keeping track of the soil moisture (Jensen et al. 1971). Irrigation scheduling by the checkbook method was further developed by Lundstrum et al. (1981) in the mid-1970's and was based on the Jensen water-balance technique. Daily water use tables, dependent on maximum daily temperatures and stage of crop growth, were developed. After determining crop emergence, an irrigator reads the estimated daily water use from a table using weeks after emergence and maximum daily air temperature as input data. A water-balance (checkbook) sheet is kept to determine when to irrigate, avoiding excessive soil water depletions, yet not over-irrigating. The concept of scheduling with computers was further advanced by the introduction of a microcomputer program (Crouch et al. 1981). This concept employed the techniques of interactive, user-oriented programming.

This study developed an irrigation scheduling methodology to be used in the High Plains area of New Mexico. The method employs the concepts presented by Jensen et al (1971) and Crouch et al (1981).

METHODS AND PROCEDURES

Data Collection

Soil moisture data were collected from fields of cooperating farmers in the Clovis, N. M. area, over a 3-year period on corn, sorghum and grazed winter wheat sprinkle irrigated with center pivots. These fields are located within a 10-mile radius of the Agricultural Science Center at Clovis. Crop varieties, along with planting and harvesting dates, are listed in table 1. Soils in the area were determined by soil analysis to be Amarillo sandy loam. Soil samples were taken, at five randomly selected locations on each field at 15, 30, 46 and 61 cm depths, 5 days per week. Soil moisture amounts in each of the samples were determined by the gravimetric technique described by Gardner (1965) and comparing the moisture amounts between days. The difference in amounts on succeeding days was assumed to be caused by evapotranspiration. Deep percolation losses were asssumed to be zero because of a caliche layer that retricted the downward movement of soil water. The caliche layer was measured and found to vary from 58 to 70 cm deep. An average depth of 62 cm was used in this study.

Rainfall and irrigation application amounts were measured for each field with small plastic rain gauges. Two gauges were installed in each field to measure rainfall and irrigation water applications. Ideally, a series of rain gauges would be installed along the length of the center pivot irrigation system, at equally spaced intervals, to estimate water application. This procedure is both time consuming and unnecessary. Two rain gauges provide adequate estimates, if properly placed. Pair

Table 1. Crop variety, planting date and harvesting date by crop type and year of application.

Crop	Year	Variety	Planting Date	Harvesting Date
Corn	1982	Pioneer 3186	05-04-82	10-15-82
	1983	Pioneer 3186	04-18-83	10-12-83
	1984	Pioneer 3186	04-20-84	Note 1.
Sorghum	1982	Pioneer 8222	05-22-82	09-27-82
	1983	Pioneer 8222	05-25-83	10-07-93
	1984	Norhtrup King 2778	05-26-84	Note 1.
Winter	1983	TAM 105	09-25-82	05-04-83
Wheat	1984	Centurk	09-15-83	05-15-84

Note 1: Harvesting data not available at the time of this writing.

(1983) shows overlapped sprinkler patterns for commonly used nozzle types. These patterns display a characteristic shape with a definite high and low point between nozzles. Rain gauges at these locations provided two application extremes that were averaged to arrive at a final application depth. These data were stored in the irrigation model for future use in calculating the soil water balance, discussed in detail later.

Daily meteorological data were collected via an automatic weather data acquisition system at the Agricultural Science Center at Clovis, N. M. The data were automatically sent to the computer main frame on the New Mexico State University campus where it was electronically stored. These data were retrieved and entered into the scheduling model as input weather data consisting of maximum and minimum temperatures, maximum and minimum relative humidities, solar radiation and total daily wind run.

Computer Model

The irrigation scheduling model was developed to be used with an IBM-PC personal home computer with PC-DOS Version 2.0, two 320K disk drives and 256K of memory. Other computer brands could be used with slight changes in the program to accommodate the various BASIC language and operating system peculiarities associated with each. The scheduling model, shown in the flow diagrams in figures 1 and 2, was developed using the Penman combination equation to evaluate potential evapotranspiration as follows:

$$ETp = (0.0017)(C1(Rn + G) + C2(W)(Ezo - Ed)) \qquad (1)$$

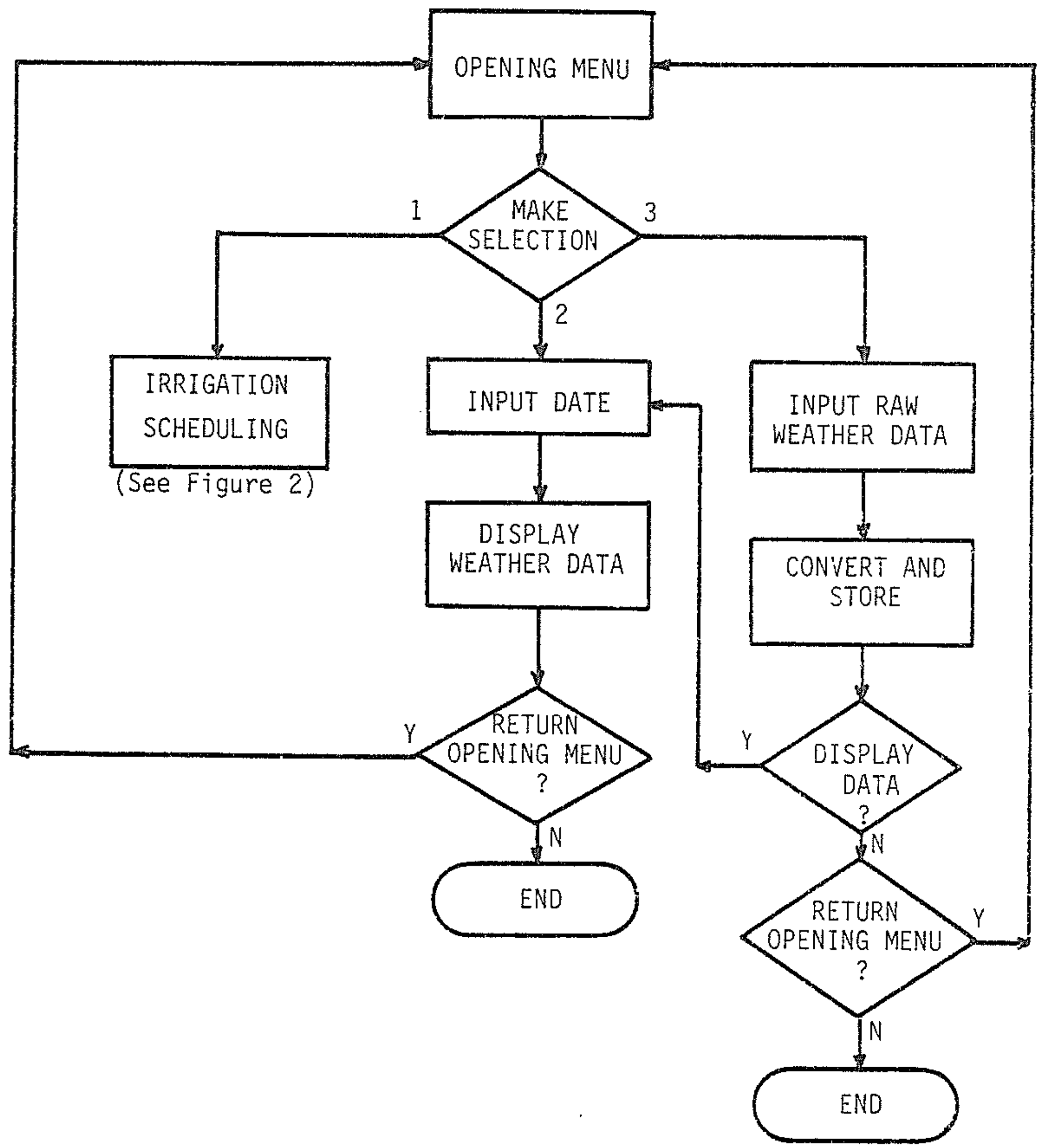

Figure 1. Flow diagram of the Opening Menu and the three selections available to the user.

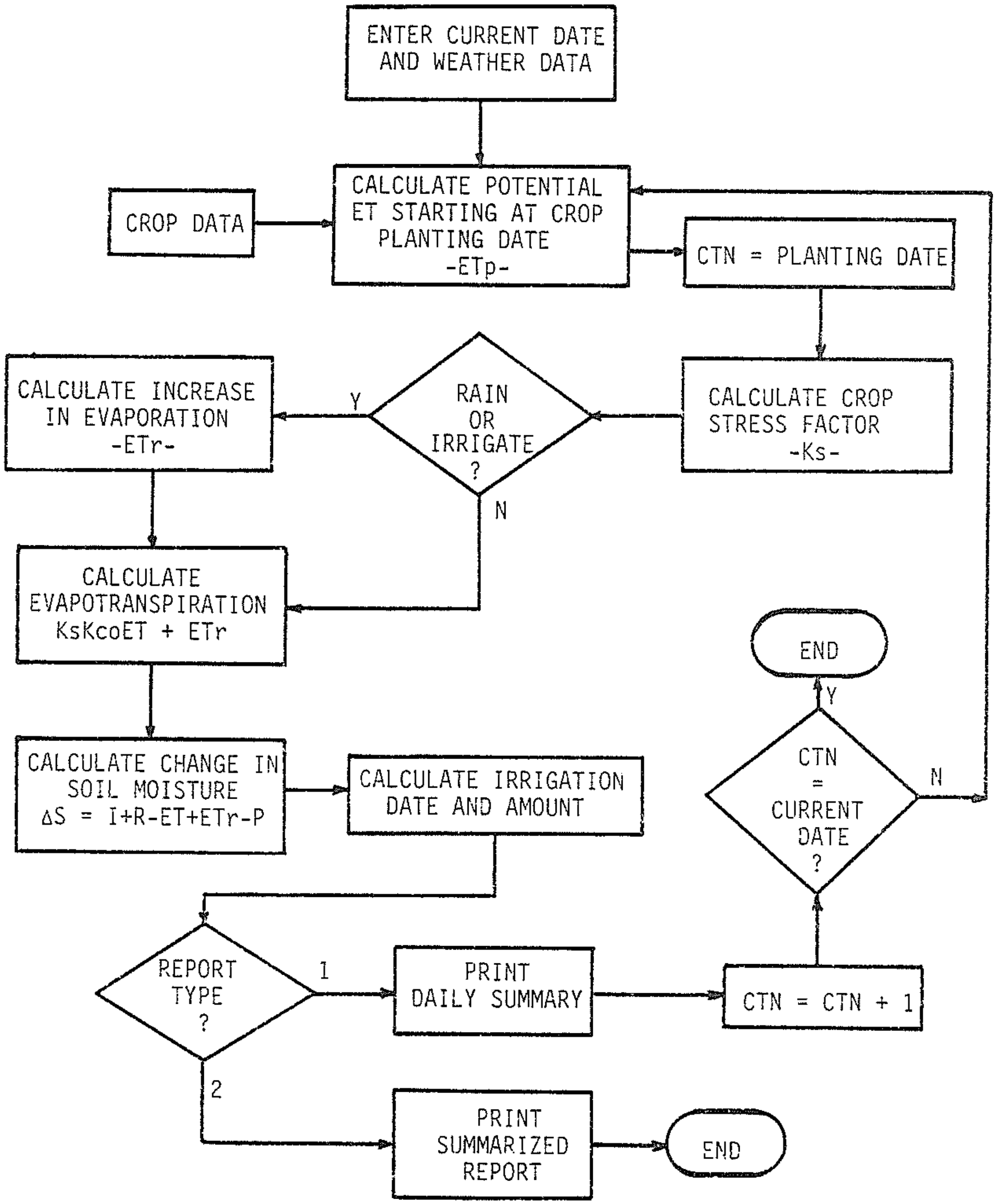

Figure 2. Flow diagram of the irrigation scheduling model.

where ETp is potential evapotranspiration, in cm, C1 and C2 are mean temperature weighting factors whose sum is equal to 1.0, Rn is net solar radiation, in calories/square centimeter/day, G is heat flux to or from the soil surface, in calories/square centimeter/day, W is total daily wind run, in kilometers/day, Ezo is mean saturated vapor pressure and Ed is the saturated vapor pressure at dewpoint temperature, both in millibars. A complete breakdown of the variables in this equation is found in appendix A.

Evapotranspiration (ET) from a crop was determined by multiplying ETp by a crop factor called the crop coefficient, Kco. Depletions based on soil moisture data were collected for a particular crop during the entire cropping season. These data were analyzed gravimetrically, as described earlier, and are termed evapotranspiration, ETg, for that crop. Meteorological data were also collected over the same period and used to calculate potential evapotranspiration, ETp. Crop coefficients were derived for each crop grown under near-optimum conditions, as described by Doorenbos et al (1975), and determined by dividing incremental values of ETg by ETp as described by Doorenbos et al (1979). A final value for Kco was found by combining all values of incremental Kco data points into a least squares, best fit routine. The resulting third degree polynomial in X, where X is the sequential day of the calendar year, was entered into the irrigation scheduling model as part of the evapotranspiration equation. The procedure outlined was followed for all three crops. Two such equations were derived for winter wheat. The growing season for this crop was divided into two parts, the fall season that started at the planting date and continued until the end of the calendar year, and the summer season that began at the first of the year and lasted until harvest.

Crop ET was further adjusted to account for the affects of soil moisture depletion. As soil moisture was depleted, the crop was subjected to a certain degree of stress and the amount of stress was proportional to the magnitude of the soil moisture depletion. The crop coefficient was modified according to the following relationship to adjust for this stress:

$$Kc = Kco\ (Ks) \tag{2}$$

where Ks is a dimensionless soil moisture stress factor described by the following conditions:

$$Ks = 1.0 \quad \text{when } (Tdpl/Avwtr) <= 0.50 \tag{3}$$

$$Ks = 2 - 2(Tdpl/Avwtr) \quad \text{when } (Tdpl/Avwtr) > 0.50 \tag{4}$$

in which Tdpl is the total soil moisture depletion, in cm, and Avwtr is the available water in the root zone, in cm, when the soil is at field capacity. This relationship describes a linear stress factor for soil moisture depletions of greater than 50 percent.

Immediately following a rainfall or irrigation event, water use will be near potential, or ETp; therefore, crop ET must be adjusted further to account for this change. Kincaid et al. (1974) introduced an empirically derived equation that is used to add an additional evaporation amount to ET:

$$ETr = Kr(0.9 - Kc)ETp \qquad (5)$$

where ETr is an additional evaporation amount, in cm, to be added to the normal ET for the day in question, Kr is a factor taking the value of 0.8 for the first day, 0.5 for the second day and 0.3 for the third day following a rainfall or an irrigation. If Kc is greater than or equal to 0.9, or if no rain or irrigation has occurred within 3 days, then ETr is equal to zero. The final equation describing evapotranspiration is:

$$ET = Kc(ETp) + ETr \qquad (6)$$

Accumulated soil moisture depletion, up to a given day, was defined as:

$$Dpl_i = Dpl_{i-1} + ET_i - R_i - I_i \qquad (7)$$

in which Dpl is the depleted quantity on day i, Dpl_{i-1} is the depletion on day i -1, R is a rainfall amount and I is an irrigation amount, all expressed in cm. If the sum of R and I is greater than Dpl_{i-1}, then the depletion amount, Dpl, was set to zero. Depletion was defined as the amount of moisture extracted from the soil profile beginning at the start of the season with the soil moisture at field capacity.

