University of California

Nitrogen Management Training

for Certified Crop Advisers

MODULE 4

Irrigation and Nitrogen Management

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Irrigation and Nitrogen Management

Successful nitrogen management depends on efficient irrigation water management:

- Nitrate is mobile and moves with water.
- You can apply the right amount of N in the root zone, but N can leach past the root zone unless the correct amount of water is applied at the correct time.
- Inefficient irrigation may result in N-deficient crops and potentially add nitrates to groundwater.

Irrigation Efficiency

- Measure of how much of the applied water goes to "reasonable and beneficial uses".
  - The major beneficial use is to supply plant water needs and grow productive crops.
  - Other beneficial uses include salt leaching and frost protection, but both of these can lead to N leaching if not carefully done.

- Non-beneficial uses or losses are:
  - Deep percolation below root zone except the amount needed to manage salinity
  - Tailwater runoff that is not reused

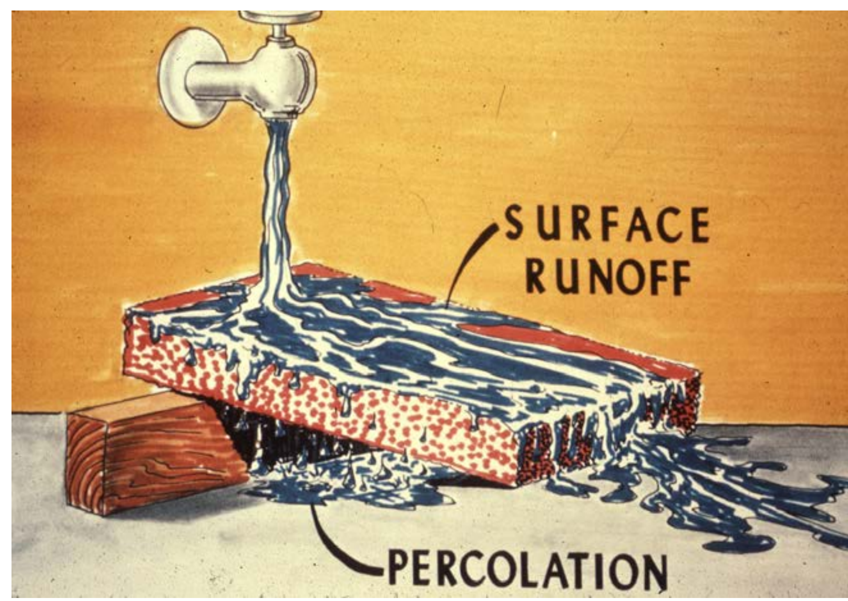
Irrigation Efficiency: Calculation

$$\text{Irrigation Efficiency (\%)} = \frac{\text{Beneficially-Used Water}}{\text{Total Water Applied}} \times 100$$

- What is a realistic efficiency?

  70% minimum eventually required by regulations

  85-90% is an impressive efficiency to target

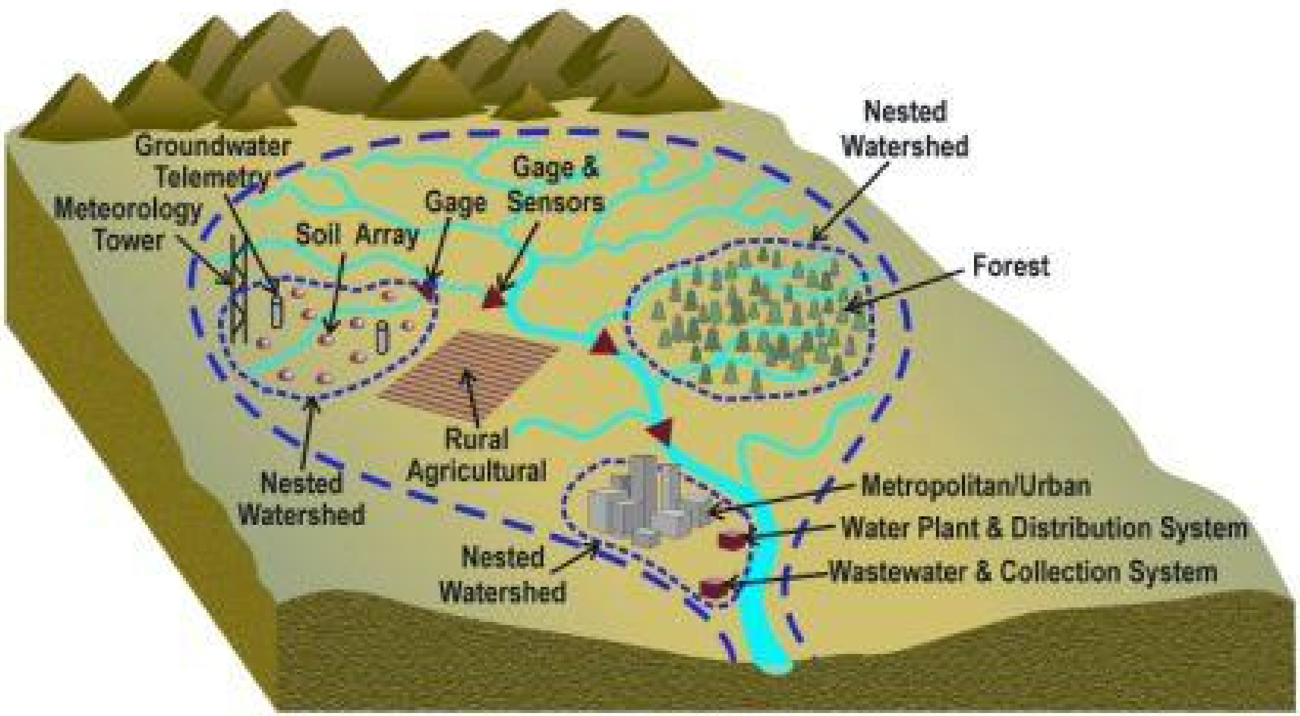


Irrigation Efficiency

Different people arrive at different estimates for Irrigation Efficiency. Why?

Field scale – vs – Watershed or basin scale

Single irrigation – vs – Sum of several irrigations in a season



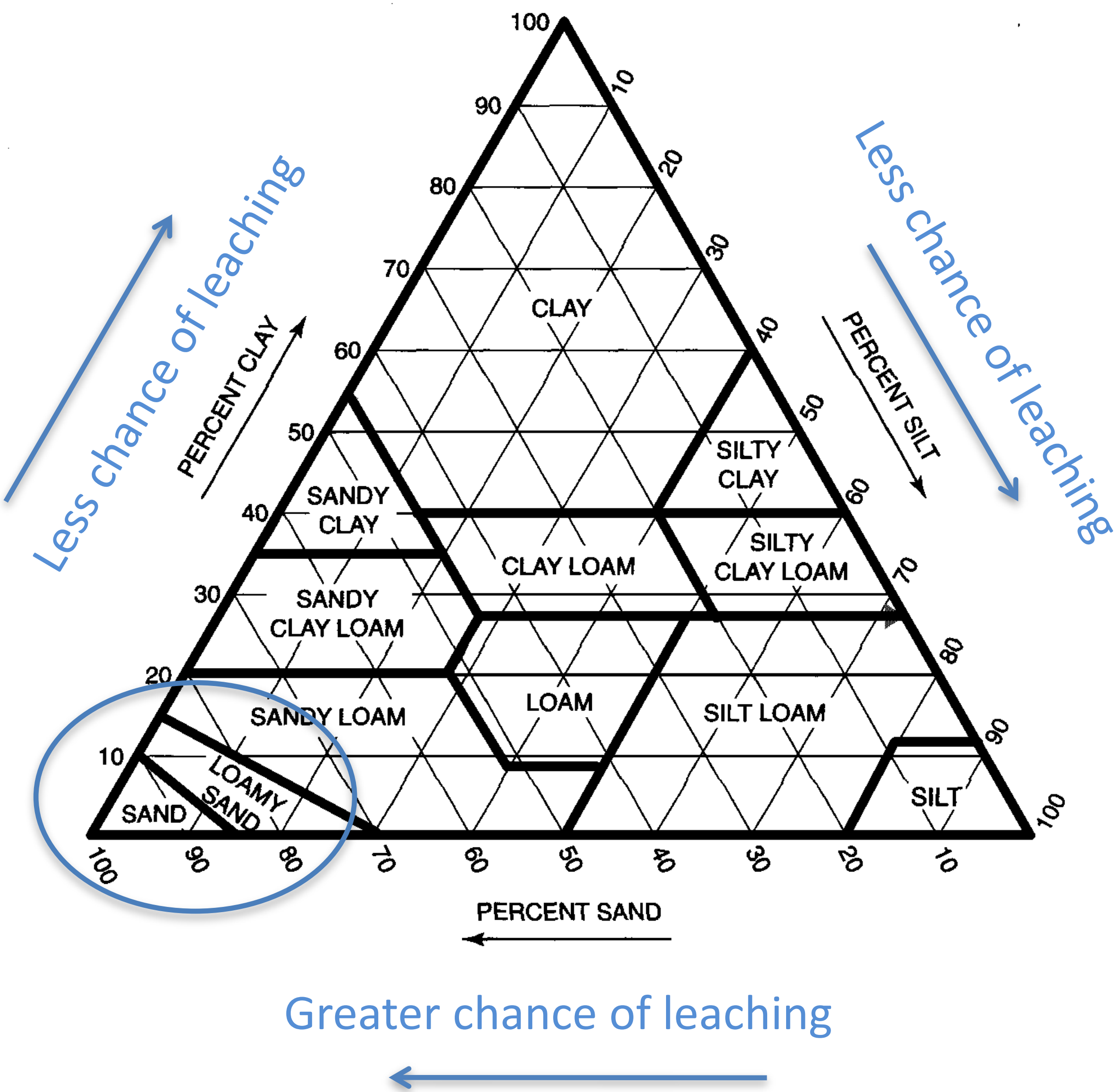
How Do We Become More Efficient Irrigators?

Achieving Efficient Irrigation

Where to begin:

- Use readily available information to look for situations where the choice of crop, soils, and irrigation method do not match up well.
  - Fertilizer bills
  - Electricity, fuel, and water bills
  - Production history

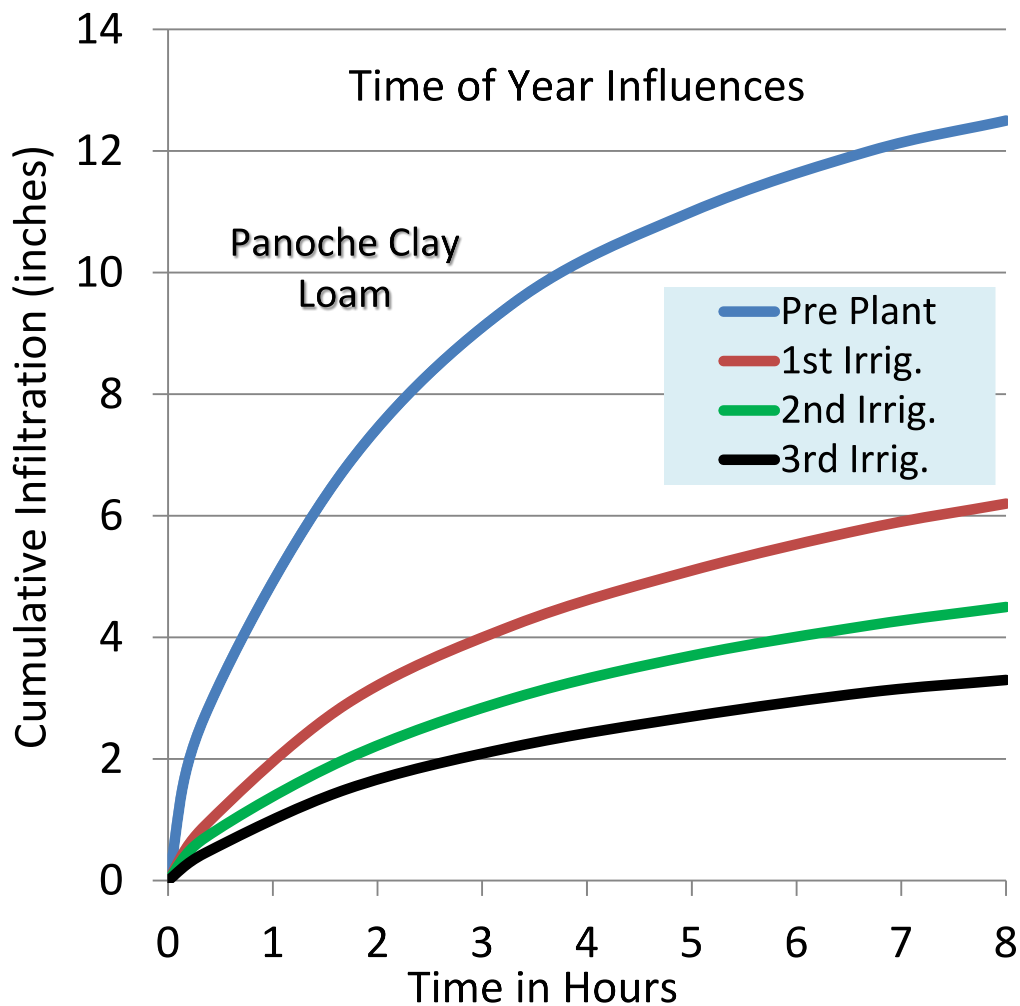
Soil texture and its influence on leaching



1. Sprinkler
2. Drip and microsprinkler
3. Flood
4. Furrow

Infiltration and N Leaching

- Both "light" and "heavy" soil types can have a wide range of soil intake rates.
- Soil moisture, soil mineralogy, soil structure, and tillage are key elements.



