Horticultural Crop Irrigation

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Horticultural Water Needs

If you take care of your soil, the soil will take care of your plants.

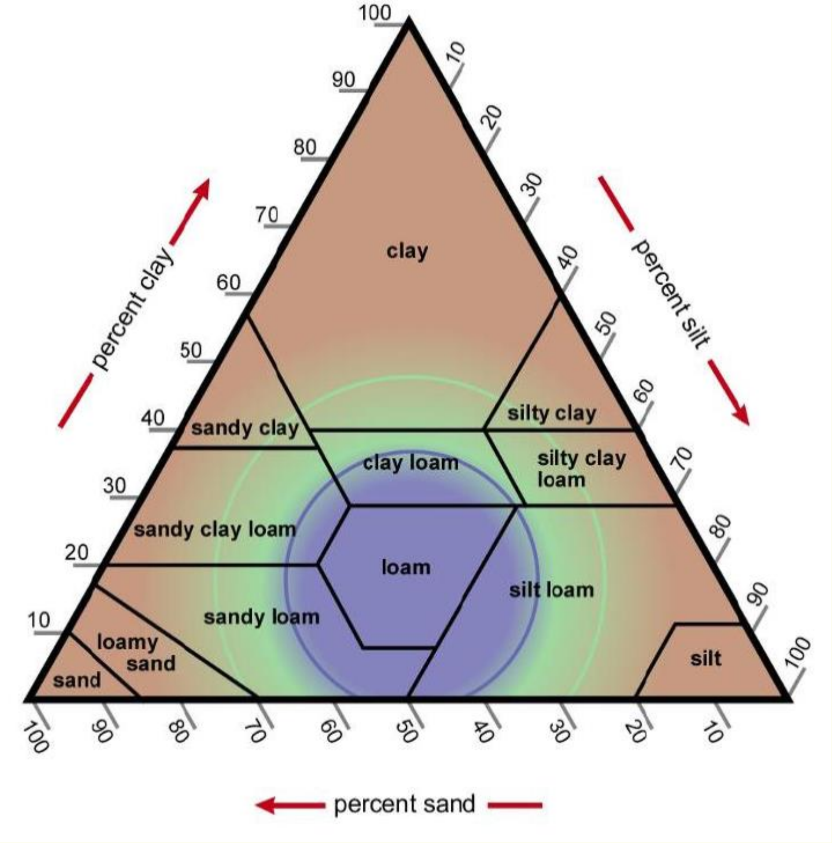
- Available Water Holding Capacity depends on:
  - Soil texture
  - Organic matter
  - Rooting depth

Table 8. Available Water Holding Capacities for Several Soil Types

	Available Water Holding Capacity	
Soil Texture	**In Inches per Inch of Soil**	**In Inches per Foot of Soil**
Loamy fine sand	0.08-0.12	0.96-1.44
Sandy loam	0.10-0.18	1.20-2.16
Loam	0.14-0.22	1.68-2.64
Silt loam	0.18-0.23	2.16-2.76
Clay loam	0.16-0.18	1.92-2.16

USDA Soil Texture Classes

- Particle size
  - Sand = 2.0-0.05 mm
  - Silt = 0.05-0.002 mm
  - Clay = <0.002 mm
- Characteristics
  - Sand adds porosity
  - Silt adds body to the soil
  - Clay adds chemical & physical properties



Determining Soil Texture

- By feel
  - Gritty, smooth, sticky
- Using the jar method
  - Fill a 1-quart jar ¼ full of soil
  - Fill the jar with water to ¾ full
  - Add 1 teaspoon of dishwashing detergent
  - Shake very well to suspend soil
  - Place on a flat surface and allow soil to settle for 2 days
  - Measure % thickness of each layer relative to all

Benefits of Using Compost

- ✓ Improves drainage & aeration of heavy clay soils
- ✓ Increases moisture-holding ability of sandy soils
- ✓ Increases earthworm & soil microbial activity that benefit plant growth
- ✓ Improves soil structure & makes it easier to work
- ✓ Contains nutrients needed for plant growth

Soil Properties

- Soils store 1.5”-2.5” of water per foot of depth (check county NRCS Soil Survey)
- Intake rate = 0.2”-2.0” per hour, rest is runoff
- Available Soil Moisture* = % of soil water between field capacity & permanent wilting point = ranges by crop from 25% to 75%
- Summer E.T. rate can be 0.25” per day
  - E.T. affected by radiation, humidity, air temperature, wind speed
- A 2-ft. deep soil at best holds a 9-15 day supply of available moisture for plants

