AGRICULTURAL WATER MANAGEMENT IN A DRY YEAR

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COOPERATIVE EXTENSION

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AGRICULTURAL WATER MANAGEMENT
IN A DRY YEAR

The lack of winter rains and snow pack for the past two years has created a severe water shortage for many surface water irrigation districts.. Projections by water planners indicate this season may be one of the driest on record. This has created a condition which could rival the 1977 season for economic impact. Agriculture, which utilizes approximately 85 percent of California's annual water supply in order to produce the majority of the nation's fruit and vegetables, stands to bear the economic brunt of this situation.

Water supplies for agriculture vary from district to district, as well as between individual fields. Conservation measures must be utilized in order to obtain maximum benefit from the limited water available. This publication intends to address these measures, wherever possible presenting data from field research and experience to substantiate the strategies suggested.

SOIL-PLANT-WATER RELATIONSHIPS

An adequate supply of water is essential for plants to grow and produce a salable crop. Water is important in these functions:

1) as a component of plant tissues,

2) as a solvent to bring nutrients to plant roots and transport within the plant,

3) as a reactant in basic reactions such as photosynthesis and respiration,

4) in maintaining turgor in order to control water vapor exit and gas entry to the leaf.

With limited supplies of water available to the plant, reductions in plant water status will occur. Obvious symptoms of increased plant water deficits are leaves that first wilt and may darken in color. More severe water stress causes leaf yellowing and eventual death. The reproductive portion of the plant is not immune to water deficits. Both quality and yield can suffer from severe water deficits. Perennial crops have the additional concern for subsequent years' crop, since in deciduous orchard crops and wine grapes, the buds for next year's crop are formed during this season.

Evidence of water stress first occurs during a short period of the afternoon when the water demand is high and water absorption by plant roots is inadequate. These short-term water deficits commonly occur and do not seem to be detrimental to yield and quality. As conditions worsen, "water stress" lasts longer and begins to affect all the important plant processes. The goal of irrigation management is to prevent long term reductions in plant water status which can reduce yield, quality and crop longevity.

IRRIGATION MANAGEMENT

Irrigated California agriculture relies upon a network of surface water delivery systems as well as ground water systems to supplement natural rainfall in the Central Valley. Irrigation is the controlled application of water to the soil in order to meet the crop needs as well as the salt leaching requirement. This involves using application rates and amounts that are consistent with the soil characteristics as well as proper timing. Proper timing or scheduling of the irrigation can be further complicated by time-based delivery schedules.

Developing an Irrigation Strategy

A successful irrigation strategy depends on site specific knowledge of:

1) **crop water use**
   a) **stage of growth**
   b) **cover crop, if any**
2) **stored winter rainfall**
3) **depth of crop rooting**
4) **irrigation system performance**
5) **scheduling of irrigation**
6) **effect of reduced seasonal water supplies**

Many of these factors are needed to determine the gross irrigation requirement for a particular season:

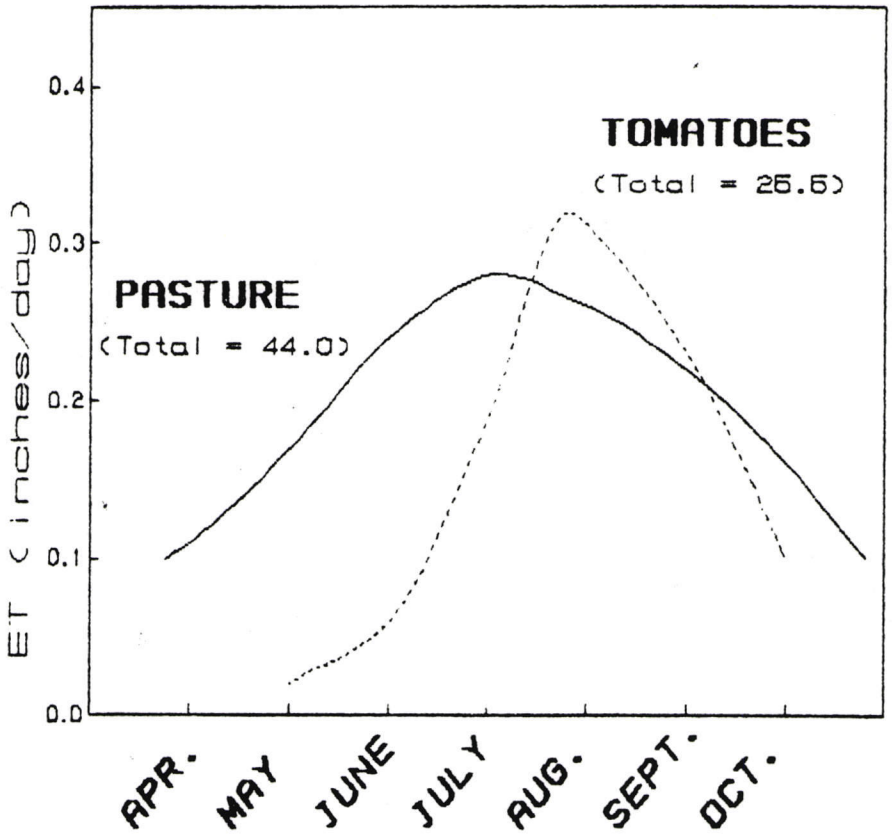
$$\text{seasonal crop water use} - \text{available soil storage of root zone} = \frac{\text{net seasonal irrigation volume}}{\text{estimated irrigation efficiency}} = \text{gross crop irrigation requirement}$$

The timing or scheduling of irrigation depend on the storage capacity of the root zone and the soil water status affecting the plant water status. When unlimited water supplies are available, irrigation should take place at a time when adequate water is remaining in the soil not to cause crop "water stress." The amount of water to apply should not exceed the water-holding capacity of the root zone, i.e., no deep percolation except in cases where salt control is required.

Water penetration difficulties as well as disease considerations should also determine the volume and rate of irrigation applied. Under conditions of limited water availability, the timing or scheduling decision is made much more difficult. Under these conditions, the goal is to minimize the effects of yield and quality reducing water stress as water supplies allow.

Crop Water Use Estimates

Water use by crops have been the subject of numerous studies by irrigation engineers and plant scientists. Crop use rates, termed evapotranspiration (ET), are correlated to the amount of ground surface covered by the leaf canopy--as the plant grows and expands its leaf area over the ground, the ET increases. Environmental factors (such as temperature, wind and humidity) also influence ET. The following graph depicts daily ET rates for two different crops: tomatoes (which start from seed and grow to maturity annually) and pasture (which is perennial and has essentially 100 percent ground cover all year.



Crop water use estimates based on average climatic conditions and planting dates have been developed for most major crops grown in San Joaquin-Stanislaus Area. The following table depicts estimated crop water use (ET) on a monthly basis throughout the growing season.

Normal Monthly Evapotranspiration Rates for Irrigated Crops in San Joaquin-Stanislaus Area (acre-inches)*

	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
alfalfa	1.5	3.9	6.0	7.0	7.8	6.6	4.8	2.0	1.2	40.8
almonds	0.6	2.5	4.0	7.5	8.0	7.0	3.5	2.0	0.7	35.8**
apricots	0.3	2.0	4.0	7.5	7.5	7.0	3.5	2.0	0.5	34.3**
beans	--	--	--	2.5	5.0	6.0	4.0	--	--	17.5
corn	--	--	2.0	4.0	6.5	8.2	4.0	0.5	--	25.2
grain	1.8	4.2	4.8	1.2	--	--	--	--	--	12.0
grapes	--	0.7	2.9	4.5	5.8	4.2	2.8	0.6	--	21.6**
pasture	1.8	4.5	6.0	7.5	9.0	7.5	5.5	2.2	--	44.0
peaches	0.2	2.0	4.0	8.0	8.5	7.5	4.5	2.5	0.5	37.7**
sudan	--	--	3.0	4.2	6.0	5.4	3.2	1.2	--	23.0
sugar beets	0.7	1.5	4.5	8.5	7.5	3.5	1.2	0.5	0.1	28.0
tomatoes	--	--	1.2	2.6	8.5	8.2	5.0	--	--	25.5
walnuts	--	1.8	5.0	8.5	9.0	8.0	4.3	2.0	--	38.6**
watermelon	--	--	--	3.0	5.0	6.0	4.0	--	--	18.0
turf (cool season)	2.2	4.9	5.9	6.4	7.5	5.9	3.9	2.5	1.0	40.2