How Do We Become More Efficient Irrigators?

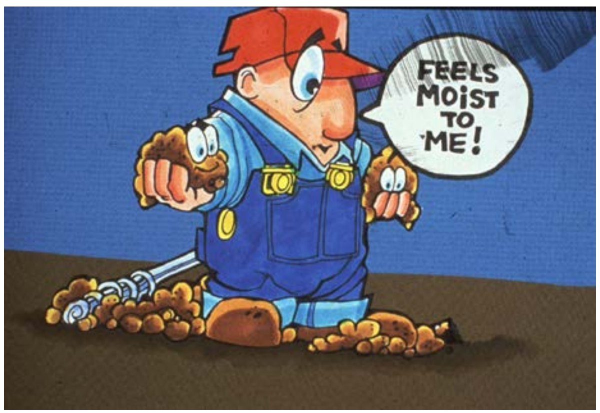
Know how much water to apply

Irrigation Scheduling

- Determining how much water to apply
  - Quantify how much water has been used by the crop since the previous irrigation or rainfall
  - When the correct amount of water is applied at the proper time, potential for deep percolation and leaching of nitrate is minimized.

Irrigation Scheduling: Soil Monitoring Approach

There are numerous soil moisture monitoring techniques, devices, and services available to growers.



"Feel Method," squeeze soil in hand to estimate its moisture level

Sophisticated devices continuously monitor soil moisture and upload data to online databases growers can check.

Irrigation Scheduling: Soil Monitoring Approach: Drawbacks

- Most soil monitoring techniques tell when to irrigate, but not all provide how much to irrigate.

- Effectiveness is subject to representative placement of sensors and good understanding of the crop root zone.

Irrigation Scheduling: Plant Monitoring Approach

- Monitoring the plant itself for signs of water stress
- Relatively new approach, equipment and knowledge still developing

Irrigation Scheduling: Plant Monitoring Approach: Drawbacks

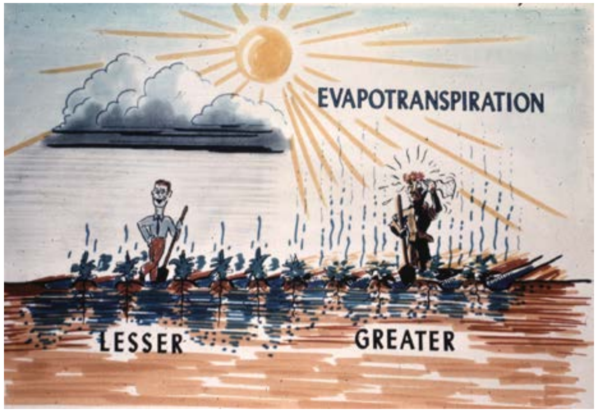
- **Limited information**, available for some crops & not for others
  - Interpreting pressure bomb readings and crop stress levels for most CA crops is unexplored

- Methods tend to be **labor intensive** – working toward automation

- Crop stress and readings tell you **when** to irrigate (plant is stressed) but not **how much**
  - How much water is needed can be learned with experience or by coupling plant monitoring with other approaches (i.e. ET)

Irrigation Scheduling: Weather Monitoring Approach

- Climatic conditions drive the water use of plants.
- Monitor the weather and use it to estimate crop water use (evapotranspiration).



Irrigation Scheduling: Weather Monitoring Approach

California has the CIMIS network to provide weather information and estimates of **Reference Crop ET** (ET of pasture grass).

Irrigation Scheduling: Weather Monitoring Approach

- Relates estimate to irrigation system design and performance

- Tells us both **when** and **how much** to irrigate

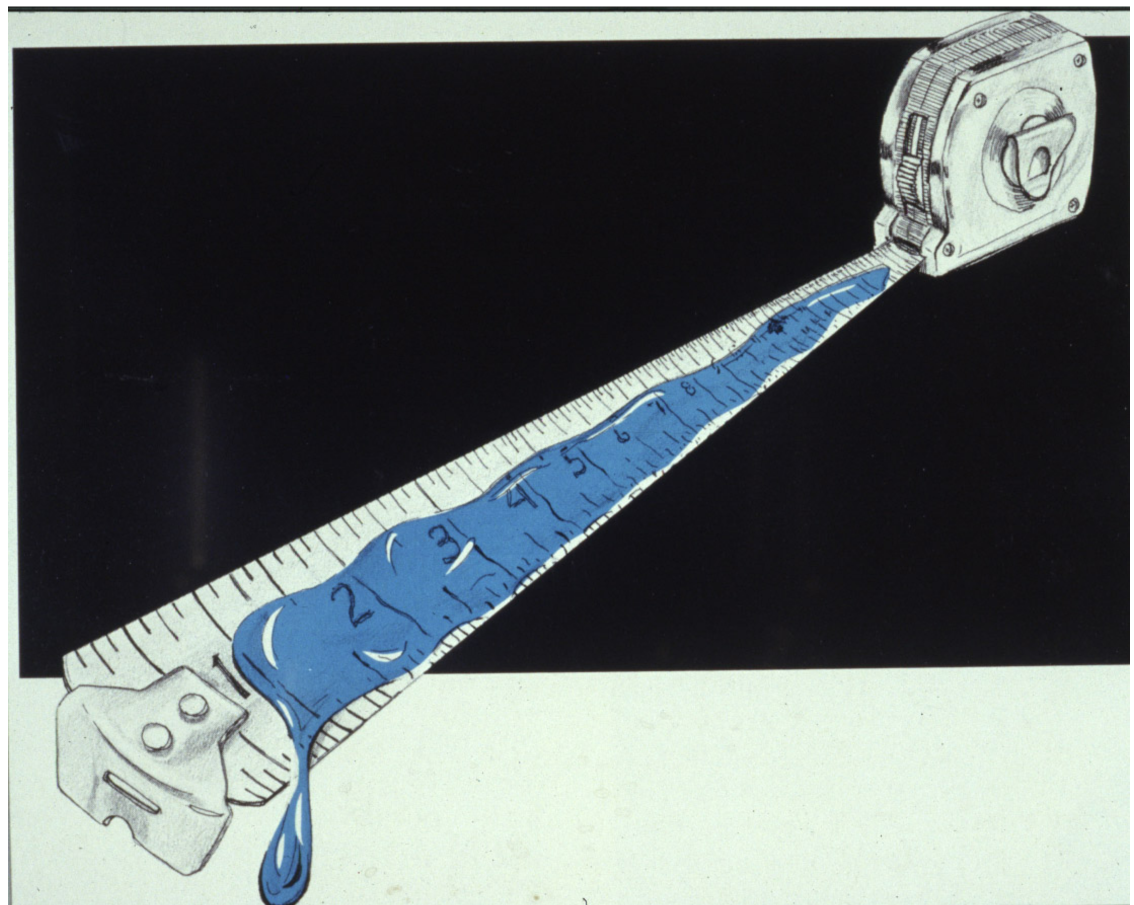
How Do We Become More Efficient Irrigators?

Apply the correct amount of water with a good irrigation system

Sound Irrigation System Design Concepts

- Ability to measure applied water and thus control leaching

Our ability to manage water improves if we have the ability to measure it.



Sound Irrigation System Design Concepts

How much water is being applied? Measure with a flow meter

Saddle Propeller Meter, the most common type of flow meter, attached by cutting through the pipe. It is sufficiently accurate for agricultural purposes.

Saddle propeller meter attached to pipe

Sound Irrigation System Design Concepts

How much water is being applied? Measure with a flow meter

Electronic flow meter, known as a MagMeter. It is a very accurate type of meter, but locating it near elbows and forks can alter pressure and decrease accuracy.

Debris in water can hinder propeller meters; installations with weeds and trash in the water need special flow meter devices.

Sound Irrigation System Design Concepts

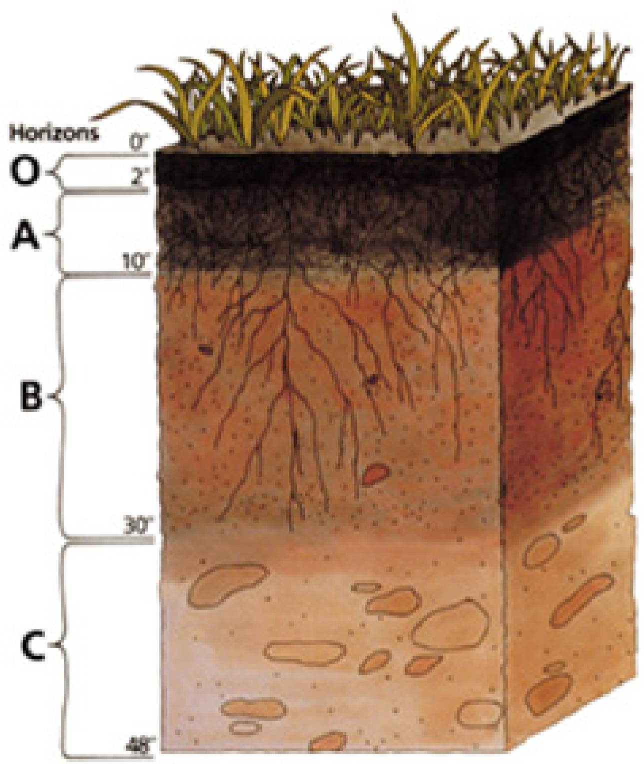
How much water is being applied? Irrigation system evaluation

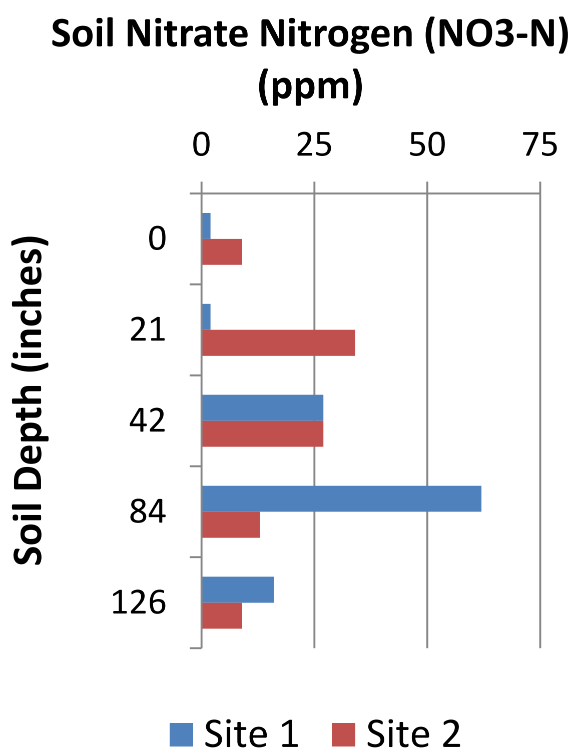
Water application rate and uniformity

Irrigation System Evaluation: Application Rate

A measure of the field-wide water application rate

- Most easily measured in pressurized irrigation systems
- Relates to how deep water (and nitrogen) will penetrate the crop root zone depending on the irrigation set time





Rapid Assessment

Step 1

Determine soil moisture depletion since last irrigation (ET)

Table CWU-8. Corn (Planted May 1) ET (in/day)

	Location					
	Madera	**Merced**	**Stockton**	**Modesto**	**Parlier**	**Visalia**
Apr 1-15						
Apr 16-30						
May 1-15	0.04	0.04	0.04	0.04	0.04	0.04
May 16-31	0.05	0.05	0.04	0.05	0.05	0.05
Jun 1-15	0.14	0.14	0.13	0.14	0.14	0.14
Jun 16-30	0.24	0.24	0.23	0.23	0.24	0.24
July 1-15	0.30	0.30	0.28	0.28	0.29	0.29
July 16-31	0.30	0.30	0.28	0.28	0.27	0.29
Aug 1-15	0.28	0.27	0.25	0.25	0.25	0.27
Aug 16-31	0.20	0.19	0.19	0.18	0.20	0.20
Sept 1-15	0.13	0.13	0.07	0.13	0.13	0.14
Sept 16-30						
Oct 1-15						
Total	**24.88**	**24.59**	**22.52**	**23.51**	**24.03**	**24.64**

Rapid Assessment

Step 2

Measure Flow and Determine how much water has been applied (flow rate)

- Flow meters the best way - on all pumps
- Irrigation District information
- Pump test - discharge will change (often a lot) if groundwater level changes.

