Blue Mountain Hort Society Annual Meeting

Irrigation Management in Fruit Orchards

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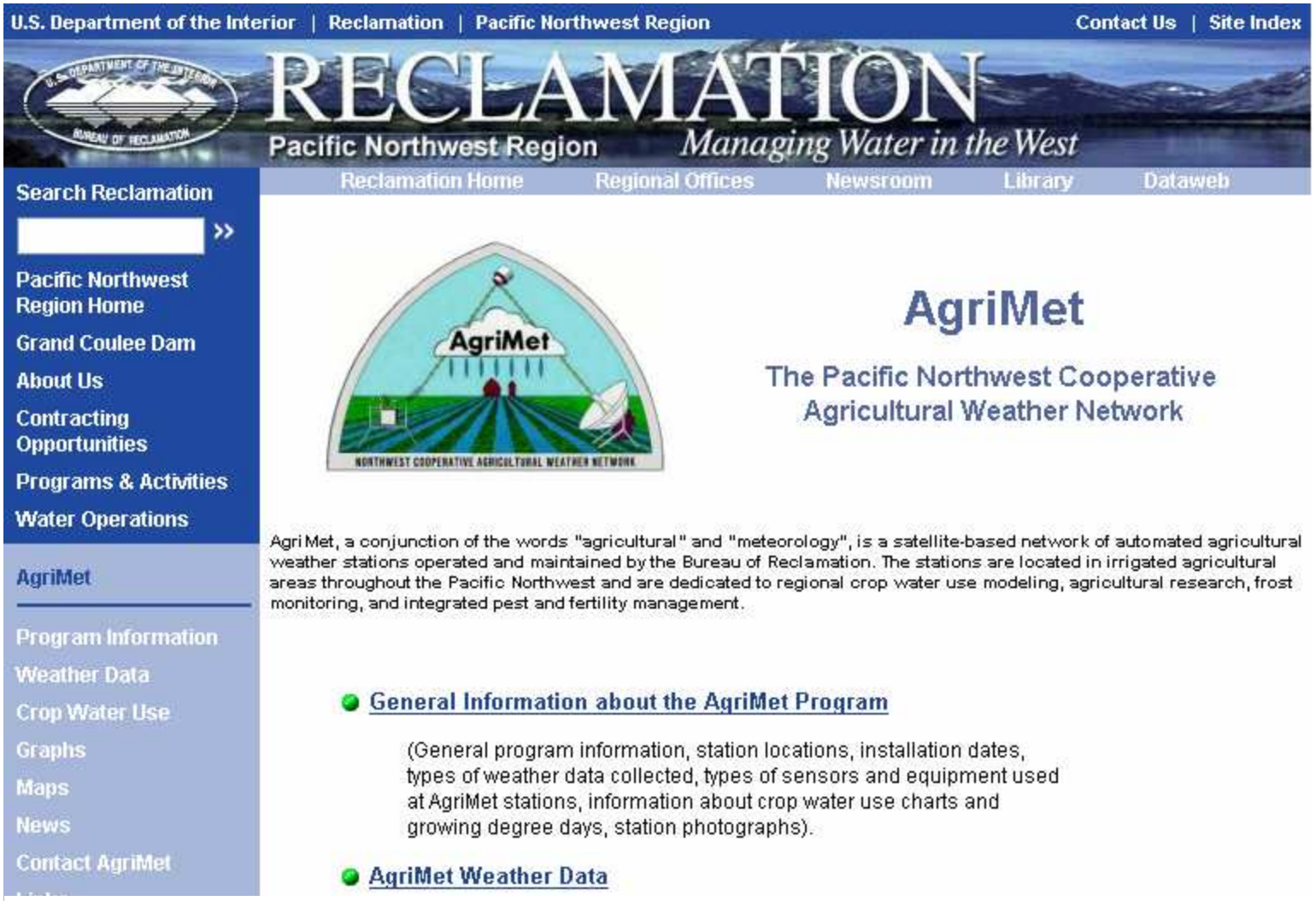
Corvallis, Oregon, USA

Oregon State University OSU

Hydrologic Science Team HST

AgriMet Irrigation Scheduling



http://www.usbr.gov/pn/agrimet/index.html

AgriMet Irrigation Scheduling – Station Map

Water Operations

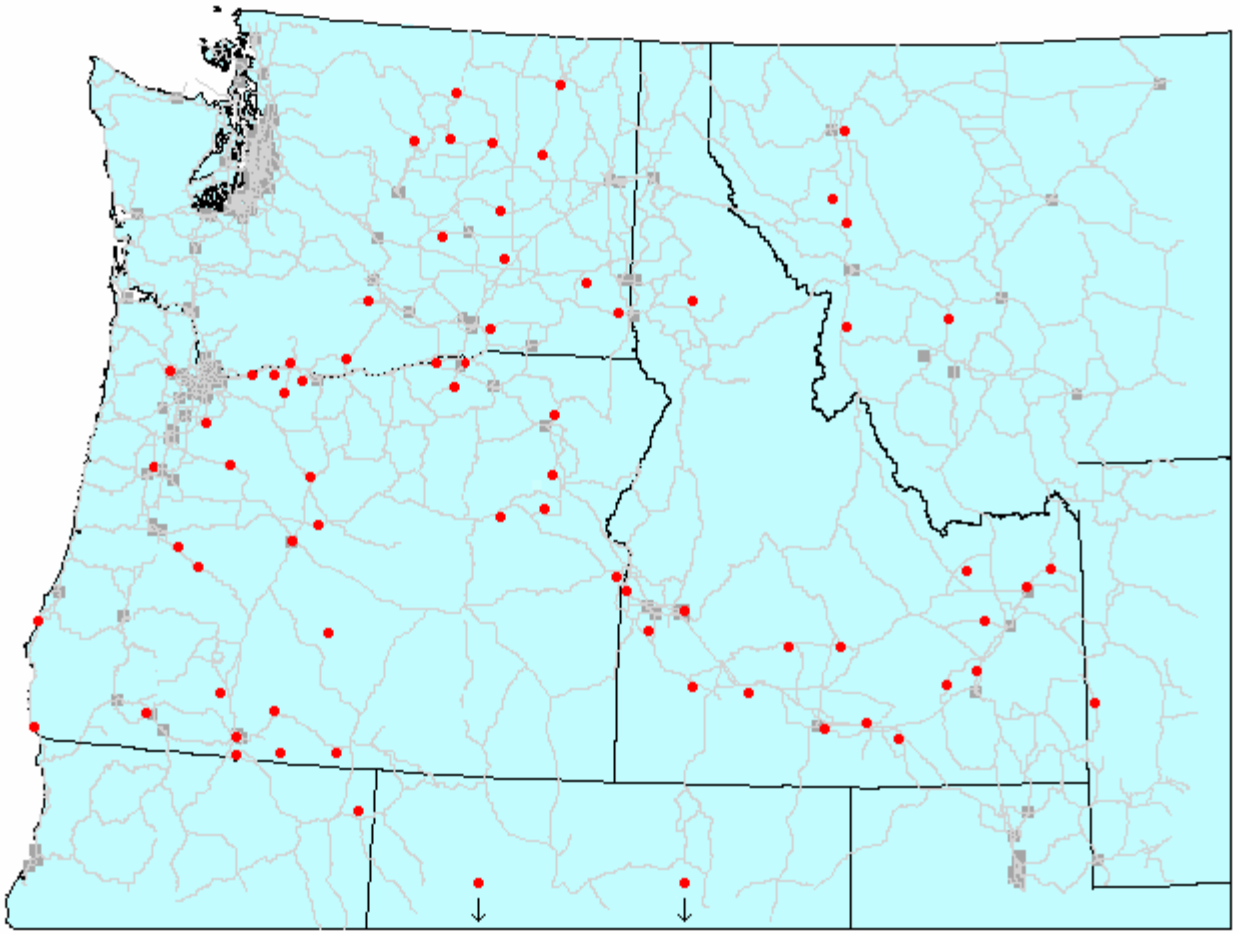
AgriMet

Program Information
Weather Data
Crop Water Use
Graphs
Maps
News
Contact AgriMet
Links
Other Information

Hydromet

U.S. Department of the Interior

AgriMet Network Map



Hover over the red dot for the name and identifier of the AgriMet weather station.
Click on a red dot for information specific to that AgriMet weather station.

AgriMet Irrigation Scheduling – Station Siting

AgriMet

- Program Information
- Weather Data
- Crop Water Use
- Graphs
- Maps
- News
- Contact AgriMet
- Links
- Other Information

Hydromet

U.S. Department of the Interior

Hermiston, Oregon AgriMet Station (HRMO)

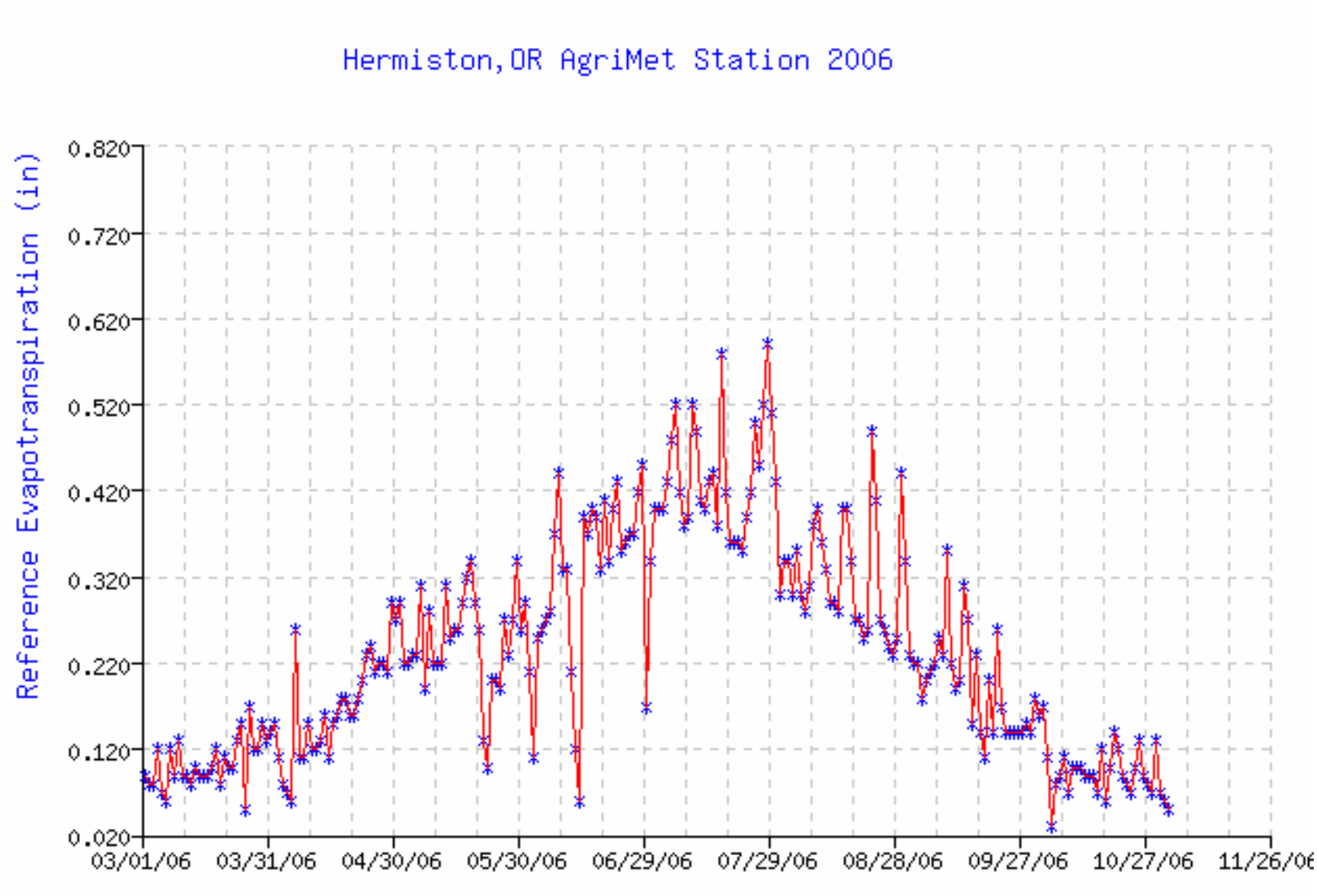
Latitude: 45° 49' 10"
Longitude: 119° 17' 00"
Elevation: 607'
Installation Date: 7/15/93

- 5 Days Weather Data
- 10 Days Weather Data
- Crop Water Use
- ET Summary
- Graphs
- Hourly Data (8 Days)
- Current Weather Data
- Historical Weather Data
- Weather Forecast (NWS)
- Station Parameters
- AgriMet Network Map

View North

AgriMet Irrigation Scheduling – ET Summary Page

AgriMet Reference ET – Kimberly Penman Method



AgriMet Irrigation Scheduling – Crop Codes

AgriMet

Program Information
Weather Data
Crop Water Use
Graphs
Maps
News
Contact AgriMet
Links
Other Information

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Key to AgriMet Crop Codes

Chart Code	Crop
ETr	REFERENCE EVAPOTRANSPIRATION (KIMBERLY-PENMAN ALFALFA REFERENCE)
ALFM	ALFALFA (MEAN)*
ALFN	ALFALFA (NEW PLANT)
ALFP	ALFALFA (PEAK)*
APPL	APPLES
ASPA	ASPARAGUS
BEAN	DRY BEANS
BEET	SUGAR BEETS
BLGR	BLUEGRASS SEED
BLUB	BLUEBERRIES
BROC	BROCCOLI
CABG	CABBAGE
CGRP	CONCORD GRAPES
CHRY	CHERRIES
CRAN	CRANBERRIES
CRTS	CARROT SEED
FCRN	FIELD CORN
GARL	GARLIC
HAYP	FESCUE GRASS HAY (PEAK DAILY CONSUMPTIVE USE FOR MATURE GRASS HAY)
HAYM	FESCUE GRASS HAY (MEAN ANNUAL USE WITH 3 SEASONAL CUTTINGS)
HOPS	HOPS
LAWN	LAWN
LILY	EASTER LILIES
MELN	MELONS
NMNT	NEW MINT
ONYN	ONION
ORCH	ORCHARDS
PAST	PASTURE
PEAR	PEARS
PEAS	PEAS
PECH	PEACHES
POP1	FIRST YEAR POPLAR TREES

