Basic Irrigation Scheduling Tools & Irrigation System Evaluation

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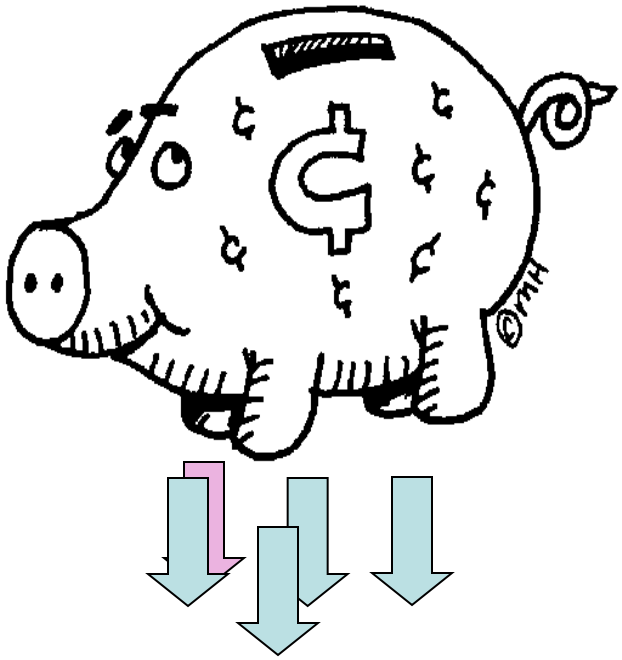
http://msue.anr.msu.edu/resources/irrigation

https://engineering.purdue.edu/ABE/Engagement/Irrigation

Irrigation Scheduling
Think of your soil as a bank

Water holding capacity:
The soil (bank) can hold only a given volume of water before it allows it to pass lower down.

Soil type :
Heavier soil can hold more water / foot of depth than light soils



Intake rate:
Water applied faster than the soil intake rate is lost.

Rooting depth:
The plant can only get water to the depth of it's roots.

Deletion:
Plants can pull out only 30 - 60% of the water

Water lost from the bottom of the profile can wash out (leach) water soluble nutrients and pesticides.

Irrigation Scheduling

- Method to determine the appropriate amount of water to be applied to a crop at the correct time to achieve healthy plants and conserve water

- Can measure soil moisture

Or

- estimate evapotranspiration (ET) using weather data

Calculating Water Holding Capacity

Soil Name	Depth Inches	Available water holding capacity	Average Available water holding capacity	Ave. Available water holding capacity (24 in.)	Ave. Available water holding capacity (36 in.)
Oshtemo	0 - 14 14 – 35 35 - 60	0.10 – 0.15 0.12 – 0.19 0.06 – 0.10	0.125 0.155 0.08	14” x 0.125=1.75 10” x 0.155=1.55 ---------- = 3.3	14” x 0.125= 1.75 21” x 0.155= 3.26 1” x 0.08 = 0.08 ---------- = 5.09
Spinks	0 – 10 10 – 26 26 - 60	0.08 – 0.10 0.08 – 0.10 0.04 – 0.08	0.09 0.09 0.06	10” x 0.09= 0.9 14” x 0.09= 1.26 ---------- = 2.16	10” x 0.09= 0.9 16” x 0.09= 1.26 8” x 0.06= 0.48 ---------- = 2.64

Available Water Holding Capacity

Soil Type / depth	Bronson	Capac	Oshtemo	Spinks
0”to 6” 0”to 6”	.84” .84”	1.2” 1.2”	.75” .75”	.54” .54”
6”to 12” 0”to 12”	.86” 1.70”	1.2” 2.4”	.75” 1.50”	.54” 1.08”
12” to 18” 0”to 18”	.90” 2.60”	.99” 3.39”	.87” 2.37”	.54” 1.62”
18” to 24” 0” to 24”	.90” 3.50”	.99” 4.38”	.93” 3.30”	.54” 2.16”
24” to 30” 0” to 30”	.58” 4.80”	.99” 5.37”	.93” 4.23”	.42” 2.58”
30” to 36” 0”to 36”	.34” 5.14”	.93” 6.30”	.86” 5.06”	.36” 2.94”

Measuring Soil Moisture

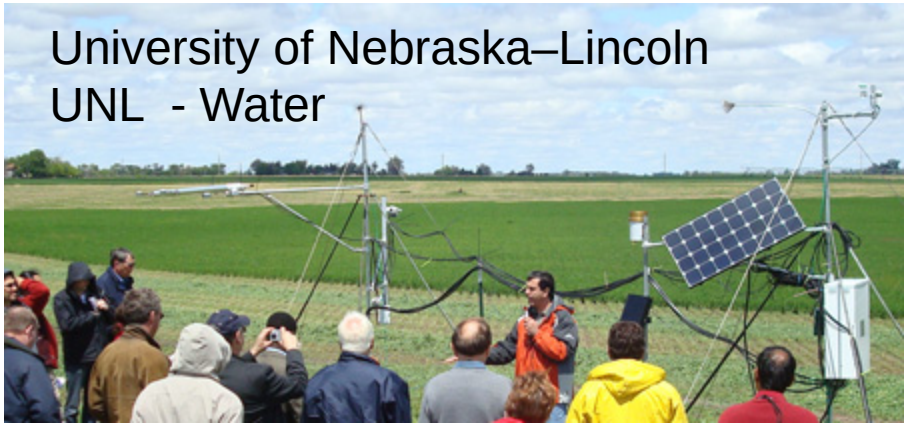
- Tensiometers and Watermarks Measure soil tension - centibars