Rapid Assessment

Step 2

Measure Flow and Determine how much water has been applied (inches)

$$D = \frac{(Q \div 449) \times T}{A}$$

D = inches of water applied

Q = gpm (gallons per minute) flow rate

T = hours irrigation set time

A = acres in irrigation set

***If flow is measured in cfs, no need to divide by 449 in equation**

Rapid Assessment

Step 3 Is the risk of deep percolation high?

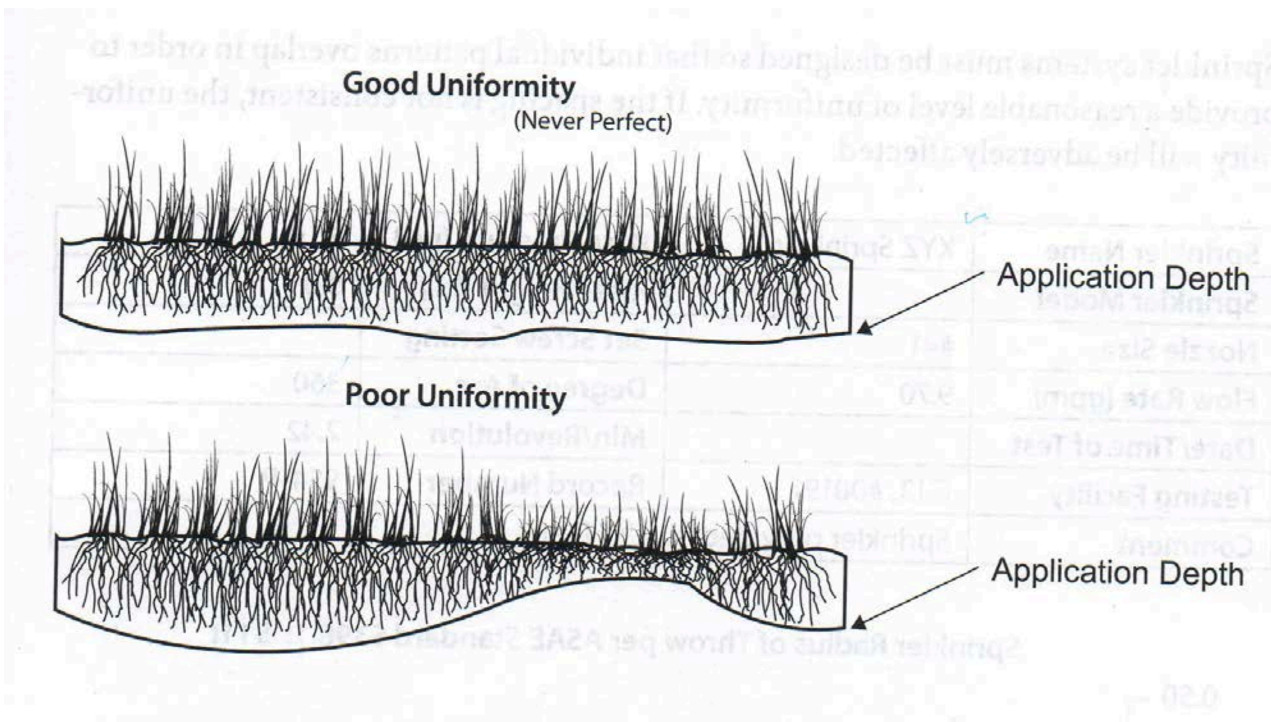
Compare the amount applied to the amount used since last irrigation.

- Leaching is likely to occur when runoff is minimal and applied water is “much” greater than crop use.

Irrigation System Evaluation: Irrigation Uniformity

A measure of how evenly water is applied to the field

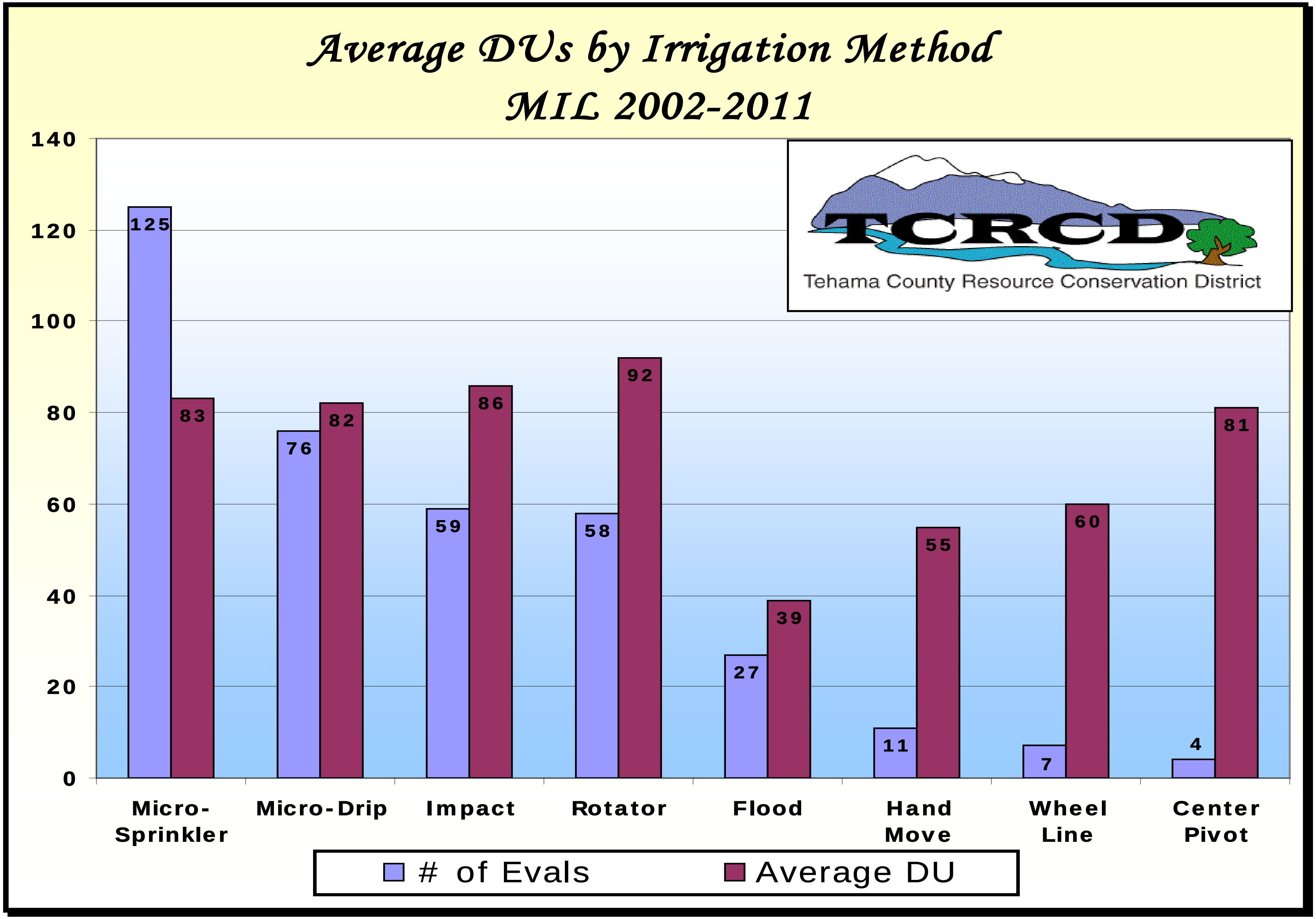
- Given as percentage with 100 % being perfect
- Various measures including Distribution Uniformity (DU), Coefficient of Uniformity (CU), and Emission Uniformity (EU).
- Knowing the general concept is more important than the details about the different measurement methods of irrigation uniformity.



Importance of Irrigation Uniformity

- Poor irrigation uniformity means that portions of the field are getting less water than others.
- Most growers do not want to under-irrigate even a portion of the crop, so they irrigate to make sure the area receiving the least water gets enough.
- Some portions of the field receive too much water. Too much water leads to deep percolation losses (leaching of water). If nitrate is in the soil profile, it can be leached with the water.
- Poor irrigation uniformity makes N leaching more likely.