AgriMet Irrigation Scheduling – Data Output

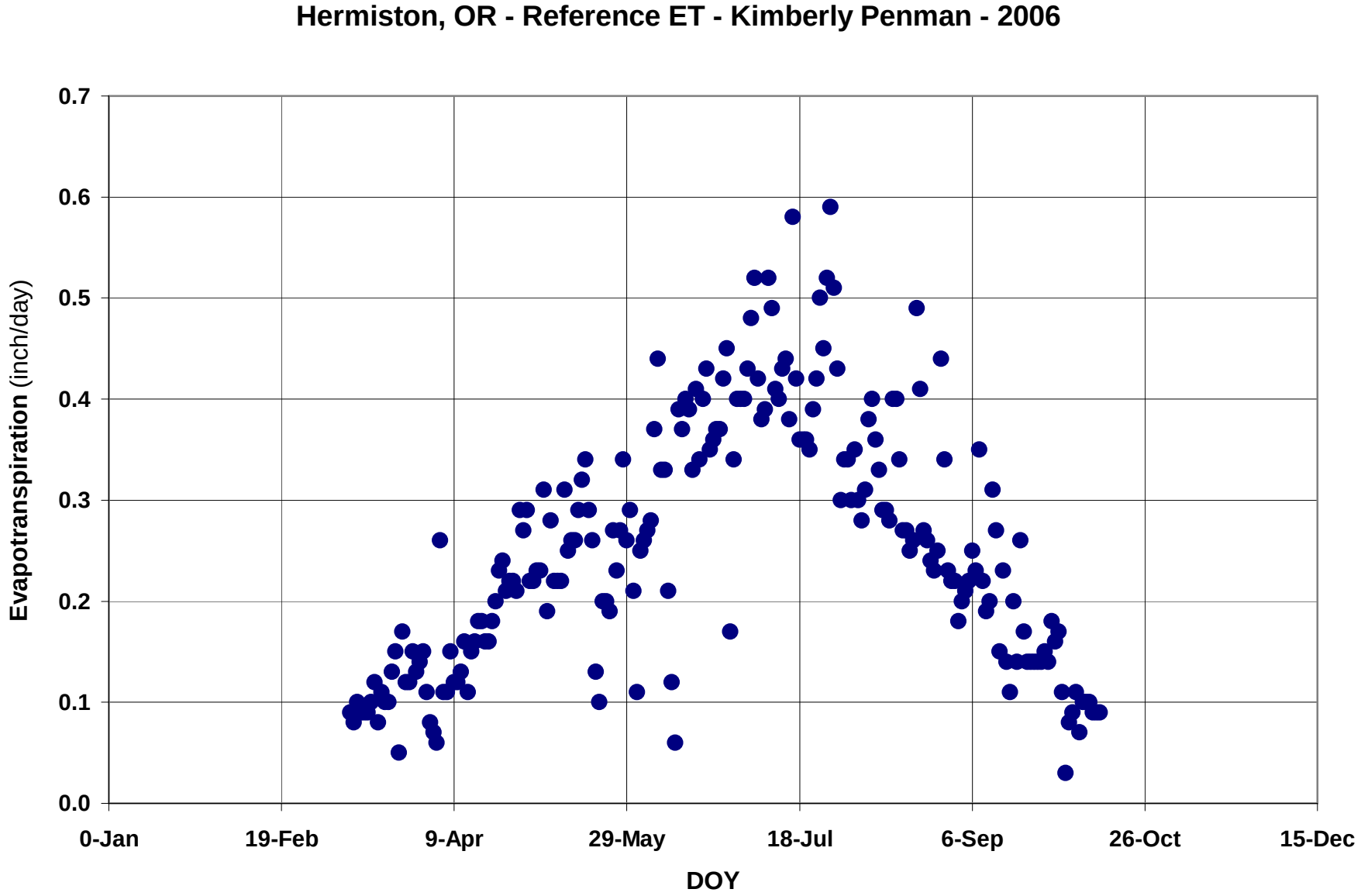
Microsoft Excel - hero06et.txt

File Edit View Insert Format Tools Data Window Help

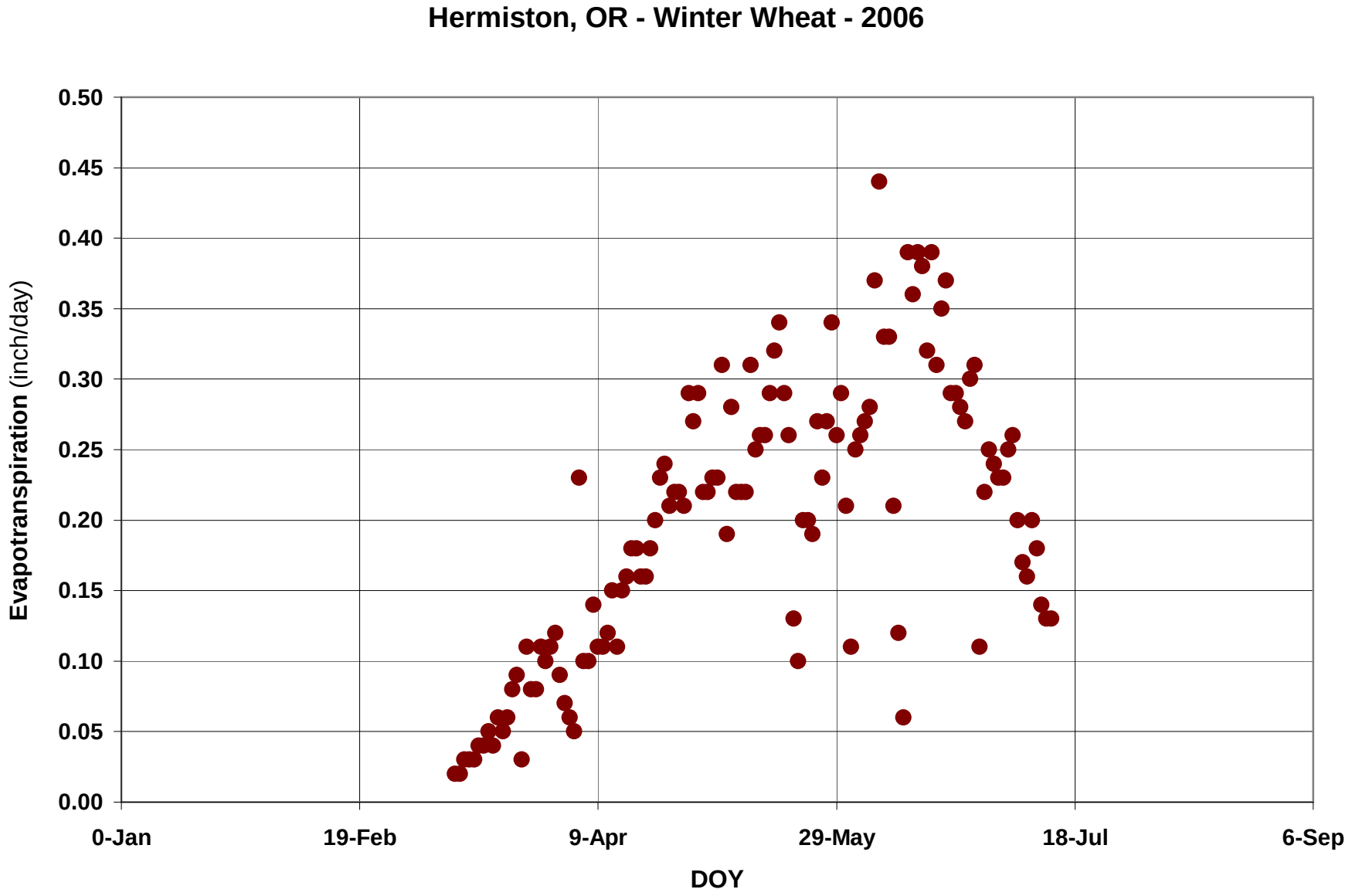
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1						HERO	ET SUMMARY		2006							
2		50	10	11	12	13	21	22	35	36	41	42	43	51	61	
3	DATE	ETr	ALFP	ALFM	PAST	LAWN	WGRN	SGRN	ONYN	ONYN	POTA	POTA	POTA	BEAN	FCRN	SC
4	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
5	311	0.09	--	--	0.02	0.01	0.02	--	--	--	--	--	--	--	--	--
6	312	0.08	--	--	0.02	0.01	0.02	--	--	--	--	--	--	--	--	--
7	313	0.1	--	--	0.03	0.02	0.03	--	--	--	--	--	--	--	--	--
8	314	0.09	--	--	0.03	0.02	0.03	--	--	--	--	--	--	--	--	--
9	315	0.09	0.01	0.01	0.03	0.02	0.03	--	--	0.03	--	--	--	--	--	--
10	316	0.09	0.01	0.01	0.03	0.03	0.04	--	--	0.03	--	--	--	--	--	--
11	317	0.1	0.02	0.02	0.03	0.04	0.04	--	--	0.03	--	--	--	--	--	--
12	318	0.12	0.02	0.02	0.04	0.05	0.05	--	--	0.04	--	--	--	--	--	--
13	319	0.08	0.01	0.01	0.03	0.04	0.04	--	--	0.03	--	--	--	--	--	--
14	320	0.11	0.02	0.02	0.04	0.06	0.06	0.02	--	0.04	--	--	--	--	--	--
15	321	0.1	0.02	0.02	0.04	0.05	0.05	0.02	--	0.04	--	--	--	--	--	--
16	322	0.1	0.03	0.03	0.04	0.06	0.06	0.02	--	0.04	--	--	--	--	--	--
17	323	0.13	0.04	0.04	0.05	0.08	0.08	0.03	--	0.06	--	--	--	--	--	--
18	324	0.15	0.05	0.05	0.06	0.09	0.09	0.03	--	0.07	--	--	--	--	--	--
19	325	0.05	0.02	0.02	0.02	0.03	0.03	0.01	0.02	0.02	--	--	--	--	--	--
20	326	0.17	0.07	0.07	0.07	0.12	0.11	0.03	0.05	0.09	--	--	--	--	--	--
21	327	0.12	0.05	0.05	0.05	0.08	0.08	0.02	0.04	0.06	--	--	--	--	--	--
22	328	0.12	0.05	0.05	0.06	0.09	0.08	0.02	0.04	0.06	--	--	--	--	--	--
23	329	0.15	0.07	0.07	0.07	0.11	0.11	0.03	0.06	0.08	--	--	--	--	--	--
24	330	0.13	0.07	0.07	0.06	0.1	0.1	0.03	0.05	0.06	--	--	--	--	--	--
25	331	0.14	0.08	0.08	0.07	0.11	0.11	0.03	0.06	0.07	--	--	--	--	--	--
26	401	0.15	0.09	0.09	0.08	0.12	0.12	0.04	0.07	0.08	--	--	--	--	--	--
27	402	0.11	0.07	0.07	0.06	0.09	0.09	0.03	0.05	0.05	--	--	--	--	--	--
28	403	0.08	0.05	0.05	0.04	0.06	0.07	0.02	0.04	0.04	--	--	--	--	--	--
29	404	0.07	0.04	0.04	0.04	0.06	0.06	0.02	0.04	0.04	--	--	--	--	--	--
30	405	0.06	0.04	0.04	0.04	0.05	0.05	0.02	0.03	0.03	--	--	--	--	--	--
31	406	0.26	0.18	0.18	0.16	0.21	0.23	0.08	0.13	0.13	--	--	--	--	--	--
32	407	0.11	0.08	0.08	0.07	0.09	0.1	0.04	0.05	0.05	--	--	--	--	--	--
33	408	0.11	0.08	0.08	0.07	0.09	0.1	0.04	0.05	0.05	--	--	--	--	--	--
34	409	0.15	0.11	0.11	0.09	0.12	0.14	0.06	0.08	0.08	--	--	--	--	--	--
35	410	0.12	0.09	0.09	0.08	0.1	0.11	0.06	0.06	0.06	--	--	--	--	--	--

hero06et

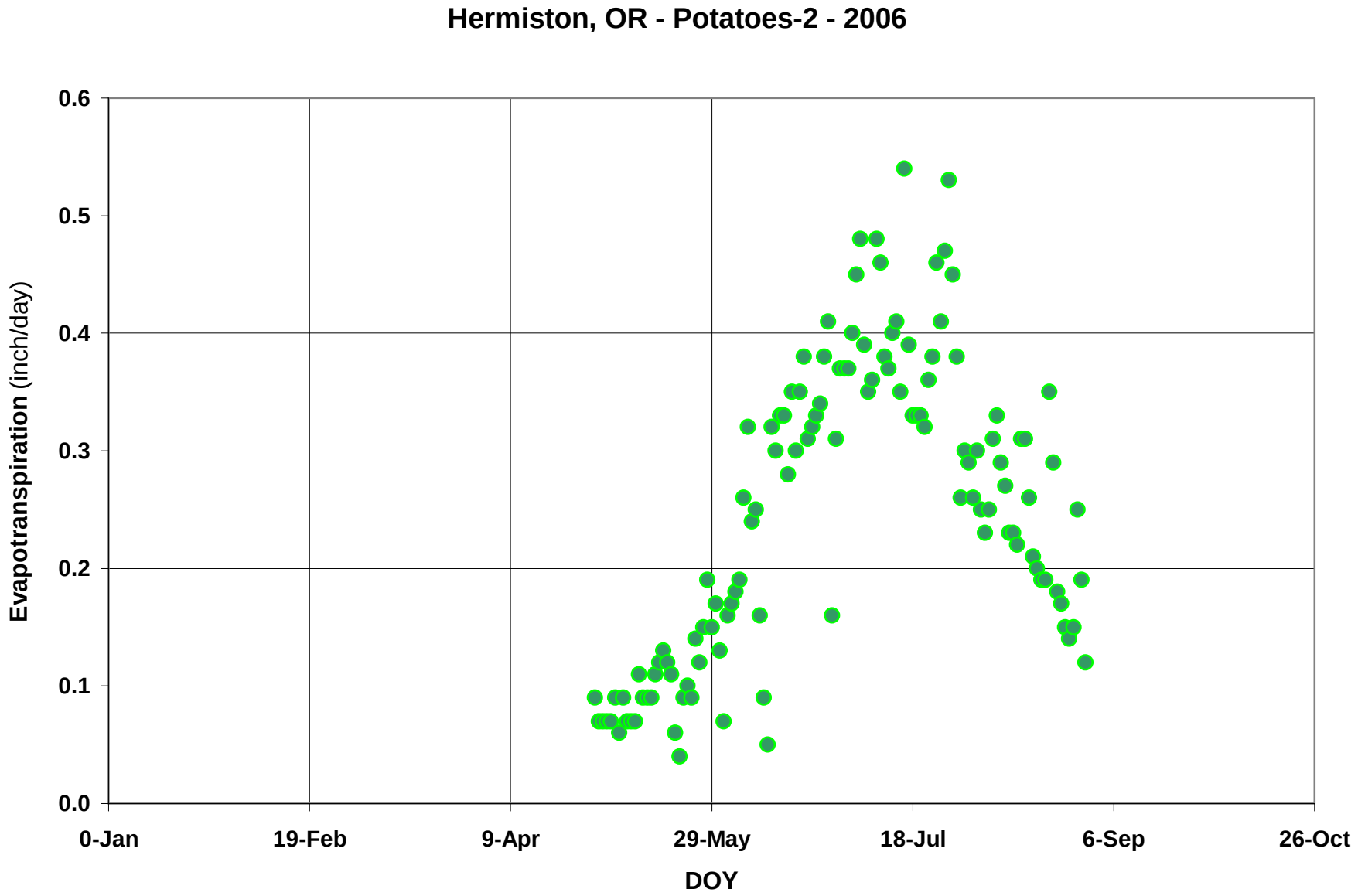
AgriMet Reference ET – Hermiston - 2006



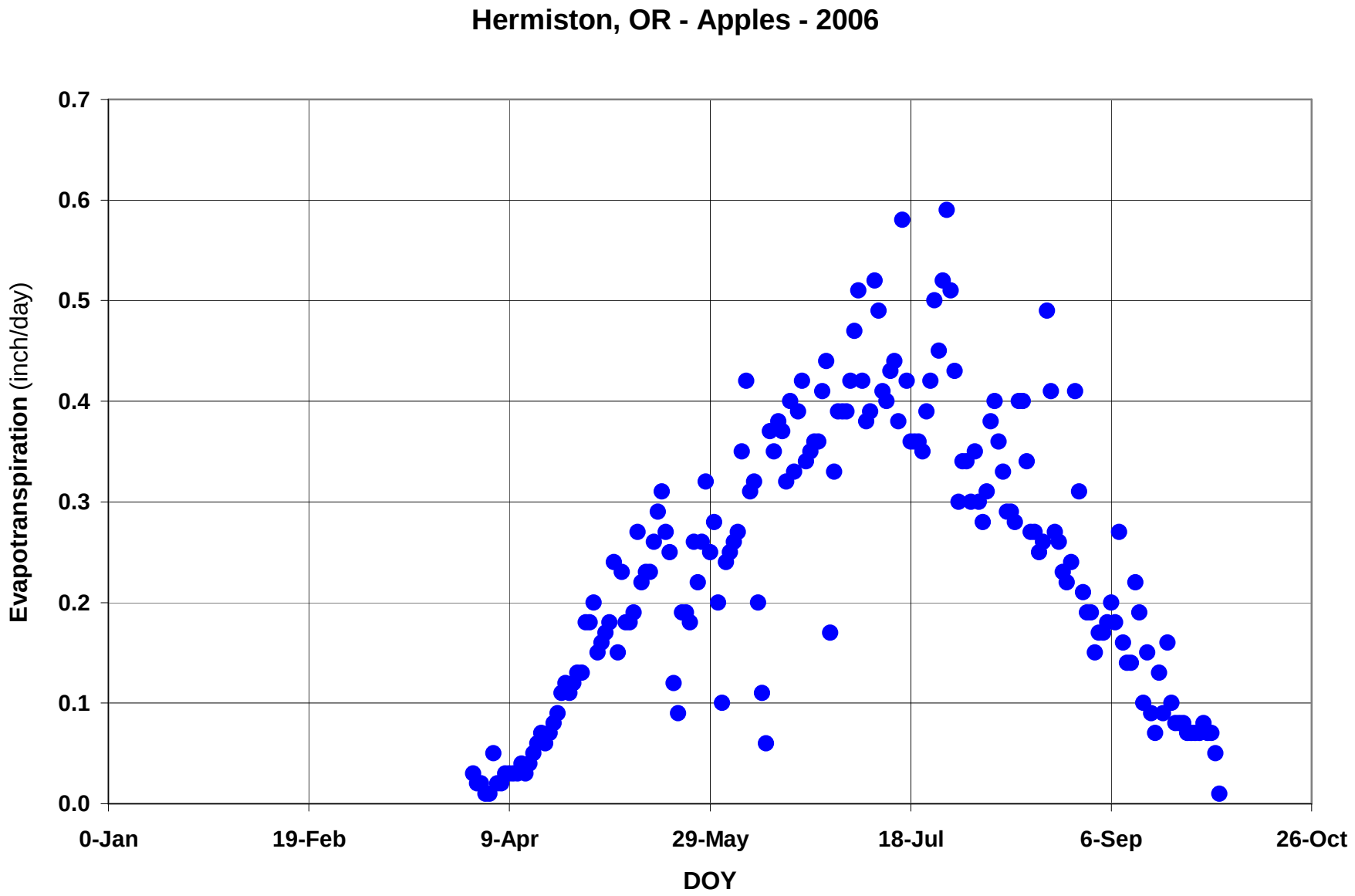
AgriMet Winter Wheat ET – Hermiston - 2006