*Reference: www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html

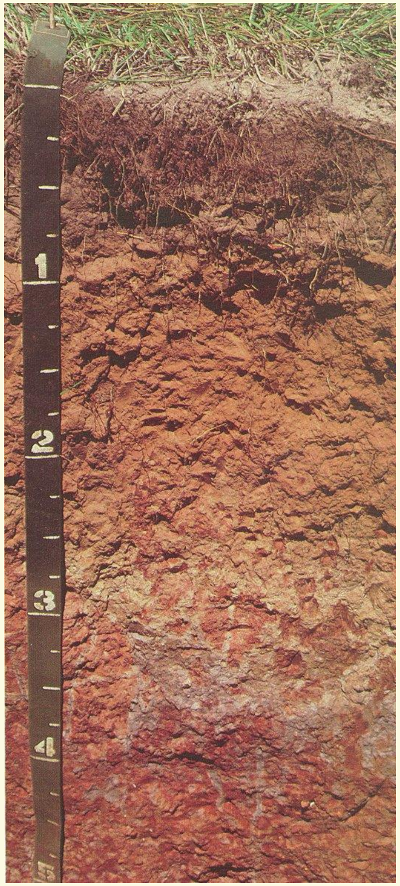
Checking Soil Drainage

- ✓ Perched water table
- ✓ Fragipan on upland soils
- ✓ Standing water after a rain

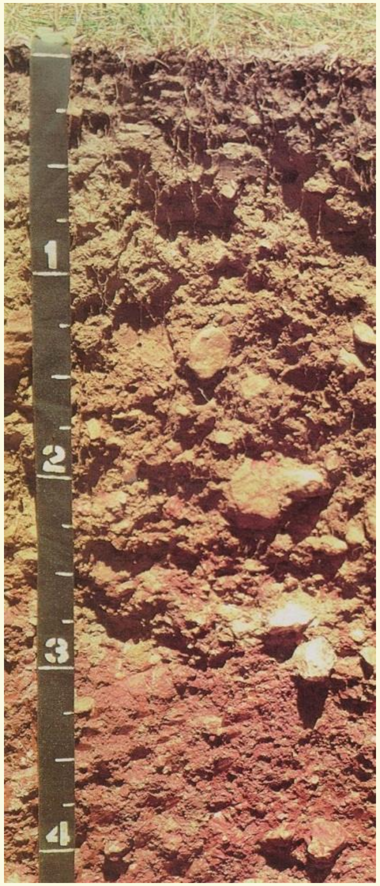
Soil Drainage Classification

Drainage Class	Matrix	Mottle
Well	Bright red	None
Moderately well	Red	Gray
Somewhat poorly	Dull	Red
Poorly		All gray

Color Indicates Drainage



Captina
Silt Loam



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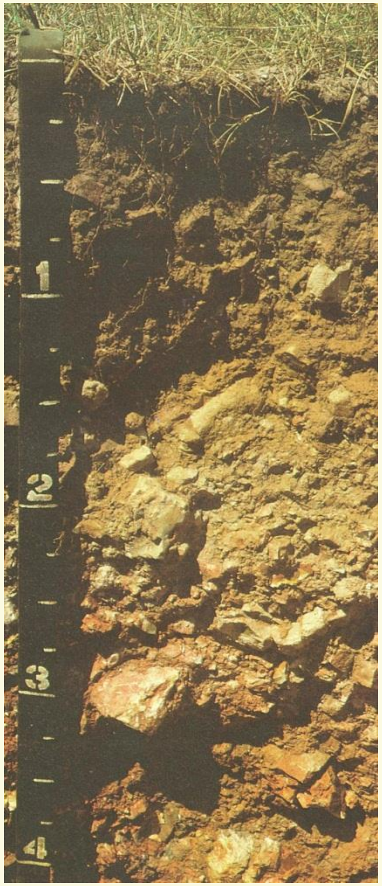
Silt Loam



Scholten Gravelly
Silt Loam

Water Needs Vary Widely

- ✓ By species & within species by age of crop
- ✓ By soil type and time of year
- ✓ By location: outdoors vs. indoors
  - ✓ Example: Tomatoes in high tunnels
    - 12 oz./plant/day when first set
    - Climbs gradually to 75 oz./plant/day upon maturity
  - ✓ Example: Greenhouses (container production)
    - A general rule is to have available from 0.3 to 0.4 gallons/sq. ft. of growing area per day as a peak use rate
- ✓ **Size irrigation system for peak use**

Relative Water Needs of Plants

Low	Medium Low	Medium
Spinach Lettuce Radish	Peas, Green Beans, Kale	Cabbage Broccoli Pepper
Medium High	**High**	**Very High**
Tomato Asparagus	Sweet Corn, Vine Squash	Muskmelon Watermelon Pumpkin

Table 6. Effective Rooting Depth of Selected Vegetables

Shallow (6-12″)	Moderate (18-24″)	Deep (> 36″)
Beet	Cabbage, Brussels Sprouts	Asparagus
Broccoli	Cucumber	Lima Bean
Carrot	Eggplant	Pumpkin
Cauliflower	Muskmelon	Sweet Potato
Celery	Pea	Watermelon
Greens & Herbs	Potato	Squash, Winter
Onion	Snap Bean	
Pepper	Squash, Summer	
Radish	Sweet Corn	
Spinach	Tomato	

Table 7. Vegetable Crops and Growth Period Most Critical for Irrigation Requirements

Crop[1]	Most Critical Period
broccoli, cabbage, cauliflower, lettuce	head development
carrot, radish, beet, turnip	root enlargement
sweet corn	silking, tasseling, and ear development
cucumber, eggplant, pepper, melon, tomato	flowering, fruit set, and maturation
bean, pea	flowering, fruit set, and development
onion	bulb development
potato	tuber set and enlargement

[1] For transplants, transplanting and stand establishment represent a most critical period for adequate water.

