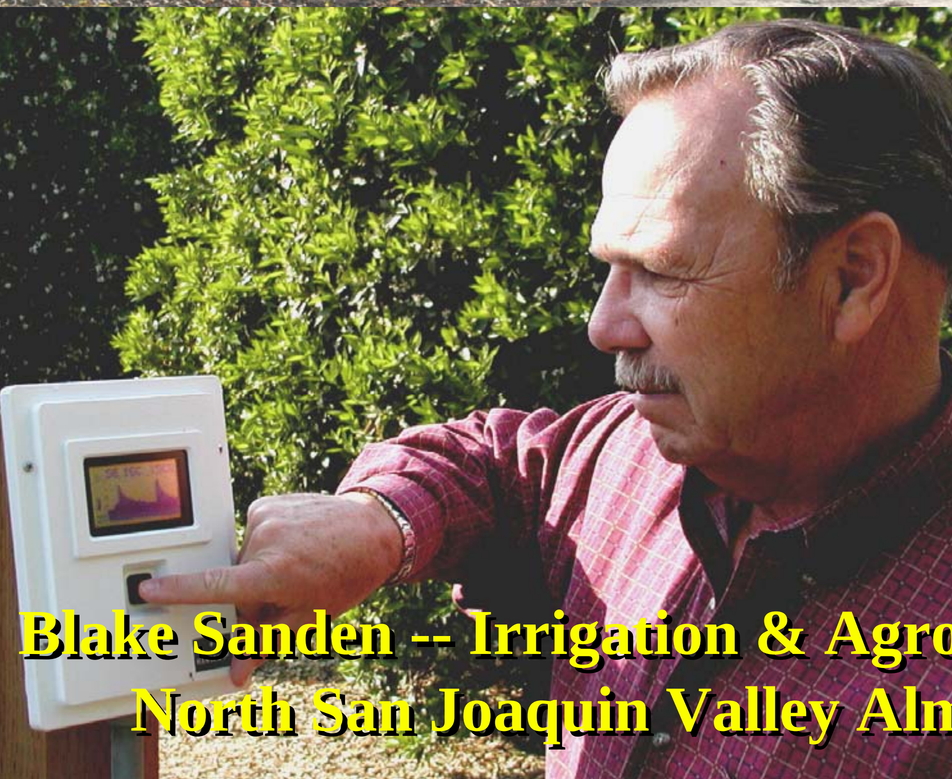
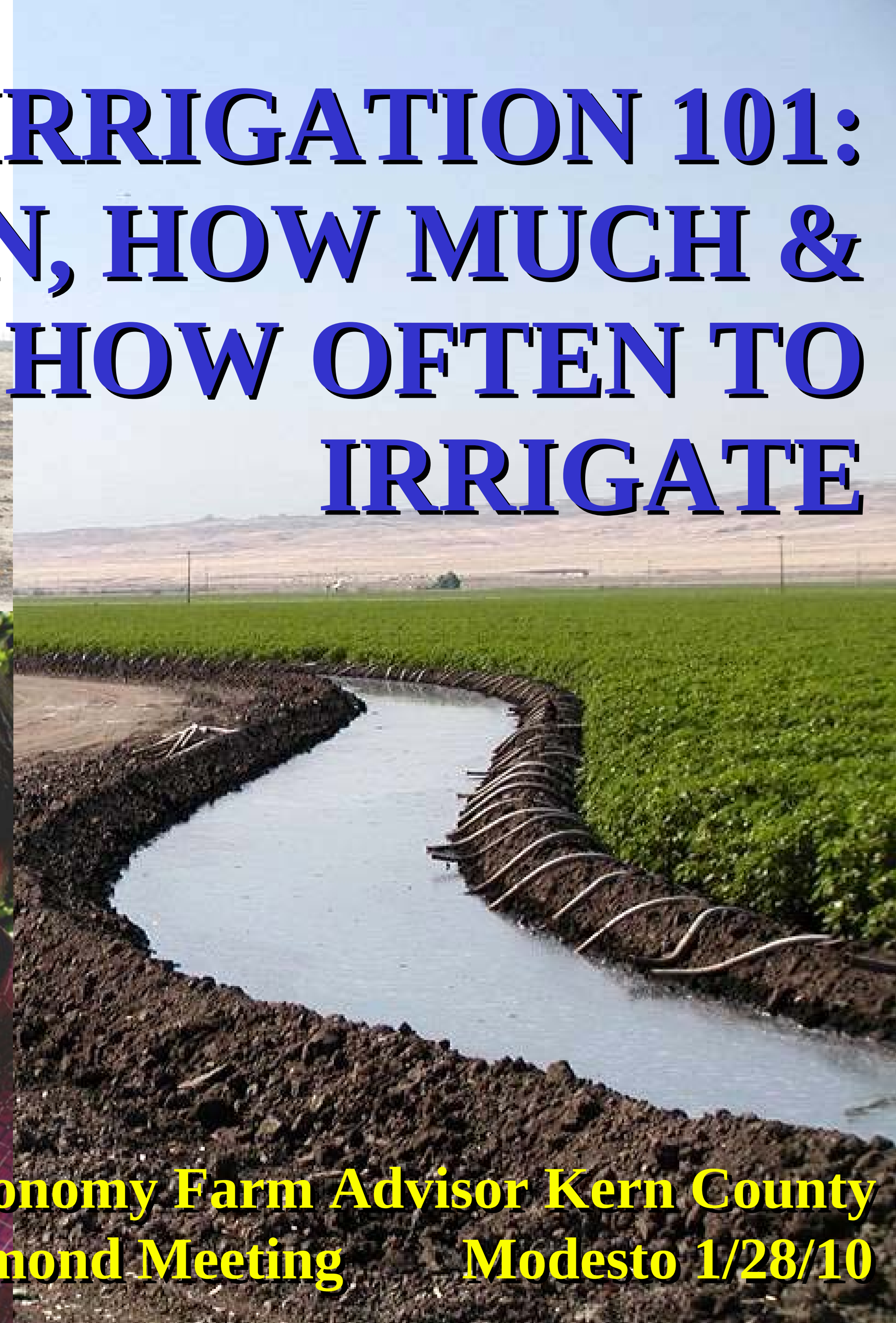




UNIVERSITY of CALIFORNIA COOPERATIVE EXTENSION

IRRIGATION 101: WHEN, HOW MUCH & HOW OFTEN TO IRRIGATE

Blake Sanden -- Irrigation & Agronomy Farm Advisor Kern County

North San Joaquin Valley Almond Meeting   Modesto 1/28/10

The District's cutting me back to 1.5 feet of water, but I need at least 3 to 4 feet to get my crop off.

California is not building more dams. We're in a drought. Urban and environmental demands further restrict supply and increase uncertainty. Ag water conservation is our only alternative to buying expensive "emergency pool" water.

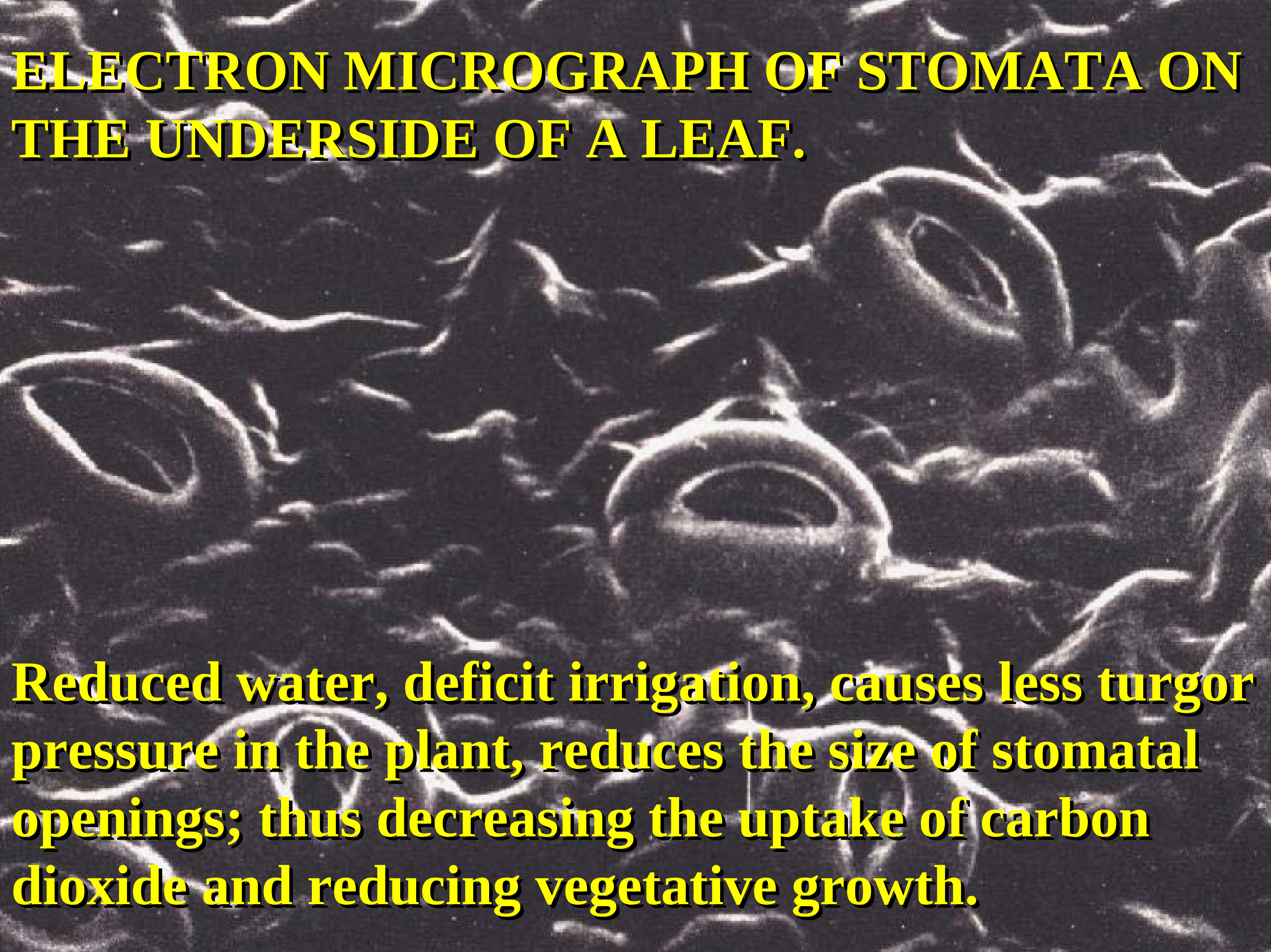
What are my options?

- Tailwater return system
- Shorten run lengths
- Pump groundwater
- Time irrigation with ET
- Install drip / micro
- Get monitoring equip
- Get a consultant
- Buy water for $300/ac-ft
- Deficit irrigate
- Eat Delta Smelt!

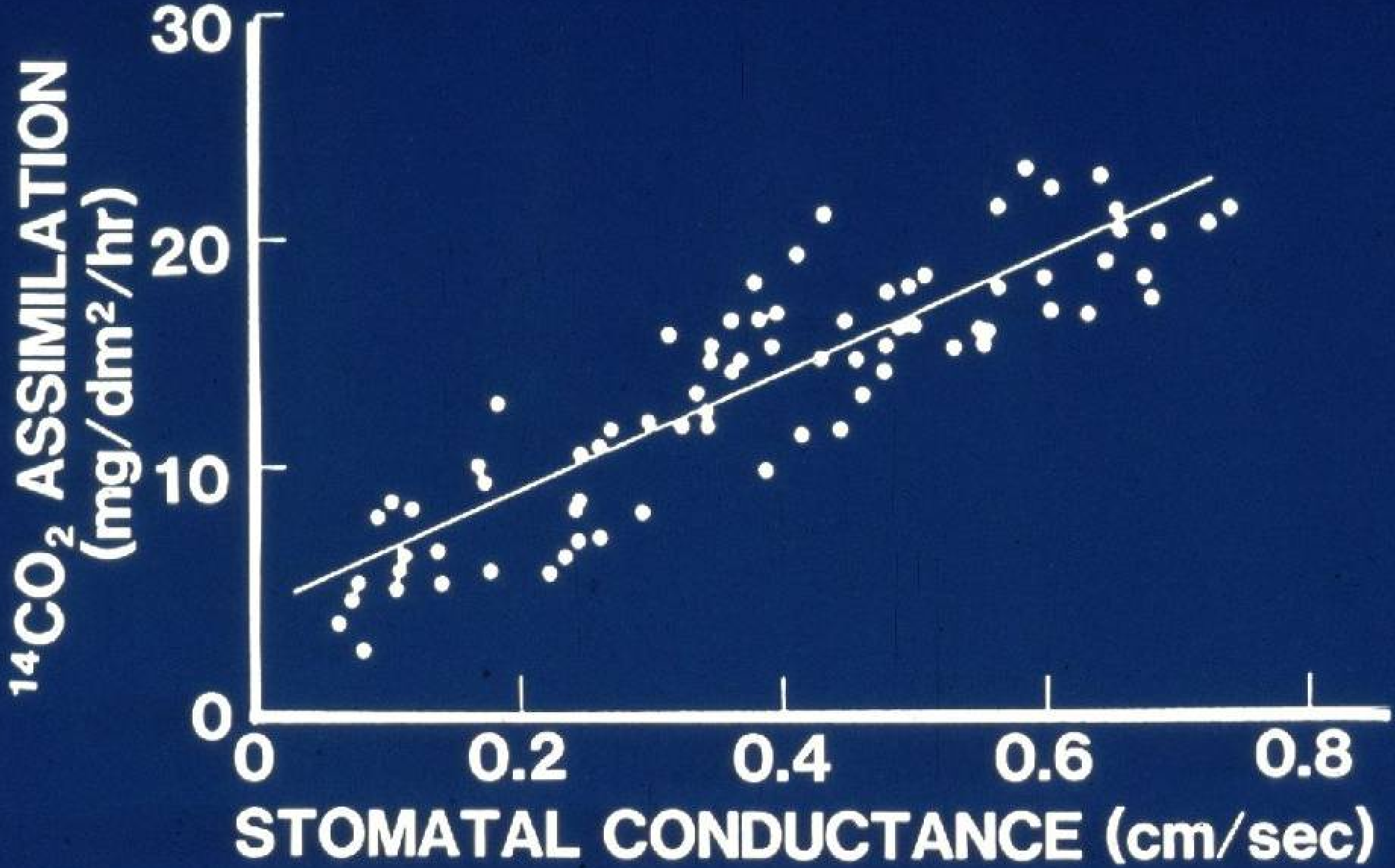
What’s the critical process that keeps the crop growing?

- **Optimal photosynthesis**
- **Maximum carbon dioxide uptake**

ELECTRON MICROGRAPH OF STOMATA ON THE UNDERSIDE OF A LEAF.



Reduced water, deficit irrigation, causes less turgor pressure in the plant, reduces the size of stomatal openings; thus decreasing the uptake of carbon dioxide and reducing vegetative growth.



30
20
10
0
$^{14}CO_2$ ASSIMILATION
(mg/dm²/hr)
0
0.2
0.4
0.6
0.8
STOMATAL CONDUCTANCE (cm/sec)

Before we continue, a public service reminder …

This is your crop.

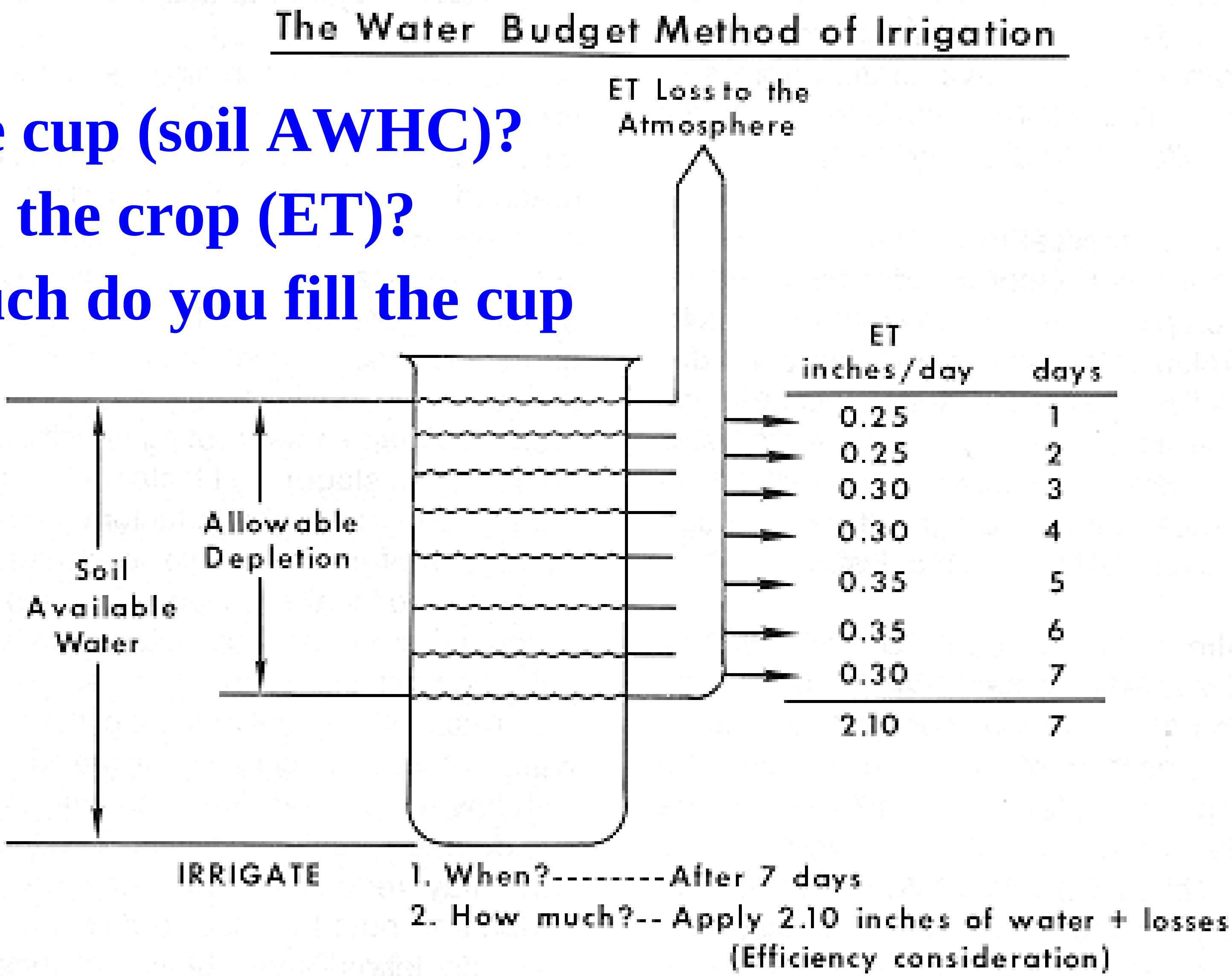
This is your crop on reduced water.

I’m screwed!

Any questions?

Creating the efficient field water balance – your soil moisture checking account!

- How big is the cup (soil AWHC)?
- How thirsty is the crop (ET)?
- How often/much do you fill the cup (Scheduling)?



SO WHAT'S ESSENTIAL for an OPTIMAL WATER BALANCE?

- **ESSENTIAL**

1 : something basic <the essentials of astronomy>

2 : something necessary, indispensable, or unavoidable

(Merriam-Websters Dictionary)

---

3 : Making 4,000 lb/ac nut meats! (Westside Almond Growers)

(Page 1)

<u>Sanden definition</u>

1. **<u>SOIL/WATER:</u> Optimizing all factors / knowledge that affect irrigation uniformity, scheduling and water use efficiency.**
2. **<u>CROP:</u> Adjust crop rotation choices to fit water supply / quality.**
3. **<u>TECHNOLOGY:</u> Adopt techniques and technology to track changes in soil/plant water status.**


“Essential” is just the basics, right?
So can flood irrigation with 8 inch
alfalfa valves @ 200 gpm be optimal?


What about 18 inch
valves @ 2000 gpm?


… or do you need this kind of system …

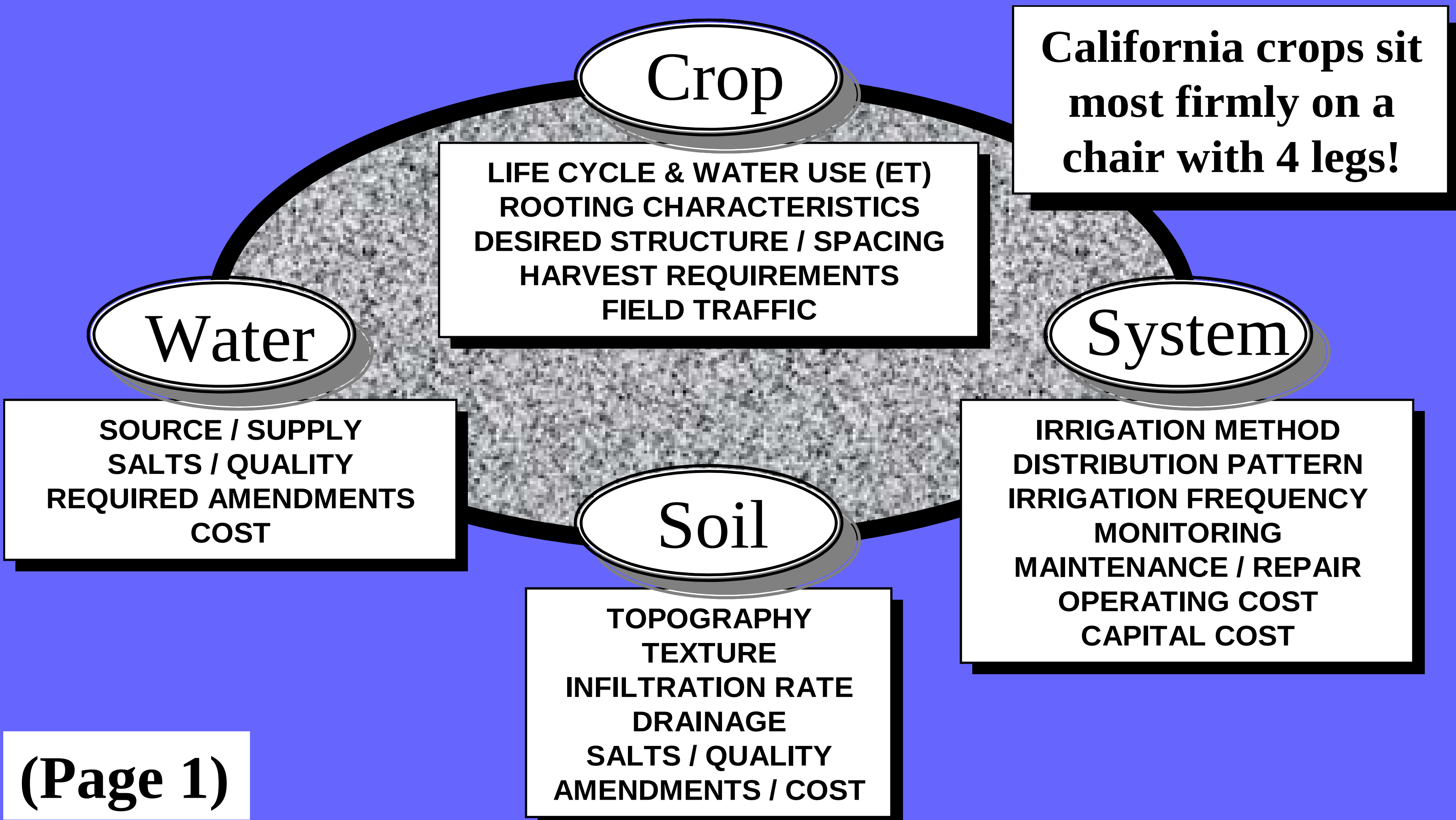
… and this much technology?

YES . . .

NO . . .

DEPENDS.

The irrigation method / system is the "ESSENTIAL" integrating factor for creating an optimal water balance.



