WELL CAPACITY, CROP WATER USE, & IRRIGATION SCHEDULING: IMPORTANT FACTORS IN IRRIGATION MANAGEMENT

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Most irrigators have some idea about these factors. Yet, the need to manage these factors more closely than ever before is upon us, as farmers are asked to positively demonstrates beneficial use and no waste of our water resources, fertilizer, and chemicals. This short discussion will be limited to some brief thoughts on identifying and managing the three factors from the perspective of the irrigator.

WELL CAPACITY

Well capacity can be defined as the pumping rate that a well will sustain for an extended time period. Most irrigators have some feel for this concept, especially those whose well capacities have diminished over the last 10 years. It is helpful to think of well capacity in terms of how much water can be applied to a circle in a 24 hour period. Refer to Table 1, below for this information.

Well Capacity, GPM	Size of Circle Acres	Inches of Water Applied at Various Efficiencies* (In One 24 – Hour Day) 100%	95%	90%	85%	80%	75%
1100	128	0.46	0.43	0.41	0.39	0.37	0.34
1050	128	0.44	0.41	0.39	0.37	0.35	0.33
1000	128	0.41	0.39	0.37	0.35	0.33	0.31
950	128	0.39	0.37	0.35	0.33	0.32	0.30
900	128	0.37	0.35	0.34	0.32	0.30	0.28
850	128	0.35	0.33	0.32	0.30	0.28	0.26
800	128	0.33	0.32	0.30	0.28	0.27	0.25
750	128	0.31	0.30	0.28	0.26	0.25	0.23
700	128	0.29	0.28	0.26	0.25	0.23	0.22
650	128	0.27	0.26	0.24	0.23	0.22	0.20
600	128	0.25	0.24	0.22	0.21	0.20	0.19
550	128	0.23	0.22	0.21	0.19	0.18	0.17
500	128	0.21	0.20	0.19	0.18	0.17	0.16
450	128	0.19	0.18	0.17	0.16	0.15	0.14
400	128	0.17	0.16	0.15	0.14	0.13	0.12

Table 1. Well Capacity Related to Inches of Water Applied.

$$\text{*Inches applied per Day} = \frac{\text{GPM x Applic.Eff.}}{\text{18.833 x Acres Irrigated}}$$

Referring to this table, we see that, at 100% application efficiency, a 1,000 GPM well will supply 0.41 inches of water to a 128 acre circle in a 24 hour period. Another example would be a 650 GPM well will supply 0.27 inches of water in a 24 hour period. Of course, we know that 100% application efficiency (per cent of water supplied that actually enters the root zone) is seldom reached in the field. Therefore, efficiencies ranging down to 75% are presented to provide some feel for the potential losses. Application efficiency will be discussed further in a later session. Suffice it to say, at this point, that for a given well capacity, we can relate this capacity to water applied to a given area on a daily basis, and this usage can also be expressed in inches per day. The basic job of the irrigator is to match the water use by the crop with the water received from irrigation and/or rainfall.

Next, a comparison of high and low capacity wells. A high capacity well has some advantages and disadvantages, as follows:

Advantages...High Capacity Wells

- More "staying power" in hot, dry weather since more water can be applied on a daily basis
- Less operating time to apply a given amount of water and hence less wear on irrigation system
- Maintenance is more convenient if there is some scheduled downtime

Disadvantages...High Capacity Wells

- Easy to overwater, or apply more than crop needs, especially early or late in the season
- Can exceed pumping limits on permit more easily
- Mulching and/or deep ripping required
- Instantaneous application rate can excceed intake rate, causing runoff
- With some nozzle packages, crusting or washouts can adversely affect germination or emergence conditions

Low capacity wells have a few advatages, namely the ability to apply water without runoff in most cases, and the ability to apply small amounts of water for germination.

The disadvantages of low capacity wells are many. Some important points are:
Go into deficit more severely during hot, dry weather (meaning that irrigation cannot keep up with crop water use),
Large number of operational hours to apply needed water,
May have to cut back on irrigated acreage in severe cases.

Some irrigators are faced with decreased well capacity during the irrigation season. The most important point here is to be aware of those decreases and the resulting well capacity so that this application rate can be built into the irrigation scheduling process. This is a big benefit of water meters applied to irrigaion, in that changes in well capacity during the season are easy to identify.

Irrigators should not voluntarily decrease pumping rates to avoid runoff. Rather, select proper nozzle packages and use ripping and mulch management practices.

