Irrigation Scheduling Using Evapotranspiration (ET):
Example Schedule

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Irrigation scheduling can be accomplished by keeping an account of crop water use relative to the amount of water available for withdrawal from the soil profile. Measurement of crop water use or evapotranspiration (ET) can be indirectly measured by monitoring soil water levels or calculated using weather information and specific crop growth characteristics. Calculating crop water use, although an estimate, is an reliable and accurate method that is finding favor with many irrigators since the information can be gathered and delivered electronically to the office and eliminates much of the labor involved in indirectly measuring water through soil sampling. Some soil monitoring is still necessary to confirm scheduling accuracy and account for rainfall and other variations. KSU bulletins, Scheduling Using Evapotranspiration Reports for Center Pivots, L-915, and Furrow Irrigation, L-914 are available from your county extension office. This example will follow the procedures discussed in those bulletins and will assume use of a center pivot system.

Basic Scheduling

Irrigation Scheduling Steps:
1. Determine the total crop water use (ET) since the last update.
2. Determine the effective rainfall and irrigation since the last update.
3. Update the schedule.
4. Begin irrigation when soil water depletion equals or exceeds the net irrigation application amount.

To initiate the scheduling steps, characteristics of the field (soil) and irrigation system and certain management guidelines must be determined.

Determine the Active Root Zone of the Crop

For the bulk of the season, a managed root of three feet for most field crops is a general recommendation. However, some soils may have restrictions that reduce root penetration. Early season irrigation should account for a shallow root zone, either using information from crop production handbooks or visual inspection through digging. Record a root zone depth of 3 feet on line A of Table 3 for this example.

Determine the Soil Water Storage Capacity

Sandy soils hold less water than silts or clays. Specific information is available from a NRSC county soil Survey. KSU bulletin L-904, Soil, Water, Plant Relationships, will have generalized information. Table 1 (from L-904), is shown below. Assume a sandy loam soil for today's example. From Table 1, the available soil water holding capacity is 1.56 inches per feet. Record this soil water holding capacity on line B of Table 3.

Determine Allowable Soil Water Depletion

Crops have differing levels of soil water depletion tolerance, although most field crops are not extremely yield sensitive to some soil water deficient. However, to maintain good growth conditions, the general management recommendation for field crops is to maintain less than 50 percent depletion in the soil profile. Record 50 percent allowable depletion on line D of Table 3. Multiply line C by line D and record this result on line E of Table 3.

Determine Irrigation Capacity

The irrigation capacity of any irrigation system depends on the well discharge rate relative to the number of acres covered. Irrigation capacity does not change with application depth. Increasing or decreasing application depth has a proportional effect on the length of the irrigation set. Use the following formula to calculate gross irrigation capacity.

$$\text{Gross Irrigation Capacity} = \frac{\text{GPM} \times \text{Hours/Day}}{450^{*} \times \text{Acres}}$$

* 450 gpm = 1 ac-in/hr (conversion factor)

Example :

$$\frac{650 \text{ gpm } (24 \text{ hr/day})}{\frac{450 \text{ gpm}}{\text{ac-in/hr}} \;\; 128 \text{ acres}} = .27 \text{ in/day}$$

Irrigation systems are not 100 percent efficient. Table 2 presents some typical estimates for efficiency for various sprinkler packages - assuming good operating conditions and no surface runoff. Multiply gross irrigation capacity by the efficiency estimate to determine the net irrigation capacity.

Net irrigation capacity = gross irrigation capacity x efficiency

Assume a sprinkler package with an efficiency estimate of 80 percent.

Net irrigation capacity (NIR) = 0.27 inches/day x 0.80 = 0.22 inches/day

The net irrigation capacity can be used to calculate the irrigation application depth by multiplying capacity by length of the irrigation. Assume, for example, the irrigator wants to complete one revolution of a center pivot in 3.5 days.

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$$0.22 \text{ in/day} \times 3.5 \frac{\text{days}}{\text{revolution}} = 0.77 \text{ inches/revolution}$$

It can also determine the length of time needed to apply a certain depth by dividing irrigation depth by capacity. How long would it take this irrigation system to apply 1.0 inches net application.

$$\frac{1.0 \text{ inches}}{0.22 \text{ inches/day}} = 4.5 \text{ days or } 109 \text{ hours}$$

Remember, however, the grow amount pumped was 0.27 inches/day or 1.22 inches in the 4.5 days.

Filling in the Schedule

The remainder of Table 3 contains 10 columns to record the daily information needed to schedule. Column 1 is the date. Column 2 is the amount of effective rainfall that enters the soil profile and becomes available for crop use. Column 3 is the net irrigation amount that was determined using the previously described procedure. Record the total application depth in Column 3 when irrigation is initiated and list in column 3 the number of days it takes to complete an irrigation cycle.

Example.

Column 1	Column 3
Date 1	1.00 1
Date 2	2
Date 3	3
Date 4	4
Date 5	4.5

Column 4,5,6, and 7 is used to record the information used to determine evapotranspiration (ET). ET may be reported as either Etr or actual ET. If actual ET information is obtained, record it directly into Column 7, marked Crop ET on Table 3, and ignore the columns marked Etr, Stage of Growth, and Crop Coefficient.