Importance of Irrigation Uniformity

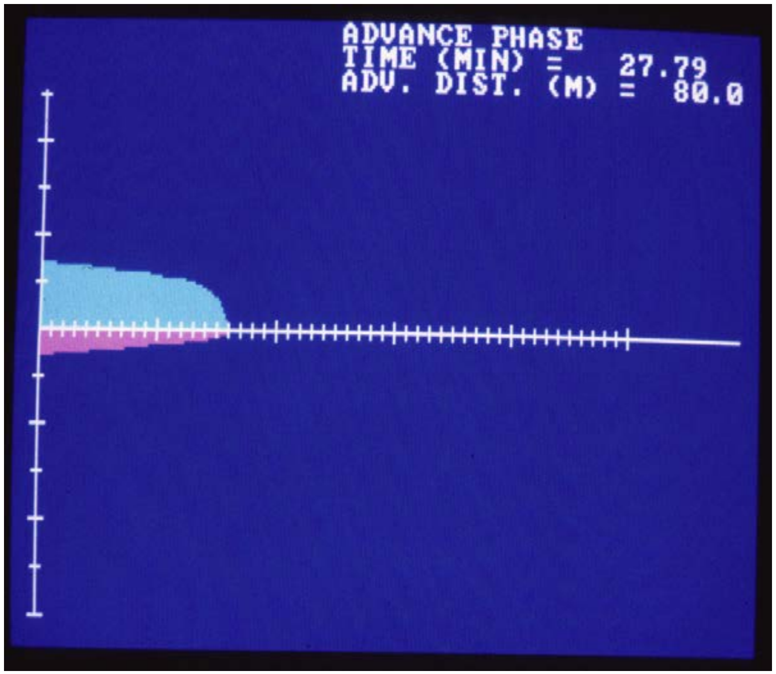


Types of Irrigation Systems

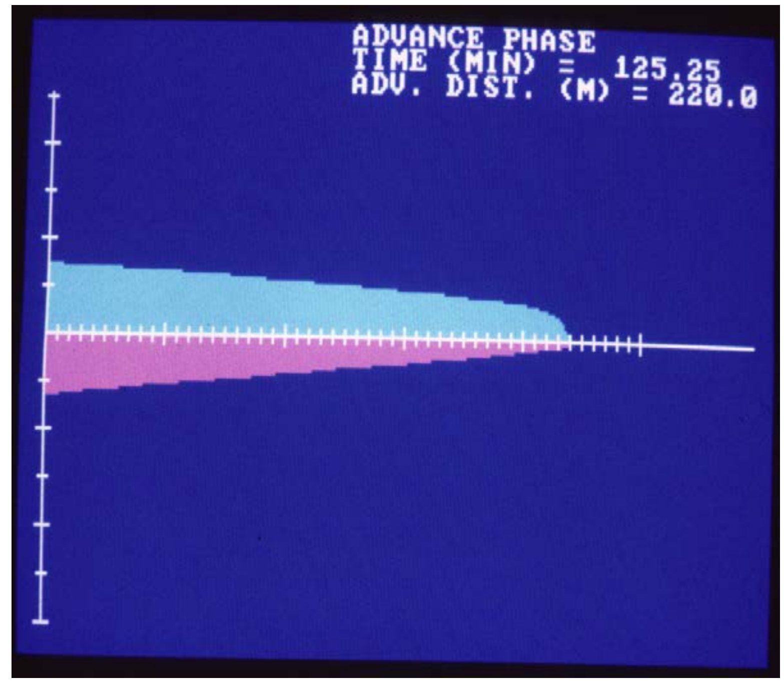
Surface Irrigation

Furrow and border strip irrigation

Surface Irrigation: Furrow Irrigation Example

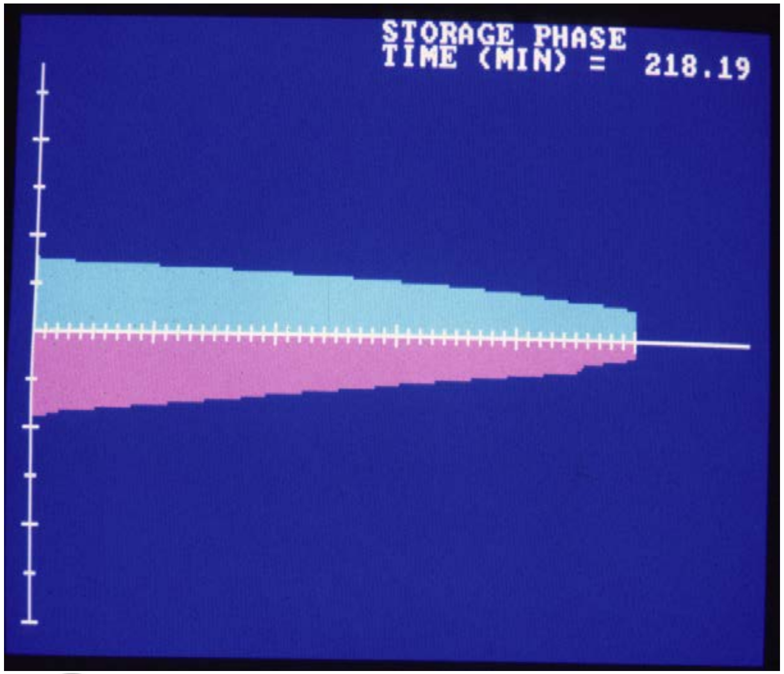


1 Water flows field top to bottom in furrow irrigation. Blue segment represents water on field surface; pink is infiltration.



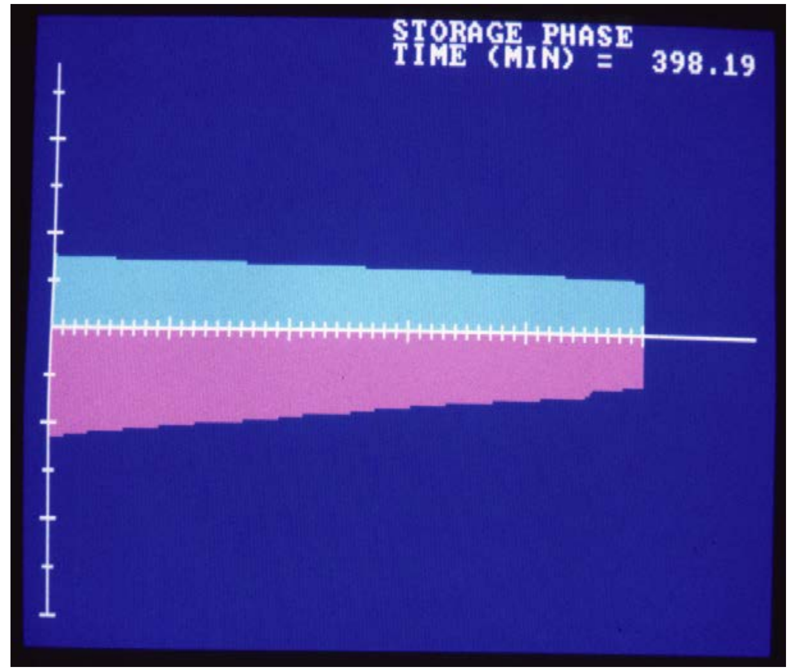
2 More water has infiltrated at field head, where it has been present the longest.

Surface Irrigation: Furrow Irrigation Example cont'd.



3

Water is run off the field tail to allow enough to infiltrate there to satisfy the crops' needs. The runoff should be collected and reused.



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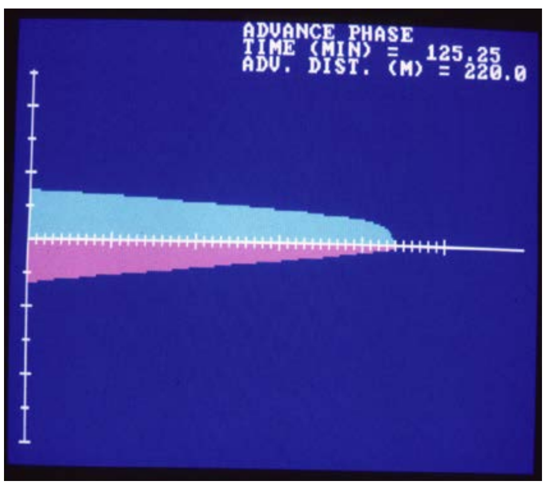
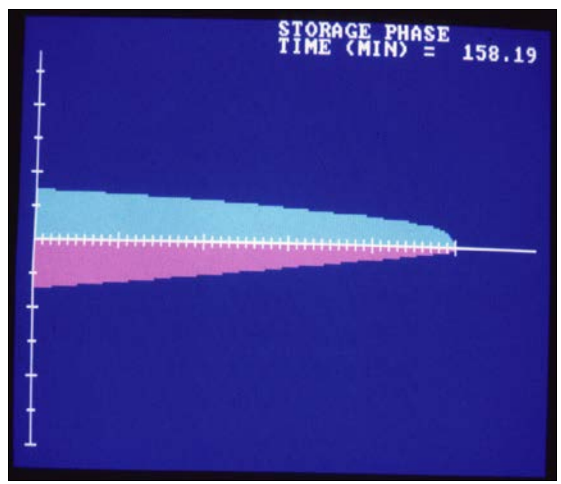
End of irrigation event. Water has infiltrated field tail, and field head has received excess. This water goes to deep percolation, leaching any N present.

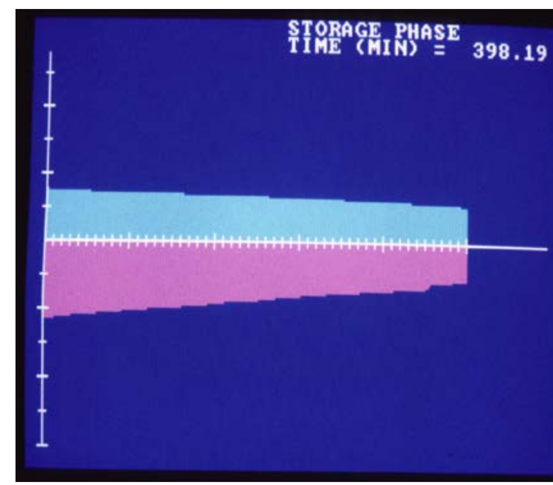
Surface Irrigation: Recognizing Non-Uniform Flood or Furrow Irrigation

$$\frac{\text{Total time water ran on an irrigation set}}{\text{Time it takes water to reach end of field}} = \text{Advance Ratio}$$

$$\frac{\text{398 minutes}}{\text{158 minutes}} = 2.5$$







Advance Ratio > 2 indicates reasonable uniformity

Surface Irrigation: Improvement with High Flow Rates

Water losses can be from deep percolation and tailwater runoff.

Losses from deep percolation and tailwater runoff are competing outcomes of surface irrigation management:

- Design steps that improve irrigation uniformity and reduce deep percolation probably increase tailwater runoof
- Design steps to reduce tailwater runoff probably cause more deep percolation and risk of N leaching

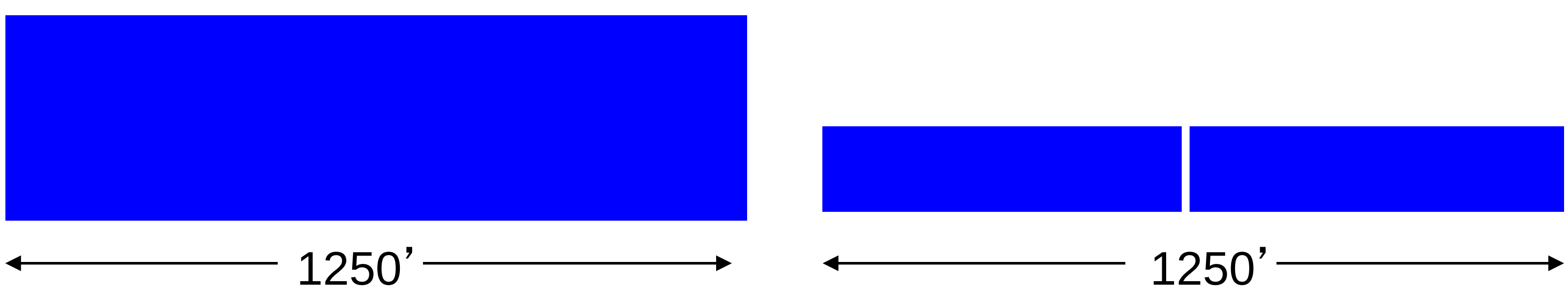
Surface Irrigation: Improvement with Shortened Field Length

Shortening field length gets water across the field more quickly, resulting in less deep percolation.

Surface Irrigation: Improvement with Shortened Field Length Example

- Reduce field length
  - Often the most effective option
  - Also often the least popular option

	1250’ Field	2-600 ‘ Fields
Irrigation Amount	9.1”	5.4”



Surface Irrigation: Improvement with Increased Field Slope Example

	0.001 slope	0.002 slope
Irrigation Applied	5.1”	4.8”

Surface Irrigation: Improvement of Border Check Irrigation

Increase the flow per foot of border check

Field Study: Usually run 2 valves per check; make checks half as wide and run 1 valve at a time → more flow per foot of check width

	Wide check (200’)	Narrow check (100’)
Irrigation Applied	5.1”	4.3”

Surface Irrigation: Improvement with Torpedoes

Using a torpedo gets water across the field more quickly, resulting in less deep percolation.

Surface Irrigation: Improvement with Torpedoes Example

Field study: Newly cultivated furrows, some "torpedoed" and some not

	Torpedoed Furrow	Non-torpedoed Furrow
Irrigation Water Applied	9.4"	12.9"

Surface Irrigation: Improvement by Reusing Tailwater Runoff

Collecting and reusing tailwater runoff makes the best use of expensive and limited irrigation water.

Water is collected and carried to a sump pump by underground pipelines, where it is pumped to a standpipe for use.

A small pond is used to collect tailwater, which is then pumped back to the head of the field using a sump pump.

Surface Irrigation: What if these options for improvement are not practical or effective?