CROP WATER USE

Crop water use has been defined with a fair amount of precision by our friends in University Research and Extension. For example, in west central Kansas where our farm is located, the crop water use for the growing season is:

Crop	Water Use for the Growing Season
Corn	24 Inches
Soybeans (Full Season)	16 Inches
Alfalfa	30 Inches

These numbers actually are the sum of irrigation and rainfall amounts. The big question for irrigators is how much of this will be supplied by rain. The amount applied by irrigation is limited by pumping permits and water right certificates in the state of Kansas. Therefore, it stands to reason that there is a big incentive to utilize available rainfall and to not waste irrigation water over and above what is needed for optimum production.

Managing crop water use requirements is a day to day process from planting (actually before planting since mulching and deep ripping practices are the key to holding moisture received during the off season) to harvest. The irrigator must develop techniques or collect data in order to arrive at daily crop water use. Crop water use estimates are available upon request in many locations from your local Research Extension Center. On our farm, we collect climatological data each day, from which potential evapotranspiration can be calculated. Then, using a factor which takes into account the stage of growth of the plants for each field, the crop water use is determined for each field on a daily basis. Rainfall must be carefully measured to know exactly how long before restarting irrigation after a rain.

Irrigators who do not calculate crop water use daily for their fields can use some indirect method such as probing, tensiometers, or gypsum blocks to estimate soil moisture depletion in the root zone. These methods estimate the net effect of irrigation, rainfall, crop water use, and deep percolation losses at the time that the probe or instrument reading is taken.
The disadvantage of this type of estimate is that irrigators lose track of the rate of soil moisture depletion changes from day to day. This can cause irrigators to overreact by overwatering, or to accidentally deplete the crop to the point of lowering yields.

This discussion leads us to our next subject, irrigation scheduling.

IRRIGATION SCHEDULING

Irrigation scheduling has been defined as a procedure for predicting the time and amount of the next irrigation. There are two ways in general to accomplish this. One way is to make a physical measurement of the net depletion in the root zone at some point in time, and then make an estimate on when to begin irrigation (or keep measuring daily until the start time is more clear). Another method is to calculate soil moisture depletion at the end of each day by accounting for crop water use, irrigation and rainfall. This latter method has been adapted for personal computers by several research groups. On our farm, we use the scheduling program developed for farm use by Drs. Gerald Buchleiter, Harold Duke, and Dale F. Heermann of the USDA-ARS, Fort Collins, Colorado. We first tried the program in 1986, and the first full season of use was in 1987.

A weather station is used to take daily measurements of maximum and minimum temperature, wind, relative humidity, and solar radiation. These data are entered into a personal computer, and reference evapotranspiration is calculated, then converted into actual crop water use by applying a crop coefficient that takes into account that crop and stage of growth. Rainfall is monitored visually each day and completed irrigations are entered knowing the pumping rate and gross application, and an estimated application efficiency.

A key point is that the operator must make an estimate of application efficiency when the irrigation is entered. If, after a week or so, the computer calculated depletion is greater than the actual depletion as checked in the field by probing, the operator knows that the assumed application efficiency was too low and should be raised for the next week. This is a way for an irrigator to get a feel for what this efficiency actually is for each irrigation system on each particular field.

Let's look at some actual field data from two different years, 1991 and 1992, to get an idea of how crop water use can vary from day to day. From July 13 – 22, 1991 the climatic data and calculated crop water use for a field of corn was:

Date	Maximum Temperature F	Minimum Temperature F	Vapor Press. kPa	Solar Radiation MJ/m^2	Wind Run miles	Calculated Water Use inches
7–13	82	64	2.10	13.60	52	0.13
7–14	86	61	2.14	25.70	74	0.21
7–15	91	65	2.33	28.30	138	0.25
7–16	96	71	2.37	29.20	197	0.33
7–17	97	71	2.33	29.40	191	0.34
7–18	99	71	2.07	30.00	229	0.41
7–19	97	71	2.21	29.50	174	0.34
7–20	98	73	2.13	28.00	224	0.40
7–21	99	73	2.10	29.00	214	0.40
7–22	97	73	2.28	28.30	173	0.35

This is data for 1992 for this same field of corn:

7–13	89	69	2.53	24.5	126	0.23
7–14	93	63	2.20	27.3	91	0.26
7–15	96	68	2.19	24.0	162	0.29
7–16	76	61	2.14	11.0	153	0.12
7–17	80	60	2.08	15.9	68	0.13
7–18	86	59	2.15	29.6	108	0.25
7–19	89	64	2.46	29.6	197	0.27
7–20	76	64	2.33	15.9	128	0.12
7–21	81	65	2.48	8.5	193	0.09
7–22	91	69	2.72	25.3	200	0.25

It's easy to see that 1992 was a year of easier growing conditions with rain during the growing season, However, crop water use during this period in 1991 still varies from a low of 0.13 inches to a high of 0.41 inches.