(Page 1)

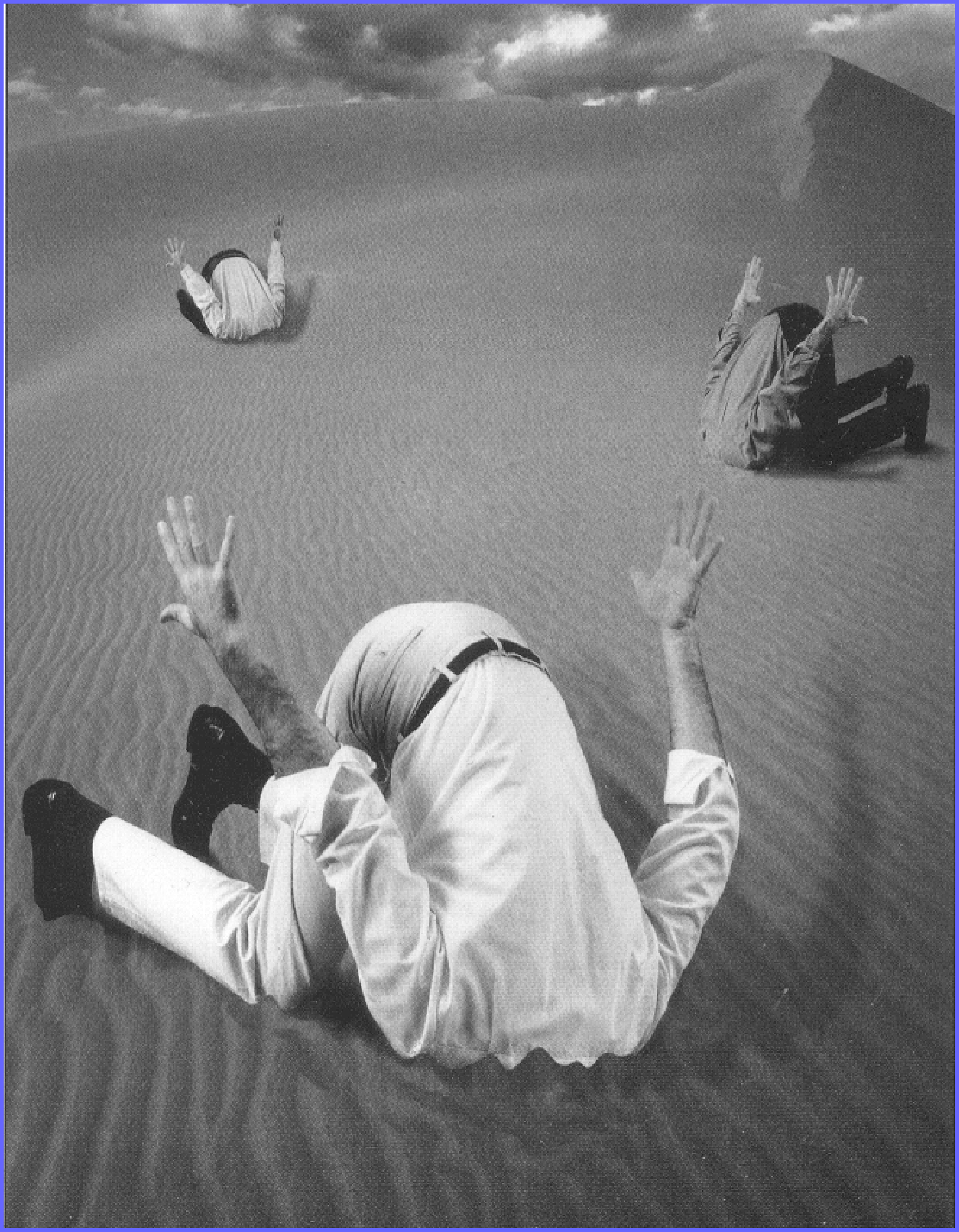
ESSENTIALS to OPTIMIZE CROP PRODUCTION

(Page 1)

- **AVAILABLE WATER**
- **ROOTZONE AERATION**
- **SUFFICIENT ROOTED VOLUME FOR ANCHORING AND NUTRIENTS**
- **AVAILABLE NUTRIENTS – N, P, K, Zinc, Boron, Iron**
- **AVOID SATURATION & HIGH HUMDITY TO DECREASE DISEASE**
- **CROP STRUCTURE FOR MAXIMUM PHOTOSYNTHESIS & FRUIT DEVELOPMENT**
- **EQUIPMENT FOR TIMELY OPERATIONS**

So how do you set up, monitor & optimize a field water balance?

There's got to be a better way!



~~4~~ 3-point sermon:

- Understanding soil water holding characteristics
- Monitoring soil moisture & irrigation uniformity impacts on yield
- Crop water requirements (ET), CIMIS
- ~~Irrigation & crop salinity tolerance~~

Check your dirt! It has more secrets than the CIA.

Check your dirt!

SOIL PROFILE

–SOIL TEXTURE

Analysis:

SP	**48 -- saturation %**
pH	7.8
EC_e	2.0 dS/m
Texture	Silty Clay Loam

SOIL SURVEY

BACKHOE PITS

AUGER, PUSH PROBE

mottles, dark yellowish brown (10YR 4/6) moist; weak fine subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; many very fine and few fine roots; common very fine and few fine tubular pores and many very fine interstitial pores; neutral; clear wavy boundary.

IIIC8—48 to 56 inches; white (10YR 8/1) silt loam, gray (10YR 5/1) moist; common medium prominent brownish yellow (10YR 6/8) mottles, dark yellowish brown (10YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; many very fine and common fine roots; many very fine and common fine tubular pores and common very fine interstitial pores; neutral; clear wavy boundary.

IXC9—56 to 65 inches; very pale brown (10YR 8/3) sand, grayish brown (10YR 5/2) moist; few fine prominent brownish yellow (10YR 6/8) mottles, dark yellowish brown (10YR 4/6) moist; single grain; loose, nonsticky and nonplastic; many very fine interstitial pores; neutral.

The soil is noneffervescent below a depth of 11 to 20 inches.

The A horizon has dry color of 10YR 5/2, 5/3, 6/2, or 6/3 and moist color of 10YR 4/2, 4/3, or 5/3. Clay content is 10 to 18 percent.

The C horizon has dry color of 10YR 6/2, 6/3, 6/6, 7/2, 7/3, 8/1, or 8/3 or 2.5Y 6/2 and moist color of 10YR 3/2, 3/3, 4/2, 4/6, 5/1, 5/2, or 5/3 or 2.5Y 4/2 or 6/2. Mottles have dry color of 10YR 5/6, 6/6, 6/8, or 8/3 or 7.5YR 5/4 and moist color of 10YR 3/6, 4/6, or 5/3 or 7.5YR 5/4. Texture is stratified sand, loamy sand, loamy fine sand, sandy loam, fine sandy loam, loam, or silt loam. Clay content is 10 to 18 percent. Reaction is slightly acid to moderately alkaline.

Exeter Series

The Exeter series consists of moderately deep, well drained soils on broad alluvial terraces. These soils formed in alluvium derived dominantly from granitic rock. Slope is 0 to 9 percent.

Soils of the Exeter series are fine-loamy, mixed, thermic Typic Durixeralfs.

Typical pedon of Exeter sandy loam, 0 to 2 percent slopes (fig. 4); on an alluvial terrace where slopes are 1 percent; about 3 miles west of Highway 65 on Highway 155, 150 feet north and 200 feet west of the southeast corner of sec. 7, T. 25 S., R. 27 E.; Richgrove Quadrangle.

Ap—0 to 4 inches; pale brown (10YR 6/3) sandy loam, dark brown (10YR 3/3) moist; weak very coarse platy structure; very hard, friable, nonsticky and nonplastic; common very fine roots; many very fine interstitial pores and few very fine tubular pores; neutral; clear smooth boundary.

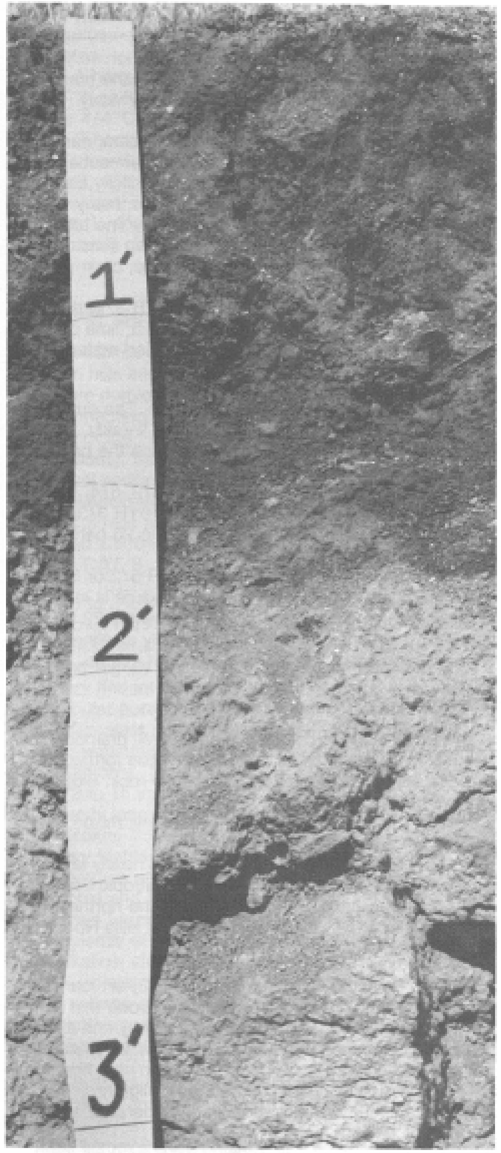
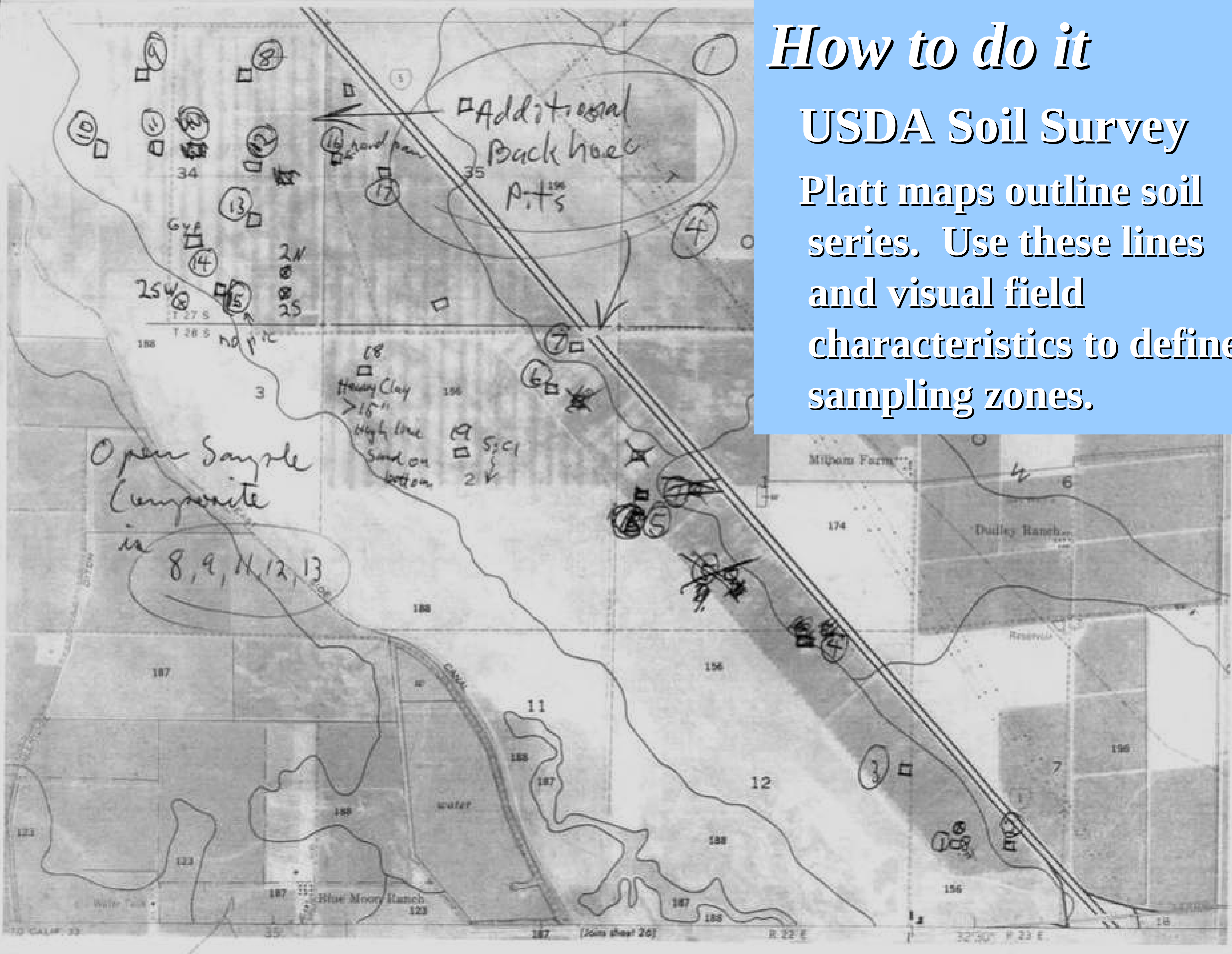


Figure 4.—Profile of Exeter sandy loam, 0 to 2 percent slopes. A duripan is at a depth of about 24 inches.

How to do it

USDA Soil Survey

Platt maps outline soil series. Use these lines and visual field characteristics to define sampling zones.



How to do it

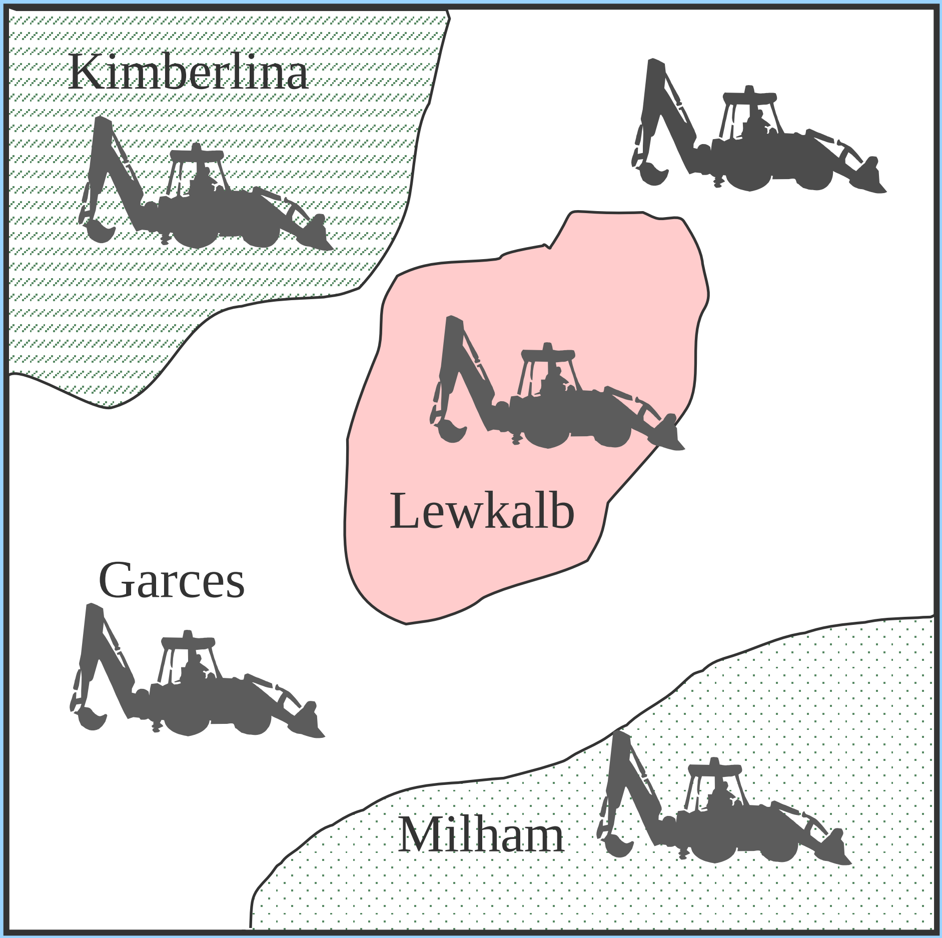
- **AERIAL/SATELITE PHOTOS**

How to do it *(pg 41)*

- **SOIL PROFILE**
- **SOIL TEXTURE -- Sampling scheme for variable 160 acres**

- Use soil probe or auger to composite sample 0-1 & 1-2 foot depths from at least 8 holes 50 feet apart for each soil type.

- Put at least one backhoe pit to 6 feet in each 40 acres of one soil type. Take deeper samples from pits.



Backhoe Pits – the Worm's Eye View!

Backhoe Pits – the Worm's Eye View!

Deep, well drained, non-alkali sandy to sandy clay loam

How to do it

- COLLECTING SAMPLES @ DEPTH IN SOIL PITS

A "composite" sample made up of subsamples taken from 6 to 12 locations throughout the *zone of interest*

How deep should you go? Do you discount high-lime layers?

SOIL TEXTURE DETERMINES AVAILABLE WATER HOLDING CAPACITY

SOIL TEXTURE
"FEEL METHOD"

(Page 2)

$$\text{AWHC} = \%\text{Volume} = \frac{\text{inch depth of water}}{\text{1 foot depth of soil}}$$

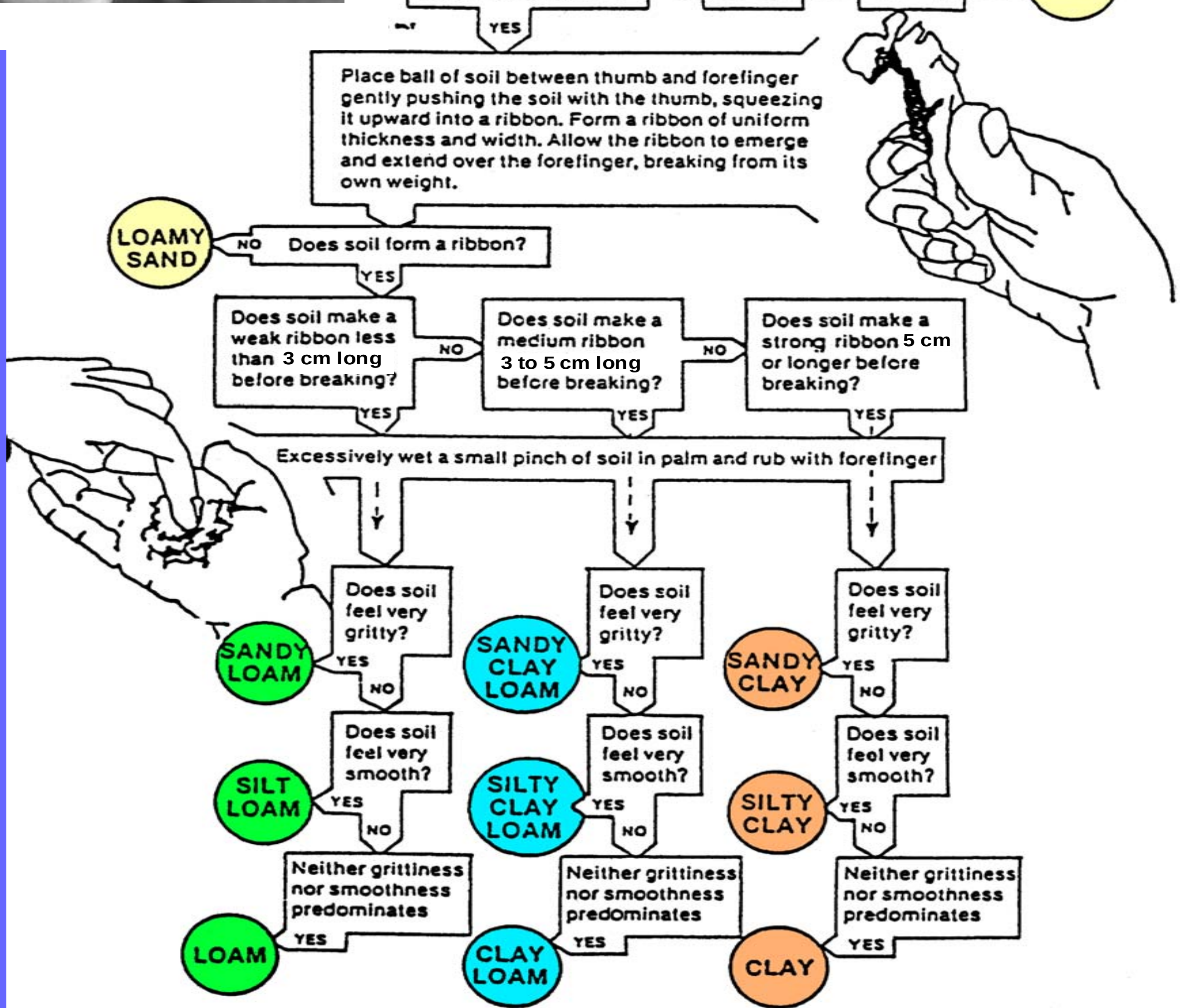
The “dirt” is the thing. Know your soil!

Soil Texture	Field Capacity (in/ft)	Wilting Point (in/ft)	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	*Moisture Reserve (gals)
Sand	1.2	0.5	0.7	2	4
Loamy Sand	1.9	0.8	1.1	3	16
Sandy Loam	2.5	1.1	1.4	4	35
Loam	3.2	1.4	1.8	5	70
Silt Loam	3.6	1.8	1.8	6	102
Sandy Clay Loam	3.5	2.2	1.3	7	100
Sandy Clay	3.4	1.8	1.6	7	123
Clay Loam	3.8	2.2	1.7	8	170
Silty Clay Loam	4.3	2.4	1.9	9	241
Silty Clay	4.8	2.4	2.4	9	305
Clay	4.8	2.6	2.2	10	345

*This is the maximum gallons of water stored to a 4' depth beneath a single drip emitter. In fine textured soils, the wetted volume of one emitter merges with another on the same hose and final gallons of moisture reserve per emitter will be less than the number shown in the table. Plant stress will usually be seen when about 50% of this reserve has been used.

Ref: Ratliff LF, Ritchie JT, Cassel DK. 1983. Field-measured limits of soil water availability as related to laboratory-measured properties. Soil Sci Soc Am. 47:770-5.

SOIL TEXTURE
"FEEL METHOD" FLOWCHART



Simplified soil texture categories, associated USDA soil textures, approximate available water holding capacity (AWHC) and length of soil “ribbon”.

(Page 2)

Category	Textures	AWHC (in/12 inch soil)	“Ribbon” Length (inches)
Coarse	S / LS	0.6 – 1.2	None. Ball only.
Sandy	LS / SL / L	1.2 – 1.8	0.4 - 1
Medium	L / SCL	1.4 – 2.2	1 - 2
Fine	SiL / SiCL / CL / SiC	1.7 – 2.4	> 2

AWHC(in/ft soil) = length of ribbon

Table 3. Guide for Estimating Actual Available Field Soil Moisture by the "Feel" Method.

SOIL TEXTURE CLASSIFICATION								
Coarse (loamy sand)		**Sandy (sandy loam)**		**Medium (loam)**		**Fine (clay loam, silty clay loam)**		
Available Water (AW) in the Soil by Appearance (inches/foot soil)								
0.6-1.2 in/ft *AW@FC		**1.2-1.8 in/ft AW@FC**		**1.4-2.2 in/ft AW@FC**		**1.7-2.4 in/ft AW@FC**		
	AW		**AW**		**AW**		**AW**	Moisture Deficiency
Leaves wet outline On hand when	**1.0**	Appears very dark leaves wet outline	**1.6**	Appears very dark leaves wet outline	**1.9**	Appears very dark, leaves slight moisture	**2.2**	0
squeezed. Appears moist,	**0.7**	on hand, makes a short ribbon (0.5-0.75 inch)		on hand , will ribbon about 1 – 2 inches.	**1.7**	on hand when squeezed, will ribbon > 2 inches.		0.2
Makes a weak ball. Appears slightly		Quite dark color makes a hard ball.	**1.2**	Dark color, forms a plastic pall, slicks when rubbed.	**1.4**	Dark color will feel slick And ribbons easily	**1.8**	0.5
moist, sticks together slightly.	**0.4**	Fairly dark color, makes a good ball	**1.0**	Quite dark, forms a hard ball	**1.2**	Quite dark, will make		0.7
Dry, loose, flows thru fingers. (wilting point)	**0**	Slightly dark color makes a weak ball	**0.7**	Fairly dark, forms a	**1.0**	thick ribbon may slick when rubbed.	**1.4**	1.0
		Lightly colored by moisture, will not	**0.4**	a good ball		Fairly dark, makes a good ball.	**1.1**	1.2
		ball. Very slight color	**0**	Slightly dark, forms weak ball	**0.6**	Will ball, small clods will flatten out rather	**0.7**	1.4
		due to moisture. (wilting point)		Lightly Colored, small clods crumble	**0.2**	Slightly dark, clods	**0.4**	1.7
				Fairly easily. Slight color due to		Crumble. Some darkness due to		1.9
				moisture, small colds hard (wilting point).	**0**	unavailable moisture, clods are hard, cracked	**0**	2.2
						(wilting point)		

(Page 4)

* **AW@FC:** Available Water @ Field Capacity = the available water a soil can store against gravity after irrigation and drainage.

