Irrigation Distribution Uniformity

From design to maintenance – why care?

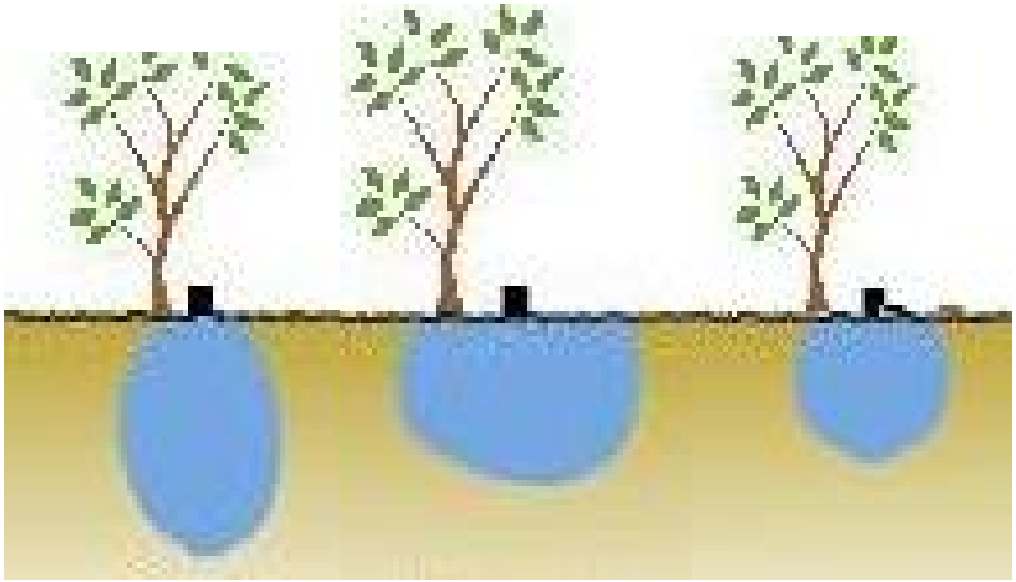
Allan Fulton
UC Cooperative Extension
Tehama, Glenn, Colusa, and Shasta Counties

Topics:

- DU … What is it?
- Why care?
- What causes low DU?
- Effective management practices