Available water in the soil was calculated by evaluating crop root development with respect to time. The time required for a plant to reach maximum rooting depth is expressed as a percent of time until effective cover multiplied by the maximum rooting depth, thus:

$$R = ((SEQ - PD)/(EC - PD)) (RTZ) \quad (8)$$

where R is the current root depth, in cm, SEQ is the sequential day of the calender year, PD is the sequential day of crop planting, EC is the sequential day of effective cover and RTZ is the maximum rooting depth, in cm, under the existing conditions. Effective cover is the sequential day of the year for tasseling in corn and for heading in wheat and sorghum.

These days were observed to be approximately 85 days after planting for corn and 75 days after planting for wheat and sorghum. Effective cover was built into the model and will not normally be adjusted by the user. Available water was calculated by multiplying the plant rooting depth by the soil water-holding capacity. The water-holding capacity was calculated by subtracting the mass water content at the permanent wilting percentage from the mass water content at field capacity. The difference was multiplied by the soil bulk density (1.596 gm/cc) to arrive at a volume water content. Available water was found by multiplying volume water content by depth increments. Mass water contents were determined by the New Mexico State University Soils Laboratory, using samples retrieved from the fields in which the crops were grown.

Scheduling

Irrigation scheduling output data were arranged in two different formats selectable from the keyboard. The first format was designed to be a detailed daily report presenting the current date, total available water in the root zone as of the current date, the management allowed depletion amount as a percent of the total available water, remaining water in the root zone, and the projected irrigation date and amount. The management allowed depletion is normally taken to be 50 percent of the available water in the root zone (Pair 1983). The model allows the user to input a depletion percentage of his choice. Any depletion beyond the recommended 50 percent, however, can affect yields because of induced water stress. The remaining water within the crop rooting depth was equal to the allowable depletion amount, less water lost to ET. A negative value for this amount indicates soil moisture has been depleted below management allowed depletion by an amount equal to the absolute value of the negative value.

The projected irrigation date was found by dividing a 7-day ET average into the remaining soil moisture to determine how many days of water use remained. The 7-day average was calculated by adding, to the present ET value, the values of ET for the past 3 days and estimated values for the next 3 days. ET for the next 3 days was determined by solving the ETg third degree polynomial for the crop in question. ET for the past 3 days was retrieved from computer memory. This sum was divided by 7 to yield an ET, which when divided into the remaining soil moisture, predicted the number of days of soil moisture remaining. This number, when added to the current date, predicted an irrigation date. The irrigation amount was the total water depletion thus far. After irrigation, the depleted amount was reset to account for the change in soil moisture.

The second format for data output was designed to be a brief, summarized report. The only data shown in this output format is the current date, the name of the crop under consideration, the moisture amount remaining in the soil, the irrigation date and the amount to be irrigated. Both output formats report the total water consumptively used and the total water that has been applied to the field thus far.

RESULTS AND DISCUSSION

Data Analysis

A comparison of average county yields to those achieved by the farmers participating in this research (table 2) shows that all, with the exception of 1982 sorghum, exceeded county averages. Average county yields were derived from 8 years of data (1975 - 1982) for Curry County (Gearhardt et al. 1982). This indicates the farmers selected for this study were above-average farmers, and the data collected from their fields indicated better-than-average water management practices during the test period. The high yields also indicate the crops studied in this report were not subjected to water stress at the time of the study. Additional evidence of this will be presented later.

The data in table 3 are coefficients for third degree polynomials describing ETg for the crops and years indicated. A plot of each of these functions can be found in figures 3 through 5. The pertinent statistical information defining how well the data fit the equations is also noted. Referring to the figures, the curves for 1982 corn and sorghum crops are somewhat lower in magnitude, compared with other years. These two crops were severely damaged by a hail storm early in the growing season, reducing ETg to less than optimum as described by Doorenbos, et al (1975). Because of this, the ETg data for these two years

Table 2. Applied nitrogen fertilizer and actual yields achieved by farmers, along with average county yields and standard deviations, for the 1975 - 1982 period for Curry County.

Year	Crop	Fertilizer Nitrogen (kg/ha)	Achieved Yields (kg/ha)	County Ave. Yields (kg/ha)	S.D.* (kg/ha)
1982	Corn	336	11290	7200	122
1983	Corn	336	12519	7200	122
1984	Corn	336	12650	7200	122
1982	Sorghum	179	5704	5808	428
1983	Sorghum	167	6633	5808	428
1984	Sorghum	292	7481	5808	428
1983	Wheat	112	4099	3172	305
1984	Wheat	101	5242	3172	305

* S.D. - Standard deviation

Table 3. Coefficients for third degree polynomials describing gravimetrically measured ET for the crops and years indicated. The coefficient of determination, variance and standard deviation are also shown.

CORN

	1982	1983	1984
a	-2.9557	-1.048998	-0.9451436
b	3.963971E-02	9.265205E-03	2.343942E-03
c	-1.471807E-04	0.091971E-06	4.135742E-05
d	1.450245E-07	-1.050278E-07	-5.156703E-07
R-sqr	0.902	0.797	0.967
Var	0.002	0.006	0.001
Dev	0.045	0.079	0.025

SORGHUM

	1982	1983	1984
a	-9.834251	-2.323027	-4.689631
b	0.134624	2.911259E-02	5.908156E-02
c	-5.861974E-04	-9.59563E-05	-2.206338E-04
d	8.23958E-07	7.470662E-08	2.470596E-07
R-sqr	0.860	0.846	0.995
Var	0.002	0.002	0.000
Dev	0.042	0.054	0.011

WINTER WHEAT

	1983	1984	Fall
a	8.779228E-02	9.805757E-02	0.8638185
b	-5.591262E-03	-7.116188E-03	2.704531E-03
c	1.045181E-04	1.193397E-04	-3.680763E-05
d	-4.299408E-07	-4.38947E-07	6.278476E-08
R-sqr	0.799	0.918	0.939
Var	0.002	0.002	0.000
Dev	0.045	0.042	0.20

a,b,c,d: coefficients of a third degree polynomial of the form a + b*X + C*X*X + D*X*X*X, where X is the sequential day of the year.

R-sqr: Coefficient of determination

Var : Variance

Dev : Deviation

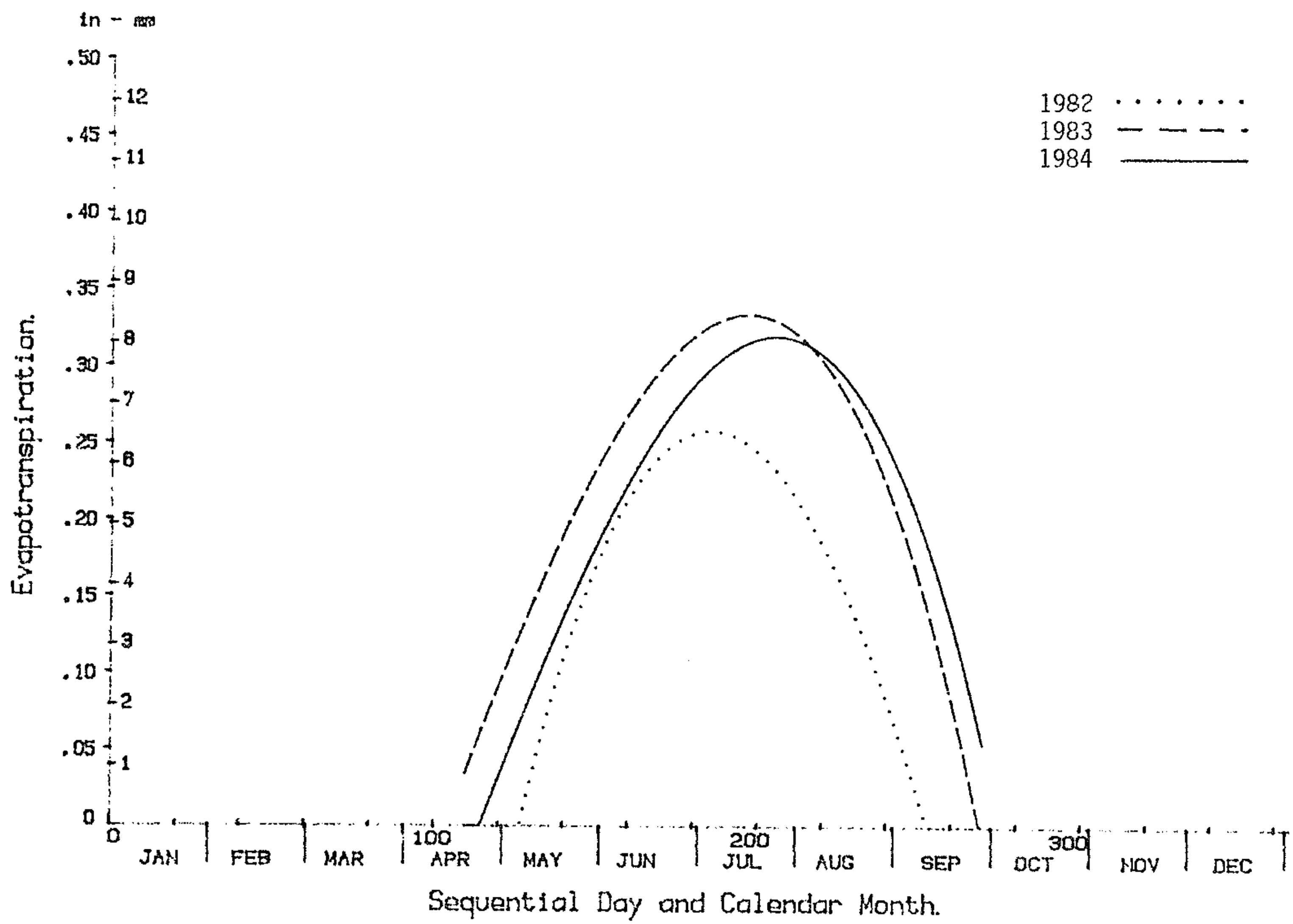

Figure 3. Evapotranspiration described by least squares best fit polynomials derived from gravimetric soil samplings for corn at Clovis, N.M.

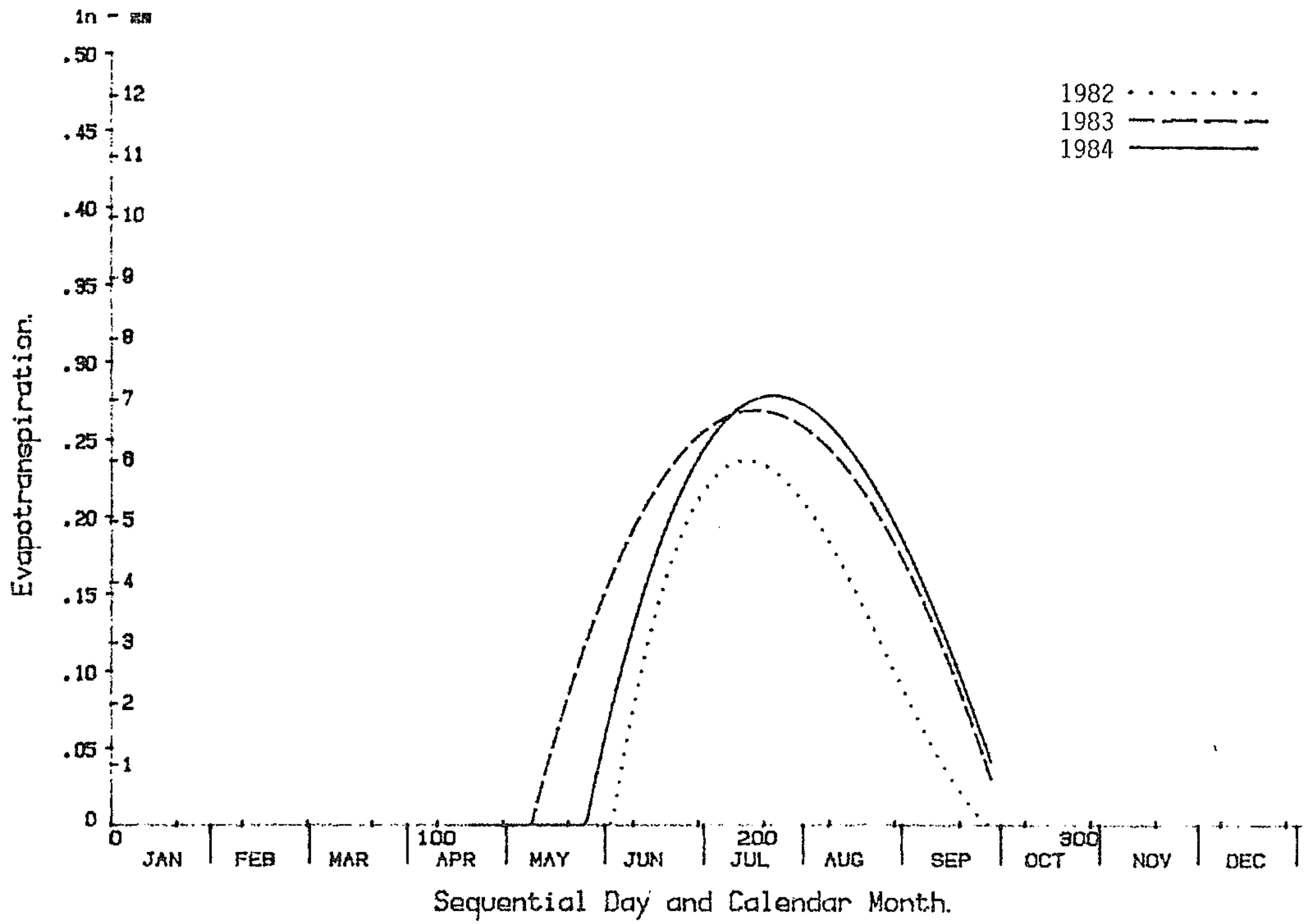

Figure 4. Evapotranspiration described by least squares best fit polynomials derived from gravimetric soil samplings for sorghum at Clovis, N.M.