Adapted from: Merriam, J.L. 1960. Field method of approximating soil moisture for irrigation. Am. Soc. Agri. Engr. Vol. 3. No.1.

Simplest "feel" guidelines for fine sandy loam to clay loam

1. Ribbons easily: 90-100%
   Plastic ball: 70 – 80%
   Hard ball: 50 – 60%
   Crumbly ball: <50%
   crop can begin to stress

Calculated irrigation interval (days of moisture reserve) by month, soil texture and rooting depth

Mature Citrus		Assume managed rooting depth of 4 feet				
		Apr	May	Jun	Jul	Aug
Soil Texture	Avg Daily ET	0.14	0.17	0.18	0.20	0.14
Available Soil Moisture to 4 feet @ 50% depletion	(in)	Days of Moisture Reserve for Average Daily ET by Month				
Sand	1.4	10	8	8	7	10
Loamy Sand	2.2	16	13	12	11	16
Sandy Loam	2.8	20	16	16	14	20
Loam	3.6	26	21	20	18	26
Silt Loam	3.6	26	21	20	18	26
Sandy Clay Loam	2.6	19	15	14	13	19
Sandy Clay	3.2	23	19	18	16	23
Clay Loam	3.4	24	20	19	17	24
Silty Clay Loam	3.8	27	22	21	19	27
Silty Clay	4.8	34	28	27	24	34
Clay	4.4	31	26	24	22	31

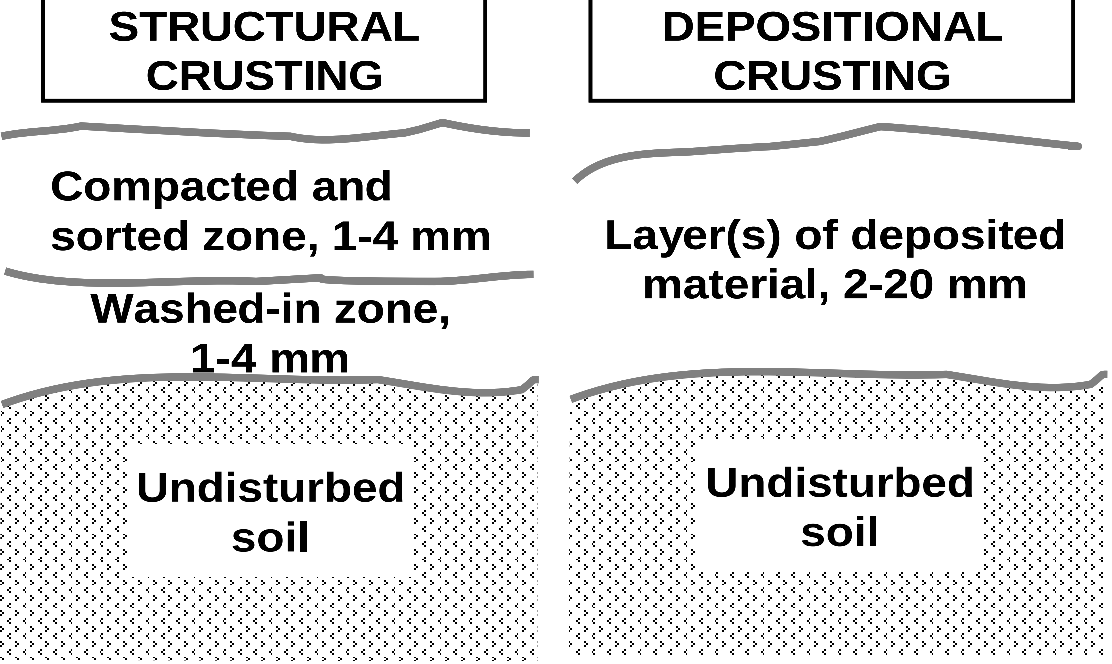
(Page 5)

So what's the big deal with about monitoring soil moisture?

One answer:

Each field, crop, climate and grower has unique characteristics. The majority of acreage in CA is still flood irrigated. Infiltration is often uncertain – maybe 1.5 inches up to 12 inches depending on the mix of soil and water chemistry.

Many Class I sandy loam soils planted to almonds in Kern County have water penetration problems due to low aggregate stability from loss of clays at the surface and irrigation with extremely low salinity water.



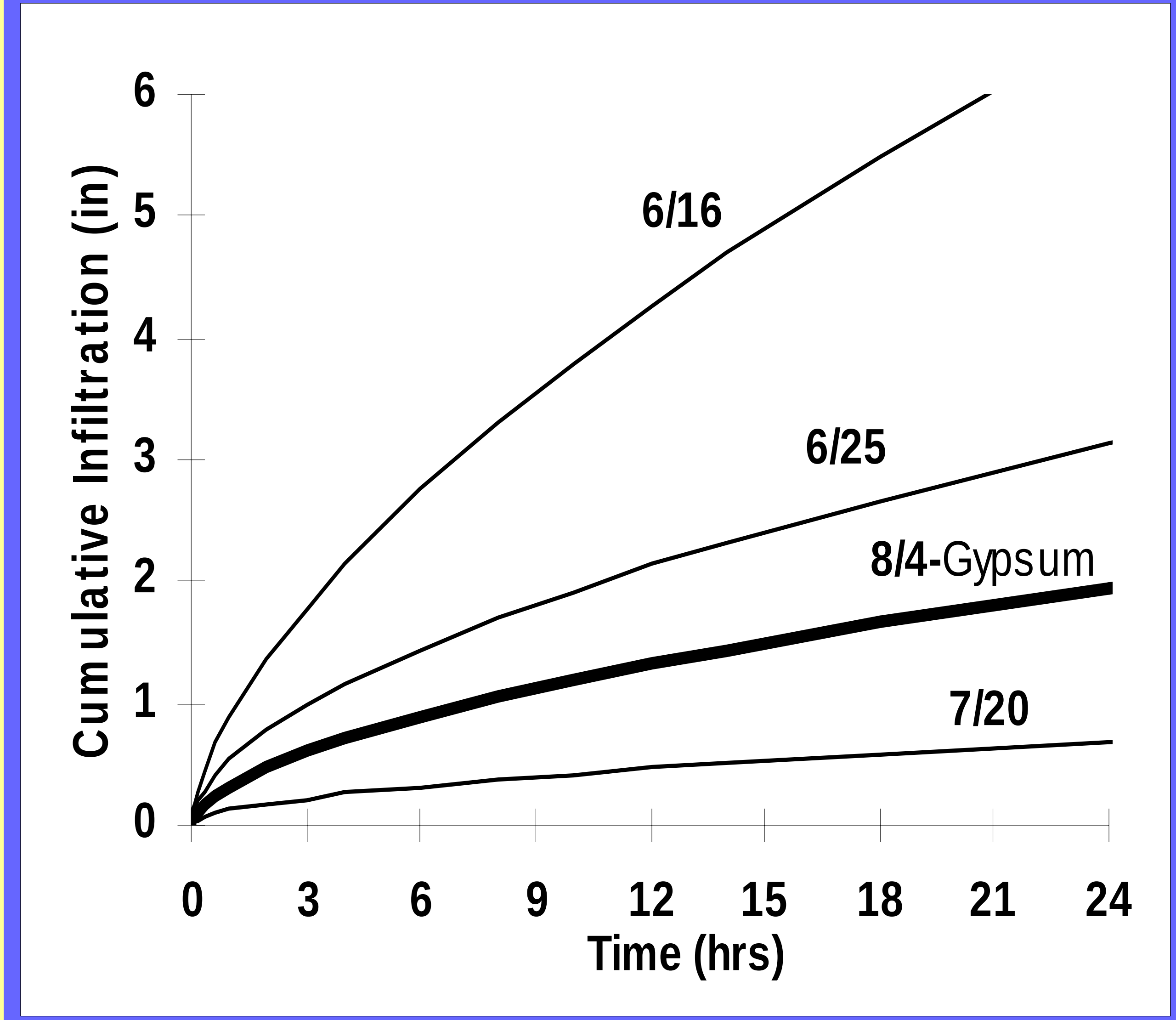
Conceptual illustration of structural and depositional crusts.

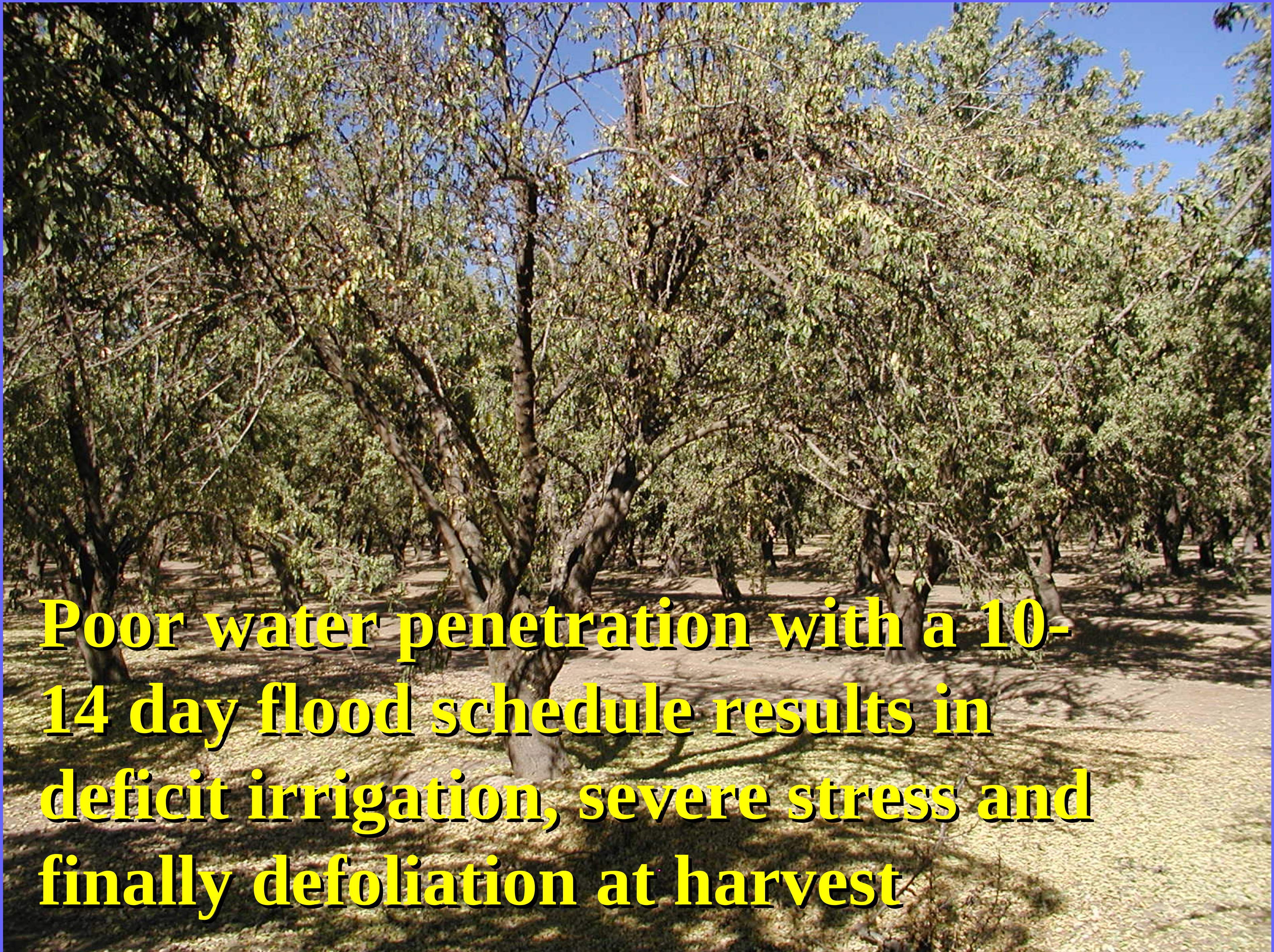
Most crusting and permeability problems in the San Joaquin Valley are "structural crusts" resulting from soil mineral characteristics and water/soil chemistry

COMBINED CRUSTING AND DISPERSION AFTER LAYBY IN COTTON

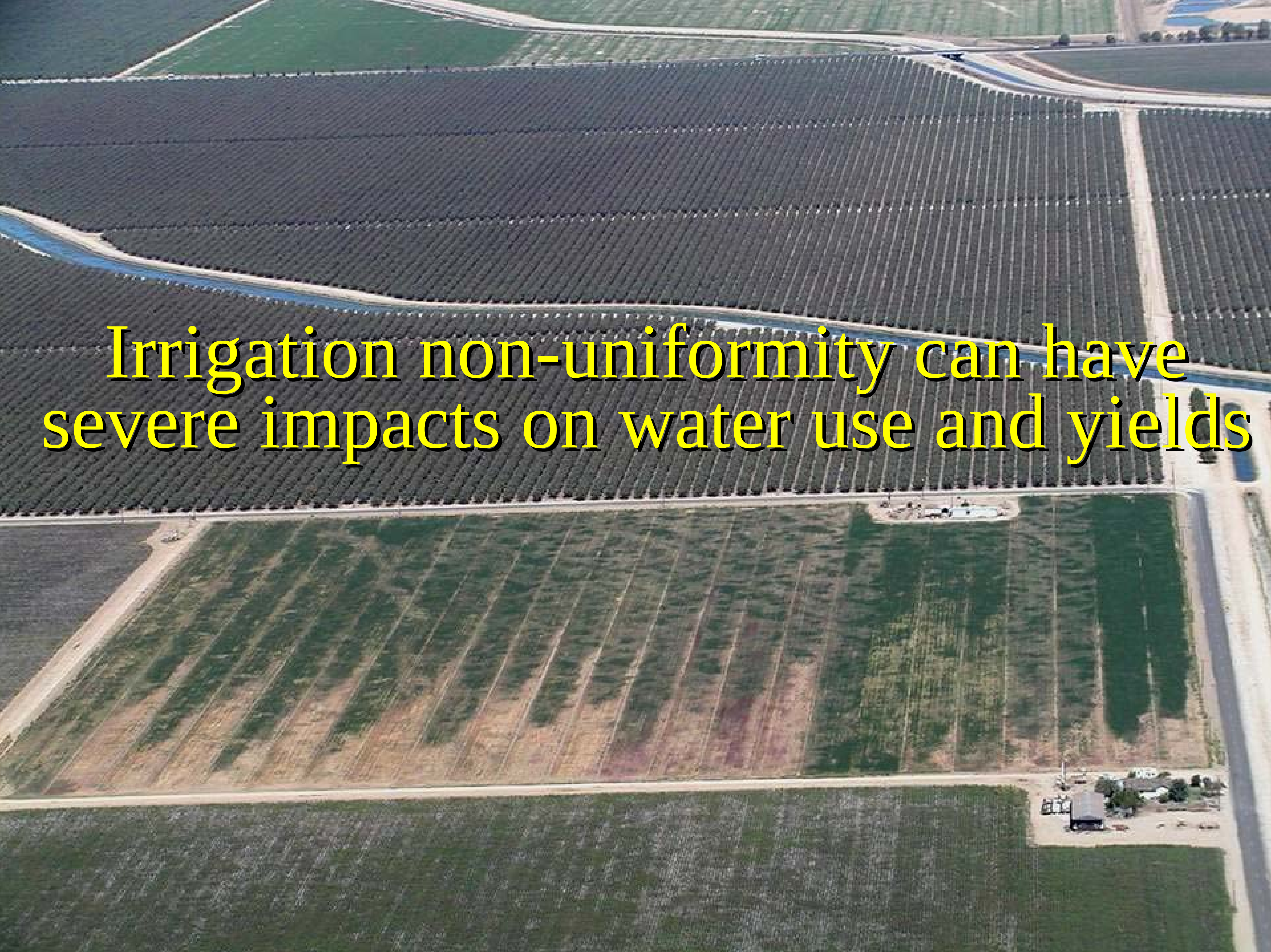
After layby cultivation infiltration over a 12 hour set went from 4.3” to 0.4” from 6/16 to 7/20/96. Water run gypsum on 8/4 improved infiltration to 1.3”.

Wasco Sandy Loam
(Shafter Field Station)




Poor water penetration with a 10-14 day flood schedule results in deficit irrigation, severe stress and finally defoliation at harvest

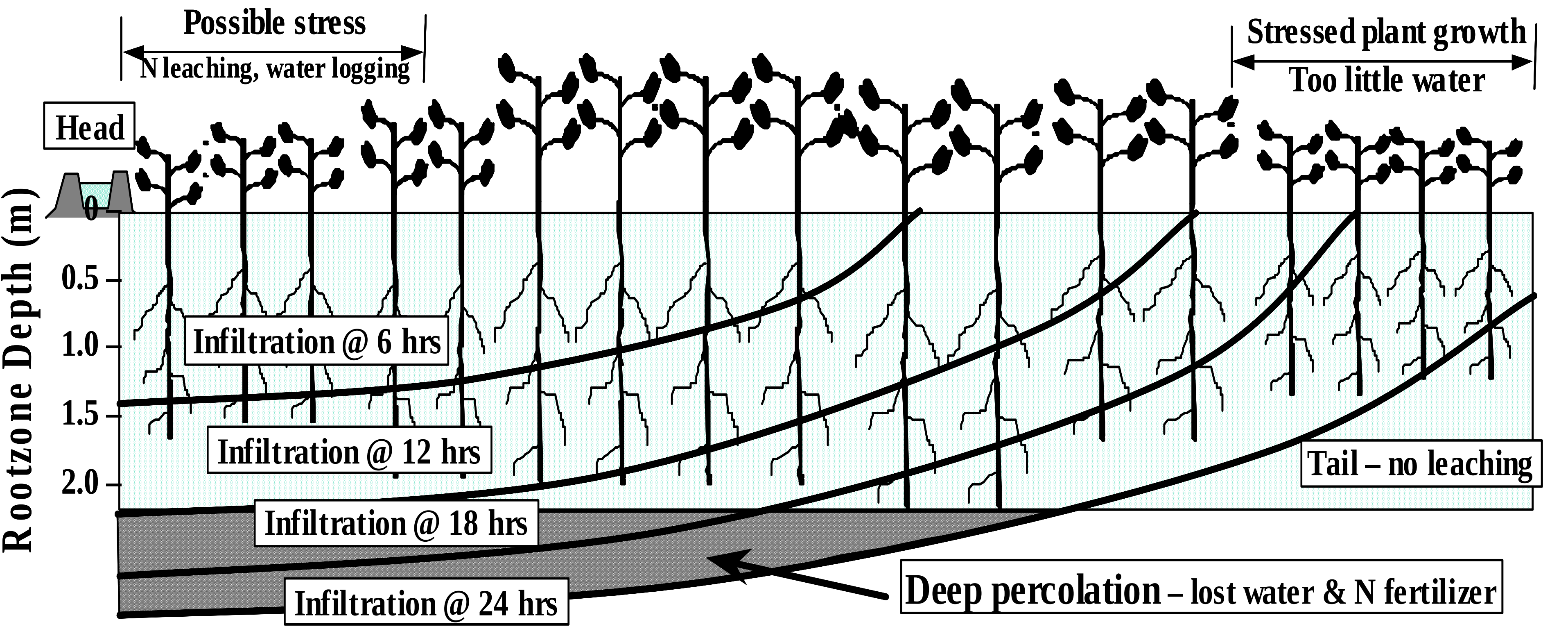

…while other orchards, even with micro systems on a high-frequency schedule, seem to stay wet on top, grow moss, still defoliate at harvest and have disease problems caused by saturated soil conditions


Irrigation non-uniformity can have
severe impacts on water use and yields

Irrigation distribution uniformity (DU) determined by soil infiltration rate, flow down the check and set duration.

(Page 6)

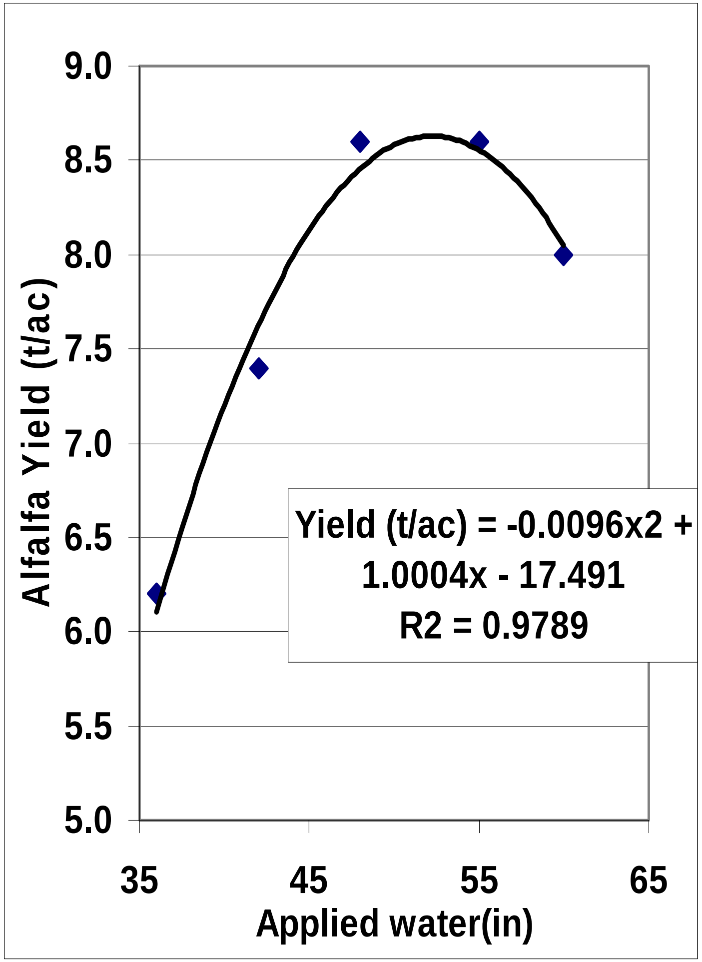
$$DU\ (\%) = 100 * \frac{\text{“low quarter” infiltration}}{\text{Average field infiltration}}$$



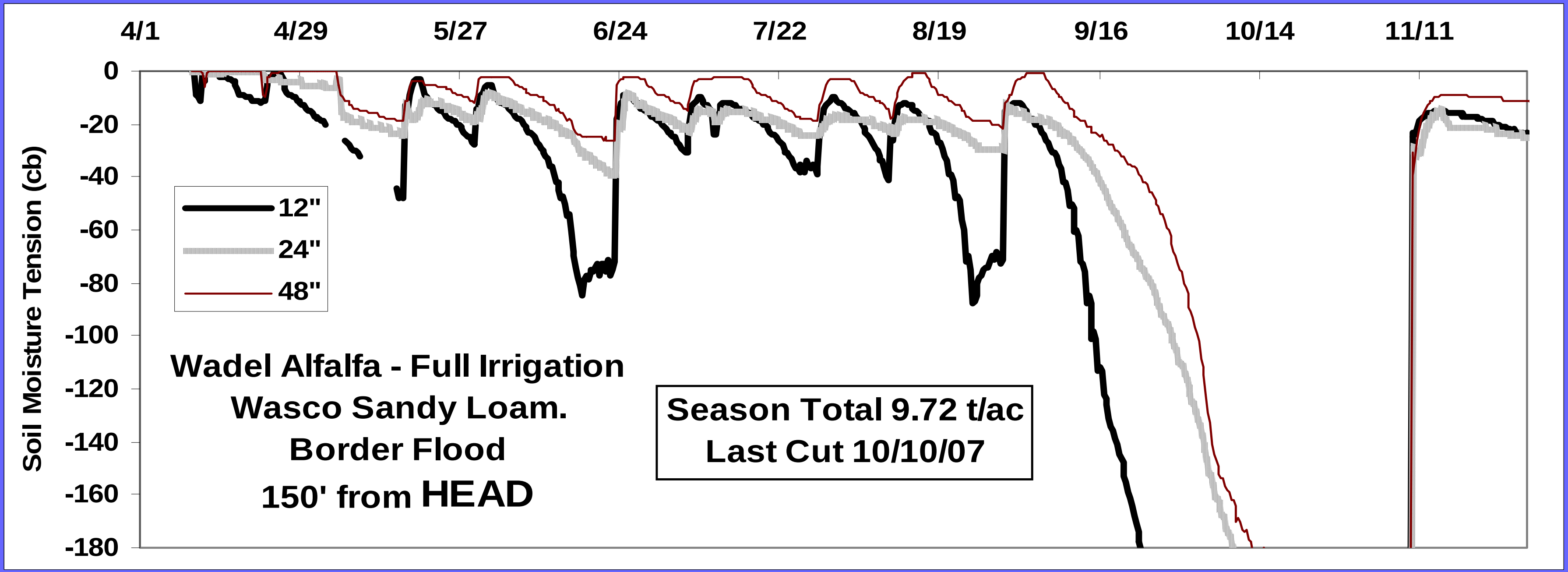
Impact of irrigation distribution uniformity (DU) on field applied water and alfalfa yield