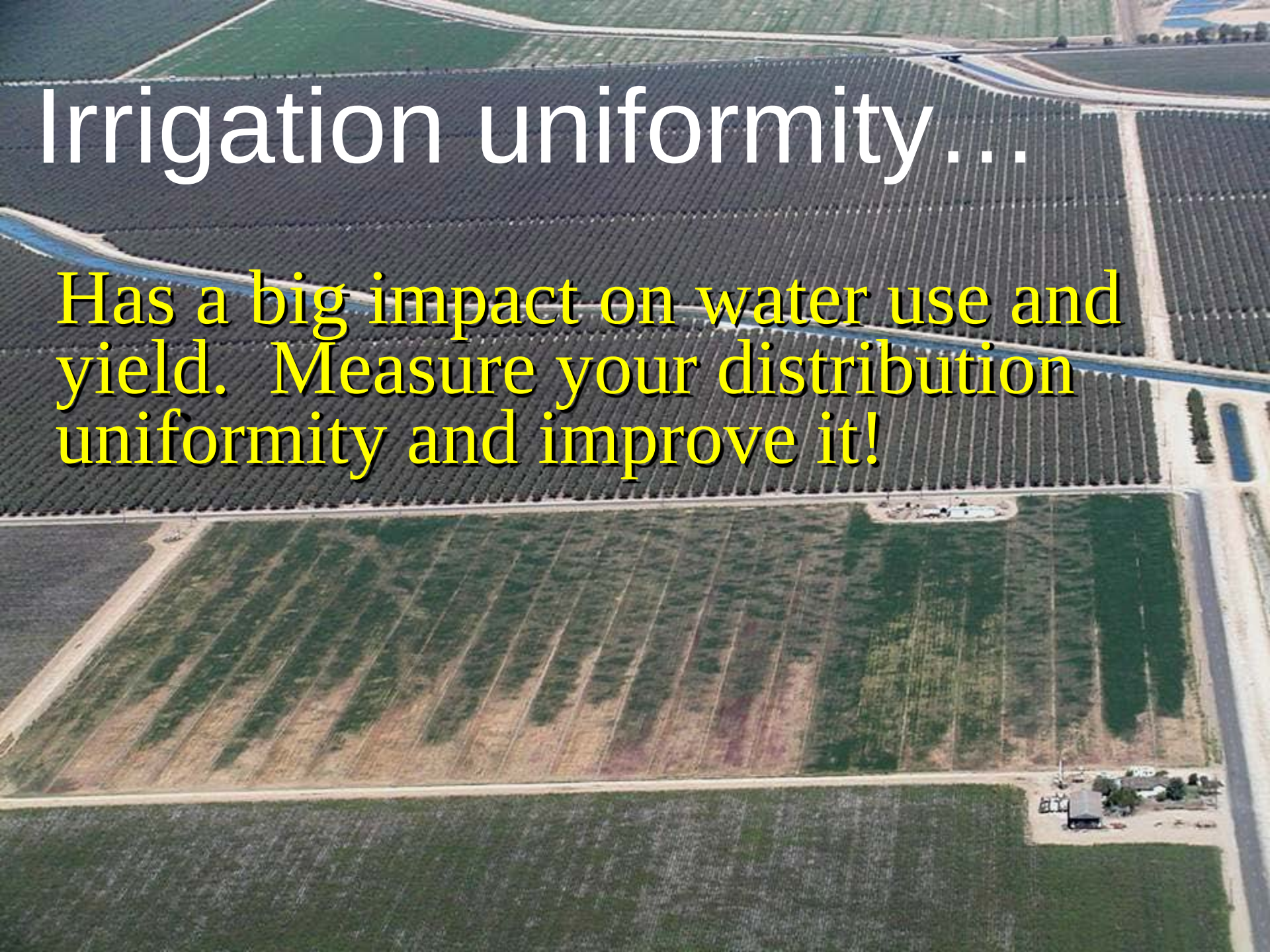


Irrigation Distribution Uniformity (DU) - Simple Concept

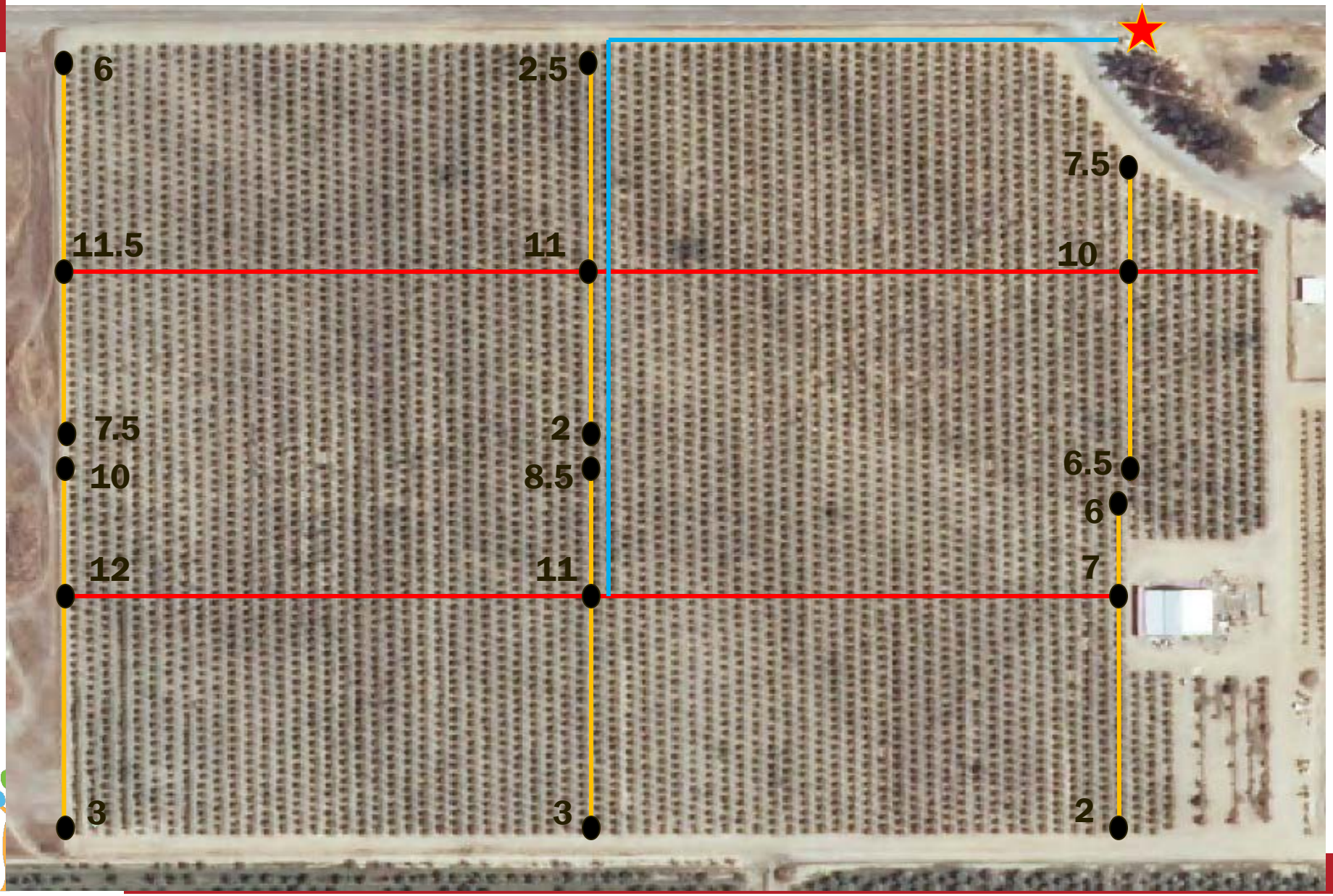


Important to the bottom line:

- water demand
- energy demand
- nitrogen use efficiency
- uniform orchard production and tree health
- efficiency - production per unit water, land, and energy


Irrigation uniformity…
Has a big impact on water use and yield. Measure your distribution uniformity and improve it!

Measuring DU is simpler with drip and micro sprinkler (Example: system pressure (psi) data Tehama County Mobile Irrigation Lab)



Measuring system pressures – simpler than measuring flows





Pressure gauge and pitot tube



Calculating water emission rates based on pressure measurements:

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

Plate Series	Plate Options	Recommended Nozzles	PSI 25	PSI 30	PSI 35	PSI 40	PSI 45	PSI 50	BAR 1.75	BAR 2	BAR 2.25	BAR 2.5	BAR 2.75	BAR 3	BAR 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).												

Going the extra mile – actually measuring flows





Tehama County Mobile Irrigation Lab
Field Team

Approximating DU

$$\text{Distribution Uniformity (DU)} = \frac{\text{Average emission rate for low quartile of pressure measurements in orchard}}{\text{Average emission rate for all pressure measurements in whole orchard}}$$

Sidebar: Approximating Hourly Rate of Water Application to Schedule Irrigation Duration and Frequency

- Determine average emission rate from drip or microsprinklers
- Count number of drippers or (micro)sprinklers per acre
- Know 1.0 acre-inch volume of water equals 27,154 gallons

Calculation for Drip and Microspinklers rated in gph:

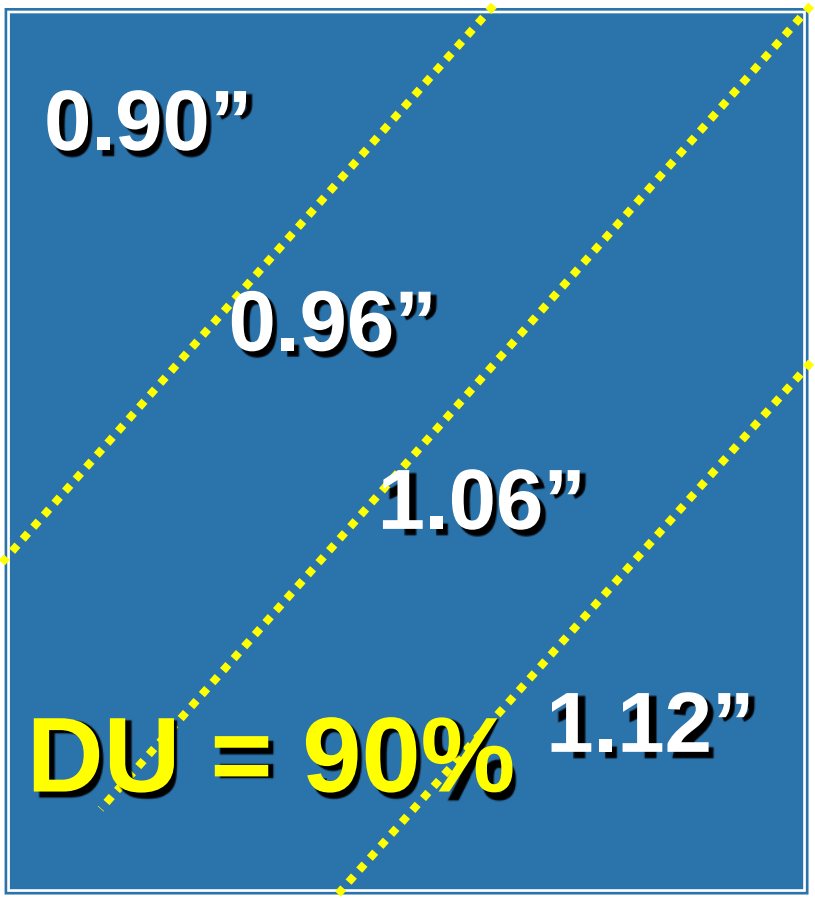
Average Emission Rate (gph) **x** Number of drippers or microsprinklers per acre **÷** 27,154 **=** I (inch/hour)