The variation in daily crop water use in either a wet, cloudy year or a hot dry year makes it difficult to schedule irrigations using a soil probe and then estimate the time of the next irrigation. Water and fuel can be saved in either of these years with the scheduling approach using the computer and climatic data.

The scheduling output sheet for this same corn field for July 14 and 15 is shown below:

07-15-1992 15:25:16

W A T E R B U D G E T F O R F I E L D R J W 1

CROP -- CORN

Date	Water Use Inches	Irrigation (1) Inches	Irrigation (2) Inches	Rain Inches	Depletions (1) Inches	Depletions (2) Inches
TUE 7-14	0.26	0.0	0.0	0.00	1.04	1.04
WED 7-15	0.29	0.9	0.0	0.24	0.19	1.10

As of 7-15 the root depth was 3.0 ft with a depletion of 4% and the crop coefficient was 0.88

U S E F U L A M O U N T S

Date	Amount Inches
THU 7-16	0.49
FRI 7-17	0.77
SAT 7-18	1.05
SUN 7-19	1.32
MON 7-20	1.59
TUE 7-21	1.86
WED 7-22	2.13
THU 7-23	2.40 *
FRI 7-24	2.66 *
SAT 7-25	2.92 *

FINISH CIRCLE —
WAIT 3 DAYS
START W/ 1"

* indicates the allowable depletion is exceeded.

Our instructions to our irrigation operator, in this case, was to finish the present irrigation, wait three days, and then start another irrigation. We probe the soil once each week to check the moisture and adjust soil moisture if warranted.

This irrigation scheduling method has been developed over the last 20 years, in various forms by researchers in the Plains states, the Rocky Mountain states, and on the Pacific coast.
Why, then, has the method been so slow to be adapted by irrigators?

First of all, a fair amount of data such as climatic data, positions of pivots, rainfall and so on must be collected on a daily basis to make the system work. The data must then be entered on a computer. The computer program must be learned, and judgment must be used in determining root development date, effective cover date, and project harvest date.
The flow rate pumped must be monitored for changes on wells that diminish in capacity during the hot, dry months. We even run a special test on our pivot timers to calibrate the dial setting with inches of water applied. All of this takes time and energy and must be performed by skilled, trained operators.

The data collection could be simplified by a counter of some type that would document date and time that a particular irrigation started and stopped (in other words, the date and time the pivot crossed the starting point and when it crossed the finish point). Also, some instrumentation needs to be developed that reads the flow meter at the start of irrigation and again at the end of irrigation to calculate actual gross water applied for that irrigation. In this manner, the irrigation component could be made more accurate, especially in situations where well capacity declines during the summer months. Optimally, these readings could be taken automatically and stored until the irrigator comes by to read them at his convenience.

In 1994, we tested a new radio control concept for center pivots with the trade name *Pivot Alert (TM)* Irrigation Monitoring Equipment. This equipment uses a base station located at our central office that communicates by radio to remote stations located at each center pivot. Some of the features include the ability to tell if a pivot is on or off, to shut a pivot off from the office, and an alarm system to tell if a pivot has malfunctioned, and if so, which one. For 1995, additional capabilities will be added to tell when a pivot has started a new irrigation revolution, and the actual position of the pivot in relation to the start point during any revolution, and when an irrigation has been completed. This new version will also interact with a personal computer so that visual status of pivots can be displayed on a computer screen.

Accurate irrigation scheduling is possible, but takes time and work. However, the payoff in water savings and fuel savings makes it worth the effort, not to mention the satisfaction in knowing that the soil moisture is adequate enough that the owner and/or irrigation employees can get a weekend off once in a while. In the state of Kansas, where our farm is located, it is imperative to stay within pumping limits imposed by the water right, and to show to all concerned that a diligent effort is being made to put every drop of irrigation water to beneficial use.