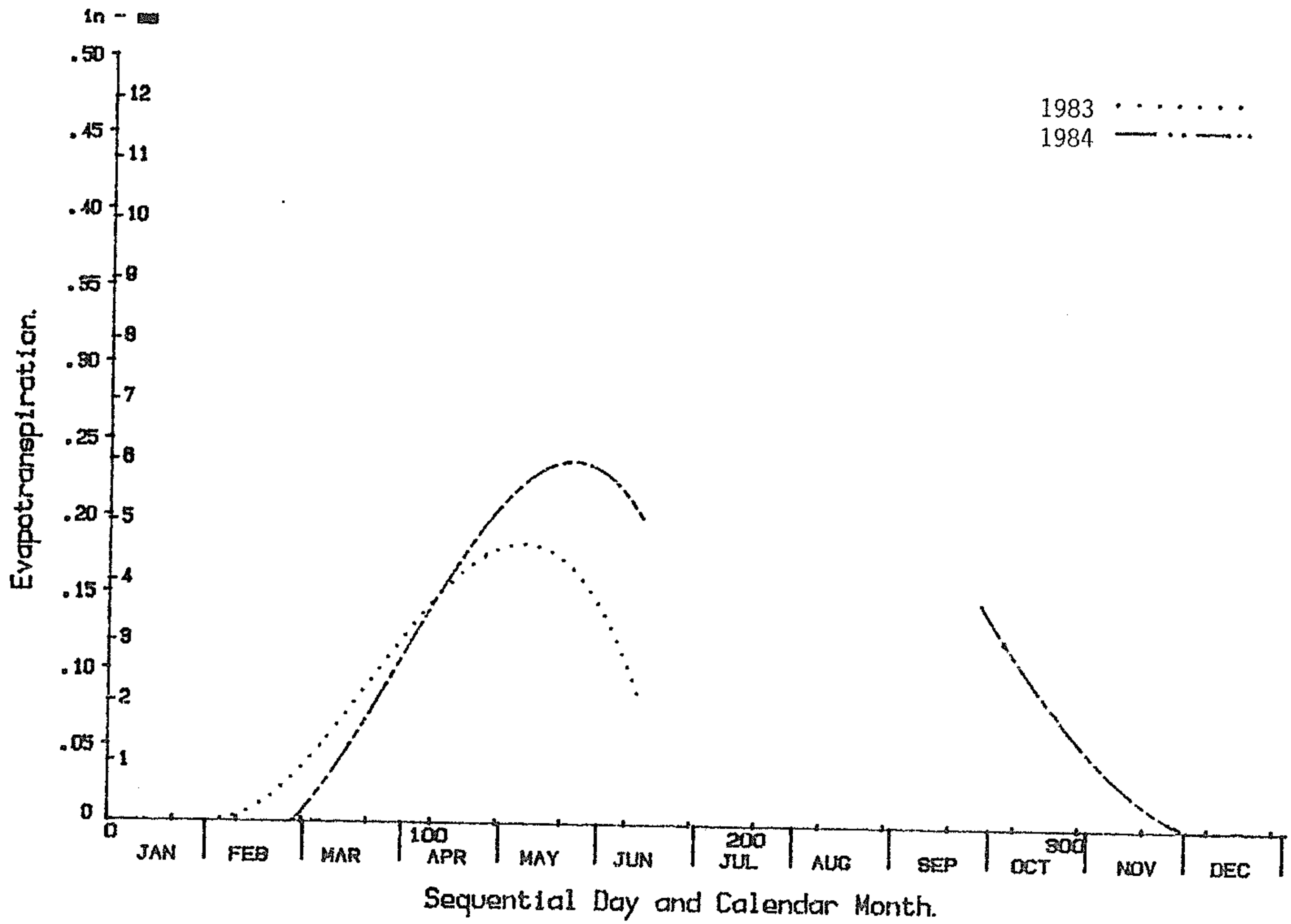

Figure 5. Evapotranspiration described by least squares best fit polynomials derived from gravimetric soil samplings for winter wheat at Clovis, N.M.

could not used to calculate crop coefficients. The same is true of the 1983 winter wheat crop ETg function shown in the table and in figure 5. Although each of these functions produced above-average yields for the county, they are below optimum when compared with the ETg functions of other years. The coefficients of determination for each of the polynomial functions are well into the 80 and high 90 percent range; for example, a 98 and 99 percent for 1984 corn and sorghum data, indicating the data fit these functions well.

The 1983 and 1984 corn and sorghum functions, and the 1984 winter wheat functions, were used to calculate the crop coefficients tabulated in table 4. A plot of these Kco functions appears in figures 6 through 8, along with the data points that define the function. Statistical relationships of coefficients of determination, variance and standard deviation are listed in the tables. The coefficients of variation for these functions are all in the low to middle 80 percentages, with Kco for the fall winter wheat function in the middle 90 percentages.

<u>Model Testing</u>

The model was tested using data gathered at the Agricultural Science Center in Clovis, N. M. Sammis et al. (1983a, 1983b) reported irrigation and yield studies on corn, (1980 through 1982) using a line source sprinkler system. The line source was an irrigation pipe laid out with impact type sprinkler devices spaced at 6.1 m intervals and operating at 300 kPa pressure. Irrigation application depths decreased with distance from the line because of the sprinklers triangular spray pattern. This irrigation technique allowed the researcher to gather yield data

Table 4. Third degree polynomial coefficients that describe the crop coefficients (Kco), for the crops indicated. The coefficient of determination, variance and the standard deviation is also shown.

	CROP COEFFICIENT			
			Winter Wheat	
	Corn	Sorghum	Summer	Fall
a	-0.9451436	0.8323011	0.3947172	4.763236
b	-3.461883E-03	-3.708407E-02	-2.820653E-02	-2.011038E-02
c	1.666711E-04	3.407026E-04	4.799241E-04	5.909489E-06
d	-5.156703E-07	-7.902252E-07	-1.873487E-06	3.614189E-08
R-sqr	0.807	0.824	0.856	0.948
Var	0.028	0.017	0.030	0.003
Dev	0.169	0.129	0.173	0.058

a,b,c,d: coefficients for a third degree polynomial of the form a + b*X + c*X*X + d*X*X*X where X is the sequential day of the year

R-sqr: coefficient of determination

Var : variance

Dev : standard deviation

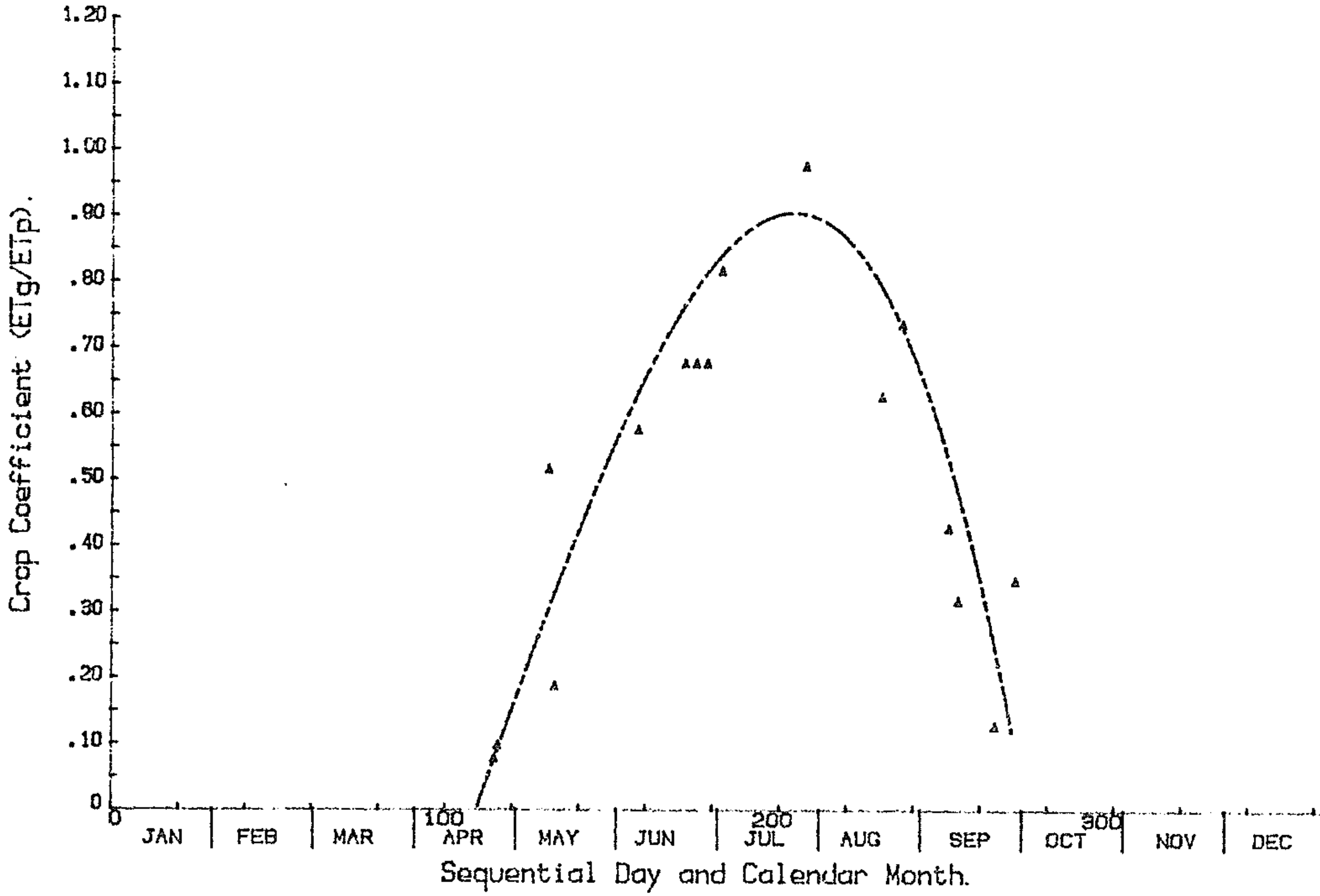

Figure 6. A crop coefficient plot for corn as described by a least squares best fit polynomial along with its data points.

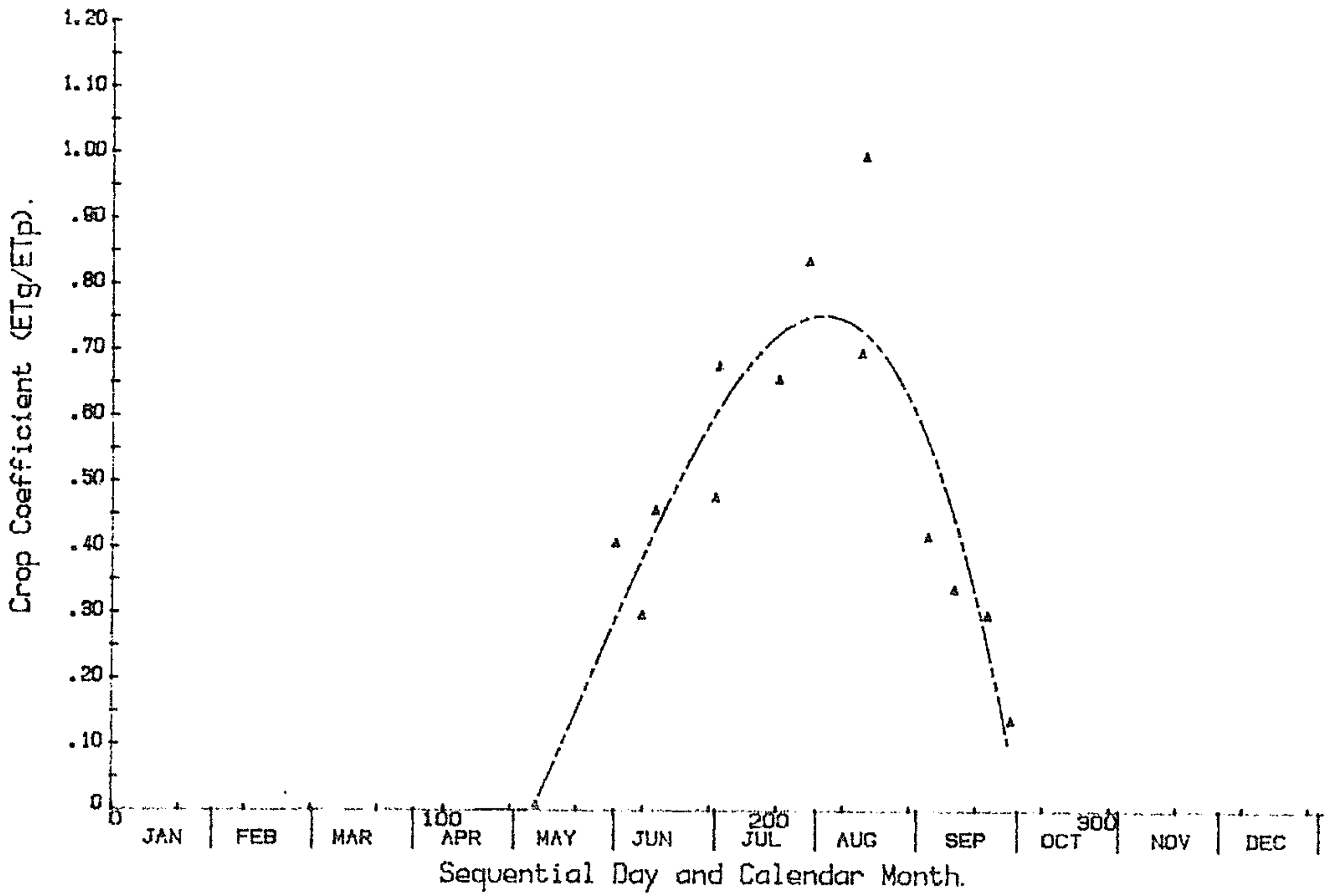

Figure 7. A crop coefficient plot for sorghum as described by a least squares best fit polynomial along with its data points.

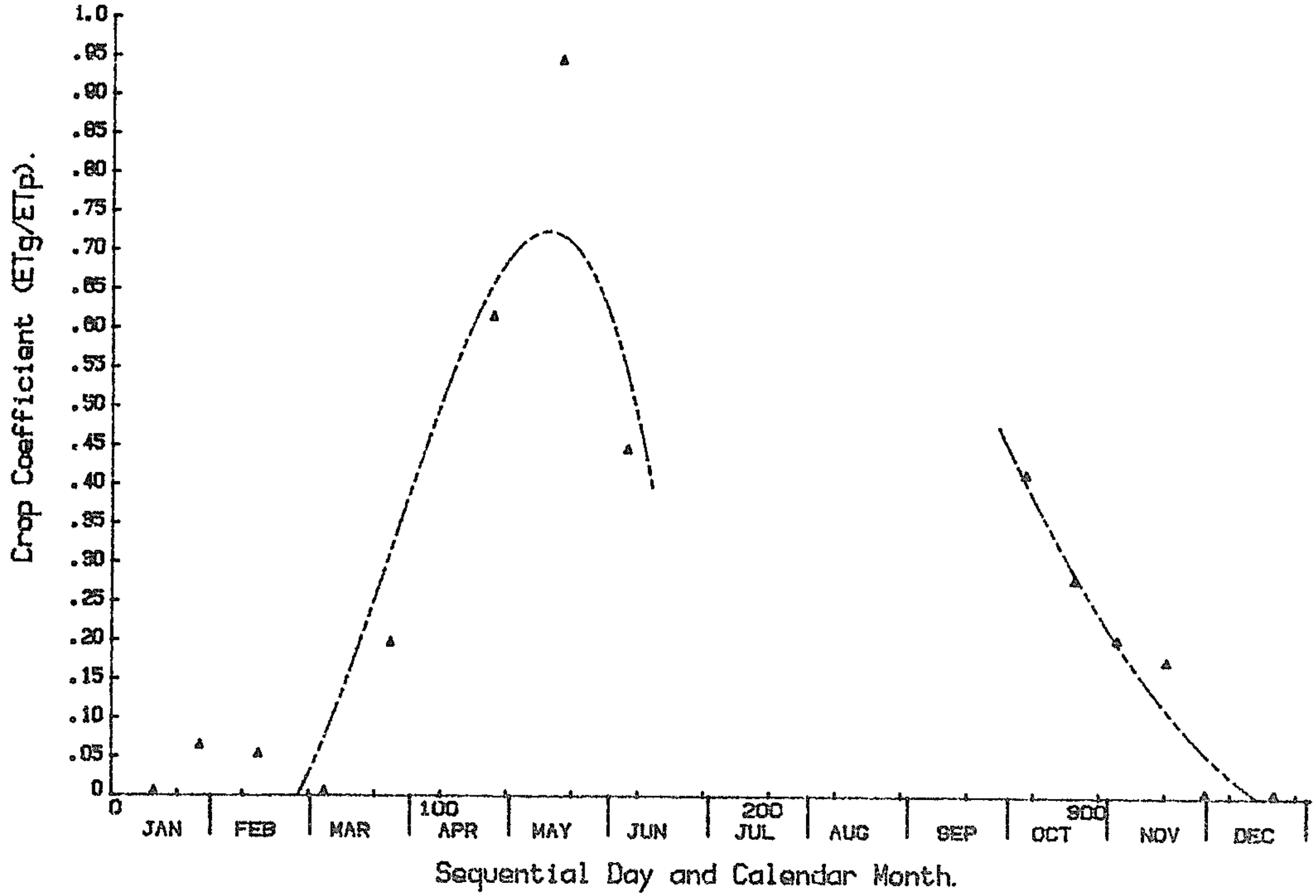

Figure 8. A crop coefficient plot for winter wheat as described by a least squares best fit polynomial along with its data points. Two separate polynomials are shown, one for the summer season and another for the fall season.

for crops irrigated under conditions of increasing water stress. Table 5 is a tabulation of eight plots irrigated with differing amounts of water on the days indicated. The ET reported by Sammis et al. (1983a) is compared with ET predicted by the model. Results of this comparison are shown in table 6. The percentage difference between the two methods is small, averaging only 0.4 percent, indicating the two methods are in close agreement. The model over-predicts ET at the extremely dry end of the spectrum, as shown by the greater percentage difference for plot number 1. This may be due to the operation of the stress function in the model (see equations 3 and 4) under conditions of extreme stress. The yields produced by the Sammis report are noted in the last column of the table. The maximum yield obtained using the line source was 9,703 kg/ha, with fertilizer applied at the rate of 336 kg/ha. Yields obtained by the farmers in this study were slightly higher than this, as noted in table 2. The difference is assumed to be due to the difference in factors other than water and nitrogen applications, such as potasium, phosphorus or other trace elements. The data indicate the crop coefficients derived in the study are correct and were obtained from fields where the soil moisture was not a limiting factor. Tables 7 and 8 provide the same data for the winter wheat model test. Again, data support the calculations of crop coefficients. The average difference between the measured ET and the model generated ET was -4.6 percent. The fact that the wheat crop in this study was grazed during the winter months, and not in the Sammis study, may account for this difference.