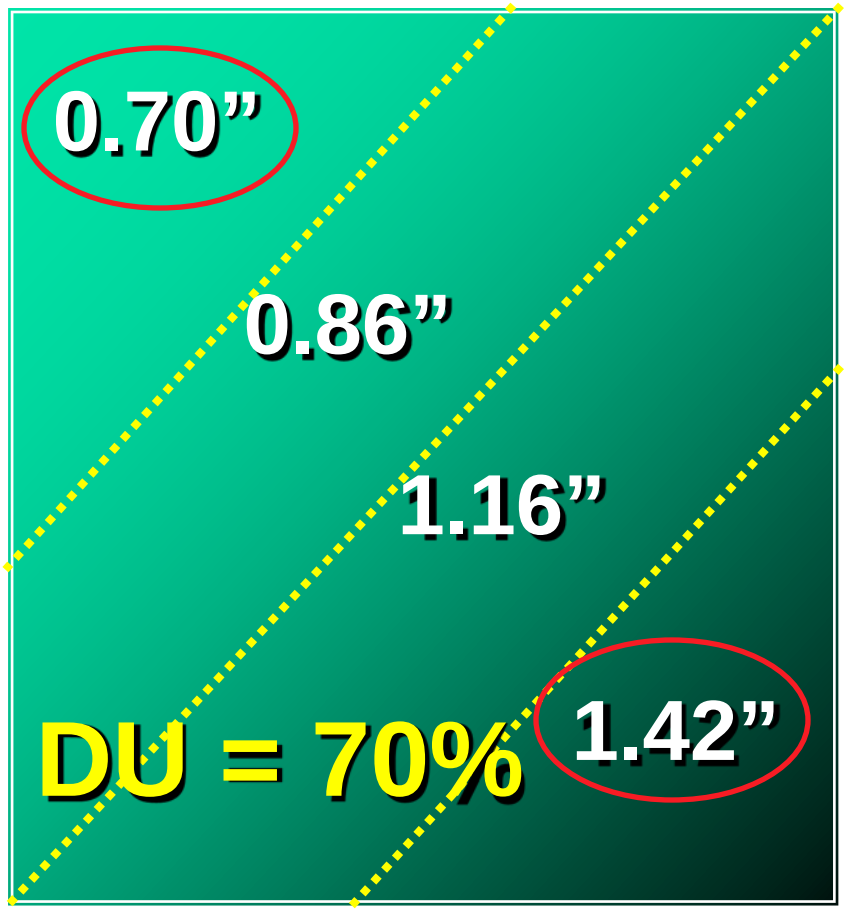
Calculation for spinklers and mini-sprinklers rated in gpm:

Average Emission Rate (gpm) **x** Number of (mini)sprinklers per acre **x** 60 **÷** 27,154 **=** I (inch/hour)

Why Care about DU?

Example: Target application 1.0 inch water





Why Care about DU?

Example: Target application 1.0 inch water

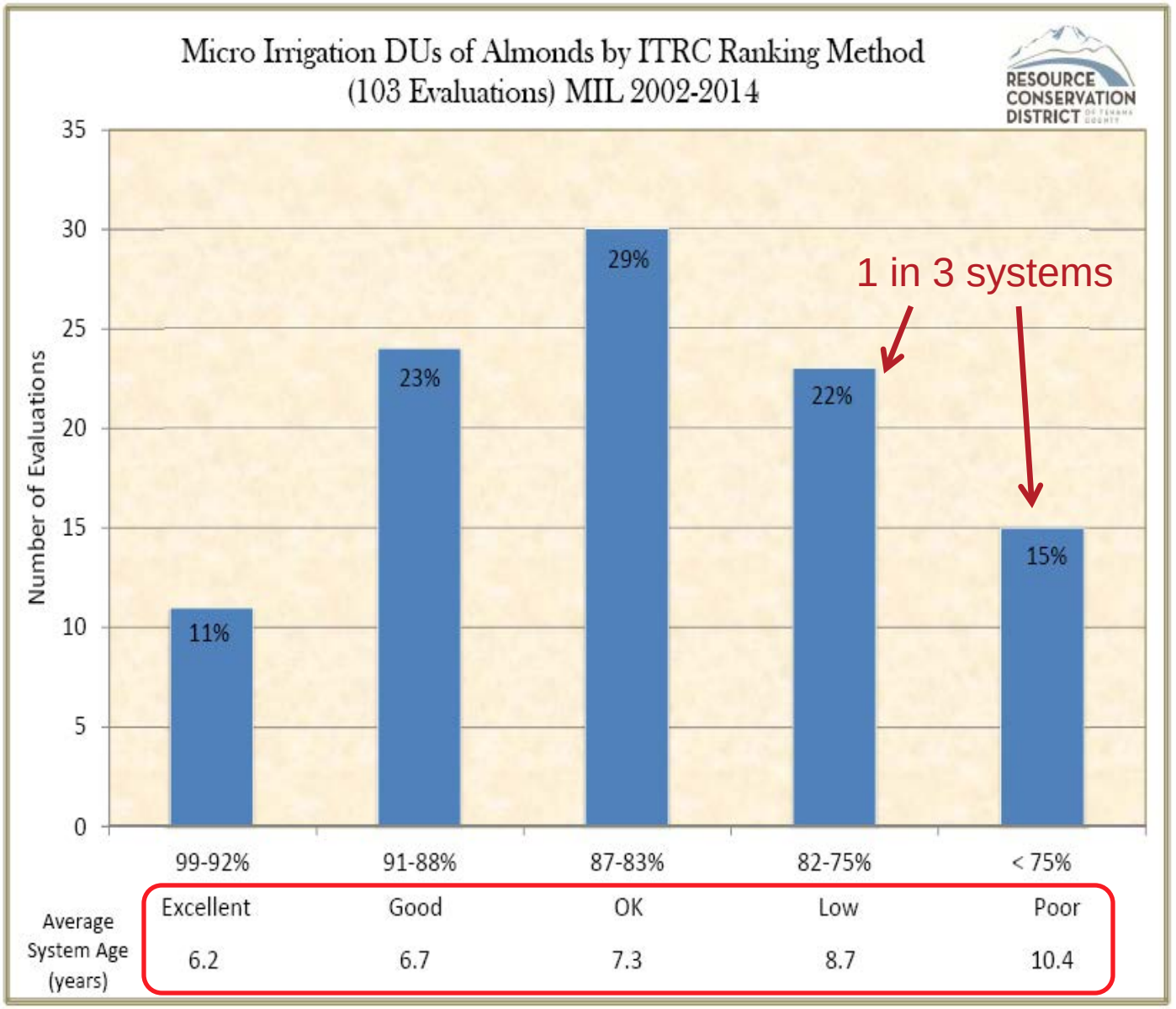
DU	Water Applied High ¼ of orchard	Water Applied Low ¼ of orchard	Difference across orchard one irrigation	Difference thirty irrigation cycles
	---------- Inches applied ----------			
90	1.12	0.90	0.22	6.6
80	1.27	0.80	0.47	14.1
70	1.42	0.70	0.72	21.6