- A change in irrigation method may be needed
  - Possibly target specific irrigation events (pre-irrigation of row crops)
  - Alternatively, make a wholesale change in methods
  - Often there will be a corresponding improvement in crop productivity when poorly performing irrigation systems are improved

Pressurized Irrigation

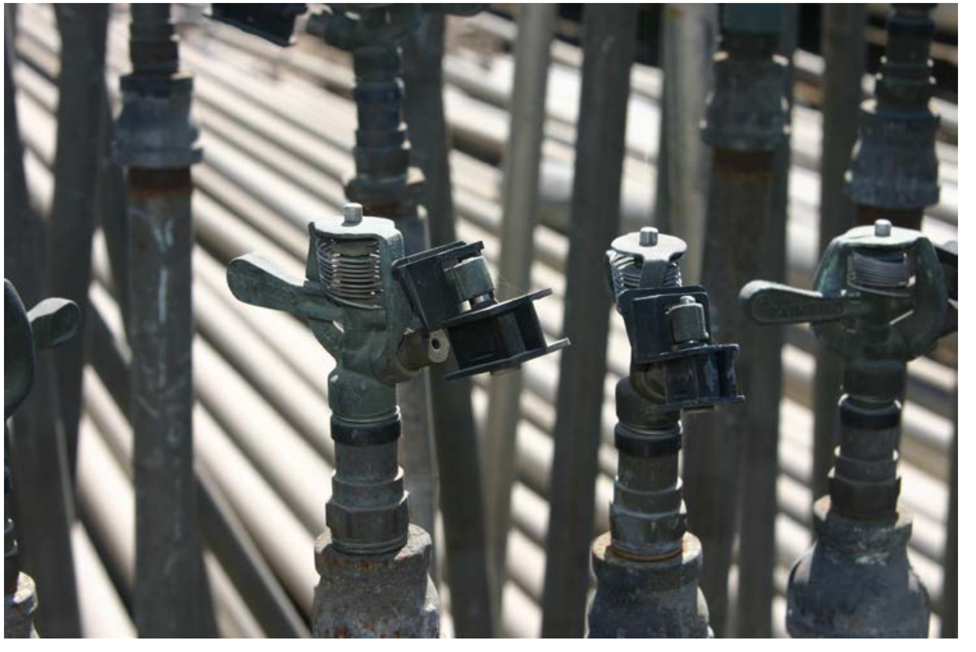
- Reduce the inherent control of the soils on irrigation efficiency
- Invest in irrigation hardware and sound irrigation system design to gain more management control of applied water






Pressurized Irrigation: Sprinkler

- How can sprinkler system performance be improved?
  - Know the **application rate**
    - We provide water use information in units of "inches of water use (per day or per week……..)"
    - Need to know the system application rate (in/hr) in order to know how long to run the system



Pressurized Irrigation: Sprinkler Application Rate

Calculating system application rate:

$$i\ (\text{in/hr}) = \frac{96.3 \times (\text{nozzle discharge in gpm})}{\text{Spacing along lateral (ft.)} \times \text{Spacing between laterals (ft.)}}$$

Pressurized Irrigation: Sprinkler Application Rate

Nozzle Discharge:

Pressure (psi)	Nozzle size (in)										
	3/32	7/64	1/8	9/64	5/32	11/64	3/16	13/64	7/32	15/64	1/4
20	1.17	1.60	2.09	2.65	3.26	3.92	4.69	5.51	6.37	7.32	8.34
25	1.31	1.78	2.34	2.96	3.64	4.38	5.25	6.16	7.13	8.19	9.32
30	1.44	1.95	2.56	3.26	4.01	4.83	5.75	6.80	7.86	8.97	10.21
35	1.55	2.11	2.77	3.50	4.31	5.18	6.21	7.30	8.43	9.69	11.03
40	1.66	2.26	2.96	3.74	4.61	5.54	6.64	7.80	9.02	10.35	11.79
45	1.76	2.39	3.13	3.99	4.91	5.91	7.03	8.30	9.60	10.99	12.50
50	1.85	2.52	3.30	4.18	5.15	6.19	7.41	8.71	10.10	11.58	13.18
55	1.94	2.64	3.46	4.37	5.39	6.48	7.77	9.12	10.50	12.15	13.82
60	2.03	2.76	3.62	4.50	5.65	6.80	8.12	9.56	11.05	12.68	14.44
65	2.11	2.88	3.77	4.76	5.87	7.06	8.45	9.92	11.45	13.21	15.03
70	2.19	2.99	3.91	4.96	6.10	7.34	8.78	10.32	11.95	13.70	15.59
75	2.27	3.09	4.05	5.12	6.30	7.58	9.08	10.66	12.32	14.19	16.14

Note: Metric conversions: 1 gal = 3.785 l; 1 in = 2.54 cm; 1 psi = 6.89 kPa

Pressurized Irrigation: Sprinkler Application Rate

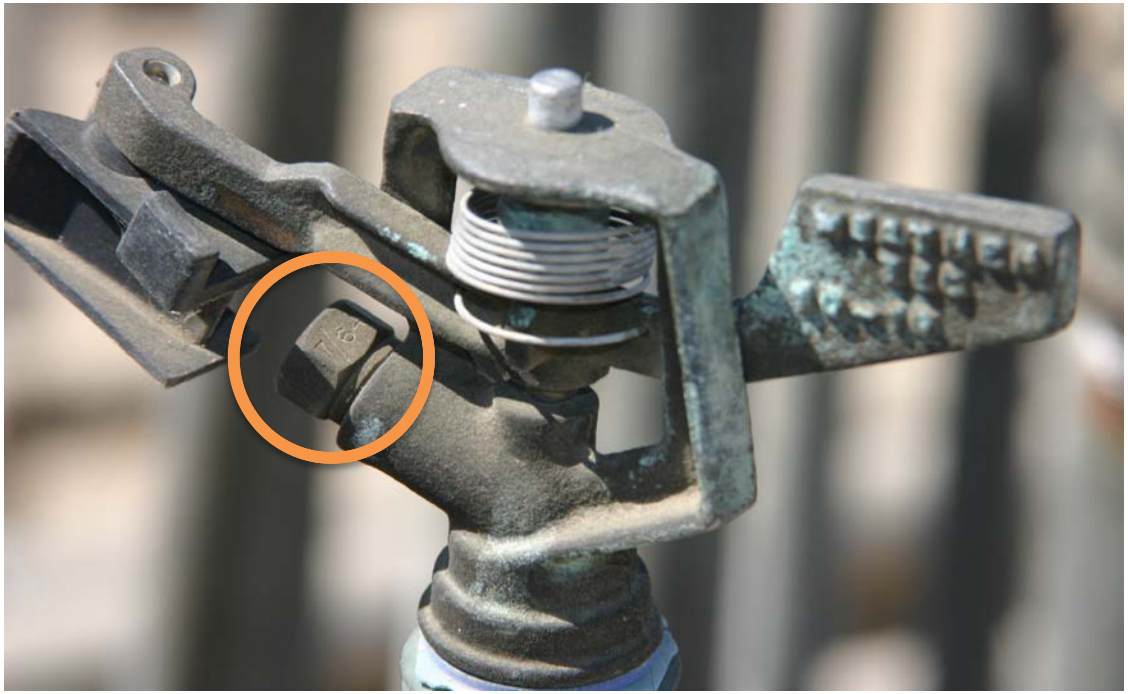
Nozzle Size (diameter):

Where to find this information?

1. Engraved on side of brass/steel nozzle

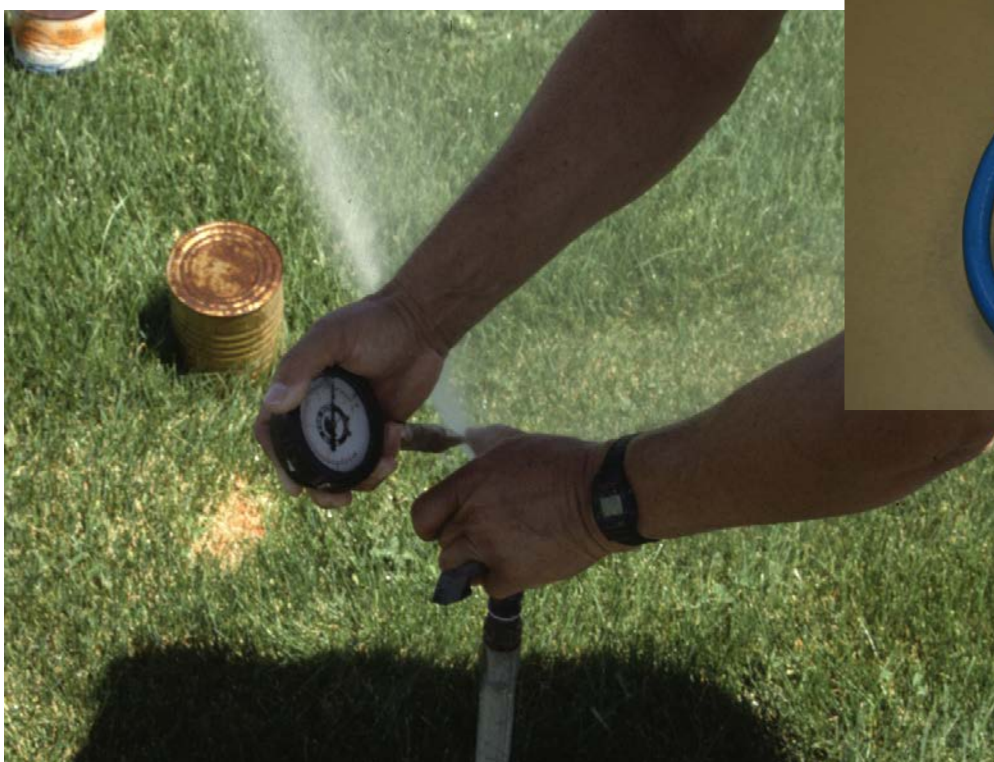
2. For a worn nozzle, compare opening with drill bit sizing

3. Plastic sprinklers often color coded by manufacturer



Pressurized Irrigation: Sprinkler Application Rate

Determining Pressure:



Pressure gauge with Pitot tube attached (above), inserted into sprinkler opening (left)

Pressurized Irrigation: Sprinkler Application Rate

Determining Pressure (another method):

R10 Plate/Nozzle Options and Flow Performance in GPM and LPH

Plate Series	Plate Options	Recommended Nozzles	PSI						BAR						
			25	30	35	40	45	50	1.75	2	2.25	2.5	2.75	3	3.25
P2	**P2 9° Red** Radius 18-20′ (5.5-6.1 m) Stream Ht.14-23″ (36-58 cm)	Lt. Blue #40	—	—	.28	.30	.32	.34	—	—	61.4	64.7	68.0	71.3	74.6
		Lt. Purple #45	.29	.32	.35	.37	.39	.42	66.4	71.3	76.3	80.6	83.9	87.2	91.5
		Dk. Green #50	.36	.39	.43	.46	.48	.51	82.3	87.2	93.4	99.4	104	108	112
		.35 10FC	Within the recommended pressure range of 25-50 PSI (1.75-3.25 BAR), the .35 10 FC flow control nozzle is flow regulating within a flow range of no more than 0% greater and 10% less than the nominal flow of .35 GPM (79.5 LPH).												
P4	**P4 9° White** Radius 18-22′ (5.5-6.7 m) Stream Ht. 14-24″ (36-61 cm)	Dk. Green #50	—	—	.43	.46	.48	.51	—	—	93.4	99.4	104	108	112
		Lt. Yellow #55	.44	.48	.52	.55	.59	.62	101	107	114	120	125	131	137
		Lt. Red #60	.51	.56	.61	.65	.69	.73	117	125	133	141	147	154	161
	P4 15° Orange Radius: 23-25′ (7.0-7.6 m) Stream Ht. 40-50″ (102-127 cm)	.50 10FC	Within the recommended pressure range of pressure range of 25-50 PSI (1.75-3.25 BAR), the .5 10 FC flow control nozzle is flow regulating within a flow range of no more than 0% greater and 10% less than the nominal flow of .5 GPM (114 LPH).												