No data were available to test the model for the sorghum crop. It is assumed this crop can be scheduled as well as the

Table 5. Schedule of irrigation amounts for eight plots of corn at the Clovis, N. M. Science Center (Sammis 1983a).

	Sequential Day of Year									
	160	175	183	191	195	199	210	219	237	246
Plots	Amount, in cm									
1	0.03	0.00	0.00	0.27	0.05	0.18	0.00	0.00	0.00	0.00
2	0.21	0.00	0.00	0.66	0.43	0.86	0.25	0.37	0.00	0.06
3	0.78	0.12	0.00	0.97	0.80	1.53	0.90	1.00	0.51	0.56
4	1.40	0.65	0.21	1.30	1.19	2.03	1.65	1.73	1.85	1.24
5	2.13	1.51	0.78	1.55	1.50	2.54	2.15	2.36	1.82	1.74
6	2.28	2.57	1.92	1.73	4.62	2.92	2.75	2.69	1.55	2.15
7	3.26	3.16	3.30	1.87	1.79	2.93	2.69	2.99	1.58	2.30
8	3.15	3.21	4.00	2.23	3.28	3.38	3.16	3.32	3.09	2.53

Table 6. A comparison of model-projected corn evapotranspiration compared with data collected at the Clovis Research Center (Sammis 1983a). Yield data and measured ET amounts are in response to 112 kgN/ha. Rainfall amount was equal to 17.45 cm for all irrigated plots.

Irrigated Plot	Measured ET (cm)	Model ET (cm)	Percent Difference (%)	Applied Water (cm)	Total Water (cm)	Yield (Kg/ha)
1	39.2	42.7	8.9	1.35	18.80	58
2	47.9	48.5	1.3	7.21	24.66	591
3	58.8	58.6	-0.3	18.21	35.66	2074
4	70.8	70.0	-1.1	33.66	51.11	4551
5	83.8	80.4	-3.5	45.92	63.37	6871
6	91.2	89.6	-1.8	56.34	73.79	8699
7	94.0	97.6	3.8	65.56	83.01	8879
8	100.5	100.3	-0.2	79.38	96.83	9703

Table 7. Schedule of irrigation amounts for eight irrigated plots for winter wheat at the Clovis, N. M. Science Center (Sammis, 1983b).

	Sequential Day of Year				
	57	97	103	115	134
Plot	Amount, in cm				
1	0.30	0.56	0.00	0.08	0.69
2	1.07	0.94	0.00	0.00	1.75
3	1.68	1.32	0.00	0.25	3.30
4	1.98	1.68	0.00	1.24	4.78
5	2.64	1.32	0.00	2.64	6.30
6	3.12	2.54	0.30	4.47	7.70
7	3.45	2.62	0.79	6.32	7.90
8	3.68	2.74	1.19	6.60	8.23

Table 8. Comparison of model-generated wheat evapotranspiration amounts with measured data at the Clovis, N. M. Research Center (Sammis 1983b). Yield data and ET amounts are in response to 112 kgN/ha. Rainfall amount is 16.82 cm for all plots.

Irrigated Plot	Measured ET (cm)	Model ET (cm)	Percent Diff (%)	Applied Water (cm)	Total Water (cm)	Yield (kg/ha)
1	38.2	36.2	-5.2	1.63	18.45	1037
2	37.5	38.2	1.9	3.79	20.61	1758
3	38.0	40.8	7.4	6.55	23.37	2165
4	46.0	43.7	-5.0	9.68	26.50	1831
5	48.0	47.4	1.3	12.90	29.72	2610
6	55.4	51.5	-5.2	18.13	34.95	2874
7	61.2	54.3	-11.3	21.08	37.90	3714
8	61.5	55.6	-9.6	22.44	39.26	4041

corn and winter wheat because data were collected and analyzed in the same manner.

Output Formats

The output shown in figure 9 is a detailed daily report showing soil moisture status of a wheat crop planted on September 15, 1983. Available water within the root zone at the end of the first day was 1.99 cm. Management will allow 0.9 cm of this to be depleted before an irrigation is due. At the end of the first day no water was lost to ET, therefore, 0.9 cm of moisture remains in the soil. The small amount of evaporative loss was replaced with sufficient rainfall to maintain the soil moisture at the recommended level. The irrigation date is replaced with the symbol 'N.A.' on such occasions. On the second day, available moisture was increased to 2.07 cm because of root development, increasing the allowable depletion to 0.93 cm. The remaining soil moisture at this time is 0.73 cm. The difference is the loss to ET of 0.20 cm. At the predicted consumptive use rate, this crop will exhaust its allowable soil water in 7 more days, as indicated by the irrigation date of September 23.

Negative amounts shown in the remaining water column indicate the soil moisture was depleted beyond the allowable depletion percentage. The value of the negative number is the amount depleted beyond this limit. The sum of the irrigation amount and the remaining water always equals the allowable depletion shown in the third column (rounding may result in small differences). When an irrigation or rainfall occurs that brings the soil moisture to field capacity, allowable depletion and the moisture remaining in the soil are the same. Under these

IRRIGATION SCHEDULING DATA FOR WHEAT IN CURRY COUNTY, NM., 1983

CURRENT DATE	AVAILABLE WATER cm	ALLOWABLE DEPLETION cm	REMAINING WATER cm	IRRIGATION DATE	IRRIGATION AMOUNT cm
SEP 15	1.99	0.90	0.90	N.A.	0.00
SEP 16	2.07	0.93	0.73	SEP 23	0.20
SEP 17	2.15	0.97	0.56	SEP 21	0.41
SEP 18	2.23	1.00	0.39	SEP 21	0.61
SEP 19	2.31	1.04	0.20	SEP 20	0.84
SEP 20	2.39	1.08	0.07	SEP 20	1.01
SEP 21	2.47	1.11	-0.07	SEP 21	1.19
SEP 22	2.55	1.15	0.38	SEP 24	0.76
SEP 23	2.63	1.18	-0.12	SEP 23	1.30
SEP 24	2.71	1.22	0.73	SEP 26	0.49
SEP 25	2.79	1.26	0.42	SEP 26	0.84
SEP 26	2.87	1.29	0.15	SEP 27	1.14
SEP 27	2.95	1.33	-0.28	SEP 27	1.61
SEP 28	3.03	1.36	0.75	SEP 30	0.62

ACCUMULATIVE CONSUMPTIVE USE IS: 4.87 CM.
ACCUMULATIVE APPLIED WATER IS: 4.25 CM.

Figure 9. Sample computer output showing a detailed daily printout for winter wheat on 9/28/83.

conditions, a projected irrigation date is not furnished and 'N.A.' appears under the irrigation date column. The amount to irrigate will be equal to zero in this case. The total water used by this crop, by the end of the day September 28, 1983, was 4.87 cm. The total applied water, which includes irrigation and rainfall, was 4.25 cm. This particular output format will be updated each day by adding one more line of data to the list. By the end of the year, the user has a complete record of all soil moisture events occurring during the season. This creates historical records that help the user make future irrigation management decisions.

The report shown in figure 10 presents daily scheduling data in a brief format. The data contained in the report are for a wheat crop that has reached the harvesting date. Soil moisture has been depleted to a value of 4.44 cm below the management-allowed depletion level. Because the last irrigation occurred a few weeks before the date shown on this report, the farmer did not need to continue running the scheduling program. He would, however, need to continue its use in order to obtain vital statistical data needed to manage the soil moisture. An example of this is the 8.03 cm of depletion that occurred since the last irrigation. This amount of water would have to be replaced to return the soil to its field capacity level. The annual summary at the bottom of the report is also vital to his water management program. This crop used 60.47 cm of water during the season while the farmer applied 68.36 cm of irrigation and rainwater, plus 8.03 cm of soil depletion, for a total of 76.39 cm for the season.

SUMMARIZED REPORT

```
TODAY'S DATE IS:  JUN 16, 1984

THE CROP UNDER CONSIDERATION IS:   WHEAT

THE REMAINING SOIL MOISTURE IS:  -4.44 CM

YOU SHOULD IRRIGATE ON:   JUN 16

THE IRRIGATION AMOUNT SHOULD BE:  8.03 CM

============================================================

ACCUMULATIVE CONSUMPTIVE USE IS:  60.47 CM.
ACCUMULATIVE APPLIED WATER IS:  68.36 CM.
```

Figure 10. Sample computer output showing an end-of-year printout for a winter wheat crop.

CONCLUSIONS

An irrigation scheduling model can be a powerful tool to predict an irrigation due date and to let the user know precisely how much water to apply. A farmer can apply the same amount of water as predicted by the model and still not achieve the same predicted crop ET, and hence maximum yield. This is because the water must by applied at the best possible time to achieve full benefit from it application. An irrigation applied too late has already induced some crop stress and will contribute to a reduction in yield, especially if irrigation timing has been off all season.

The model presented here uses a meteorologically based equation to predict crop water use. The equation combines an energy balance function with an aerodynamic function to utilize all meteorological variables in the derivation of ETp. A precise water-balance bookkeeping system is maintained of all soil moisture inputs and outputs. The model has been tested for corn and winter wheat with studies of known irrigaton applications and yields. The results indicate the model predicts ET well for these crops and should do well as an irrigation scheduling tool.

The material presented in this report, up to and including appendix A, is also available as a Research Report (Hulsman 1985), and may be obained from the Agricultural Information, Box 3AI, New Mexico State University, Las Cruces, New Mexico 88003. The documentation software package developed by Hulsman et al. (1984) is also available, with a complete computer program listing, from the Cooperative Extension Service, P. O. Box 3AE, New Mexico State University, Las Cruces, New Mexico 88003.

Appendix A

Derivation of Equations

APPENDIX A

Derivation of the ETp equation used in the computer model. All components are referenced to Jensen (1973) unless otherwise noted.

$$ETp = (1.71E\text{-}03)(C1(Rn - G) + C2(W)(Ezo - Ed))$$

$$C1 = \frac{\Delta}{\Delta + \gamma}$$

$$\gamma = Cp\ (P)/\ 0.622\ \lambda \quad ,\ mb\ ^\circ C^{-1}$$

$$\lambda = 595 - 0.51\ T,\ cal\ g^{-1}$$ (Latent heat of vaporization)

T = mean daily air temperature, °C

Cp = 0.242 (specific heat of air at constant pressure)

P = 1013 - 0.03217 (Elev) , mb (pressure, elevation in feet)

$$\Delta = \frac{de}{dT}$$ (slope of saturated vapor pressure curve)

$$= 33.8639(0.05904(0.00738(T) + 0.8072)^7 - 0.0000342)$$

$$C2 = 1 - C1$$

$Rn = a(1 - \alpha)(Rs) - b$, langley/day Ref: (Abdul-Jabbar, 1983)

a and b are calibration constants which convert solar radiation to net radiation.

$a = 0.95$

$b = 64$

$\alpha = 0.21$

Rs = incoming solar radiation, langley/day

$G = 9(T - Tb)$, langley/day　　　Ref: (Kincaid et al. 1974)

T = as defined above

Tb = Average three day mean temperature, °C

$W = 15.36(1 + 0.0171(W_2))$, miles/day

W_2 = total wind run at 2 meters elevation

$Ezo = (En + Ex)/2$, mb

$En = 1.3329 \, Exp(21.07 - 5336/Tk)$

Tk = temperature in degree Kelvin, (minimum daily temp)

$Ex = 1.3329 \, Exp(21.07 - 5336/Tk)$

Tk = temperature in degree Kelvin, (maximum daily temp)

$Ed = (Ed_1 + Ed_2)/2$

$Ed_1 = RH_x(Ex)$

RH_x = maximum relative humidity

$Ed_2 = RH_n \, (En)$

RH_n = minimum relative humidity

Appendix B

Irrigation Scheduling

-Computer Program Documentation Handbook-

IRRIGATION SCHEDULING
-COMPUTER PROGRAM DOCUMENTATION-

Problem Statement

The purpose of the irrigation scheduling model is to provide farmers in eastern New Mexico with an accurate means of predicting irrigation water amounts and dates. The model can be used for three crops; corn, milo and winter wheat and is intended to be used on a small personal computer in the farmer's home. It may be run once per day or once per week at the users discretion.

Problem Solution

The irrigation scheduling model uses daily meteorological data as inputs to calculate evapotranspiration. It also maintains a water balance ledger to keep track of water removed from the soil and water added to the soil. Irrigations are predicted according to how long it would take, given a seven day average use-rate, to deplete the moisture remaining in the soil. The model will either save the farmer on water resources, energy and labor, or it will increase his yields and income on less irrigated land.

Computer Requirements

The program requires an IBM-PC, or compatible home computer, with PC-DOS Version 2.0, or later, with two disk drives and 256K of RAM. A monochrome or color display monitor will both work. Two diskettes are required, one with the programs in drive A and the other with the weather data storage in drive B. A printer is not required.

Program Structure

Flow diagrams of the programs needed to schedule irrigations are shown in figures 1 and 2. After the model has been initialized for a particular crop the only inputs to the model will be daily weather data. All model operations are accomplished using prompt commands. Accurate response to these commands will assure smooth operation. Model output is available in two formats. The detailed format, shows daily water use and irrigation scheduling history and begins on the day the crop was planted up to the current date. The second format is more brief and lacks the detail of the first. Both outputs present a running total of the water consumptively used and the water applied thus far. See appendix A for a detailed description of both formats.