Etr refers to reference ET. Etr is the expected ET from a uniform, green,actively growing reference crop due to atmospheric demand. Actual ET is usually less than Etr since plant characteristics of other crops and stage of growth reduce the amount. If Etr is used, it must be modified to reflect the crop type and maturity.

Example: Etr = 0.35 State of Growth = 7 leaf corn
From Figure 1 Kco = 0.45

$$\begin{aligned} ET &= Etr \times Kco \\ &= 0.35 \times 0.45 \\ &= 0.16 \text{ inches} \end{aligned}$$

The soil water depletion is calculated and recorded in column 8 and 9 to represent two locations in the field. Location 1 is the start of the irrigation cycle and Location 2 is the end of the irrigation cycle for this example. Other locations, or additional locations, in the field could be used if desired, but the starting and stopping points are important. The new soil water depletion is calculated as follows:

Soil water depletion = previous day's soil water depletion + ET
- net irrigation - effective rainfall

Soil water depletion cannot be negative. If this occurs, record zero for the depletion level.

Soil water status when recorded as depletion means bigger numbers are less desirable. Zero depletion means the soil profile is at field capacity. Crop water use removes water from the profile and increases depletion. Rain and irrigation reduce depletion. To help remind you, the depletion formula appears on Table 3. Column 7 has a plus (+) sign to indicate it adds to depletion while columns 2 & 3 have negative (-) signs to indicate they subtract from depletion.

Example: Schedule calculation

New Soil Depletion = Previous Soil Depletion +ET - NIR - RAIN

Prev = 1.00 ET = 0.25 NIR = 0.75 RAIN = 0

NEW = 1.00 + 0.25 - 0.75 - 0

= 0.50 inches

You are now ready to complete Table 3. In Table 3 Etr values are listed for a 21 day period along with stages of growth for corn. Use Figure 1 to select an appropriate Kco value and calculate ET (Column 7). Remember in the real world you would only get one day at a time. The stage of growth progress more rapidly than what a normal corn crop. This was done to help illustrate the selection of Kco values from Figure 1. Select a Kco from Figure 1 and record this in Column 6. Kco values are sometimes determined by calculation using days past emergence or growing degree days or fraction of the growing. Any of these Kco selection methods make computerization of scheduling easier.

At date 0, soil water depletion values were determined (assumed for this exercise) to be 0.90 inches. The allowable depletion from line E is 2.34. The remaining soil water then is (2.34 - 0.90) 1.44 inches. If crop ET was 0.25 inches/day, this means almost 6 days (1.44 inches/ 0.25in/day) of water supply remains in profile. Then net irrigation capacity is 0.22 inches/day and a 4.5 day irrigation is planned which applies a net irrigation of 1.00 inches. Since the NIR and the soil depletion are approximately equal at Day 0, irrigation can begin.

Complete Table 3 assuming the first irrigation is started on day 1 and effective rainfall of 0.78 and 0.23 occurs on day fourteen and fifteen. You determine when to start or stop all subsequent irrigations.

Table 1: Average Water Holding Capacities of Kansas Soils (Source: NRCS Kansas Irrigation Guide)

	Percent Water Content				Inches per Foot			
Soil Texture	Wet Bulk Density At F.C	1/ F.C.	2/ W.P.	3/ A.W.C.	4/ W.P. F.C.	1/ F.C.	2/ W.P.	3/ A.W.C.
Sand	1.70	7.0	3.0	4.0	43	1.44	0.60	0.84
Loamy sand	1.70	10.0	4.2	5.8	42	2.04	0.84	1.20
Sandy loam	1.65	13.4	5.6	7.8	42	2.64	1.08	1.56
Fine sandy loam	1.60	18.2	8.0	10.2	44	3.48	1.56	1.92
Loam	1.55	22.6	10.3	12.3	46	4.20	1.92	2.28
Silt loam	1.50	26.8	12.9	13.9	48	4.80	2.28	2.52
Silty clay loam	1.45	27.6	14.5	13.1	52	4.80	2.52	2.28
Sandy clay loam	1.50	26.0	14.8	11.2	57	4.68	2.64	2.04
Clay loam	1.50	26.3	16.3	10.0	62	4.68	2.88	1.80
Silty clay	1.40	27.9	18.8	9.1	67	4.68	3.12	1.56
Clay	1.35	28.8	20.8	8.0	72	4.68	3.36	1.32

1/ Field Capacity
2/ Wilting point
3/ Available water capacity
4/ Percent of field at wilting point

Table 2. Probable Range of Irrigation Application Efficiency for Various Sprinkler Packages with No Runoff*

System Type	Application Efficiency Range (%)
High pressure - high angle impact	70 to 80
Medium pressure - low angle impact	75 to 85
Spray on top truss	75 to 85
Spray on drop	80 to 90
In-canopy spray	75 to 95
Bubble mode or sock LEPA	85 to 95

*See K-State Bulletin L-908, *Considerations for Sprinkler Packages on Center Pivot*, for more information.