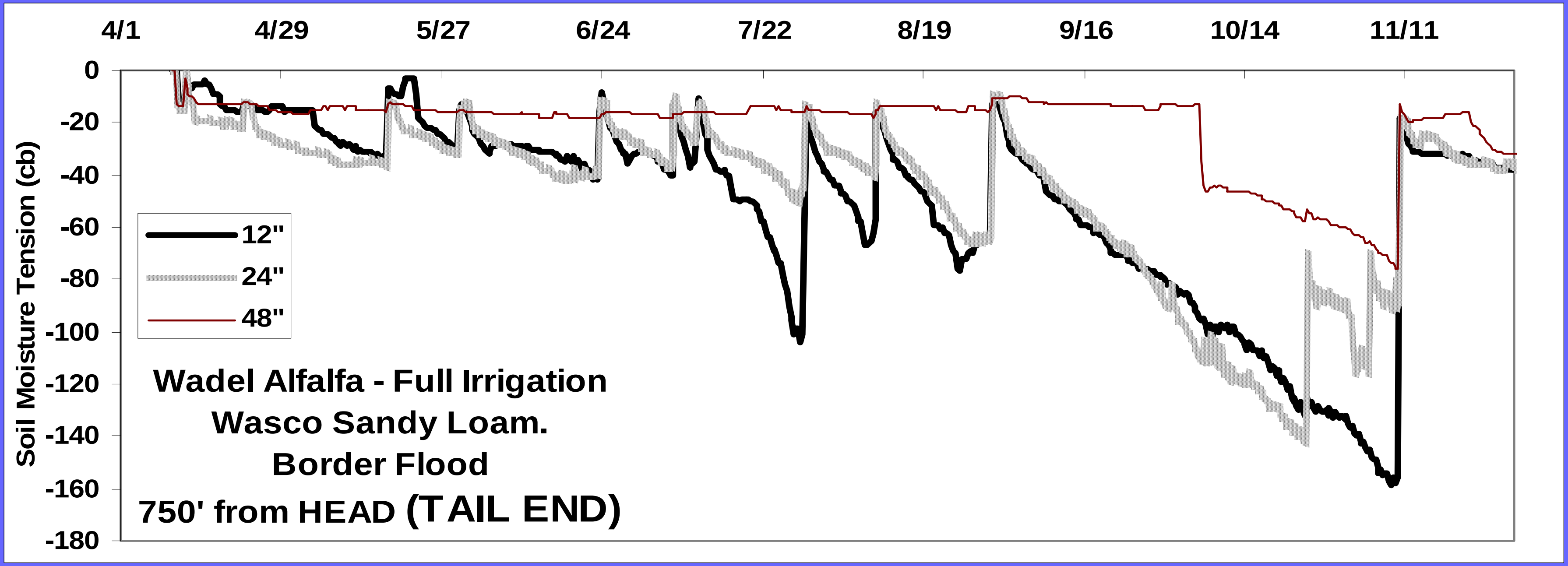
(Page 7)

Field Qtr	Qtr Irrig by Avg Depth (in)				Qtr Yield by Avg Depth (t/ac)			
70% DU	**42**	**48**	**54**	**60**	**42**	**48**	**54**	**60**
Wettest	55	62	70	78	8.5	7.6	6.0	5.0
Wet	46	53	59	66	8.2	8.6	8.1	6.7
Drier	38	43	49	54	6.6	7.8	8.5	8.5
Dry	29	34	38	42	3.6	5.3	6.6	7.6
	Field Average Yield (t/ac):				**6.7**	**7.3**	**7.3**	**7.0**
80% DU	**42**	**48**	**54**	**60**	**42**	**48**	**54**	**60**
Wettest	50	58	65	72	8.5	8.3	7.0	5.9
Wet	45	51	58	64	8.1	8.6	8.3	7.2
Drier	39	45	50	56	7.0	8.1	8.5	8.4
Dry	34	38	43	48	5.3	6.8	7.8	8.4
	Field Average Yield (t/ac):				**7.2**	**7.9**	**7.9**	**7.5**
90% DU	**42**	**48**	**54**	**60**	**42**	**48**	**54**	**60**
Wettest	46	53	59	66	8.2	8.6	8.1	6.7
Wet	43	50	56	62	7.8	8.5	8.4	7.6
Drier	41	46	52	58	7.3	8.3	8.6	8.2
Dry	38	43	49	54	6.6	7.8	8.5	8.5
	Field Average Yield (t/ac):				**7.5**	**8.3**	**8.4**	**7.8**



Watermark Readings: "Full Irrigation" Sandy Loam Alfalfa
2 Irrigations per cutting peak season






Slime or algae on hose screens can ruin drip system uniformity


What about
Available Water
Holding Capacity
with
microsprinklers …


… or double-line drip?

Estimating Water Holding Capacity & Microirrigation Set Times for Orchards

(Page 8)

Soil Texture	Field Capacity (in/ft)	Wilting Point (in/ft)	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	*Moisture Reserve (gals)
Sand	1.2	0.5	0.7	2	4
Loamy Sand	1.9	0.8	1.1	3	16
Sandy Loam	2.5	1.1	1.4	4	35
Loam	3.2	1.4	1.8	5	70
Silt Loam	3.6	1.8	1.8	6	102
Sandy Clay Loam	3.5	2.2	1.3	7	100
Sandy Clay	3.4	1.8	1.6	7	123
Clay Loam	3.8	2.2	1.7	8	170
Silty Clay Loam	4.3	2.4	1.9	9	241
Silty Clay	4.8	2.4	2.4	9	305
Clay	4.8	2.6	2.2	10	345

*This is the maximum gallons of water stored to a 4' depth beneath a single drip emitter. In fine textured soils, the wetted volume of one emitter merges with another on the same hose and final gallons of moisture reserve per emitter will be less than the number shown in the table. Plant stress will usually be seen when about 50% of this reserve has been used.

Ref: Ratliff LF, Ritchie JT, Cassel DK. 1983. Field-measured limits of soil water availability as related to laboratory-measured properties. Soil Sci Soc Am. 47:770-5.

Estimating Water Holding Capacity & Microirrigation Set Times for Orchards

Refill Times for Different Soil Textures and Micro Systems

(Page 8)

Soil Texture	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	[1]Irrigation Time to Refill & Moisture Reserve of 4 Foot Wetted Rootzone @ 50% to 100% Available					
			Dble-Line Drip 1-gph, 10 per tree (hrs)	Moisture Reserve @ 0.25"/day (days)	**10 gph Fanjet**, 1 per tree (hrs)	Moisture Reserve @ 0.25"/day (days)	**14 gph Fanjet**, 1 per tree (hrs)	Moisture Reserve @ 0.25"/day (days)
Sand	0.7	2	2.2	0.4	11.6	1.9	12.5	2.8
Loamy Sand	1.1	3	7.8	1.3	19.6	3.2	20.9	4.7
Sandy Loam	1.4	4	17.5	2.8	26.9	4.3	28.3	6.4
Loam	1.8	5	28.7	4.6	37.1	6.0	38.6	8.7
Silt Loam	1.8	6	35.9	5.8	39.7	6.4	40.8	9.2
Sandy Clay Loam	1.3	6	25.9	4.2	28.6	4.6	29.5	6.7
Sandy Clay	1.6	7	38.3	6.2	37.6	6.1	38.3	8.6
Clay Loam	1.7	8	47.5	7.7	42.6	6.9	42.9	9.7
Silty Clay Loam	1.9	9	60.6	9.8	50.6	8.2	50.5	11.4
Silty Clay	2.4	9	76.6	12.4	64.0	10.3	63.8	14.4
Clay	2.2	10	79.0	12.7	62.3	10.0	61.5	13.9

[1]Based on a tree spacing of 20 x 20'. Drip hoses 6' apart. 10 gph fanjet wets 12' diameter. 14 gph fanjet @ 15' diameter.

Note: Peak water use @ 0.25"/day and 20 x 20' spacing = 62 gallons/day/tree. 0.20"/day = 50 gallons/day/tree.

Table takes into account merging water patterns below soil surface for drip irrigation.

~~4~~ 3-point sermon:

- Understanding soil water holding characteristics
- Monitoring soil moisture & irrigation uniformity impacts on yield
- Crop water requirements (ET), CIMIS
- ~~Irrigation & crop salinity tolerance~~

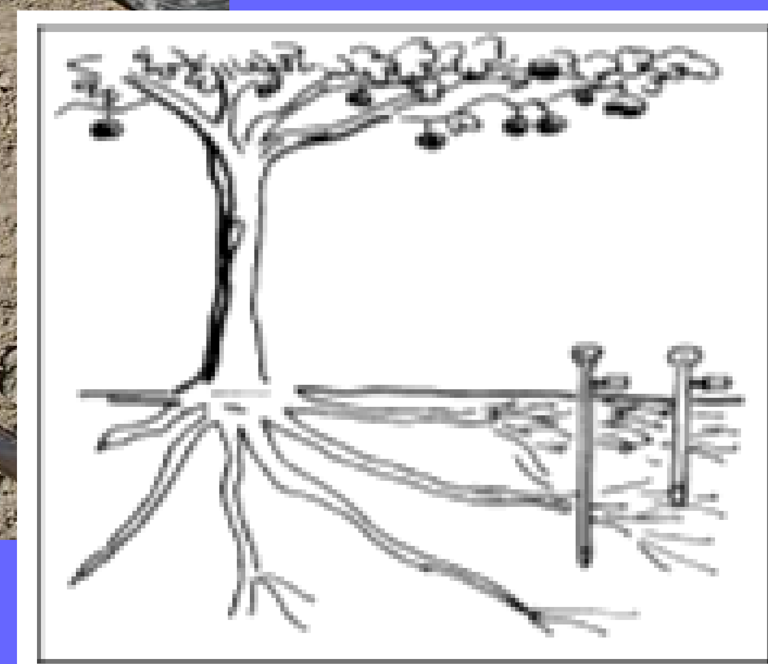
Hand-powered twist augers
($150 - $300)




3 foot push or slide hammer probe ($150-$250)

<u>Tensiometer</u>

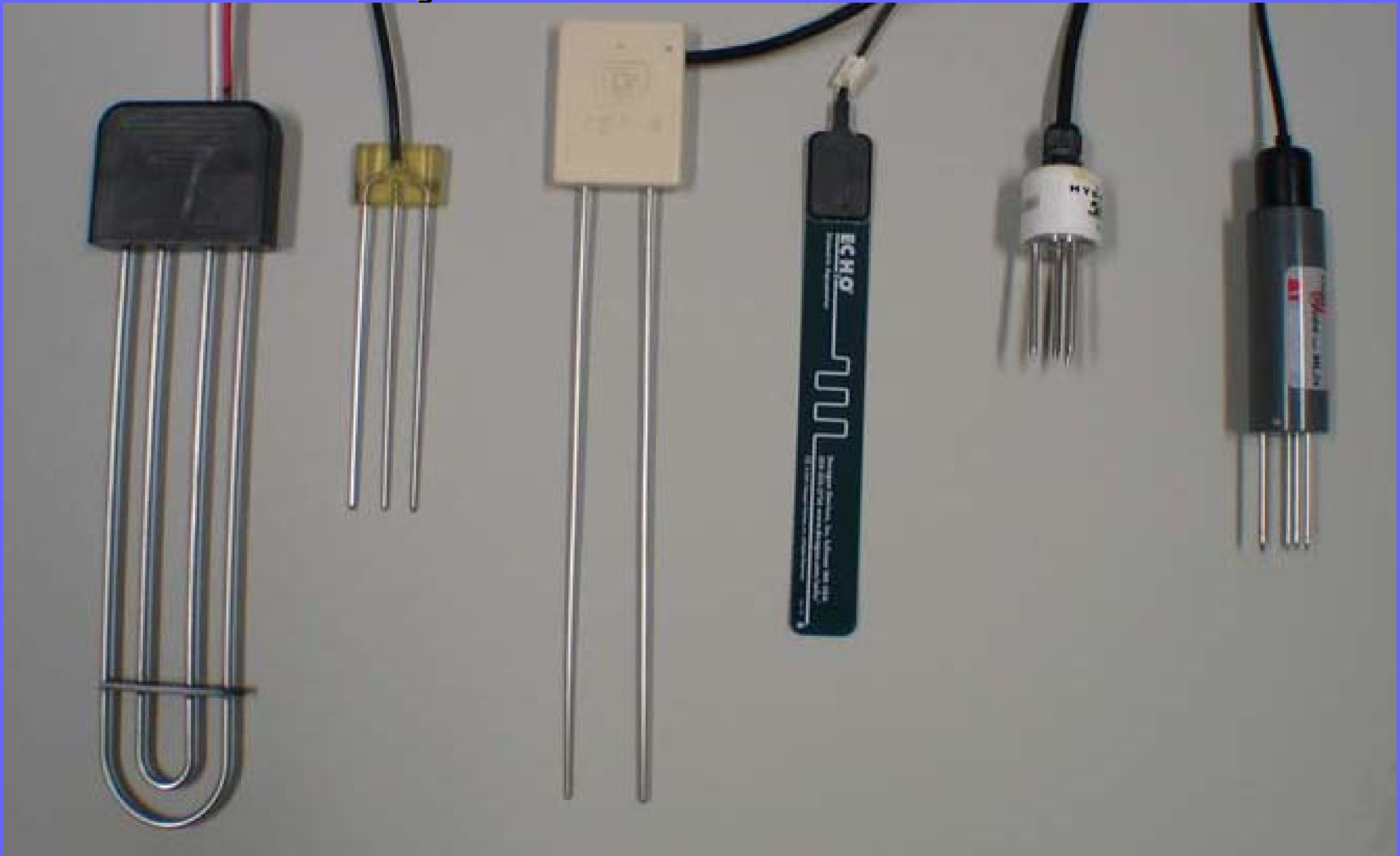
The first "at a glance" in-situ soil moisture sensor ($60-$90, depending on length)



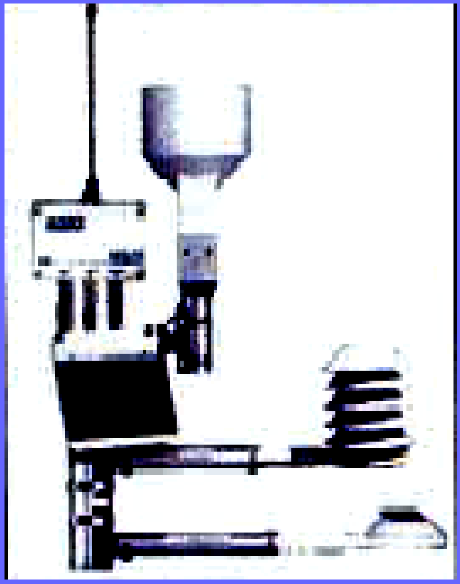
A device using low levels of radiation, the neutron probe, was developed in the 1960's for checking soil moisture. Used mostly by researchers and irrigation consultants, it is often the standard check for the accuracy of other instruments. Largest sample "volume" to estimate moisture.

Watermark blocks estimate soil moisture tension (matric potential) using electrical resistance and require no maintenance (~$30). However, a separate meter or logger ($200+) is needed to read the device.

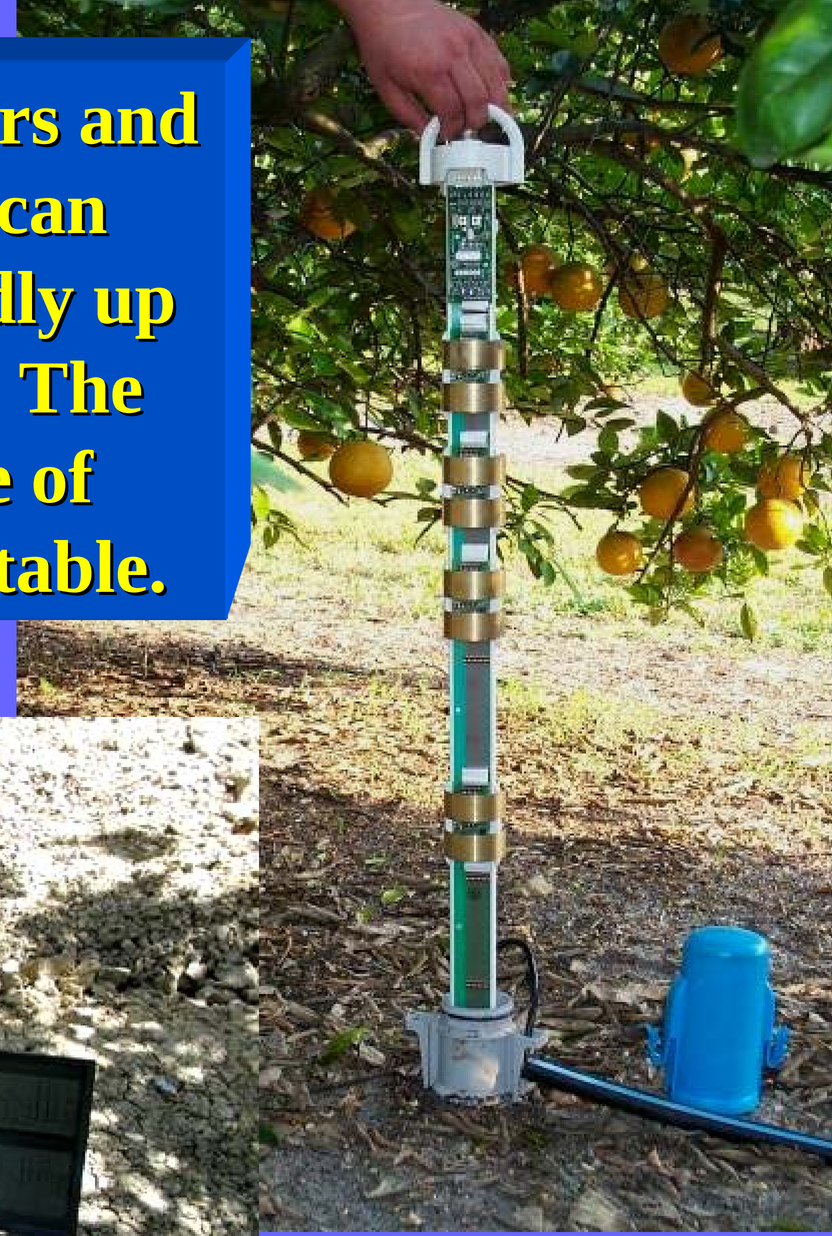
Dozens of new soil moisture sensors and logger combinations have come on the market in the last 10 years



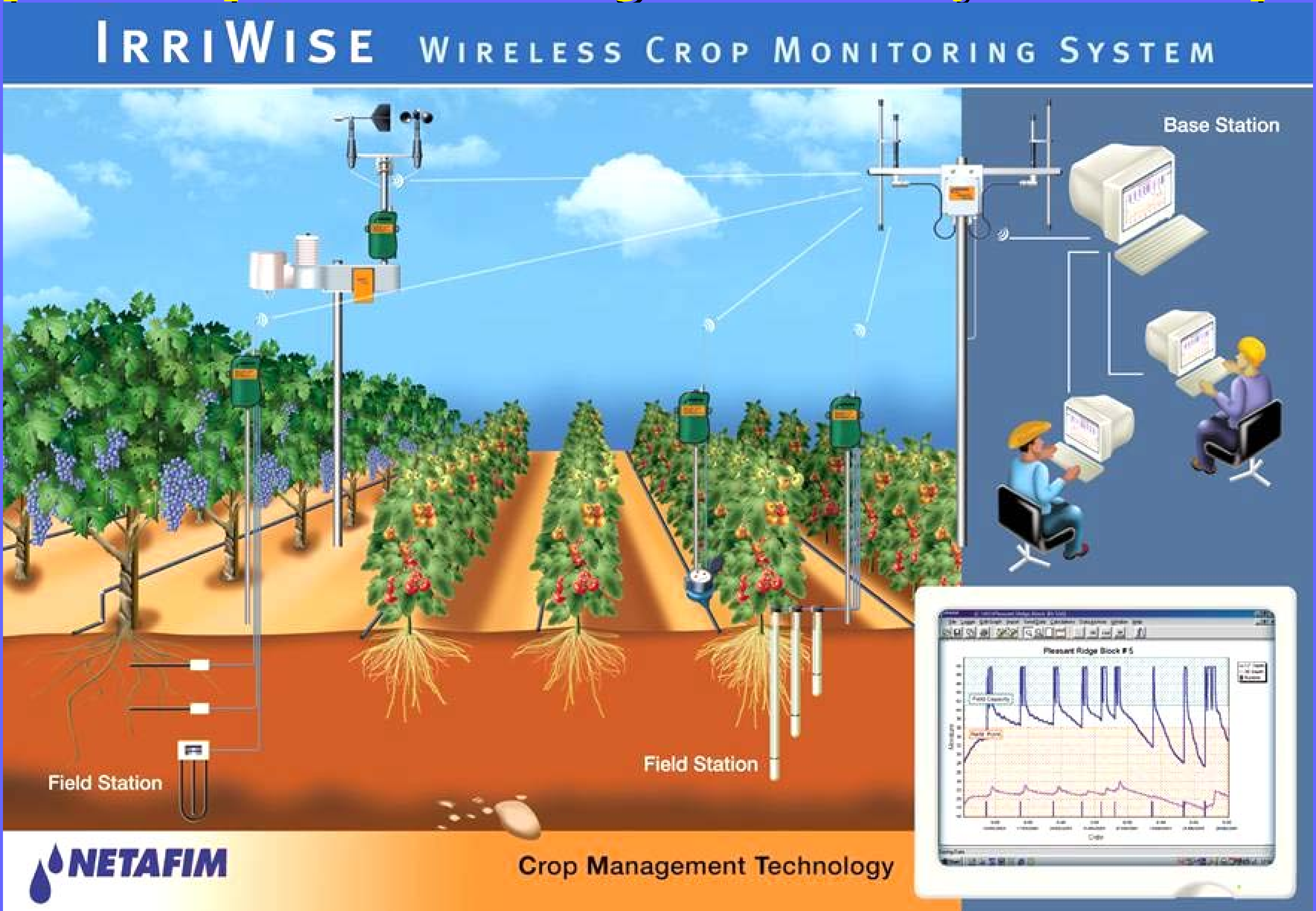
A variety of loggers can be used for various sensors. $200 WatchDog, $400 Irrometer & Hanson are a few. Downloads are to a laptop, data shuttle or possible radio/cell phone uplink.



Electronics, data loggers and multi-stage sensors can increase the cost rapidly up to $5,000 to $10,000. The need for this degree of sophistication is debatable.



"Expert" water monitoring/control telemetry systems promise precision management from your desktop.



Where do I monitor?

How many sensors are enough? What type is best for which crop?