Program Commands (Prompts)

I. Opening Menu

A. The following menu, outlined by the state of New Mexico, appears on the screen after the introduction and warranty declaration statements, when the system is initially activated:

```
Option      Description

    1.   Irrigation Scheduling
    2.   Display selected weather data
    3.   Convert weather data
    Q    Quit the program and return
         to the operating sytem

    Please enter 1, 2, 3, or Q
```

The selection of one of these choices will call up the program needed to execute the request. Selection 1 activates the irrigation scheduling programs; selection 2 provides for the review of weather data for any given day; selection 3 converts weather data received from the weather station into units which are compatible with irrigation scheduling and "Q" will exit the program and return to the operating system of the computer. A discussion of each of these selections will be conducted in more detail below. Pressing any key other than 1, 2, 3 or Q will cause the menu to reappear.

II. Irrigation Scheduling

A. Enter the current month, day, and year (mm,dd,yyyy). This command prompts the user to enter the current date. The month, day and year should be entered as shown in parenthesis, with each element separated by commas, as in; 6,13,1983 for June 6, 1983. When all numbers are entered press the <ENTER> key. Entering the date in the wrong format will cause a ?REDO FROM START message to appear on the screen. The date must be re-entered in the correct format.

B. The following menu is used to select the desired crop for scheduling:

```
            CROP SELECTION

               C<ORN>
               M<ILO>
               W<HEAT>

         Select output number
```

The letter corresponding to the desired crop is pressed. For example, for the menu item C<ORN>, the user need only press the letter "C" on the keyboard. No other action is necessary. Do not press the <ENTER> key at this time. Either a small "c" or a capital "C" may be pressed, each produces the same result. Any response other than "C", "M", or "W" (in upper or lower case) will cause the menu to reappear on the screen.

C. Has the program been initialized for this crop, Y/N ? This question is a reminder that the program must be initialized for each individual crop at the beginning of the season. Failure to initialize the crop will result in erroneous scheduling predictions. The initialization provides for the selection of the soil type associated with the crop, sets the planting date, maximum rooting depth for the crop, and the precentage the soil moisture will be allowed to be depleted before and irrigation event will take place. If the crop has been initialized pressing "Y" or "y" will allow the program to proceed. Do not press <ENTER> after pressing the "Y" or "N" key. Any response other than a "Y" or "N" (upper or lower case) will cause the prompt line to reappear. Another choice must then be made.

D. This menu provides for the selection of soil types.

SOIL TYPES

1. SANDY
2. SANDY LOAM
3. LOAM
4. CLAY LOAM
5. CLAY

SELECT ONE

E. Enter the month and day the crop was planted, (mm,dd). A missing reply to the prompt above will result in another prompt asking for the date the crop was planted. The month and day are all that is necessary here. They must be entered in the format shown in the prompt. For example, May 13 should be entered as 5,13 followed by pressing the <ENTER> key. A date not entered in the format shown will cause a ?REDO FROM START message to appear on the screen. The date must then be entered in the format shown in the prompt line.

F. Enter the maximum crop rooting depth, (nn,dd). This entry must be a two-digit number, in feet, which tells the computer how deep the roots will grow in the soil conditions available. A caliche layer, for example will retrict root development to the soil above the layer.

G. This menu facilitates the selection of output type.

OUTPUT SELECTION

1. DAILY SUMMARY
2. SUMMARIZED REPORT

Select output number

The daily summary prints a continuing daily report to the screen beginning at the planting date and continuing on to the current date. Each time the program is run this output selection will present a complete report covering the entire period. A chronological history of soil moisture and irrigation events is presented in this way. A typical screen display is presented in appendix A. The summarized report, selection number 2, is a shortened format which indicates only the most recent soil moisture events and an irrigation prediction. This output selection is also presented appendix A. To make a selection the number corresponding to the output desired should be pressed. Do not press <ENTER> following this selection. If a number 1 or 2 has not been selected the output menu will reappear on the screen. The proper selection may then be made.

F. Enter the month and day for the weather entry, (mm,dd). The date entered here will always be the current date unless weather data is entered for more than one day. If weather data is entered for more than one day the first day is entered by typing the month and day separated by commas as follows: the entry for August 27 will be 8,27 followed by <ENTER>. The weather data for this date will be entered after which a new prompt will appear asking Do you wish to enter more weather data, Y/N?. A "Y" response will cause the Enter the month and day for the weather entry, (mm,dd). to re-appear on the screen. If weather data is to be entered for the current day only, the date for that day is entered. An "N" response will cause the program to advance to the next step. Any other response will cause the prompt line to reappear.

G. Tx = max temp; Tn = min temp; Hx = max humidity; Hn = min humidity; S = solar radiation; W = total wind; R = rainfall; I = irrigation. This definition line appears at the top of the screen as an aid to identifying weather data inputs and remains on the screen until all weather data has entered. No action is needed in response to this line.

H. Enter the following data: Tx, Tn, Hx, Hn, S, W, R, I. All pertinent weather data is now entered into the computer. Care must be taken at this point to assure that all data entries are separated by commas. Do not enter a comma after the last entry. Data entered in the wrong format will result in a ?REDO FROM START message on the screen. The data must be re-entered in the proper format.

I. You may enter your own amounts for rainfall and irrigations.

In most cases the rainfall amounts, and in all cases the irrigation amounts, will be unique to each farm location. The user should always use rainfall and irrigation amounts for his location is order to assure accuracy in the water balance calculations of the model. All weather data entered into the computer will be stored on the diskette in drive B for a permanent record.

III. Display selected weather data

A. Enter the month, day and year (mm,dd,yyyy). The month, day and year of weather desired to be displayed in entered in the format shown. Place a comma after each of the entries and press <ENTER> when all numbers are printed. This will tell the computer where to look in the weather file for the date you wish to review. Data entered in the wrong format will result in a ?REDO FROM START message on the screen. The date must be re-entered in the proper format.

B. **The weather data for (mm,dd,yyyy) is:**

SEQ DAY	MAX TEMP	MIN TEMP	MAX HUM	MIN HUM	SOLAR RAD	TOTAL WIND	PRECIP	IRR

The weather data will be displayed in the format shown. The SEQ DAY refers to the sequential day of the year. June 1,1983, for example is the 152nd day of the year. Temperature will be in degrees Fahrenheit, humidity in a decimal less than one, solar radiation in langleys/day, total wind in miles/day, precipitation in inches and irrigation in inches.

C. **Please record this data for future use.** This message will appear at the lower center of the screen as a reminder to record the weather data for later use with the irrigation scheduling program.

D. Do you wish to return to the Opening Menu, Y/N? An answer of "Y" to this prompt will cause the Opening Menu to reappear on the screen. A "N" reply exits all programming while any other reply will cause the prompt line to reappear.

IV. Convert weather data.

A. Only two prompt lines are used with this selection. After all weather data have been converted and stored in the appropriate storage files the user will have an opportunity to review the latest data input to the files. This will usually be the current weather since that will be the last weather entered.

B. Do you wish to display the current weather, Y/N? An affirmative answer will yield the current weather while a negative reply will cause the computer to display the next prompt line. Any other reply will cause the prompt line to reappear.

C. Do you wish to return to the Opening Menu, Y/N? An affirmative reply will return to the Opening Menu for further program operation. A negative rely will exit all programs. Any other rely will cause the prompt line to reappear.

Common User Errors

I. Most of the responses to the prompts are either a Y (yes) or a N (no). If neither of these reponses are given the program will continue to prompt the user until one of them is received. Entries requiring a date in a definite format will continue to ask for that date until it is entered in the format requested by the prompt. Only incorrect entry numbers will result in programming errors. These errors are addressed below.

II. INCORRECT ENTRY OR NO ENTRY FOR CROP PLANTING DATE. The entry of a planting date starts the model working on that day. If a date other than the planting date was entered, it would be assumed by the computer to be the correct starting date. If no entry was made, the computer would assume this number to be zero. In any case output data would be incorrect and therefore unuseable. It would be very difficult to spot this error unless the output data is obviously wrong. To correct the error, rerun the program from the beginning and re-initialize the crop when the appropriate prompt line appears.

III. DAILY WEATHER DATA ENTERED FOR THE WRONG DATE. When daily weather data has been entered for the wrong date, it will either override existing data or will be filed in a file space yet unused. If an attempt is made to run the program for a day in which there is no weather data on file irrigation scheduling output will also be in error. Obvious output errors may be corrected by rerunning the program from the beginning and entering the weather data for the proper date.

File Management

All data files are automatically established by the program. Data will be sent to the proper files when the current date is entered at the beginning of the program. No action is required of the operator. A check of the directory listing will reveal that the files have indeed by established.