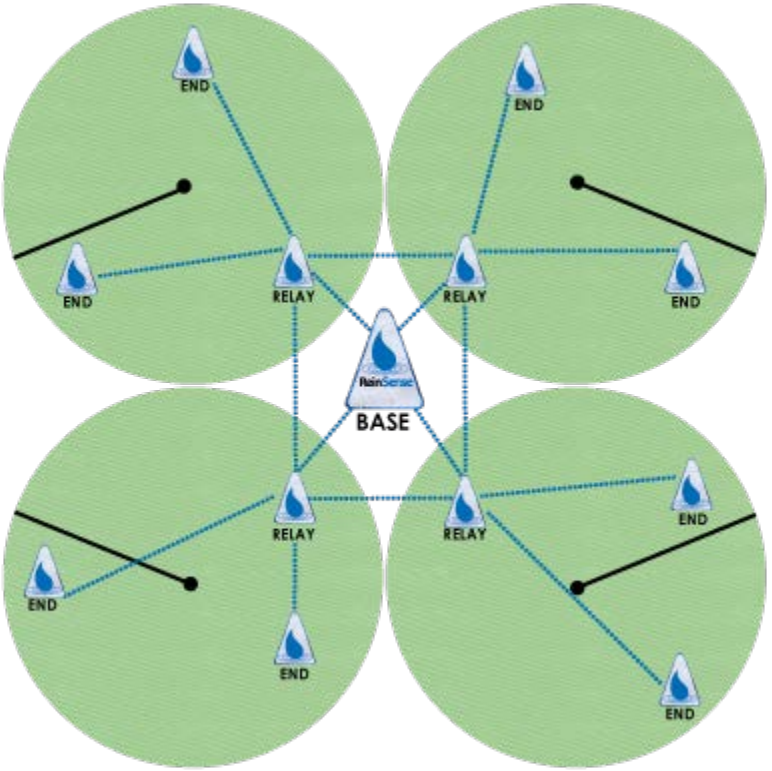
Volumetric Probes TDR

- FDR
- Capacitance Probes

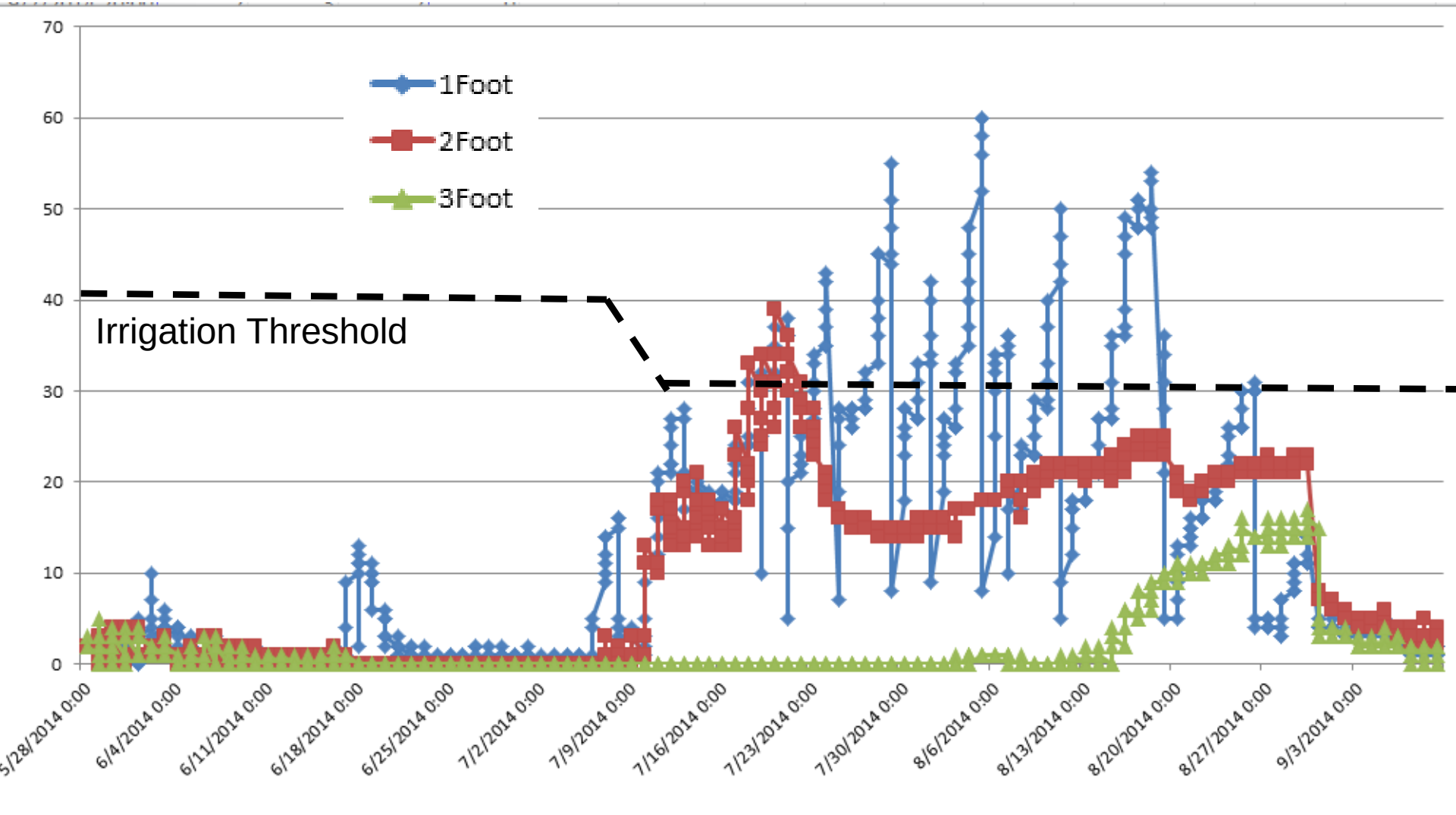
http://water.unl.edu/cropswater/nawmdn

Reinke
MORE RIGHT THAN RAIN





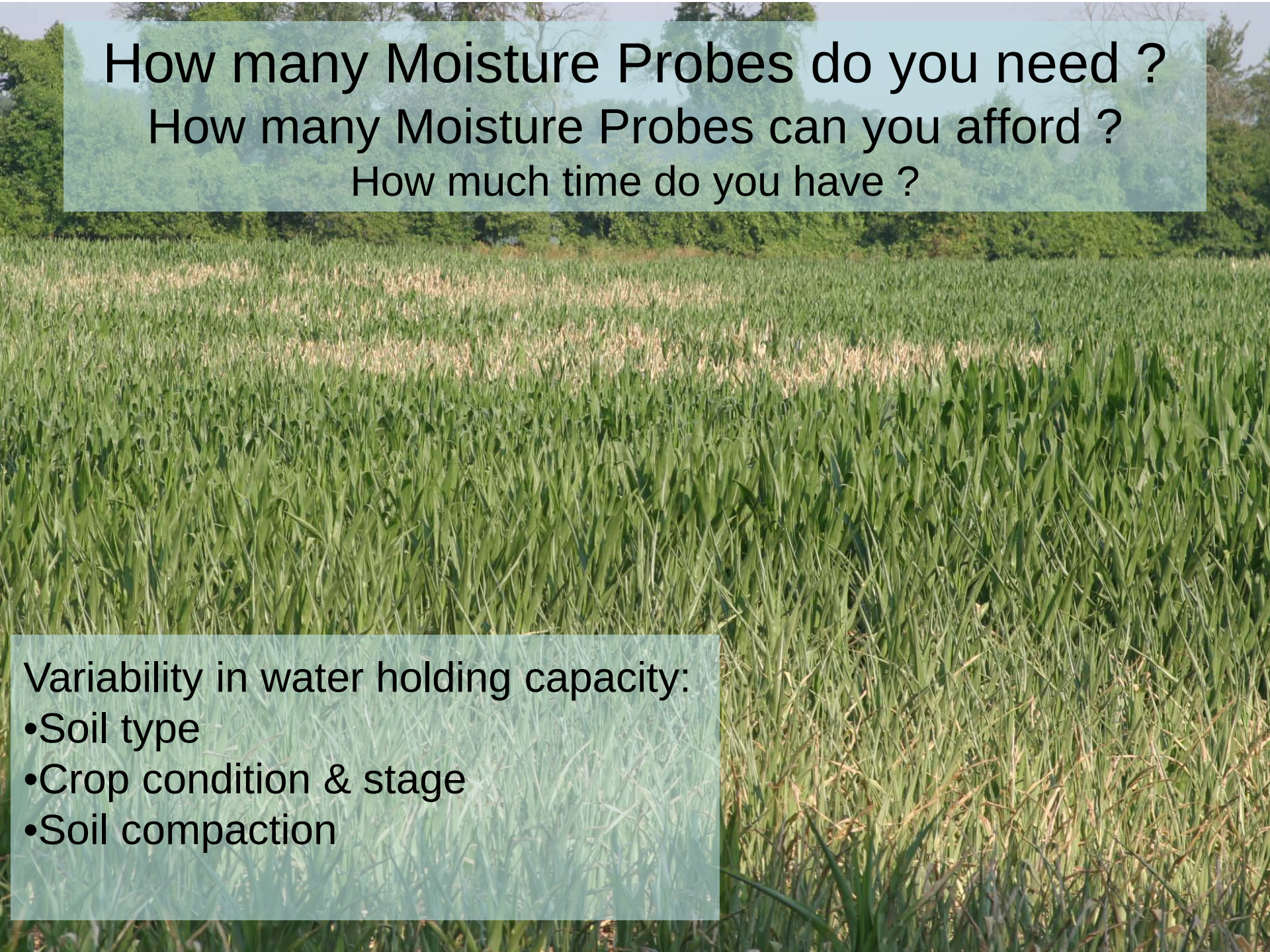
Watermark Soil Moisture, 2014 Soybean, Constantine MI



How many Moisture Probes do you need ?

How many Moisture Probes can you afford ?

How much time do you have ?



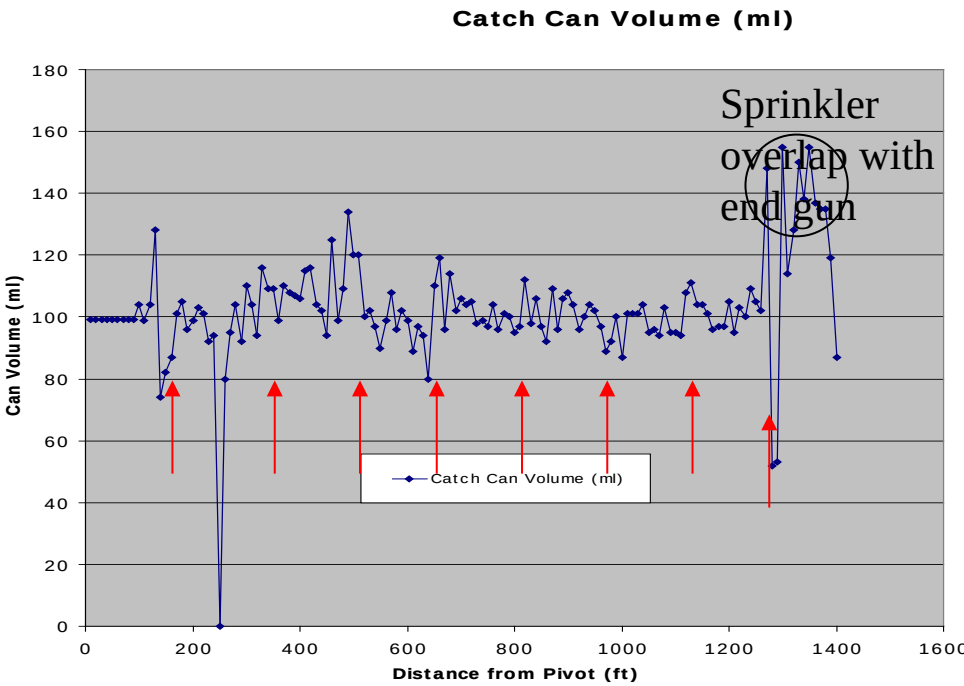
Variability in water holding capacity:

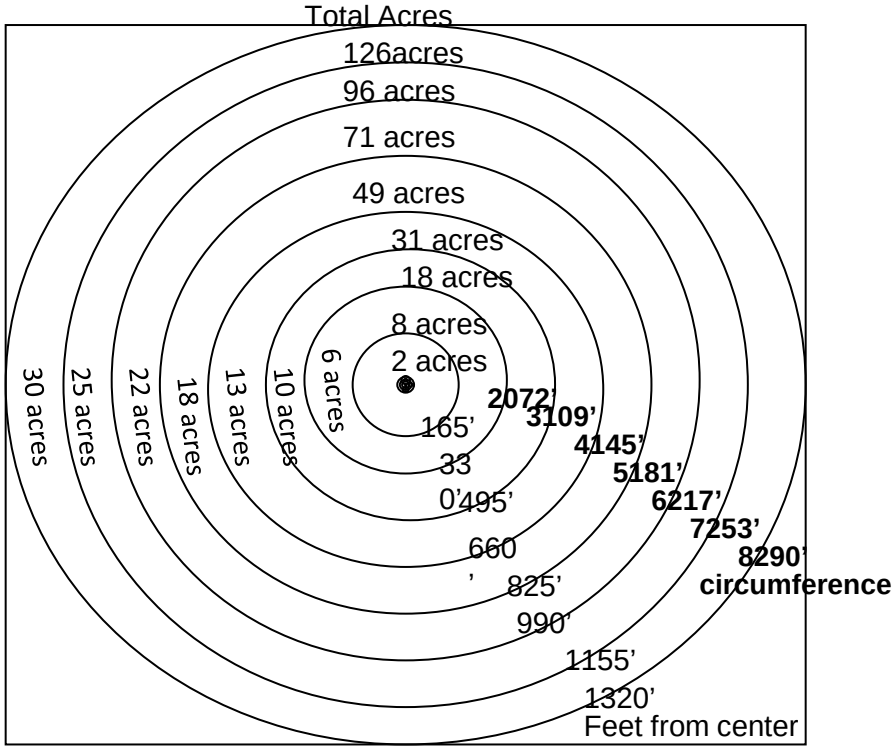
- Soil type
- Crop condition & stage
- Soil compaction

Moisture Probe Placement

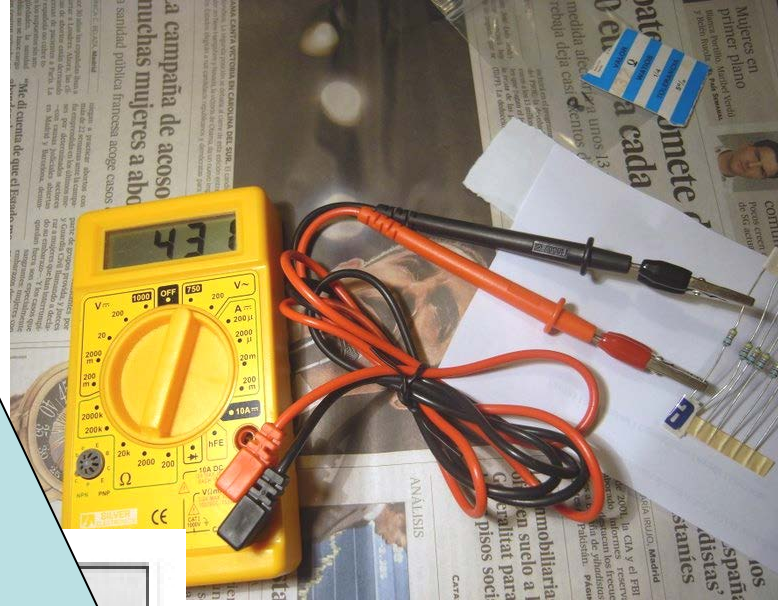
-will it represent the field

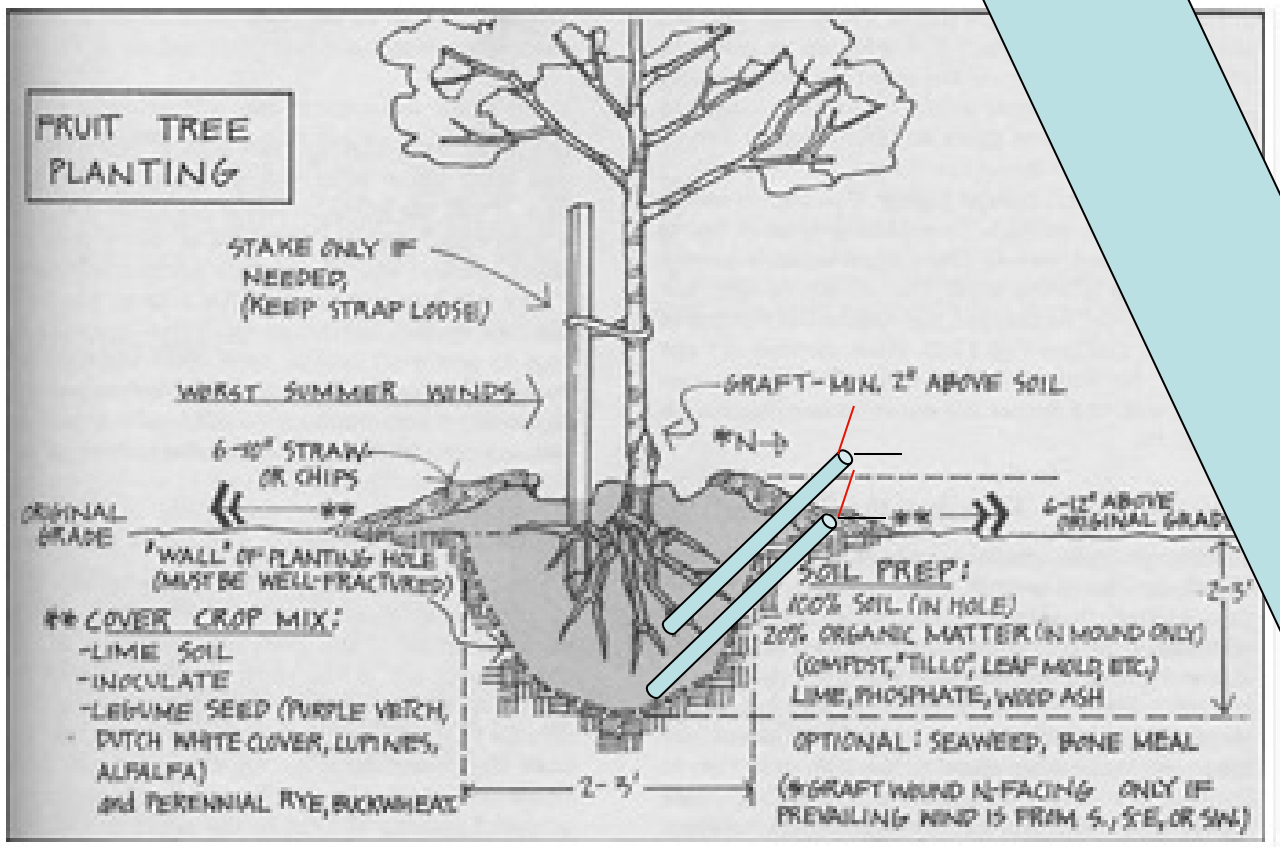
System uniformity





How far down is the irrigation water going ?

