FO-01322 Revised 2002 To Order

Irrigation Scheduling Checkbook Method

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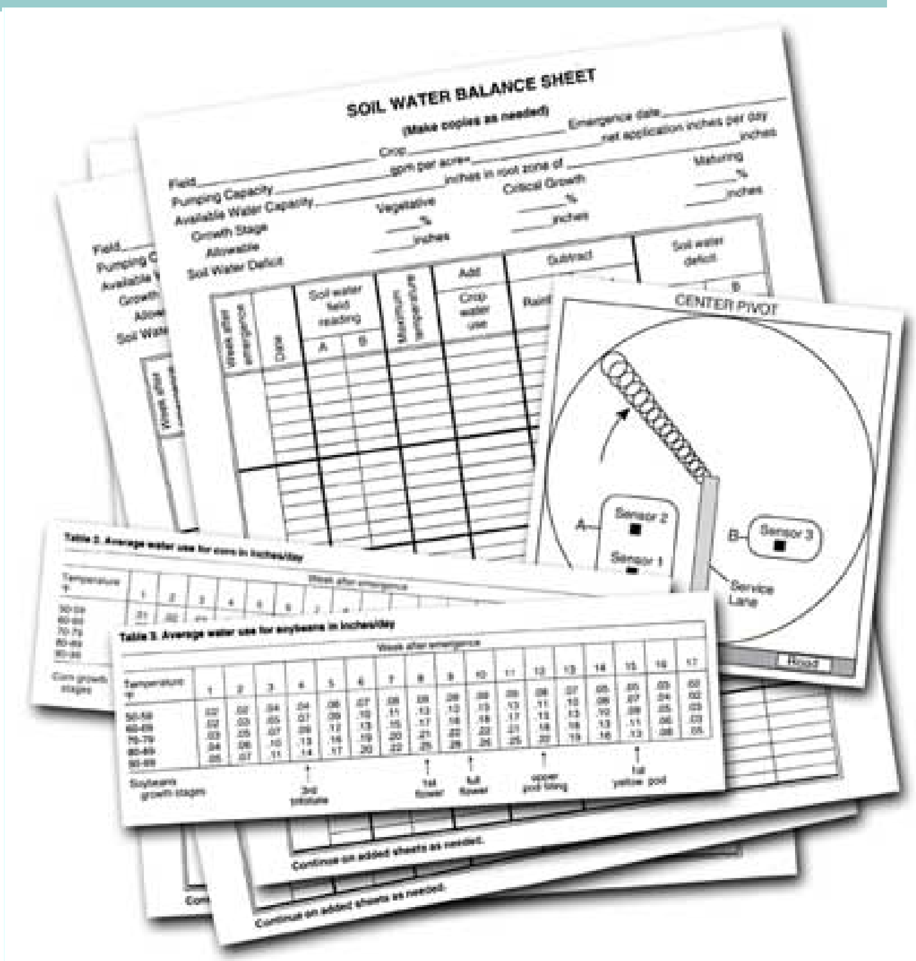

ACKNOWLEDGEMENTS

The author wishes to thank former University of Minnesota colleagues Hal Werner, Extension Engineer at South Dakota State University, and Fred Bergsrud, retired Extension Engineer, for their previous development efforts in earlier issues of this bulletin. Also, thank you to the original developers of this scheduling tool, Darnell Lundstrom and Earl Stegman, Agricultural Engineering Department, North Dakota State University.

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INTRODUCTION

Irrigation scheduling is planning when and how much water to apply in order to maintain healthy plant growth during the growing season. It is an essential daily management practice for a farm manager growing irrigated crops.

Proper timing of irrigation water applications is a crucial decision for a farm manager to: 1) meet the water needs of the crop to prevent yield loss due to water stress; 2) maximize the irrigation water use efficiency resulting in beneficial use and conservation of the local water resources; and 3) minimize the leaching potential of nitrates and certain pesticides that may impact the quality of the groundwater.

Effective irrigation is possible only with regular monitoring of soil water and crop development conditions in the field, and with the forecasting of future crop water needs. Delaying irrigation until crop stress is evident, or applying too little water, can result in substantial yield loss. Applying too much water will result in extra pumping costs, wasted water, and increased risk for leaching valuable agrichemicals below the rooting zone and possibly into the groundwater.

Several scheduling tools are available to assist a farm manager in irrigation scheduling: soil probes, soil moisture sensors, in-field weather stations, crop water use estimators, daily soil water balance checkbook worksheets, computerized daily soil water balance accounting programs, and private consultants.

The purpose of this bulletin is to describe the set-up and operating procedure for a manual soil water balance accounting method, commonly referred to as the **CHECKBOOK** method. A computer spreadsheet beta-version of this method (which creates monthly soil water balance graphs) is available from author Jerry Wright, or spreadsheet co-author Tom Scherer, Extension Agricultural Engineer at North Dakota State University.