Appendix C

Irrigation Scheduling Model

Program Listing

```
10  '**** IRRIGATION SCHEDULING MODEL  Ver 1.1  1/20/85 ******
20  KEY OFF: CLEAR
30  COLOR 2,6,4
40  CLS
50  GOSUB 450             'This subroutine sets the variables.
60  GOSUB 1810            'This draws the outline of the state.
70  LOCATE 19,37:COLOR 1,6: PRINT CHR$(15)
80  IF FLIP THEN GOTO 130
90  GOSUB 870           'This is the first screen of information.
100 GOSUB 1530          'This clears the inside of the state.
110 GOSUB 1130          'This is the copyright information.
120 GOSUB 1530          'This clears the inside of the state.
130 GOSUB 1590          'This is the opening screen menu.
140 ANS$ = INKEY$:IF ANS$ = "" THEN  GOTO 140
150 IF ANS$ = "q" OR ANS$ = "Q" THEN GOTO 160 ELSE GOTO 210
160 CLS: PRINT: PRINT: PRINT: PRINT
170 PRINT TAB(15):PRINT"You may re-enter the scheduling program"
180 PRINT TAB(15):PRINT"by typing SCHEDULE and pressing <ENTER>."
190 COLOR 7
200 END
210 IF ANS$ = "1" THEN GOTO 220 ELSE GOTO 270
220 GOSUB 9100
230 GOSUB 2180           'This is the CES information screen.
240 CLS
250 GOSUB 1810           'This draws the state outline.
260 GOTO 130             'Draw the opening screen menu.
270 IF ANS$ = "2" THEN GOTO 280 ELSE GOTO 330
280 GOSUB 9100
290 GOSUB 8010           'This runs the weather display routine.
300 CLS
310 GOSUB 1810           'This draws the state outline.
320 GOTO 130
330 IF ANS$ = "3" THEN GOTO 340 ELSE GOTO 390
340 GOSUB 9100
350 GOSUB 8480                    'Convert the weather data.
360 CLS
370 GOSUB 1810                    'This draws the state outline.
380 GOTO 130                      'Draw the opening screen menu.
390 '*********** All responses here are incorrect
400 BEEP
410 COLOR 16,6
420 LOCATE 21,51:PRINT "  Incorrect response  "
430 COLOR 4,6
440 GOTO 140                          'Go back to the inkey input.
450 '      SUBROUTINE   Sets variables for front end
460 REM LET WID = 42
470 REM LET FST = 1
480 LET NMSU$ = "New Mexico State University"
490 NL = LEN(NMSU$)
500 TITLE$ = "  "
510 TL = LEN(TITLE$)
520 DEPARTMENT$ = " "
530 DL = LEN(DEPARTMENT$)
540 EXT$="Cooperative Extension Service"
550 EL = LEN(EXT$)
```

```
560  TITLE2$ = ""
570  TL2 = LEN(TITLE2$)
580  BLANKLINE$ = SPACE$(41)
590  SUBJECT$ = "Subject Area: Irrigation Scheduling"
600  SL = LEN(SUBJECT$)
610  VERSION$ = "Version 1.10"
620  ADDRESS1$ = "P.O. Box "
630  ADDRESS2$ = "3AE"
640  ADDRESS3$ = " NMSU"
650  ADDRESS4$ = "Las Cruces, NM 88003"
660  AL = LEN(ADDRESS2$)
670  ADDRESS$ = ADDRESS1$ + LEFT$(ADDRESS2$,AL) + ADDRESS3$
680  AL2 = LEN(ADDRESS$)
690  VL = LEN(VERSION$)
700  NMSUR = 4
710  NMSUC = ((42-27)/2)+19
720  EXTR = 5
730  EXTC = ((42-EL)/2)+19
740  TITLER = 1 + 7
750  TITLEC = ((42-TL)/2)+19
760  TITLE2R = 9
770  TITLE2C = ((42-TL2)/2)+19
780  SUBJECTR = 12
790  SUBJECTC = ((42-SL)/2)+19
800  VERSIONR = 9
810  VERSIONC = ((42-VL)/2)+19
820  DEPARTMENTR = 15
830  DEPARTMENTC = ((42-DL)/2)+19
840  ADDRESSR = 16
850  ADDRESSC = ((42-AL2)/2)+19
860  RETURN
870  '      SUBROUTINE  First screen of front end
880  S = 1
890  SOUND 400,S:SOUND 600,S
900  LOCATE NMSUR,NMSUC:COLOR 4,6: PRINT NMSU$
910  SOUND 800,S:SOUND 1000,S
920  LOCATE EXTR,EXTC:PRINT EXT$
930  SOUND 1200,S:SOUND 1400,S
940  COLOR 4,6
950  LOCATE TITLER,TITLEC:PRINT TITLE$
960  SOUND 1600,S:SOUND 1800,S
970  LOCATE VERSIONR,VERSIONC:PRINT VERSION$
980  SOUND 2000,S: SOUND 2200,S
990  LOCATE TITLE2R,TITLE2C:PRINT TITLE2$
1000  SOUND 2400,S:SOUND 2600,S
1010 LOCATE SUBJECTR,SUBJECTC:PRINT SUBJECT$
1020 SOUND 2800,S: SOUND 2200,S
1030 LOCATE DEPARTMENTR,DEPARTMENTC:PRINT DEPARTMENT$
1040 SOUND 3500,S:SOUND 4000,S
1050 LOCATE ADDRESSR,ADDRESSC:PRINT ADDRESS$
1060 SOUND 4500,S:SOUND 400,S
1070 LOCATE ADDRESSR+1,ADDRESSC-2:PRINT ADDRESS4$
1080 COLOR 4,6
1090 LOCATE 23,50:PRINT "  Strike any key to continue  "
1100 COLOR 4,6
```

```
1110 A$ = INKEY$:IF A$ = "" THEN GOTO 1110
1120 RETURN
1130 '     SUBROUTINE   Copyright screen
1140 '
1150 STA = STA +1
1160 COPYRIGHT$ = "   (C) Copyright  1984  NMSU "
1170 DISCLM$ = "New Mexico State University makes no "
1180 DISCLM1$ = "New Mexico State University  makes no re-"
1190 DISCLM2$ = "presentations or warranties  with respect"
1200 DISCLM3$ = "to the contents  hereof and  specifically"
1210 DISCLM4$ = "disclaims any implied  warranties of mer-"
1220 DISCLM5$ = "chantibility or fitness for  any particu-"
1230 DISCLM6$ = "lar purpose.  Further, NMSU  reserves the"
1240 DISCLM7$ = "right to  revise this  publication and to"
1250 DISCLM8$ = "make  changes from  time  to  time in the"
1260 DISCLM9$ = "content hereof without obligation of NMSU"
1270 DISCLM10$ = "to notify any  person or  organization of"
1280 DISCLM11$ = "such revision or changes."
1290 COPIES1$ = "To obtain this software contact:"
1300 COPIES2$ = "CES Software Library                 "
1310 COPIES3$ = "P.O Box 3AE NMSU, Las Cruces, NM 88003"
1320 COPIES4$ = "Las Cruces, NM 88003"
1330 PC = 20
1340 LOCATE 18,36:PRINT CHR$(0)
1350 LOCATE 3,PC:PRINT COPYRIGHT$
1360 LOCATE 5,PC:PRINT DISCLM1$
1370 LOCATE 6,PC:PRINT DISCLM2$
1380 LOCATE 7,PC:PRINT DISCLM3$
1390 LOCATE 8,PC:PRINT DISCLM4$
1400 LOCATE 9,PC:PRINT DISCLM5$
1410 LOCATE 10,PC:PRINT DISCLM6$
1420 LOCATE 11,PC:PRINT DISCLM7$
1430 LOCATE 12,PC:PRINT DISCLM8$
1440 LOCATE 13,PC:PRINT DISCLM9$
1450 LOCATE 14,PC:PRINT DISCLM10$
1460 LOCATE 15,PC:PRINT DISCLM11$
1470 LOCATE 17,PC:PRINT COPIES1$
1480 LOCATE 18,PC:PRINT COPIES2$
1490 LOCATE 19,PC:PRINT COPIES3$
1500 COLOR 4,6:LOCATE 23,50:PRINT "  Strike any key to continue"
1504 COLOR 4,6
1510 V$ = INKEY$:IF V$ = "" THEN GOTO 1510
1520 RETURN
1530 '     SUBROUTINE   Blanks lines inside the state
1540 FOR X = 2 TO 19
1550   LOCATE X,20:PRINT BLANKLINE$      'This blanks the inside
1560 NEXT X                              'of the state.
1570 LOCATE 23,39:PRINT BLANKLINE$
1580 RETURN
1590 '     SUBROUTINE  This is the main menu
1600 LOCATE 3,25:PRINT "All options except Quit will "
1610 LOCATE 4,25:PRINT "return to this screen."
1620 LOCATE 4,5:PRINT ""
1630 COLOR 1,6
1640 LOCATE 6,22:PRINT "Option":COLOR 4,6
```

```
1650 COLOR 1,6
1660 LOCATE 6,35:PRINT "Description"
1670 COLOR 4,6
1680 LOCATE 9,24:PRINT "1":COLOR 4,6
1690 COLOR 4,6:LOCATE 9,30:PRINT "Irrigation Scheduling"
1700 COLOR 4,6:LOCATE 11,24:PRINT "2":COLOR 4,6
1710 COLOR 4,6:LOCATE 11,30:PRINT"Display selected weather data"
1720 COLOR 4,6:LOCATE 13,24:PRINT "3":COLOR 4,6
1730 COLOR 4,6:LOCATE 13,30:PRINT "Convert NMSU weather data"
1740 COLOR 4,6:LOCATE 15,24:PRINT "Q":COLOR 4,6
1750 COLOR 4,6:LOCATE 15,30:PRINT "Quit the program and return"
1760 LOCATE 16,30:PRINT "to the operating system"
1770 COLOR 4,6
1780 LOCATE 23,45:PRINT "  Please enter 1, 2, 3, or Q  "
1790 COLOR 4,6
1800 RETURN
1810 '      SUBROUTINE  Draw state of New Mexico
1820 COLOR 15,0
1830 FOR X = 19 TO 61
1840    LOCATE 1,X:PRINT CHR$(196)                    'Top of state
1850 NEXT X
1860 LOCATE 1,62:PRINT CHR$(191)
1870 FOR X = 2 TO 19
1880    LOCATE X,62:PRINT CHR$(179)                   'Left side
1890 NEXT X
1900 LOCATE 20,62:PRINT CHR$(217)
1910 FOR X = 61 TO 39 STEP -1
1920    LOCATE 20,X:PRINT CHR$(196)                   'Bottom right
1930 NEXT X
1940 LOCATE 20,38:PRINT CHR$(218)
1950 FOR X = 21 TO 18
1960    LOCATE X,38:PRINT CHR$(179)      'Down to El Paso
1970 NEXT X
1980 LOCATE 21,38:PRINT CHR$(217)
1990 FOR X = 37 TO 25 STEP -1
2000    LOCATE 21,X:PRINT CHR$(196)      'El Paso to the West
2010 NEXT X
2020 LOCATE 21,24:PRINT CHR$(218)
2030 FOR X = 22 TO 22 STEP -1
2040    LOCATE X,24:PRINT CHR$(179)
2050 NEXT X
2060 LOCATE 23,24:PRINT CHR$(217)
2070 FOR X = 23 TO 19 STEP -1
2080   LOCATE 23,X:PRINT CHR$(196)       'Last bottom
2090 NEXT X
2100 LOCATE 23,18:PRINT CHR$(192)
2110 FOR X = 22 TO 2 STEP -1
2120   LOCATE X,18:PRINT CHR$(179)       'Left side of state
2130 NEXT X
2140 LOCATE 1,18:PRINT CHR$(218)     'Top left corner of state
2150 COLOR 7,0
2160 REM LOCATE 19,37:PRINT CHR$(15)
2170 RETURN
2180 '      SUBROUTINE  Part one of irrigation scheduling model.
```

```
2190 CLS: KEY OFF
2200 COLOR 0,1,7
2210 CLS
2220 CLS
2230 LOCATE 5,30: PRINT "CROP SELECTION"
2240 LOCATE 8,33: PRINT"C<ORN>"
2250 PRINT TAB(33);:PRINT"M<ILO>"
2260 PRINT TAB(33);:PRINT"W<HEAT>"
2270 LOCATE 13,29: PRINT"Select crop letter"
2280 KO$ = INPUT$(1)
2290 IF KO$ = "C" OR  KO$ = "c" OR  KO$ = "M" OR  KO$ = "m" OR
        KO$ = "W" OR KO$ = "w"  THEN GOTO 2300 ELSE GOTO 2230
2300 IF KO$ = "C" OR KO$ = "c" THEN KO = 1
2310 IF KO$ = "M" OR KO$ = "m" THEN KO = 2
2320 IF KO$ = "W" OR KO$ = "w" THEN KO = 3
2330 IF KO = 1 THEN CRP$ = "CORN" ELSE IF KO = 2 THEN
      CRP$ = "MILO" ELSE IF KO = 3 THEN CRP$ = "WHEAT"
2340 CLS
2350 EL = 4244     'Elevation, in feet
2360 DIM CDAT(4,7),CKCO(5,5),MET(365,7),TA(10)
2370 FOR K = 1 TO 4                  ' Read in crop coefficients
2380      FOR M = 1 TO 4
2390           READ CKCO(K,M)
2400      NEXT M
2410 NEXT K
2420 DATA -0.91514363,-3.461883E-03,1.666711E-04,-5.156703E-07
2430 DATA -0.8323011,-3.708407E-02,3.407026E-04,-7.902252E-07
2440 DATA  0.4147172,-2.820653E-02,4.799241E-04,-1.873487E-06
2450 DATA  5.263236,-2.011038E-02,5.909489E-06,3.614189E-08
2460 '  Initialization of crop data.
2470 CLS
2480 OPEN "B:CROPDATA" AS #1 LEN = 20      ' file of crop data
2490 FIELD #1, 2 AS P$, 2 AS E$, 4 AS Z$, 4 AS IRZ$, 4 AS MADEF$,
              4 AS AWTR$
2495 LOCATE 6,19
2500 PRINT"Has the program been initialized for this ";
2510 PRINT USING "&"; CRP$;: PRINT " crop, Y/N "
2520 IN$ = INPUT$(1)
2530 IF IN$ = "Y" OR IN$ = "y" THEN GOTO 2570
2540 IF IN$ = "N" OR IN$ = "n" THEN GOTO 2550 ELSE GOTO 2500
2550 CLS
2560 GOSUB 4540   'SUBROUTINE to initialize crop and soil data
2570 CLS
2580      GET #1, KO                     'Data retrieval location
2590      CDAT(KO,0) = CVI(P$)           'Planting date of the crop.
2590      CDAT(KO,0) = CVI(P$)           'Planting date of the crop.
2600      CDAT(KO,1) = CVI(E$)           'Effective cover date.
2610      CDAT(KO,2) = CVS(IRZ$)         'Initial rooting depth.
2620      CDAT(KO,3) = CVS(MADEF$)       'Manag't allowed depletion.
2630      CDAT(KO,4) = CVS(Z$)           'Final rooting depth.
2640      CDAT(KO,5) = CVS(AWTR$)        'Available water/foot depth.
2650 CLOSE #1
2660 GOSUB 9220
2670 '  Output selection by entering number for output.
```

```
2680 LOCATE 5,30: PRINT "OUTPUT SELECTION "
2690 LOCATE 8,31: PRINT "1. DAILY SUMMARY "
2700 PRINT TAB(31);: PRINT "2. SUMMARIZED REPORT"
2710 LOCATE 12,29: PRINT "Select output number."
2720 DETAIL$ = INPUT$(1)
2730 DETAIL = VAL(DETAIL$)
2740 CLS
2750           ' Initialize beginning average temperatures
2760 FOR J = 0 TO 9
2770    TA(J) = 0
2780 NEXT J
2790 TA(1) = 15         ' Set initial temperature, deg cent
2800 TA(2) = 15         '  "      "         "        "   "
2810 TA(3) = 15         '  "      "         "        "   "
2820 'Read in the weather data from the weather file on disk #2.
2830 CLS
2840 LOCATE 6,12
2850 PRINT"Enter the month and day for the weather entry, (mm,dd)"
2860 LOCATE 7,25: INPUT "==>  ",IM,ID
2870 GOSUB 3470        'Calculate the seq day of the Wx input date
2880 SEQD = SEQDAY
2890 CLS
2900 LOCATE 4,7
2910 PRINT"Tx = max temp; Tn = min temp; Hx = max humidity; ";
2912 PRINT "Hn = min humidity"
2920 PRINT TAB(7);
2930 PRINT"S = solar rad.; W = total wind; R = rainfall; ";
2932 PRINT "I = irrigation"
2940 LOCATE 8,13
2950 PRINT"Enter the following data: Tx, Tn, Hx, Hn, S, W, ";