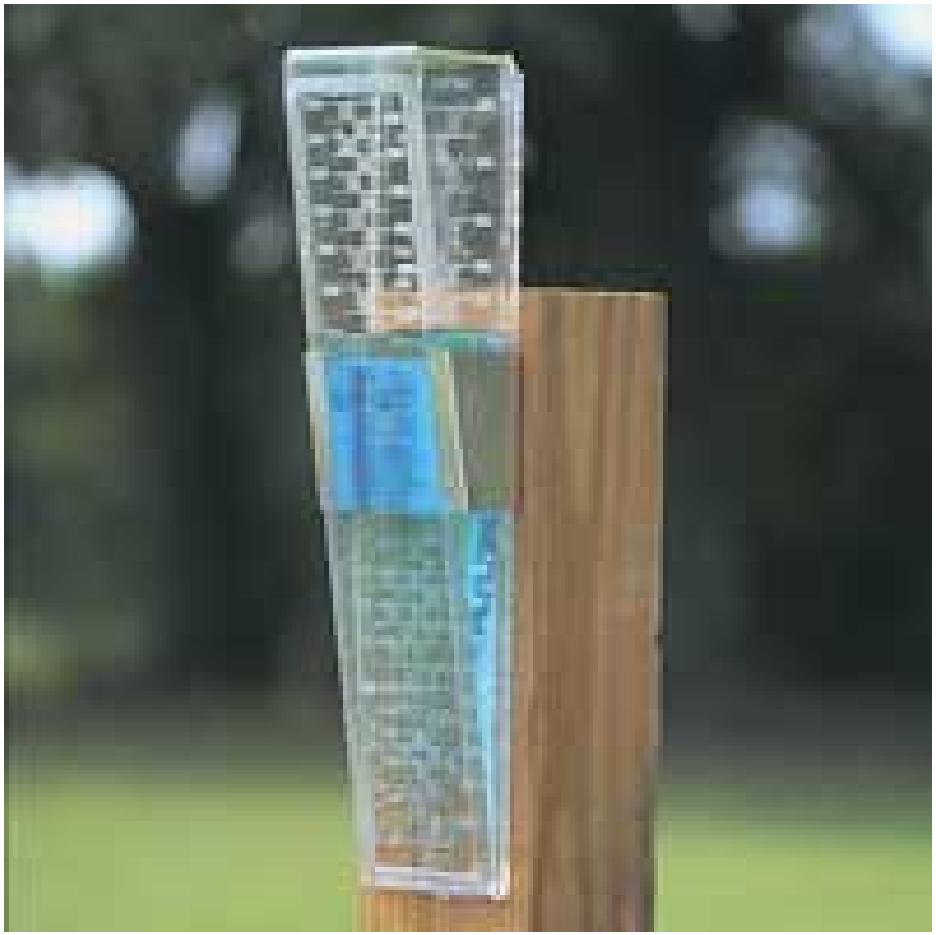




½" PVC pipe and electrical wire capacitance probe

Rain Gauges and data

- Basic unit – 2 inch opening
- Cost less than $10
- One rain gauge for each 80 acres.
- Recording rain gauge cost $50 - $100



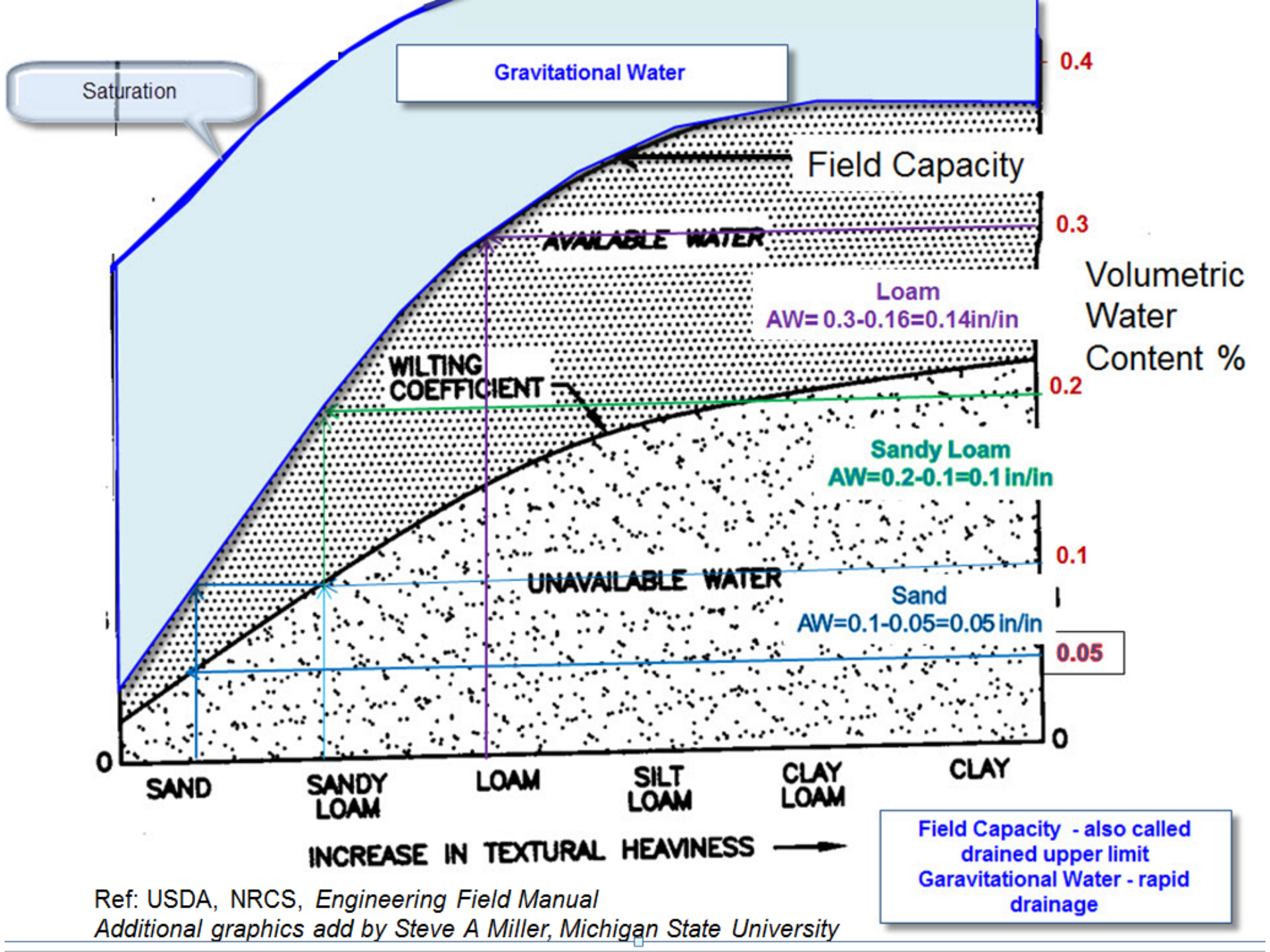
http://www.cocorahs.org/state.aspx?state=in

Determining irrigation requirements

- The plant water requirement includes the water lost by evaporation into the atmosphere from the soil and soil surface

- and by transpiration, which is the amount of water used by the plant.

- The combination of these is **evapotranspiration (ET).**



Ref: USDA, NRCS, *Engineering Field Manual*

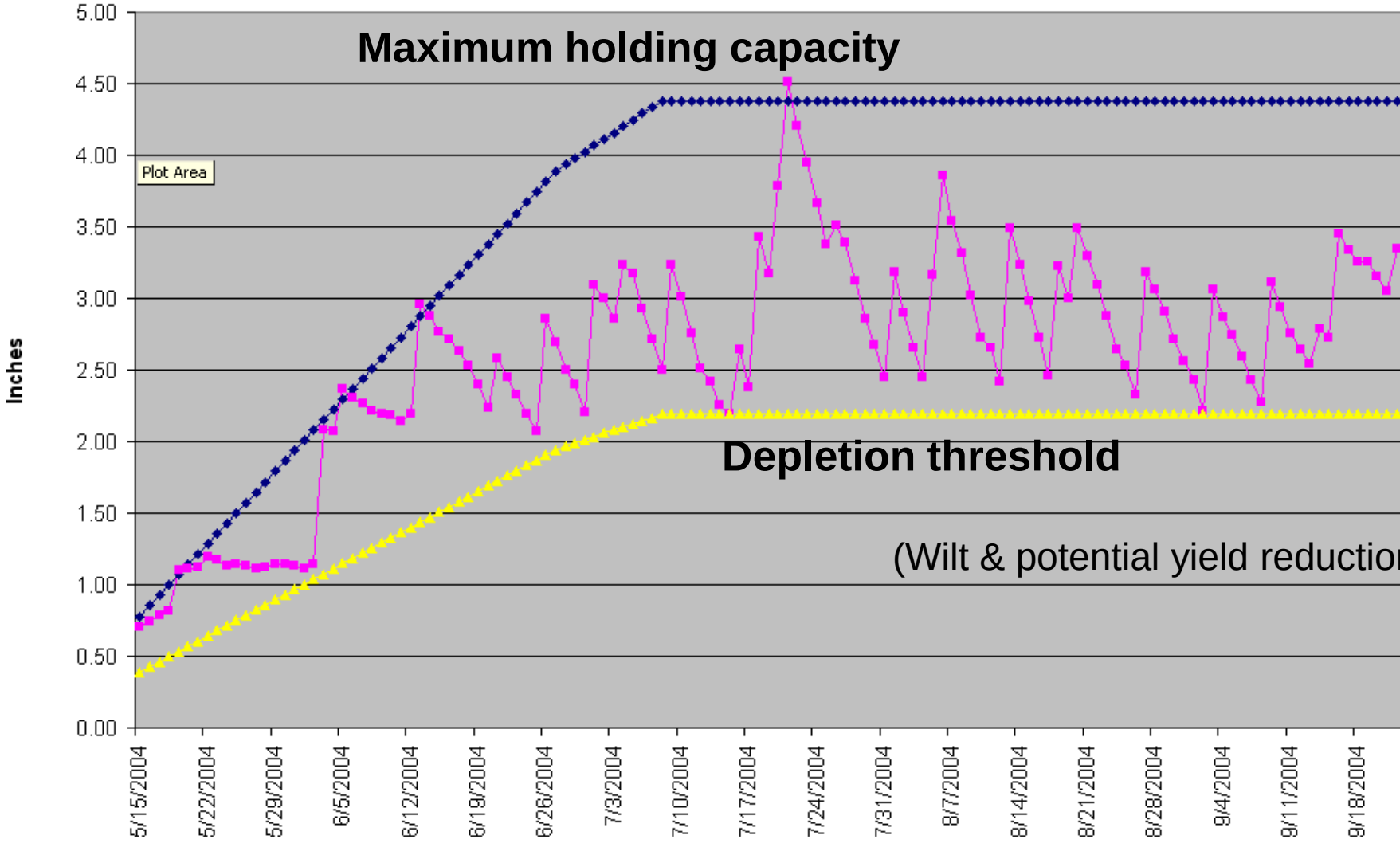
Additional graphics add by Steve A Miller, Michigan State University

Microsoft Excel - Irr_cbook_corn_rev_const

File Edit View Insert Format Tools Chart Window Help

Soil Moisture

(Wasted energy & potential N los



Estimating ET for Different Crops

- Combining a “Crop Coefficient Curve” with the reference ET.
- Crop Curve is a relationship between the specific plants’ growth characteristics and its water use relationship to the **reference crop**.
- Six inch grass used as reference crop.