Typical field layout for flood systems.
Total soil moisture monitoring system cost: $600

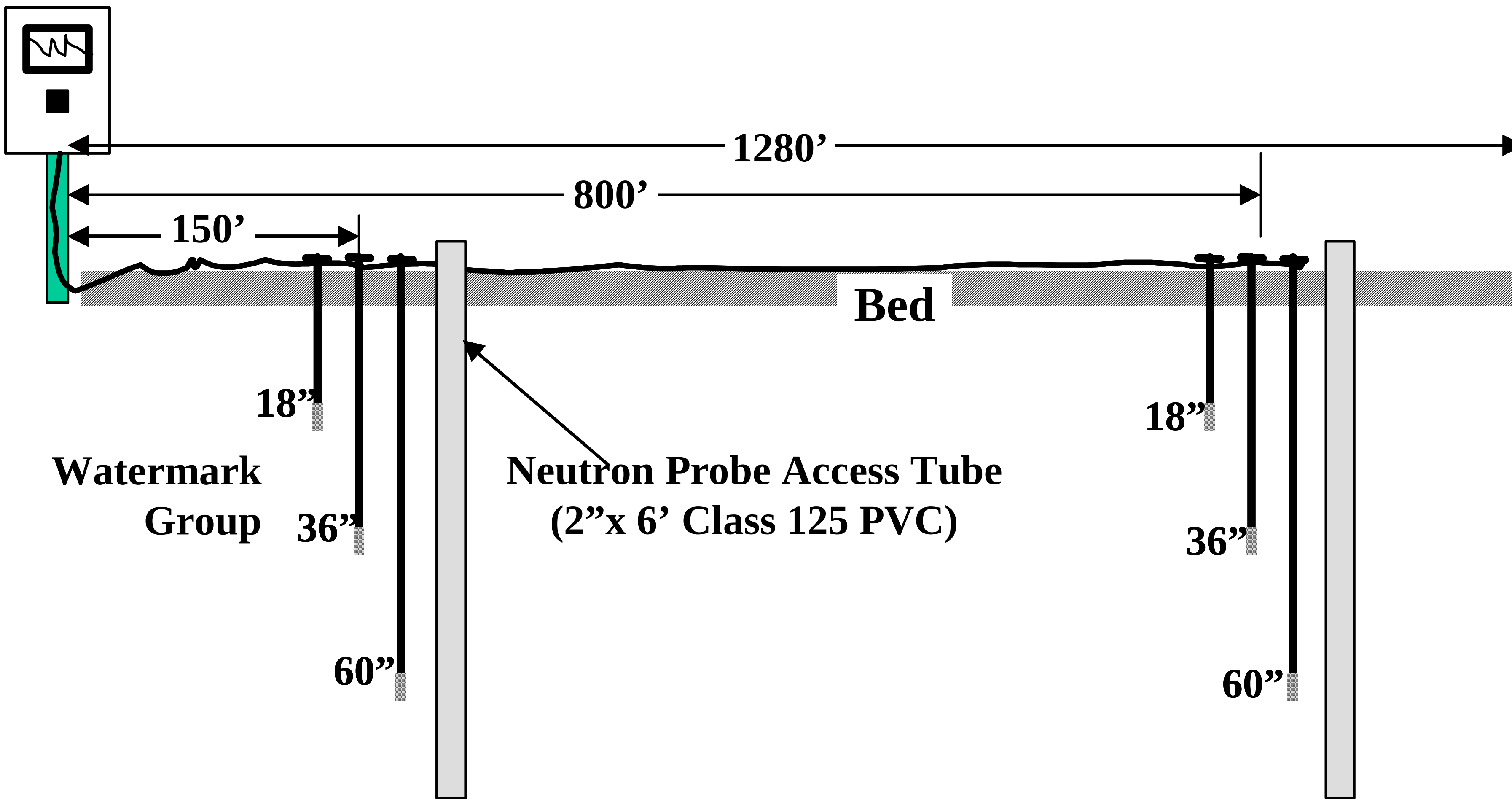
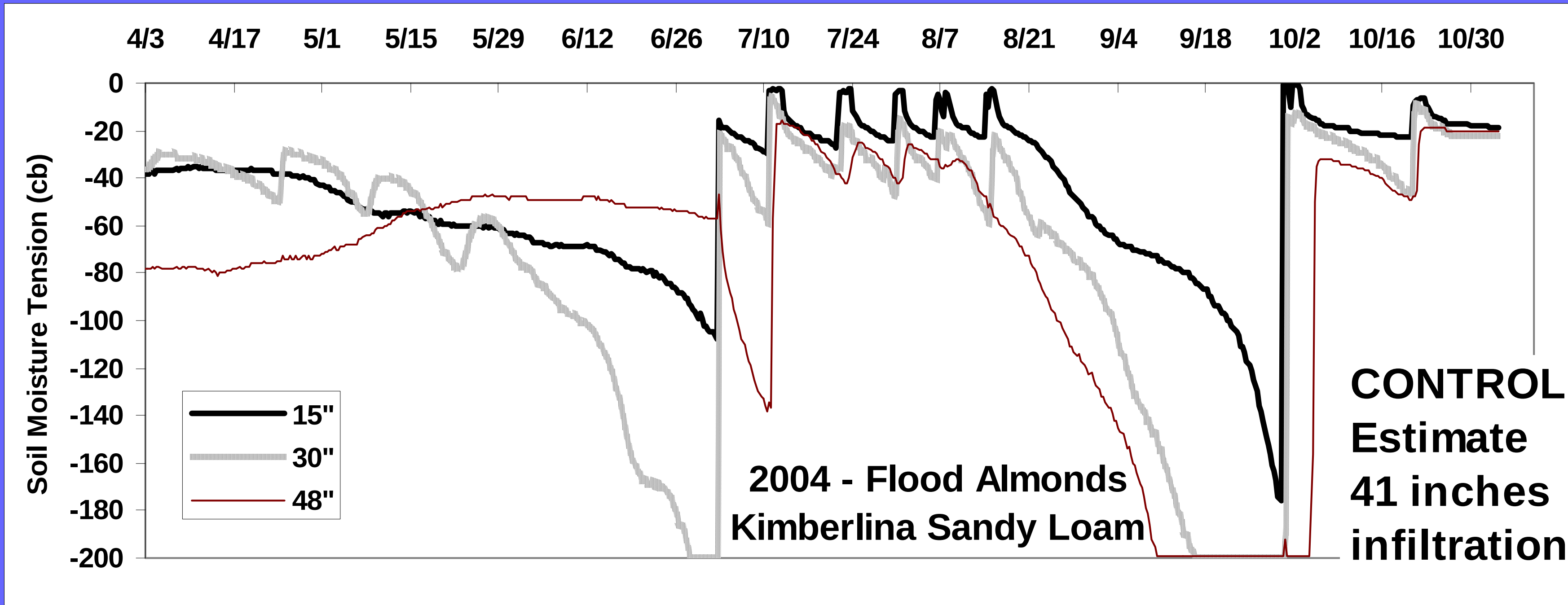


Fig. 1. Typical field layout of monitoring sites with surface irrigation. Spacing of Watermark sensor groups varied according to irrigation system, but usually set @ 18, 36 and 60 inch depths. (Not to scale.)


Poor water penetration results in
deficit irrigation, increasing stress
and finally defoliation at harvest



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10/16
10/30
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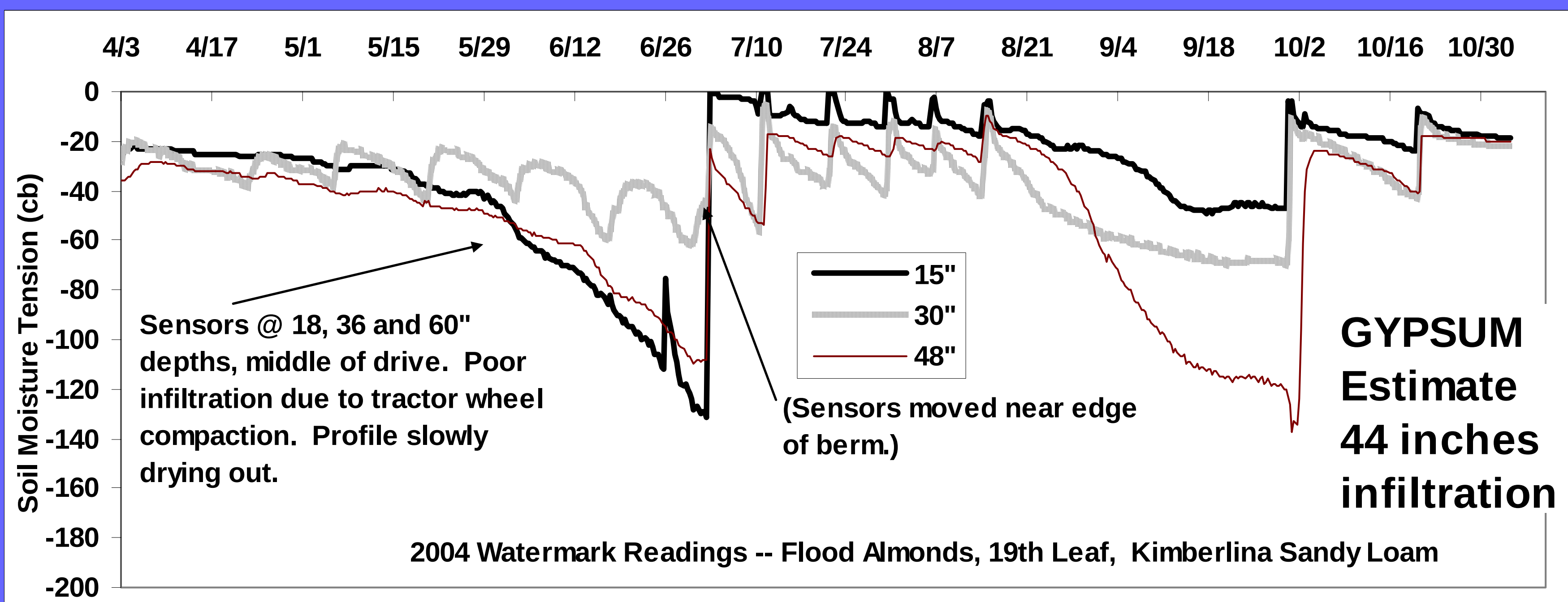
-60
-80
-100
-120
-140
-160
-180
-200
Soil Moisture Tension (cb)
15"
30"
48"
2004 - Flood Almonds
Kimberlina Sandy Loam
CONTROL
Estimate
41 inches
infiltration



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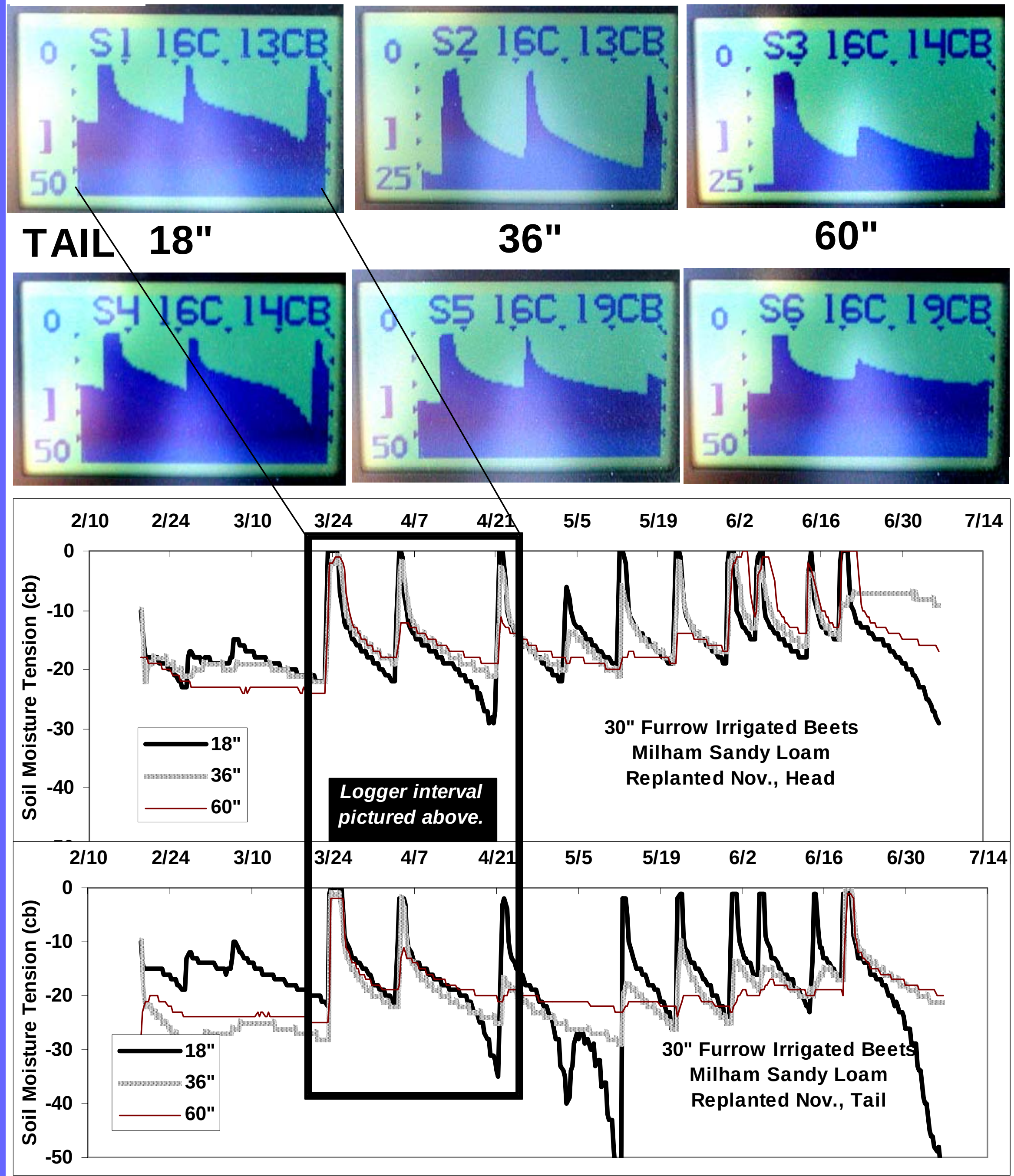
9/18
10/2
10/16
10/30
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Soil Moisture Tension (cb)
15"
30"
48"
Sensors @ 18, 36 and 60" depths, middle of drive. Poor infiltration due to tractor wheel compaction. Profile slowly drying out.
(Sensors moved near edge of berm.)
GYPSUM
Estimate
44 inches
infiltration
2004 Watermark Readings -- Flood Almonds, 19th Leaf, Kimberlina Sandy Loam

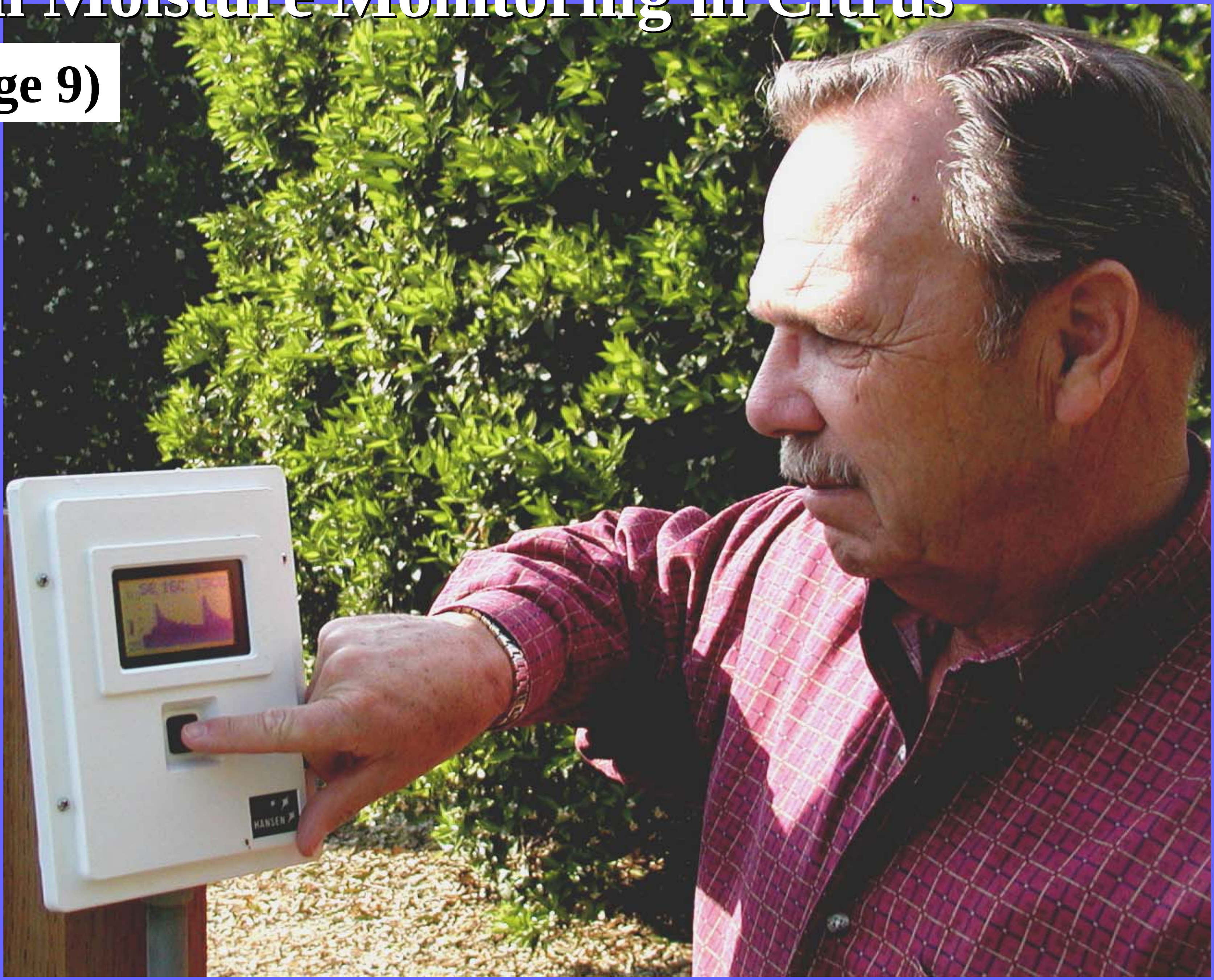
HEAD

AM400 LOGGER SCREENS FROM 3/19 TO 4/23/01



Soil Moisture Monitoring in Citrus

(Page 9)



Installing Watermark blocks and a Hanson AM400 logger in citrus

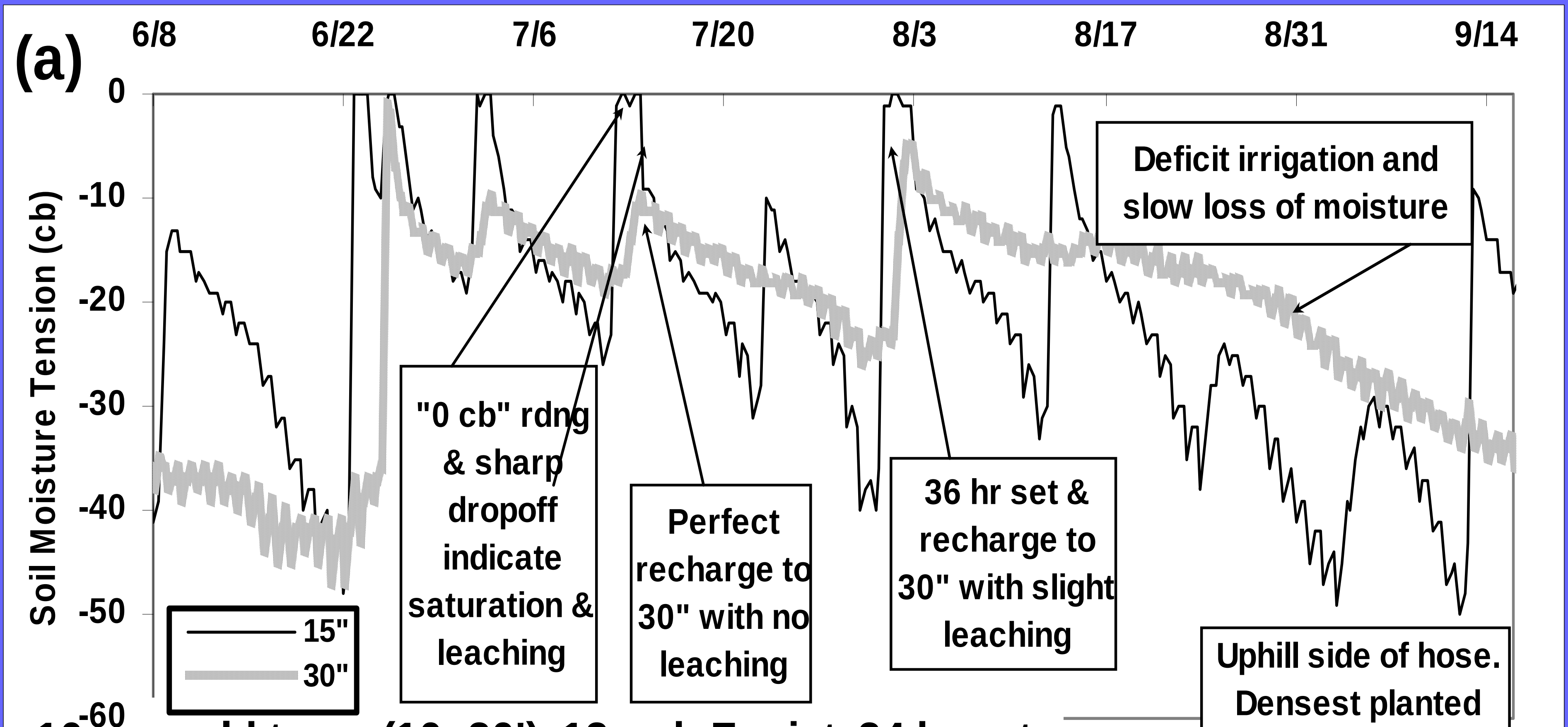
Fine silty soil and a good shot of water down the hole improves contact with soil pores. Good capillary movement of water is what makes these sensors work.