2952 PRINT "R, I"
2960 LOCATE 11,11
2970 PRINT"You must enter your own amounts for rainfall and ";
2972 PRINT "irrigation."
2980 LOCATE 13,13
2990 INPUT"==>  ",HITEMP,LOTEMP,HH,LH,SOLRAD,TOTWIND,PRECIP,IRR
3000 GOSUB 3730                 '  Store current Wx into file
3010 GOSUB 3850                 '  Store current precip/irr into file
3020 ON KO GOTO 3030,3030,3060
3030 GOSUB 4230                 '  Xfr Wx data into MET() array
3040 GOSUB 4060                 '  Xfr irr/precip data into MET()
3050 GOTO 3090
3060 IF SEQD >= CDAT(KO,0) THEN 3030
3070 GOSUB 3930                     '  Xfr Wx into MET()
3080 GOSUB 4450                     '  Xfr precip/irrig into MET()
3090 CLS: LOCATE 6,15
3100 PRINT"Do you wish to enter more weather data, Y/N ?"
3110 AN$ = INPUT$(1)
3120 IF AN$ = "Y" OR AN$ = "y" THEN GOTO 2850
3130 '  Print table headings for DAILY SUMMARY output
3140 CLS
3150 IF DETAIL = 2 THEN GOTO 3450
3160 COLOR 0,1,0
3170 CLS
3180 QZ$="IRRIGATION SCHEDULING DATA FOR "
```

```
3190 PRINT TAB(12): COLOR 0,1: PRINT USING "& "; QZ$;
3200 COLOR 31,1
3210 PRINT USING "&";CRP$;
3220 COLOR 0,1
3230 IY = VAL(IY$)
3240 PRINT USING ", ####";IY
3250 GOSUB 3620          '  Places borders on title lines
3260 A$ = "CURRENT"
3270 B$="AVAILABLE"
3280 BA$ = "ALLOWABLE"
3290 C$="REMAINING"
3300 D$="IRRIGATION"
3310 AA$=" DATE"
3320 BB$="WATER"
3330 CC$="DEPLETION"
3340 DD$="AMOUNT"
3350 PRINT TAB(14):COLOR 0,1: PRINT USING "&  ";A$;
3360 PRINT USING " &  ";B$;BA$;C$;:PRINT USING "  &";D$
3370 'COLOR 4,4
3380 PRINT TAB(14);:COLOR 0,1: PRINT USING "&       ";AA$;
3390 PRINT USING "&     ";BB$;CC$;:PRINT USING "&    ";BB$;
3400 PRINT USING "&    ";AA$;DD$
3410 SI$ = "           in"
3420 PRINT TAB(26):COLOR 0,1: PRINT "(in)";:PRINT TAB(38);
3422 PRINT "(in)";
3430 PRINT TAB(50);: PRINT"(in)";: PRINT TAB(68);: PRINT "(in)"
3440 GOSUB 3620
3450 GOTO 5100        'Part two of the model
3460 '     SUBROUTINE to calculate the seq day of crop season
3470 IF IM = 1 THEN TMON = 0
3480 IF IM = 2 THEN TMON = 31
3490 IF IM = 3 THEN TMON = 59
3500 IF IM = 4 THEN TMON = 90
3510 IF IM = 5 THEN TMON = 120
3520 IF IM = 6 THEN TMON = 151
3530 IF IM = 7 THEN TMON = 181
3540 IF IM = 8 THEN TMON = 212
3550 IF IM = 9 THEN TMON = 243
3560 IF IM = 10 THEN TMON = 273
3570 IF IM = 11 THEN TMON = 304
3580 IF IM = 12 THEN TMON = 334
3590 SEQDAY = TMON + ID
3600 RETURN
3610 '     SUBROUTINE used to border title lines
3620 COLOR 0,1
3630 PRINT TAB(12)
3640 FOR NX = 0 TO 63
3650 COLOR 0,15
3660     PRINT CHR$(61);
3670 NEXT NX
3680 COLOR 0,1
3690 PRINT "      ";
3700 COLOR 0,1
3710 RETURN
3720 '     SUBROUTINE to place METWX.CXX data into file
```

```
3730 OPEN FILE1$ AS #2 LEN = 28
3740 FIELD #2, 4 AS HITEMP$, 4 AS LOTEMP$, 5 AS HH$, 5 AS LH$,
                                    5 AS SOLRAD$, 5 AS TOTWIND$
3750     LSET HITEMP$ = MKS$(HITEMP)
3760     LSET LOTEMP$ = MKS$(LOTEMP)
3770     LSET HH$     = MKS$(HH)
3780     LSET LH$     = MKS$(LH)
3790     LSET SOLRAD$ = MKS$(SOLRAD)
3800     LSET TOTWIND$= MKS$(TOTWIND)
3810     PUT #2, SEQD
3820 CLOSE #2
3830 RETURN
3840 '      SUBROUTINE places irr/precip data into file
3850 OPEN FILE4$ AS #2 LEN = 10
3860 FIELD #2, 5 AS PRECIP$, 5 AS IRR$
3870    LSET PRECIP$ = MKS$(PRECIP)
3880    LSET IRR$    = MKS$(IRR)
3890    PUT #2, SEQD
3900 CLOSE #2
3910 RETURN
3920 '      SUBROUTINE  loads Wx data into MET() for spring wheat
3930 OPEN FILE2$ AS #2 LEN = 28
3940 FOR J = CDAT(KO,0) TO 365
3950     GET #2, J
3960     MET(J,0) = CVS(HITEMP$)
3970     MET(J,1) = CVS(LOTEMP$)
3980     MET(J,2) = CVS(HH$)
3990     MET(J,3) = CVS(LH$)
4000     MET(J,4) = CVS(SOLRAD$)
4010     MET(J,5) = CVS(TOTWIND$)
4020 NEXT J
4030 CLOSE #2
4040 RETURN
4050 '      SUBROUTINE enters irr/precip data into MET()
4060 OPEN FILE4$ AS #2 LEN = 10
4070 FIELD #2, 5 AS PRECIP$, 5 AS IRR$
4080 ON KO GOTO 4090,4090,4120
4090 XI = CDAT(KO,0)
4100 YI = 365
4110 GOTO 4150
4120 IF SEQ >= CDAT(KO,0) THEN 4090
4130 XI = 1
4140 YI = SEQDY
4150 FOR I = XI TO YI
4160    GET #2,I
4170    MET(I,6) = CVS(PRECIP$)
4180    MET(I,7) = CVS(IRR$)
4190 NEXT I
4200 CLOSE #2
4210 RETURN
4220 '      SUBROUTINE to enter METWX.CXX data into MET() array
4230 OPEN FILE1$ AS #2 LEN = 28
4240 FIELD #2, 4 AS HITEMP$, 4 AS LOTEMP$, 5 AS HH$, 5 AS LH$,
                                    5 AS SOLRAD$, 5 AS TOTWIND$
```

```
4250 ON KO GOTO 4260,4260,4290
4260 XI = CDAT(KO,0)
4270 YI = 365
4280 GOTO 4330
4290 SEQ = SEQ - 365
4300 IF SEQ >= CDAT(KO,0) THEN 4260
4310 XI = 1
4320 YI = SEQDY
4330 FOR I = XI TO YI
4340     GET #2, I
4350     MET(I,0) = CVS(HITEMP$)
4360     MET(I,1) = CVS(LOTEMP$)
4370     MET(I,2) = CVS(HH$)
4380     MET(I,3) = CVS(LH$)
4390     MET(I,4) = CVS(SOLRAD$)
4400     MET(I,5) = CVS(TOTWIND$)
4410 NEXT I
4420 CLOSE #2
4430 RETURN
4440 '      SUBROUTINE enters irr/precip data into MET()
4450 OPEN FILE5$ AS #2 LEN = 10
4460 FIELD #2, 5 AS PRECIP$, 5 AS IRR$
4470 FOR I = CDAT(KO,0) TO 365
4480    GET #2,I
4490    MET(I,6) = CVS(PRECIP$)
4500    MET(I,7) = CVS(IRR$)
4510 NEXT I
4520 CLOSE #2
4530 RETURN
4540 '  SUBROUTINE selects soil, root depth, planting date
4550 LOCATE 6,30: PRINT "SOIL TYPES"
4560 LOCATE 9,28: PRINT "1.  SANDY"
4570 PRINT TAB(28);: PRINT "2.  SANDY LOAM"
4580 PRINT TAB(28);: PRINT "3.  LOAM"
4590 PRINT TAB(28);: PRINT "4.  CLAY LOAM"
4600 PRINT TAB(28);: PRINT "6.  CLAY"
4610 LOCATE 16,30: PRINT "Select One"
4620 SOIL$ = INPUT$(1)
4630 SOIL = VAL(SOIL$)
4640 ON SOIL GOTO 4650,4680,4710,4740,4770,4800
4650 PW = .05
4660 BD = 1.65
4670 GOTO 4820
4680 PW = .0824
4690 BD = 1.596
4700 GOTO 4820
4710 PW = .12
4720 BD = 1.4
4730 GOTO 4820
4740 PW = .14
4750 BD = 1.35
4760 GOTO 4820
4770 PW = .16
4780 BD = 1.3
4790 GOTO 4820
```

```
4800 PW = .18
4810 BD = 1.25
4820 VWTR = PW * BD
4830 AW = 12 * VWTR
4840 CLS: LOCATE 6,20
4850 PRINT"Enter month and day crop was planted, (mm,dd)."
4860 PRINT TAB(20);: INPUT "==>  ", IM,ID
4870 GOSUB 3460   ' Calculate sequential day of the crop season
4880 SEQP = SEQDAY
4882 LOCATE 10,20
4890 PRINT "Enter the maximum crop rooting depth, (nn,dd)."
4900 PRINT TAB(21);: INPUT "==>  ", RZ
4902 LOCATE 14,12
4910 PRINT"Enter percent allowable soil moisture depletion, (XX)>"
4920 PRINT TAB(12);: INPUT "==>  ", MA
4930 MAD = MA/100
4940 GOSUB 3460     ' Calculate seq day of the cropping season
4950 SEQP = SEQDAY
4960 ON KO GOTO 4970,4990,4970
4970 EC = SEQP + 85   ' Effective cover day for corn and wheat
4980 GOTO 5000
4990 EC = SEQP + 75   ' Effective cover day for sorghum(milo)
5000 INITRZ = .5       ' Initial rooting depth for all crops
5010     LSET P$      = MKI$(SEQP)    ' Store crop planting date
5020     LSET E$      = MKI$(EC)      ' Store effective cover date
5030     LSET IRZ$    = MKS$(INITRZ)  ' Store initial root depth
5040     LSET MADEF$  = MKS$(MAD)     ' Store allowed depletion
5050     LSET Z$      = MKS$(RZ)      ' Store max rooting depth
5060     LSET AWTR$   = MKS$(AW)      ' Store avail water/ ft
5070 PUT #1, KO                       ' Data storage location
5080 CLS
5090 RETURN
5100 '             Part two of the irrigation scheduling model.
5110 DEF SEG = &H3F94
5120 BLOAD "SCROLLUP.MOD"
5130 SCROLLUP = 0
5140 COUNT = 0
5150 DIM ET(365)
5160 TET = 0: TWTR = 0: AVWTR = 0: KCO = 0: RMN = 0: WTR = 0
5170 TDPL = 0, ETR = 0, WTR1 = 0: WTR2 = 0
5180 FOR J = 1 TO 365    '  Zero out the ET array
5190    ET(J) = 0
5200 NEXT J
5210 SEQ = CDAT(KO,0)    '  Sets seq day to crop planting date
5220 GOSUB 6360          '  Calculate Penman's ETp
5230 GOSUB 7250          '  Calculate root devel. and avail water
5240 GOSUB 7380          '  Calculate crop coefficients
5250 KS = 2 - 2*(TDPL/AVWTR)
5260 IF (TDPL/AVWTR <= .5) THEN KS = 1!
5270 IF (TDPL/AVWTR > 1) THEN KS = 0
5280 KC = KS*KCO
5290 GOSUB 7540   ' Calculate incr ET due to precip or irr.
5300 MAD = CDAT(KO,3)*AVWTR    ' Manag't allowable depletion
5310 ET(SEQ) = KC*ETP + ETR    '  Calculate evapotranspiration
5320 IF ET(SEQ) < 0 THEN ET(SEQ) = 0
```

```
5330 IF SEQ > 0 AND SEQ < 47 AND KO = 3 THEN ET(SEQ) = 0
5340 GOSUB 7860     '  Calculate depletion and remaining water.
5350 GOSUB 7940     '  Calculate ET over the past three days
5360 ON KO GOSUB 6920,7010,7090       'Calc. ET over next 3 days
5370 AVET = (ETPAS + ETNEX + ET(SEQ))/7  ' Seven day ET average
5380 SQDY = SEQ
5390 IF DETAIL = 2 THEN GOTO 5600
5400 GOSUB 6740    ' Determine day and month of growing season
5410 COUNT = COUNT + 1
5420 IF COUNT <= 17 THEN GOTO 5460
5430 COLOR 4,4
5440 CALL ABSOLUTE(SCROLLUP)
5450 LOCATE 23,1
5460 COLOR 0,1,7
5470 PRINT TAB(12): COLOR 0,7: PRINT USING "   &";NEXM$;
5480 PRINT USING " ##      ";NEXD;
5490 PRINT USING "##.##       ";AVWTR;MAD;
5492 PRINT USING " ##.##";RMN;
5500 GOSUB 6680    '  Determine number of days to next irr.
5510 GOSUB 6730    '  Calc. day of the month of next irr.
5520 IF AMT <= .006 THEN NEXM$ = "  N.A."
5530 PRINT USING "     &";NEXM$;
5540 IF AMT <= .006 THEN GOTO 5560
5550 PRINT USING " ##"; NEXD;
5560 PRINT USING "  ##.##    ";AMT;
5570 COLOR 0,1,7
5580 PRINT "      ";
5590 GOTO 5910
5600 COLOR 0,2,7
5610 CLS
5620 LOCATE 6,35:  PRINT "Please Standby"
5630 IF SEQ <> SEQDY THEN GOTO 5860
5640 COLOR 0,7,7
5650 CLS
5660 BLANKLINE$ = SPACE$(49)
5670 FOR I = 4 TO 23
5680    LOCATE I,17: COLOR 0,0: PRINT BLANKLINE$
5690 NEXT I
5700 LOCATE 5,30: COLOR 7,0: PRINT "SUMMARIZED REPORT"
5710 LOCATE 8,19: PRINT "TODAY'S DATE IS: ";
5720 GOSUB  6730       ' Calculate day of month of next irr.
5730 IY = VAL(IY$)
5740 PRINT USING " &";NEXM$;: PRINT USING " ##";NEXD;
5742 PRINT USING "_,#### ";IY
5750 LOCATE 10,19: PRINT "THE CROP UNDER CONSIDERATION IS:  ";
5760 PRINT USING " & ";CRP$
5770 LOCATE 12,19: PRINT"THE REMAINING SOIL MOISTURE IS: ";
5780 PRINT USING" ##.## ";RMN;: PRINT "in."
5790 GOSUB 6480       '  To determine number of days to next irr.
5800 IF SQDY < SEQ THEN GOTO 5820
5810 GOSUB 6740             '  Calculate day of month of next irr.
5820 LOCATE 14,19: PRINT"YOU SHOULD IRRIGATE ON:  ";
5830 COLOR 31,0: PRINT USING "  &"; NEXM$;: PRINT USING" ## ";NEXD
5832 COLOR 0,7: LOCATE 16,19
5840 COLOR 7,0: PRINT"THE IRRIGATION AMOUNT SHOULD BE:  ";
```

```
5850 COLOR 31,0: PRINT USING " ##.## "; AMT;: PRINT "in."
5860 GOTO 5900
5870 GOSUB 6740          '  Determine the day and month of next irr.
5880 GOTO 5820
5890                     '  Calculate the total seasonal water.
5900 PRINT: PRINT: PRINT
5910 ETPAS = 0
5920 ETNEX = 0
5930 AVET = 0
5940 KCO = 0
5950 WTR = 0
5960 IF SEQ = SEQDY THEN GOTO 5990
5970 IF DETAIL = 1 THEN GOTO 5990
5980 PRINT TAB(40):  PRINT USING "###";SEQ: COLOR 0,15
5990 SEQ = SEQ + 1
6000 COLOR 2,1,7
6010 IF KO <> 3 THEN GOTO 6040
6020 IF SEQDY < CDAT(KO,0) AND SEQ >= CDAT(KO,0) AND
                              SEQ <= 365 THEN GOTO 5220
6030 IF SEQ > 365 THEN GOSUB 4230: GOSUB 4060
6040 IF SEQ <= SEQDY THEN GOTO 5220
6050 IF DETAIL = 1 THEN GOTO 6110
6060 LOCATE 21,19: COLOR 7,0:
6062 PRINT "ACCUMULATIVE CONSUMPTION USE IS: ";
6070 PRINT USING " ##.## ";TET;: PRINT "in."
6080 LOCATE 22,19: PRINT "ACCUMULATIVE APPLIED WATER IS: ";
6090 PRINT USING " ##.## ";TWTR;: PRINT "in.":
6100 GOTO 6340
6110 CALL ABSOLUTE(SCROLLUP)
6120 LOCATE 23,1
6130 COLOR 1,1
6140 GOSUB 3610
6150 CALL ABSOLUTE(SCROLLUP)
6160 LOCATE 23,1
6170 PRINT;
6180 CALL ABSOLUTE(SCROLLUP)
6190 LOCATE 23,1
6200 PRINT;
6210 CALL ABSOLUTE(SCROLLUP)
6220 LOCATE 23,1
6230 COLOR 2,0
6240 PRINT TAB(12): PRINT"  ACCUMULATIVE CONSUMPTIVE USE IS: ";