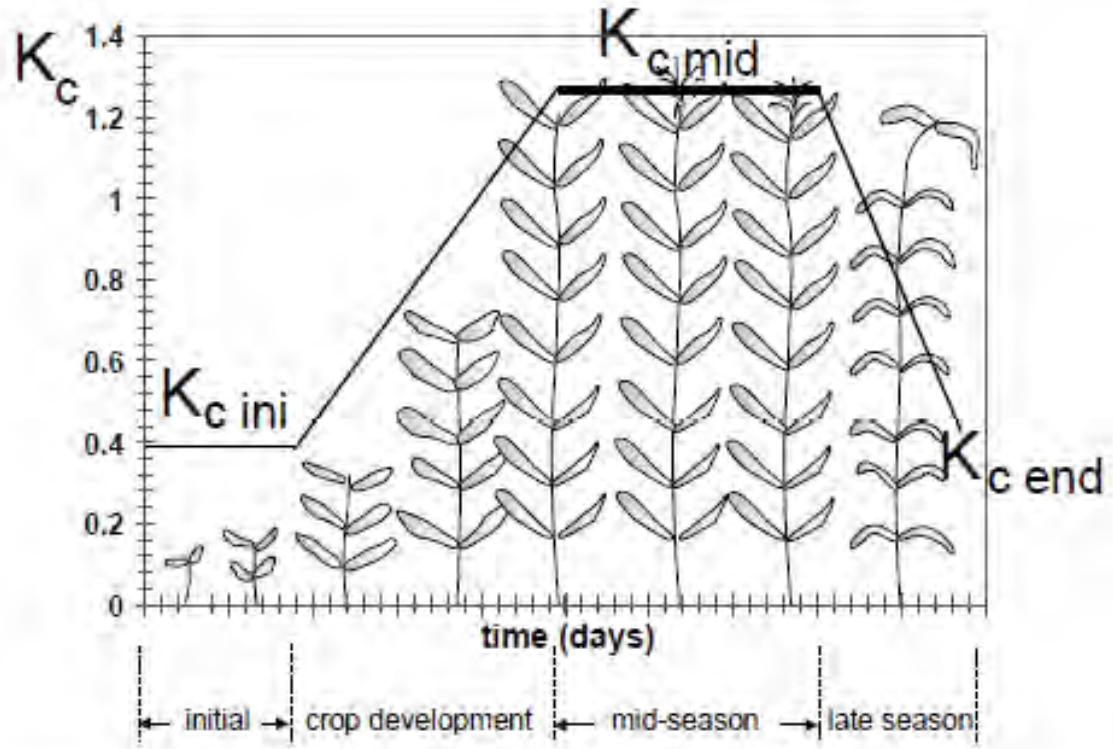
  (Nebraska uses 12” alfalfa reference)

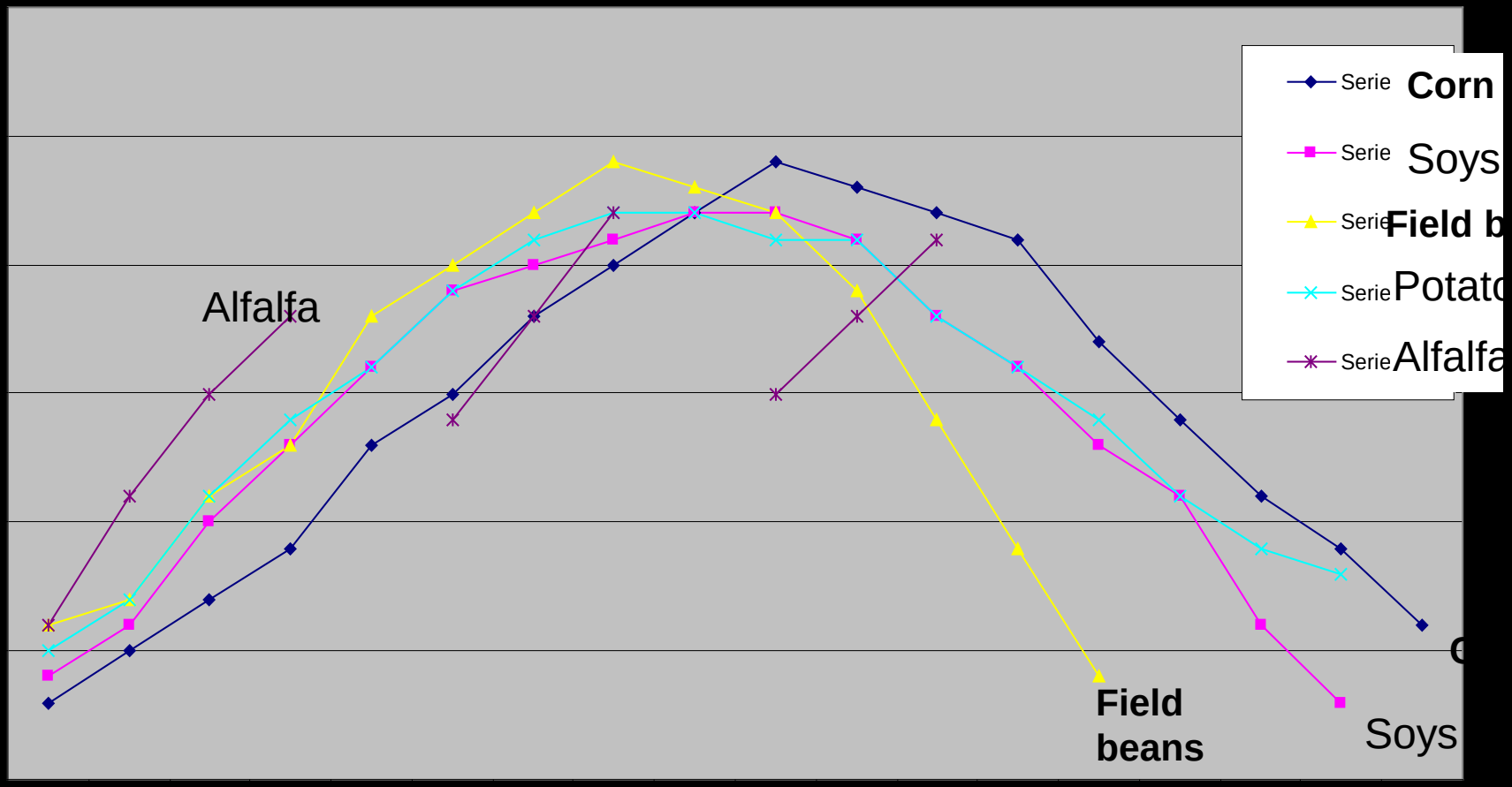
ET gage note:

#30 cover simulates grass reference ET

#54 cover simulates alfalfa reference ET

FIGURE 25
Generalized crop coefficient curve for the single crop coefficient approach





From Minnesota Extension bulletin “Irrigation Scheduling”, assuming temperature 80-89

Do I have enough capacity

- Maximum water use for most crops is .27 - .32 in./day
- 3 gal/minute/acre pump capacity = 1”/week
- 5 gal/minute/acre pump capacity = .25”/day
- 7 gal/minute/acre pump capacity =.33”/day, 1” every 3 days
- 500 gal/minute pump can provide 1” every 4 days on 100 acres

Can you Irrigate every hour you want ?

27/31 =90%

Soybean Water use

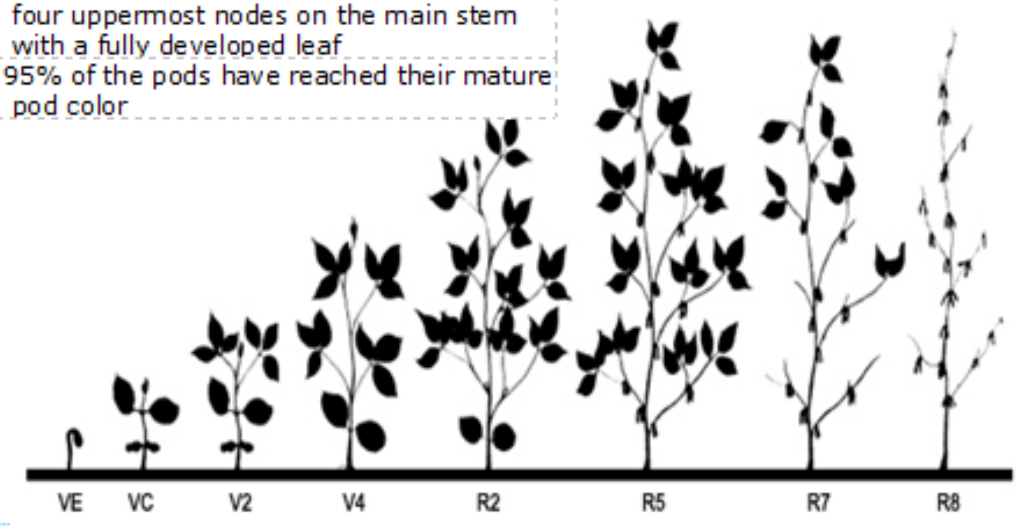
Average water use for Soybeans in inches/day –adapted From " Irrigation Scheduling Checkbook Method, Jerry Wright, University of Minnesota, 2002

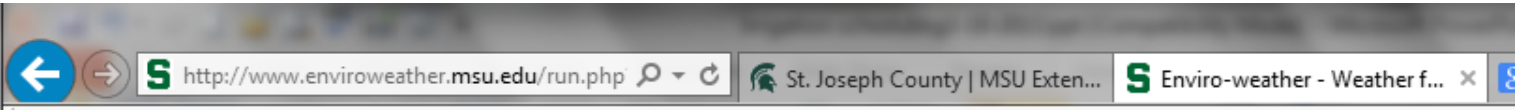
	Week after emergence																
Temperature	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
50-59	02	02	.04	.04	.06	.07	.08	.09	09	09	09	08	.07	.05	.05	.03	.02
60-69	.02	.03	.05	.07	.09	.10	.11	.13	.13	.13	.13	.11	.10	.08	.07	.04	.02
70-79	.03	.05	.07	.09	.12	.13	.15	.17	.18	.18	.17	.15	.13	.10	.09	.05	.03
80-89	.04	.06	.10	.13	.16	.19	.20	.21	.22	.22	.21	.18	.16	.13	.11	.06	.03
90-99	.05	.07	.11	.14	.17	.20	.22	.25	.26	.26	.25	.22	.19	.16	.13	.08	.05
Soybean growth stages				2nd trifoli-ate		1st flower			seed filling			leaves yel-lowing					

Soybean Growth Stages

V2	Unifoliolate and first two trifoliolate leaves are fully developed
V6	Unifoliolate and six trifoliolate leaves are fully developed
R1	Open flower at any node on the main stem
R3	Pod is 5 mm (3/16 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf
R8	95% of the pods have reached their mature pod color

Crop Stage	Crop coeffient Kc	Root Depth (in)	% of Growing Season
V2	0.1	6	0
	0.17	11.14	10
V4	0.27	16.28	20
	0.39	21.43	30
	0.58	24	40
R1	0.74	24	50
	0.89	24	60
R3	1.02	24	70
	0.92	24	80
	0.77	24	90
R8	0.66	24	100





Constantine Potential Evapotranspiration Daily Summary (Report issued 6/30/2014 14:51)

Note that frozen precipitation amounts may not be accurate.