Pressurized Irrigation: Sprinkler Application Rate

Calculating Application Rate (another method):

1. Time how long it takes to fill pale of known volume

1. This is the application rate in gpm

1. Plug into formula to get application rate in in/hr

Pressurized Irrigation: Sprinkler Application Uniformity

- How can sprinkler performance be improved?
  - Determine and improve sprinkler application uniformity

Pressurized Irrigation: Sprinkler Application Uniformity

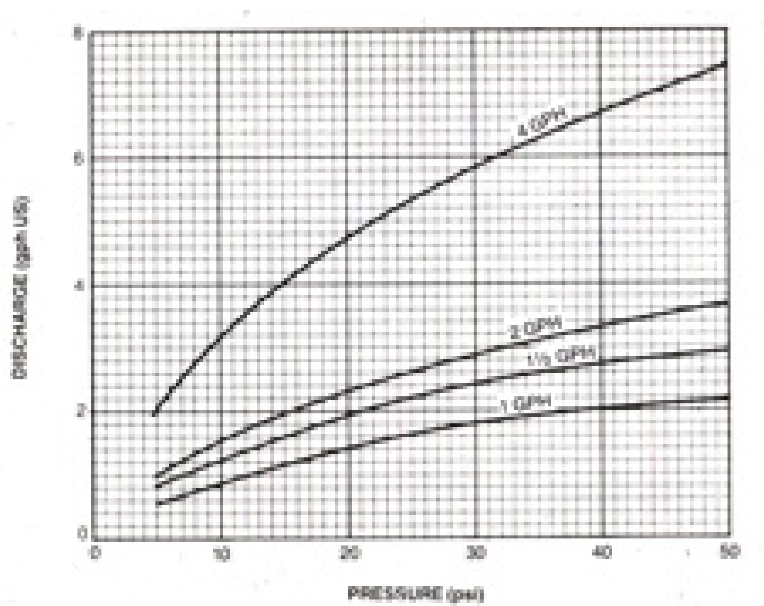
Determining uniformity with a **catch can test**. A consultant or mobile team can be hired to conduct this type of test and provide suggestions for improvement.

Pressurized Irrigation: Microirrigation Application Uniformity

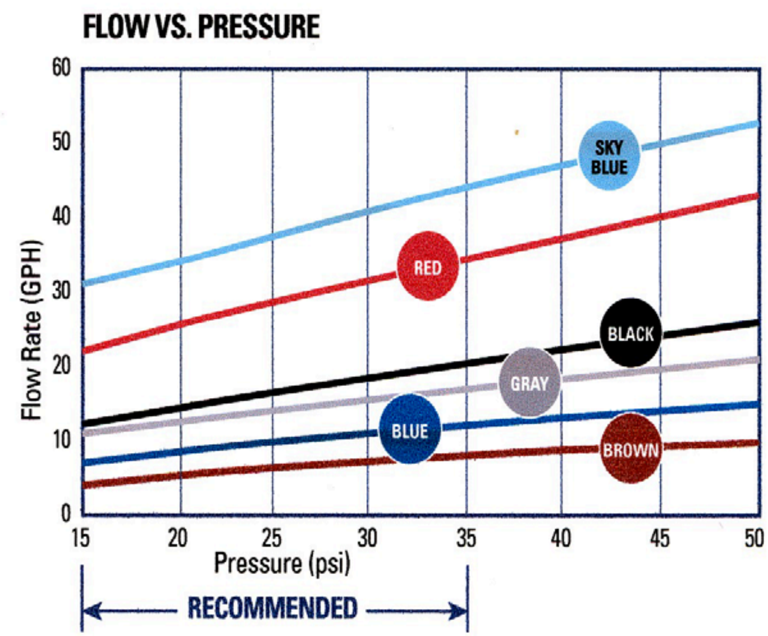
- Irrigation uniformity can be a problem with microirrigation systems too.
- What causes non-uniformity?
  - Poor microirrigation system design – pressure differences too great

Pressurized Irrigation: Microirrigation Application Uniformity

Pressure differences cause changes in rates of discharge, affecting uniformity:



The discharge from a drip emitter is shown on the Y-axis. As pressure increases (X-axis), so does discharge.

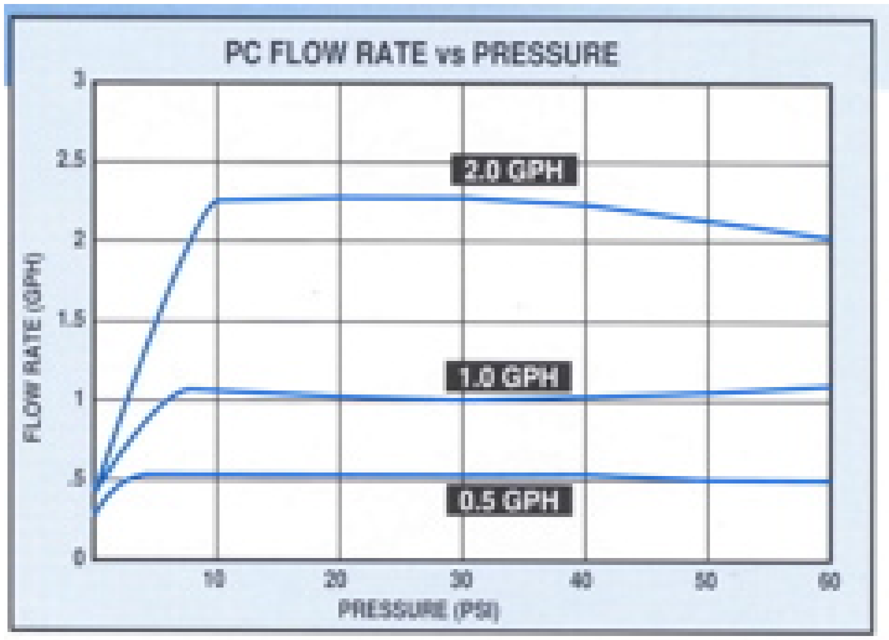


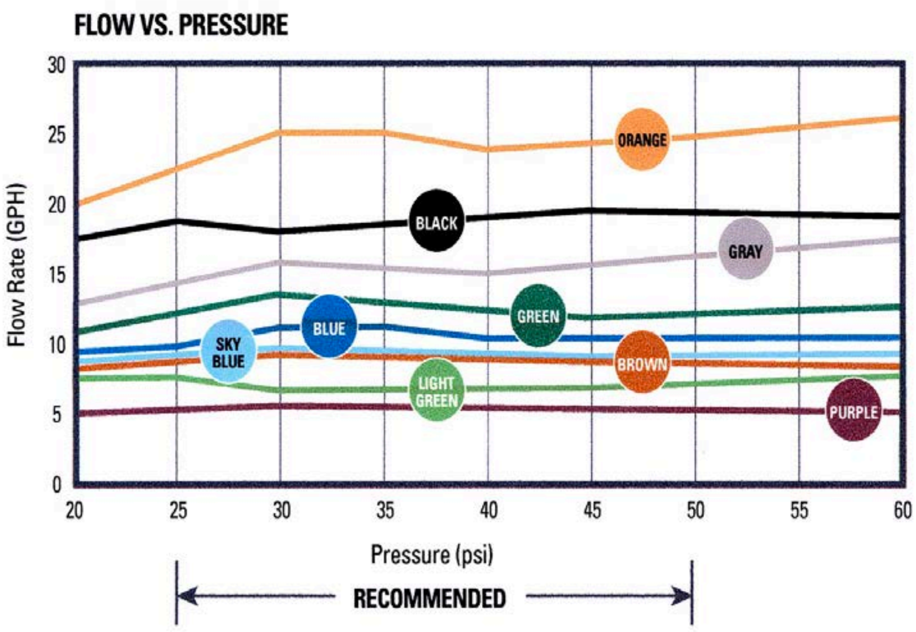
Similar to the drip emitter, the microsprinkler flow rate represented here increases as pressure increases.

Pressurized Irrigation: Microirrigation Application Uniformity

How do system designers address pressure differences that cause non-uniformity?

Pressure-compensating (PC) drippers (left) and microsprinklers (right) are used to equalize discharge when pressure is not constant.





Pressurized Irrigation: Microirrigation Application Uniformity

- What causes non-uniformity?
  - Maintenance problems
    - Clogging can lead to serious non-uniformity problems. Almost all clogging problems can be solved or prevented with good filtration and routine maintenance.

Pressurized Irrigation: Microirrigation Application Uniformity

Maintenance Tips:

Clean and flush filters regularly

Automatic backflush system

Flush lines regularly

Silt and clay are small enough to make it through filters but often settle in the lateral lines of drip tape and tubing.

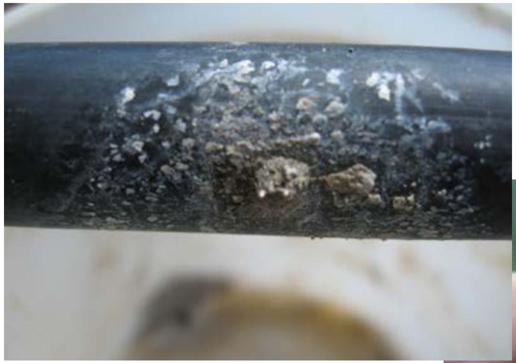
Pressurized Irrigation: Microirrigation Application Uniformity

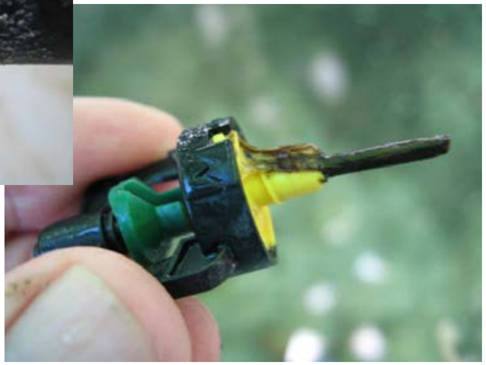
Maintenance Tips:

Monitor for leaks and breaks

Many of the most successful microirrigation system users check for leaks and breaks every time the system is turned on. This picture shows where a microsprinkler has been broken off.

Check lines for chemical clogging at least twice per season





Check for bacteria or calcium buildup around emitters and nozzles. Surface waters are prone to organic problems (above right), and groundwater is more prone to chemical precipitation problems (above left).

Fertigation

Accounting for N in Irrigation Water

- Converting between Nitrate and Nitrate-N
  - Nitrate reported as: nitrate (NO_3^-) or as nitrate-N (NO_3^--N)