Why Care about DU?

Example: Target 1.0 inch of water in low ¼ of orchard using a micro sprinkler system with 0.05 inch/hr application rate

DU	Hours to apply 1" low ¼ of orchard	Total hours thirty irrigation cycles	Hours irrigation (pump) time increased between DU's	Relative Increase %
100	20	600	Reference Point	----
90	22	660	60	10
80	24	720	120	20
70	26	780	180	30

Who Should Care?



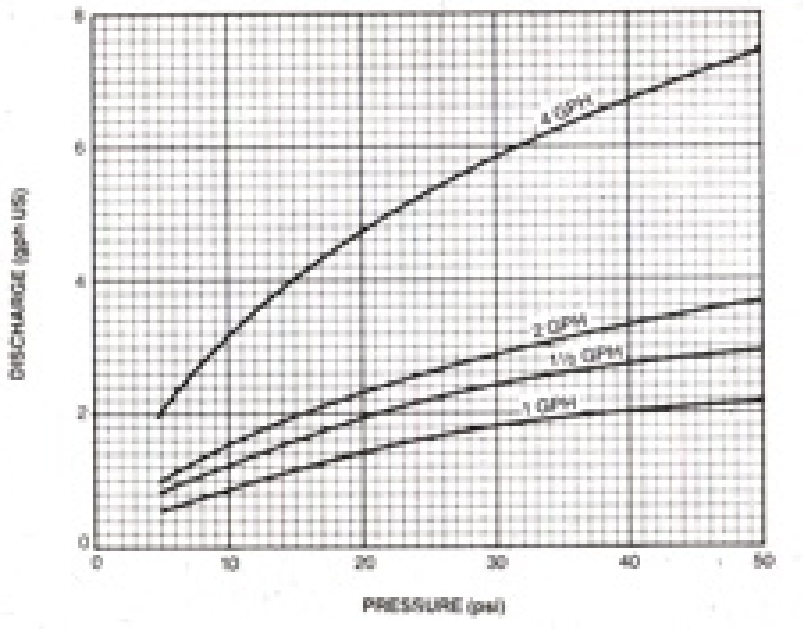
Factors Affecting DU?

When designing a system:

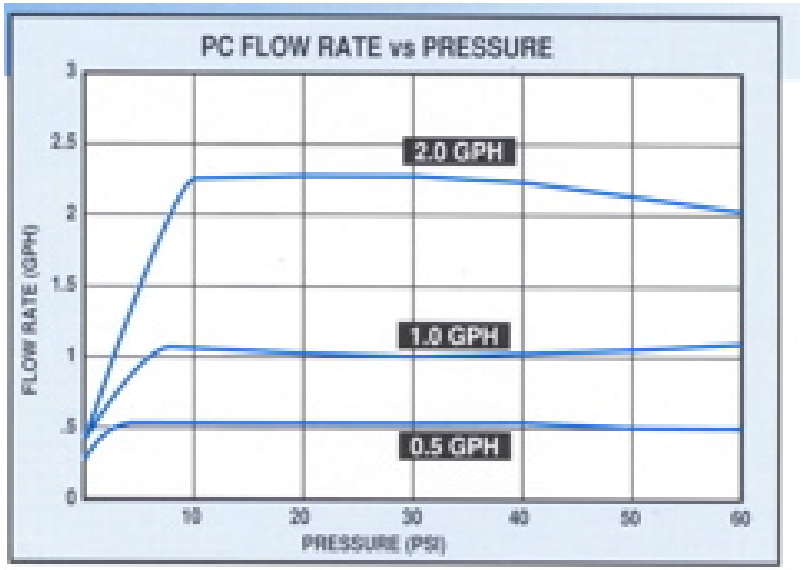
- Drip emitter, microsprinkler, or mini sprinkler features
- Pressure regulation or flow compensation
- Lateral lines – material, size, length, placement
- Mainline and sub-main pipe sizes
- Filtration and back flush system
- Pumping plant performance
- Ability to measure system flow and pressure