*** Portions extrapolated from DWR Bulletin 113-2**

Estimating crop water use for a given time period or current season is possible utilizing the California Irrigation Management Information System (CIMIS). CIMIS is a program developed by Cooperative Extension and operated by the California Department of Water Resources. The program maintains weather stations in many areas of California which are used to estimate crop water use. In Stanislaus County, a station is located on Highway 132 near the San Joaquin River. In San Joaquin County, stations are located in Lodi and Manteca.

Soil Storage

Soil water storage is dependent upon the soil type as well as the effective rooting of a particular crop. Soils vary in the total amount of water they can hold and the amount of water which is available to the crop. The following table lists several major soil types and their water-holding capacity.

Water-Holding Capacity of Several Soils

Soil Type	Total Water Holding Capacity*	Plant Available Moisture**
Delhi sand	0.5	0.4
Hanford loamy sand	1.0 - 1.4	0.75 - 1.0
Greenfield loamy sand	1.0 - 1.4	0.75 - 1.0
Hanford sandy loam	1.4 - 2.0	1.00 - 1.5
Ripperdan sandy loam	1.4 - 2.2	1.00 - 1.6
Dinuba sandy loam	2.5	1.75
Vernalis loam	2.5	1.75
Pleasanton clay loam	3.8	2.25
Vernalis clay loam	4.4	2.40
Meyers clay	5.2	2.60
Wyman loam	2.6	1.8

* Total water-holding capacity of the soil expressed in inches of water per foot of soil. This is the amount often reported with neutron probe measurements and includes available water and unavailable water.

** Amount of water available to the plant expressed in inches of water per foot of soil.

A plant can extract all of the available water from its root zone; although, as the majority is used, plant water deficit will occur. When scheduling an irrigation, application should occur before the majority of the available water is depleted to minimize the effects of water deficits.

The following table shows normal rooting of mature plants on good soil. It is only necessary to irrigate deep enough to supply the roots. Excess water can stand on fields and drown crops; or in sandy soils, it can be lost through deep percolation.

Crop	Avg. Rooting Depth When Mature (feet)*
alfalfa	3 - 6
almonds (almond root)	8 - 12
almonds (peach root)	6 - 7
apricots (apricot & plum roots)	4 - 4
beans	3 - 4
berries (Boysen)	2 - 4
strawberries	1.5 - 2
corn	2 - 6
grain	3 - 4
grapes	4 - 9
irrigated pasture	2
peaches	5 - 7
sudan	4 - 6
beets (sugar)	4 - 6
tomatoes	4 - 6
walnuts	5 - 10
watermelons	4 - 6
turf	0.5 - 1.5

* Rooting depths are expressed as a range in feet, assuming no barriers (compaction, hardpan, etc.) and the plants are allowed to root unrestrained in medium textured soils.

Rainfall stored in the soil profile which will be available and used by the crop varies depending upon both duration and intensity of winter rainfall. Measurements of soil water on April 1, 1988, indicated 5.7 inches available water in an 8-foot root zone of a perennial crop. In annuals (with a smaller root zone), the amount would, of course, be less. Most of this available moisture was in the top four feet of soil. In a normal season, 8-12 inches would be expected in this area.

Irrigation System

Measuring Irrigation. When using crop water use estimates and replacing that use by irrigation, it is essential that one be able to measure the applied water volume. The easiest system to measure is a controlled point application system, such as sprinkler or drip irrigation since the sprinkler or dripper volume is known or can easily be measured by catching outflow. It is much more difficult for an irrigator to estimate the applied water volume in a furrow or border check system. To determine application rate for these systems, use pump test data, ditch flow, or siphon flow tables available in the Appendix.

