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Small Acreage Irrigation Management

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Field irrigation application methods include surface (wild flooding, border, furrow, basins), sprinkler (hand line, wheel move, solid set, center pivot), low flow or micro-irrigation (drip, trickle, micro-spray), and sub-irrigation (water table manipulation under special conditions). Prevalent small-acreage irrigation methods used on pasture and hay crops are surface and sprinkler. Landscape shrubs and trees, including windbreaks, may be irrigated with low flow (drip) irrigation methods.

Properly managing irrigation is analogous to managing money in a bank account. In addition to knowing your current bank balance (soil water content), it is important to track both expenses (plant water use/evaporation or evapotranspiration) and income (rainfall and irrigation).

The Soil Water Bank

First, some terminology:

- Field Capacity. The amount of water that can be held in the soil after excess water has percolated out due to gravity.
- Permanent Wilting Point. The point at which the water remaining in the soil is so small it is not available for uptake by the plant. When the soil water content reaches this point, plants die.
- Available Water. The amount of water held in the soil between field capacity and permanent wilting point. (Figure 1.)
- Readily Available Water. The amount of water available for plant use before the plant starts to exhibit drought stress (the water between Field Capacity and Allowable Depletion).
- Allowable Depletion. The point where plants begin to experience drought stress. For forage crops, the amount of allowable depletion represents about 50 percent of the total available water. (Figure 1.)
- Acre Inch: The amount of water needed to cover an acre (43,560 sq ft) 1 inch deep.

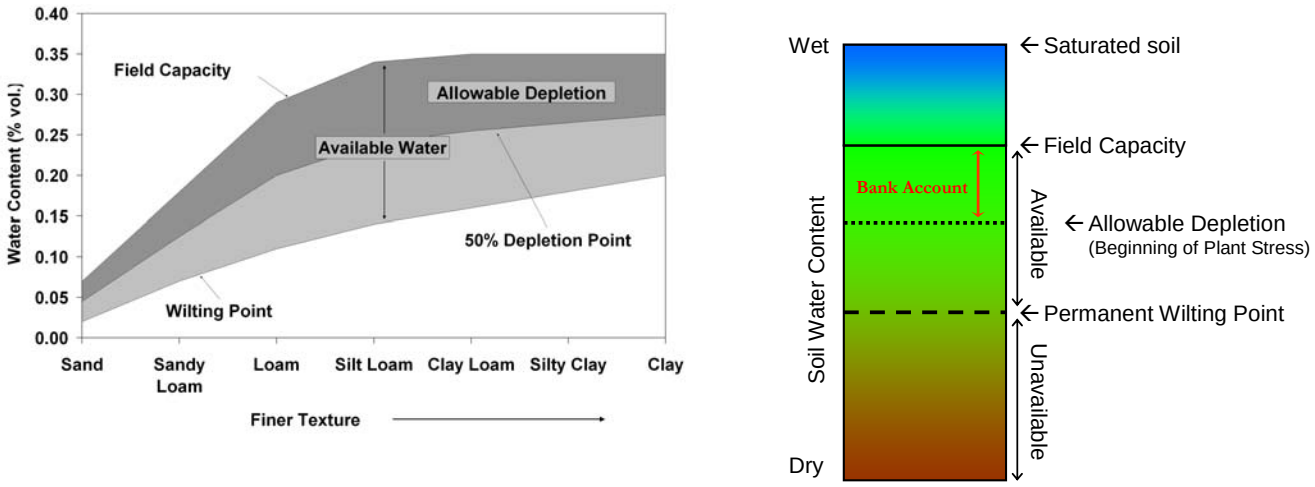
The goal of a well-managed irrigation program is to maintain the soil moisture between field capacity and the point of allowable depletion, or in other words, to make sure that there is always readily available water.

The amount of readily available water is related to the effective rooting depth of the plant, and the water holding capacity of the soil. The effective rooting depth depends on soil conditions and crop type. Although alfalfa roots can grow several feet deep, nearly all pasture and cereal grain crops grow roots in the 1.5-2.5 feet range. The water holding capacity within that rooting depth is related to soil texture, with coarse soils (sands) holding less water than fine textured soils such as silts and clays. (See Table 1.) For example, a deep sandy loam soil at field capacity would contain 1.2 to 1.5 inches of available water in every foot of soil.

Table 1. Typical soil characteristics and crop rooting depths.