Table 3. Soil Water Balance Worksheet

A. Field ___Example___ E. Crop ___Example___

B. Root Zone Depth ________ feet F. Root Zone Available Water Holding Capacity ________ inches

C. Soil Type ___Sandy Loam___ G.% Allowable Depletion ________ %

D. Available Water Holding Capacity ________ in/ft H. Allowable Depletion ________ inches

New Depletion = Soil Depletion + Et - Net irrigation - Rainfall

(1) Date	(2) Effective Rainfall Inches (-)	(3) Net Irrigation Inches (-)	(4) Etr Inches	(5) Stage of Growth	(6) Kco Crop Coefficient	(7) Crop ET Inches +	(8) Soil Water Depletion Location 1	(9) Soil Water Depletion Location 2	(10) Comments
0							0.90	0.90	
1			0.28	7 Leaf					
2			0.27	7leaf					
3			0.30	8 leaf					
4			0.31	8 leaf					
5			0.18	9leaf					
6			0.19	leaf					
7			0.28	10 leaf					
8			0.31	10leaf					
9			0.29	11 leaf					
10			0.36	11 leaf					
11			0.39	12 leaf					
12			0.42	12 leaf					
13			0.48	14 leaf					
14	0.78		0.41	14 leaf					
15	0.23		0.21	16 leaf					
16			0.35	16 leaf					
17			0.20	Silk					
18			0.22	Silk					
19			0.28	Blister					
20			0.30	Blister					
21			0.24	Dough					

Table 4. Soil Water Balance Worksheet

A. Field_______________________________ E. Crop____

B. Root Zone Depth__________________feet F. Root Zone Available Water Holding Capacity________inches

C. Soil Type ___________________________ G.% Allowable Depletion______________________________%

D. Available Water Holding Capacity______in/ft H. Allowable Depletion___________________________inches

New Depletion = Soil Depletion + Et - Net irrigation - Rainfall

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Date	Effective Rainfall Inches (-)	Net Irrigation Inches (-)	Etr Inches	Stage of Growth	Kco Crop Coefficient	Crop ET Inches +	Soil Water Depletion Location 1	Soil Water Depletion Location 2	Comments
0									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									

Table 5. Soil Water Balance Worksheet

A. Field Example | E. Crop Example

B. Root Zone Depth 3 feet | F. Root Zone Available Water Holding Capacity 4.68 inches

C. Soil Type Sandy Loam | G.% Allowable Depletion 50 %

D. Available Water Holding Capacity 1.56 in/ft | H. Allowable Depletion 2.34 inches

New Depletion = Soil Depletion + Et - Net irrigation - Rainfall

(1) Date	(2) Effective Rainfall Inches (-)	(3) Net Irrigation Inches (-)	(4) Etr Inches	(5) Stage of Growth	(6) Kco Crop Coefficient	(7) Crop ET Inches +	(8) Soil Water Depletion Location 1	(9) Soil Water Depletion Location 2	(10) Comments
0							0.90	0.90	
1		1.00 1	0.28	7 lf	0.45	0.13	0.03	1.03	Begin 1st
2		2	0.27	7 lf	0.45	0.12	0.15	1.15	
3		3	0.30	8 lf	0.60	0.18	0.33	1.33	
4		4	0.31	8 lf	0.60	0.19	0.52	1.52	
5		4.5	0.18	9 lf	0.80	0.14	0.66	0.66	End 1st OFF
6			0.19	9 lf	0.80	0.15	0.81	0.81	
7		1.00 1	0.28	10 lf	0.90	0.25	0.06	1.06	Begin 2nd
8		2	0.31	10 lf	0.90	0.28	0.34	1.34	
9		3	0.29	11 lf	0.95	0.28	0.62	1.62	
10		4	0.36	11 lf	0.95	0.34	0.96	1.96	
11		4.5 1.00	0.39	12 lf	1.00	0.39	1.35 0.35	1.35 1.35	End 2nd Begin 3rd
12		1	0.42	12 lf	1.00	0.42	0.77	1.77	
13		2	0.48	14 lf	1.00	0.48	1.25	2.25	
14	0.78	3	0.41	14 lf	1.00	0.41	0.88	1.88	
15	0.23	4 4.5	0.21	16 lf	1.00	0.21	0.86	0.86	End 3rd
16		1.00 1	0.35	16 lf	1.00	0.35	0.21	1.21	Begin 4th
17		2	0.20	Silk	0.95	0.19	0.40	1.40	
18		3	0.22	Silk	0.95	0.21	0.61	1.61	
19		4	0.28	Blister	0.90	0.25	0.86	1.86	
20		4.5 1.00	0.30	Blister	0.90	0.27	1.13 0.13	1.13 1.13	End 4th Begin
21		1	0.24	Dough	0.60	0.14	0.27	1.27	5th

Figure 1. Corn Crop Coefficient vs.
Stage of Growth