Irrigation Efficiency. Irrigation system inefficiencies due to water losses from deep percolation and runoff should be reduced as much as possible. Water losses exist even in the best designed and operated systems, requiring field water applications to be greater than crop water use.

Estimated Irrigation System Efficiency

System	Efficiency
New, well-maintained sprinkler	75% - 80%
Basin check (flood)	
1 to 2 acre basins	70%
Well managed	
1/2 to 1 acre basins (short runs)	70%
Furrow irrigation	40% - 60%
Furrow with return system	60% - 70%

Crop Water Use, Typical Irrigation Efficiency, and Estimated Gross Irrigation Requirement for Various Crops (Without Winter Rainfall Soil Storage)

Crop	Seasonal ET (inches)	Typical Efficiency (Percent)	Estimated Gross Irrigation Requirement (inches)
alfalfa	40.8	75	55
almonds	35.8	80	45
apricots	34.3	70	49
beans	17.5	60	30
corn	25.2	70	36
grains	12.0	70	18
grapes	21.6	70	31
pasture	44.0	65	68
peaches	37.7	70	54
sudan	23.0	70	33
sugar beets	28.0	55	51
tomatoes	25.5	55	47
walnuts	38.6	70	56

Distribution Uniformity. The uniformity of water application within the field may be the single most important factor when attempting to make the most of a limited water supply. The uniform application of irrigation water insures each area of the field, top to bottom of the irrigation run, receives the same (or close to the same) amount of infiltrated water. A sprinkler or drip system depends on its design criteria to insure adequate distribution uniformity. A furrow or border system relies on the soil and slope to move water across the surface from field top to bottom, making the inflow volume and set time of most importance. The time the water is exposed to the soil has a large effect on the amount of water infiltrated at the top and bottom of the run and, therefore, the distribution of infiltrated water. An irrigator should attempt to maximize distribution uniformity by using a large stream to quickly cover the entire run while returning the tail water or cutting back the onflow volume to reduce run off. Another strategy would be to shorten the run length.

Calculating Seasonal Water Requirement

Example:
given conditions:

crop: wine grapes
soil: sandy loam
root zone: 6 feet
winter storage: 5.7 inches
seasonal water use: 21.6 inches
irrigation system type: furrow
estimated irrigation efficiency: 80% = 0.80

$$21.6 - 5.7 = \frac{15.9}{.80} = 19.9"$$ **seasonal gross irrigation requirement**

Scheduling the Irrigation

Adequate water supply. **In our example above, 19.9 inches of irrigation would be required for a mature, wine grape vineyard during the entire 1988 season. In an adequate water supply season, a wine grape grower would schedule an irrigation when the available water contained in the root zone was depleted by crop use to a level which would not cause detrimental effects to yield and quality due to water deficit. The water capacity and depth of root zone would be of prime concern in planning an irrigation volume. The example indicates a sandy loam soil with an available water holding capacity of 1.25 inches per foot (typical Hanford sandy loam). When approximately 50 percent of the available water is used, the plant visual symptoms indicate and irrigation is required. Since the active root zone is 6 feet, the gross irrigation volume would be determined by:**

$$(1.25) \times (.50) \times 6 = \frac{3.75}{.80} = 4.7 \text{ inches}$$

Soil moisture monitoring devices can be used to indicate the soil water status as an indicator of when to schedule the irrigation. Tensiometers, resistance blocks, as well as neutron probes can be used. These devices are also useful for evaluating the effectiveness and uniformity of an irrigation.

Reduced water supply. **Under conditions of reduced water supplies, the scheduling decisions are made much more difficult and differ from annual to perennial crops.**

> ***Annual crops.*** **Research and experience has shown the result of supplying less than full water requirement in other than a few crops, such as cotton, results in reduced yield and quality. The following table presents data from an experiment showing the effect of deficit drip irrigation on tomato yield.**

Water Applied (inches)	ET (inches)	Fruit Yield Total (tons/acre)	Fruit Yield Ripe (tons/acre)	Relative ET (%)	Relative Ripe Fruit Yield (%)
26.9	25.0	82.3	59.5	100	100
21.7	22.6	64.2	50.3	90	85
16.1	17.7	48.0	38.2	71	64

Perennial crops. Perennial crops are more complex in that water is required for different distinct requirements.