AgriMet Potatoes-2 ET – Hermiston - 2006



AgriMet Apples ET – Hermiston - 2006



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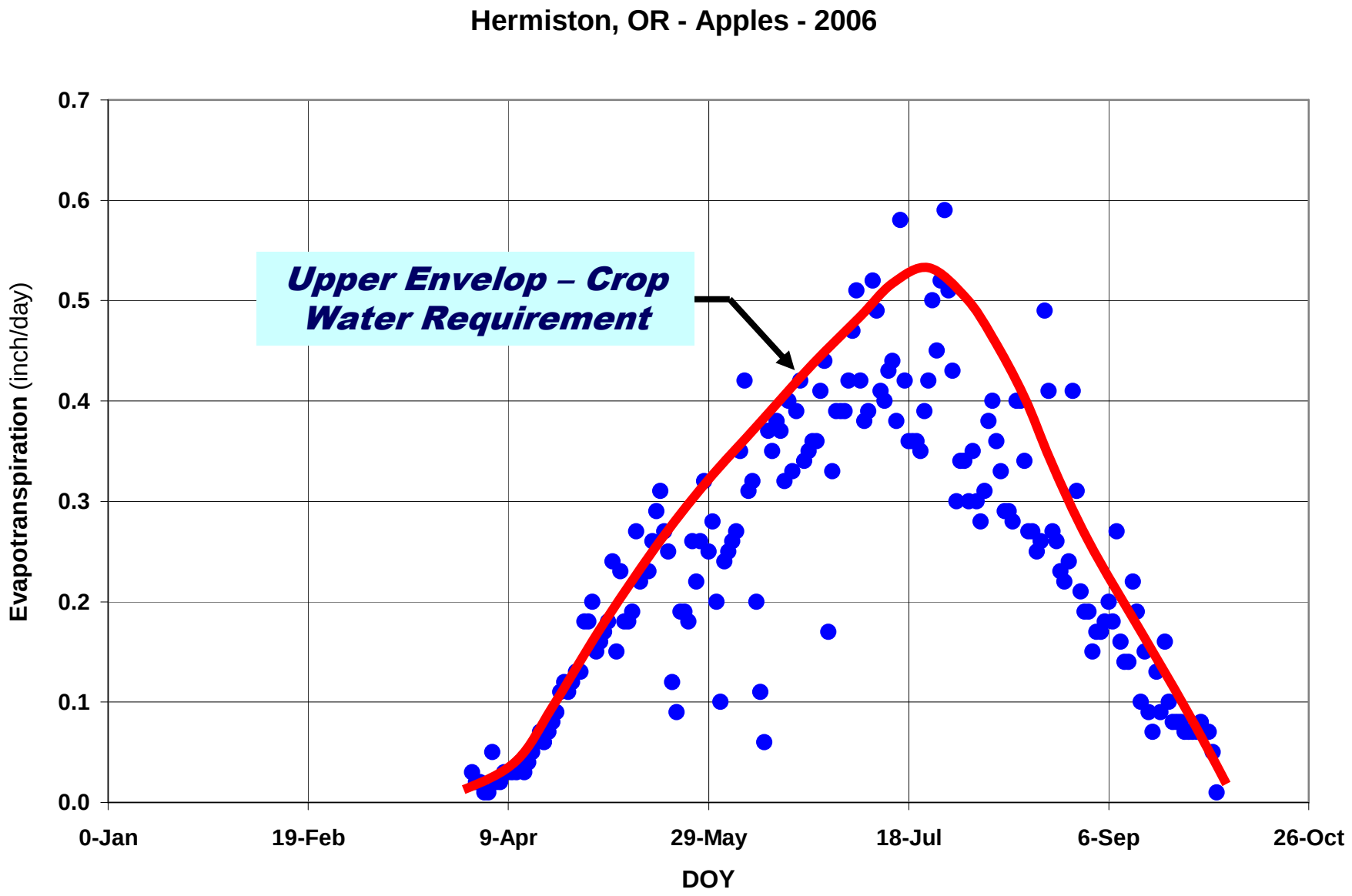

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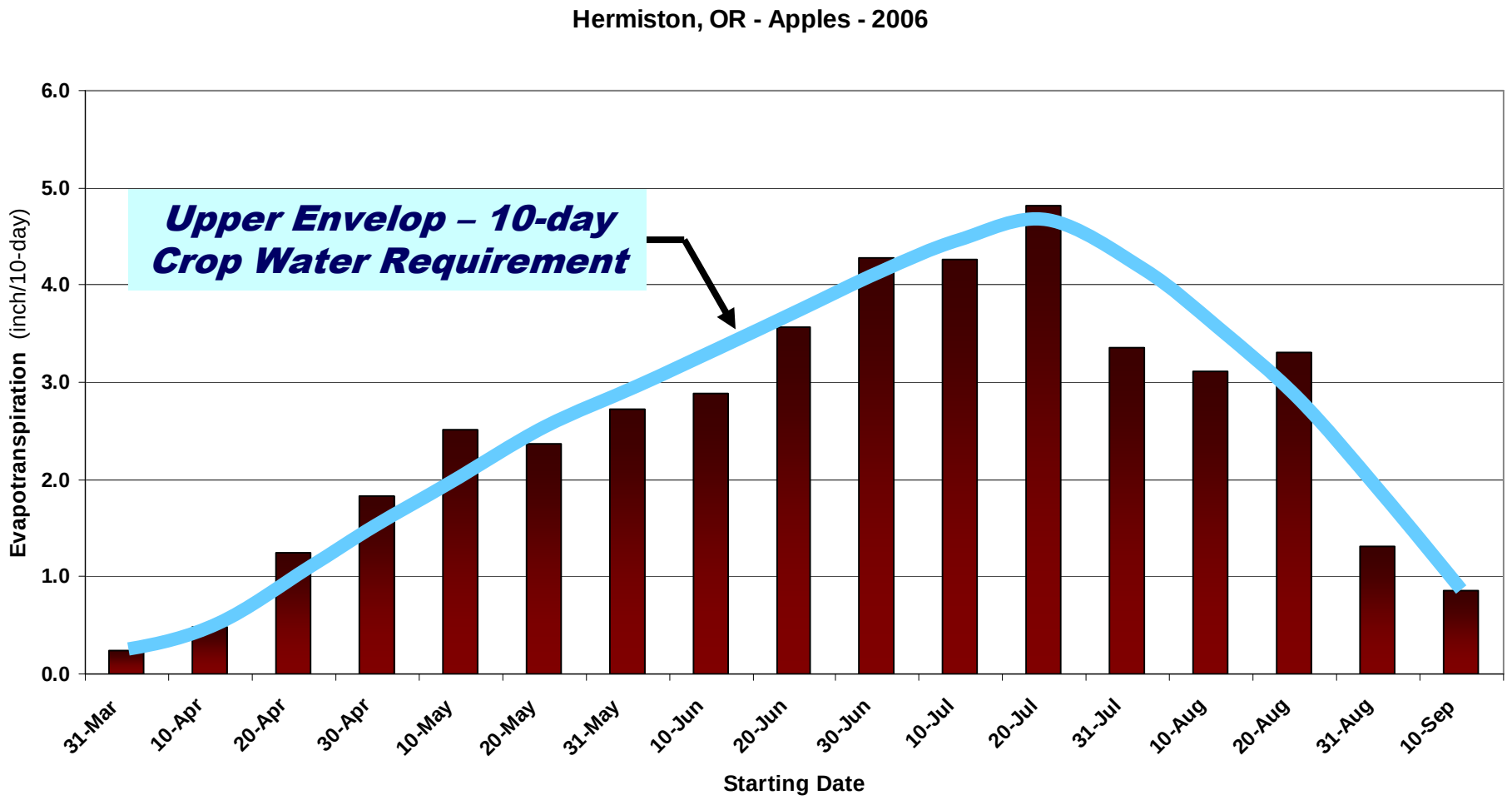
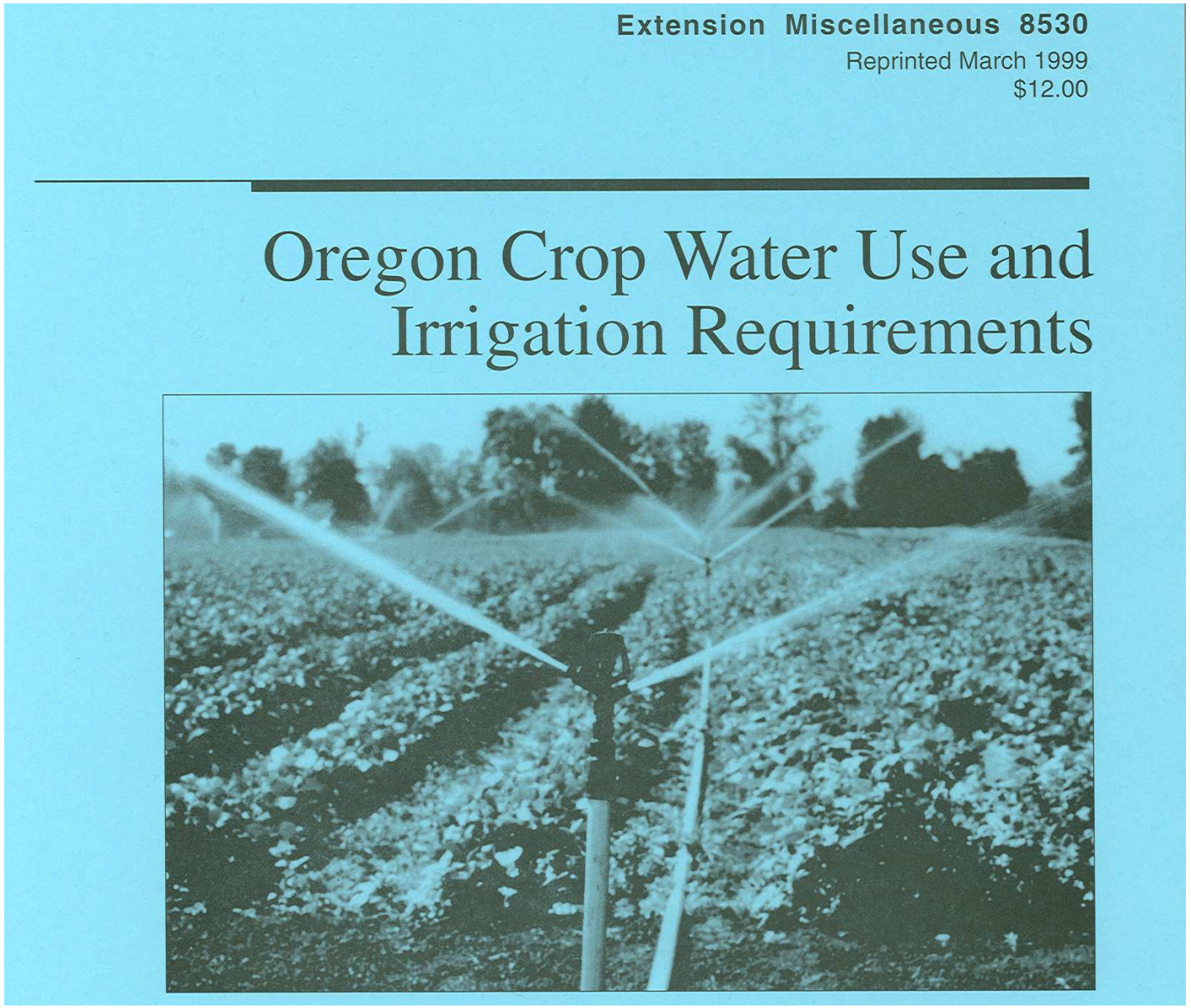
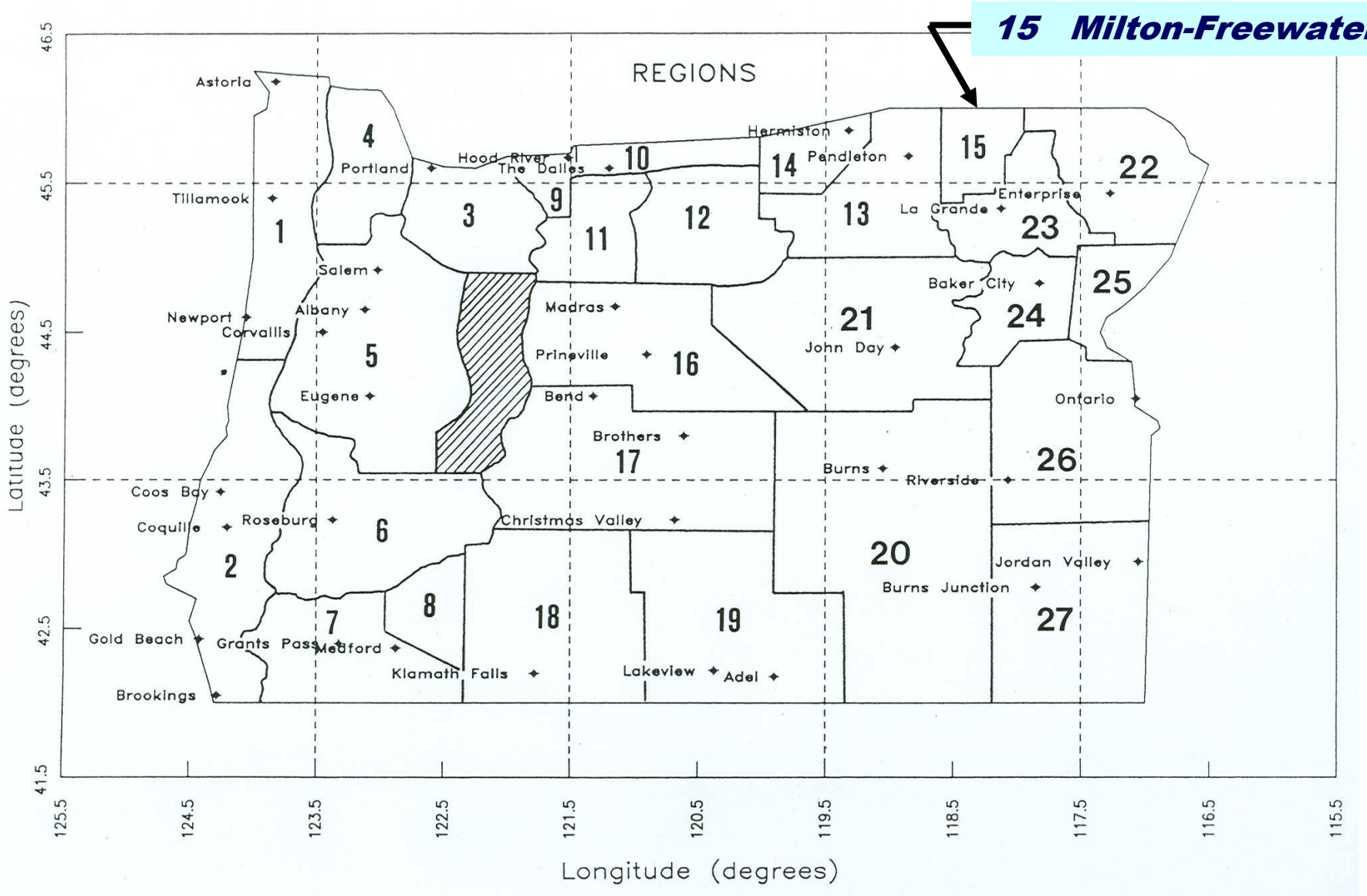