CHECKBOOK SCHEDULING

The **CHECKBOOK** method of scheduling enables an irrigation farm manager to monitor a field's daily soil water balance (in terms of inches of **soil water deficit),** which can be used to plan the next irrigation. This method requires the manager to monitor the growth of the crop, observe the maximum air temperature each day, select the daily ET estimation from the crop water use table, measure the rainfall or irrigation applied to the field, and calculate the new soil water deficit balance. To calculate the new soil water deficit and keep a record of daily changes, the data is entered into the soil water balance sheet like the example. The best time for daily update is early morning after the in-field rain gauges are measured.

Items to Conduct Checkbook Irrigation Scheduling

- Two or more rain gauges
- Max-Min thermometer or access to local temperature reports
- Soil probe or in field moisture sensors
- Daily crop water use table or local ET hotline or website report
- Soil water balance worksheets

The water balance worksheet is operated just like a "checkbook." Each day the estimated crop water use is added to the previous day's soil water deficit, and any rainfall or irrigation amounts are subtracted from this deficit. If a daily rainfall or irrigation event minus the daily crop water use is greater than the current deficit, most of the excess is considered lost due to deep percolation below the rooting zone, and the new deficit balance is generally set to zero. However, for most soils some of the excess water is still available to the plant during deep percolation. This period of excess soil water may last from one day on sandy soils to over two days on a heavy textured soil. **Therefore, during this period or until the excess water is consumed by crop water use (ET), the soil water deficit should be kept equal to zero.**

To decide when to start irrigating, the farm manager should compare the latest soil water deficit balance in relationship to the selected irrigation water management strategy for that crop, the crop's projected water needs, and the weather forecast.

An irrigation water management strategy outlines the manager's plans for irrigating, including the manager's selected allowable soil water deficit limits for different growth stages of the crop. The crop's soil water balance should be maintained within the set deficit limits by either rainfall or irrigation.

Effectiveness of the **CHECKBOOK** method depends on the accuracy and regularity of the in-field observations and measurements made by the manager. Since crop water use estimates are influenced by more climatic factors than considered in this method, **to be successful, regular field visits every 3 to 7 days are necessary to determine the existing soil water deficit in the field and then compared to the soil water balance sheet prediction. If found to be different, change the balance sheet prediction to the in-field estimation. Note that when using the crop water use tables, the week after emergence should be adjusted to correspond with the existing growth stage of the crop.**

If for any reason the soil water balance worksheet is interrupted and a period of time elapses, the balance sheet can be easily restarted anytime by the farm manager to assist in scheduling future irrigations.

The **CHECKBOOK** method can be used to schedule several fields in no more than 1 to 3 hours each week, depending on the number of crops grown and the field locations. However, each field's soil water balance should be kept on individual balance sheets because of the differences in soil, crop, planting date, rainfall, and plant growth rates.

To setup and operate an effective soil water accounting system like the **CHECKBOOK** method, several field characteristics and soil-water-plant factors (of which many are interrelated) need to be understood and quantified by the operator.

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STARTING THE CHECKBOOK METHOD

To set up the **CHECKBOOK** method for a given field, first locate the water use table for the planted crop from Tables 2-9. Next cut out or copy the chosen water use table and place over the crop water use section in the balance worksheet (example for corn is shown). Finally, make several copies of the blank soil water balance worksheet, so they can be easily carried by the manager.

After a copy of the soil water balance sheet is made, write on the balance sheet the field name, crop emergence date, irrigation pumping capacity, available soil water capacity within the crop's rooting zone, and the manager's selected allowable soil water deficit limits for various crop growth stages. A detailed discussion on determining these factors can be found in the upcoming sections.

To start the **CHECKBOOK** method, the current date's soil water deficit in the field must be estimated and entered as the initial value in the first row and far right columns (A & B) on the balance sheet.

The two soil water deficit columns (A & B) are provided for the manager to observe more than one location in a field, such as one at the start and another near the end of the field. **Figure 1** shows potential locations for soil water monitoring. The second location will help in planning the next irrigation event to insure that no part of the field will exceed the allowable soil water depletion limits.

Estimation of the current in-field soil water deficit can be determined from each layer of soil in the root zone by one of several methods. If a heavy rainfall recently occurred, especially on a coarse textured soil early in the growing season, the soil water deficit could be assumed to be zero after the rainfall event.

Accurate measurements of rainfall and irrigation water applied are essential in estimating a field's daily soil water deficit. Locate at least two rain gauges within the field to give representative values of the net water received from either rainfall or irrigation. If soil moisture sensing devices are located in the field, locating a rain gauge at each site would be a good choice.

Rain gauges should be read within a day after a precipitation event occurs. To be fairly accurate, rain gauges should have an opening of at least 2 inches and be positioned in the irrigated field near the top of the crop canopy.