ppm (NO_3^-) = ppm (NO_3^--N) x 4.43

ppm (NO_3^--N) = ppm (NO_3^-) ÷ 0.23

- Converting from ppm in irrigation water to lbs/ac-in

ppm (NO_3^-) x 0.052 = lbs N / ac-in

ppm (NO_3^--N) x 0.23 = lbs N / ac-in

- Converting from ppm in irrigation water to lbs/ac-ft

ppm (NO_3^-) x 0.62 = lbs N / ac-ft

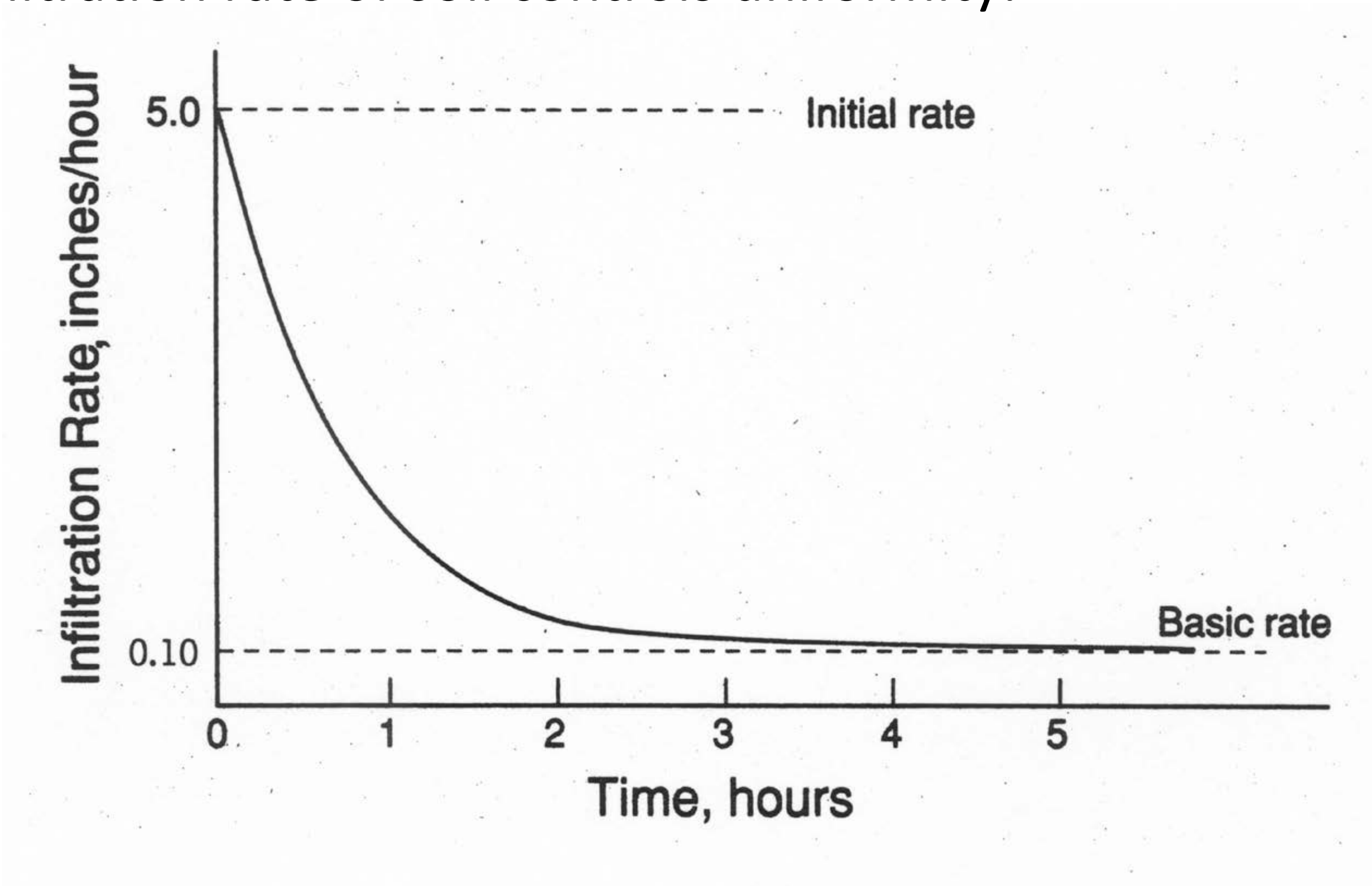
ppm (NO_3^--N) x 2.79 = lbs N / ac-ft

Fertigation in Surface and Pressurized Systems

- Source of nutrients (very often N) through fertigation
- Fertigation (with anhydrous ammonia and UAN) is commonly used in sprinkler and microirrigation, but is also done in flood irrigation

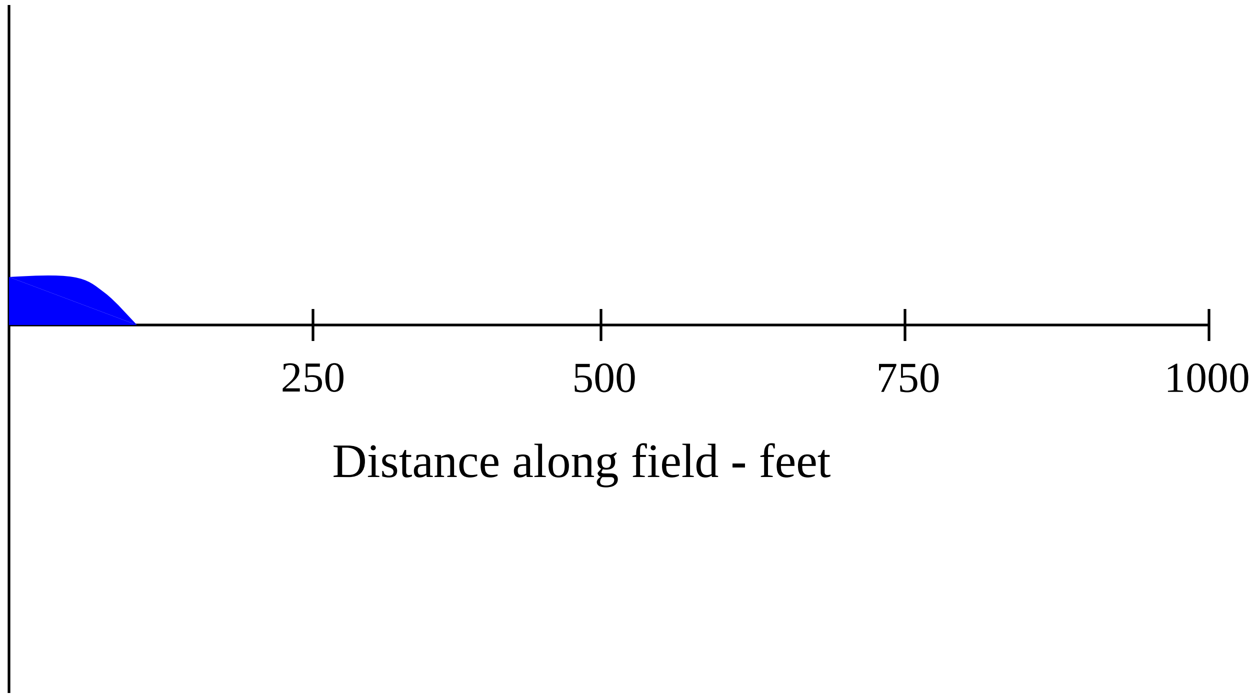
Fertigation in Surface Systems

Infiltration rate of soil controls uniformity:



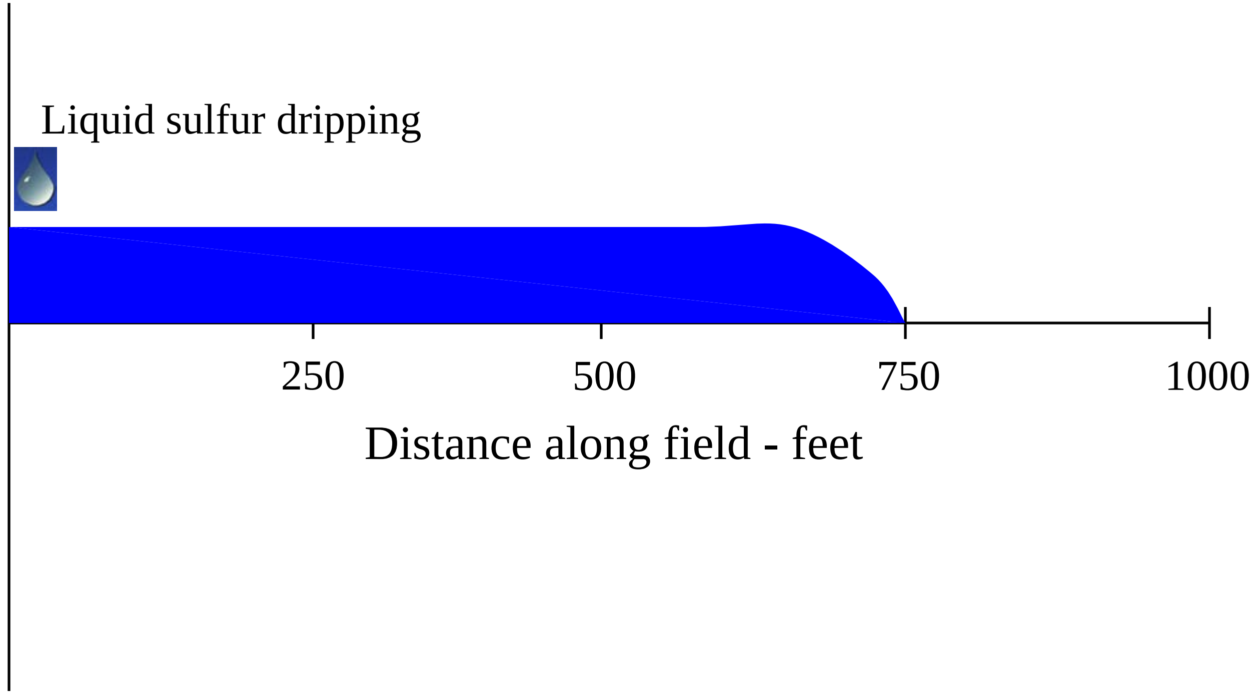
Fertigation in Surface Systems: Example

Irrigation started with clean water



Fertigation in Surface Systems: Example cont'd.

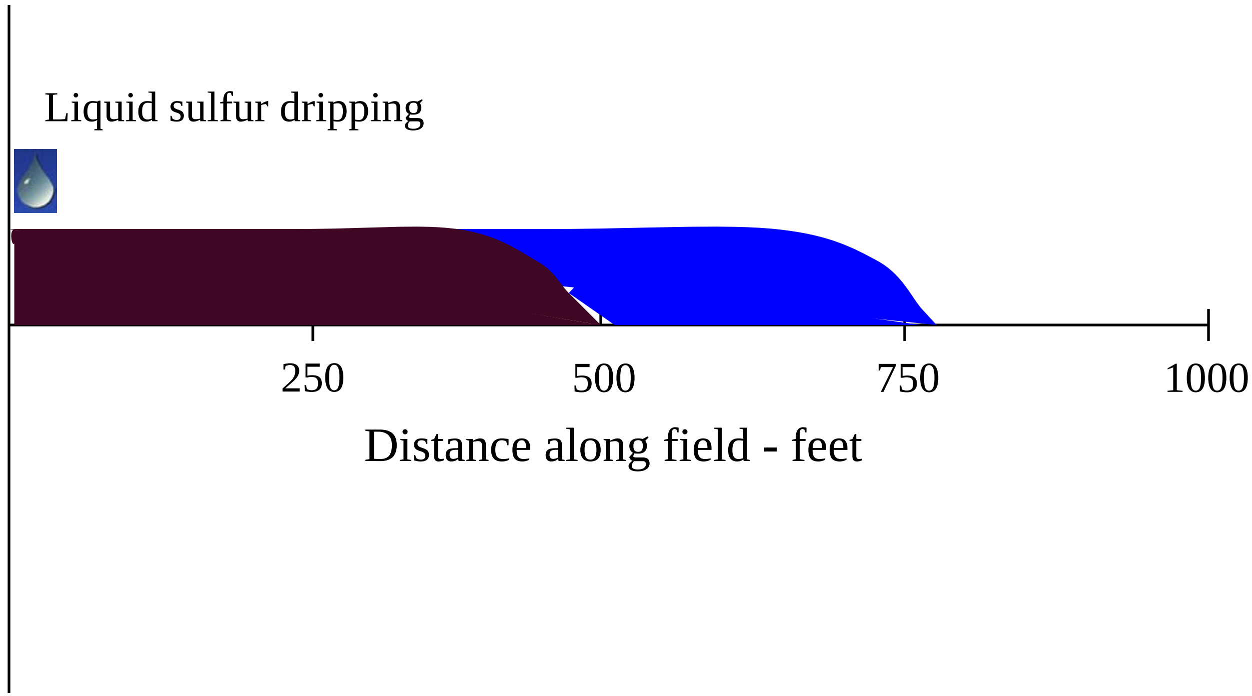
Liquid sulfur drip started when fresh water advance at 750'. Sulfur begins to quickly move down the furrow.



Fertigation in Surface Systems: Example cont'd.