Season Total = 43.2 inches

Oregon Crop Water Use and Irrigation Requirements



Oregon Crop Water Use and Irrigation Requirements - Map



Oregon Crop Water Use and Irrigation Requirements

Oregon Crop Water Use and Irrigation Requirements

Region: **15** **Milton-Freewater**
Crop: **Pasture**

	Mean		60 % Probability		70 % Probability		80 % Probability		90 % Probability		95 % Probability	
	5 out of 10 years		6 out of 10 years		7 out of 10 years		8 out of 10 years		9 out of 10 years		19 out of 20 years	
Month	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)
March	0.55	0.04	0.55	0.04	0.59	0.04	0.63	0.16	0.71	0.31	0.75	0.43
April	2.99	1.26	3.07	1.57	3.15	1.93	3.23	2.28	3.50	2.68	3.62	2.95
May	4.49	2.80	4.57	3.03	4.72	3.35	4.84	3.62	5.12	4.49	5.20	4.92
June	5.12	3.82	5.20	4.09	5.31	4.33	5.51	4.61	5.67	4.84	5.83	5.39
July	7.36	6.97	7.44	7.13	7.48	7.28	7.56	7.44	7.76	7.60	7.91	7.80
Aug	6.02	5.59	6.10	5.87	6.18	6.02	6.26	6.18	6.42	6.30	6.61	6.50
Sep	4.02	2.80	4.06	3.15	4.17	3.46	4.29	3.94	4.41	4.25	4.53	4.37
Oct	2.09	0.67	2.13	0.91	2.17	1.18	2.20	1.46	2.28	1.77	2.40	2.17
Season	**32.64**	**23.95**	**33.12**	**25.79**	**33.77**	**27.59**	**34.52**	**29.69**	**35.87**	**32.24**	**36.85**	**34.53**

Oregon Crop Water Use and Irrigation Requirements

Oregon Crop Water Use and Irrigation Requirements

Region: **15** **Milton-Freewater**
Crop: **Apples**

	Mean		60 % Probability		70 % Probability		80 % Probability		90 % Probability		95 % Probability	
	5 out of 10 years		6 out of 10 years		7 out of 10 years		8 out of 10 years		9 out of 10 years		19 out of 20 years	
Month	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)
March	1.18	0.04	1.26	0.08	1.30	0.08	1.38	0.08	1.50	0.47	1.54	0.67
April	2.83	1.18	2.95	1.50	3.03	1.81	3.11	2.13	3.35	2.48	3.46	2.72
May	4.76	3.11	4.89	3.39	5.04	3.66	5.20	3.94	5.47	4.80	5.59	5.28
June	6.14	4.69	6.26	5.00	6.34	5.28	6.57	5.59	6.73	5.91	6.97	6.50
July	9.17	8.74	9.25	8.94	9.33	9.13	9.41	9.33	9.65	9.53	9.84	9.76
Aug	7.48	7.05	7.60	7.28	7.68	7.48	7.80	7.68	7.99	7.87	8.27	8.07
Sep	4.69	3.54	4.80	3.86	4.92	4.17	5.04	4.69	5.20	5.00	5.31	5.16
Oct	1.85	0.51	1.93	0.75	2.05	0.94	2.09	1.26	2.13	1.65	2.28	2.01
Nov	0.31	0.04	0.39	0.04	0.43	0.04	0.43	0.04	0.51	0.04	0.51	0.04
Season	**38.41**	**28.90**	**39.33**	**30.84**	**40.12**	**32.59**	**41.03**	**34.74**	**42.53**	**37.75**	**43.77**	**40.21**

Oregon Crop Water Use and Irrigation Requirements

Oregon Crop Water Use and Irrigation Requirements

Region: **15** **Milton-Freewater**
Crop: **Cherries**

	Mean		60 % Probability		70 % Probability		80 % Probability		90 % Probability		95 % Probability	
Month	5 out of 10 years		6 out of 10 years		7 out of 10 years		8 out of 10 years		9 out of 10 years		19 out of 20 years	
	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)
March	1.18	0.04	1.26	0.08	1.30	0.08	1.38	0.08	1.50	0.47	1.54	0.67
April	2.83	1.18	2.95	1.50	3.03	1.81	3.11	2.13	3.35	2.48	3.46	2.72
May	4.76	3.11	4.88	3.39	5.04	3.66	5.20	3.94	5.47	4.80	5.59	5.28
June	6.14	4.69	6.26	5.00	6.34	5.28	6.57	5.59	6.73	5.91	6.97	6.50
July	9.17	8.74	9.25	8.94	9.33	9.13	9.41	9.33	9.65	9.53	9.84	9.76
Aug	7.48	7.05	7.60	7.28	7.68	7.48	7.80	7.68	7.99	7.87	8.27	8.07
Sep	4.69	3.54	4.80	3.86	4.92	4.17	5.04	4.69	5.20	5.00	5.31	5.16
Oct	1.85	0.51	1.93	0.75	2.05	0.94	2.09	1.26	2.13	1.65	2.28	2.01
Nov	0.31	0.04	0.39	0.04	0.43	0.04	0.43	0.04	0.51	0.04	0.51	0.04
Season	**38.41**	**28.90**	**39.32**	**30.84**	**40.12**	**32.59**	**41.03**	**34.74**	**42.53**	**37.75**	**43.77**	**40.21**

Oregon Crop Water Use and Irrigation Requirements

Oregon Crop Water Use and Irrigation Requirements

Region: **14** **Hermiston**
Crop: **Apples**

	Mean		60 % Probability		70 % Probability		80 % Probability		90 % Probability		95 % Probability	
Month	5 out of 10 years		6 out of 10 years		7 out of 10 years		8 out of 10 years		9 out of 10 years		19 out of 20 years	
	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)	ET Crop (inch)	Net IRR (inch)
March	1.81	1.26	1.85	1.34	1.93	1.42	2.01	1.50	2.09	1.65	2.20	1.77
April	3.86	3.19	3.94	3.43	3.98	3.58	4.06	3.86	4.29	4.06	4.33	4.13
May	6.34	5.83	6.50	5.98	6.73	6.18	6.85	6.46	6.97	6.73	7.05	6.85
June	8.03	7.48	8.11	7.60	8.27	7.80	8.43	7.95	8.62	8.27	8.86	8.78
July	9.29	9.17	9.37	9.33	9.49	9.49	9.65	9.61	9.96	9.80	10.04	9.96
Aug	7.87	7.68	7.95	7.80	8.23	8.07	8.46	8.31	8.62	8.62	8.90	8.74
Sep	5.16	4.76	5.20	4.92	5.28	5.04	5.35	5.16	5.55	5.39	5.59	5.51
Oct	2.40	1.85	2.44	1.93	2.48	2.05	2.48	2.17	2.56	2.36	2.68	2.44
Nov	0.59	0.04	0.59	0.04	0.63	0.04	0.63	0.04	0.67	0.12	0.71	0.39
Season	**45.35**	**41.26**	**45.95**	**42.37**	**47.02**	**43.67**	**47.92**	**45.06**	**49.33**	**47.00**	**50.36**	**48.57**

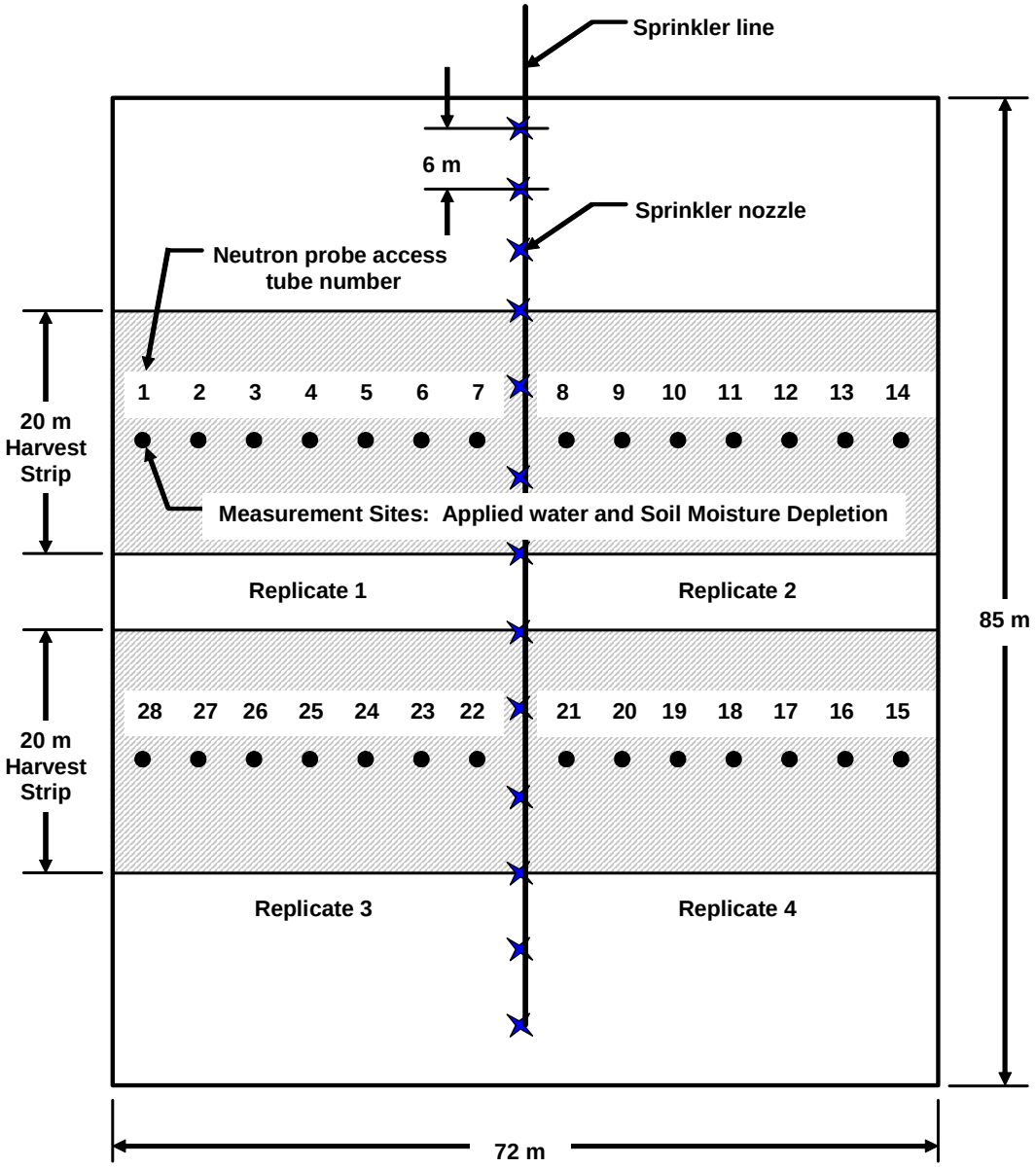
Crop Water Production Function - Application

- Determine yield response to applied water, i.e. irrigation + precipitation
- Determine yield response to evapotranspiration
- Required input data for economic optimization analysis

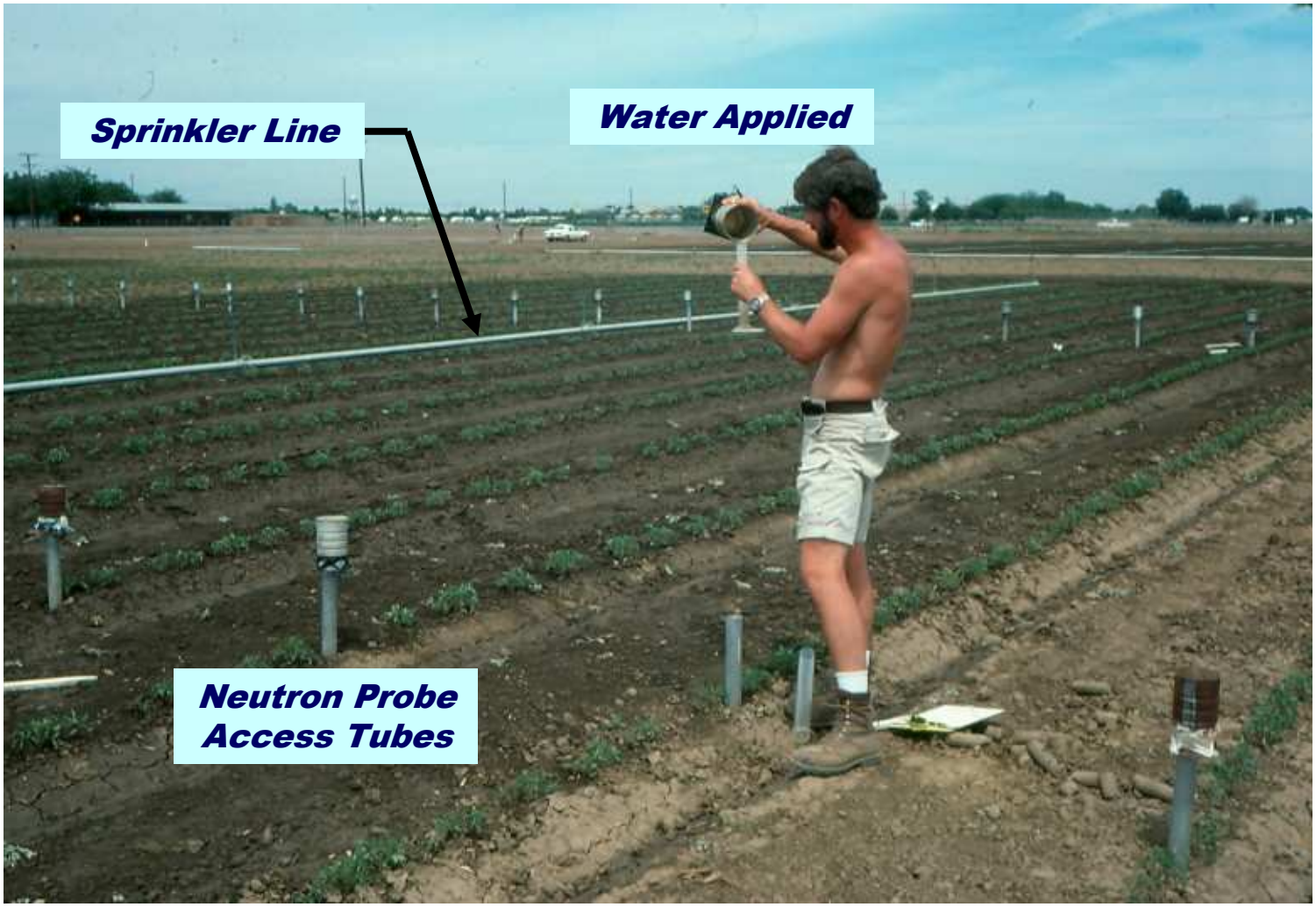
Crop Water Production Function - Experiment

- Line source sprinkler system - single nozzle sprinkler, high uniformity along line, triangular application pattern
- Monitoring sites for applied water and soil moisture depletion coincident with yield measurement
- Over-irrigate center of field causing yield depression
- No irrigation at edges of field – only soil moisture depletion