6250 PRINT USING " ##.## ";TET;: PRINT "in."
6260 CALL ABSOLUTE(SCROLLUP)
6270 LOCATE 23,1
6280 PRINT TAB(12): PRINT "  ACCUMULATIVE APPLIED WATER IS: ";
6290 PRINT USING " ##.## ";TWTR;: PRINT "in.            ";
6300 CALL ABSOLUTE(SCROLLUP)
6310 LOCATE 23,1
6320 CALL ABSOLUTE(SCROLLUP)
6330 LOCATE 23,1
6340 COLOR 7
6350 GOTO 190
6360 '      SUBROUTINE used to calculate Penman's ETp
6370 TB = (TA(1) + TA(2) + TA(3))/3
```

```
6380 TA(1) = TA(2)
6390 TA(2) = TA(3)
6400 MET(SEQ,0) = (MET(SEQ,0) - 32)/1.8   'Convert deg F to deg C
6410 MET(SEQ,1) = (MET(SEQ,1) - 32)/1.8   'Convert deg F to deg C
6420 N = 0
6430 TA(3) = (MET(SEQ,0) + MET(SEQ,1))*.5    '  Average daily temp
6440                      '  Calculate potential evapotranspiration.
6450 DEL1 = .05904*(.00738*TA(3) + .8072)^7    ' Components of C1
6460 DEL = (DEL1 - .0000342)*33.8639           '      "     "  "
6470 ELEV = 1013 - .03217 * EL
6480 LAM1 = .242 * ELEV                        '      "     "  "
6490 LAM = LAM1/(.6220001*(595 - .51*TA(3)))   '      "     "  "
6500 C1 = DEL/(DEL + LAM)
6510 C2 = 1 - C1
6520 ALPHA = .21
6530 RN = .95*(1 - ALPHA)*MET(SEQ,4) - 64  ' Net rad., langleys/day
6540 G = 9*(TA(3) - TB)                   ' Heat flux, langleys/day
6550 W = 15.36*(1 + .0106*MET(SEQ,5))     ' Wind run, km/day
6560 T = MET(SEQ,1)                       ' Minimum daily temp
6570 GOSUB 6870          '  Calculate vapor pressure at T-min
6580 EN = E
6590 T = MET(SEQ,0)
6600 GOSUB 6870          '  Calculate vapor pressure at T-max
6610 EX = E
6620 ED1 = EX*MET(SEQ,3)
6630 ED2 = EN*MET(SEQ,2)
6640 ED = (ED1 + ED2)/2
6650 EZO = (EN + EX)/2
6660 ETP = .000673*(C1*(RN - G) + C2*W*(EZO - ED)) 'Penmans pot ET
6670 RETURN
6680 '     SUBROUTINE determines number of days til the next irr.
6690 NDS = (MAD - TDPL)/AVET
6700 SQDY = SEQ + CINT(NDS)
6710 IF CINT(NDS) < 1 THEN SQDY = SEQ
6720 RETURN
6730 '     SUBROUTINE determines day and month of the next irr.
6740 IF SQDY > 0 AND SQDY <= 31 THEN NEXM$ = "JAN": NEXD = SQDY
6745 NEXD = SQDY
6750 IF SQDY > 31 AND SQDY <= 59 THEN NEXM$ = "FEB"
6755 NEXD = SQDY - 31
6760 IF SQDY > 59 AND SQDY <= 90 THEN NEXM$ = "MAR"
6765 NEXD = SQDY - 59
6770 IF SQDY > 90 AND SQDY <= 120 THEN NEXM$ = "APR"
6775 NEXD = SQDY - 90
6780 IF SQDY > 120 AND SQDY <= 151 THEN NEXM$ = "MAY"
6785 NEXD = SQDY - 120
6790 IF SQDY > 151 AND SQDY <= 181 THEN NEXM$ = "JUN"
6795 NEXD = SQDY - 151
6800 IF SQDY > 181 AND SQDY <= 212 THEN NEXM$ = "JUL"
6805 NEXD = SQDY - 181
6810 IF SQDY > 212 AND SQDY <= 243 THEN NEXM$ = "AUG"
6815 NEXD = SQDY - 212
6820 IF SQDY > 243 AND SQDY <= 273 THEN NEXM$ = "SEP"
```

```
6825 NEXD = SQDY - 243
6830 IF SQDY > 273 AND SQDY <= 304 THEN NEXM$ = "OCT"
6835 NEXD = SQDY - 273
6840 IF SQDY > 304 AND SQDY <= 334 THEN NEXM$ = "NOV"
6845 NEXD = SQDY - 304
6850 IF SQDY > 334 AND SQDY <= 365 THEN NEXM$ = "DEC"
6855 NEXD = SQDY - 334
6860 RETURN
6870 '     SUBROUTINE used to calculate vapor pressures.
6880 TK = T + 273.1
6890 E = 1.3329*EXP(21.07 - (5336/TK))
6900 RETURN
6910 '     SUBROUTINE calculates ET for CORN predictions
6920 ETNEX = 0
6930 NA = SEQ
6940 NA1 = NA*NA
6950 NA2 = NA1*NA
6960 ETNEX =ETNEX - .511254 + 2.343942E-03*NA + 4.135742E-05*
                                             NA1 - 1.597805E-07*NA2
6970 NA = NA + 1
6980 IF NA < (SEQ + 4) THEN GOTO 6940
6990 RETURN
7000 '     SUBROUTINE calculates ET for SORGHUM predictions
7010 ETNEX = 0
7020 NB = SEQ
7030 NB1 = NB*NB
7040 NB2 = NB1*NB
7050 ETNEX = ETNEX - 4.688631 + 5.908156E-02*NB - 2.206338E-04*
                                                   NB1 + 2.470596E-07
7060 NB = NB + 1
7070 IF NB < (SEQ + 4) THEN GOTO 7030
7080 RETURN
7090 '    SUBROUTINE used to calculate ET for WHEAT predictions
7100 IF SEQ < CDAT(KO,0) THEN GOTO 7180
7110 ND = SEQ
7120 ND1 = ND*ND
7130 ND2 = ND1*ND
7140 ETNEX = ETNEX + .8638185 + 2.704531E-03*ND - 3.680763E-05*
                                            ND1 + 6.278476E-08*ND2
7150 ND = ND + 1
7160 IF ND < (SEQ + 4) THEN GOTO 7120
7170 GOTO 7240
7180 NC = SEQ
7190 NC1 = NC*NC
7200 NC2 = NC1*NC
7210 ETNEX =ETNEX + 9.805757E-02 - 7.116188-3*NC + 1.193397E-04*
                                              NC1 - 4.38947E-07*NC2
7220 NC = NC + 1
7230 IF NC < (SEQ + 4) THEN GOTO 7190
7240 RETURN
7250 '     SUBROUTINE to calculate rooting depths
7260 IF KO = 3 AND SEQ < CDAT(KO,0) THEN SEQ = SEQ + 365
7270 IF SEQ <= CDAT(KO,1) THEN GOTO 7300
7280 R = SEQ - CDAT(KO,1)     ' After effective cover
7290 GOTO 7310
```

```
7300 R = (SEQ - CDAT(KO,0))/(CDAT(KO,1) - CDAT(KO,0)) ' Before EC
7310 IF R <= 0 THEN RT = CDAT(KO,2)
7320 IF R = 0 THEN GOTO 7350
7330 IF R < 1 THEN RT = CDAT(KO,2) + R*(CDAT(KO,4) - CDAT(KO,2))
7340 IF R >= 1 THEN RT = CDAT(KO,4)
7350 IF KO = 3 AND SEQ > 365 THEN SEQ = SEQ - 365
7360 AVWTR = RT*CDAT(KO,5)  'Calculate avail water.
7370 RETURN
7380 '      SUBROUTINE used to calculate crop coefficients
7390 KCO = 0
7400 IF SEQ > CDAT(KO,0) AND SEQ <= 365 AND KO = 3
                                          THEN GOTO 7480
7410 KCO = 0
7420    FOR M = 1 TO 4
7430       KCO = KCO + CKCO(KO,M)*SEQ^(M - 1)
7440    NEXT M
7450 IF SEQ < 50 AND SEQ > 0 THEN KCO = 0
7460 IF KCO < 0 THEN KCO = 0
7470 GOTO 7530
7480 KCO = 0
7490 FOR M = 1 TO 4
7500      KCO = KCO + CKCO(4,M)*SEQ^(M - 1)
7510 NEXT M
7520 IF KCO < 0 THEN KCO = 0
7530 RETURN
7540 '      SUBROUTINE calculate incr ET due recent precip or irr.
7550 ETR = 0
7560 WTR = 0
7570 IF (MET(SEQ,6) > 0) OR (MET(SEQ,7) > 0) THEN GOTO 7610
7580 IF L > 0 THEN GOTO 7620
7590 TEMP = 0
7600 GOTO 7840
7610 L = 0
7620 L = L + 1
7630 IF L > 3 THEN GOTO 7820
7640 IF L = 1 THEN KR = .8
7650 IF L = 2 THEN KR = .5
7660 IF L = 3 THEN KR = .3
7670 WTR = MET(SEQ,6) + MET(SEQ,7)
7680 TWTR = TWTR + WTR
7690 WTR1 = WTR1 + MET(SEQ,6)
7700 WTR2 = WTR2 + MET(SEQ,7)
7710 ADJ = ADJ + WTR
7720 IF KC => .9 THEN KR = 0
7730 ETR = KR*(.9 - KC)*ETP
7740 ETRT = ETRT + ETR
7750 IF ETR < ADJ THEN GOTO 7780
7760 L = 0
7770 ETR = ADJ
7780 IF ETRT => ADJ THEN GOTO 7810
7790 TEMP = ETRT
7800 GOTO 7850
7810 ETR = ADJ - TEMP
7820 ETRT = 0
7830 ADJ = 0
```

```
7840 L = 0
7850 RETURN
7860 '      SUBROUTINE  calc depl, remaining wtr, & irr. amt
7870 TDPL = TDPL + ET(SEQ) - WTR
7880 IF TDPL < 0 THEN TDPL = 0
7890 TET = TET + ET(SEQ)        '   Totalizing annual ET
7900 RMN = MAD - TDPL
7910 AMT = TDPL
7920 IF KC < 0 THEN DPL = 0
7930 RETURN
7940 '      SUBROUTINE  calculate ET over past three days
7950 FOR M = 1 TO 3
7960    PAST = (SEQ - M)
7970    IF (SEQ - M) <= 0 THEN PAST = 365 - (M - SEQ)
7980    ETPAS = ETPAS + ET(PAST)
7990 NEXT M
8000 RETURN
8010 '      SUBROUTINE  This is the program called WXDISPLA.BAS
8020 CLS: KEY OFF
8030 OPEN FILE1$ AS #1 LEN = 28
8040 FIELD #1, 4 AS HITEMP$, 4 AS LOTEMP$, 5 AS HH$, 5 AS LH$,
                                     5 AS SOLRAD$, 5 AS TOTWIND$
8050 SQDY = SEQDAY
8060 GOSUB 6730
8070    GET #1, SEQDAY
8080       A = CVS(HITEMP$)
8090       B = CVS(LOTEMP$)
8100       C = CVS(HH$)
8110       D = CVS(LH$)
8120       E = CVS(SOLRAD$)
8130       F = CVS(TOTWIND$)
8140 CLOSE #1
8150 CLS
8155 LOCATE 6,15
8160 PRINT "Enter crop number to retrieve irrig/precip data;"
8170 LOCATE 7,15: PRINT "(1) Corn,  (2) Milo,  (3) Winter wheat. "
8180 XX$ = INPUT$(1)
8190 KO = VAL(XX$)
8200 GOSUB 9220
8210 OPEN FILE4$ AS #2 LEN = 10
8220 FIELD #2, 5 AS PRECIP$, 5 AS IRR$
8230     GET #2,SEQDAY
8240     G = CVS(PRECIP$)
8250     H = CVS(IRR$)
8260 CLOSE #2
8270 CLS
8280 LOCATE 6,15
8290 PRINT "The weather data for ";:PRINT USING"&";NEXM$;
8300 PRINT USING" ##";ID;:PRINT USING"_,####";VAL(IY$);
8305 PRINT " is as follows:"
8310 LOCATE 8,7: PRINT"  SEQ    MAX     MIN    MAX    MIN    ";
8315 PRINT "SOLAR   TOTAL"
8320 PRINT TAB(7);
8330 PRINT"  DAY    TEMP    TEMP   HUM    HUM     RAD    WIND     ";
8335 PRINT "PRECIP IRR"
```

```
8340 PRINT TAB(7);
8350 PRINT STRING$(67,45)
8360 PRINT TAB(7);
8370 PRINT USING"  ###";SEQDAY;:PRINT USING"   ###.#";A,B;
8380 PRINT USING "   #.##"; C,D;: PRINT USING"   ###.#";E,F;
8390 PRINT USING "   #.##";G,H
8400 LOCATE 15,16: PRINT"Please record this data for future use."
8405 LOCATE 20,13
8410 PRINT"Do you wish to return to the Opening Menu, Y/N?"
8420 AN$ = INPUT$(1)
8430 IF AN$ = "Y" OR AN$ = "y" THEN GOTO 8450
8440 IF AN$ = "N" OR AN$ = "n" THEN GOTO 8470 ELSE 8410
8450 FLIP = 1
8460 GOTO 30
8470 GOTO 190                ' End of WXDISPLAY SUBROUTINE
8480 '     SUBROUTINE converts Wx data, downloaded from mainframe
8490 '     at NMSU into useable units for the irrigation
8500 '     scheduling model.
8510 CLS
8520 OPEN FILE1$ AS #1 LEN = 28
8530 FIELD #1, 4 AS HITEMP$,4 AS LOTEMP$,5 AS HH$,5 AS LH$,
                                    5 AS SOLRAD$, 5 AS TOTWIND$
8540 FILE3$ = "B:CLOV"
8550 FILE4$ = ".MET"
8560 FILE5$ = FILE3$ + RIGHT$(IY$,2) + FILE4$
8570 OPEN FILE5$ FOR INPUT AS #2
8580 INPUT #2, ID, YR, MO, DAY, MAXTEMP, MINTEMP, AVTEMP, MAXHUM,
               MINHUM,PRECIP, AVWIND, MAXWIND, VECTMAG, VECTDIR,
           SLRD, SOILTEMP, SOILMOIST, NETRAD, DAYWIND, NITEWIND
8590 JD = DAY - 1
8600 JD = JD + 1
8610 INPUT #2, ID, YR, MO, DAY, MAXTEMP, MINTEMP, AVTEMP, MAXHUM,
               MINHUM, PRECIP, AVWIND, MAXWIND, VECTMAG, VECTDIR,
           SLRD, SOILTEMP, SOILMOIST, NETRAD, DAYWIND, NITEWIND
8620 '
8630 '  CONVERSION OF UNITS
8640 '
8650 SOLRAD = SLRD * 23.89  'Converts MegaJoules/Day to Langleys/Day
8660 TOTWIND = AVWIND * 24!* 1.6          ' Converts wind to km/day
8670 HITEMP = MAXTEMP
8680 LOTEMP = MINTEMP
8690 HIHUM = MAXHUM/100
8700 LOHUM = MINHUM/100
8710 GOTO 8770
8720 SOLRAD = 0
8730 TOTWIND = 0
8740 HITEMP = 0
8750 HHUM = 0
8760 LHUM = 0
8770    LSET HITEMP$ = MKS$(HITEMP)
8780    LSET LOTEMP$ = MKS$(LOTEMP)
8790    LSET HH$ = MKS$(HIHUM)
8800    LSET LH$ = MKS$(LOHUM)
8810    LSET SOLRAD$ = MKS$(SOLRAD)
8820    LSET TOTWIND$ = MKS$(TOTWIND)
```

```
8830 PUT #1, JD
8840 GET #1, JD
8850 PRINT USING "###  ";JD;
8860 PRINT USING "###  ";CVS(HITEMP$);
8870 PRINT USING "###  ";CVS(LOTEMP$);
8880 PRINT USING "##.##  ";CVS(HH$);
8890 PRINT USING "##.##  ";CVS(LH$);
8900 PRINT USING "###.##  ";CVS(SOLRAD$);
8910 PRINT USING "###.##  ";CVS(TOTWIND$)
8920 IF EOF(2) GOTO 8940
8930 GOTO 8600
8940 CLOSE #1
8950 CLOSE #2
8960 PRINT
8970 PRINT "******* CONVERSIONS COMPLETE - DATA STORED *******"
8980 CLS
8985 LOCATE 4,13
8990 PRINT"Do you wish to display the current weather data, Y/N?"
9000 AN$ = INPUT$(1)
9010 IF AN$ = "Y" OR AN$ = "y" THEN GOTO  9030
9020 IF AN$ = "N" OR AN$ = "n" THEN GOTO 9040 ELSE 8990
9030 GOTO 8450
9035 LOCATE 5,13
9040 PRINT"Do you wish to return to the Opening Menu, Y/N?"
9050 ANS$ =INPUT$(1)
9060 IF ANS$ = "Y" OR ANS$ = "y" THEN GOTO 9080
9070 IF ANS$ = "N" OR ANS$ = "n" THEN GOTO 9090 ELSE 9040
9080 RETURN
9090 GOTO 190
9100 '      SUBROUTINE used to name weather storage files
9110 CLS
9115 LOCATE 6,20
9120 PRINT" Enter current month, day and year (mm,dd,yyyy)."
9130 PRINT TAB(20): INPUT "==>  ",IM,ID,IY$
9140 GOSUB 3470
9150 SEQDY = SEQDAY
9160 FILE$ = "B:METWX.C"
9170 A = VAL(IY$) - 1
9180 IY2$ = STR$(A)
9190 FILE1$ = FILE$ + RIGHT$(IY$,2)
9200 FILE2$ = FILE$ + RIGHT$(IY2$,2)
9210 RETURN
9220 '      SUBROUTINE nameS irrigation and precipitation files
9230 ON KO GOTO 9240,9260,9280
9240 FILE3$ = "B:CRNPRECI.C"
9250 GOTO 9290
9260 FILE3$ = "B:MLOPRECI.C"
9270 GOTO 9290
9280 FILE3$ = "B:WHTPRECI.C"
9290 FILE4$ = FILE3$ + RIGHT$(IY$,2)
9300 FILE5$ = FILE3$ + RIGHT$(IY2$,2)
9310 RETURN
```

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