The net irrigation amount can also be estimated from **Table 1** by knowing the irrigation system's pumping capacity, application efficiency, and operating time. But, in-field measurement of irrigation water applied is more accurate. Note this table assumes 24 hours of operating time per day.

Figure 1. Soil moisture sensor placement in the field.

CENTER PIVOT **TRAVELING GUN**

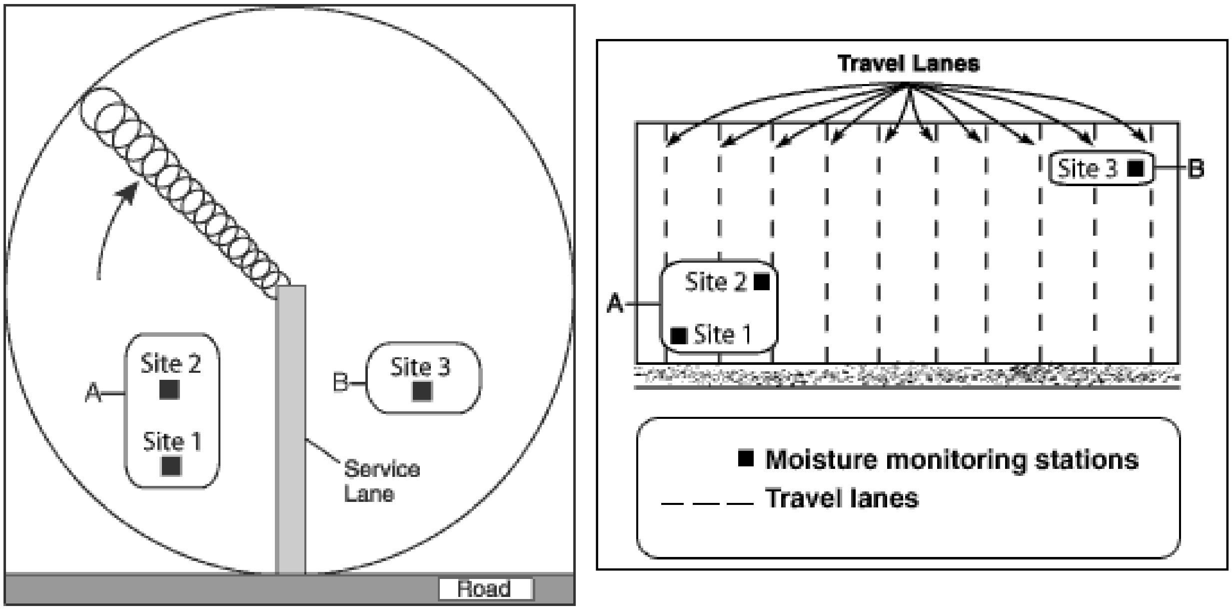


Table 1. Average daily net application depths for various pumping capacities.

Pumping capacity (gpm/acre)	Average Application Efficiency		
	65%	75%	85%
	***** net inches per day *****		
4	0.14	0.16	0.18
5	0.17	0.20	0.23
6	0.21	0.24	0.27
7	0.24	0.28	0.32
8	0.28	0.32	0.36
9	0.31	0.36	0.41

IRRIGATION AMOUNT

When possible, the amount of applied irrigation water should be somewhat less than the soil water deficit in order to provide some soil water storage reserve for rainfall. For most soils the net irrigation application during early plant growth and the last few weeks before maturity should be only 30-50 percent of the soil water deficit. This practice will increase the opportunity to store more rainfall and reduce the potential for leaching from normal rainfall events.

On most sandy soils the irrigation depth should be 80-100 percent of the soil water deficit during the crop's critical growth period . On medium to fine textured soils irrigation application depth should be 50-100 percent of the soil water deficit depending on the irrigation system's pumping capacity.

IRRIGATION MANAGEMENT STRATEGY

Deciding when to irrigate to optimize production is a daily judgment decision requiring consideration of several factors by the farm manager. Many of these factors change as the crop develops. Some general guidelines to consider in developing a water management plan and setting allowable soil water deficit limits are as follows:

In the spring, always make sure the soil in the germination and early growth root zone is moist at the time of planting. If necessary, irrigate to wet this zone. As the plant grows, moist soil is necessary for proper root development as roots will not grow through a dry layer of soil. A dry layer will result in a shallower rooting depth than is desirable. For corn, experience has shown that the soil water deficit can be as high as 60-65 percent in the early vegetative growth stage (germinating to 10th leaf) without affecting plant development. Root zone at this time may only be 1/2 to 2/3 of the crop's potential. Holding back on irrigating during this time promotes deeper root growth, increases the opportunity to store rainfall when it occurs, and decreases the risk for leaching valuable nutrients.