1) vegetative growth
2) bloom
3) crop sizing and quality
4) bud development
5) storage of carbohydrates

Vegetative growth is of most concern in young orchards. Attempts should be made to control irrigation to maximize growth by limiting the distribution of the water to the smaller tree's root zone. During bloom, adequate moisture is in the soil from winter rainfall. Bud development and differentiation for the next season's crop begins in midseason and can be affected by severe water deficits into late season. Therefore, the full impact of water deficits may not be fully realized until the next season.

How do you irrigate when there is not enough water? First, some crop yield loss and quality reduction will occur. If water supplies are further restricted, reducing yields drastically, concern for the next year's crop is in order. A grower who has flexibility in scheduling irrigations can allow the crop to undergo moderate water deficits reducing water use, then replenishing the supply period. Repetitive use of this strategy can reduce water use with the least impact on this year's and subsequent year's yield and quality.

The current consensus generally supports the contention that if deciduous orchards and vines are to be water-stressed, the least impact would be observed by post harvest water stress, rather than during the earlier part of the season. Crops such as peaches, which are early fruiting and require adequate moisture for sizing, should be stressed only after harvest.

Our best estimates of the net irrigation requirement for perennial crops are listed in the following table. Caution! These amounts are only enough to ensure survival of the tree with some hope of crop for next season considering a full supply of water in the next year.

Crop	Minimum Net Irrigation Required (in.)	Approx. Irrigation Prebloom	Post Bloom
almond	18	6	May (6), June 6
grapes	12	6	Late June (6)
apricot	24	12	May (4), June (4), July (4)
peach, clingstone early varieties	24	6	Mid-April (4), late May (4), June (4), July (4), Aug (2)
late varieties	26	6	Mid-April (4), late May (4), June (4), July (4), Aug. (4)
walnuts	26	8	Late May (6), June (6), Aug. (6)

STRATEGIES FOR LIMITED WATER SUPPLY

These strategies can help growers cope with reduced water supplies, minimizing the effect both horticultural and economic hardships this season and the following 1988-89 season.

- **Start the season with the crop's root zone full of moisture (field capacity). This provides a readily available supply of water, allowing the roots to fully explore the soil profile. *Remember, roots will not penetrate dry soil!***

- **Texture of soil should determine the size of irrigation checks--sandy soil should be leveled into smaller acreages than finer clay soils. On sandy soil, one acre is usually the most practical size check, with maximum lengths of checks of 700 to 800 feet. On fine type soils, one- to two-acre checks are generally the most practical size checks to manage. Irrigation checks larger than two acres often require too much time to get water across, with the result of excess water on one end.**

- **Be realistic. Adjust the planted acres to the projected water supply, both as to its quantity and quality. Plant the best land.**

- **Be efficient. Run-off from the lower end of an irrigated field is usually reusable because its quality is only slightly degraded. If the irrigation water is usable, the run-off water should be recycled. Tail-water return flow systems will allow recovery of run-off for increased efficiency of irrigation.**

- **Careful land-planing or smoothing of irrigation checks aids in uniform water applications thus preventing percolation losses below the root zone. Land must be flat to irrigate quickly and evenly. A few extra minutes spent to get water on a high spot often puts too much water on lower areas.**

- **Long irrigation runs may cause excessive water application at the upper end and run-off at lower end. Water can be spread more rapidly and evenly by constructing and/or maintaining short and narrow irrigation checks and short furrows.**

- **Repair leaks in canals, ditches, pipelines, distribution systems, etc. Replace worn orifices in nozzles of sprinkler heads. Head gates should be tight--a 1/2-inch gap in headboards can waste several acre-inches of water a day. Gophers and rodents not only cause a loss of water through dikes and ditches, but do a great deal of damage each year to crops. Control gophers with poison bait or traps.**

- **Better distribution uniformity can be obtained when irrigating by sprinklers if high wind conditions are avoided. In some locations this can be accomplished by irrigating during the hours of darkness.**