Line Source Experiment – Schematic



Line Source Experiment – Measurement

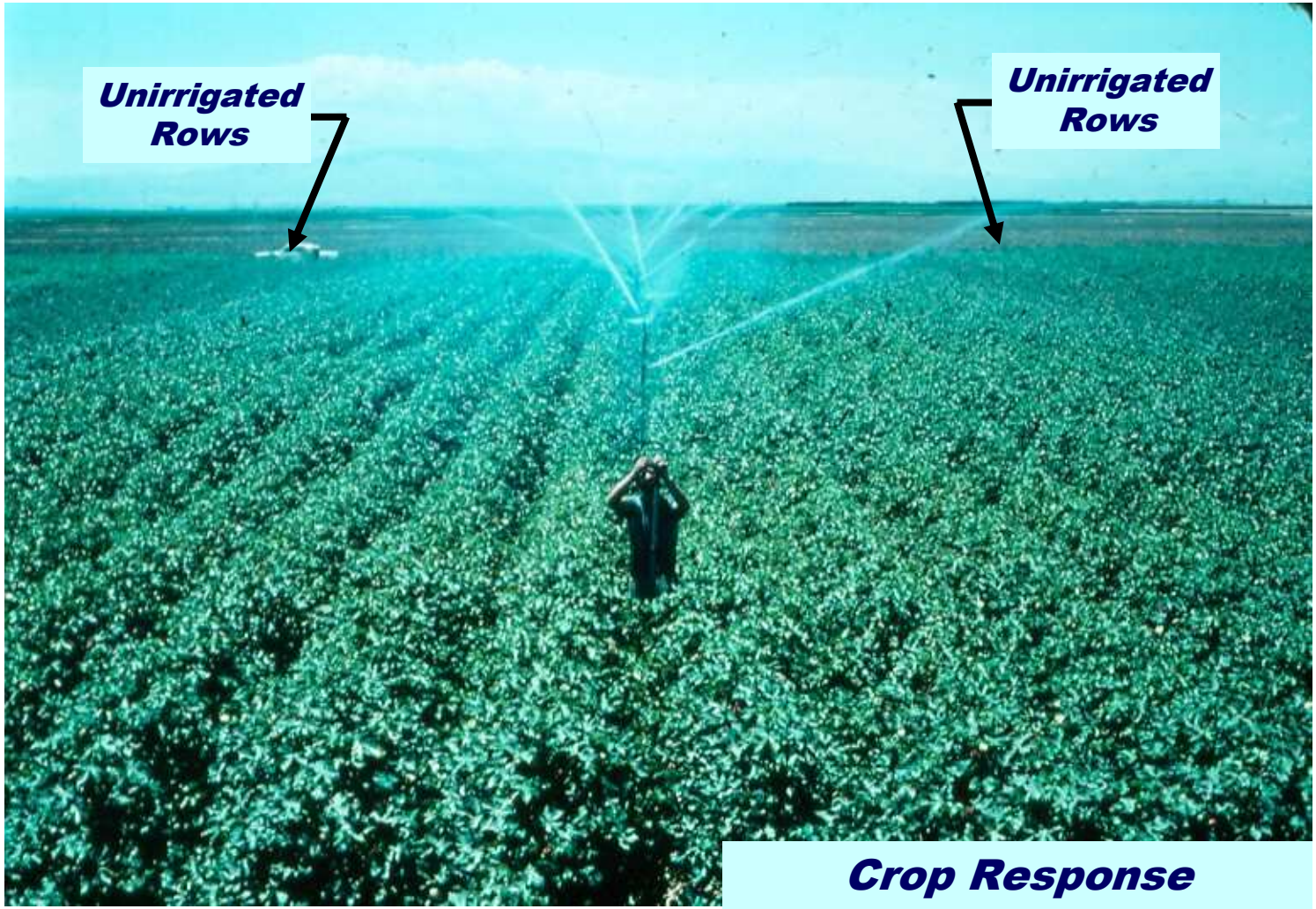


Line Source Experiment – SJ2 Cotton

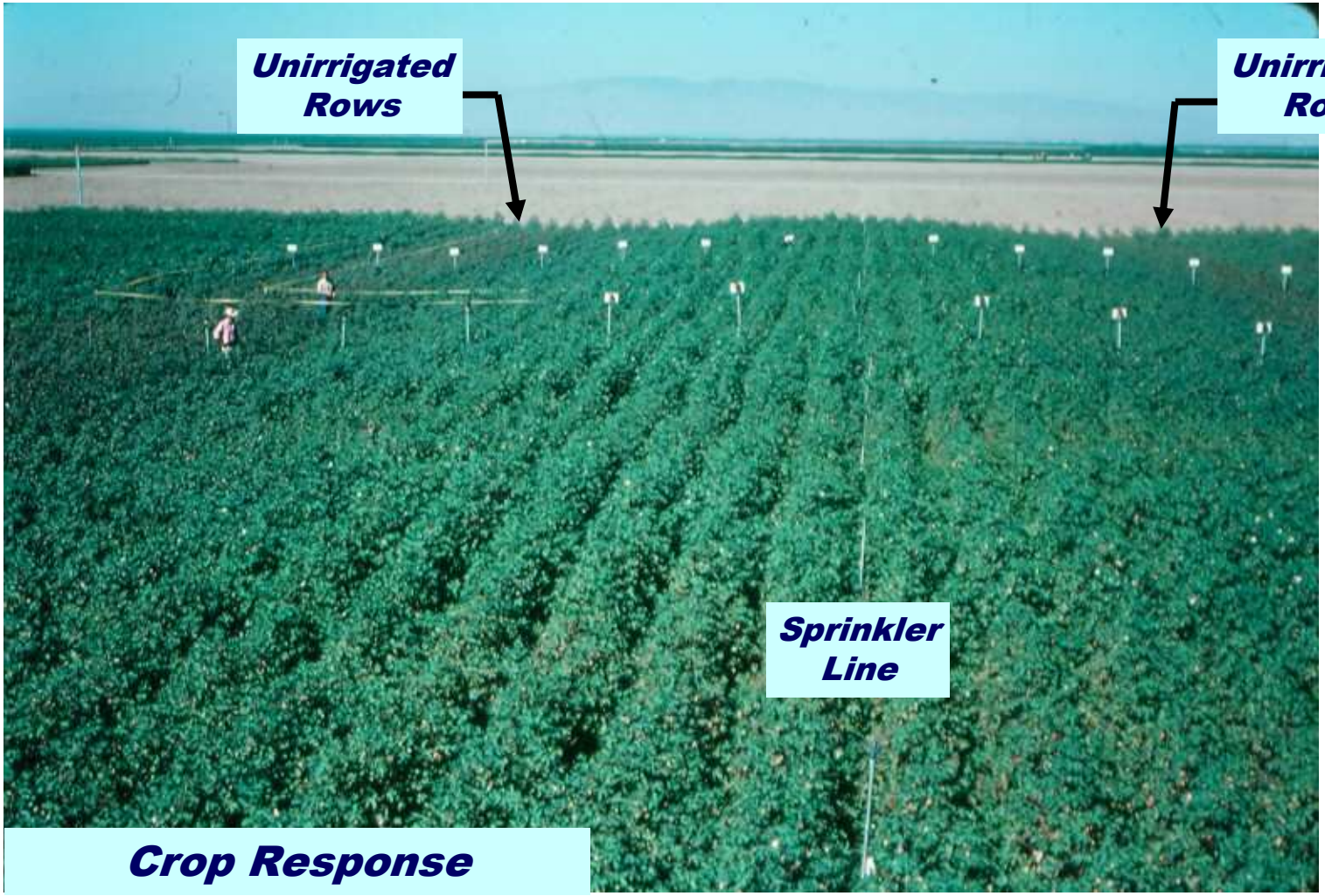
Experimental Plot in Middle of Uniformly Irrigated Field

Early Season Irrigation

Line Source Experiment – SJ2 Cotton



Line Source Experiment – SJ2 Cotton



Line Source Experiment – SJ2 Cotton

Crop Water Production Function

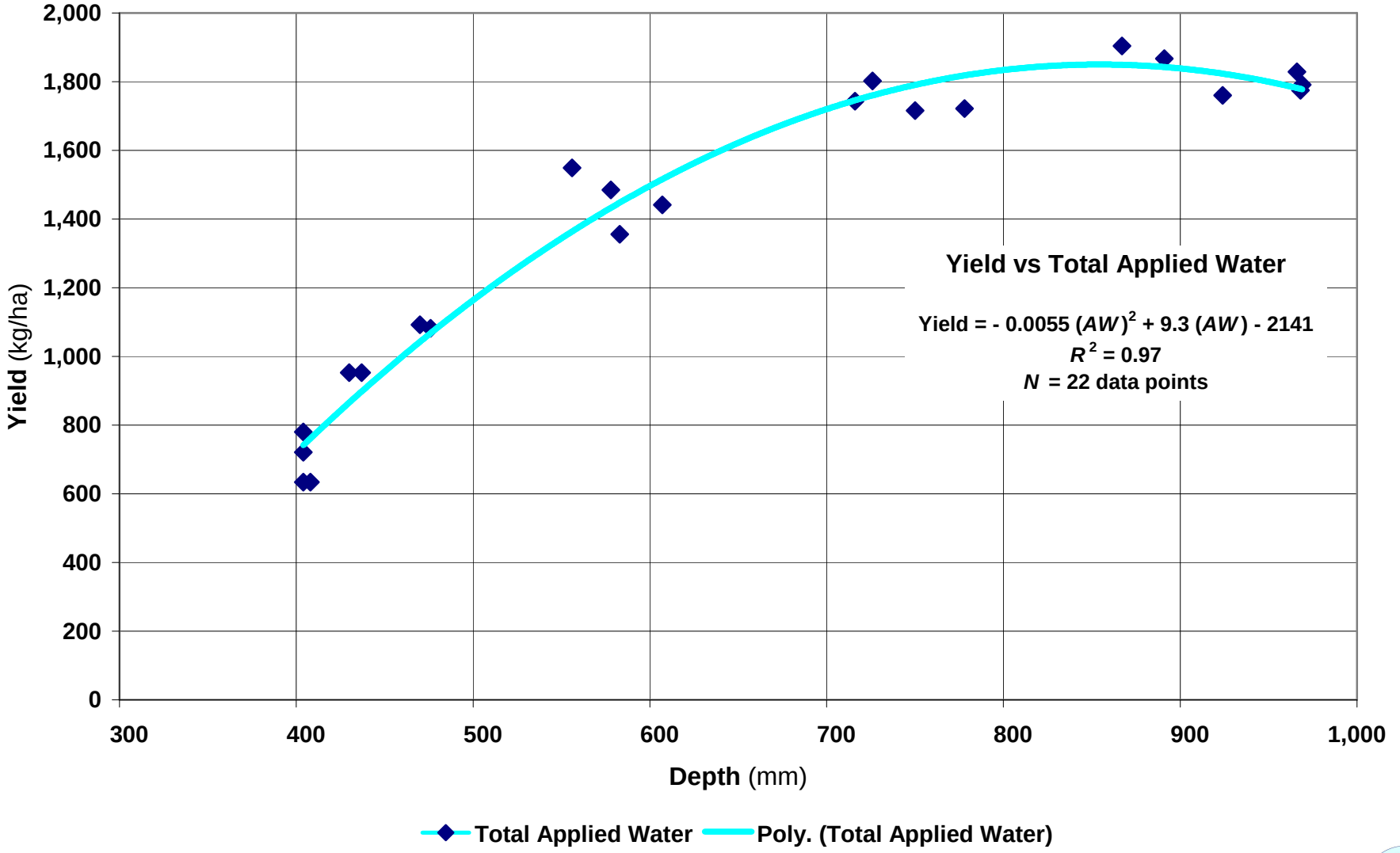
Crop: SJ2 Cotton **Location:** UC West Side Field Station

Year: 1976 **Source:** Cuenca et al. (1978)

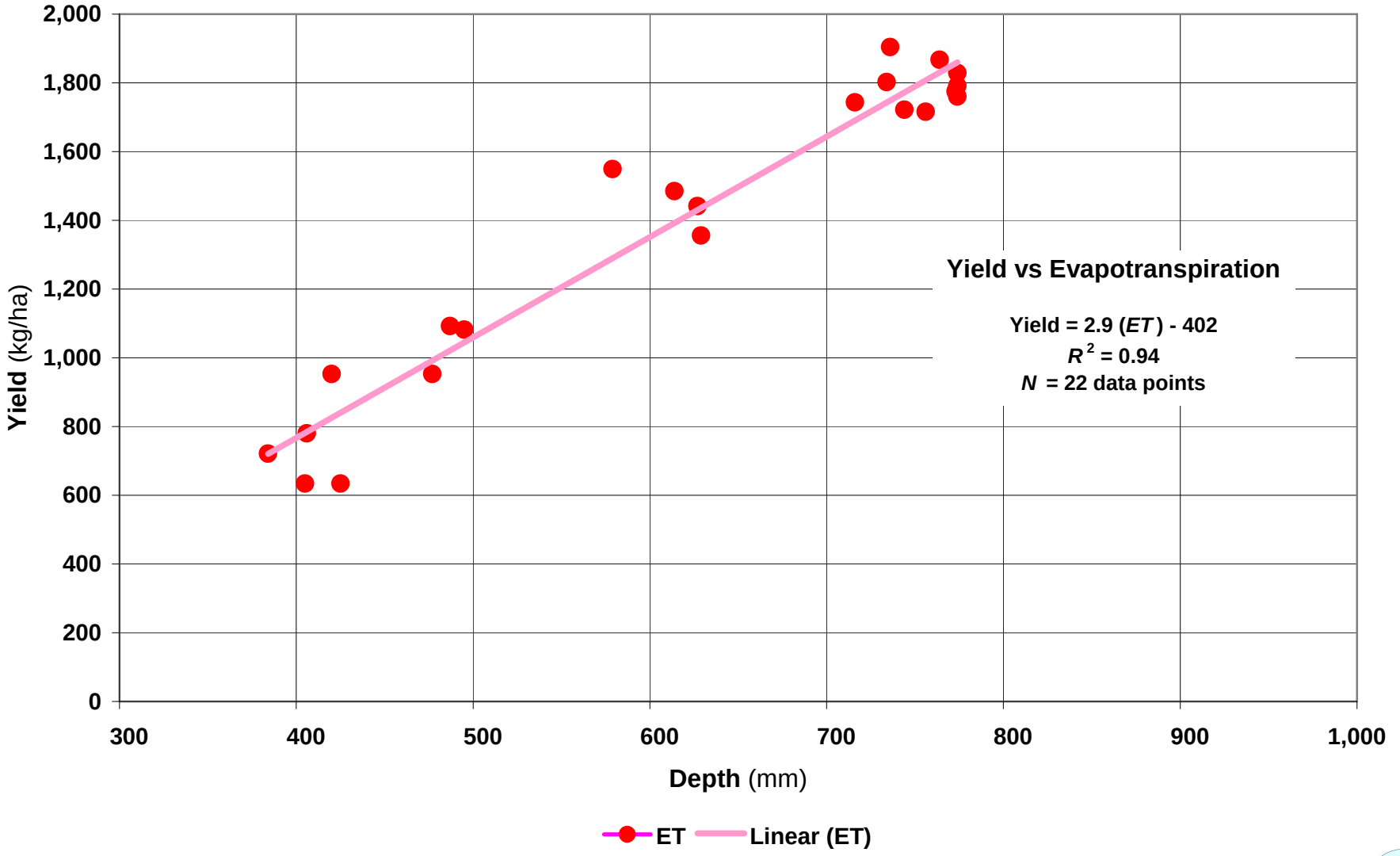
Irrigation Level	Applied Water (mm)	Soil Moisture Depletion (mm)	ET (mm)	Yield (kg/ha)	ET / ET_{max}	Yield / $Yield_{max}$
1	67	338	406	692	0.547	0.375
2	96	352	449	953	0.605	0.517
3	135	355	491	1,087	0.662	0.589
4	243	367	612	1,458	0.825	0.791
5	405	348	737	1,746	0.993	0.947
6	556	273	742	1,844	1.000	1.000
7	630	254	727	1,798	0.980	0.975
		Maximum	**742**	**1,844**		

Note: Applied Water includes seasonal irrigation and precipitation.