Day	Date	Max Temp (° F)	Min Temp (° F)	Ave Temp (° F)	Rainfall (in.) Today	Rainfall (in.) Since 6/28	Chance of Rain	Reference Potential Evapotranspiration (in.) Daily Total	Reference Potential Evapotranspiration (in.) Since 6/28
Sat	6/28/14	82.7	65.8	74.3	0	0	--	0.12	0.12
Sun	6/29/14	86.3	70.9	78.6	0	0	--	0.17	0.29

Today's data:

Day	Date	Max Temp (° F)	Min Temp (° F)	Ave Temp (° F)	Rainfall (in.) Today	Rainfall (in.) Since 6/28	Chance of Rain	Reference Potential Evapotranspiration (in.) Daily Total	Reference Potential Evapotranspiration (in.) Since 6/28
Mon	6/30/14	Forecast: 80	Actual (7:30-7:35AM): 70.6	75.3	0	0	44%	Observed: 0.05 Forecast: 0.13	0.42

Forecast data:

Day	Date	Max Temp (° F)	Min Temp (° F)	Ave Temp (° F)	Rainfall (in.) Today	Rainfall (in.) Since 6/28	Chance of Rain	Reference Potential Evapotranspiration (in.) Daily Total	Reference Potential Evapotranspiration (in.) Since
Tue	7/1/14	82	70	76	--	--	75%	0.2	0.62
Wed	7/2/14	69	60	64.5	--	--	38%	0.11	0.73
Thu	7/3/14	71	51	61	--	--	32%	0.17	0.9
Fri	7/4/14	75	50	62.5	--	--	10%	0.18	1.08
Sat	7/5/14	77	54	65.5	--	--	12%	0.19	1.27
Sun	7/6/14	80	58	69	--	--	19%	0.16	1.43

http://www.enviroweather.msu.edu

Bookmark for easy access or daily text or E-mail sent to you

For example, 120 day Corn36 (a corn variety with an effective rooting depth of 36 inches) and has an emergence date of May 15th, 10% of the growing season is May 27th.

10% of 120 = 12 15 + 12 = 27

Fill in Root Depth

Fill in Canopy Cover

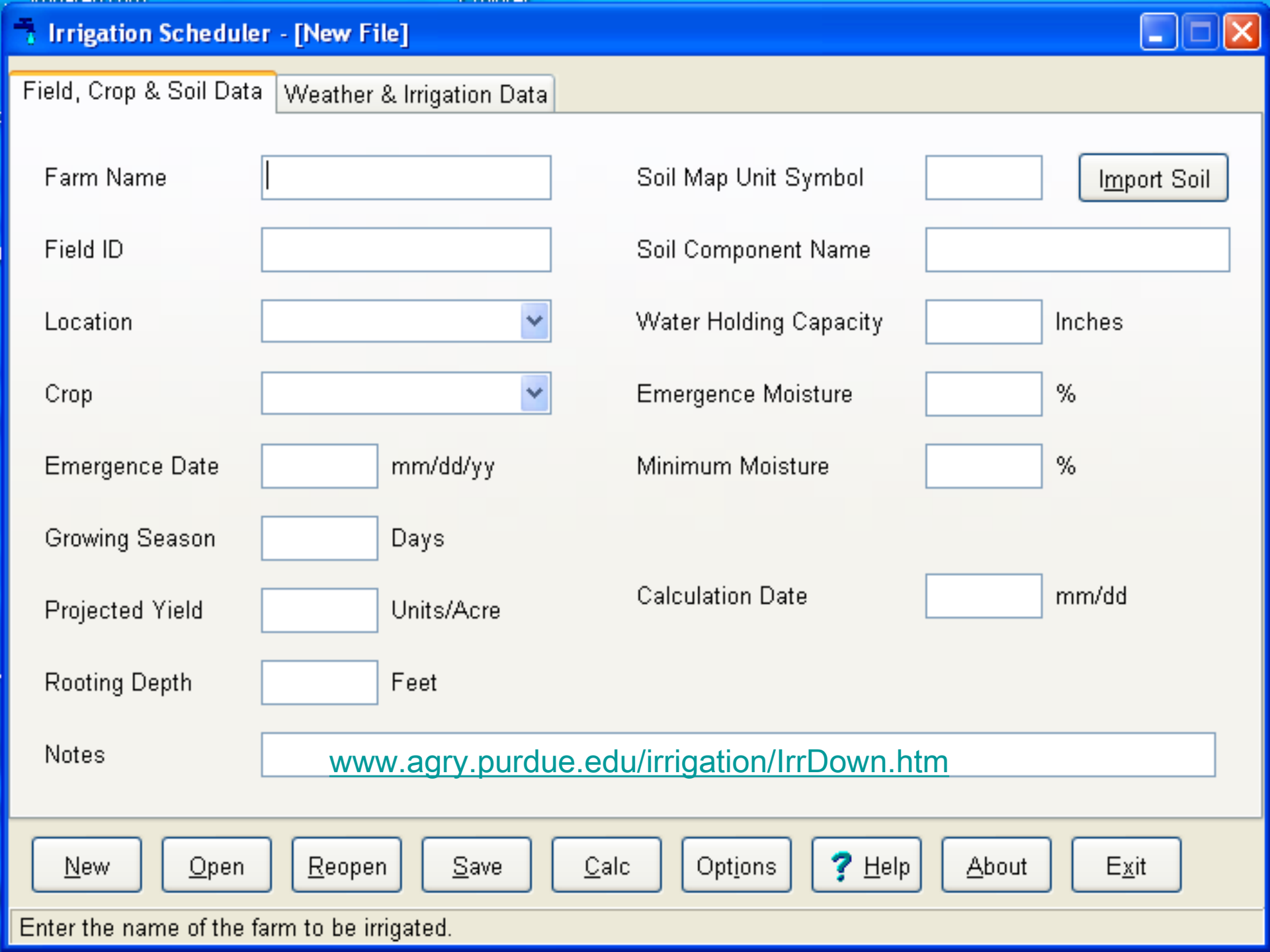
http://www.enviroweather.msu.edu

Available water (AW) holding capacity of soil – (inches water/inch soil). See								
Range (in)	0 - 6	6 - 12	12 - 18	18 - 24	24 - 30	30 - 36	36 - 42	42 - 48
AW (in/in)	0.125	0.125	0.125	0.150	0.084	0.070	0.070	0.030
Capacity filled (%)	60	80	95	95	95	95	95	95

Soil Type (Bronson or Oshtemo)	Oshtemo
Crop (Corn24 or Corn36):	Corn36
Length of Growing Season (days	105
Emergence Date (mm/dd/yyyy):	5/20/2014

Irrigation increment/amount per application (inches)	1	Irrigate at this % of Available Soil Water in Root Zone	60

						Calculated in XLS								
Date	Root Depth (inches)	Rainfall (inches)	Irrigation added (inches)	Potential ET (inches)	% Canopy Cover (Kc)	ET modified for crop (inches)	Capacity of root zone (inches)	Available Water in root zone (inches)	% capacity filled	Drainage (inches)	Additional capacity of root zone	Proj ETO	Proj ET	NOTES
23-Jun	28.67	2.5		0.08	0.66	0.05	3.54	3.65	103	2.27	0.00		0.00	
24-Jun	29.34	0.7		0.09	0.70	0.06	3.60	3.71	103	0.58	0.00		0.00	
25-Jun	30	0.1		0.15	0.74	0.11	3.66	3.73	102	0.00	0.00		0.00	
26-Jun	30.67	0		0.18	0.78	0.14	3.70	3.62	98	0.00	0.08		0.00	
27-Jun	31.34	0		0.19	0.82	0.16	3.75	3.49	93	0.00	0.26		0.00	
28-Jun	32	0		0.12	0.86	0.10	3.80	3.41	90	0.00	0.38		0.00	
29-Jun	32.67	0		0.17	0.90	0.15	3.84	3.29	86	0.00	0.55		0.00	
30-Jun	33				0.91	0.00	3.87	3.30	85	0.00	0.58		0.00	
1-Jul	33.34				0.92	0.00	3.89	3.32	85	0.00	0.59		0.00	
2-Jul	33.67				0.93	0.00	3.91	3.33	85	0.00	0.59		0.00	
3-Jul	34				0.94	0.00	3.94	3.35	85	0.00	0.60		0.00	
4-Jul	34.34				0.95	0.00	3.96	3.36	85	0.00	0.61		0.00	
5-Jul	34.67				0.96	0.00	3.98	3.37	84	0.00	0.62		0.00	
6-Jul	35				0.97	0.00	4.01	3.39	84	0.00	0.63		0.00	
7-Jul	35.33				0.98	0.00	4.03	3.40		0.00			0.00	
8-Jul	35.67				0.99	0.00	4.05	3.42		0.00			0.00	
9-Jul	36				1.00	0.00	4.08	3.43		0.00			0.00	


Irrigation Scheduler - [New File]
Field, Crop & Soil Data
Weather & Irrigation Data
Farm Name
Field ID
Location
Crop
Emergence Date
mm/dd/yy
Growing Season
Days
Projected Yield
Units/Acre
Rooting Depth
Feet
Notes
Soil Map Unit Symbol
Import Soil
Soil Component Name
Water Holding Capacity
Inches
Emergence Moisture
%
Minimum Moisture
%
Calculation Date
mm/dd
www.agry.purdue.edu/irrigation/IrrDown.htm
New
Open
Reopen
Save
Calc
Options
Help
About
Exit
Enter the name of the farm to be irrigated.

Michiana Irrigation Scheduler: Purdue Agronomy web site –Est. From High/Low temp. & date

Irrigation Scheduler - J&L home 08.irr

Field, Crop & Soil Data | Weather & Irrigation Data

Day	Date	Normal Temp.	High Temp.	Low Temp.	Rainfall (in.)	Irrigation (in.)
44	Jul 04	71	77	52		
45	Jul 05	71	84	52		
46	Jul 06	71	84	53		
47	Jul 07	71	84	66	.1	
48	Jul 08	72	83	71	.2	
49	Jul 09	72	76	60		
50	Jul 10	72	83	57		
51	Jul 11	72	86	61	.1	
52	Jul 12	72	82	69		1.0
53	Jul 13	72	77	62		

Get Temps

Import Data

www.agry.purdue.edu/irrigation/IrrDown.htm

New | Open | Reopen | Save | Calc | Options | Help | About | Exit

Enter the field's daily temperature, rainfall and irrigation data.