- Balancing these factors with cost

Factors Affecting DU – Understand Emission Device

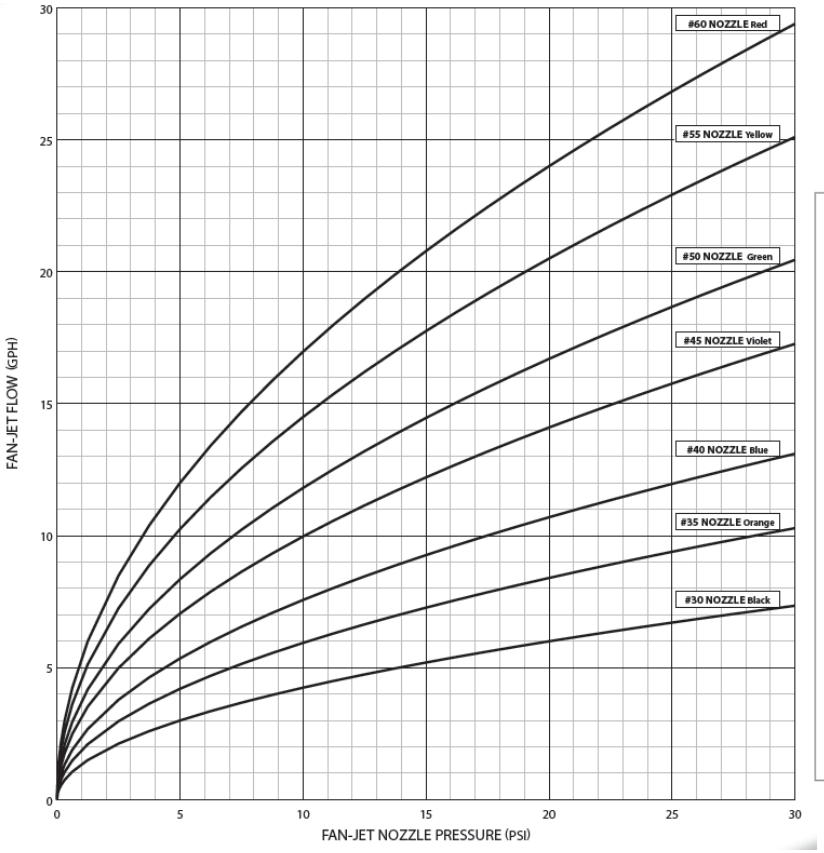


Non-pressure compensating drip emitter

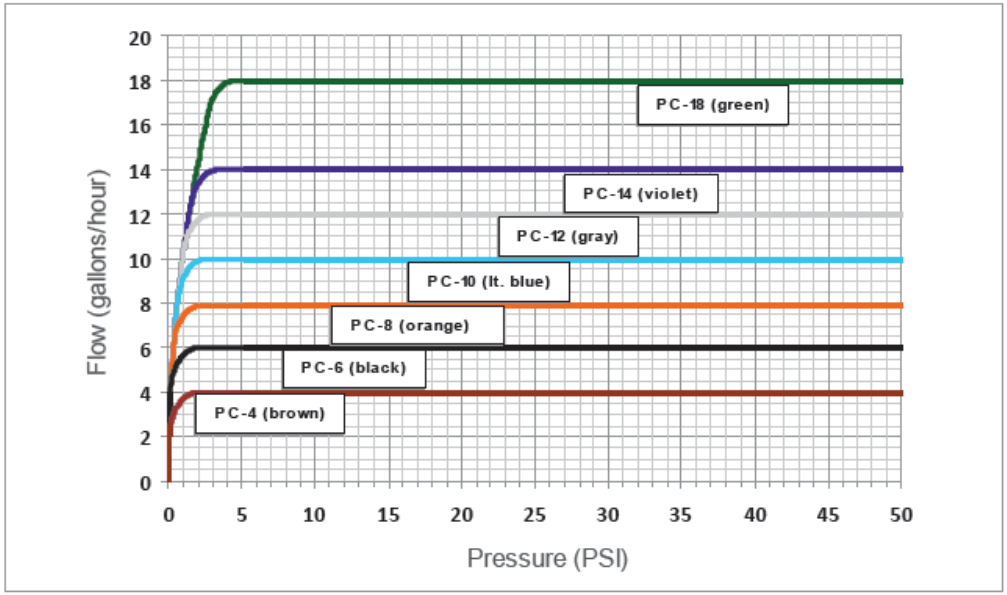


Pressure compensating drip emitter

Factors Affecting DU – Understand Emission Device



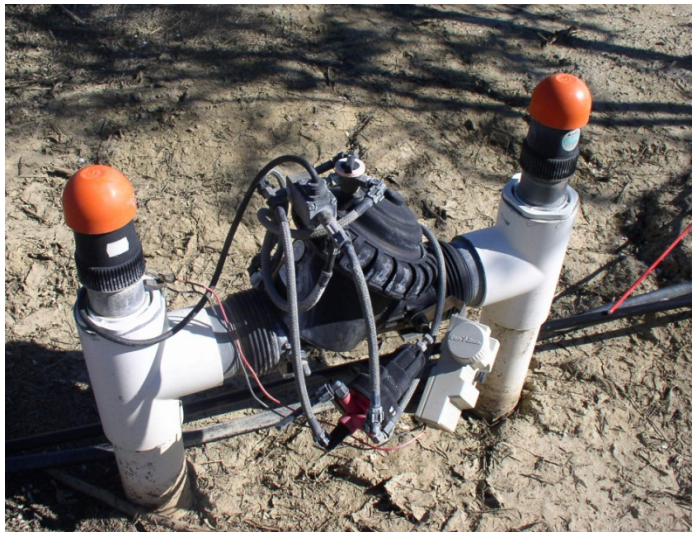
Non-pressure compensating micro sprinkler



Pressure compensating micro sprinkler

Factors Affecting DU – Pressure Regulation and Flow Compensation





Pressure regulating valves



Pressure reducing regulators



Factors Affecting DU- Mainline, lateral line materials, placement, sizes, and lengths



Materials = Durability

Placement = Exposure to damage

Size/Length = Pressure and flow distribution. Water hammer.

Source: http://www.rainbird.com/landscape/resources/FrictionLossCharts.htm

psi Loss per 100 Feet of Pipe (psi/100 ft.)