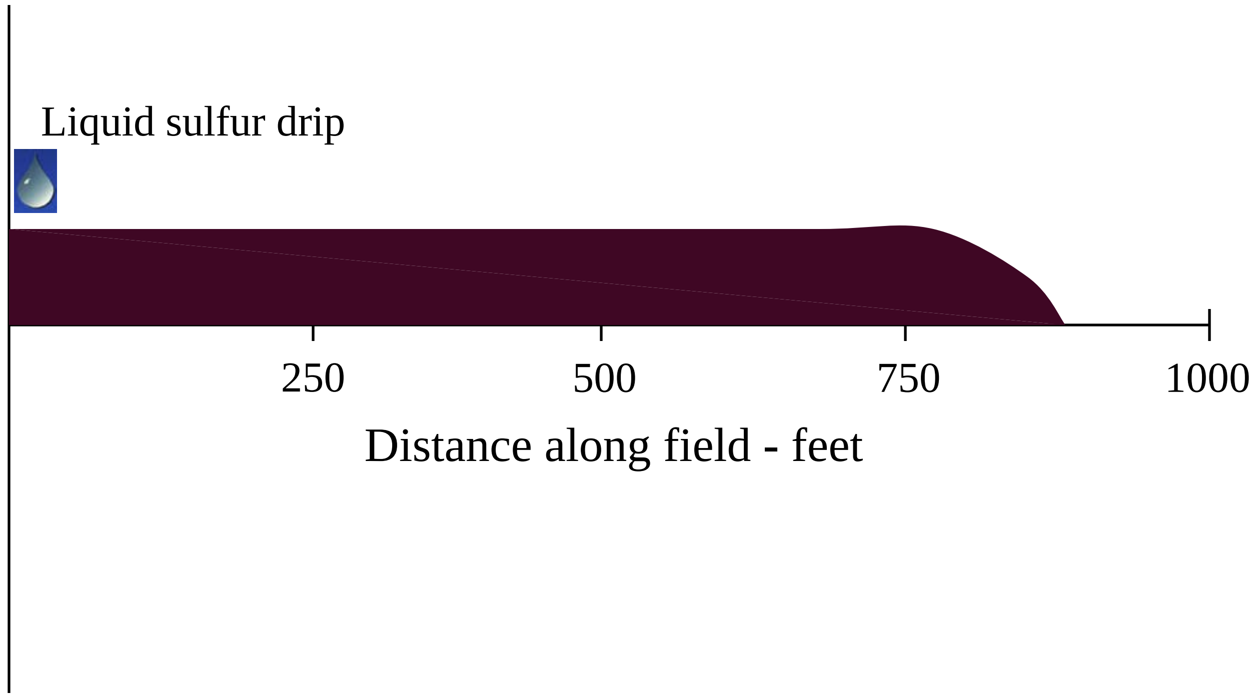
Clean water advance at 800'

Injected material advance at 500'



Fertigation in Surface Systems: Example cont'd.

Liquid sulfur drip was started when fresh water advance was at 750'. Sulfur "caught up" by 850'.



Fertigation in Surface Systems: Flood Irrigation Example

Fertigation Added:	**Nitrogen Applied (lbs/ac)**	**Uniformity of application**
During entire irrigation	242	+
When freshwater advance to 75% of field length	86	++
When freshwater advance to 85% of field length	31	++++

*field length = 1200’ , avg. irrig. amt = 7.1”

Improved the uniformity of fertilizer application and allowed a smaller amount to be applied per irrigation.

Fertigation in Pressurized Systems

Goals:

- Material injected into the drip system should be applied as evenly (**uniformly**) as water applied by the system. It takes time for water and injected chemical to move through a drip irrigation system.
- Target fertilizer **in the root zone** where crop can use it

Fertigation in Pressurized Systems: Uniformity

- Trees & vines: injections should last at least 1 hour for uniform application, and at least 1 hour of clean water irrigation should follow so that all fertilizer is delivered to the crop.

- Row crop drip: injections should be at least 2 hours in length, and there should be at least 2 hours of clean water irrigation following injection.

Fertigation in Pressurized Systems: Orchard Uniformity Example

Water / chemical travel times through the pipelines and drip lateral lines for several vineyard and orchard field sites:

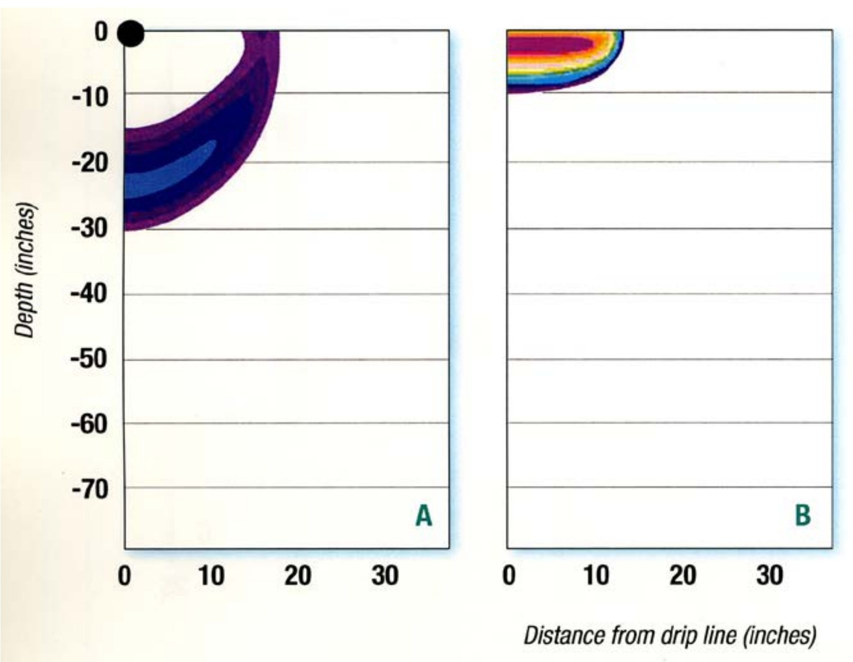
Site	Mainline and Submain		Lateral Line		Total Travel
	Travel Time (min.)	Length (ft)	Travel Time (min.)	Length (ft)	Time (min)
1	22	1000	10	175	32
2	30	1500	10	340	40
3	65	5000	10	340	75
4	15	1400	30	630	45
5	8	700	25	625	33
6	17	800	28	600	45

Fertigation in Pressurized Systems: Root Zone Targeting Example

When during the irrigation do you inject (for different soil types)?

Surface Drip

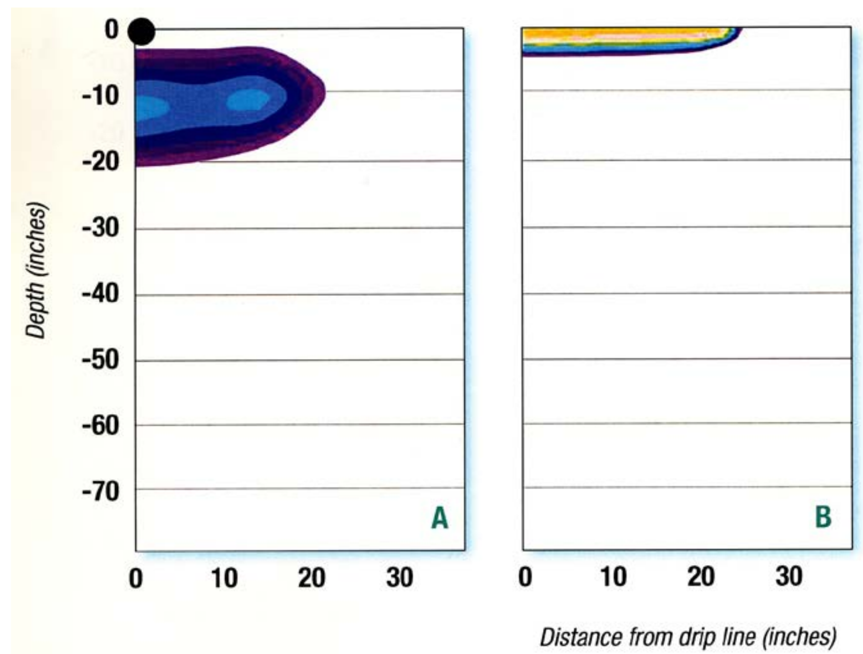
Loam



2 hour injection near start of 27 to 36 hour Irrigation.
N levels elevated at 30 in.

2 hour injection near end of 27 to 36 hour Irrigation
N confined to top 10 in.

Silt Loam



2 hour injection near start of 27 to 36 hour Irrigation
N levels elevated at 30 in

2 hour injection near end of 27 to 36 hour Irrigation
N confined to top 6 in.

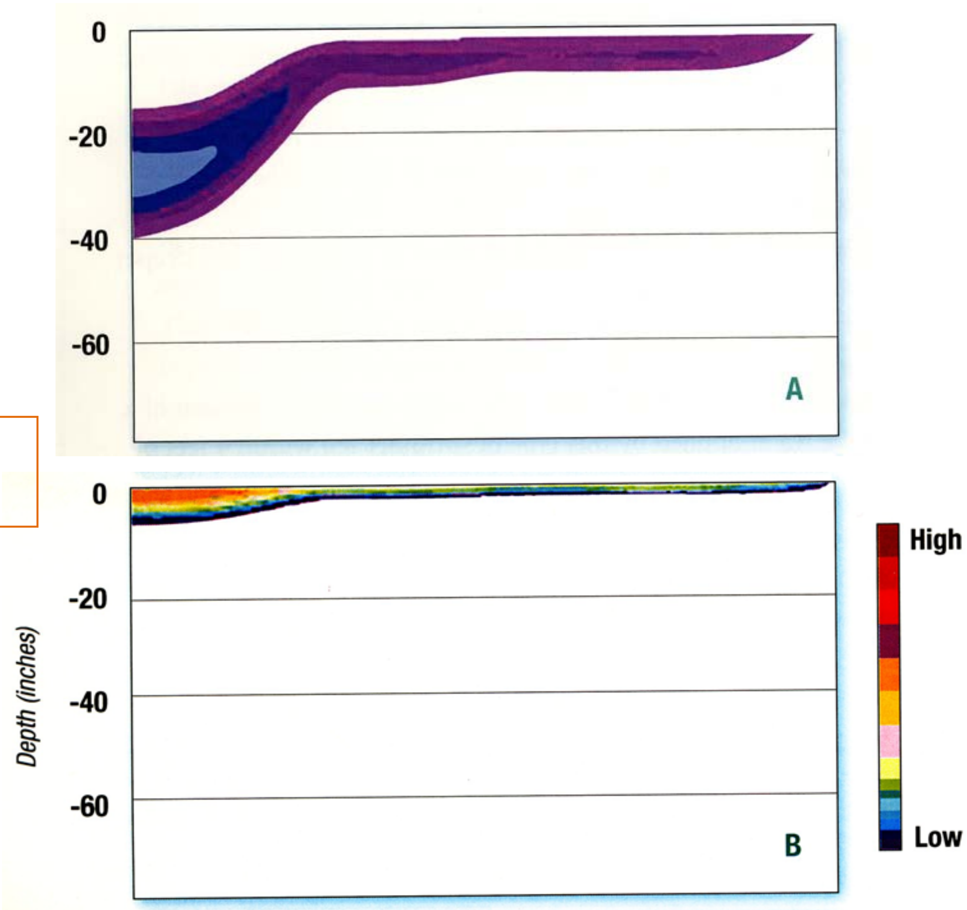
(Blaine Hanson, “Fertigation with Microirrigation”)

Fertigation in Pressurized Systems: Root Zone Targeting Example

Silt Loam

When during the irrigation do you inject?

*Microsprinklers



2 hour injection near start of Irrigation

2 hour injection near end of Irrigation

(Blaine Hanson, “Fertigation with Microirrigation”)

Other Issues Faced by California Growers

Salinity

- It is a fact that leaching is necessary to sustain crop production where salinity approaches crop tolerance. This is considered a beneficial water use.
- How do we leach to manage root zone salinity without leaching nitrogen fertilizers?

Salinity: Tips for Leaching Salts and Not Nitrate

- Leaching is not necessary every irrigation or perhaps even every season but only when crop tolerances are approached.
- Periodic soil and irrigation water testing will help determine when and how much leaching is needed.
- The amount of applied water must exceed ET, and the soil water content must exceed field capacity for leaching to occur.
- Leaching is most efficient in the winter when land is fallow or crops are dormant and should not coincide with critical periods of nitrogen uptake and fertilization.

Rainfall

- Rainfall can be a source of water for leaching.
- We have little control over the amount and timing of rainfall.
- Can we control the N available to be leached at the time of rainfall?
  - Coordinate timing of N fertilizers with the period of highest crop demand
  - Apply reasonable rates for crop production levels
  - Minimize amount of N in the root zone going in to rainy season

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Nitrogen Management Training

for Certified Crop Advisers

Course materials available at:

ciwr.ucanr.edu/NitrogenManagement

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