Available Soil Water-holding Capacity and Intake Rate			Typical Crop Rooting Depths	
Soil Texture	Inches of available water per foot of moist soil	Intake rate[1] Inches/Hour	Crop	Typical active root Zone depth, feet
Sands and fine sands	0.5 - 0.75	1.0 - 10	Alfalfa	5
Loamy sandy, very			Corn	4 - 5
fine sands	.8 - 1.0	1.0 - 3	Small Grains	3 - 4
Sandy Loam	1.2 - 1.5	0.5 - 3		
			Dry Beans	3
Loam	1.9 - 2.0	0.3 - 0.8	Pasture	1 ½ - 2 ½
Silt loam, Silt	2.0	0.2 - 0.4	Potatoes	1 ½ - 2 ½
Silty clay loam	1.9 - 2.0	0.01 - 0.2		
			Turf	1 - 2
Clay loam, Sandy			Vegetables	1 ½ - 3
clay loam	1.7 - 2.0	0.1 - 0.6		

Note: Allowable depletion to avoid crop water stress is usually about 50 percent of available water holding capacity for most field crops. [1]Normal ranges. Intake rates vary greatly with soil structure and structural stability.



Figures 1a and 1b. The amount of allowable depletion, or the readily available water, represents about 50 percent of the total available water.

Irrigation Management

Not all water applied by an irrigation system is used by the crop. Some water is lost to deep percolation, evaporation, or runoff. Application efficiency (Ea) is a term that indicates how much of the water applied by the system is actually stored in the root zone for crop use. Field irrigation (application) efficiency is the ratio of water stored in the root zone divided by the water delivered to the field.

Application efficiency (Ea %) = 100 x Water stored in root zone / Water delivered to field

For example, if 50 acre inches of water are delivered to a 10 acre field during an irrigation, and 30 acre inches are stored in the root zone, then the application efficiency (Ea) is 60% (60 = 100 × 30/50).

Over-irrigation occurs from applying amounts of water greater than the available soil water storage capacity. This could be the result of using an irrigation system

with more capacity than is suited for the soil and/or from scheduling irrigations at too short of intervals. Thus, knowledge of the soil moisture content prior to irrigation is essential to maintaining high application efficiencies while providing for optimum crop water use and growth. The actual Ea depends upon how evenly the water is distributed across the field and irrigation scheduling as well as other factors that are irrigation method specific.

Typical irrigation application efficiencies are:

Surface
- wild flooding 15-25%
- furrow 35-55%
- border 45-65%
- level basin 85-90%

Sprinkle
- handline 30-65%
- wheelmove 45-70%\
- center pivot 75-85%

Low flow/Drip
- drip 85-90%
- micro-sprinkler 75-85%

When to Irrigate and How Much to Apply

The timing and amount of irrigation water required by a crop depends on crop water use rates, soil water holding capacity, and irrigation system characteristics. Crop water use or evapotranspiration (Et) is the combination of transpiration from plant leaves plus evaporation from adjacent soil surfaces. Evapotranspiration is affected by weather conditions and crop growth progress. Thus, crop water use varies throughout the state of Utah. Pasture will be used in the following text and examples to illustrate irrigation scheduling principles.

Air temperatures and other weather conditions change from early spring through the middle of the summer and continuing on into the fall. This suggests that the daily crop water use rate of pasture is relatively low in the spring, increases toward the end of June into July and then decreases through August continuing into October. The amount of vegetation present, sometimes expressed as height but also as leaf area, also affects the rate at which pasture will use water. For example, grass that is approximately 10 inches tall, perhaps prior to a grazing, will use more water than grass that is 3 to 4 inches tall immediately following grazing.

Estimated 30 year average monthly crop water use (Et) for pasture at selected Utah sites is given in Table 2. Seasonal Et for pasture varies from 38.9 inches at St. George to 19.8 inches at Panguitch. Generally, lower seasonal total Et values (less than 23.3 inches) are realized at higher elevation sites (Coalville, Lake Town, Monticello, and Panguitch). The highest monthly (July) pasture Et was 7.3 inches at St. George and the lowest was 5.0 inches at Coalville.

Unless there is a limiting layer in the soil, most of the pasture roots will be found in the top 2 to 3 feet. This contrasts with the deeper rooted alfalfa (Table 1). Assume a pasture root depth of 2.5 feet for this discussion.