As the crop nears its critical growth period or its usual peak water use period, the manager's selected allowable soil water deficit should be reduced to minimize the risks of not meeting the crop's water needs and causing economic yield losses. For most crops, this may mean changing to a 30-40 percent soil water deficit limit before entering the critical growth stage--such as the 10-12th leaf stage for corn, or early flower for soybeans. During these critical periods of high water use, projecting the next 2 to 3 days of water needs should be done regularly to plan ahead and avoid stressing any part of the field before it is irrigated. For example, when using a center pivot which takes three days, to cover the field, project what the water deficit will be after three days and use this to determine when to start irrigating. To reduce the leaching potential of a rainfall event, always consider the weather forecast for the next upcoming days in scheduling the next irrigation.

As the crop nears maturity, the soil water deficit generally can be allowed to increase to greater limits without causing stress to the crop. For example, after corn kernels have begun to dent, research has shown that allowing the soil water deficit to increase to 60-70 percent should not reduce yields in most years. Table 10 shows field test results which support this early cutoff strategy. These results are from a 1989-1990 AURI supported research/demonstration project conducted in west central Minnesota on a Renshaw sandy loam soil.

Generally a corn crop will need about 2-2.5 inches of ET after first dent to come to full maturity, depending on emergence date. For soils holding at least 3.5 inches of available water at this time there should be no additional irrigation needed if air temperatures remain at or below normal. A heavier soil may tolerate an even earlier cutoff, but a lighter soil may need one or two more irrigations. **Table 11** lists estimated ET requirements between several crop stages of growth and maturity for corn and soybeans under normal weather conditions in central Minnesota. Managing a larger soil water deficit near maturity may reduce the irrigation water needs by 1-3 inches per acre, which saves pumping costs and conserves the irrigation water supply.

More information on variable soil water deficit strategies is discussed in the University of Minnesota Extension Service bulletins *Irrigation Water Management Consideration for Sandy Soils in Minnesota FO-03875 and IPM Control of White Mold in Irrigated Dry Beans,* BU-07397, available at county extension offices or from the Extension website: www.extension.umn.edu/units/dc or the Minnesota Vegetable Crop Management website: www.extension.umn.edu/specializations/horticulture/Vegecrop.html

Another possible irrigation water management plan is to set the allowable soil water deficit equal to, or slightly greater than, the irrigation system's normal net application amount. For example, if the typical application is .75 inch net, then choose a planning deficit limit of .75-1 inch. If this is greater than 50 percent of the available water capacity in the root zone, the amount should be made smaller (especially during the critical stages of crop growth) to reduce the risk of moisture stress. This strategy will require more irrigation applications than the variable deficit strategy discussed earlier.

For irrigation systems with limited or underdesigned pumping capacities for a specific crop and soil type, water management strategy alternatives are limited for reducing the risk of moisture stress. For example, research on irrigated corn in west central Minnesota has shown that to reduce the risk of stress with an underdesigned system, the allowable deficit should be set no greater than .75 inch starting in mid-vegetative stage (about 10th leaf) and continuing until late dent.

Table 10. Impact of early irrigation cutoff on corn grown in west central Minnesota on a Renshaw soil with 3.5" available water capacity.

Growth Stage at Cutoff	1989			1990		
	Yield Bu/ac	Irrig	Rain*	Yield Bu/ac	Irrig	Rain*
		... in. ...			... in ...	
late dent	199	8.2	3.7	148	9.0	1.9
first dent	202	7.5	5.8	144	8.3	3.5
dough	202	6.2	6.5	141	7.6	3.7
blister	204	4.2	6.7	122	5.3	3.8
LSD (.05)	8.0			5.2		

* amount of rainfall between cutoff stage and corn maturity

Source: M. Westgate, A. Olness and J. Wright. 1991. *Final report of Energy Conserving Irrigation Management: Impact of early irrigation cutoff on corn.* AURI/Greater Minnesota Corporation project #EP106.

Table 11. Estimated normal crop ET requirements between various growth stages and maturity in central Minnesota

Stage of Growth	Days to Maturity	Water Use (ET) to Maturity
		---in.---
CORN		
blister	45 - 50	7.0 - 7.5
milk	38 - 42	4.8 - 5.3
dough	30 - 35	3.2 - 3.6

first dent	23 - 27	2.1 - 2.4
full dent	19 - 21	1.6 - 1.8
1/2 milk line	12-14	0.9 - 1.2
1/4 milk line	6-8	0.4 - 0.6
SOYBEANS		
full flower - R2	48 - 54	6.8 - 7.6
full pod - R4	35 - 39	4.0 - 4.8
begin seed fill - R5	27 - 31	2.7 - 3.3
full seed fill - R6	16 - 18	1.1 - 1.4
begin maturity - R7	9 - 11	0.4 - 0.7

Table 12. Guide for judging soil water deficit based on soil feel and appearance for several soil textures.

