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EC84-724 Irrigation Scheduling Using Tensiometers in Sandy Soils

Thomas W. Dorn

Dean E. Eisenhauer
University of Nebraska-Lincoln, deisenhauer1@unl.edu

Paul E. Fischbach

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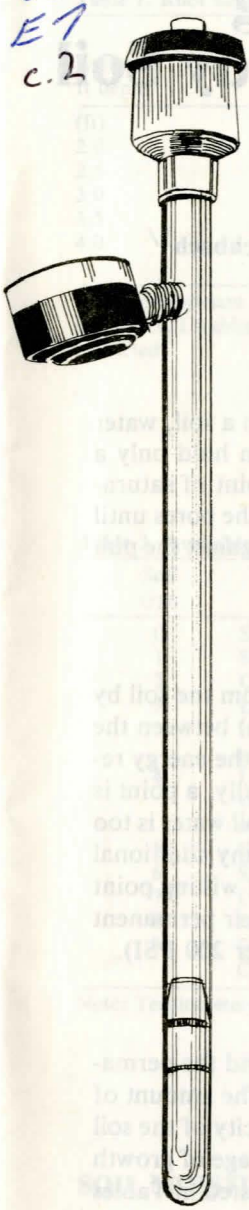

Irrigation Scheduling Using Tensiometers in Sandy Soils

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Irrigation Scheduling Using Tensiometers in Sandy Soil

Thomas W. Dorn, Dean E. Eisenhauer and Paul E. Fischbach[1/]

SOIL MOISTURE CONCEPTS

FIELD CAPACITY

A soil holds moisture in much the same way as a sponge. In a soil, water is held in partially filled pores and, just like a sponge, it can hold only a given quantity of water. If water is applied to a soil to the point of saturation, then left undisturbed, the excess water will drain out of the pores until capillary forces are high enough to hold the remaining water against the pull of gravity. This condition is known as field capacity.

PERMANENT WILTING POINT

Water that is transpired by a growing crop is withdrawn from the soil by the plant roots. As a soil gets drier, the attraction (or tension) between the water and the soil particles becomes increasingly greater and the energy required to pull the water away from the soil increases. Eventually, a point is reached when the soil becomes so dry that the tension of the soil water is too great for the plant to overcome, and the plant cannot extract any additional water from the soil. This condition is known as the permanent wilting point and will result in the death of the plant. Most plants reach their permanent wilting point at a soil moisture tension of about 15 bars (over 200 PSI).

AVAILABLE WATER CAPACITY

The moisture contained in the soil between field capacity and the permanent wilting point is known as the available water capacity. The amount of water available to a crop depends on the available water capacity of the soil and the depth of crop root development. The root depth by stage of growth and the available water-holding capacity of several soils are listed in Tables 1 and 2, respectively.

[1]Extension Irrigation and Conservation Specialist, Northeast Station; Extension Irrigation Specialist, South Central Station; Extension Irrigation Specialist, University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources.

Table 1. Root depth versus stage of growth.

Assumed ft depth (ft)	Stage of crop development: Corn	Grain sorghum	Soybeans
2.0	12 leaf		Early bloom
2.5	Early tassel—16 leaf	Flag Leaf	Full bloom
3.0	Silking	Boot	Pod development
3.5	Blister	Bloom	
4.0	Beginning dent	Dough	Full seed fill (green bean)

Root development may be restricted to a depth less than assumed due to compaction or limiting layers. Established alfalfa has a root zone greater than 4 feet unless root development is restricted.

Table 2. Available water capacity of various soil profiles.

Soil type	Soil profile		Inches per foot
0	Sandy clay loam		2.0
1	Silty clay loam		1.8
2	Clay loam		1.8
3	Loam, very fine sandy loam, or silt loam topsoil	Silty clay loam, or silty clay subsoil	2.0
4	Loam, very fine sandy loam, or silt loam topsoil	Medium textured subsoil	2.5
5	Fine sandy loam		1.8
6	Sandy loam		1.4
7	Loamy sand		1.1
8	Fine sands		1.0
9	Silty clay Clay		1.6

Note: Tensiometers should be used on soil types 5, 6, 7, and 8.

SOIL MOISTURE DEFICIT

The soil moisture deficit is defined as the amount of water below "field capacity" that has been removed from the soil reservoir or the crop root zone. Conversely, it is the quantity of moisture required to refill the root zone at its present moisture condition and bring it back to field capacity. When the soil moisture deficit gets too great the crop can undergo stress.