The soil water holding capacity varies from about 1 inch per foot of depth in a sandy soil to about 2 inches per foot of depth in a loamy soil (Table 1). Approximately 2.5 inches of water is available in a sandy soil for plant use in the 2.5 foot root zone (2.5 in = 1 in/ft x 2.5 ft). Whereas, in a loamy soil (see Table 1), about 5 inches of water would be available for the pasture to use in the same 2.5 foot root depth (5 in = 2 in/ft x 2.5 ft). For best growth of pastures, we recommend that irrigation take place when approximately 50 percent of the water has been used or depleted out of the root zone. This means that for a pasture on a sandy soil, the irrigation should occur when approximately 1.25 inches of water has been used. In comparison, about 2.5 inches of soil water would be used between irrigations on a loamy soil.

As an example of the scheduling of irrigations, assume the crop water use rate is averaging ¼ of an inch per day. Thus, on a sandy soil, to maintain a pasture at its most vigorous growth, irrigation would be needed approximately every 5 days (5 days = 1.25in/ 0.25 in per day) and 1.25 inches of water should be added to the soil. However, on a loamy soil the pasture would need to be irrigated about every 10 days with 2.5 inches (10 = 2.5/0.25) of irrigation water. In contrast, because alfalfa is deeper rooted, it could go about twice as long without irrigation, but would need to be irrigated with twice the amount of water.

The irrigation depths used here are “Net,” i.e., what is actually stored in the root zone. The relatively small amount of 1.25 inches may be practical with sprinkle but not surface irrigation.

Irrigation application requirements may be as much as double the net value depending on the application efficiency. Assuming wheelmove sprinkler irrigation with an application efficiency of 65%, about 2 inches (2 = 1.25/0.65) of water should be delivered through the system during each irrigation to store 1.25 inches in the sandy soil root zone.

The irrigation schedule for pasture should take into account the grazing cycle. This means that on a loamy soil (10 day irrigation interval) with a 5-day grazing period followed by 25 days of rest, there would need to be an irrigation approximately 5 days prior to the beginning of grazing with an irrigation immediately after the grazing and one approximately 10 days later - such that in each 4-week grazing cycle, there would be three 2.5 inch irrigations (net) if the crop water use rate continued at 0.25 of an inch a day.

Table 2. Monthly Pasture Crop Evapotranspiration for selected sites in Utah. Thirty year average for period 1961-1990.

Site	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Season Total
Pasture Water Use, Inches											
Beaver			1.2	4.21	5.42	6.16	4.83	3.06			24.87
Castledale			1.44	3.35	6.04	6.53	5.23	3.99	1.44		28.01
Cedar City			2.06	4.51	5.44	5.87	5.01	3.79	1.19		27.88
Coalville			0.48	3.01	4.64	4.97	4.4	2.94			20.43
Corrine		0.04	1.86	4.2	5.52	6.27	5.52	3.68	1.73		28.83
Delta			2.14	4.38	5.42	6.26	5.22	3.57	0.79		27.79
Ephriam			1.26	4.47	5.66	6.22	5.39	3.73	0.82		27.55
Farmington USU Field Station		0.56	2.22	3.98	5.29	5.95	5.03	3.22	1.47		27.71
Heber			0.51	3.65	4.94	5.7	4.87	3.34	0.65		23.66
Kanab		1.09	3	4.87	5.72	6.09	5.18	3.9	2.26		32.13
Lake Town			0.27	3.35	4.85	5.49	4.84	3.31	1.01		23.1
Logan (USU)			1.74	3.75	5	5.55	4.89	3.88	1.05		25.06
Milford			1.34	4.52	5.82	6.36	5.32	3.87	0.36		27.59
Moab	0.16	1.47	2.88	4.7	5.8	6.32	5.39	4.15	2.58	0.48	33.93
Monticello			1.36	3.66	4.68	5.23	4.49	3.19	0.58		23.19
Panguitch				2.86	5.01	5.33	4.41	2.17			19.78
Pleasant Grove		0.3	2.2	4.28	5.29	6.06	4.93	3.42	1.46		27.76
Roosevelt			1.39	4.15	5.76	6.24	5.2	3.34	1.12		27.2
Salt Lake		0.33	2.29	3.93	5.39	6.26	5.26	3.16	1.6		28.22
St. George	0.12	2.26	3.59	5.61	6.68	7.28	5.82	4.25	2.5	0.8	38.89
Tooele		0.44	2.11	4.48	5.49	5.9	4.91	3.01	1.45		27.79

Adapted from: Consumptive Use of Irrigated Crops in Utah, Utah Agricultural Experiment Station Research Report No. 145. Oct. 1994.