Preview Irrigation Schedule - J&L.IRR

Schedule Calculated For	**Sep 20**	Amount That Can Be Safely Added	**0.01 in.**
Evapotranspiration Rate	**0.00 in.**	If No Rain, You Can Add 1 Inch In	**354 days**
Soil Profile Moisture Content	**100 %**	Estimated Water Loss For Season	**17.39 in.**

Day	Date	Temp. (°F)	Dev. from Normal	Rainfall (in.)	Irrigation (in.)	Soil Mois. (%)	Soil Mois. (relative)
1	May 08	66	+14			100	+++++++
2	May 09	70	+17	0.70		105	++++++++
3	May 10	70	+17	0.10		113	++++++++++
4	May 11	73	+19	0.10		105	++++++++
5	May 12	68	+13			100	+++++++
6	May 13	70	+15	1.00		105	++++++++
7	May 14	54	-2	0.70		103	++++++++
8	May 15	57	+1			100	+++++++

Print Close

Browse the daily calculations.

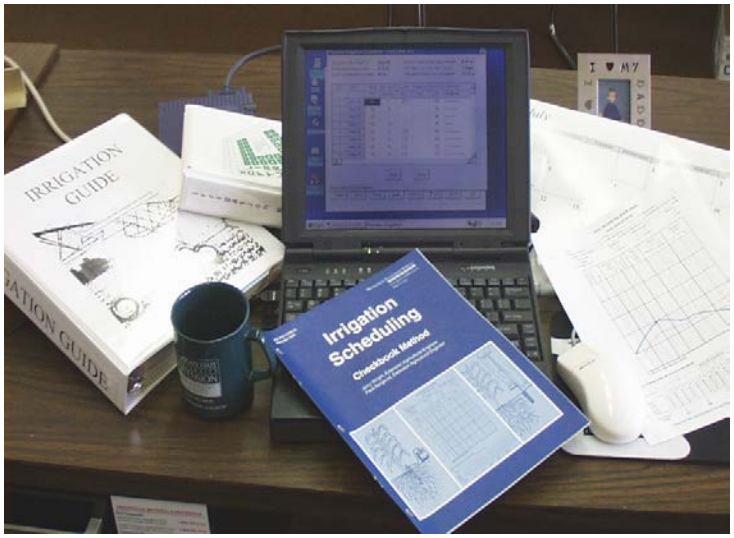
Ideal Irrigation Application Volume

- wet at least top half of root mass
- allow room for a predictable rain fall – 1”
- never wet below the root zone
- large enough to minimize the number of times soil surface and crop are wetted. (save water / reduce disease)

Typical applications:

- May to mid June 0.3” to 0.5”
- Last half of June 0.6” to 0.8”
- July to early August 1.0” to 1.5”
- Last half of August 0.6” to 0.8”
- Finish 0.3” to 0.5”

Irrigation Scheduling Checkbook Challenges



Errors will accumulate over time -Weekly ground truthing needed

Rainfall variability is more than often considered

Only "effective" rainfall and irrigation should be considered - Only water entering root zone uniformly is "effective"

Corn crop mature in program by calendar, not heat

?? Soil Moisture ??

Fine sand and loamy fine sand soils

Appearance of fine sand and loamy fine sand soils at various soil moisture conditions.
Available water capacity ..... 0.6–1.2 inches/foot

Available Soil Moisture	Description	Illustration
0-25	Appears dry, will hold together if not disturbed, loose sand grains on fingers.	
25-50	Slightly moist, forms a very weak ball with well-defined finger marks, light coating of loose and aggregated sand grains remain on fingers.	
50-75	Moist, forms a weak ball with loose and aggregated sand grains on fingers, darkened color, light uneven water staining on fingers.	

Scheduling by comparison

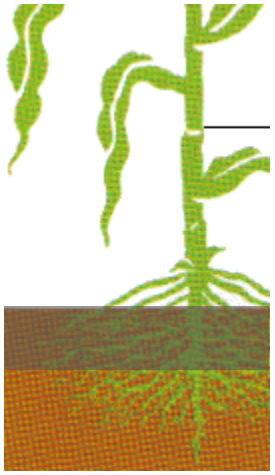
Irrigated portion of field should look better than the dry corners/area

Over water observation area should not look significantly better than the adjacent irrigated portion of field.

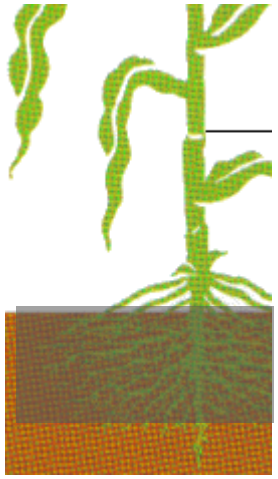
Probe and compare:
- Dry corners
- Over irrigated
- Normal irrigated field

- Soaker hose attached at pivot point
- 100% higher output sprinkler

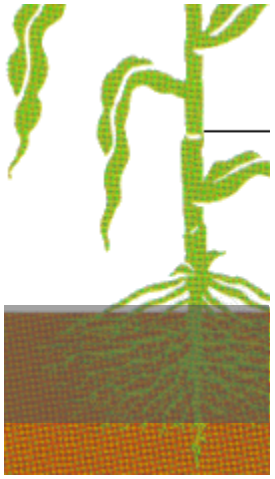
Monitoring soil wetted front -12 hrs. after irrigation



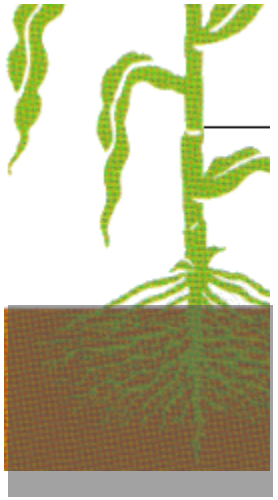
½” into dry soil



½” into moist soil



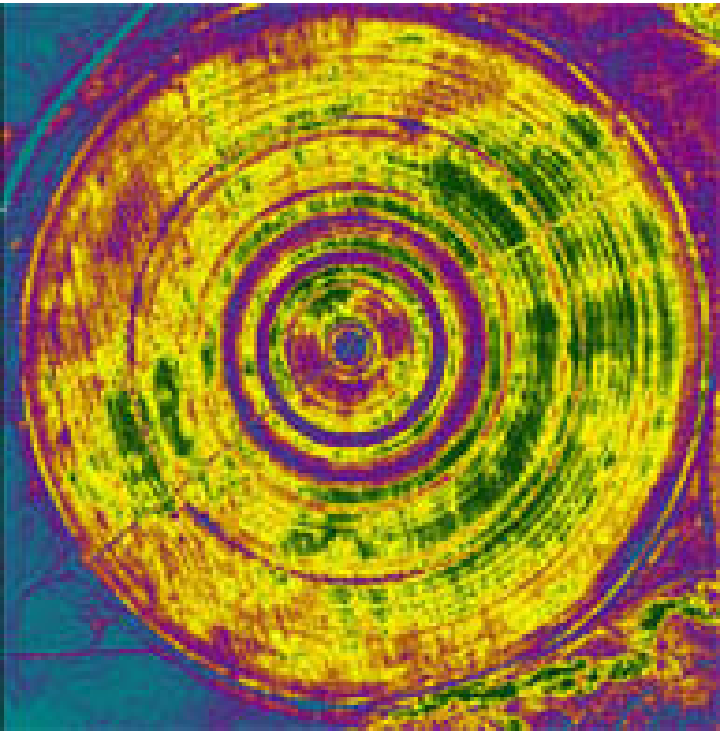
1” into dry soil



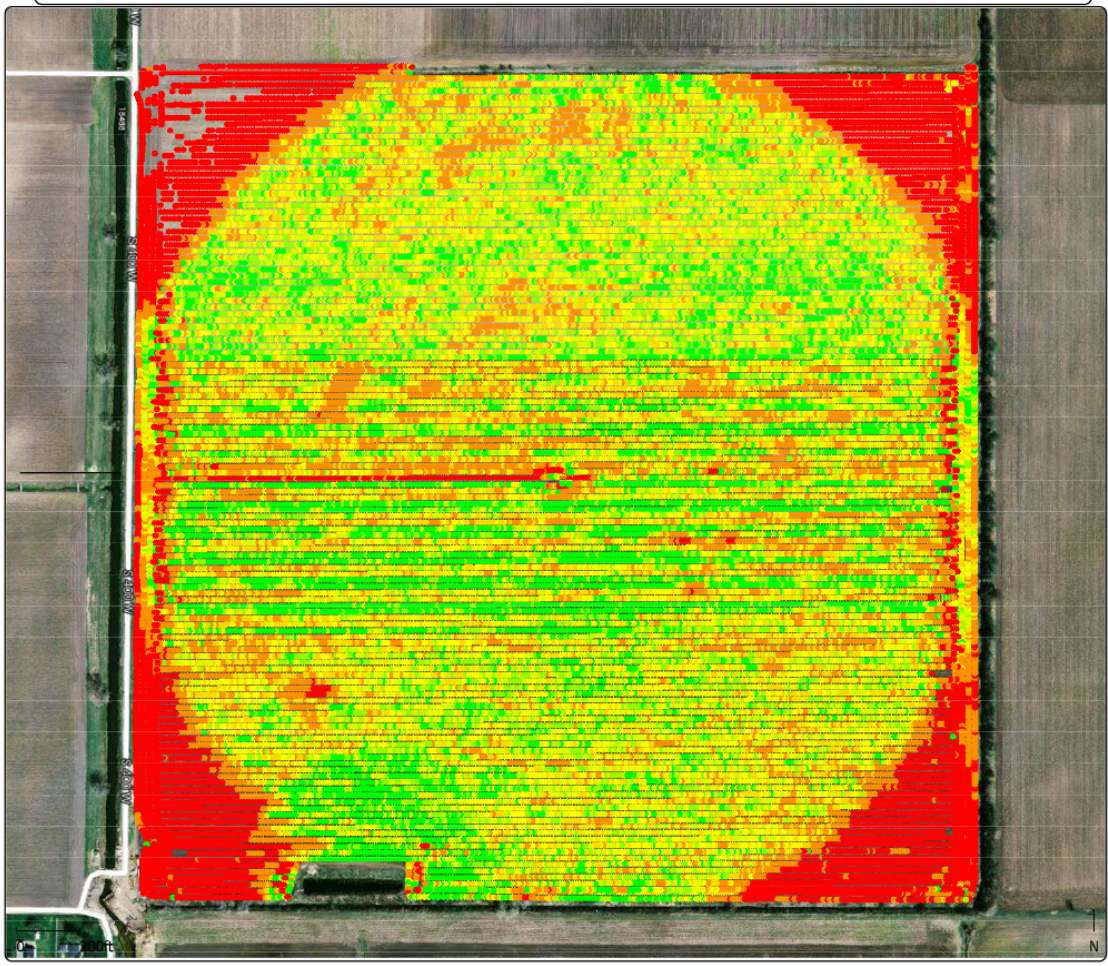
1” into moist soil

If your 1” application did not go down as far as it did last week - your irrigation is not keeping up.

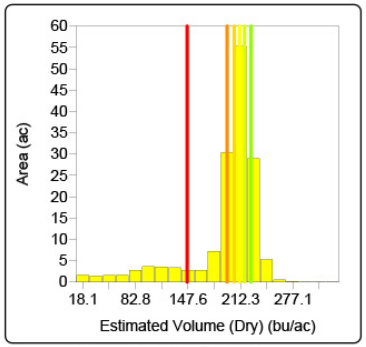
Have you seen yield map patterns that match the irrigation system configuration?



Grain Harvest 2012 - Good South(CORN)



Grower :
Farm : Good
Field : Good South
Year : 2012
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 152.77 ac
Avg. Yield : 187.77 bu/ac
Avg. Moisture : 18.55 %



Estimated Volume (Dry) (bu/ac)

225.46	399.32	(21.80 ac)
217.56	225.46	(22.02 ac)
211.28	217.56	(22.04 ac)
204.93	211.28	(22.17 ac)
195.98	204.93	(22.32 ac)
146.88	195.98	(21.48 ac)
10.00	146.88	(20.95 ac)

Irrigation System Uniformity

An 1” application should be 1” everywhere in the irrigated field

- 10% or less deviation from the average is ideal
- Over applied area will likely be over applied each application
- Under applied areas will likely be under applied each application

A 30% deviation on a field in an 8” irrigation application year will have areas receiving as little as 5.6” and as great as 10.4”

Repair all visible system leaks and problems first.