	SOIL TEXTURE CLASSIFICATION				
Moisture deficiency	Coarse (loamy sand)	Sandy (sandy loam)	Medium (loam)	Fine (clay loam)	Moisture deficiency
in./ft.					in./ft.
.0	(field capacity) Leaves wet outline on hand when squeezed.	(field capacity) Appears very dark, leaves wet outline on hand, makes a short ribbon.	(field capacity) Appears very dark, leaves wet outline on hand, will ribbon out about one inch.	(field capacity) Appears very dark, leaves slight moisture on hands when squeezed, will ribbon out about two inches.	.0
.2	Appears moist, makes a weak ball.				.2
.4	Appears slightly moist, sticks together slightly.	Quite dark color, makes a hard ball.	Dark color, forms a plastic ball, slicks when rubbed.	Dark color, will slick and ribbons easily.	.4
.6		Fairly dark color, makes a good ball.		Quite dark, will make thick ribbon, may slick when rubbed.	.6
.8	Appears to be dry, will not form a ball under pressure.	Slightly dark color, makes a weak ball.	Quite dark, forms a hard ball.		.8
1.0		Lightly colored by moisture, will not ball.	Fairly dark, forms a good ball.	Fairly dark, makes a good ball.	1.0
1.2	Dry, loose, single-grained flows through fingers. (wilting point)	Very slight color due to moisture, loose, flows through fingers. (wilting point)	Slightly dark, forms weak ball.	Will ball, small clods will flatten out rather than crumble.	1.2
1.4			Lightly colored, small clods crumble fairly easily.		1.4
1.6				Slightly dark, clods crumble.	1.6
1.8			Slight color due to moisture, powdery, dry, sometimes slightly crusted but easily broken down in powdery condition. (wilting point)	Some darkness due to unavailable moisture, hard, baked, cracked sometimes has loose crumbs on surface. (wilting point)	1.8
2.0					2.0

Table 13. Soil water deficit estimates in inches per foot for various soil tensions.

	Soil tension--centibars						
Soil texture	**10**	**30**	**50**	**70**	**100**	**200**	**1500***
Coarse sand	0	0.1	0.2	0.3	0.4	0.6	0.7
Fine sand	0	0.3	0.4	0.6	0.7	0.9	1.1
Loamy sand	0	0.4	0.5	0.8	0.9	1.1	1.4
Sandy loam	0	0.5	0.7	0.9	1	1.3	1.7
Loam-Clay							
Clay loams	0	0.2	0.5	0.8	1.0	1.6	2.4

*1500 centibars is permanent wilting point and the soil water deficit value is equal to the soil's total available water holding capacity.

ALLOWABLE SOIL WATER DEFICIT

Allowable soil water deficit is a planning limit that the farm manager needs to establish for various crop growth stages for each irrigated field. It specifies the maximum amount of soil water the manager chooses to be used from the rooting zone before scheduling the next irrigation event to reduce the probability of incurring crop moisture stress.

Allowable soil water deficit is expressed in either inches of soil water or a percentage of the total available water in the rooting zone. To express the percentage deficit in terms of inches of water, multiply the set percentage deficit by the available water capacity in the root zone. For example, if a 30 percent deficit limit is desired for a soil holding 3.50 inches of water, the deficit level in inches of soil water would be 1.05 inches (.30 x 3.50 = 1.05).

In the past, irrigations were planned to prevent the soil water deficit from becoming greater than 50 percent of the total available water capacity in the rooting zone. This was a general guideline and today's research suggests that it should be varied depending on the crop, stage of growth, soil water capacity, and the irrigation system's pumping capacity. This variable deficit plan will better assist a manager to optimize the field's production and minimize any impact to the local water supply. More discussion on setting these limits can be found in the **Irrigation Management Strategy** section of this bulletin.

SOIL WATER DEFICIT

Soil water deficit is the amount of water required at a given time to restore a soil profile's active crop rooting zone to field capacity. Any additional water will percolate through the soil profile within 24-48 hours. There are several in-field tools available (details in following section) to assist a manager in estimating the current soil water deficit in the rooting zone.

Regular updating and reviewing of the soil water deficit in a field every 2-3 days can provide the manager useful information in planning for the next irrigation. In the **CHECKBOOK** method the predicted soil water deficit on the balance sheet should be adjusted to the actual in-field soil water deficit, if found to be different.

SOIL WATER MEASUREMENTS

Two common ways of estimating soil water deficit are by the feel/appearance method or use of soil water sensors. The feel method involves collecting soil samples in the root zone with a soil probe or spade. Then, the water deficit for each sample is estimated by feeling the soil and judging the soil moisture as outlined in **Table 12.** Soil samples should be taken at several depths in the root zone and at several places in the field. Finally, use these estimated deficits to estimate the total soil water deficit in the root zone. This method requires frequent use by a manager to develop the art of estimating consistently.