Loggers used in Kern County irrigation projects

Understanding mid-season soil moisture trends in citrus using Watermark Blocks

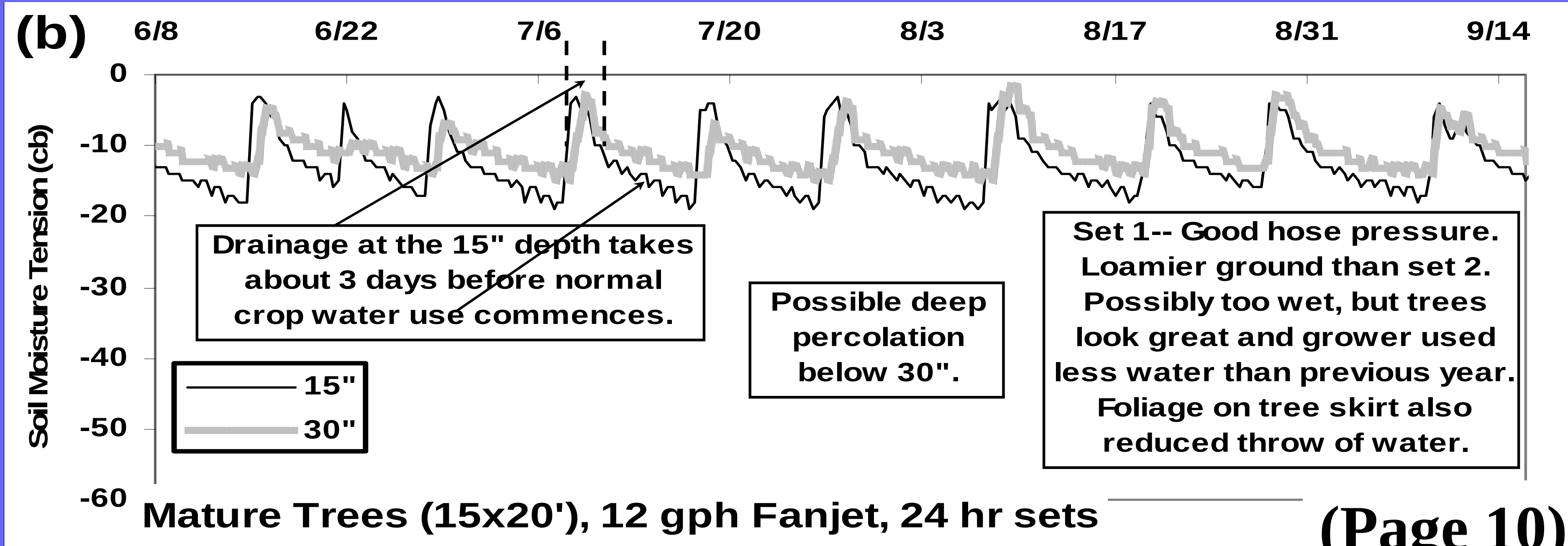
(Page 10)

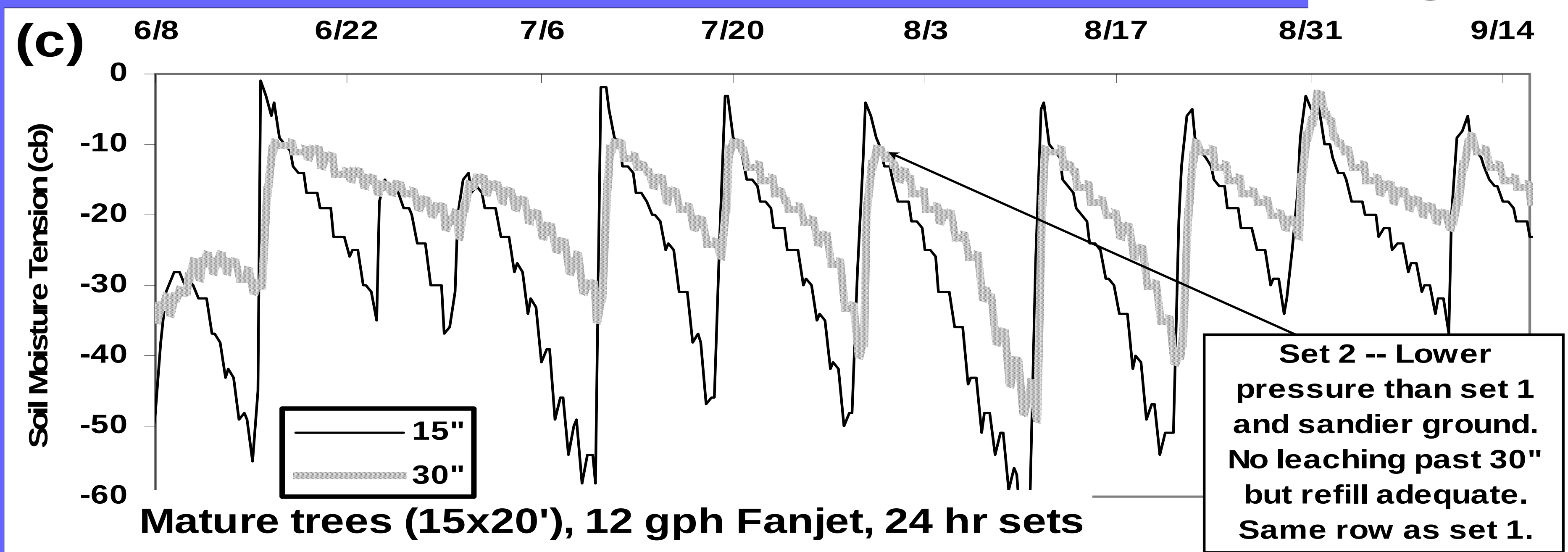
Microsprinkler Irrigation

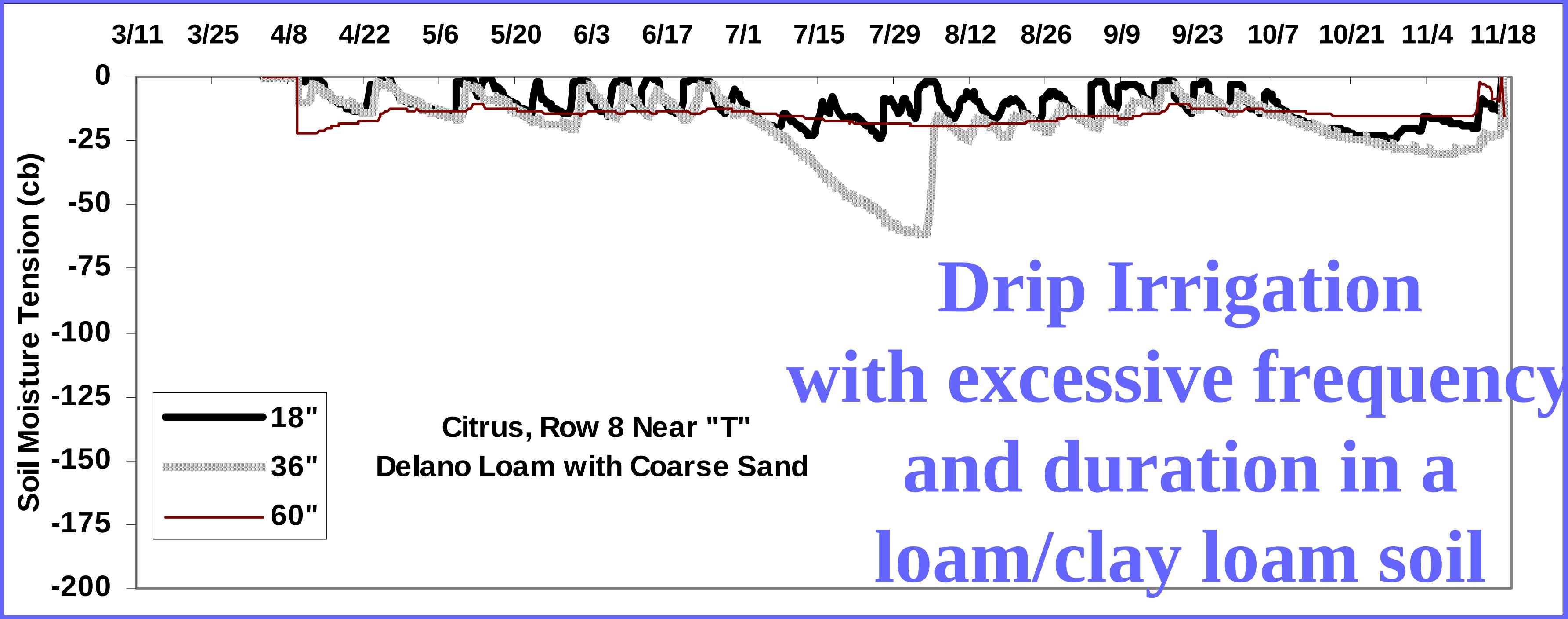


10 year old trees (10x20'), 12 gph Fanjet, 24 hr sets

Soil Moisture Changes in Citrus Under Different Set Pressures



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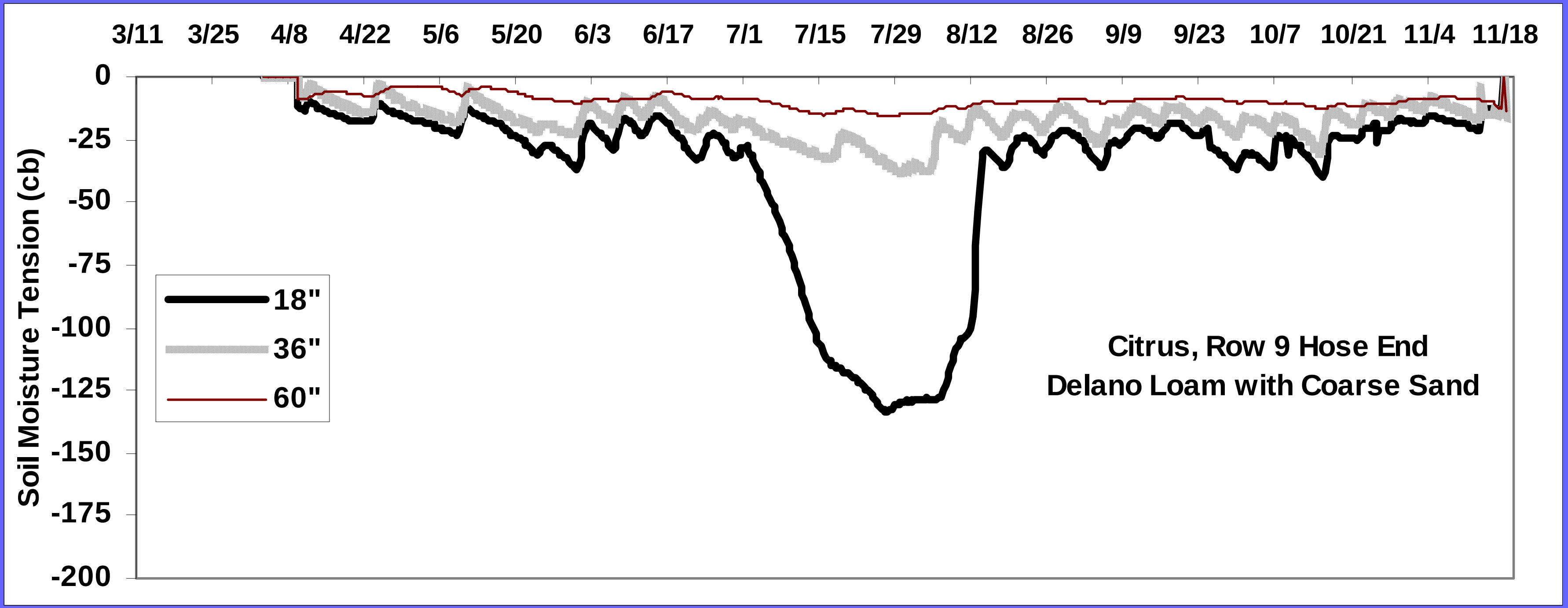
9/9
9/23
10/7
10/21
11/4
11/18
0
-25
-50
-75
-100
-125
-150
-175
-200
Soil Moisture Tension (cb)
18"
36"
60"
Citrus, Row 8 Near "T"
Delano Loam with Coarse Sand
Drip Irrigation
with excessive frequency
and duration in a
loam/clay loam soil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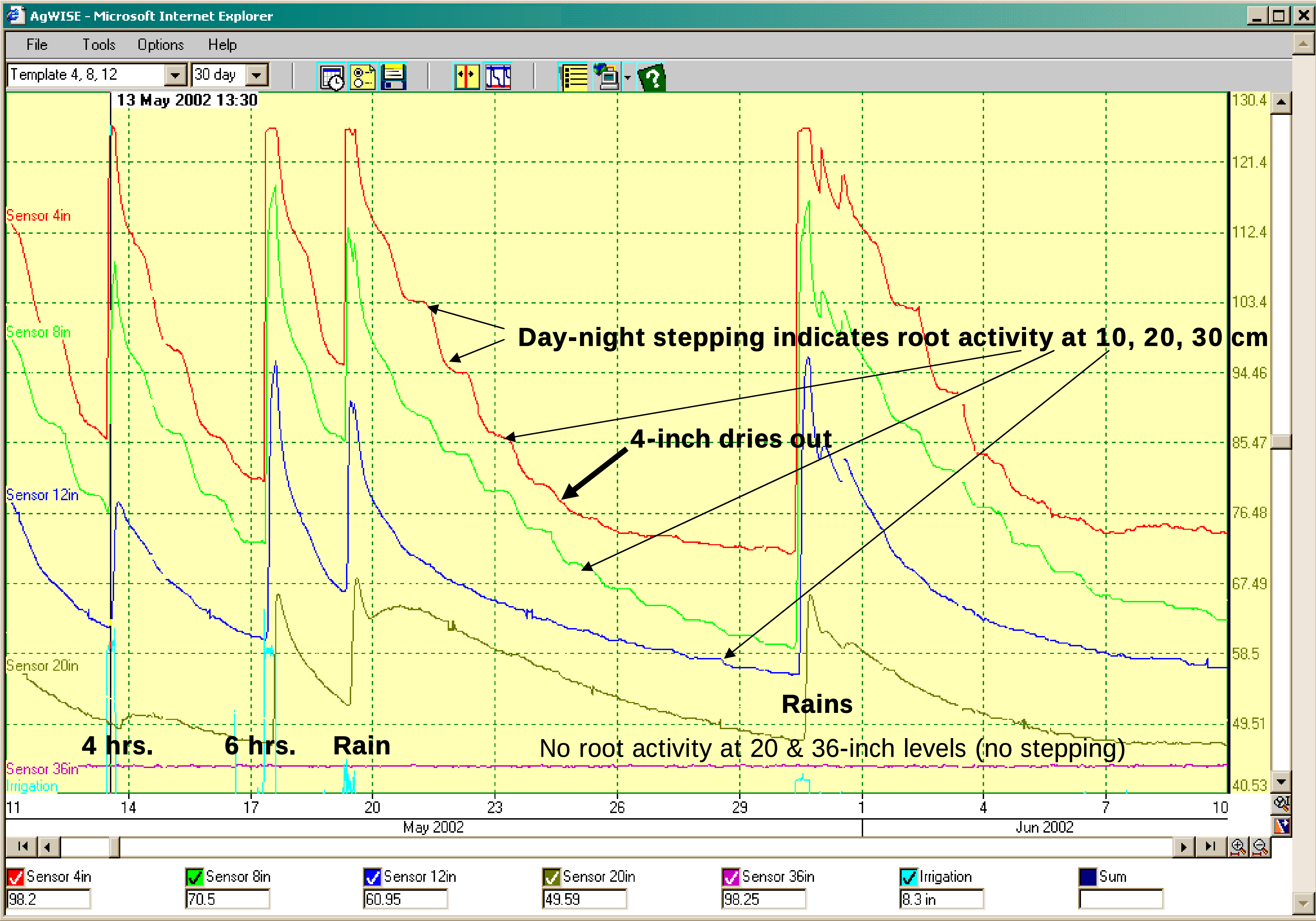
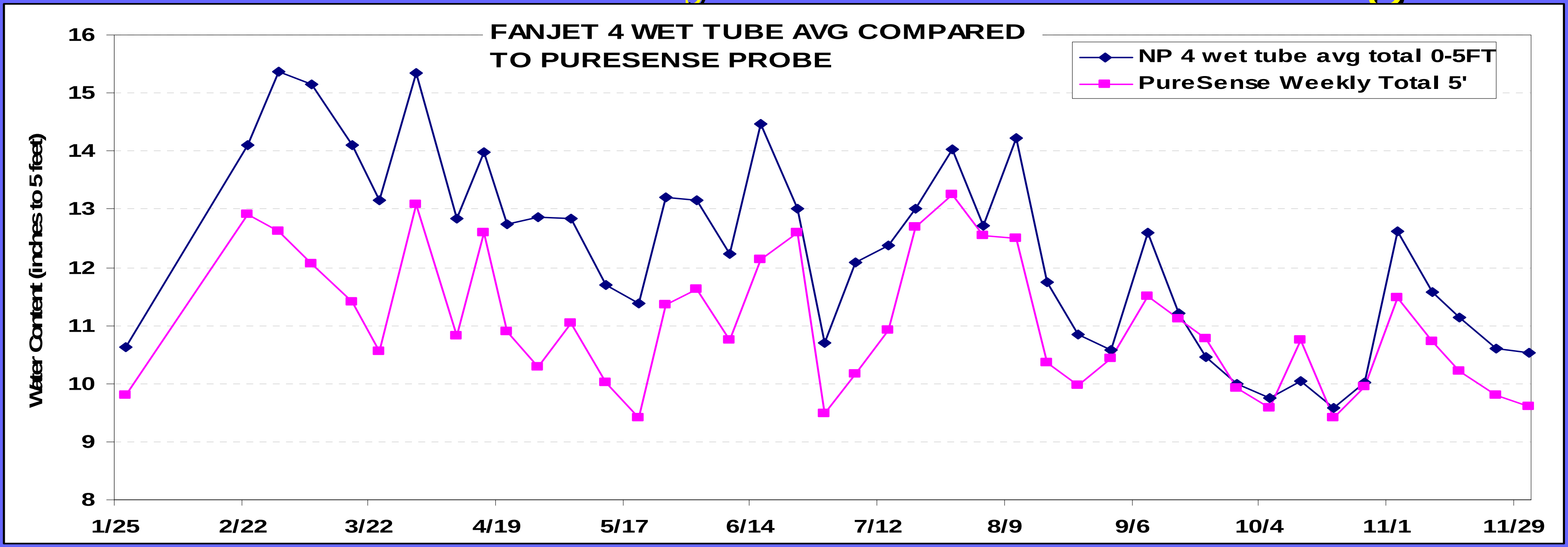
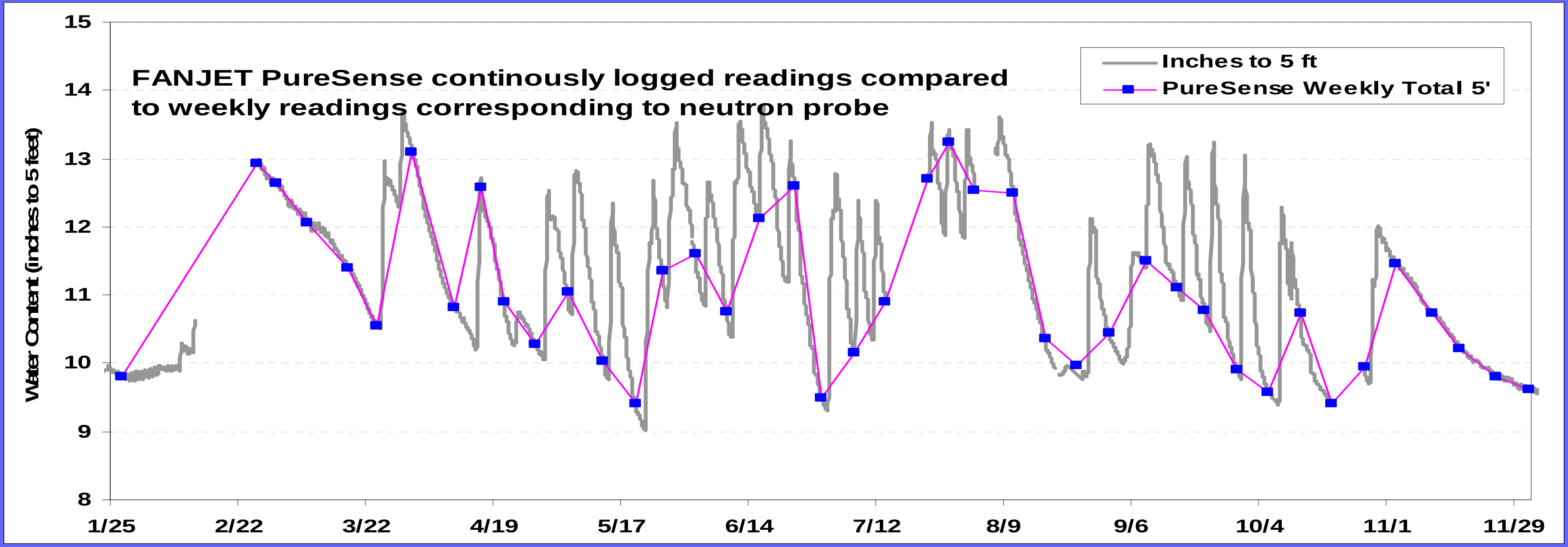
9/9
9/23
10/7
10/21
11/4
11/18
0
-25
-50
-75
-100
-125
-150
-175
-200
Soil Moisture Tension (cb)
18"
36"
60"
Citrus, Row 9 Hose End
Delano Loam with Coarse Sand

Separate Layer Graph: do you need this much detail?



What about weekly vs. continuous readings?





GENERAL COMPARISON OF SOIL MOISTURE SENSORS (All prices are an approximation for comparison only)

Sensor Type	Advantages	Disadvantages	Cost
Tensiometer (Irrometer, Soil Moisture Equip)	Mechanical, no power required, not affected by salinity, good for veg crops, easy installation, can be hooked to a logger if pressure transducers substituted for pressure gauge on instrument	Requires maintenance, not good for drier soil moisture levels, must read gauge at site, manual record keeping of occasional readings, reads soil water "tension" and not actual content	**$60 – 90, depending on length, pressure transducer $210**
Modified Electrical Resistance (Watermark)	No maintenance, least cost sensor, can be buried and remotely monitored with logger or checked with hand meter, good in dry conditions, easy installation	Can have problems with good contact in coarse sandy soil, can be affected by high salinity (>5 mmhos/cm), reads "tension" and not water content	**$30 – 60, depending on logger adapter, $240 hand meter**
Capacitance (Aquatel, Aquapro, Echo, Enviroscan, Troxler Sentry)	Can be calibrated to read actual soil water content, long-lasting sensors-some hermetically sealed, some can detect very small changes in water content	Signal strength/accuracy variable from one model to another, wire run length maybe limited, can be highly influenced by salinity and heavy soil, can require more power, some only "%" moisture	**$100 – 6000, plus logger or hand meter reqd & misc $200-4000**
Time Domain Reflectometry TDR (FDR, TDT) (Trime, Tektronic, Acclima, Gro-Point)	Potential for greatest accuracy over a wide range of soil types on high end models with site specific calibration, access tube types read multiple depths	Requires most power, factory calibration in %moisture, **movable access tube type not suitable for automated readings**	**$250 – 7500, proprietary logger/meter/ tubes reqd $1000 - 6000**
Neutron Probe	Most adaptable to wide range of soil types, accuracy increases with local calibration, gives actual water content, least sensitive to installation precision, use cheap 2" PVC Class 125 pipe for site	Needs radiation license and monitoring, **not suitable for automated readings**	**$6,000 for unit, ~$2 for 6 foot PVC tube**

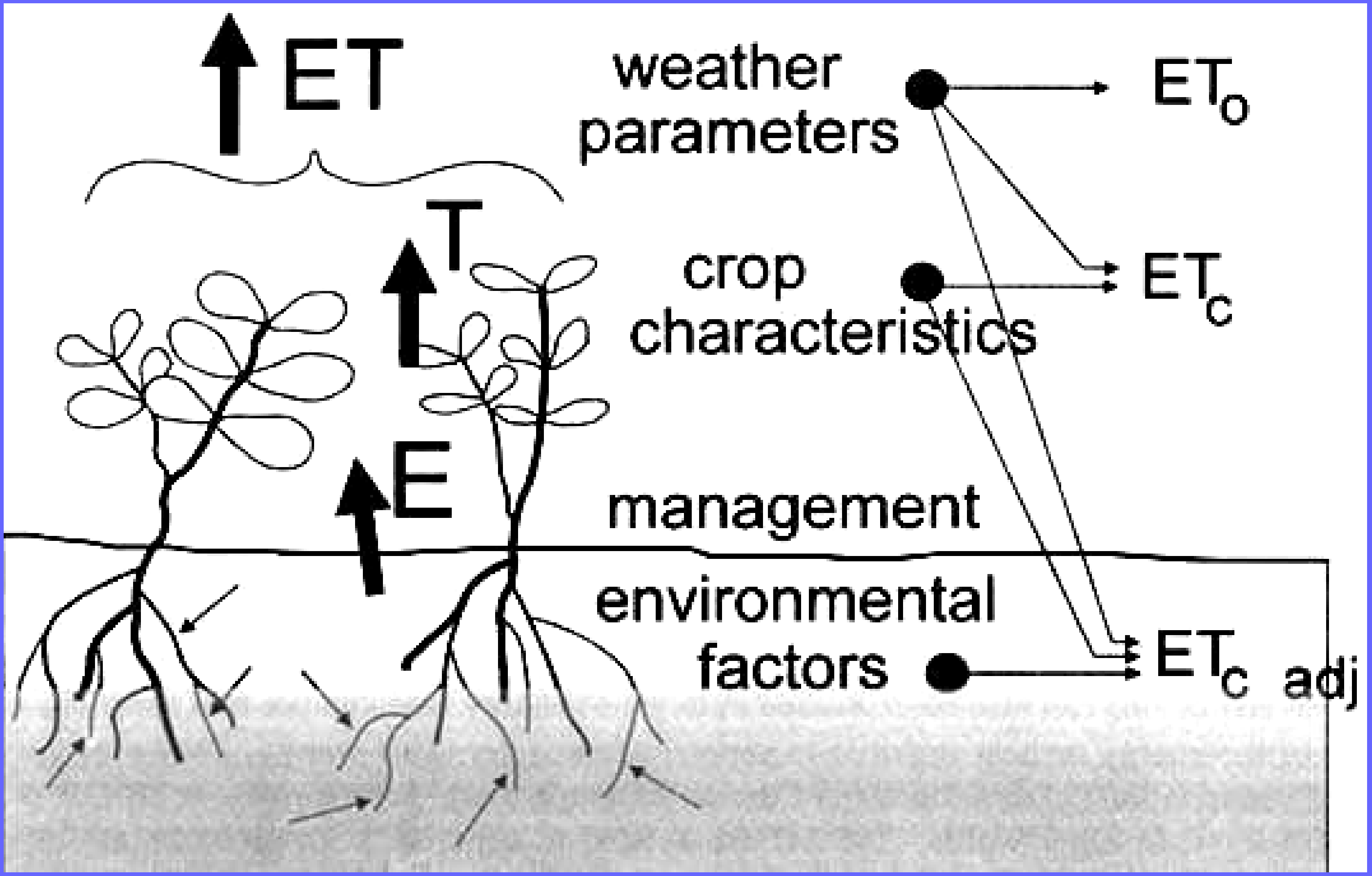
Equipment for checking soil moisture

- Most Common Method

~~4~~ 3-point sermon:

- Understanding soil water holding characteristics
- Monitoring soil moisture & irrigation uniformity impacts on yield
- Crop water requirements (ET), CIMIS
- ~~Irrigation & crop salinity tolerance~~

Crop water use is made up of EVAPORATION (E) from the wet soil and leaves and TRANSPIRATION (T), hence ET




Blake with his first soil probe checking alfalfa

We haven’t been out of the cave that long regarding a scientific understanding of crop water use and “Normal Year” ET

From 1968 to 1990 detailed records of Class A pan evaporation were recorded in dozens of locations around the SJV.