Sizes 1/2" through 6" Flow 1 through 600 gpm

Size	1/2"		3/4"		1"		1 1/4"		1 1/2"		2"		2 1/2"		3"		4"		6"	
O.D.	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500		4.500		6.625	
I.D.	0.622		0.824		1.049		1.380		1.610		2.067		2.469		3.068		4.026		6.065	
Wall Thk	0.109		0.113		0.133		0.140		0.145		0.154		0.203		0.216		0.237		0.280	
Flow gpm	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss	Velocity fps	psi Loss
1	1.06	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.16	0.00	0.10	0.00	0.07	0.00	0.04	0.00	0.03	0.00	0.01	0.00
2	2.11	1.55	1.20	0.39	0.74	0.12	0.43	0.03	0.32	0.02	0.19	0.00	0.13	0.00	0.09	0.00	0.05	0.00	0.02	0.00
3	3.17	3.28	1.80	0.83	1.11	0.26	0.64	0.07	0.48	0.03	0.29	0.01	0.20	0.00	0.13	0.00	0.08	0.00	0.03	0.00
4	4.22	5.58	2.41	1.42	1.48	0.44	0.86	0.12	0.64	0.06	0.38	0.02	0.26	0.01	0.17	0.00	0.10	0.00	0.04	0.00
5	5.28	8.43	3.01	2.15	1.86	0.66	1.07	0.17	0.80	0.09	0.48	0.02	0.33	0.01	0.22	0.00	0.13	0.00	0.06	0.00
6	6.34	11.81	3.61	3.01	2.23	0.93	1.29	0.24	0.96	0.12	0.57	0.03	0.40	0.01	0.26	0.01	0.15	0.00	0.07	0.00
7	7.39	15.71	4.21	4.00	2.60	1.24	1.50	0.33	1.12	0.16	0.67	0.05	0.46	0.02	0.30	0.01	0.18	0.00	0.08	0.00
8	8.45	20.12	4.81	5.12	2.97	1.58	1.72	0.42	1.28	0.20	0.76	0.06	0.53	0.02	0.35	0.01	0.20	0.00	0.09	0.00
9	9.50	25.01	5.41	6.37	3.34	1.97	1.93	0.52	1.44	0.25	0.86	0.07	0.59	0.03	0.39	0.01	0.23	0.00	0.10	0.00
10	10.56	30.40	6.02	7.74	3.71	2.39	2.15	0.63	1.60	0.31	0.96	0.09	0.66	0.04	0.43	0.01	0.25	0.00	0.11	0.00
11	11.61	36.26	6.62	9.23	4.08	2.85	2.36	0.75	1.76	0.37	1.05	0.11	0.73	0.04	0.48	0.02	0.28	0.00	0.12	0.00
12	12.67	42.59	7.22	10.84	4.45	3.35	2.57	0.88	1.91	0.43	1.15	0.12	0.79	0.05	0.52	0.02	0.30	0.00	0.13	0.00
14	14.78	56.64	8.42	14.42	5.20	4.45	3.00	1.17	2.23	0.57	1.34	0.16	0.92	0.07	0.61	0.02	0.35	0.01	0.16	0.00
16	16.89	72.52	9.63	18.46	5.94	5.70	3.43	1.50	2.55	0.73	1.53	0.21	1.06	0.09	0.69	0.03	0.40	0.01	0.18	0.00
18	19.01	90.17	10.83	22.95	6.68	7.09	3.86	1.87	2.87	0.91	1.72	0.26	1.19	0.11	0.78	0.04	0.45	0.01	0.20	0.00
20	21.12	109.58	12.03	27.89	7.42	8.62	4.29	2.27	3.19	1.10	1.91	0.32	1.32	0.13	0.87	0.05	0.50	0.01	0.22	0.00
22			13.24	33.27	8.17	10.28	4.72	2.71	3.51	1.32	2.10	0.38	1.45	0.15	0.95	0.06	0.55	0.01	0.24	0.00
24			14.44	39.08	8.91	12.07	5.15	3.18	3.83	1.55	2.29	0.45	1.58	0.18	1.04	0.07	0.60	0.02	0.27	0.00
26			15.64	45.32	9.65	14.00	5.58	3.69	4.15	1.79	2.49	0.52	1.71	0.21	1.13	0.08	0.66	0.02	0.29	0.00
28			16.85	51.98	10.39	16.06	6.01	4.23	4.47	2.06	2.68	0.59	1.85	0.24	1.22	0.09	0.71	0.02	0.31	0.00
30			18.05	59.05	11.14	18.24	6.44	4.80	4.79	2.34	2.87	0.67	1.98	0.27	1.30	0.10	0.76	0.03	0.33	0.00
35					12.99	24.26	7.51	6.39	5.58	3.11	3.35	0.89	2.31	0.36	1.52	0.13	0.88	0.03	0.39	0.00
40					14.85	31.06	8.58	8.18	6.38	3.98	3.82	1.15	2.64	0.46	1.74	0.17	1.01	0.04	0.44	0.01
45					16.71	38.62	9.65	10.17	7.18	4.95	4.30	1.42	2.97	0.58	1.95	0.21	1.13	0.06	0.50	0.01
50					18.56	46.94	10.73	12.36	7.98	6.02	4.78	1.73	3.30	0.70	2.17	0.25	1.26	0.07	0.56	0.01
55							11.80	14.74	8.78	7.18	5.26	2.06	3.63	0.84	2.39	0.30	1.39	0.08	0.61	0.01
60							12.87	17.32	9.57	8.43	5.74	2.43	3.96	0.98	2.60	0.36	1.51	0.09	0.67	0.01
65							13.94	20.08	10.37	9.78	6.21	2.81	4.29	1.14	2.82	0.41	1.64	0.11	0.72	0.01
70							15.02	23.03	11.17	11.21	6.69	3.23	4.62	1.31	3.04	0.47	1.76	0.13	0.78	0.02
75							16.09	26.17	11.97	12.74	7.17	3.66	4.95	1.48	3.25	0.54	1.89	0.14	0.83	0.02
80							17.16	29.49	12.77	14.36	7.65	4.13	5.28	1.67	3.47	0.60	2.02	0.16	0.89	0.02
85							18.23	32.99	13.56	16.06	8.13	4.62	5.60	1.87	3.69	0.68	2.14	0.18	0.94	0.02
90							19.31	36.67	14.36	17.85	8.61	5.14	5.93	2.08	3.91	0.75	2.27	0.20	1.00	0.03
95									15.16	19.73	9.08	5.68	6.26	2.30	4.12	0.83	2.39	0.22	1.06	0.03
100									15.96	21.69	9.56	6.24	6.59	2.53	4.34	0.91	2.52	0.24	1.11	0.03
110									17.55	25.88	10.52	7.44	7.25	3.01	4.77	1.09	2.77	0.29	1.22	0.04
120									19.15	30.40	11.47	8.74	7.91	3.54	5.21	1.28	3.02	0.34	1.33	0.05
130											12.43	10.14	8.57	4.11	5.64	1.48	3.28	0.40	1.44	0.05
140											13.39	11.63	9.23	4.71	6.08	1.70	3.53	0.45	1.55	0.06
150											14.34	13.21	9.89	5.35	6.51	1.93	3.78	0.52	1.67	0.07
160											15.30	14.89	10.55	6.03	6.94	2.18	4.03	0.58	1.78	0.08
170											16.25	16.65	11.21	6.74	7.38	2.44	4.28	0.65	1.89	0.09
180											17.21	18.51	11.87	7.50	7.81	2.71	4.54	0.72	2.00	0.10
190											18.17	20.46	12.53	8.29	8.25	2.99	4.79	0.80	2.11	0.11
200											19.12	22.50	13.19	9.11	8.68	3.29	5.04	0.88	2.22	0.12
225													14.84	11.33	9.76	4.09	5.67	1.09	2.50	0.15
250													16.48	13.77	10.85	4.98	6.30	1.33	2.78	0.18
275													18.13	16.42	11.93	5.94	6.93	1.58	3.05	0.22
300															13.02	6.97	7.56	1.86	3.33	0.25
325															14.10	8.09	8.19	2.16	3.61	0.29
350															15.19	9.27	8.82	2.47	3.89	0.34
375															16.27	10.54	9.45	2.81	4.16	0.38
400															17.36	11.87	10.08	3.16	4.44	0.43
425															18.44	13.28	10.71	3.54	4.72	0.48
450															19.53	14.76	11.34	3.93	5.00	0.54
475																	11.97	4.35	5.28	0.59