Calculating an Irrigation Interval

The information needed to determine the interval between irrigations is available soil water in the root zone, crop water use (Et) rate (inches per day), and allowable soil water depletion at time of irrigation.

Steps to determine an irrigation interval include:

A. Identify the soil texture and use Table 1 to estimate the water holding capacity.
B. Estimate the average rooting depth of the crop using Table 1 and multiply this amount by the soil water holding capacity which is the root zone available water.
C. Caculate allowable depletetion by multiplying root zone available water by 50%.
D. Estimate crop water use (evapotranspiration or ET) using Table 2. Compute daily crop water use. Note: real-time crop water use is available for 15 sites throughout Utah at the Web site: extension.usu.edu/agweather.
E. The irrigation interval is calculated by dividing allowable depletion by daily crop water use.

An alternate method can be used to calculate the irrigation interval. The applied water depth (if fixed for all irrigations) can be used in place of the allowable depletion in the last step.

Example A: Simple Irrigation Calendar. Determine the irrigation interval and application depth for pasture on sandy loam soil. Assume that the July pasture crop water use (Et) is 6.26 inches (From Table 2 for Salt Lake) and the root depth is 2.5 ft (from Table 1). Irrigate when 50% of the available water or the readily available water is depleted.

A. Soil water holding capacity (sandy loam) is 1.5 inches/ft (from Table 1).
B. Root zone available water = 2.5 ft x 1.5 in/ft = 3.8 inches.
C. Allowable depletion amount = 3.8 x 50% = 1.9 inches between irrigations.
D. Crop water use 6.26 in (from Table 2).
E. Irrigation interval = Amount/daily E_t rate
   = 1.9 inches/(6.26 inches/31 days)
   = 1.9 inches/0.20 in per day, = about 10 days

Example B: Alternate schedule from sprinkler net irrigation, twice per day moves. Assume a net application rate of 0.20 inches per hour.

Net irrigation of 2.3 inches stored in the soil (2.3 inches = 0.20 inches per hour x 11.5 hours per set). Irrigation Interval = 2.3 inches/0.20 inches per day, = about 12 days. The amount of water applied, 2.3 inches, exceeds the allowable depletion 1.9 inches. Approximately, 0.4 inches would be unavailable due to deep percolation. The interval of 12 days is longer than obtained in the above example, thus some crop stress may occur even though the application amount exceeds the allowable depletion. A remedy would be changing the nozzle size, the pressure and/or the hours per set to match the desired stored water amount to avoid additional deep percolation and reducing the interval to 10 days.

Example C: Alternate schedule from surface irrigation, infiltrated water application rate of 4 inches per irrigation.

Irrigation interval = 4.0 inches/0.20 inches per day, = about 20 days. This example is more extreme than example B above, in that the amount stored in the root zone, 4 inches, greatly exceeds the allowable depletion amount of 1.9 inches. Also, the corresponding interval between irrigations is double the 10 days of the first example resulting in considerable crop stress prior to refilling the root zone. Thus, under-irrigation would occur as a result of over-irrigations spaced too far apart - ***not recommended***.

Summary: Since the irrigation intervals from parts B (12 days) and C (20 days) are longer than in part A (10 days), the lesser interval governs for best crop growth. Thus, irrigate every 10 days, storing 1.9 inches of irrigation water in the root zone. With sprinklers, the nozzle size, operating pressure and/or the length of irrigation time should be changed to match the 1.9 inch net application to avoid additional water losses. It may not be possible to uniformly apply only 1.9 inches with surface irrigation without considerable effort.

Typical irrigation intervals, by month, for pasture are given in Table 3 for selected Utah sites. The intervals in Table 3 were derived from the water use values in Table 2. They vary from 25 days in September for pasture on a silt loam soil at Beaver and Tooele (21 days in May at Logan) to 8 days in June and July on loamy sand at several sites.

Table 3. Days Between Irrigations for Pasture at Selected Utah Sites.

	Soil	May	Jun	Jul	Aug	Sep
Beaver	LS	12	9	8	10	16
	SL	18	14	13	16	25
Cedar City	LS	11	9	9	10	13
	SL	17	14	13	15	20
Ephraim	LS	11	9	8	9	13
	SL	17	13	12	14	20
Logan (USU)	LS	13	10	9	10	16
	SL	21	15	14	16	24
Pleasant Grove	LS	12	9	8	10	14
	SL	18	14	13	16	22
Roose-velt	LS	12	8	8	10	15
	SL	19	13	12	15	22
Salt Lake	LS	13	9	8	10	15
	SL	20	14	12	15	24
Tooele	LS	11	9	9	10	16
	SL	17	14	13	16	25

Note: LS denotes Loamy Sand (WHC 1.3 in/ft) and SL – Silt Loam (WHC 2.0 in/ft). For pasture root depth of 2.5 ft, the management allowable root zone depletion is 1.6 and 2.5 inches, respectively, for LS and SL. Intervals given assume no rain.