- **Match water applications closely to crop needs. The amount of water to be applied to refill the soil just to the depth of rooting. Evapotranspiration data can be used to estimate the rate of water use by any particular crop. Also, the soil capacity for water storage in the root zone can be estimated. Then a simplified budget procedure can be followed to determine approximate time of irrigation and amount to be applied without wasting water.**

- Control weeds and cover crops. Weeds use water and compete with crops for valuable moisture. Normal evaporation from the surface of weed-free land only dries the soil to a depth of 2-4 inches. Irrigation canals or ditches and areas between trees and vines should all be kept weed-free by using herbicides, a weed knife, or mowers. Frequent shallow disking between each irrigation for weed control is beneficial, but this practice does not conserve as much water as frequent mowing or chopping. If no weeds are present, cultivation between irrigations is not necessary.

- Leaching for salinity control should be kept to the minimum dictated by crop tolerance and a realistic yield expectation for the supply of water available. Seldom does average soil salinity of a root zone build up to damaging concentrations during a one- or two-year period.

- Fertilization. A strong vigorous plant and root system will make better use of available water. Follow your normal fertilization practices. Higher than usual application rates will not be beneficial.

- Select crops and growing seasons, where possible, which use less water. By combining planting dates with selected varieties, it is possible to save some water by shortening the growing season and/or avoiding high evaporative demand periods. Small grains and, to some extent, safflower will use significantly less water than summer season field crops.

- Most crops, if supplied with less than full evapotranspiration requirements, will produce less than maximum yields; though in some crops, the reduction in yield is less marked than in others. If you have poor pasture that is not producing feed, there are several alternate crops which have lower water requirements and produce large amounts of feed such as sudan and corn for grain. A good alternate field crop is beans. Cotton, sorghum, and wine or raisin grapes are crops relatively insensitive to reduced water supply. Alfalfa, corn silage, and pasture are examples of crops sensitive to water deficiency.

- Know your head of water. A 15-cubic feet per second head of water will irrigated one acre with 6 inches of water in 24 minutes when land is level.

APPENDIX

Water Measurement

In order to determine water measurements and provide a basis for comparison, several terms should be defined.

1 gallon	=	8.3 pounds
1 cubic foot	=	7.5 gallons
1 acre foot	=	12 acre inches
	=	325,851 gallons
1 cubic foot per second	=	450 gallons per minute
	=	1 acre inch per hour
15 cubic feet per second	=	5 acre inches in 20 minutes

A simple formula for estimating the amount of water applied:

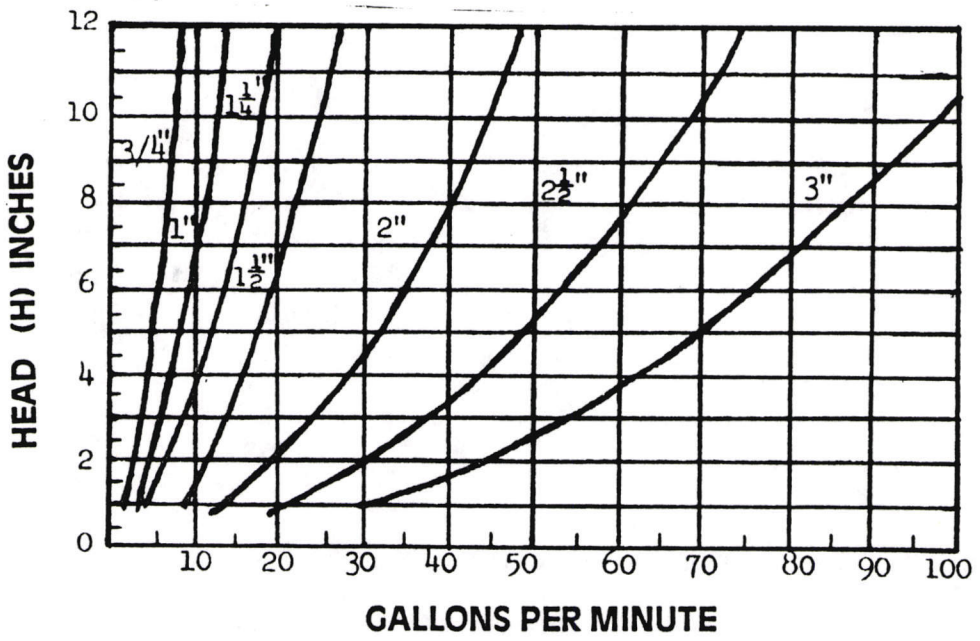
$$\text{inches applied} = \frac{\text{Head x Time}}{\text{Acres}}$$