Factors Affecting DU- Filtration and Back Flushing

Types of Filters:

- Pressurized screen or disk filter
- Centrifugal sand separator
- Sand media filter





Back flushing:

- Automated
  - Pressure differential
  - Clock
- Manual





Factors Affecting DU- Filtration and Back Flushing

Table 1. Relative microirrigation system clogging potential of irrigation water

Water characteristics	Minor	Moderate	Severe
suspended solids (ppm)	< 50	50–100	> 100
pH	< 7.0	7.0–8.0	> 8.0
total dissolved solids (ppm)	< 500	500–2,000	> 2,000
electrical conductivity (dS/m)	< 0.8	0.8-3	> 3
manganese (ppm)	< 0.1	0.1–1.5	> 1.5
iron (ppm)	< 0.2	0.2–1.5	> 1.5
hydrogen sulfide (ppm)	< 0.2	0.2–2.0	> 2.0
bacterial population (number per ml)	< 10,000	10,000–50,000	> 50,000

Source: Bucks and Gilbert 1979; Nakayama and Bucks 1991.

Filtration Guidelines

Many options are available for filtration. Guidelines developed by the industry are shown in table 6.

References

Bruce, D. A. 1985. Filtration analysis and application. In Drip/trickle irrigation in action. Proceedings of the Third International Drip/Trickle Irrigation Congress, Fresno, CA. Vol. 1.

Table 6. Filtration guidelines

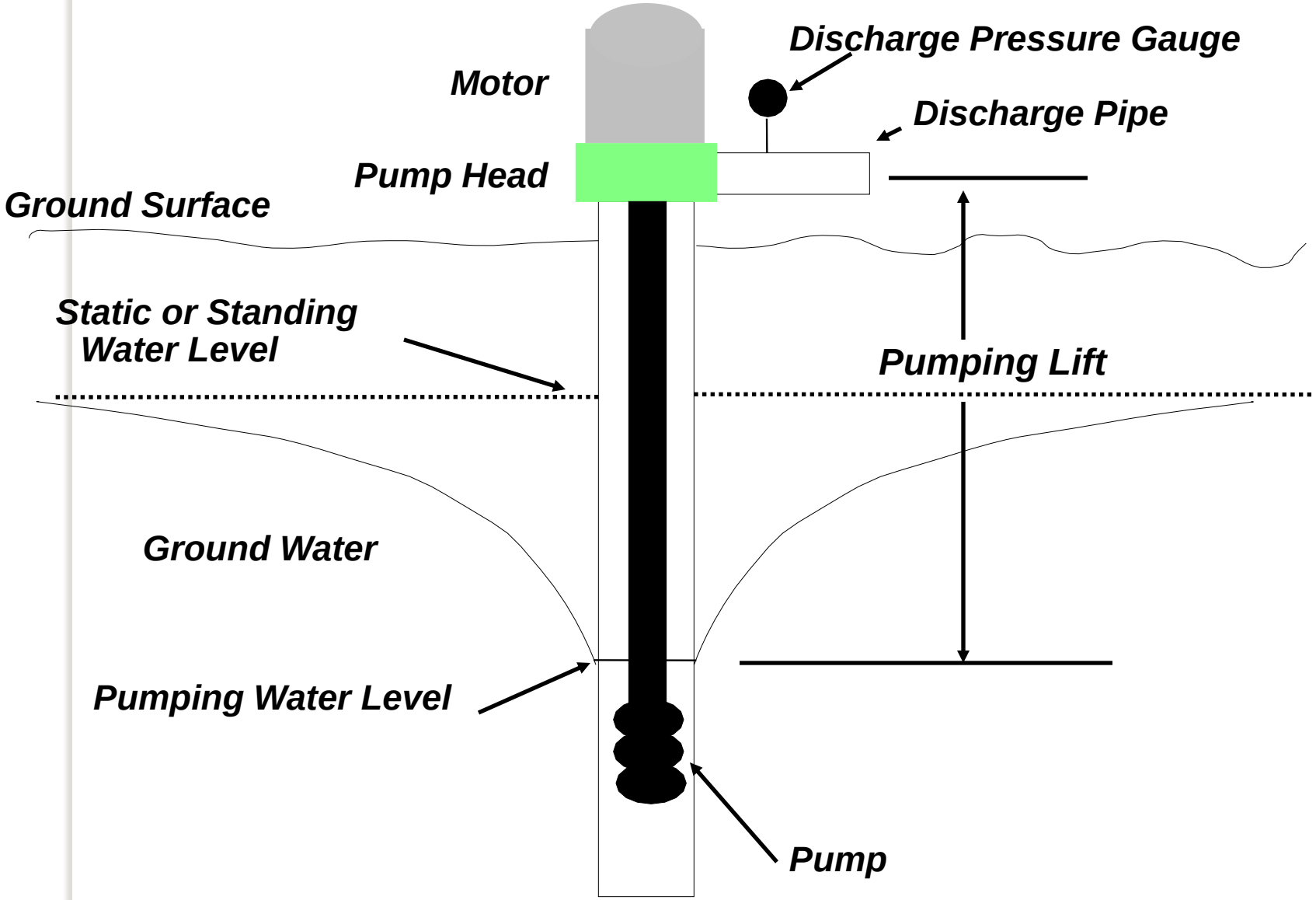
Flow rate (gpm)	Concentration		Filtration*
	Organic	Inorganic	
< 50 gpm	L	L	A
	L	M	A+C
	L	H	A+C
	M	L	D or A
	M	M	C+D or C+A
	M	H	C+D or C+A
	H	L	D or A
	H	M	C+D or C+A
	H	H	C+D or C+A
50 to 200 gpm	L	L	A
	L	M	C+A
	L	H	C+A
	M	L	B or E
	M	M	C+B or C+D
	M	H	C+B, C+D, or C+E
	H	L	B, D, or E
	H	M	C+D or C+E
	H	H	C+B, C+D, or C+E
> 200 gpm	L	L	A
	L	M	C+A
	L	H	C+F or E, C+A or C+E
	M	L	B or E
	M	M	C+B or C+E
	M	H	C+B or C+E
	H	L	B or E
	H	M	C+B or C+E
	H	H	C+B or C+E

Source: Bruce 1985.