Stick with the Plan!!!!

Make sure the system is within it’s design.

- Has the system changed in length or coverage area?
- Is the water supply flow and pressure what was designed for?
- Sprinkler height?
- End drive changes?
- Tire changes?


Fix all visible issues first.

Signs Your System Need an Uniformity Evaluation

- System pressure at pivot point deviates from the sprinkler chart by > 10% psi.
- Pressure at last Sprinkler deviates from the sprinkler chart by > 10% psi.
- Pressure gage does not reflect end chart predicted gun/cornering arm changes (on/off)
- Yield map show irrigation configuration

Irrigation System Uniformity

Irrigation System Uniformity

Basic system evaluation

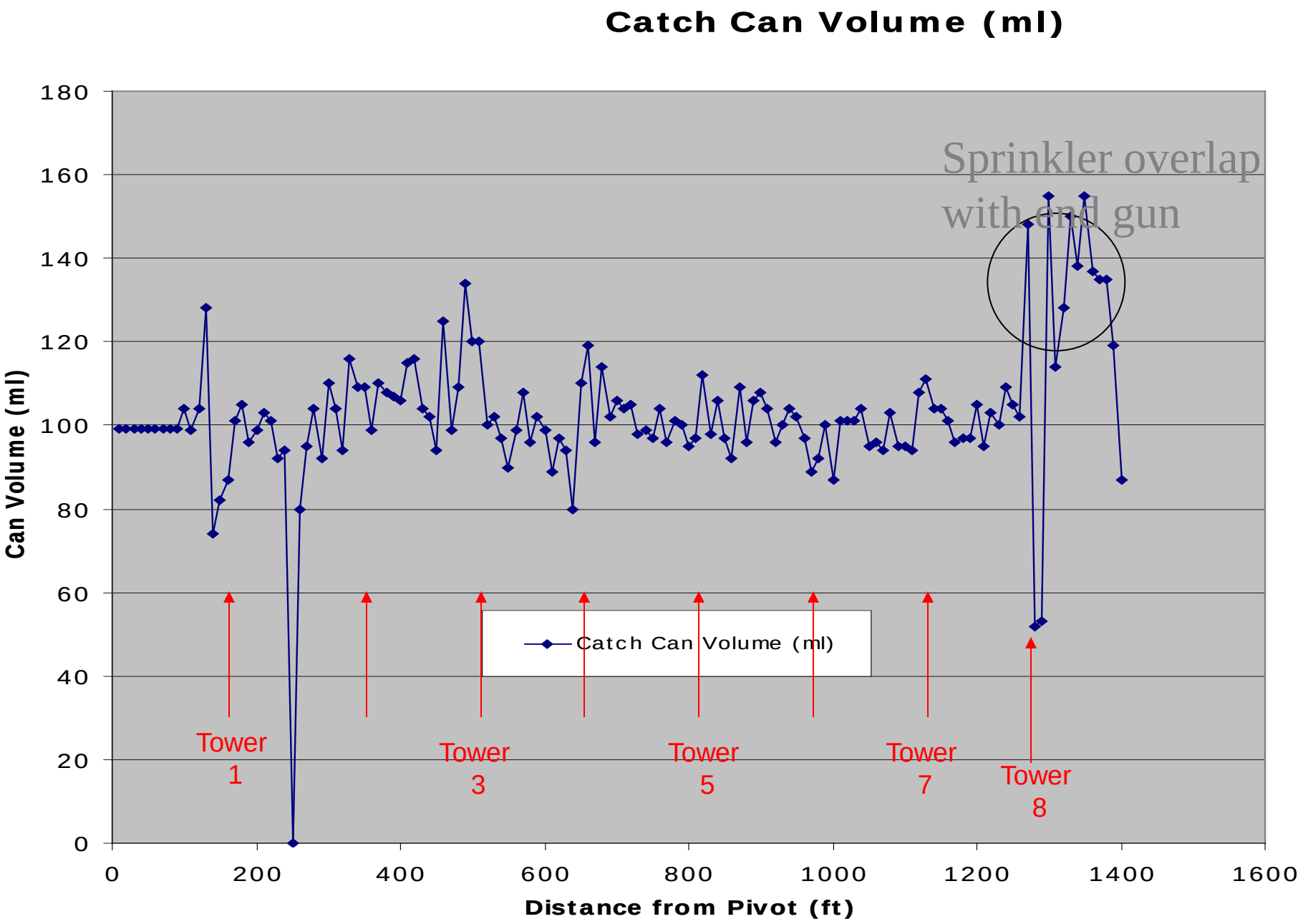
Collect enough uniform containers to place every 10 feet the length of the system or across the application pattern.

Spread the containers every ten feet from the center point to the outside edge of the application area.

Run the system at standard setting over the container.

Measure and record the water volume caught by each container.

Note sample point varying greater than 50% of the average.



http://msue.anr.msu.edu/resources/irrigation

Greatest improvement needed

Pivots

- End gun stop adjustment
- Water supply over or under design
- End gun orifice, too little or too much
- Wrong sprinkler or tip
- Leaks, plugs and **no turn sprinklers**

Trickle/Drip

- Follow a good design
- Line length matched to design
- Supply pressure issues at manifold

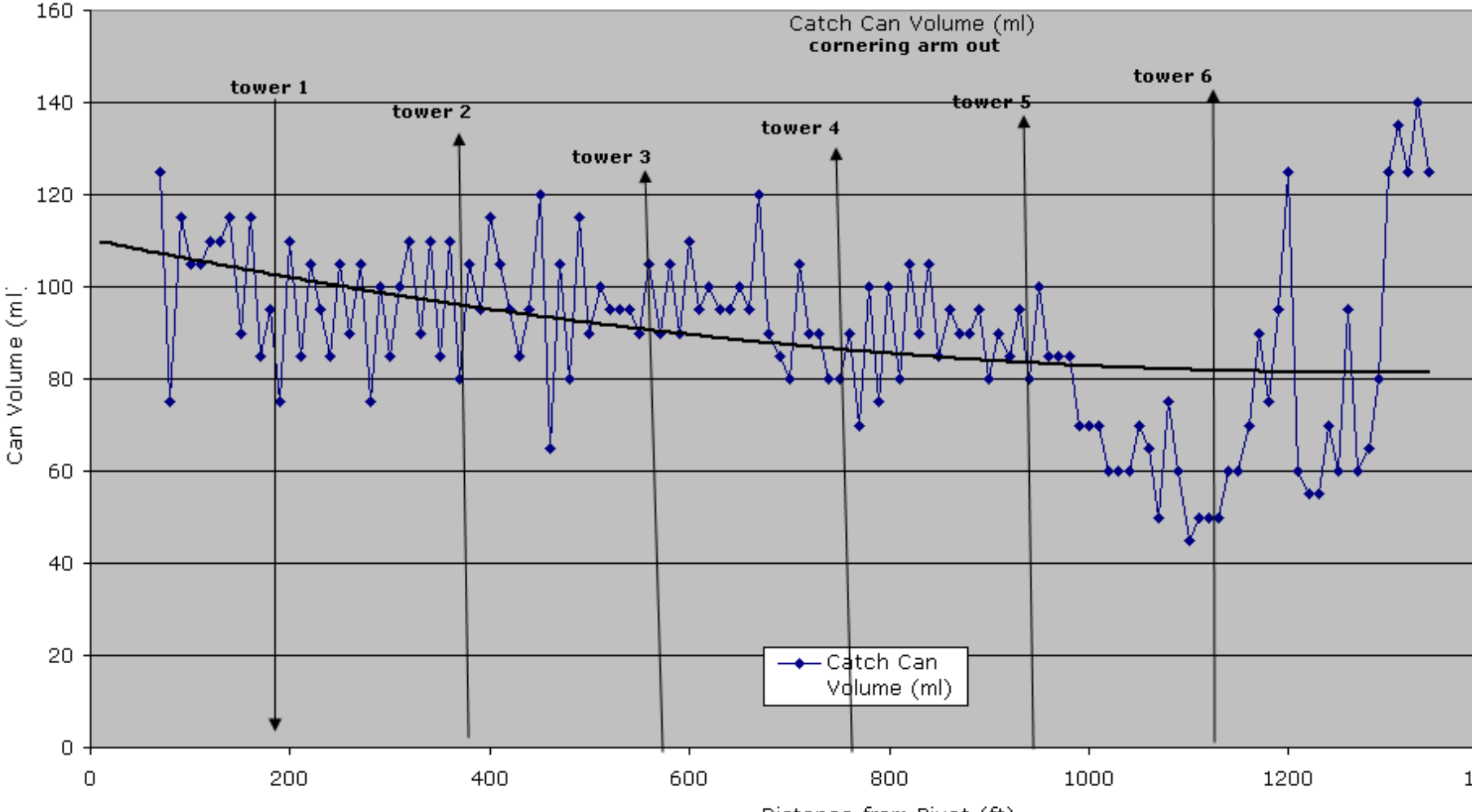
Big Gun Travelers

- Traveler lane gap spacing
- Water supply over or under design (pressure at gun)
- Gun orifice, tip wrong
- Wind differences

Water supply over or under design

supply over design yield tail up, supply under design yield tail down

Example of Water supply under volume for sprinkler design



Most systems apply within 85% of the expected application

MSU Extension Irrigation System Evaluation Tool, 1-23-07

Farm Name [redacted] Farm

System Uniformity Coefficient = 79

System Identification: Cornering Arm System on [redacted] Farm-Behind House

Good System uniformity coefficient are 85 or greater

Cornering Arm Extended

Deviation from desired application = -0.04

Application is 4 % under expectation

System Settings

Application rate (in)	0.5	Wind speed (mph)	4 mph
Percent timer Setting (%)	19	Wind Condition (variable or steady)	steady
Operating Pressue (psi)			

Rate of application calculator

Time from start to end of application at highest rate section of system (min.)	22	Inches/Hour	1.25
Rate of application for the highest rate section of system (minute /one inch)	48.00		
Average Application (cm)			1.164
Length of evaluation area (ft)	1340	Average Application (in)	0.46
Catch Can Spacing Distance (ft)	10		
Average catch, collected only (ml)			88.95
number of cans data collected from	129	*70% average catch can (ml)*	*59.94*
number of cans set	134	Evaluation area, full circle (acres)	122.82
catch can openning area (sq cm)			76.977
Diameter of catch can (cm)	9.9	catch can openning area (sq in)	11.767