Where: Head is expressed in cubic feet per second
Time is expressed in hours

Furrow Irrigation

The following figure provides a guide for determining the rate of flow through small siphons. The head (measured in inches) is defined as the difference in height of the water surface in the supply ditch and the height of the water surface at the discharge end of the siphon (furrow).

Rate of Flow Through Small Siphons



Border Check Irrigation

The following tables can be used as guides in determining how long irrigation is required to obtain a desired amount of water. For example, using both tables, a 15-cubic-feet-per-second head will provide sufficient water in 1 hour to saturate 5 acres of sandy soil to a depth of 24-36 inches.

Table of Various Heads of Water & Application

Flood (sec. ft.)	Acres of Land to be Irrigated With This Head	Applied Depth	Time
2	1	6"	3 hrs.
4	1	6"	1.5 hrs.
6	1	6"	1 hr.
15	1	3"	12 min.
15	1	6"	24 min.
15	3	3"	36 min.
15	3	6"	72 min.
15	5	3"	1 hr.
15	5	6"	2 hrs.

How deep will water saturate your soil?

Acre/in. Applied	Sand	Loam	Clay
1 inch	6 - 12 in.	4 - 6 in.	3 - 4 in.
2 inches	12 - 24 in.	8 - 12 in.	6 - 8 in.
3 inches	24 - 36 in.	12 - 18 in.	9 - 12 in.
4 inches	36 - 48 in.	16 - 24 in.	12 - 16 in.
5 inches	48 - 60 in.	20 - 30 in.	15 - 20 in.
6 inches	60 - 72 in.	24 - 36 in.	18 - 24 in.

Sprinkler, Drip Irrigations

These controlled application methods of irrigation are best measured using a volumetric container and stop watch to determine the rate of application per unit area. Area is determined by the distance between sprinklers. The following chart gives typical spacings and flow per sprinkler to estimate gross application rates.

Drip irrigation typically provides a number of emitters per plant. Knowing the emitter flow rates and spacing, one can calculate the gross application rate.

Spacing Feet	Gallons per Minute From Each Full Circle Sprinkler				
	1	2	3	4	5
20 x 20	.24	.48	.72	.96	1.20
20 x 30	.16	.32	.48	.64	.80
20 x 40	.12	.24	.36	.48	.60
25 x 25	.15	.30	.46	.61	.77
30 x 30	.11	.21	.32	.43	.54
30 x 40	.08	.16	.24	.32	.40
30 x 45	.07	.14	.21	.29	.36
30 x 50	-	.13	.19	.25	.32
30 x 60	-	.11	.16	.21	.27
40 x 40	-	.12	.18	.24	.30
40 x 50	-	.10	.14	.19	.24
40 x 60	-	-	.12	.16	.20

Water Quality Concerns

Irrigated agriculture will always be confronted with potential salinity and water quality problems. Water used for irrigation purposes contains salts. Most of the salt added by the irrigation water is left behind in the soil as water is removed by the crop. These salts tend to accumulate and compete with the plant for soil moisture. Other cultural practices also involve adding salts to the soil (pesticides and fertilizers are salts).

Low rainfall years accentuate the salinity problem as the salts are not washed down (leached) out of the root zone. Salts tend to move with the front of the water; to leach salts, water must be applied to the top of the soil (rain, sprinklers, or flood irrigation). Furrow irrigation tends to concentrate the salts in the beds, many times only leaching the furrow bottoms.