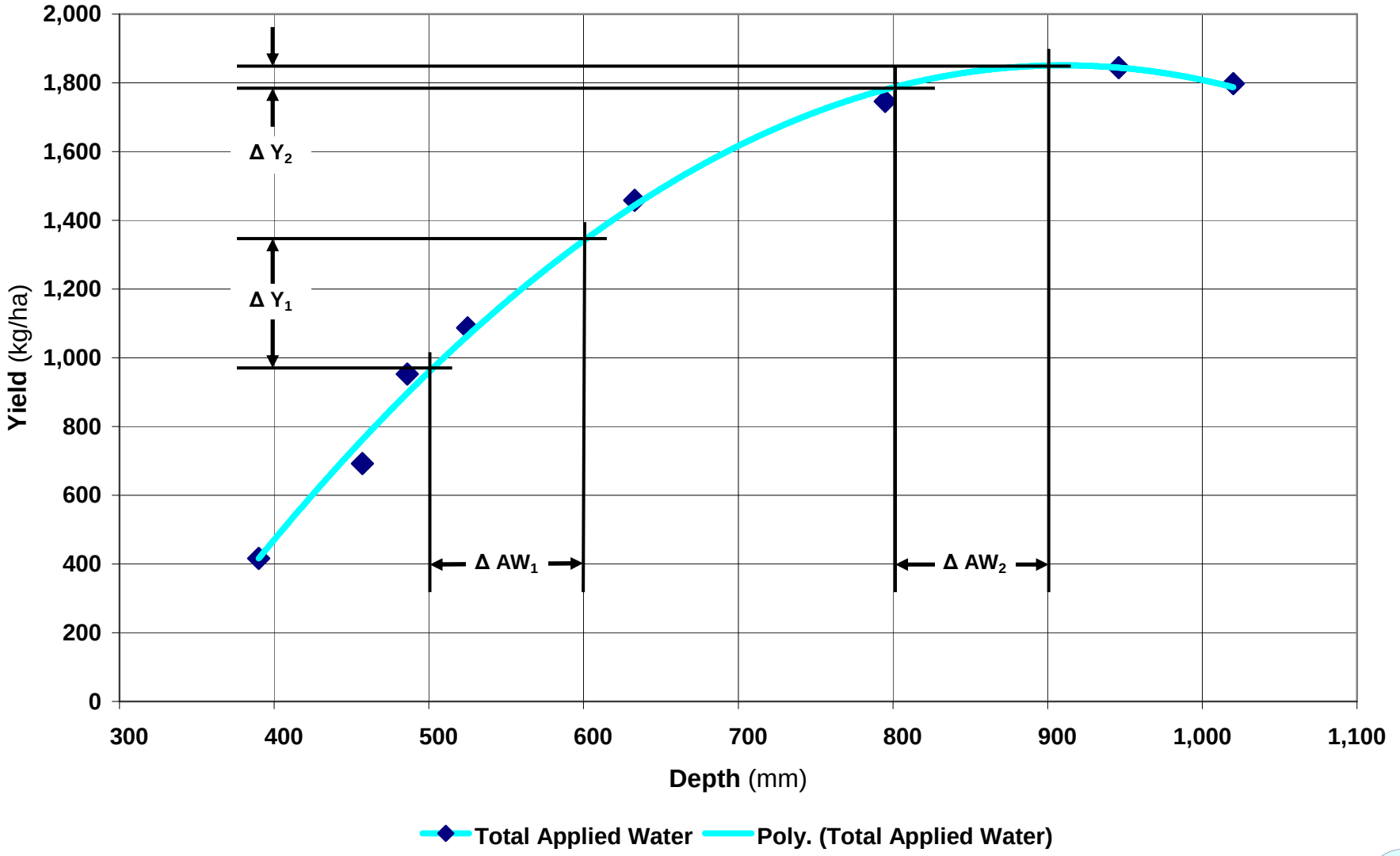
Line Source Experiment – SJ2 Cotton



Line Source Experiment – SJ2 Cotton



Line Source Experiment – SJ2 Cotton



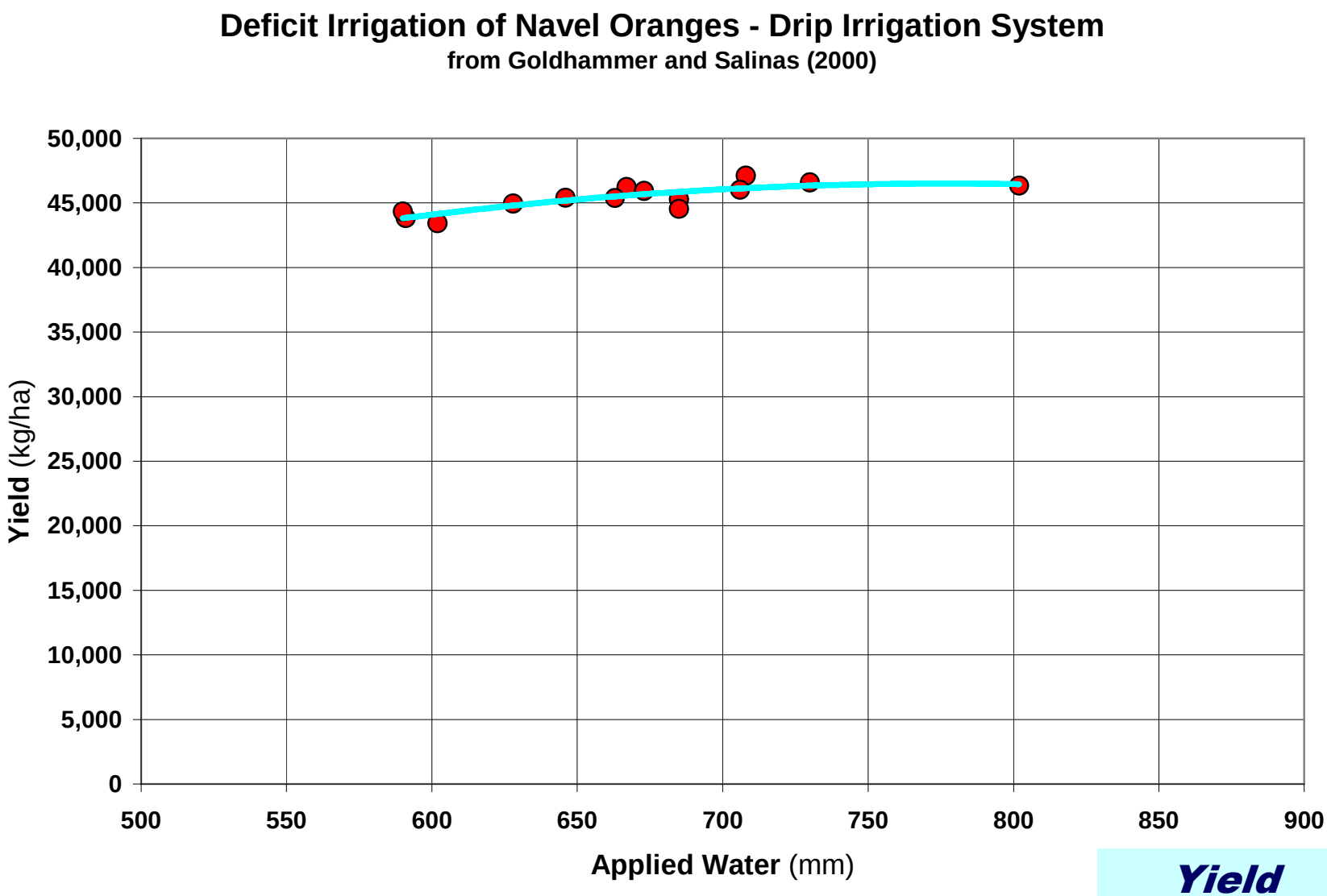
Yield Reduction – Not Linearly Proportional

100% Irrigation
100% Yield

74% Irrigation
93% Yield

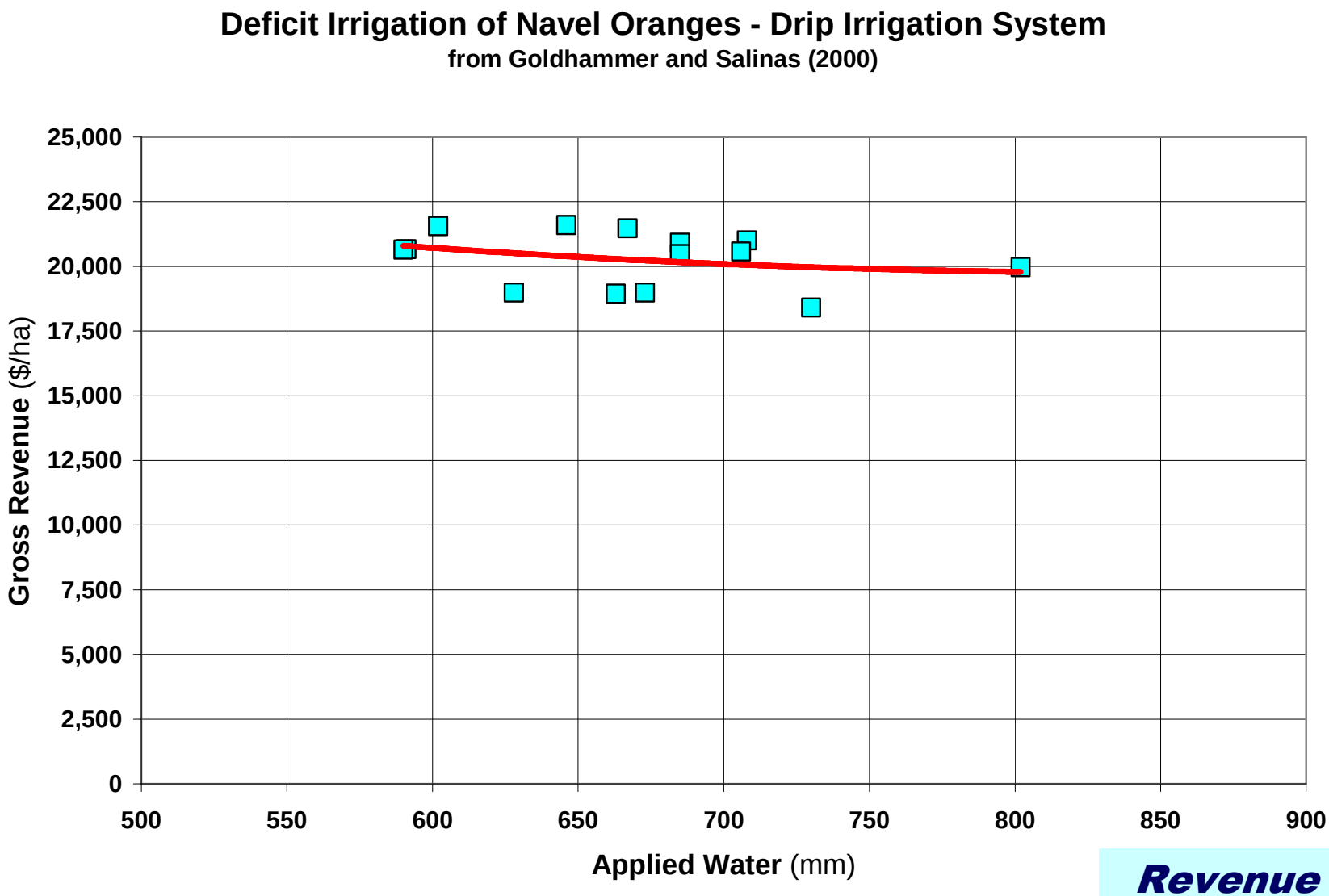
30% Irrigation
48% Yield

Deficit Irrigation – Navel Oranges - Drip



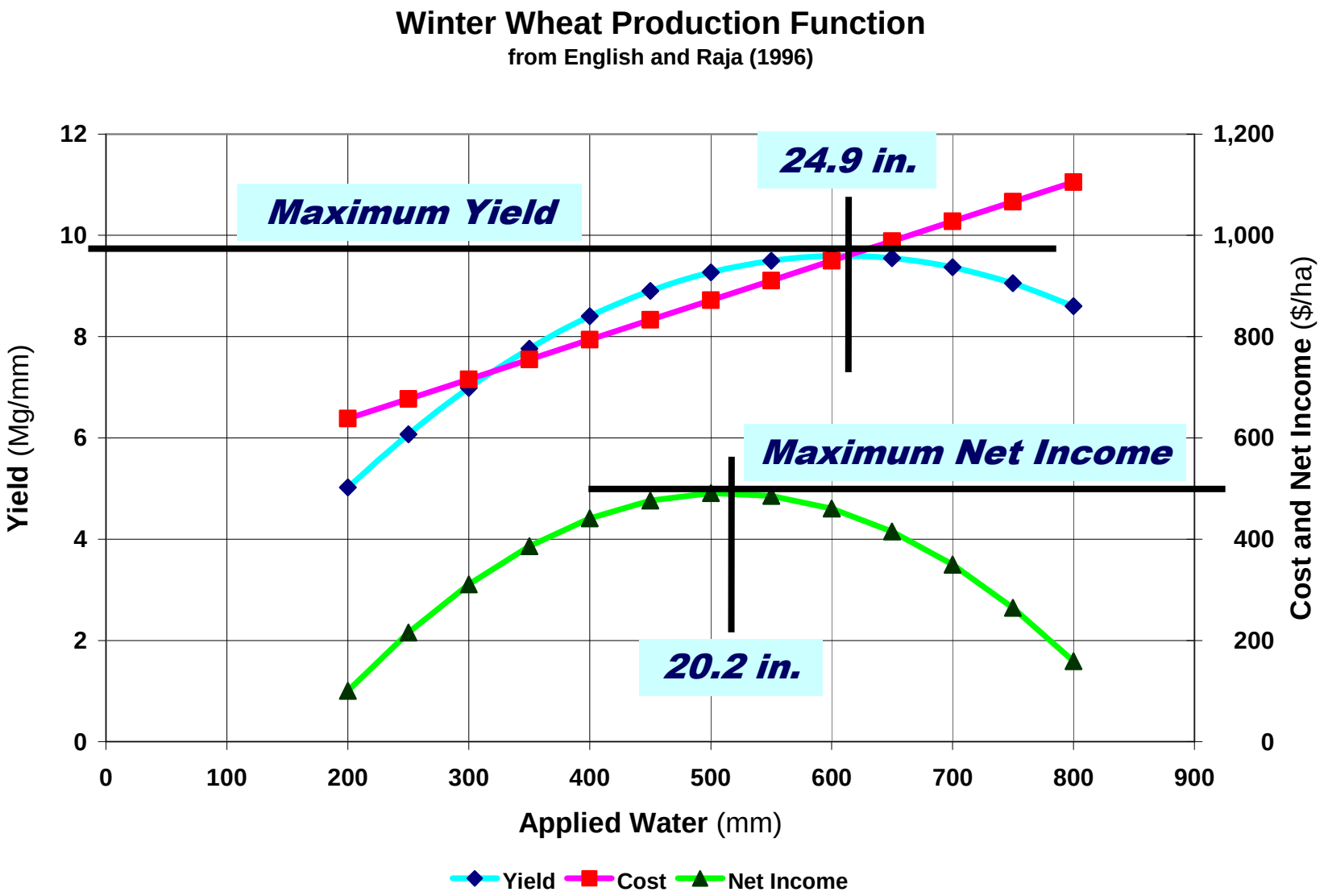
Yield

Deficit Irrigation – Navel Oranges - Drip



Revenue

Winter Wheat Crop Production Function



"No Cost" Water for Irrigation - Rainfall

- Occurring at "right" time during crop growth cycle
- "Right" intensity to promote infiltration and not runoff
- "Right" depth related to crop water requirement

Potential "Costs" of Irrigation Water

- Energy cost for on-farm pumping / distribution
- Cost of grower's time
- Cost to irrigation district / project for distribution
- Opportunity cost to apply same water to higher valued crop on same farm / irrigation district
- Cost to society for alternative uses of water

Irrigation Management in Fruit Orchards

Example Operating Costs

No ET Deficit **65 % Efficiency**

Input:		Results:	
Overall irrigation efficiency (e_i) =	**0.65**	Operating pressure (psi) =	**30.0**
Pump plus motor efficiency (E_p) =	**0.80**	Miscellaneous head (ft.) =	**40.0**
Power cost (c/kWh) =	**6.00**	Total head (ft.) =	**109.2**

Crop	ET_c (in.)	Irr_{req} (in.)	I_g (in.)	Area (acre)	Volume (acre ft.)	Hours of Operation	Power (kW)	Power (kWh)	Cost ($)
Sweet Corn	19.10	14.58	22.43	125.0	233.7	1,300	25	32,658	1,959
Onions	20.16	15.00	23.08	125.0	240.4	1,400	24	33,599	2,016
Peas	10.95	3.83	5.89	125.0	61.4	1,000	9	8,579	515
Potatoes	22.56	16.03	24.66	125.0	256.9	1,500	24	35,906	2,154
Tomatoes	16.57	12.16	18.71	125.0	194.9	1,200	23	27,238	1,634
Total				**625.0**	**987.2**				**8,279**

Terms

ET_c = crop evapotranspiration (water use) (in.)