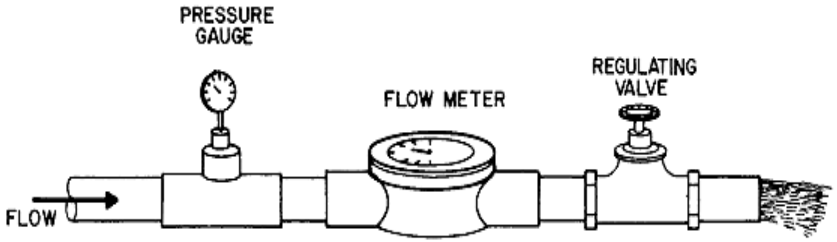
catch can number	Distance from center point	catch volume in ml	Data adjustment	Comments	Water volume (cm)	Water volume (in)	% applied of average	Deviation from average (%)	Area covered per catch can (acres)	Area covered per catch can (% of total)	Weighted Deviation
1	10		88.95		1.156	0.455	99.26%	-0.74%	0.01623	0.01%	0.0001
2	20		88.95		1.156	0.455	99.26%	-0.74%	0.02885	0.02%	0.0002
3	30		88.95		1.156	0.455	99.26%	-0.74%	0.04327	0.04%	0.0003
4	40		88.95		1.156	0.455	99.26%	-0.74%	0.05770	0.05%	0.0005
5	50		88.95		1.156	0.455	99.26%	-0.74%	0.07212	0.06%	0.0006
6	60		88.95		1.156	0.455	99.26%	-0.74%	0.08655	0.07%	0.0007
7	70	125	0.00		1.624	0.639	139.48%	39.48%	0.10097	0.08%	0.0011
8	80	75	0.00		0.974	0.384	83.69%	-16.31%	0.11539	0.09%	0.0008
9	90	115	0.00		1.494	0.588	128.32%	28.32%	0.12982	0.11%	0.0014
10	100	105	0.00		1.364	0.537	117.16%	17.16%	0.14424	0.12%	0.0014

Data Entry | Uniformity Graph

Check your percent timers for accuracy

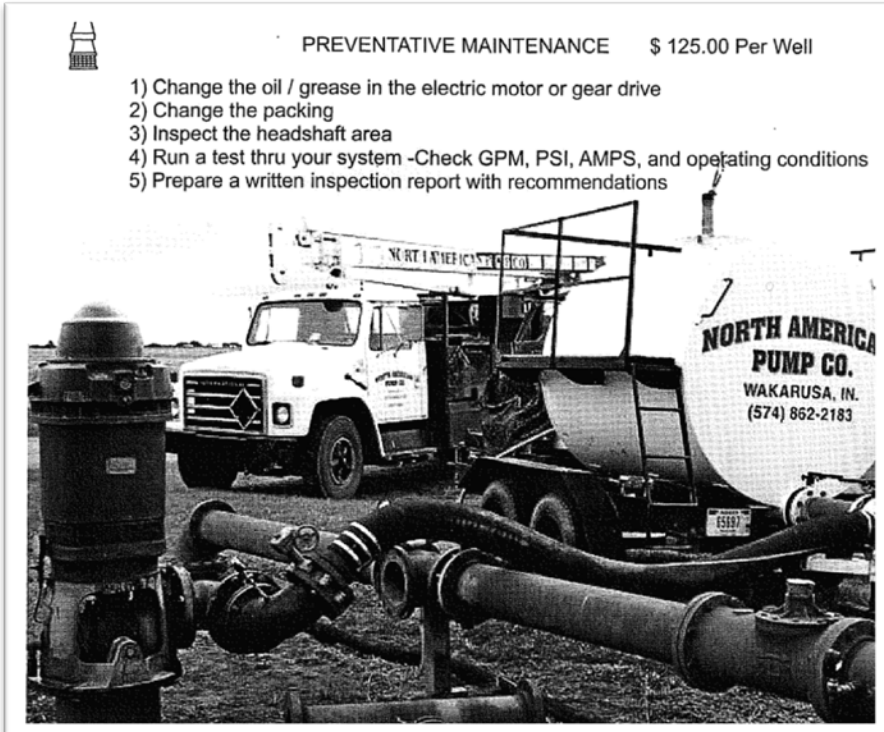
- Time lead motors “On Time” and “Off Time”
- Time the total revolution and compare to chart

Measure flow at desired pressure and match to sprinkler package



Poor performance:

Ask dealer to measure flow at peak water use season and compare to design parameters.



MICHIGAN STATE UNIVERSITY EXTENSION

PURDUE UNIVERSITY

Center Pivot Percent Timer , Water Applied Estimator Chart

MSU Extension, St. Joseph County **V 1.0**

7/24/2007

	% Timer Setting	Hours to Run Circle	Water Applied
Measured	40	72	1.25
Estimated	5	576.00	10.00
	10	288.00	5.00
	15	192.00	3.33
	20	144.00	2.50
	25	115.20	2.00
	30	96.00	1.67
	35	82.29	1.43
	40	72.00	1.25
	45	64.00	1.11
	50	57.60	1.00
	55	52.36	0.91
	60	48.00	0.83
	65	44.31	0.77
	70	41.14	0.71
	75	38.40	0.67
	80	36.00	0.63

Preventing Irrigation Runoff

(comparing irrigation application rate to soil infiltration rate)

The larger the wetted area the slower the rate of application. Average 1’ rainfall comes over 4 hours.

An 1’ rainfall over an hour is considered a “toad strangler”

Sprinkler packages are commonly available with instantaneous application rates from 1” per 12 minutes to 1” per 80 minutes

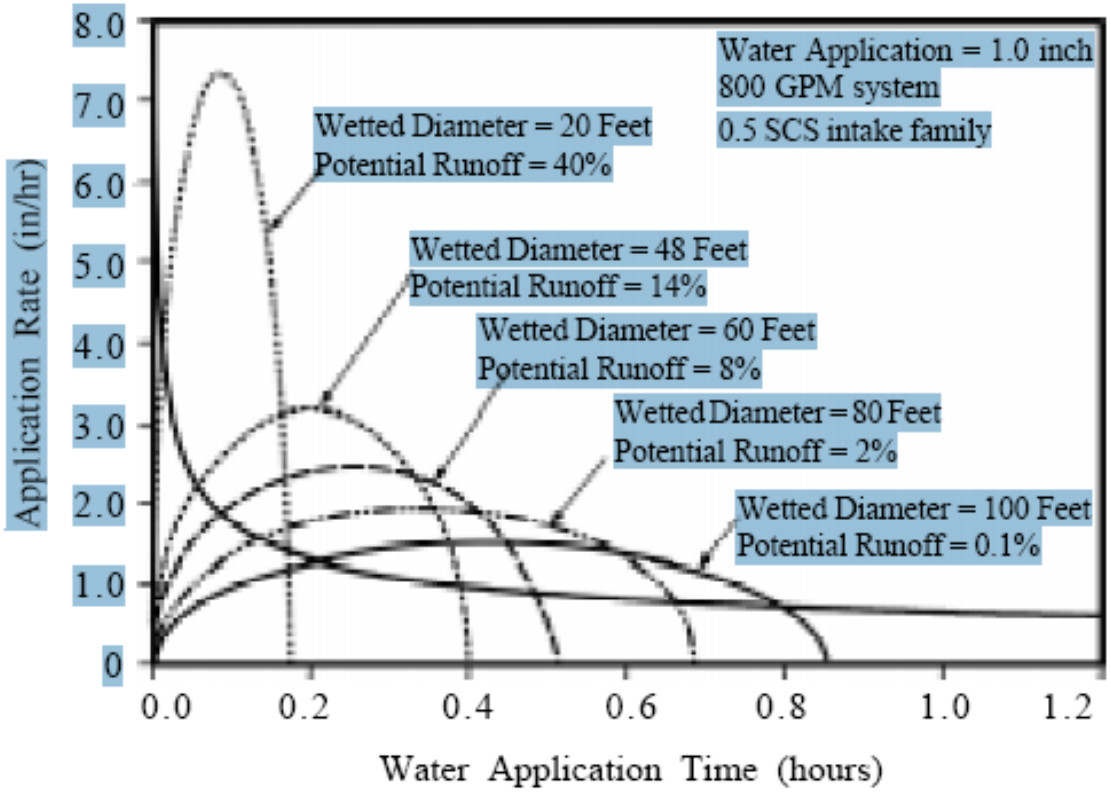
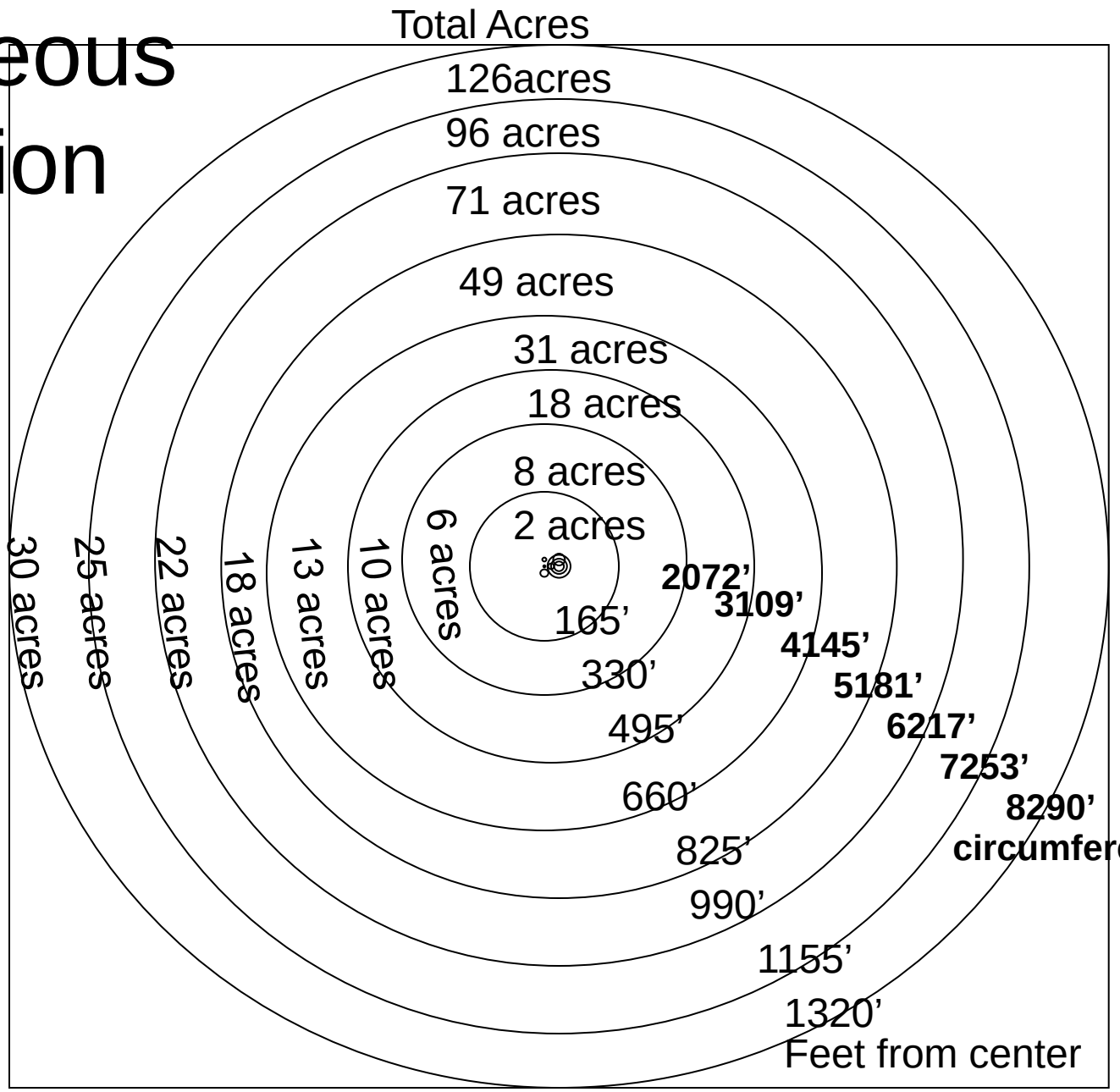


Figure 8. Effect of wetted diameters on the potential for runoff.

NebGuide – G-1532- Operating Characteristics of Center Pivot sprinklers

Instantaneous application rate



3 days / circle @ 1”
3 days = 4320 min.

8290’ / 4320 min.=
= 1.92’/minute

20’ ft. wetted area=
= 1” / 10.4 Minutes

40’ ft. wetted area=
= 1” / 20.8 Minutes