For optimum growth and forage production of pastures it is important that adequate nitrogen fertilizer be correlated with the timing of irrigations, particularly following grazing. It is also important that excessive irrigation not be applied because this could wash out the nitrogen and reduce the effectiveness of fertilizer purchases.

How Long to Irrigate (Duration)

The duration of irrigation needed to store the crop irrigation requirement (evapotranspiration, Et) in the root zone depends on the application rate. Application rate is calculated by the following formula:

Irrigation Duration (hours) = crop irrigation requirement (inches)/application rate (in/hr)

For sprinklers the application rate is a function of nozzle size, operating pressure, and sprinkler spacing.

The steps to determine irrigation duration include:

A. Estimate crop irrigation requirements.
B. Determine sprinkler net application rate per hour.
C. Calculate the number of irrigation hours required to deliver crop irrigation requirement by dividing crop irrigation requirement by net application rate.
D. Compute the number of irrigations required by dividing the number of irrigation hours by the irrigation hour sets.

Example D: Determine how many hours to irrigate in July.

A. Assume a crop irrigation requirement (Et) of 6.5 inches.
B. Assume a sprinkler net application rate of 0.15 inches/hour.
C. Hours to irrigate in July = 6.5 inches/ 0.15 inches/hour = 43 hours.
D. Assuming that the sprinklers were moved twice per day (11.5 hour sets) then about four irrigations (4 = 43/11.5) are needed in July. This is equivalent to one 11.5 hour irrigation about every 8 days [8 = 31/(43/11.5)].

Table 4 identifies irrigation duration from known irrigation parameters. Calculated irrigation duration for nozzle sizes of 1/8 to 3/16 and pressures of 30 to 50 psi are given. The durations shown in Table 4 were obtained from assuming a sprinkler spacing of 40' by 60' and 70% application efficiency. The Table 4 duration value corresponding to the above example is 42.9 hours, which is found at the intersection under the 11/64 nozzle, 40 psi column and the 6.5 inches of water required row.

Most often flood or surface irrigators receive water turns from their irrigation company or water master as to when they will have irrigation water and for how long. Table 5 is most appropriately applied to flood irrigation, but can also be applied to sprinkler irrigation if the right field conditions exist. It shows the amount of time required for a given flow rate of water to deliver depths between 0.5 - 6 inches of water to a 1 acre field.

Table 4. Required Sprinkler Irrigation Duration (hours) for Selected Crop Water Use Values.

Crop Water Use, Inches	Nozzle Sizes, Inches														
	1/8			9/64			5/32			11/64			3/16		
	Pressure, psi														
	30	40	50	30	40	50	30	40	50	30	40	50	30	40	50
0.5	7.1	6.1	5.6	5.9	5.1	4.6	4.6	4.0	3.6	3.8	3.3	3.0	3.2	2.8	2.5
1	14.2	12.3	11.1	11.9	10.2	9.1	9.1	7.9	7.1	7.6	6.6	5.9	6.5	5.7	5.1
1.5	21.4	18.4	16.7	17.8	15.3	13.7	13.7	11.9	10.7	11.4	9.9	8.9	9.7	8.5	7.6
2	28.5	24.6	22.3	23.7	20.3	18.3	18.3	15.8	14.2	15.2	13.2	11.9	12.9	11.3	10.2
2.5	35.6	30.7	27.8	29.7	25.4	22.8	22.8	19.8	17.8	18.9	16.5	14.8	16.2	14.1	12.7
3	42.7	36.8	33.4	35.6	30.5	27.4	27.4	23.7	21.4	22.7	19.8	17.8	19.4	17.0	15.3
3.5	49.8	43.0	38.9	41.5	35.6	32.0	32.0	27.7	24.9	26.5	23.1	20.8	22.7	19.8	17.8
4	57.0	49.1	44.5	47.5	40.7	36.5	36.5	31.6	28.5	30.3	26.4	23.7	25.9	22.6	20.3
4.5	64.1	55.2	50.1	53.4	45.8	41.1	41.1	35.6	32.0	34.1	29.7	26.7	29.1	25.4	22.9
5	71.2	61.4	55.6	59.3	50.9	45.6	45.6	39.6	35.6	37.9	33.0	29.7	32.4	28.3	25.4
5.5	78.3	67.5	61.2	65.3	55.9	50.2	50.2	43.5	39.2	41.7	36.3	32.6	35.6	31.1	28.0
6	85.4	73.7	66.8	71.2	61.0	54.8	54.8	47.5	42.7	45.5	39.6	35.6	38.8	33.9	30.5
6.5	92.6	79.8	72.3	77.1	66.1	59.3	59.3	51.4	46.3	49.2	42.9	38.6	42.1	36.7	33.1
7	99.7	85.9	77.9	83.1	71.2	63.9	63.9	55.4	49.8	53.0	46.2	41.5	45.3	39.6	35.6
7.5	107	92.1	83.4	89.0	76.3	68.5	68.5	59.3	53.4	56.8	49.4	44.5	48.5	42.4	38.1
8	114	98.2	89.0	94.9	81.4	73.0	73.0	63.3	57.0	60.6	52.7	47.5	51.8	45.2	40.7
8.5	121	104	94.6	101	86.5	77.6	77.6	67.3	60.5	64.4	56.0	50.4	55.0	48.0	43.2
9	128	110	100	107	91.6	82.2	82.2	71.2	64.1	68.2	59.3	53.4	58.3	50.9	45.8
9.5	135	117	106	113	96.6	86.7	86.7	75.2	67.6	72.0	62.6	56.4	61.5	53.7	48.3