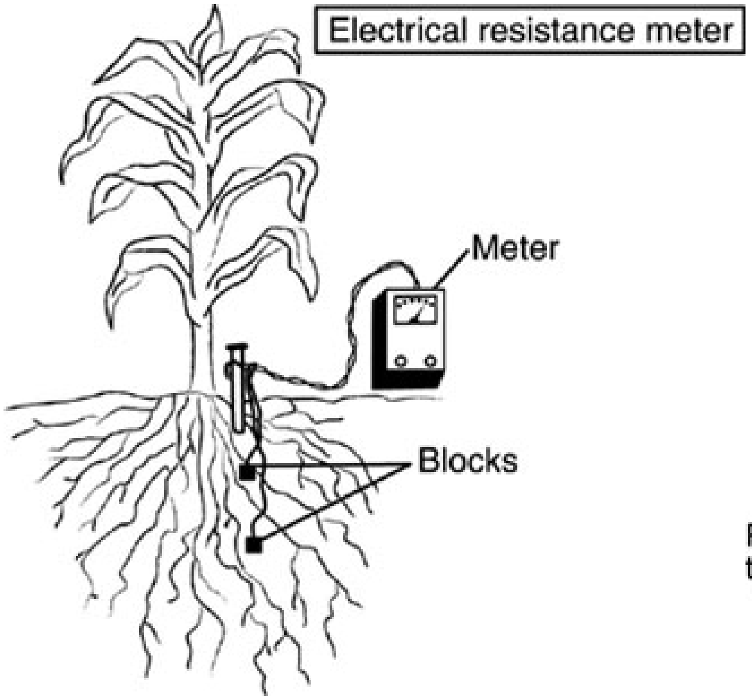
Soil tension is a measurement usually expressed in centibars, and describes how tightly the water is held in the soil profile. It can be measured at any point in the soil profile by the use of sensors such as tensiometers or electrical resistance blocks. If the soil texture is known the amount of soil water deficit for a given tension reading can be estimated by the use of **Table 13.**

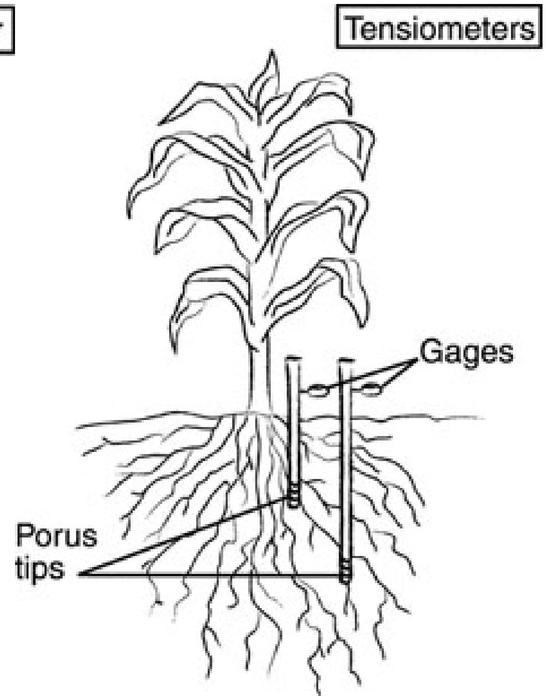
Tensiometers directly read soil tension between 0 and 80 centibars and work best in sandy loam or lighter textured soils. Resistance blocks work in a wider soil texture range; some models work as well in lighter textured soils as do tensiometers. To convert electrical resistance block readings to soil tension values, a calibration curve from the manufacturer is necessary and should be provided with the meter.

To obtain representative soil tension readings with any sensors, they should be left installed throughout the irrigation season and preferably at two or more locations in the field (**Figure 1**). Two depths are generally desired at each location. These depths should be about one-third and two-thirds of the active root zone (**Figure 2).**

General instructions on sensor usage and installation can be found in the University of Minnesota Extension Service bulletin ***IPM Control of White Mold in Irrigated Dry Beans*, BU-07397, available at county extension offices or from the Extension website www.extension.umn.edu/units/dc**

Figure 2.





CROP WATER USE

Crop water use is the amount of water given up to the atmosphere by a crop due to evaporation from the soil surface and transpiration through the plant leaves. Crop water use is also called evapotranspiration or ET. Daily crop water use changes throughout the growing season due to weather variation and crop development. Daily ET estimations are needed for the **CHECKBOOK** method to update the soil water deficit balance.

Crop water use depends on many factors including crop type, stage of growth, climatic conditions, and soil moisture. Climatic parameters having a major effect on a crop's daily water use include maximum and minimum temperatures, solar radiation, humidity, and wind.