Irr_{req} = net irrigation requirement (in.)

I_g = gross irrigation requirement (in.)

P = power (kW)

Q = pump discharge (m^3/s)

E_p = pump plus motor efficiency (fraction)

H = total head (m)

Formulas

$$Irr_{req} = ET_c - Precip$$

$$I_g = \frac{Irr_{req}}{e_i}$$

$$P = \frac{Q(H)}{0.102(E_p)}$$

Example Operating Costs

No ET Deficit **75 % Efficiency**

Input:

Overall irrigation efficiency (e_i) = **0.75**

Pump plus motor efficiency (E_p) = **0.80**

Power cost (c/kWh) = **6.00**

Results:

Operating pressure (psi) = **30.0**

Miscellaneous head (ft.) = **40.0**

Total head (ft.) = **109.2**

Crop	ET_c (in.)	Irr_{req} (in.)	I_g (in.)	Area (acre)	Volume (acre ft.)	Hours of Operation	Power (kW)	Power (kWh)	Cost ($)
Sweet Corn	19.10	14.58	19.44	125.0	202.5	1,300	22	28,304	1,698
Onions	20.16	15.00	20.00	125.0	208.3	1,400	21	29,119	1,747
Peas	10.95	3.83	5.11	125.0	53.2	1,000	7	7,435	446
Potatoes	22.56	16.03	21.37	125.0	222.6	1,500	21	31,119	1,867
Tomatoes	16.57	12.16	16.21	125.0	168.9	1,200	20	23,606	1,416
Total				**625.0**	**855.6**				**7,175**

Terms

ET_c = crop evapotranspiration (water use) (in.)

Irr_{req} = net irrigation requirement (in.)

I_g = gross irrigation requirement (in.)

P = power (kW)

Q = pump discharge (m^3/s)

E_p = pump plus motor efficiency (fraction)

H = total head (m)

Formulas

$$Irr_{req} = ET_c - Precip$$

$$I_g = \frac{Irr_{req}}{e_i}$$

$$P = \frac{Q(H)}{0.102(E_p)}$$

Example Operating Costs

10 % ET Deficit 65 % Efficiency

Input:

Overall irrigation efficiency (e_i) = **0.65**

Pump plus motor efficiency (E_p) = **0.80**

Power cost (c/kWh) = **6.00**

Results:

Operating pressure (psi) = **30.0**

Miscellaneous head (ft.) = **40.0**

Total head (ft.) = **109.2**

Crop	ET_c (in.)	Irr_{req} (in.)	I_g (in.)	Area (acre)	Volume (acre ft.)	Hours of Operation	Power (kW)	Power (kWh)	Cost ($)
Sweet Corn	17.19	12.67	19.49	125.0	203.0	1,300	22	28,380	1,703
Onions	18.14	12.98	19.98	125.0	208.1	1,400	21	29,083	1,745
Peas	9.86	2.74	4.21	125.0	43.8	1,000	6	6,126	368
Potatoes	20.30	13.77	21.19	125.0	220.7	1,500	21	30,853	1,851
Tomatoes	14.91	10.50	16.16	125.0	168.3	1,200	20	23,526	1,412
Total				**625.0**	**844.0**				**7,078**

Terms

ET_c = crop evapotranspiration (water use) (in.)

Irr_{req} = net irrigation requirement (in.)

I_g = gross irrigation requirement (in.)

P = power (kW)

Q = pump discharge (m^3/s)

E_p = pump plus motor efficiency (fraction)

H = total head (m)

Formulas

$$Irr_{req} = ET_c - Precip$$

$$I_g = \frac{Irr_{req}}{e_i}$$

$$P = \frac{Q(H)}{0.102(E_p)}$$

Example Operating Costs

10 % ET Deficit 75 % Efficiency

Input:

Overall irrigation efficiency (e_i) = **0.75**

Pump plus motor efficiency (E_p) = **0.80**

Power cost (c/kWh) = **6.00**

Results:

Operating pressure (psi) = **30.0**

Miscellaneous head (ft.) = **40.0**

Total head (ft.) = **109.2**

Crop	ET_c (in.)	Irr_{req} (in.)	I_g (in.)	Area (acre)	Volume (acre ft.)	Hours of Operation	Power (kW)	Power (kWh)	Cost ($)
Sweet Corn	17.19	12.67	16.89	125.0	176.0	1,300	19	24,596	1,476
Onions	18.14	12.98	17.31	125.0	180.3	1,400	18	25,206	1,512
Peas	9.86	2.74	3.65	125.0	38.0	1,000	5	5,309	319
Potatoes	20.30	13.77	18.37	125.0	191.3	1,500	18	26,739	1,604
Tomatoes	14.91	10.50	14.00	125.0	145.9	1,200	17	20,389	1,223
Total				**625.0**	**731.5**				**6,134**

Terms

ET_c = crop evapotranspiration (water use) (in.)

Irr_{req} = net irrigation requirement (in.)

I_g = gross irrigation requirement (in.)

P = power (kW)

Q = pump discharge (m^3/s)

E_p = pump plus motor efficiency (fraction)

H = total head (m)

Formulas

$$Irr_{req} = ET_c - Precip$$

$$I_g = \frac{Irr_{req}}{e_i}$$

$$P = \frac{Q(H)}{0.102(E_p)}$$

Surface Irrigation Simulation – Definition of Terms

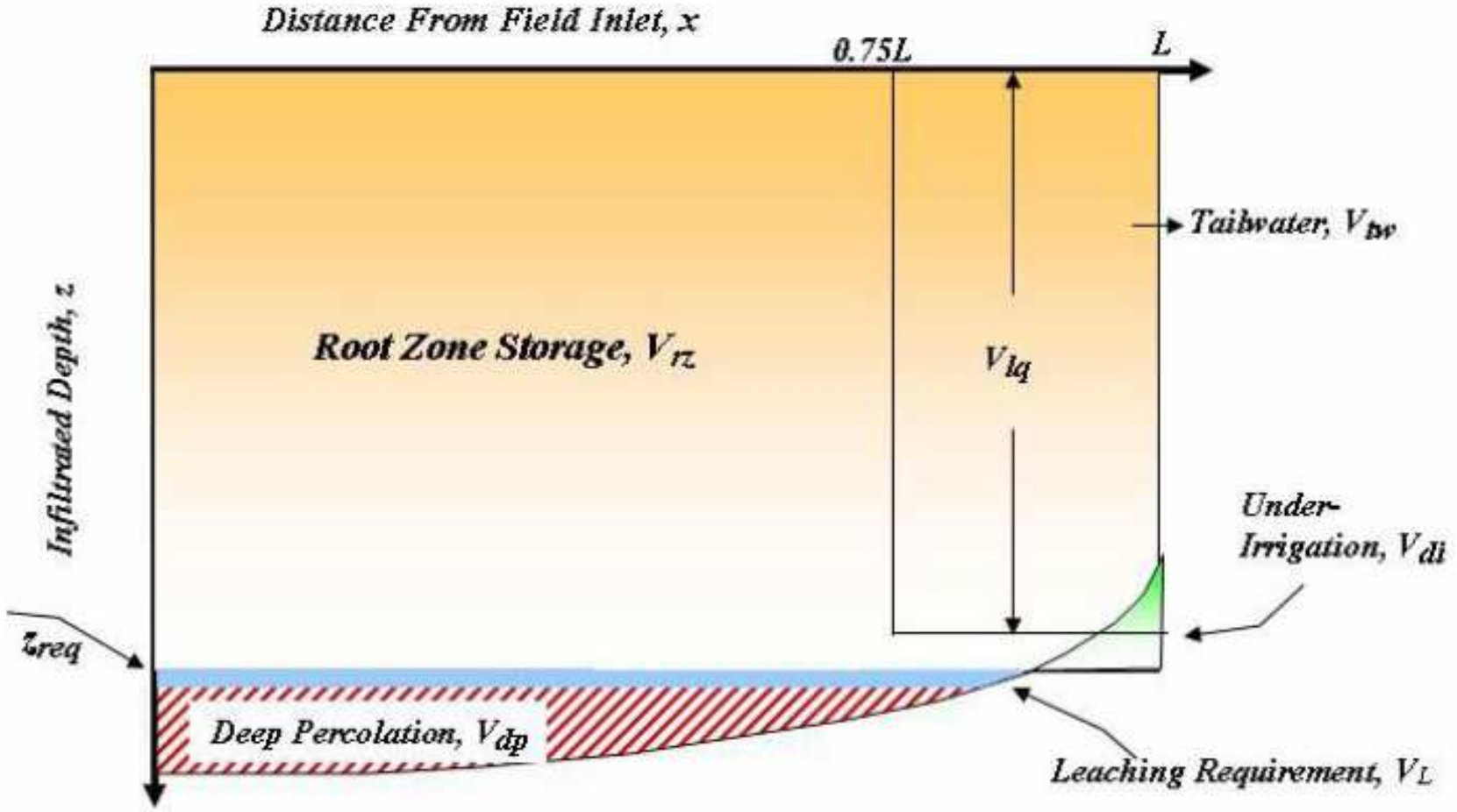


Figure 2.8. Components of infiltrated water under surface irrigation.

Surface Irrigation Simulation – Definition of Terms

Distribution Uniformity, DU

Merriam and Keller (1978) proposed that ***distribution uniformity*** be defined as the average infiltrated depth in the low quarter of the field divided by the average depth infiltrated over the whole field.

$$DU = \frac{V_{lq}}{(V_{rz} + V_{dp})}$$

where V_{lq} = volume delivered to the low quarter

V_{rz} = volume delivered to the root zone

V_{dp} = volume of deep percolation

Irrigation Efficiency, E_i

Fraction of total water applied to field that is beneficially used.

$$E_i = \frac{V_{rz} + V_L}{V_{in}} = \frac{V_{rz} + V_L}{V_{rz} + V_{dp} + V_{tw}}$$

where V_L = volume of leaching requirement

V_{in} = total volume applied to the field

V_{tw} = volume that flows off the field as tailwater

Surface Irrigation Simulation – Definition of Terms

Application Efficiency, E_a

Fraction of total water applied that goes to the root zone,

$$E_a = \frac{V_{rz}}{V_{in}} = \frac{V_{rz}}{V_{rz} + V_{dp} + V_{tw}}$$

Water Requirement Efficiency, E_r

Fraction of water applied that goes to the root zone compared to total crop water requirement for the field,

$$E_r = \frac{V_{rz}}{V_{RZ}} = \frac{V_{rz}}{z \cdot W \cdot L}$$

where V_{RZ} = total volume of crop water requirement for the field

z = depth of crop water requirement (i.e. soil moisture deficit)

W = field width

L = field length

Surface Irrigation Simulation – Definition of Terms

Deep Percolation Ratio, DPR

Fraction of total water applied that goes to deep percolation,

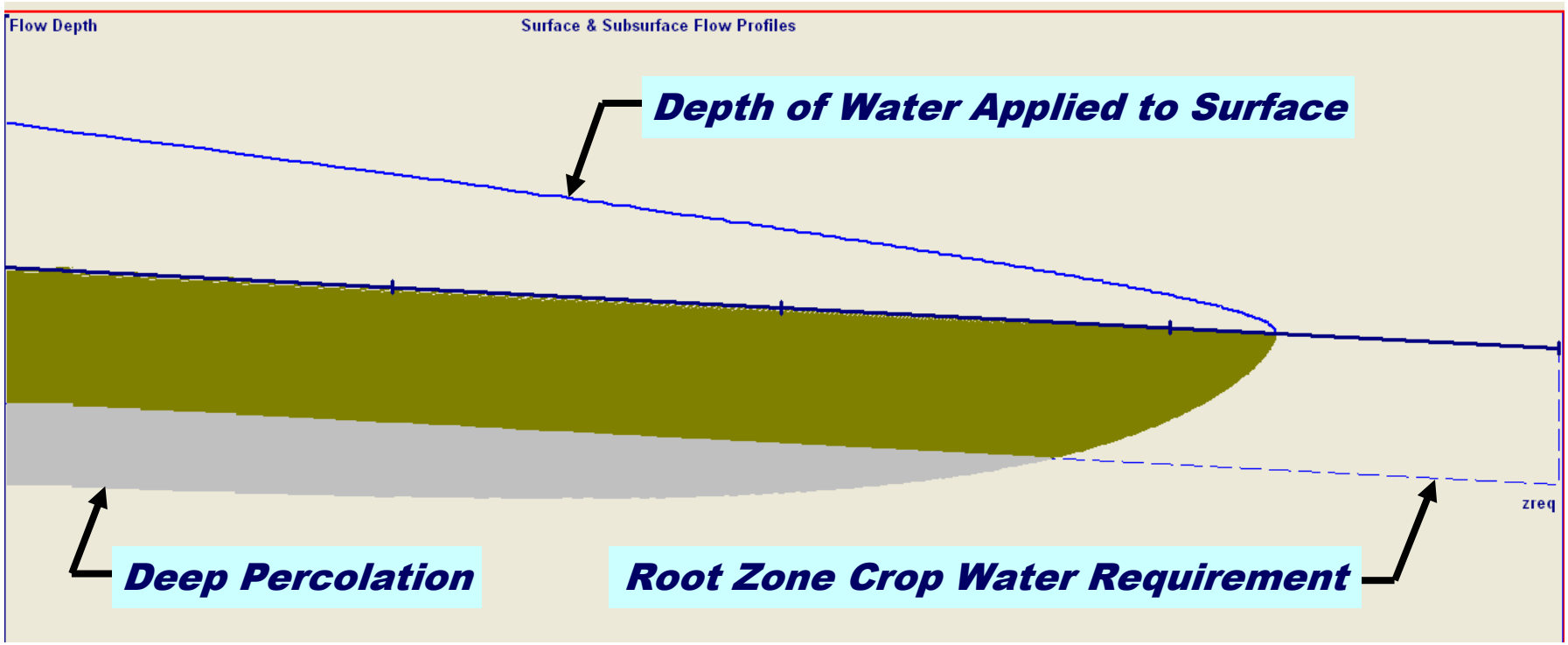
$$DPR = \frac{V_{dp}}{V_{in}} = \frac{V_{dp}}{V_{rz} + V_{dp} + V_{tw}}$$