ALLOWABLE SOIL MOISTURE DEFICIT

This is the maximum deficit before water must be added to the soil to prevent crop stress. For most crops grown under irrigated conditions, the allowable soil moisture deficit is 50% of the available moisture during critical growth stages, and up to 65% during non-critical growth stages. Beyond that point, the crop is considered in danger of undergoing enough stress to suffer a reduction in yield.

Critical growth stages for most crops are during the germination, flowering, and grain filling periods. Less critical growth stages are the vegetative stage before flowering and during the grain dry-down period.

Since the soil water reservoir expands as the roots grow deeper, the allowable soil moisture deficit becomes greater as the season progresses. On deep soils, use Table 3 as a guide to determine when to apply water to prevent stress on crops. This table is based on 50% removal of available soil moisture.

Table 3. Allowable soil moisture deficit (inches).

Soil type (See Table 2)	0	1	2	3	4	5	6	7	8	9
Root depth (ft.)										
1.5	1.5	1.4	1.4	1.5	1.9	1.4	1.0	0.8	0.8	1.2
2.0	2.0	1.8	1.8	2.0	2.5	1.8	1.4	1.1	1.0	1.6
2.5	2.5	2.2	2.2	2.5	3.1	2.2	1.8	1.4	1.2	2.0
3.0	3.0	2.7	2.7	3.0	3.8	2.7	2.1	1.6	1.5	2.4

For corn and grain sorghum, 75% of available soil moisture may be removed after dough stage of growth when monitoring a 3 foot depth.

TENSIOMETERS

Tensiometers (tension meters), as the name implies, measure the tension on the soil water and can be used to indicate the soil moisture status. For tensiometers to give a reliable estimate of the soil moisture status, however, they must be placed in representative locations in the field, prepared properly, and correctly installed.

Preparing Tensiometers

There are two different makes of tensiometers sold in Nebraska suitable for irrigation scheduling purposes. In both, the tensiometer consists of a water-filled tube equipped with a vacuum gauge on the uper end and a por-

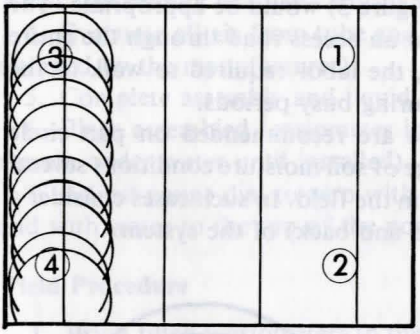


Figure 1. Set-type sprinkler systems.

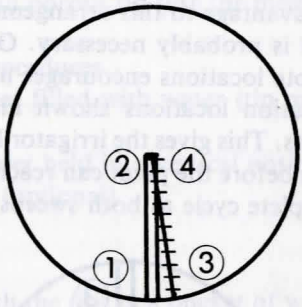


Figure 2. Normal arrangement.

ous ceramic tip on the lower end. However, tensiometers from the two manufacturers differ in construction. Both manufacturers sell a preparation kit which is suitable for their instrument. Read the instructions prepared by the manufacturer on how to fill and adjust your type of tensiometer.

A vertical tensiometer filled according to instructions will not read zero before insertion in the soil. This is because the tip of the tube is below the gauge. The longer the tube, the greater the pressure difference. For each 12 inches of tube length, the gauge should register 3 centibars when the porous tip is immersed in a cup of water. The tip in the cup is of zero pressure. The gauge of one make of tensiometer is adjustable, and can be reset to zero. The gauge of the other make of tensiometer is not adjustable.

Location of Tensiometer Stations

A minimum of four stations will be needed for each field. For set type sprinkler systems, such as tow lines, traveling guns and booms, place one station near each end of the irrigation sets. Place the stations far enough from the ends of the sets so that a complete watering pattern takes place (Figure 1). For center pivots, place stations 1 and 3, 85%, and stations 2 and 4, 15% of the length of the center pivot system from the pivot point. Be sure to place the stations far enough away from park position to insure that water does not reach them when the center pivot is in park position.

Locations shown in Figure 2 could be used where the entire pivot is planted to the same crop and where the soil is uniform. This arrangement has the advantage that the stations are located close to the pivot access road and therefore easy to read. The disadvantage of this placement occurs when

the system is being operated continuously. All monitoring locations are within less than one day's coverage of the water pattern.

If the field is planted to two separate crops or if large differences in soil types occur, a different arrangement (Figure 3) would be appropriate. The disadvantage to this arrangement is that an access road through the entire field is probably necessary. Otherwise, the labor required to walk to the remote locations encourages non-use during busy periods.