The effects of salinity and methods of dealing with saline conditions have been the subject of numerous studies. These studies have also included permeability effects and specific ion (sodium, chloride, boron) toxicities. A set of guidelines for interpretation of irrigation water quality has been developed in order to assist growers and water managers. General water quality guidelines are given in the following table.

Guidelines for Interpretation of Quality of Water for Irrigation

Interpretations are based on possible effects of constituents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil and methods of irrigation.

Potential Irrigation Problem	Units	Degree of Restriction on Use None	Slight to Moderate	Severe
Salinity **(affects crop water availability)**				
ECw*	dS/m	< 0.7	0.7 - 3.0	> 3.0
or				
TDS	mg/l	< 450	450 - 2000	> 2000
Infiltration **(affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)****				
SAR = 0 - 3 and ECw =		> 0.7	0.7 - 0.2	< 0.2
= 3 - 6 =		> 1.2	1.2 - 0.3	< 0.3
= 6 - 12 =		> 1.9	1.9 - 0.5	< 0.5
=12 - 20 =		> 2.9	2.9 - 1.3	< 1.3
=20 - 40 =		> 5.0	5.0 - 2.9	< 2.9
Specific Ion Toxicity **(affects sensitive crops)**				
Sodium (Na)				
surface irrigation	SAR	< 3	3 - 9	> 9
sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)				
surface irrigation	me/l	< 4	4 - 10	> 10
sprinkler irrigation	me/l	< 3	> 3	
Boron (B)	mg/l	< 0.7	0.7 - 3.0	> 3.0
Miscellaneous Effects **(affects susceptible crops)**				
Nitrogen (NO_3 - N)	mg/l	< 5	5 - 30	> 30
Bicarbonate (HCO_3) (overhead sprinkling only)	me/l	< 1.5	1.5 - 8.5	> 8.5
pH		Normal Range 6.5 - 8.4		

* EC = electrical conductivity reported in dS/m or mmhos/cm; to convert to ppm, multiply EC x 640.

** SAR = sodium adsorption ratio, sometimes reported by the symbol RNa. At a given SAR, infiltration rate increases as water salinity increases.

Crops vary in their susceptibility to soil and water salinity levels. The following table depicts potential yield losses due to varying soil (ECe) and water (ECw) salinity levels for selected crops. As you review the levels developed by UC and USDA, keep in mind that germinating seeds and seedlings are less tolerant than mature plants.

Salinity Tolerances of Crops

	0 Percent[1]		10 Percent[1]		25 Percent[1]		50 Percent[1]	
	ECe[2]	ECw[3]	ECe	ECw	ECe	ECw	ECe	ECw
barley	8.0[4]	5.3	10.0[4]	6.7	13.0	8.7	18.0	12.0
sugar beets	7.0[4]	4.7	8.7[4]	5.8	11.0	7.5	15.0	10.0
wheat	6.0[4]	4.0	7.4[4]	4.9	9.5	6.4	13.0	8.7
safflower	5.3	3.5	6.2	4.1	7.6	5.0	9.9	6.6
sorghum	4.0	2.7	5.1	3.4	7.2	4.8	11.0	7.2
sudan grass	2.8	1.9	5.1	3.4	8.6	5.7	14.4	9.6
tomato	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0
cantaloupe	2.2	1.5	3.6	2.4	5.7	3.8	9.1	6.1
alfalfa	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9
spinach	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7
corn silage	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7
walnut	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2
peach	1.7	1.1	2.2	1.4	2.9	1.9	4.1	2.7
apricot	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5
pepper	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4
almond	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.7
onion	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9
beans	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4

[1] Yield loss to be expected due to salinity.
[2] ECe = measure of soil salinity (to convert to ppm, multiply EC x 640).
[3] ECw = measure of irrigation water salinity (to convert to ppm, multiply Ec x 640).
[4] Tolerance during germination (beets) or early seedling stage (wheat, barley) is limited to ECe about 4 mmhos/cm.

Interpretation of water quality guidelines require certain laboratory determinations and calculations. For more detailed information, please refer to FAO Irrigation and Drainage paper #29, Rev. 1, 1985.