Several tools are available to estimate daily crop water use such as the evaporation pan, potential ET equation, local crop ET hotline services, regional website at www.soils.wisc.edu/wimnext/et/wimnet.html or crop water use (ET) tables. Tables 2 through 8 give estimated crop water use values for various maximum temperature ranges at different growth stages for several commonly irrigated crops in central Minnesota. Table 9 gives an estimated daily ET for any other crop such as vegetables or small fruit that has reached full canopy. Prior to full canopy the ET estimate should be reduced by a crop correction value between 0.2-1.0, depending on stage of growth. These crop water use tables were originally developed by North Dakota State University, but have been recalibrated to central Minnesota average climatic conditions by agricultural engineering researchers at the University of Minnesota.

Daily crop water use can be estimated from these ET tables by observing the maximum daily temperature, crop growth stage, and the weeks after emergence. Maximum daily temperatures can be obtained from local weather broadcasting stations or an on-farm max-min thermometer. If a season's climatic conditions cause the crop to grow slower or faster than normal, use the crop growth stages listed in the table instead of the week after emergence to select the appropriate ET estimation.

Information on other methods of estimating crop water use similar to that found on www.soils.wisc.edu/wimnext/et/wimnet.html can be obtained from the author of this bulletin.

AVAILABLE WATER in ROOT ZONE

"Available water capacity in the root zone" is defined by the total amount of water capable of being held by the soil that is available for plant use. Soil texture and crop rooting depth are the primary governing factors. The total available water in the soil root zone for a specific crop is equal to the crop's rooting depth multiplied by the available water holding capacity per unit depth of the soil. However, only a portion (40-60%) of this total amount can readily be used by the plant without developing crop water stress.

In most fields there are many soil types. Generally, the soil with the lowest water holding capacity should be managed for irrigation as long as it exists in a significant (30-50 percent) part of the field. Soil types in most fields are identified in county soil surveys. County and area personnel from the Natural Resource Conservation Service (NRCS), Soil Water Conservation District (SWCD), or University of Minnesota Extension Service can assist in determining a field's water storage characteristics.

Table 14 lists suggested rooting depths for irrigation water management of some commonly irrigated crops in Minnesota. Each crop has the potential to develop a greater rooting depth. However, since most of a plant's roots are located in the upper portion of the root zone, irrigation water applications are generally managed to a shallower depth than the crop's full rooting depth. For annual cropshis rooting depth is not usually achieved until 30-50 days after planting.

Table 14. Range of maximum crop rooting zones for irrigation water management at mid-season.*

Crop	Depth (inches)
Alfalfa (established)	24-36
Corn, Sugar Beet	24-36
Asparagus, Small Grain	24-36
Potato, Sweet Corn	18-24
Soybean, Field Bean	24-30
Tomato, Muskmelon	12-24
Broccoli, Cauliflower	12-18
Blueberry, Strawberry	9-18

** Local soil and climatic conditions may reduce these values.*

If the field's soil profile is shallower because of a restrictive layer such as coarse sand and gravel, which will prevent deeper root penetration, the irrigation management depth must be reduced accordingly. **Table 15** shows an example of a typical irrigated soil's water holding characteristics that can be identified for any soil in your field. In the example, note that there is a root restriction layer of sand and gravel starting at 18 inches which limits the available water capacity to 3.5 inches for any crop having a greater rooting potential. County and area personnel from the Natural Resource Conservation Service (NRCS), Soil Water Conservation District (SWCD), or University of Minnesota Extension Service can assist in determining a field's water storage characteristics.

Table 15. Available Water Capacity (AWC) characteristics of a Renshaw Soil Series.

		AWC--Inches		
Profile Depth inches	**Texture class**	**per inch**	**per zone**	**cumm.**
0 - 12	Loam	.21	2.52	2.52
12 - 18	Sandy Loam	.16	.96	3.48
18 - 24	Sand & Gravel	.04	.24	3.72
24 - 60	Sand & Gravel	.03	1.08	4.80

AWC info for others soil series can be obtained from county soil survey or SWCD/NRCS office.

PUMPING CAPACITY

A system's pumping capacity defines the ability of the irrigation system to refill the soil profile with water. Knowledge of this capacity enables a farm manager to better judge when to start an irrigation in order to complete an irrigation before any part of the field exceeds the allowable soil water deficit.

Pumping capacity can be expressed in terms of either the pumping rate in gallons per minute (gpm) divided by the number of acres irrigated (gpm per acre), or the average daily application amount (inch per day). For example, the pumping capacity of a traveling gun covering 100 acres and pumping 500 gpm is 500 divided by 100, or 5 gpm per acre. To obtain an accurate measurement of the pumping rate and to monitor for changes, the installation of a water meter is recommended.