Station locations shown in Figure 4 are recommended on part-circle pivots. This gives the irrigator knowledge of soil moisture conditions several days before the pivot can reach a point in the field. In such cases consider a complete cycle as both sweeps (forward and back) of the system.

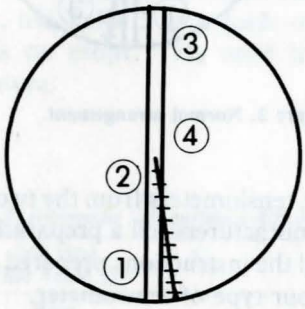


Figure 3. Two crops or different soil types.

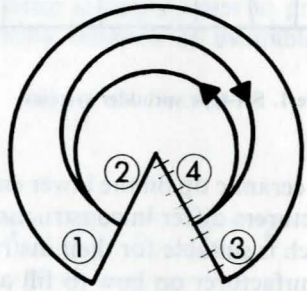


Figure 4. Part circle systems.

Tensiometer Installation

Equipment needed:

Soil probe

Metal rod, minimum of four feet long with one end rounded in the same shape as a tensiometer tip

Small sledge hammer

Flags

Water and bucket

Filling bottle with tube

Algae prevention fluid

Tensiometers (6-12 per field)

Pre-Field Procedure

1. Check all tensiometer components, including tubes, seals, gauges and tips, to make sure they are in good condition. Repair or replace components if necessary.

2. Read manufacturer's tensiometer assembly instructions and assemble required number of tensiometers.

3. Fill tube with water-algae prevention combination (cooled, boiled water will require less work during next stage).

4. Evacuate all air from tube and gauge and porous tip (use the method outlined by the manufacturer).

5. Complete assembly and liquid filling procedures.

6. Place assembled tensiometer in container filled with water (tip must remain under water until installed).

7. Adjust gauge dial to zero with tensiometer held in a vertical position and with water to the top of the porous cup (optional).

Field Procedure

1. Bring filled tensiometers to the field with the tips in a bucket of water or wrapped in a moist cloth and in a plastic bag.

2. Use the soil probe to make a hole in the crop row for the tensiometer. Each hole should end about four to six inches shallower than the desired final depth.

3. Finish the hole using the round tipped metal rod and small sledge hammer. Remember, the rounded end should be at the bottom of the hole.

4. Place tensiometer in hole and push to the bottom of the small diameter portion made with the metal rod. Make sure the tip fits snugly in the hole or erratic readings will occur.

5. Pack the soil around the tube at the top and make sure the soil surface at the tube is slightly elevated above the surrounding areas.

6. Identify each tensiometer in some manner so that you can tell the tube length. Waterproof tags work well. Some tensiometers are premarked. Stations should also be identified.

7. Use flags so that tensiometer stations can be found easily.

8. Be sure to properly mark the row in which the tensiometers are placed. Tensiometer stations become hard to find as the crop grows, especially in soybean fields. It is a good idea to place marker flags on either side of the station in the crop row and then move the flags into the row middle following lay-by. It is also good practice to mark the row at the edge of the field and record the distance from the edge of the field to the station.

9. Install the tensiometers early, before the lay-by stage for row crops if possible (but no later than a few days after lay-by), to allow time for the plant roots to grow around the tip. If the tensiometers are installed late in the growing season with all the crop roots in place, it may create problems in getting representative tension readings.

10. Tensiometers may break suction at about 50 centibars on units with adjusted gauges. This condition can be identified since the liquid level in the tube will be lowered. If tension is broken for a gauge reading below 50 cen-

tibars (adjusted), check the unit for a bad "O" ring or tip which is allowing air into the system. To put a tensiometer back into service, refill the liquid column and evacuate all air in the tube. Use the method outlined by the manufacturer.

11. If the liquid level in the tube becomes lower than the gauge, take care to insure that all air is removed from the gauge or faulty readings will result.

Irrigation Scheduling Using Tensiometers in Sandy Soils

Irrigation takes some risk out of crop production by providing a reliable source of water which allows the producer to eliminate moisture stress and maximize yields. The goal of irrigation scheduling is to maximize the effectiveness of irrigation by keeping the soil moisture level above the point where crop stress would occur but below the point that some water will be lost to deep percolation. The procedure that follows will help you meet that goal.