Using ETo = 0.85 Evaporation

a 20 year average ETo of 49.3 inches was published by CA Dept of Water Resources

CIMIS

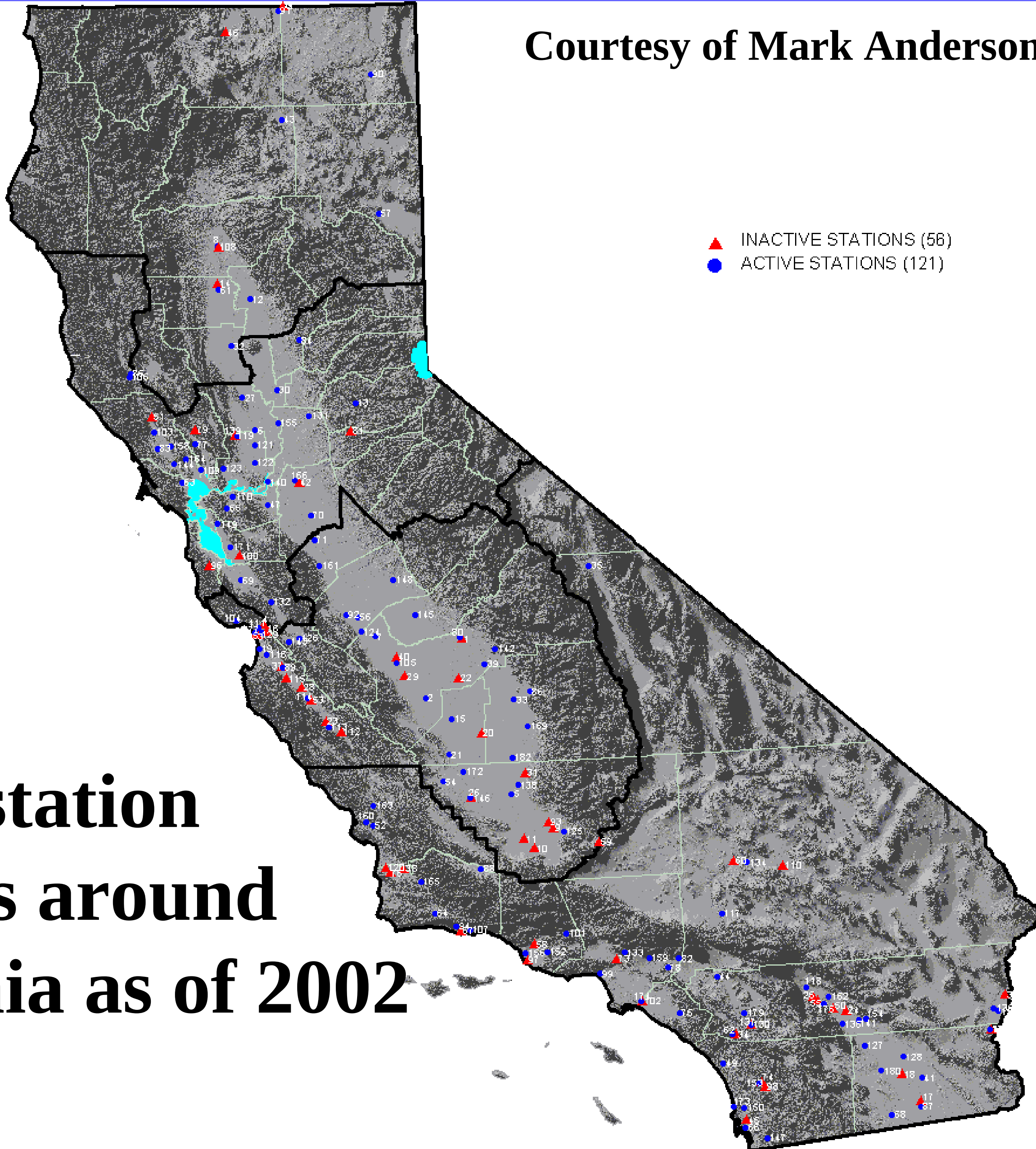
CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SERVICE

Courtesy of Mark Anderson, DWR

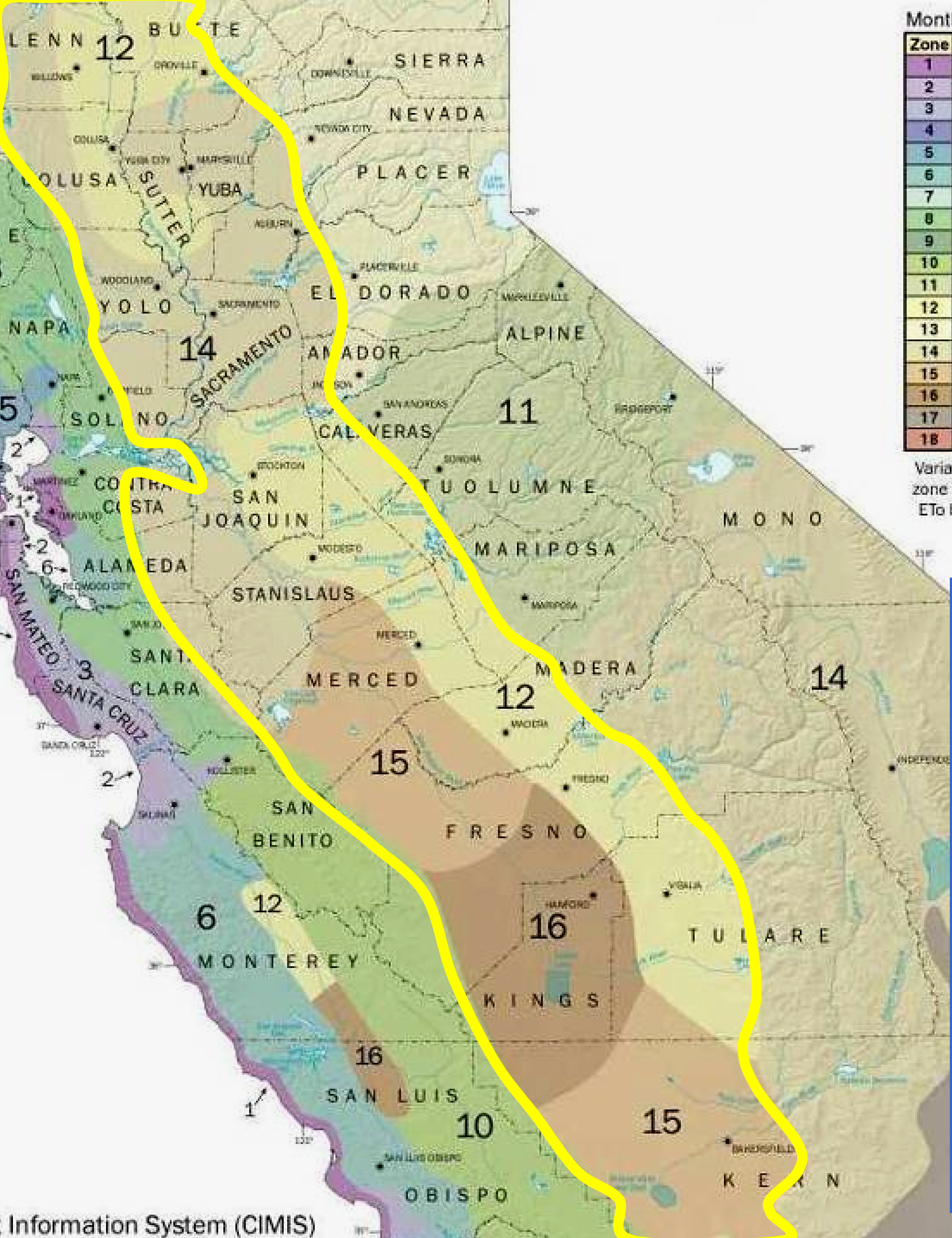
CIMIS Weather Station

Courtesy of Mark Anderson, DWR

Courtesy of Mark Anderson, DWR



CIMIS station locations around California as of 2002



Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

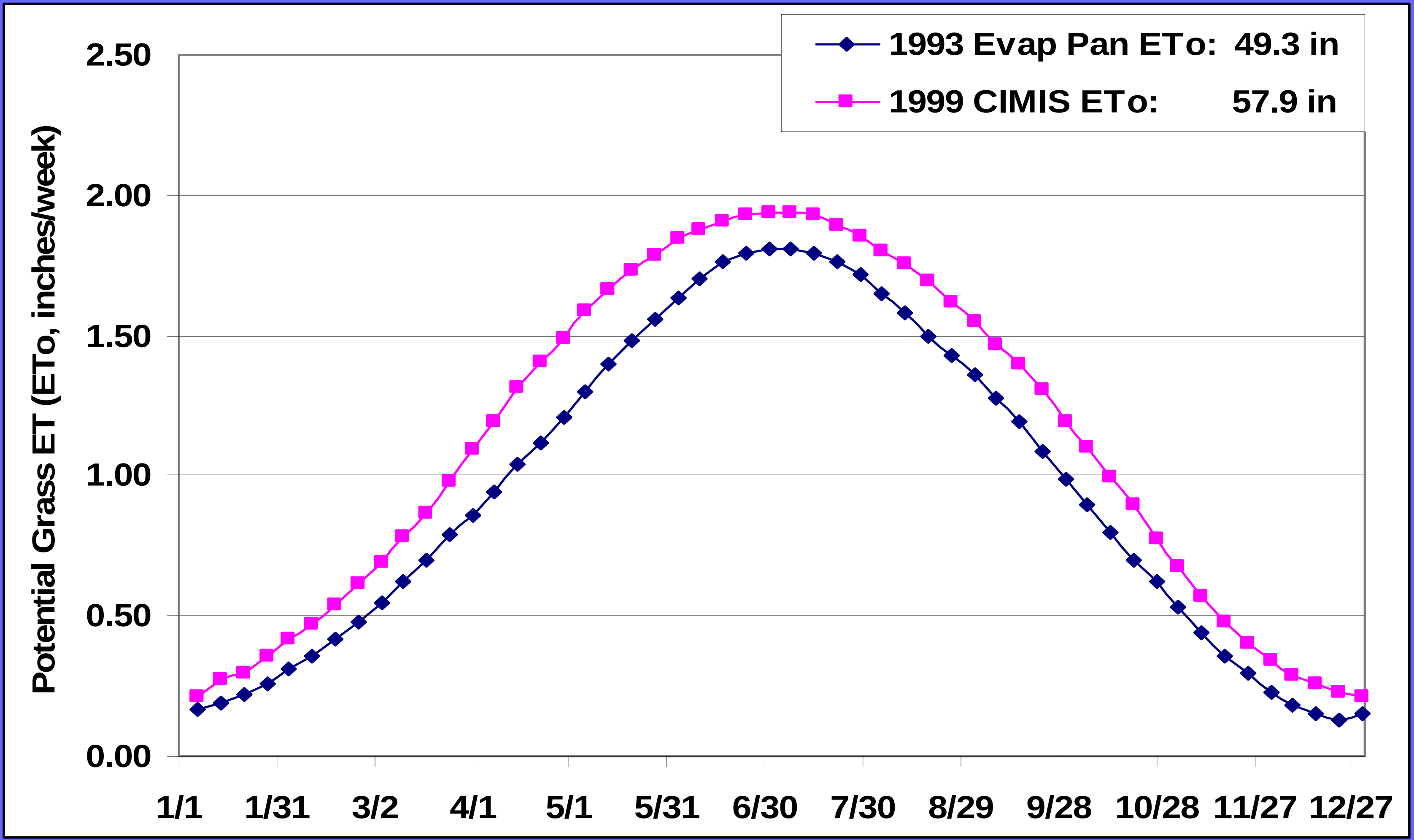
Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

The whole Central Valley covers Zones 12 to 16: for an "normal year" ETo of 53.3 to 62.5 in/yr, with most area @ 53 to 58 inches.

Comparing 1993 and 1999 estimates of Potential Evapotranspiration (ETo) for SJV

(Potential ETo, reference crop ET, is water use by a tall cool-season non-stressed pasture grass)



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CALIFORNIA THE GOLDEN STATE

CALIFORNIA HOMEPAGE | GOVERNOR'S HOMEPAGE

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Note: To make multiple selections from any list, hold down the control key while you make your selections.

1

Select Stations

Select any combination of weather stations, regions and/or zip codes. Highlighting a region will select the stations in that region. Likewise, specifying zip codes will select associated weather stations.

Weather Stations

134 - Barstow NE
135 - Blythe NE
136 - Oasis
137 - Temecula East II
138 - Famoso
139 - Winters
140 - Twitchell Island

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* Weather stations that are "(inactive)" no longer record weather data.
Historical data does exist, but please refer to the weather station list to

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CIMIS (California Irrigation Management Information System)

Daily Report

Rendered in ENGLISH Units.
March 26, 2002 - April 1, 2002
Printed on April 2, 2002

Famoso - San Joaquin Valley - Station 138

Date	CIMIS ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Pt (°F)	Avg wSpd (MPH)	Wnd Run (miles)	Avg Soil Temp (°F)
03/26/2002	0.15	0.00	539	10.8	70.1	41.2	55.0	97	48	73	46.5	3.1	74.9	58.1
03/27/2002	0.17	0.00	559	10.9	74.5	45.8	58.6	93	37	65	46.8	3.2	77.7	58.7
03/28/2002	0.18	0.00	555	10.4	76.0	45.4	61.5	92	32	56	45.7	3.5	84.3	59.5
03/29/2002	0.19	0.00	577	11.3	80.5	50.8	65.0	75	33	54	47.8	3.5	84.2	60.6
03/30/2002	0.19	0.00	574	12.7	83.2	55.4	67.1	83	35	56	50.8	3.4	82.7	61.7
03/31/2002	0.20	0.00	578	13.0	85.9 Y	52.4	66.7	88	30	58	51.6	3.1	75.7	62.5
04/01/2002	0.19	0.00	577	13.3	85.6	49.9	66.5	91	31	60	52.1	3.1	76.0	62.9
Total/Avg	1.27	0.00	566	11.8	79.4	48.7	62.9	88	35	60	48.8	3.3	79.4	60.6

Calculating ET for crops:

$$ET_{crop} = ET_o * K_c * E_f$$

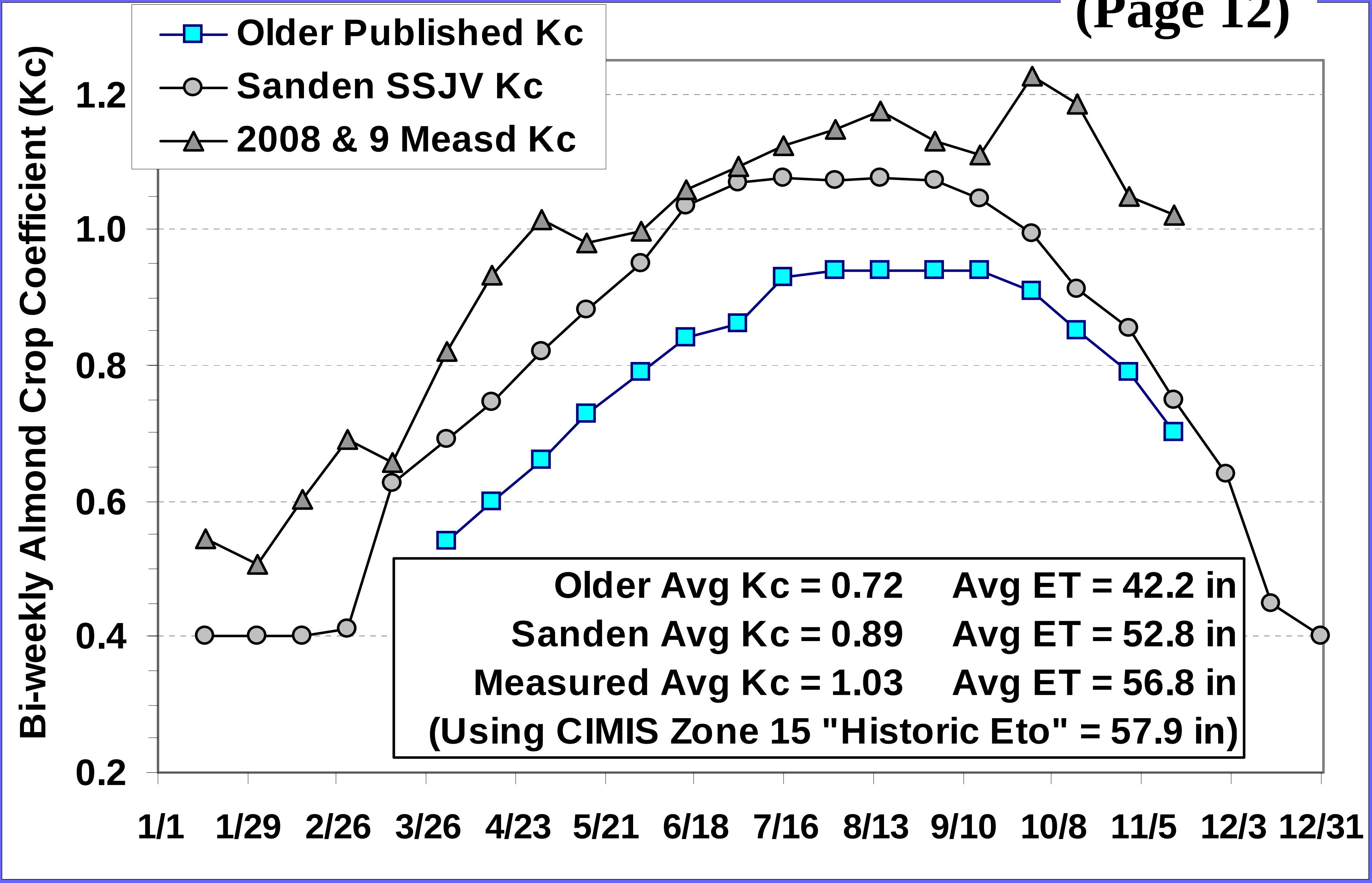
ET_o = **reference crop** (tall grass) ET

K_c = **crop coefficient** for a given stage of growth as a ratio of grass water use. May be 0 to 1.3, standard values are good starting point.

E_f = an "**environmental factor**" that can account for immature permanent crops and/or impact of salinity. May be 0.1 to 1.1, determined by site.

What are optimal almond Kc's and crop ET?

(Page 12)



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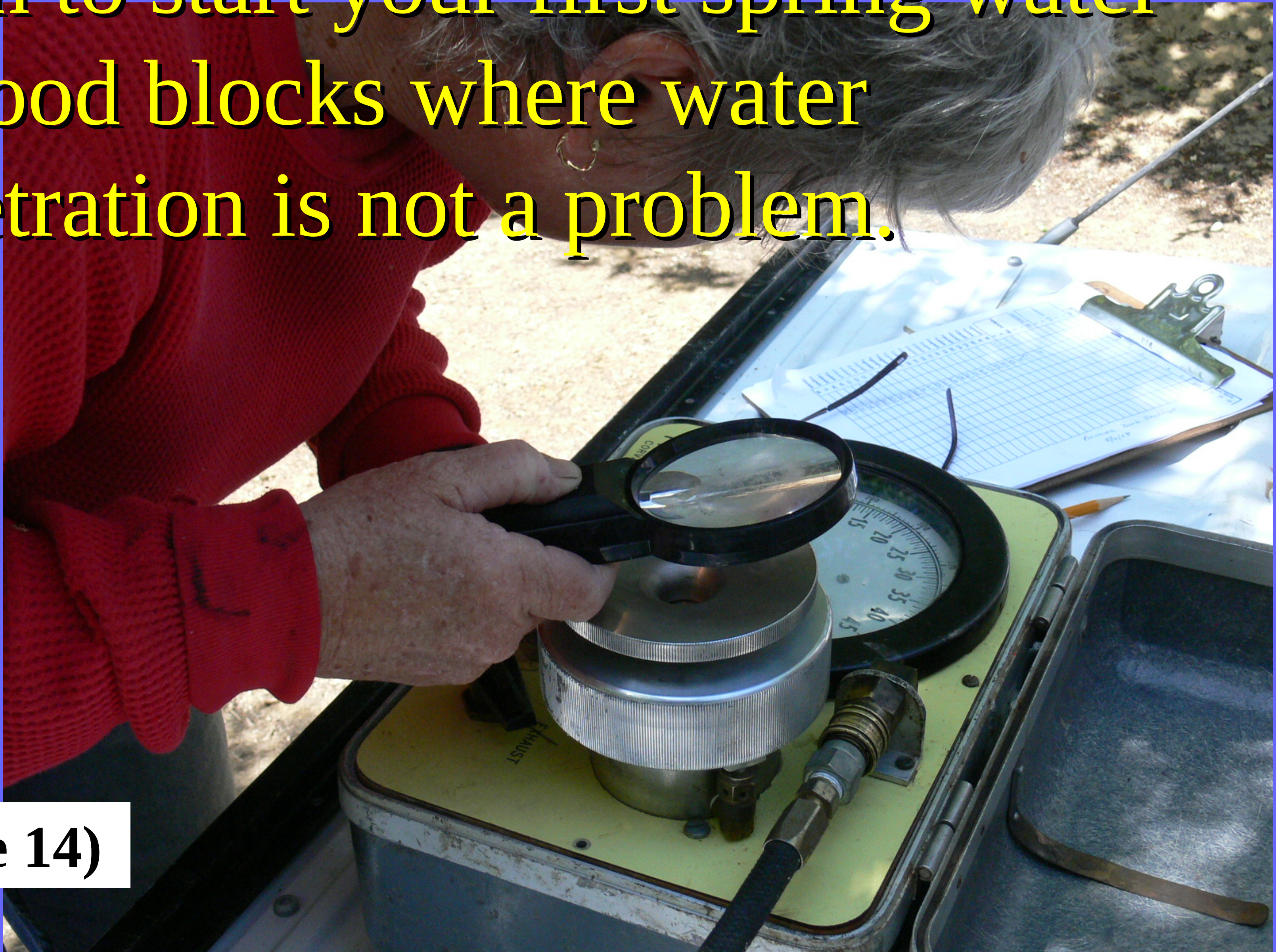
CIMIS ET Estimates Using "Historic" Eto for Modesto (CIMIS Zone 12)

Week	Normal Year Grass Eto (in)	Mature Crop Coefficient (Kc)	Almond ET -- Some Cover Crop, MIcrosprinkler (N. San Joaquin Valley Modesto, CA) 1st Leaf @ 40%	2nd Leaf @ 55%	3rd Leaf @ 75%	4th Leaf @ 90%	Mature	Gallon / day / tree
1/6	0.23	0.40	0.03	0.05	0.07	0.08	**0.09**	**3**
1/13	0.30	0.40	0.04	0.07	0.09	0.11	**0.12**	**4**
1/20	0.32	0.40	0.04	0.07	0.10	0.12	**0.13**	**4**
1/27	0.39	0.40	0.05	0.09	0.12	0.14	**0.16**	**5**
2/3	0.32	0.40	0.04	0.07	0.10	0.12	**0.13**	**6**
2/10	0.36	0.40	0.04	0.08	0.11	0.13	**0.15**	**7**
2/17	0.42	0.40	0.05	0.09	0.13	0.15	**0.17**	**8**
2/24	0.47	0.40	0.06	0.10	0.14	0.17	**0.19**	**9**
3/3	0.60	0.42	0.08	0.14	0.19	0.23	**0.25**	**10**
3/10	0.68	0.61	0.13	0.23	0.31	0.38	**0.42**	**17**
3/17	0.77	0.64	0.15	0.27	0.37	0.44	**0.49**	**20**
3/24	0.85	0.67	0.17	0.31	0.42	0.51	**0.56**	**23**
3/31	0.94	0.72	0.20	0.37	0.51	0.61	**0.68**	**28**
4/7	1.04	0.74	0.23	0.42	0.58	0.69	**0.77**	**31**
4/14	1.15	0.75	0.26	0.47	0.65	0.78	**0.86**	**35**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9/15	1.31	1.04	0.41	0.75	1.02	1.22	**1.36**	**52**
9/22	1.23	1.02	0.37	0.69	0.94	1.12	**1.25**	**47**
9/29	1.12	0.97	0.33	0.60	0.82	0.98	**1.09**	**41**
10/6	1.03	0.95	0.29	0.53	0.73	0.87	**0.97**	**37**
10/13	0.93	0.88	0.25	0.45	0.62	0.74	**0.82**	**31**
10/20	0.84	0.88	0.22	0.41	0.55	0.66	**0.74**	**28**
10/27	0.72	0.83	0.18	0.33	0.45	0.54	**0.60**	**23**
11/3	0.59	0.78	0.14	0.25	0.35	0.41	**0.46**	**19**
11/10	0.50	0.71	0.11	0.20	0.27	0.32	**0.36**	**14**
11/17	0.42	0.68	0.09	0.16	0.22	0.26	**0.29**	**12**
11/24	0.37	0.60	0.07	0.12	0.16	0.20	**0.22**	**9**
12/1	0.31	0.50	0.05	0.09	0.12	0.14	**0.16**	**6**
12/8	0.26	0.40	0.03	0.06	0.08	0.09	**0.10**	**4**
12/15	0.24	0.40	0.03	0.05	0.07	0.09	**0.10**	**4**
12/22	0.22	0.40	0.03	0.05	0.06	0.08	**0.09**	**4**
12/29	0.18	0.40	0.02	0.04	0.05	0.07	**0.07**	**3**
Total	**53.37**		**14.57**	**26.71**	**36.42**	**43.71**	**48.57**	

Use the pressure bomb to determine when to start your first spring water in flood blocks where water penetration is not a problem.