Key:
L= less than 5 ppm
M = 5–50 ppm
H = more than 50 ppm
A = pressurized screen or disk filter
B = suction screen filter
C = centrifugal sand separator
D = gravity flow screen filter
E = sand media filter

Note:
* Letter sequence indicates the sequence of the filters: C+E means a centrifugal separator followed by a sand media filter.

Factors Affecting DU – Pumping Plant Design: Adequate Supply and Pressure as Groundwater Levels Change



Factors Affecting DU – Ability to Measure Flow and Pressure



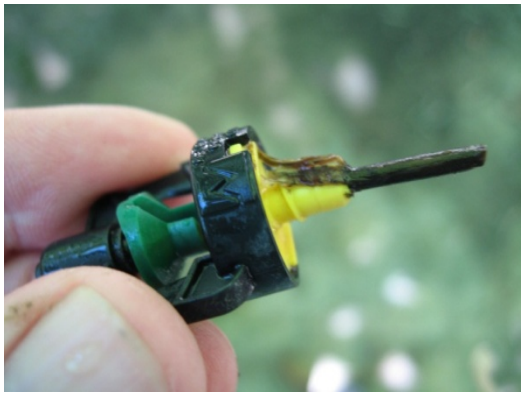






Self-flushing end caps

As the system ages: plugs, leaks, and breaks occur













Photos: By Kevin Greer and Allan Fulton.

Keys to maintaining high DU's (what works well)

- Check often (quick check at start up, thorough check including **hose flushing** monthly or more often, **check pressure regulator valves**)
- Balanced and sufficient pressures
- Be cautious with system additions or modification
- Maintenance - sprinkler and emitter types – must match
- Maintenance - nozzle sizes – must match
- Maintenance – Clean filters, keep in good condition
- Maintenance – fix breaks and leaks
- Maintenance - chemigation

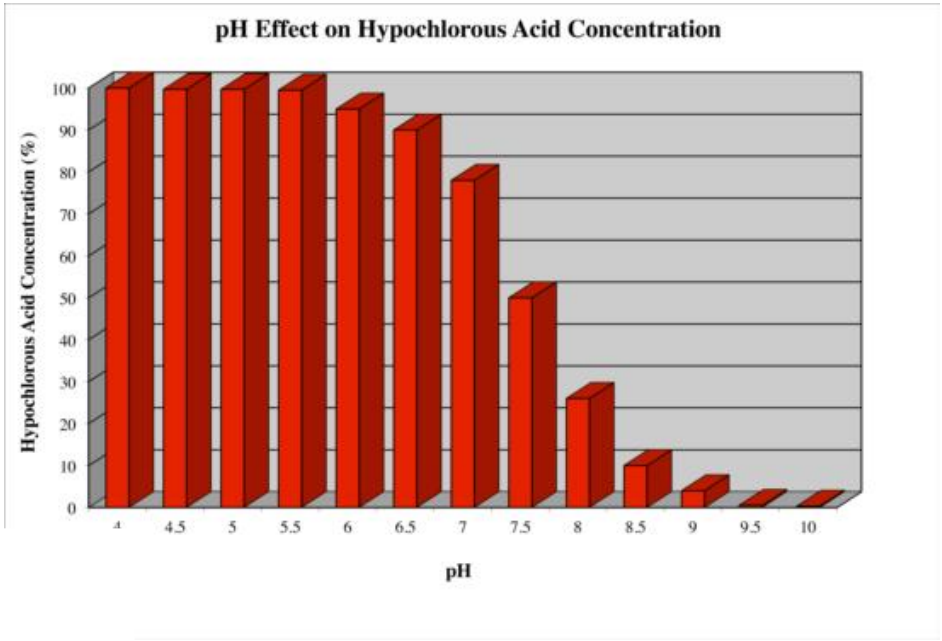
Suggestions for Chemigation

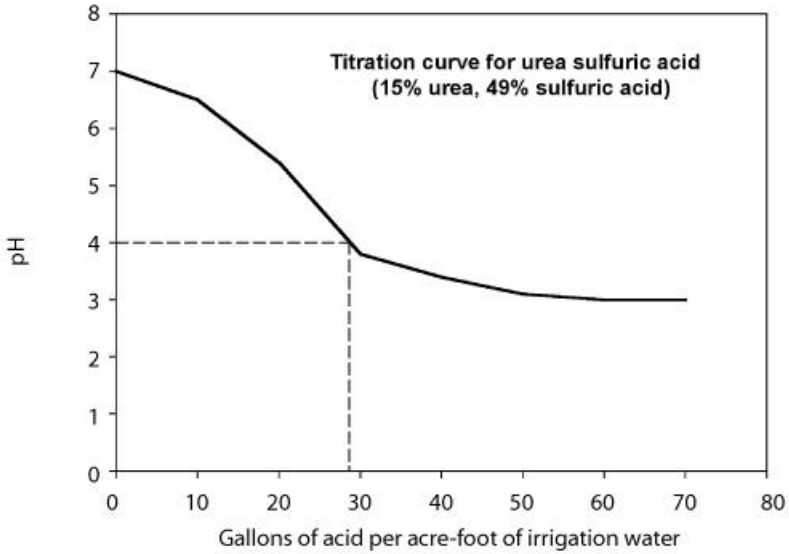
Biological plugging

- Good filtration lessens chemigation
- Three effective methods
  - Chlorination with pH adjustment
  - Copper products
  - Ozone

Chemical precipitate plugging

- Add acids to neutralize alkalinity
- Amount of acidification depends on water quality and acid strength
- Usually lower pH to 4 to 7 range
- Exercise caution
  - Personal safety
  - Corrosive and other damage





To conclude about Distribution Uniformity (DU)

Important to the bottom line:

- water demand
- energy demand
- nitrogen use efficiency
- uniform orchard production and tree health
- efficiency - production per unit water, land, and energy

AN ONGOING BATTLE OVER TIME!

http://micromaintain.ucanr.edu/Solutions/

THANK YOU!