Note: Irrigation duration, hours, calculated assuming sprinkler spacing of 40' by 60' and 70% application efficiency. Irrigation water required is equivalent to crop evapotranspiration, if rainfall is ignored (see Table 2).

Flood irrigators can determine appropriate irrigation duration with the following steps:

A. Determine the amount of water delivered every turn.
B. Determine the length of the water turn and the length of time between turns.
C. Estimate daily crop water use or Et.
D. Compute the soil water replacement by multiplying the length of time between turns by daily crop water use.
E. Use Table 5 to estimate the time required to deliver the soil water replacement amount to 1 acre

Example E: A land owner has 5 acres of pasture and he wants to determine how much land he can irrigate adequately. Estimate crop irrigation requirements.

A. The water turn is 1 cfs.
B. The water turn occurs every 14 days for 12 hours.
C. Daily Et is 0.25 inches per day.
D. Soil water replacement every 14 days is 3.5 inches (3.5 in = 14 days x 0.25 in).
E. Use Table 5 to estimate the hours needed to add 3.5 inches to the root zone.
F. Locate the row with 1 cfs, slide over to the number below 3.5 at the top, and find 210 minutes. This is the required time to deliver 3.5 inches to 1 acre at the rate of 1 cfs. For 5 acres, it would require 5 times this which is 1050 minutes (1050 = 5 x 210).

Table 5. Time Required for Delivering Given Depth of Water to a 1 Acre Field

	Depth d, inches											
Flow rate cfs*	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
	Application Time, minutes											
0.50	60	120	180	240	300	360	420	480	540	600	660	720
1.00	30	60	90	120	150	180	210	240	270	300	330	360
1.50	20	40	60	80	100	120	140	160	180	200	220	240
2.00	15	30	45	60	75	90	105	120	135	150	165	180
2.50	12	24	36	48	60	72	84	96	108	120	132	144
3.00	10	20	30	40	50	60	70	80	90	100	110	120
3.50	9	17	26	34	43	51	60	69	77	86	94	103
4.00	8	15	23	30	38	45	53	60	68	75	83	90
4.50	7	13	20	27	33	40	47	53	60	67	73	80

Note: To store two inches of water in the root zone with an irrigation application efficiency of 50% would require a delivery of four inches of water to the field.
*cfs – Cubic feet per second is a stream of water 1 foot wide 1 foot deep traveling at the rate of 1 foot per second. One CFS is 448.8 (450) gallons per minute.

In this example, the landowner only has 720 minutes of water, which would allow him to irrigate approximately 3.4 acres without consideration for the system efficiency. Flood irrigation is usually less than 50% efficient; therefore, the land owner could expect to adequately irrigate only 1.75 acres

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Additional information on irrigation management is available on the Utah State University Web site at: http://extension.usu.edu Select “Publications” and then select “Irrigation Engineering”

Where Can You Get Help?

Utah State University - Extension Service
Utah Counties – Extension Office see: http://extension.usu.edu/htm/counties for directory.

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