Irrigation scheduling is similar to balancing your checkbook. Think of the soil reservoir as a bank account. Rainfall or irrigation can be considered a deposit and the water used by the crop or evaporated from the soil surface a withdrawal. Irrigation scheduling carefully monitors your account so you can make a deposit whenever necessary to maintain a minimum balance.

To carry the checkbook analogy one step further, tensiometers allow you to check your current balance periodically to correct any errors in the water balance. The procedure outlined here uses this approach. A worksheet is provided that has blanks to fill in all the pertinent data and takes you step-by-step through to a solution.

Tables accompanying the worksheet allow you to interpret your tensiometer readings and report the current soil moisture status, in terms of soil moisture deficit in inches of water per foot of soil.

This allows calculation of the amount of water remaining in the root zone available for crop use—the current balance. The final step, then, is to estimate how many days it will take the crop to use the remaining moisture so you can "make a deposit" before the soil moisture has reached the minimum balance.

One final feature, which doesn't follow the checkbook analogy, is the calculation of the first day that you can irrigate without overfilling the root zone. This is called a no-sooner-than date on the worksheet.

HOW TO USE THE WORKSHEET

Field Information

1. Fill in the field information at the top of the sheet.

Table 4. Soil moisture depletion (in/ft) vs. tensiometer readings.

Soil type[1/]	5	6	7	8
Soil moisture tension (cb)	(1.8 in/ft)	(1.4 in/ft)	(1.1 in/ft)	(1.0 in/ft)
0	0	0	0	0
5	0	0	0	0
10	0	0	0	0.10
15	0	0.18	0.16	0.25
20	0.20	0.30	0.28	0.35
25	0.35	0.40	0.36	0.43
30	0.48	0.48	0.44	0.50
35	0.59	0.54	0.50	0.56
40	0.68	0.60	0.55	0.60
45	0.76	0.65	0.60	0.65
50	0.83	0.70	0.64	0.68
55	0.90	0.74	0.68	0.72
60	0.96	0.78	0.71	0.75
65	1.02	0.81	0.74	0.78
70	1.07	0.85	0.77	0.81
75	1.11	0.88	0.80	0.83

Beyond 75 — estimate deficit by hand-feel method

[1/] Alfalfa water use rates should be multipled by 0.50 during first ten days following cutting and 0.75 from the tenth to twentieth day following cutting.

2. Find the estimated root zone depth in Table 1 that matches the stage of crop development.
3. Find the soil type number in Table 2.

Soil Moisture Measurements

1. Record the tensiometer readings on the data sheet.
2. Convert each tensiometer reading to deficit-inches/foot (Table 4).
3. Calculate an average total deficit for the two positions.

Water Management

1. Find the allowable deficit in the root zone in Table 3.
2. Transfer present deficit from above.
3. Calculate the remaining usable moisture by subtracting the present deficit from the allowable deficit (No. 1- No. 2).
4. Reserve water holding capacity in the root zone for rainfall if desired. **Note. On sandy soils, keep rainfall allowance at zero until after the grain fill stage of growth.**
5. Find the estimated average daily water use rate in Table 5 or use current predictions issued by the Cooperative Extension Service or NRD. (Radio, Newspaper, Hotline).

Table 5. Approximate water use rates by stage of growth for various crops.

Water use rate	Corn	Grain sorghum	Soybeans	Alfalfa[1/]
in/day				
0.18				
0.20			Full bloom	
0.24	12 Leaf			
0.26		Flag leaf	Beginning pod	
0.28	Early tassel	Boot		June 15
0.30	Silking	Half bloom	Full pod development	July 1
0.28				August 1
0.26	Blister kernel	Soft dough		
0.24	Milk		Full seed fill	August 15
0.22				September 1
0.20	Beginning dent			
0.18	Full dent	Hard dough		

[1/] Alfalfa water use rates should be multipled by 0.50 during first ten days following cutting and 0.75 from the tenth to twentieth day following cutting.

6. Record depth of water applied by the sprinkler system with each pass.

7. The first date to irrigate at that field position without overfilling the root zone (no-sooner-than date) is calculated by adding the irrigation application depth (6) and the rainfall reserve (4), subtracting the present deficit (2), and dividing by the daily water use rate (5). [(6 + 4-2) /5].

8. The last date to irrigate at that field position without stressing the crop is calculated by dividing the remaining usable moisture (3) by the daily water use rate (5). [(3 / 5)].

Note that in steps 7 and 8 you calculated the range of dates acceptable for irrigating at a given spot in the field. The time required to cover the area from the present irrigation position to that spot must be included in the decision of when to start or stop the irrigation system.