The average application amount based on a 24-hour pumping day can be determined from **Table 1** for various pumping capacities and application efficiencies. Since sprinkler irrigation is not 100 percent efficient, the calculated average application rate (inches per day) needs to reflect losses from evaporation, wind drift, and system uniformity. Different system types give different application efficiencies depending on method of operation and time of day. Center pivots and linear movement systems generally have between 80-90 percent application efficient. Traveling guns are 65-75 percent efficient. If the average daily pumping time is less than 24 hours, the application rate must be reduced proportionally.

To make an interpretation of a system's capability for example, let's assume a center pivot with a pumping capacity of 5 gpm/acre with an application efficiency of 85%. As shown in **Table 1**, this system will give a net daily application amount of .23 inches per day. If it is set to make a revolution in three and half days, the system will apply a total of .80 inches (3.5 days x .23 in/day = .80 in/revolution). In mid-July, we know that daily crop water use may be as high as .25 to .30 inch per day. Since the daily application amount in the example is slightly lower than the peak, this tells the manager that it may be wise to start irrigating earlier in the year to avoid getting behind in meeting the crop's water needs.

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SOIL WATER BALANCE SHEET

Record crop, field name, and emergence date

Field #5 Crop CORN Emergence date 13 May

Pumpinng Capacity 5 gpm per acre= .23 net application inches per day

Available Water Capacity 3.5 inches in root zone of 18 inches

Estimated net application amount **Table 1.**

Available water in root zone, **Table 15**

Growth Stage	Vegetative	Critical Growth	Maturing
Allowable	65 %	35 %	65 %
Soil Water Deficit	2.25 inches	1.25 inches	2.25 inches

Allowable deficits for various crop growth stages.

Week after emergence	Date	Soil water field reading	Maximum temperature	Add: Crop water use	Subtract: Rainfall	Subtract: Net irrigation	Soil water deficit A	Soil water deficit B
5	6-10	50cbs		Initial	Value ⟶		.70	.70
	11		63	.08			.78	.78
	12		64	.08			.86	.86
	13		68	.08			.94	.94
	14		77	.10			1.04	1.04
	15		73	.10	1.40		0	0
7-8 leaf	16		78	.10			0	0
6	17		87	.15			.15	.15
	18		85	.15			.30	.30
	19		70	.12			.42	.42
	20		72	.12			.54	.54
	21		86	.15			.69	.69
	22		85	.15			.84	.84
10-11 leaf	23	70/50 cbs	81	.15			.99	.99
7	24		71	.15			1.14	1.14
	25		84	.18		.92	.40	1.32
	26		93	.21			.61	1.53
	27		70	.15			.76	1.68
	28		67	.11			.87	.87
	29		68	.11		.92	.06	.98
13th leaf	30		74	.15		X	.21	1.13
8	7-1		.81	.20		X	.41	1.33
	2		.85	.20		X	.61	.61
	3		.79	.16			.77	.77
	4	40/70cbs	.90	.24		.92	.09	1.01
	5	=.8	.75	.16		X	.25	1.17
	6		81	.20		X	.45	1.37
1st Tassel	7		89	.20			.65	.65
9	8		95	.26	.50		.41	.41
	9		85	.22			.63	.63
	10		82	.22		.92	0	.85
	11		88	.22		X	.15	1.07
	12		79	.17		X	.32	1.24
	13		87	.22		X	.54	.54
Silking	14		90	.26			.80	.80

Two locations in the field, **Figure 1.**

Initial deficits based on in-field measurements **Table 12 or 13.**

Week after emergence date and growth stage.

If rainfall exceeds previous day's deficit, soil water deficit may be held at zero for one or two extra days.

Maximum temperature is recorded and water use estimated from **Tables 2-9.**

Soil water deficit should be regularly compared to in-field measurement and adjusted if different.

Water deficit is estimated each day by adding daily crop water use to previous day's balance and subtracting rain and irrigation.

Irrigation is started early enough so deficit at end of field (b) does not exceed allowable deficit.

Make a copy or cut appropriate water use chart from **Tables 2-9**, and place here before making copies of this page.

Table 2. Average water use for CORN in inches/day

Temperature °F	Week after emergence: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
50-59	.01	.02	.03	.04	.05	.06	.08	.09	.09	.10	.10	.10	.09	.07	.06	.05	.04	.03
60-69	.02	.03	.04	.06	.08	.09	.11	.12	.13	.15	.14	.14	.13	.11	.09	.07	.06	.04
70-79	.03	.04	.05	.07	.10	.12	.15	.16	.17	.19	.19	.18	.17	.14	.11	.09	.07	.05
80-89	.03	.05	.07	.09	.13	.15	.18	.20	.22	.24	.23	.22	.21	.17	.14	.11	.09	.06
90-99	.04	.06	.08	.11	.15	.18	.21	.24	.26	.28	.27	.26	.25	.20	.17	.13	.11	.07
Corn growth stages		↑ 3 leaf			↑ 8 leaf			↑ 1st tassel	↑ silk		↑ blister kernel			↑ early dent	↑ dent			