Tailwater Ratio, TWR

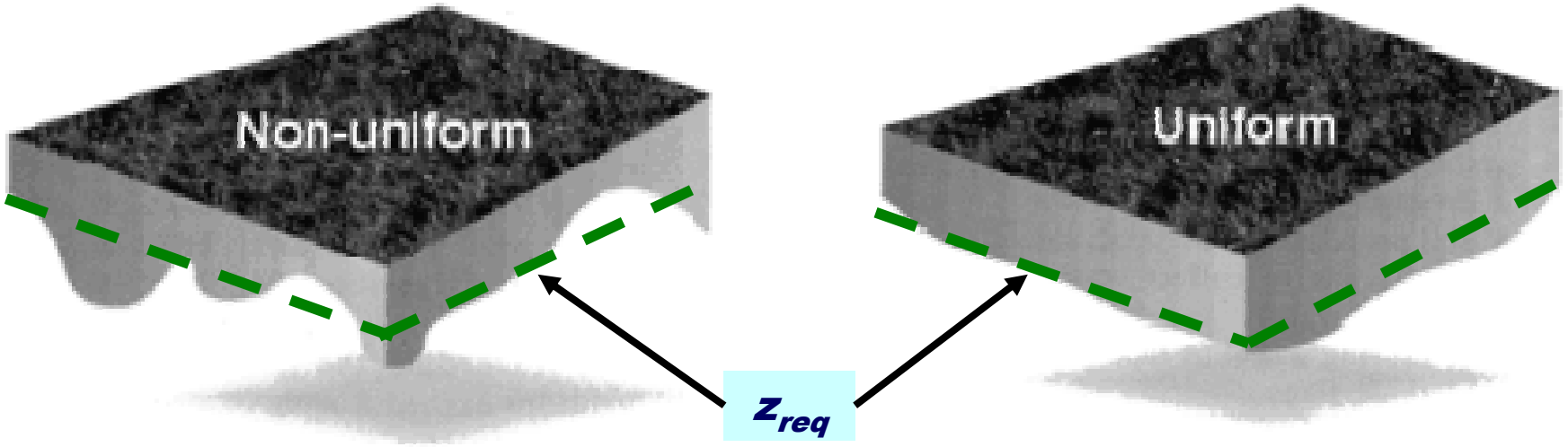
Fraction of total water applied that goes to tailwater,

$$TWR = \frac{V_{tw}}{V_{in}} = \frac{V_{tw}}{V_{rz} + V_{dp} + V_{tw}}$$

Surface Irrigation Simulation



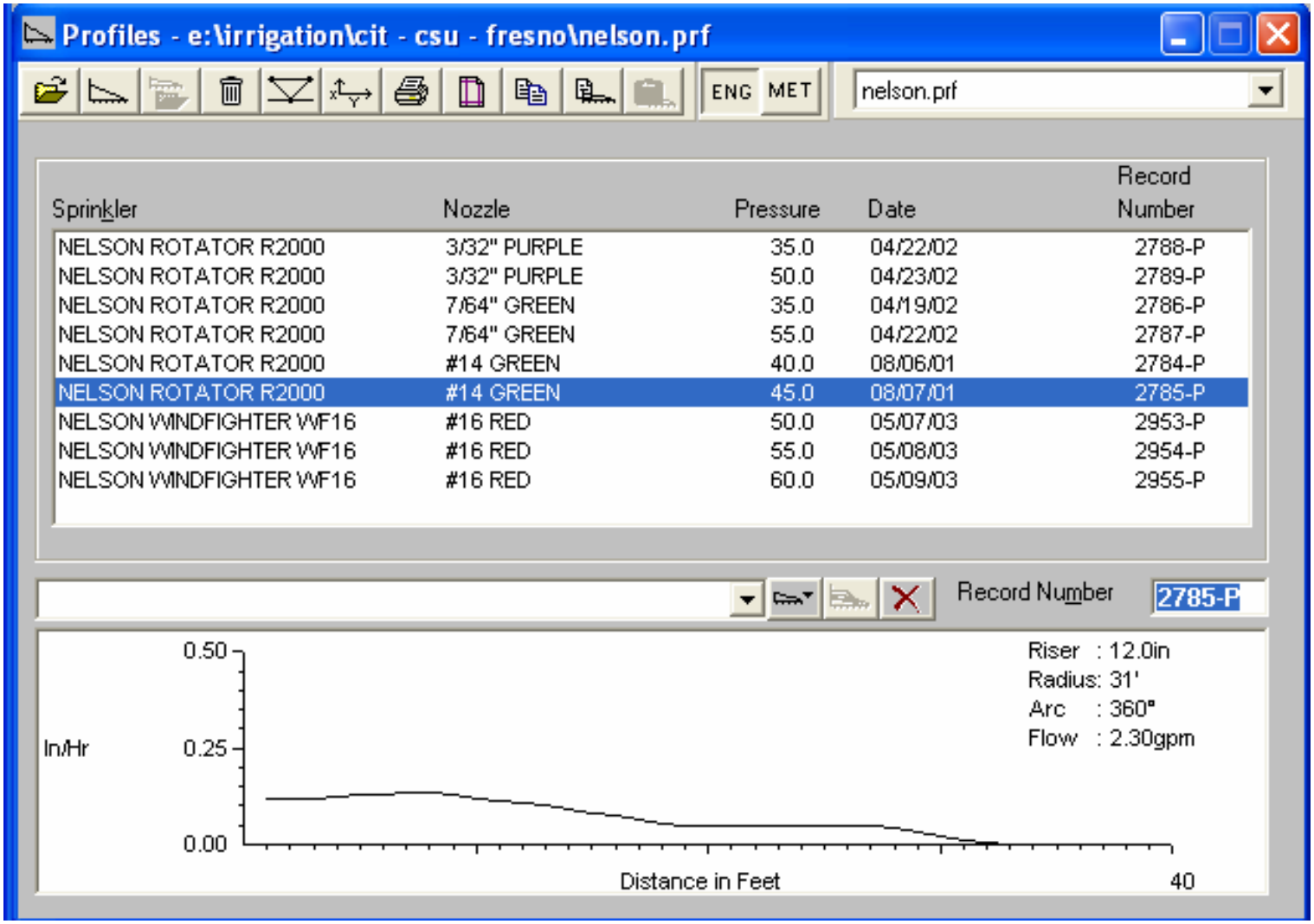
Sprinkler Nozzle Evaluation – Center for Irrigation Technology



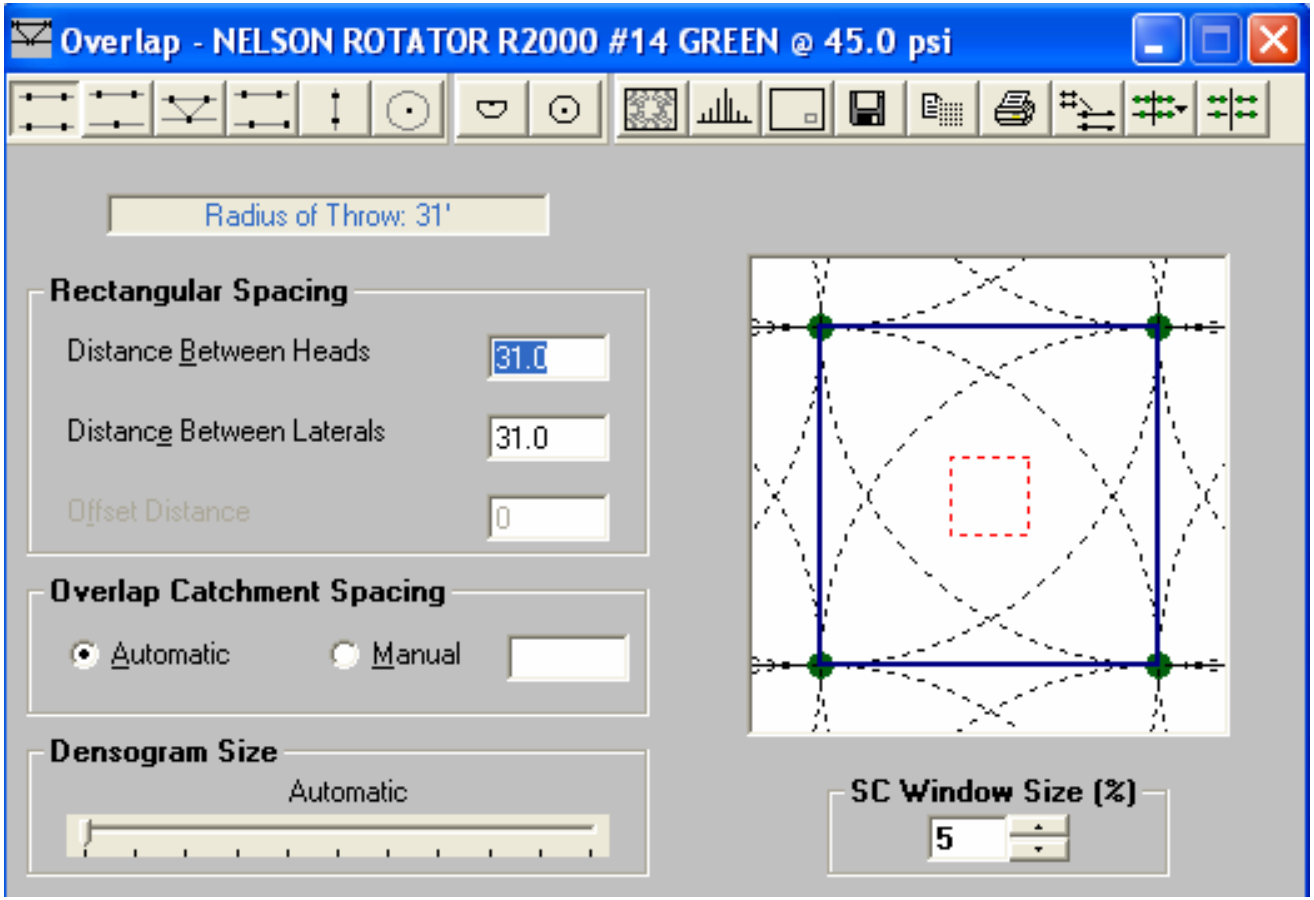
Underirrigation and Deep Percolation due to Non-Uniform Application Pattern

Reduced Underirrigation and Deep Percolation due to Uniform Application Pattern

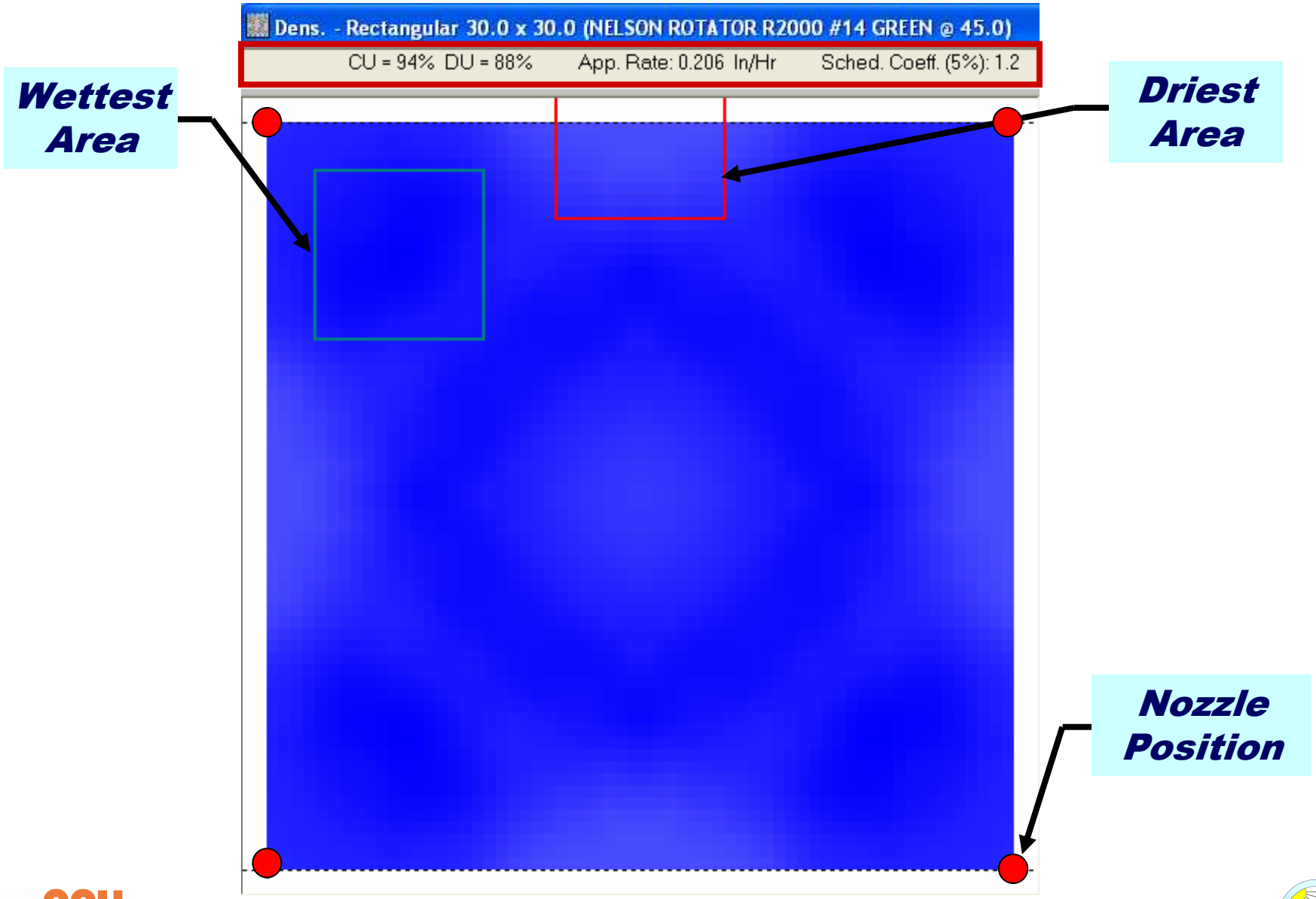
Sprinkler Nozzle Evaluation – Profile Data (CIT Database)



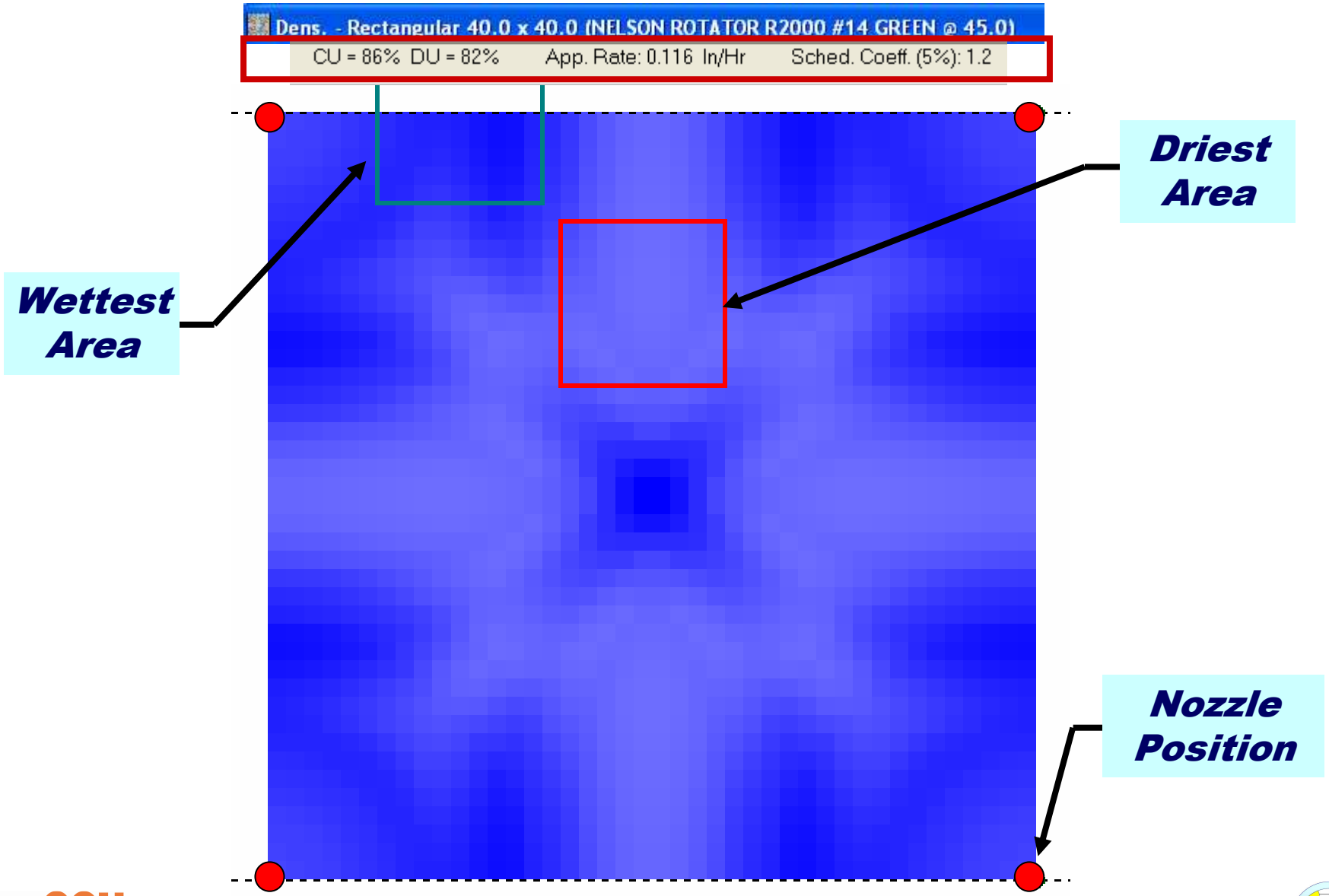
Sprinkler Nozzle Evaluation – Automatic Spacing: 31 ft by 31 ft



Sprinkler Nozzle Evaluation – Application Pattern: 30 ft by 30 ft



Sprinkler Nozzle Evaluation – Application Pattern: 40 ft by 40 ft



Sprinkler Nozzle Evaluation – Application Pattern: 40 ft by 60 ft