Caution! Always avoid stressing the crop even if irrigation must begin before the root zone can hold the total irrigation depth, i.e., 8 has priority over 7.

In practice, this problem might be encountered early in the season when the root zone is shallow, especially when applying relatively heavy application depths. If this is the case, apply a lighter depth of water until the root zone expands to hold the usual application depth.

Example:

Following is an example of how to use tensiometer readings and the scheduling data forms in the back of this publication to calculate an irrigation schedule. When you finish working through the example, compare your work with the example worksheet.

Assume the following tensiometer readings were taken on July 30 when the corn was in the silking growth stage. The field is irrigated by a center pivot which covers 130 acres and has a capacity of 850 gpm. The manager of the pivot usually applies 1 inch of water per revolution. Each complete revolution takes 69 hours. Also, assume that the soil is sandy loam in texture and the tensiometers are installed as shown in Figure 2. The pivot is stopped in the park position. Since this is before the grain fill stage of growth, don't reserve room for rainfall.

Position 1

Station 1

Depth	Tensiometer readings
6"	35
18"	30
30"	15

Station 2

Depth	Tensiometer readings
6"	15
18"	20
30"	15

Position 2

Station 3

Depth	Tensiometer readings
6"	25
18"	25
30"	10

Station 4

Depth	Tensiometer readings
6"	25
18"	20
30"	10

Important items in this example are:

1. In both position 1 and position 2, the present deficit is nearly equal to the intended application depth. In fact, in less than one day you could irrigate at either position without incurring deep percolation. See 7, the no-sooner-than date.

2. You have a comfortable safety margin before the crop would undergo moisture stress at either position 1 or 2, 4 1/4 days and 5 days, respectively. See 8, the no-later-than date.

3. Soil moisture is somewhat uneven at position 1. If the difference in the readings between station 1 and station 2 gets larger as the season progresses, you should try to discover why and attempt to correct the problem. The most frequent causes for uneven readings are:

1. Poor tensiometer site selection.
2. A faulty tensiometer gauge.
3. A tensiometer with a broken seal (this will read zero).
4. Soil type differences that you haven't accounted for.
5. Uneven water distribution.

Irrigation Management

The procedure described in this publication helps you calculate the range of dates when irrigation would be acceptable at the two field positions. However, when to start the center pivot again is left up to management.

Items to consider before making a decision include:

1. How reliable is the irrigation system.

2. The capacity of the system compared to the estimated ET rate, that is, can you play catch-up if you get behind.

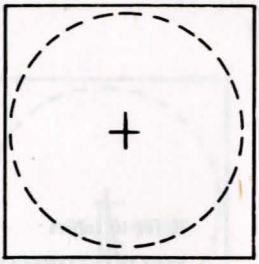
3. The cushion of available moisture remaining in the soil (the no-later-than date).

4. The stage of crop growth.

5. What is the potential yield reduction from moisture stress if unexpected downtime should occur?

6. Is the crop close to maturity? Ideally, the last irrigation should be timed so the soil is at least 60% depleted of available moisture at maturity.

Irrigation management is more than just calculating an irrigation schedule. The manager must also weigh the relative risks involved based on knowledge of the soil moisture condition, crop factors, and a knowledge of the capacity and reliability of the irrigation system before deciding when to start or stop the irrigation system. However, until you have calculated an irrigation schedule no further managerial refinements are possible.



SCHEDULING DATA SHEET

Refer to tables

FIELD INFORMATION

NAME _____ DATE _____

LEGAL DESCRIPTION _____ ¼ SEC ___ T ___ R ___ CROP _____

STAGE OF GROWTH _____ EST. ROOTZONE DEPTH _____ (Table 1)

SOIL TYPE _____ SOIL TYPE NO. _____ (Table 2)

SOIL MOISTURE MEASUREMENTS

	POSITION 1				POSITION 2			
	Station 1		Station 2		Station 3		Station 4	
Depths (inches)	Reading	Deficit (inches)	Reading	Deficit (inches)	Reading	Deficit (inches)	Reading	Deficit (inches)
6								
18								
30								
Total Deficit	Station 1		Station 2		Station 3		Station 4	

(See Table 4 for Deficit, Tensiometers)

Average Deficit Position 1 _____ (inches) Position 2 _____ (inches)