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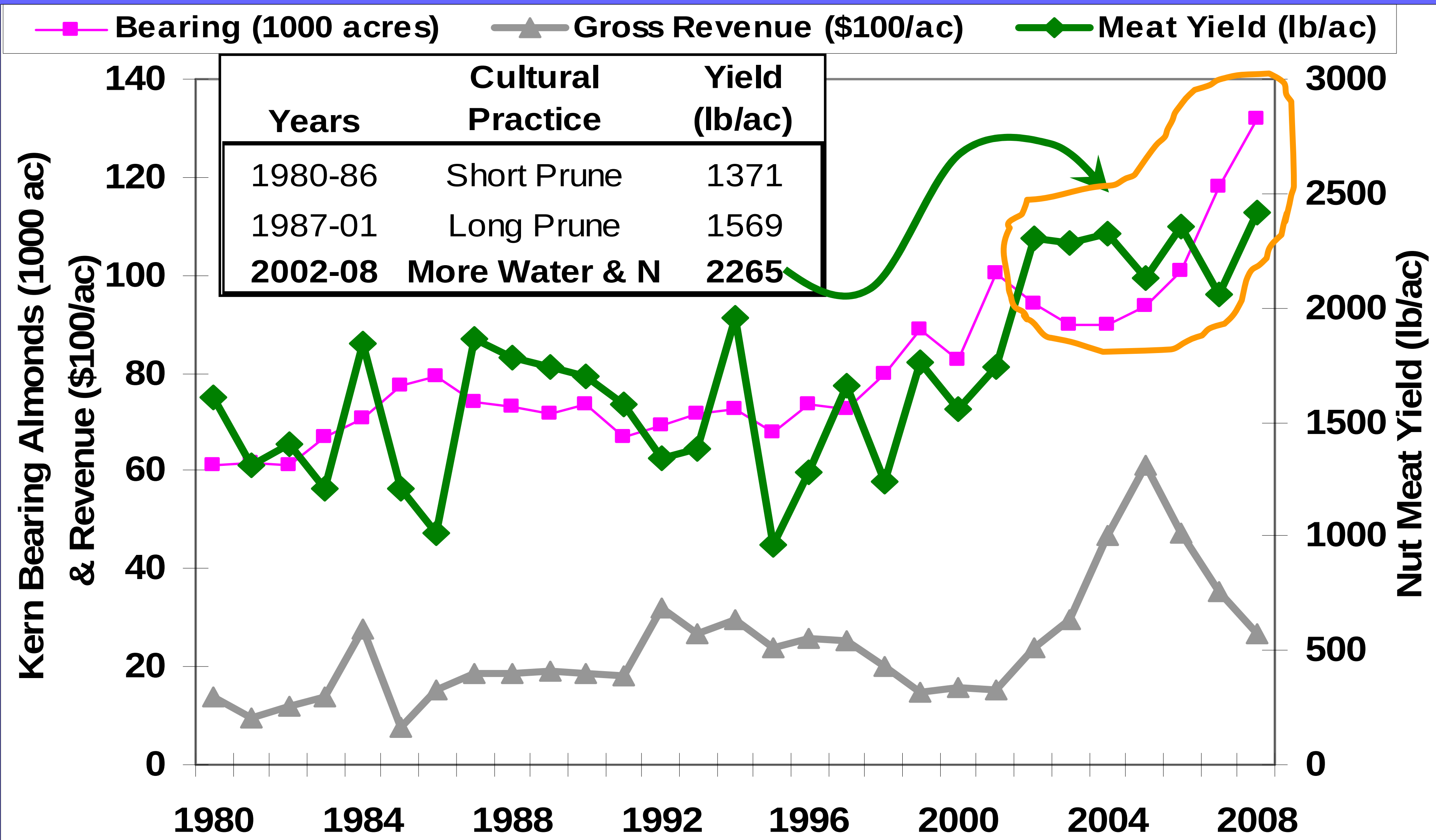
Stem / bagged leaf water potential guidelings for almonds:

- < 10 bars: no stress
- 10 – 12 bars: mild stress
- 12 – 16 bars: moderate stress
- 14 – 18 bars: recommended level for hull rot reduction, 14-15 bars the perfect zone.
- 16 – 20 bars: high stress
- > 20 bars: wilt and eventual defoliation

Changes in Kern County almond yield and acreage from 1980-2008



Years	Cultural Practice	Yield (lb/ac)
1980-86	Short Prune	1371
1987-01	Long Prune	1569
2002-08	**More Water & N**	**2265**

Westside Almond Irrigation & N trial – Yields, applied water, & 2003 soil moisture.

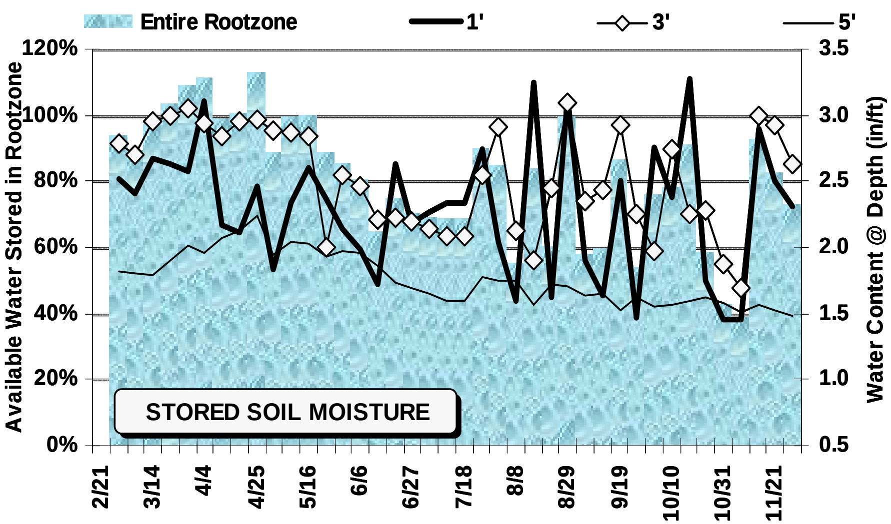
Nonpariel yields (lb/ac) by applied irrigation & N fertilizer (lb/ac) (starting year 5th leaf, NW Kern)

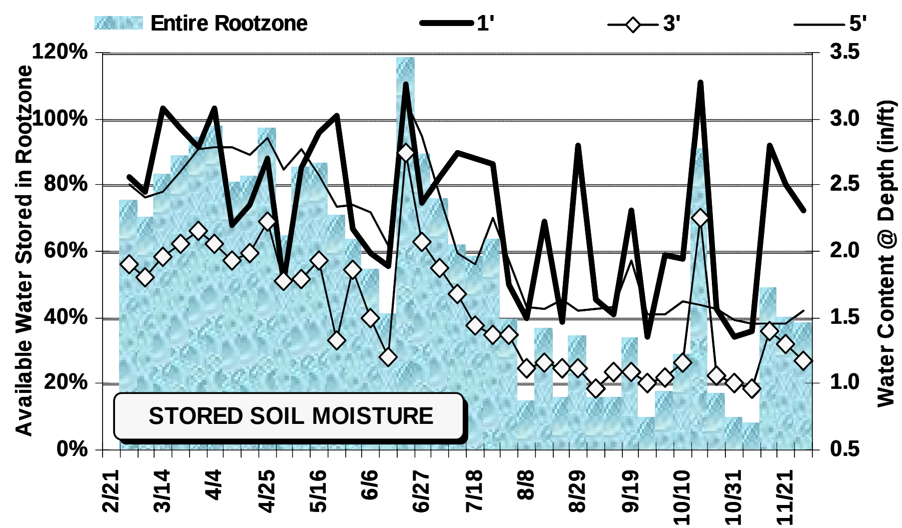
	Full Irrigation (in)	N~250	N~125	Reduced Irrigation (in)	N~250	N~125
2001	?	1926	1898	(-25%)	1979	1992
2002	48.5	1922	1275	38.8	1593	1215
2003	57.6	3004	2030	47.1	2352	1901
2004	59.7	2838	2752	47.9	2307	2209
2005	53.8	2227	1493	44.5	1758	1538
2006	52.5	3241	2697	41.5	2739	2330
2002-6	**272.1**	**13232**	**10247**	**219.8**	**10749**	**9193**
Wtr Use Eff (lb/in)		**48.6**	**37.7**		**48.9**	**41.8**

Lampinen, B., T.Dejong, S.Weinbaum, S.Metcalf, C. Negron, M.Viveros, J. McIlvane, N.Ravid, and R.Baker. 2007. Spur dynamics and almond productivity. CA Almond Board 2006 Conference Proceedings, 18pp.

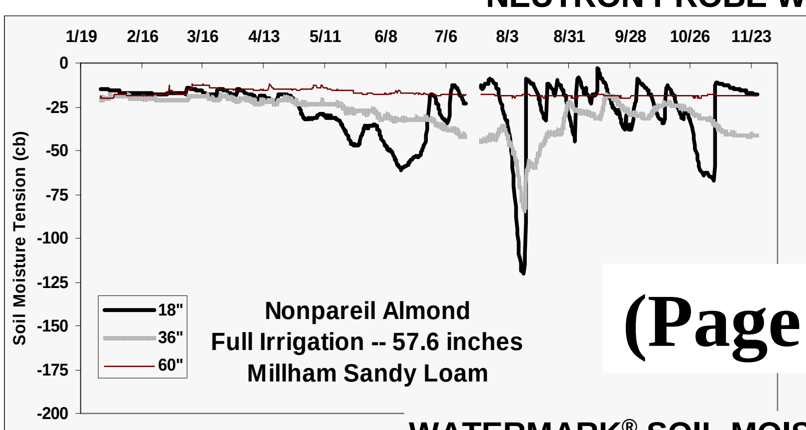
Full Irrigation
57.6 Total for 2003
3.2" Dormant Refill
54.4" In-Season

Reduced Irrigation
47.9 Total for 2003
2.9" Dormant Refill
45.0" In-Season





NEUTRON PROBE WATER CONTENT OVER SEASON



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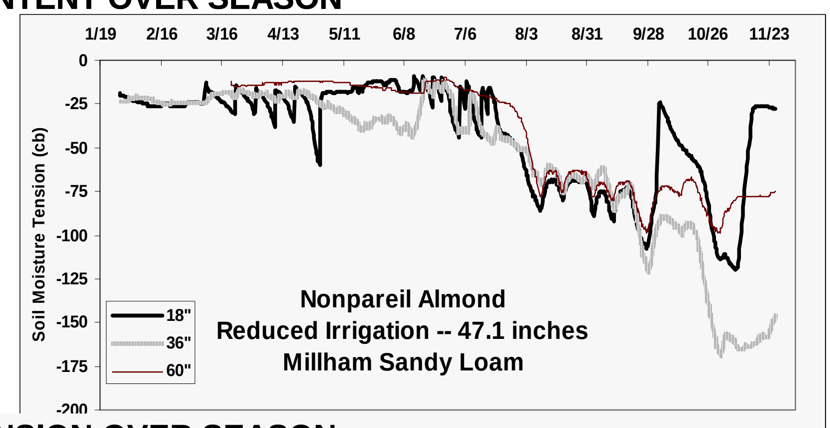

WATERMARK® SOIL MOISTURE TENSION OVER SEASON

Nonpariel yields (lb/ac) by applied irrigation & N fertilizer (lb/ac) (starting year 5th leaf, NW Kern)

	Full Irrigation			Reduced Irrigation		
	(in)	N~250	N~125	(in)	N~250	N~125
2001	?	1926	1898	(-25%)	1979	1992
2002	48.5	1922	1275	38.8	1593	1215
2003	57.6	3004	2030	47.1	2352	1901
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2002-6	**272.1**	**13232**	**10247**	**219.8**	**10749**	**9193**
Wtr Use Eff (lb/in)		**48.6**	**37.7**		**48.9**	**41.8**

Reduced N applications always maintained July leaf tissue >2% N.

Lampinen, B., T.Dejong, S.Weinbaum, S.Metcalf, C. Negron, M.Viveros, J. McIlvane, N.Ravid, and R.Baker. 2007. Spur dynamics and almond productivity. CA Almond Board 2006 Conference Proceedings, 18pp.

Conclusions

-Get organized!

-Put all your info together for each field

-Excel spreadsheets, Ag Water, Roy, PureSense (new platform), Oregon State Irrigation Scheduling On-line

IRRIGATION REPORT -- Fertilization Trial FANJET 12-2

Adjustment factor (% of Mature Water Use): 100%

CURRENT DATE: 9/9/2009 | LAST READING DATE: 9/8/2009

SOIL TYPE: Milham/Panoche sandy clay loam
FIELD CAPACITY (in/ft): 2.4
REFILL POINT (in/ft): 0.9
ROOTING DEPTH (ft): 6
ROW SPACING: 21' x 24'
IRRIGATION SYSTEM: 18, 1.2 gph drip
NORMAL RUN TIME (hrs): 24
WETTED VOLUME (%): 50%

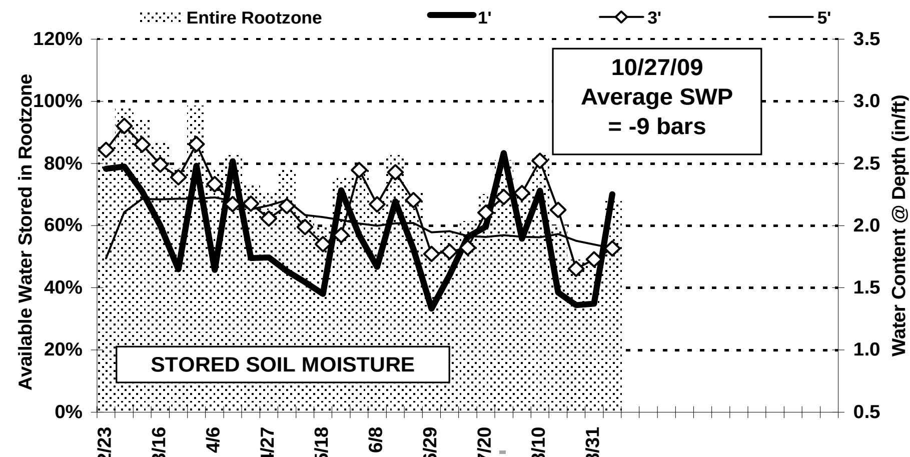
Total Avail @ 100% (in): 9
AREA/TREE (sq ft): 504
DESIGN FLOW (gph/tree): 21.6
WET AREA APPLIC (in): 3.30
NUMBER of SETS: 3
TOTAL AREA APPLIC (in): 1.65

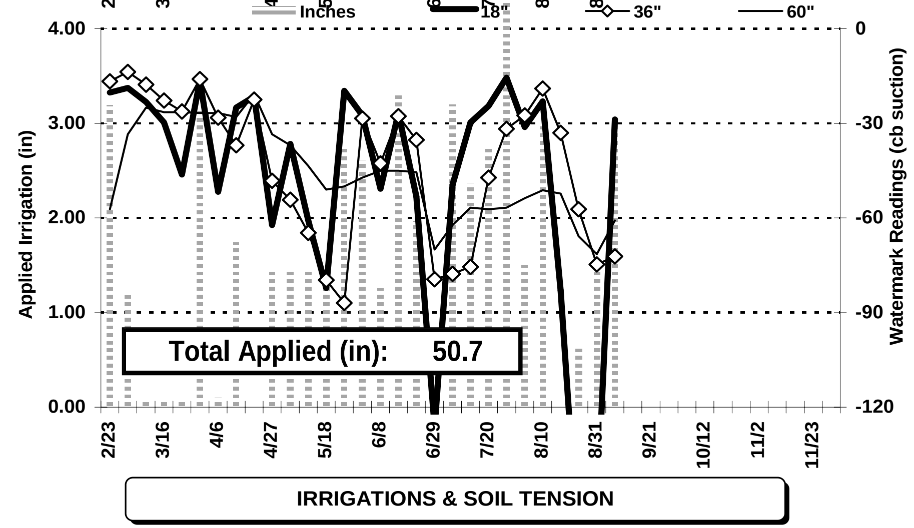
CURRENT DEPLETION 3.11 (in)

PROJECTED IRRIGATIONS: 9/9 | 9/17 | 9/26

CIMIS ET Estimates

Week	Avg ET	2009 ET	Measured Use & Drainage
1/5	0.00	0.00	0.00
1/12	0.00	0.00	0.00
1/19	0.00	0.00	0.00
1/26	0.00	0.00	0.00
2/2	0.00	0.00	0.00
2/9	0.00	0.00	0.00
2/16	0.00	0.00	0.00
2/23	0.25	0.23	0.10
3/2	0.30	0.31	0.61
3/9	0.50	0.50	0.25
3/16	0.58	0.65	0.40
3/23	0.67	0.77	0.42
3/30	0.80	0.97	2.22
4/6	0.91	1.12	1.02
4/13	1.02	0.92	1.51
4/20	1.17	1.24	0.46
4/27	1.28	1.45	1.55
5/4	1.41	1.16	1.15
5/11	1.55	1.66	2.08
5/18	1.68	1.71	1.57
5/25	1.77	1.95	2.01
6/1	1.85	1.94	2.45
6/8	1.89	1.66	1.77
6/15	1.99	1.77	2.62
6/22	2.09	2.10	2.53
6/29	2.11	2.27	0.85
7/6	2.14	2.28	2.92
7/13	2.14	2.08	2.21
7/20	2.06	2.18	2.34
7/27	2.05	2.10	3.86
8/3	1.97	2.07	1.94
8/10	1.95	1.90	2.43
8/17	1.87	1.89	1.05
8/24	1.79	1.64	1.11
8/31	1.71	1.78	1.46
9/7	1.60	1.61	2.17
9/14	1.49	1.42	3.06
9/21	1.37		
9/28	1.20		
10/5	1.07		
10/12	0.91		
10/19	0.81		
10/26	0.66		
11/2	0.54		
11/9	0.42		
11/16	0.34		
11/23	0.26		
11/30	0.18		
12/7	0.13		
12/14	0.12		
12/21	0.11		
12/28	0.09		
Total	52.8	45.3	50.1





You wouldn't buy a pump without a "boiler plate" showing H.P., rpm, etc? You need the "boiler plate" for your irrigation system.

Fertilization Trial FANJET 12-2

Adjustment factor (% of Mature Water Use):	100%		
CURRENT DATE:	**9/9/2009**	**LAST READING DATE:**	**9/8/2009**
SOIL TYPE:	Milham/Panoche sandy clay loam		
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REFILL POINT (in/ft):	0.9	**Total Avail @ 100% (in):**	**9**
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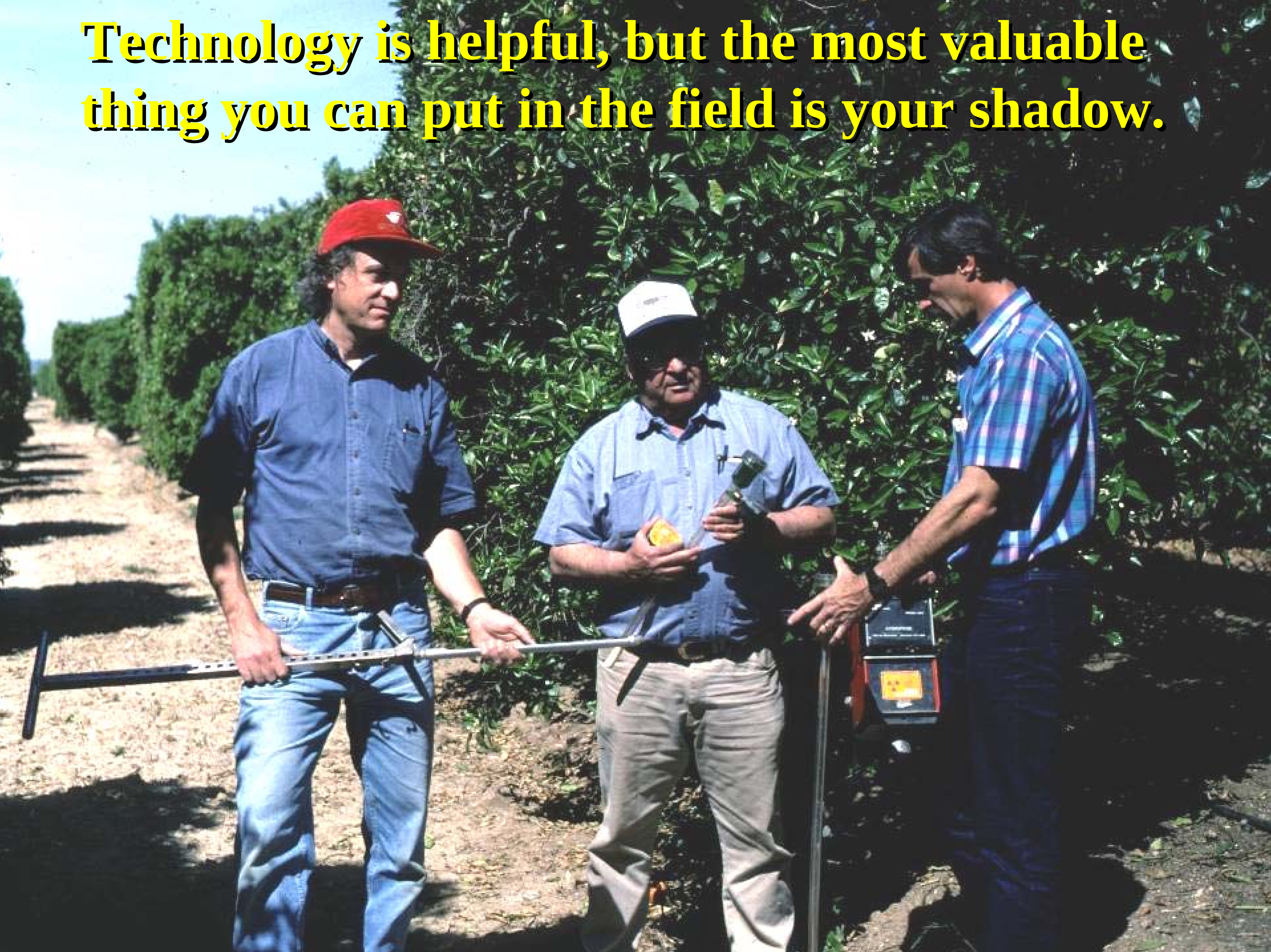
ROW SPACING:	21' x 24'	**DESIGN FLOW (gph/tree):**	21.6
IRRIGATION SYSTEM:	18, 1.2 gph drip		
NORMAL RUN TIME (hrs):	24	**WET AREA APPLIC (in):**	3.30
WETTED VOLUME (%):	50%	**NUMBER of SETS:**	3
		TOTAL AREA APPLIC (in):	1.65

CURRENT DEPLETION	**PROJECTED IRRIGATIONS**		
3.11 (in)	**9/9**	**9/17**	**9/26**


Technology is helpful, but the most valuable thing you can put in the field is your shadow.

SOME SIMPLE ECONOMIC CONCLUSIONS:

For soil moisture monitoring and scheduling:

- Soil moisture equipment costs: $200-4,000/field
- Consulting costs: $800 (one neutron probe site) to $20/ac ($3000/ac for 150 acres)
- Cheap water, good prices, no soil sealing: not a big payback
- $60 water, on 150 acres: 6” = $4,500
- $100 water on 150 acres: 6” = $7,500
- $500 water on 150 acres: 6” = $37,500
- 200 lb/ac kernels on 150 acres @ $2/lb = $60,000


"A picture's worth …"
… maybe several $1000!