WATER MANAGEMENT DATA

	Position 1	Position 2
1. Allowable deficit in rootzone before irrigation is recommended —See Table 3 (at 50% depletion).	_____	_____
2. Present deficit in top 3 feet.	_____	_____
3. Remaining usable moisture in top 3 feet (1-2).	_____	_____
4. Reserve _____ inches in rootzone for rainfall.	_____	_____
5. Estimated average daily water use rate (Table 5).	_____	_____
6. Irrigation application depth _____	_____	_____
7. Irrigate no sooner than (6 + 4-2) ÷ 5.	_____ days	_____ days
8. Irrigate no later than (3 ÷ 5) 8 HAS PRIORITY OVER 7.	_____ days	_____ days

SCHEDULING DATA SHEET

Refer to tables

FIELD INFORMATION

NAME _____ DATE _____

LEGAL DESCRIPTION _____ ¼ SEC ___ T ___ R ___ CROP _____

STAGE OF GROWTH _____ EST. ROOTZONE DEPTH _____ (Table 1)

SOIL TYPE _____ SOIL TYPE NO. _____ (Table 2)

SOIL MOISTURE MEASUREMENTS

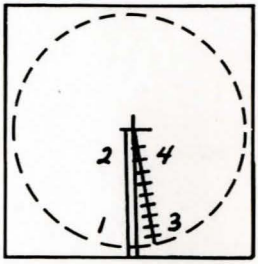
	POSITION 1				POSITION 2			
	Station 1		Station 2		Station 3		Station 4	
Depths (inches)	Reading	Deficit (inches)	Reading	Deficit (inches)	Reading	Deficit (inches)	Reading	Deficit (inches)
6								
18								
30								
Total Deficit	Station 1		Station 2		Station 3		Station 4	

(See Table 4 for Deficit, Tensiometers)

Average Deficit Position 1 _____ (inches) Position 2 _____ (inches)

WATER MANAGEMENT DATA

	Position 1	Position 2
1. Allowable deficit in rootzone before irrigation is recommended —See Table 3 (at 50% depletion).	_____	_____
2. Present deficit in top 3 feet.	_____	_____
3. Remaining usable moisture in top 3 feet (1-2).	_____	_____
4. Reserve _____ inches in rootzone for rainfall.	_____	_____
5. Estimated average daily water use rate (Table 5).	_____	_____
6. Irrigation application depth _____	_____	_____
7. Irrigate no sooner than (6 + 4-2) ÷ 5.	days	days
8. Irrigate no later than (3 ÷ 5) 8 HAS PRIORITY OVER 7.	days	days



SCHEDULING DATA SHEET

Refer to tables

FIELD INFORMATION

NAME SANDY IRRIGATOR DATE 7/30

LEGAL DESCRIPTION SE ¼ SEC 20 T 20 R 6 CROP CORN

STAGE OF GROWTH SILKING EST. ROOTZONE DEPTH 3.0 ' (Table 1)

SOIL TYPE SANDY LOAM SOIL TYPE NO. 6 (Table 2)

SOIL MOISTURE MEASUREMENTS

Depths (inches)	POSITION 1 Station 1 Reading	POSITION 1 Station 1 Deficit (inches)	POSITION 1 Station 2 Reading	POSITION 1 Station 2 Deficit (inches)	POSITION 2 Station 3 Reading	POSITION 2 Station 3 Deficit (inches)	POSITION 2 Station 4 Reading	POSITION 2 Station 4 Deficit (inches)
6	35	0.54	15	0.18	25	0.40	25	0.40
18	30	0.48	20	0.30	25	0.40	20	0.30
30	15	0.18	15	0.18	10	0.00	10	0.00
Total Deficit	Station 1	1.20	Station 2	0.66	Station 3	0.80	Station 4	0.70

(See Table 4 for Deficit, Tensiometers)

Average Deficit Position 1 0.93 (inches) Position 2 0.75 (inches)

WATER MANAGEMENT DATA

	Position 1	Position 2
1. Allowable deficit in rootzone before irrigation is recommended —See Table 3 (at 50% depletion).	2.2	2.2
2. Present deficit in top 3 feet.	0.93	0.75
3. Remaining usable moisture in top 3 feet (1-2).	1.27	1.45
4. Reserve 0 inches in rootzone for rainfall.	0	0
5. Estimated average daily water use rate (Table 5).	0.3	0.3
6. Irrigation application depth 1.0	1.0	1.0
7. Irrigate no sooner than (6 + 4-2) ÷ 5.	0.23 days	0.83 days
8. Irrigate no later than (3 ÷ 5) 8 HAS PRIORITY OVER 7.	4.23 days	4.83 days

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