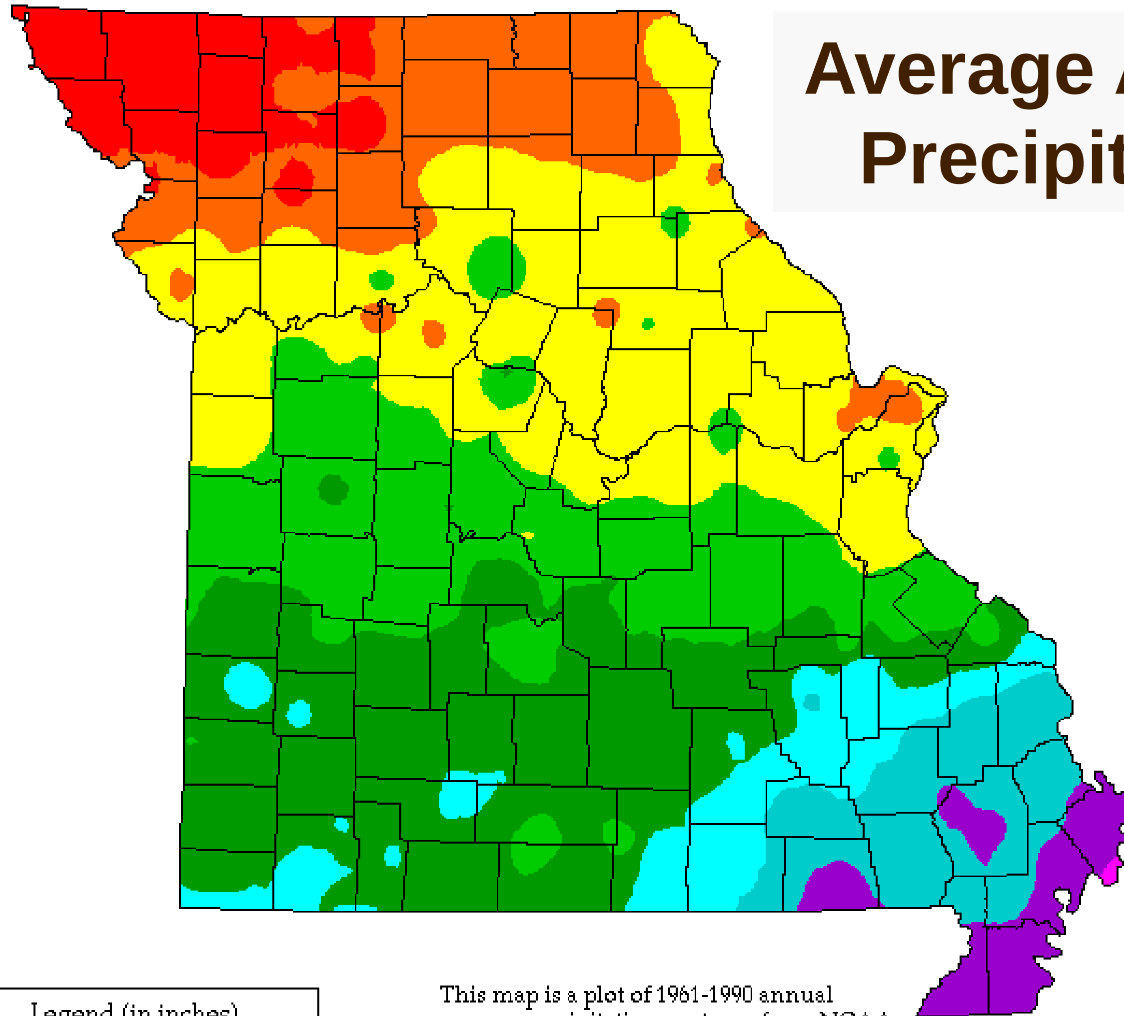
Most of the active root system for water uptake may be between 6”-12”

Reference: irrigationtraining.tamu.edu/docs/irrigation-training/south/crop-guidelines/estimatedwaterrequirementsvegetablecrops.pdf

Plants are 80-95% Water

- Water shortages early in crop development = delayed maturity & reduced yields
- Water shortages later in the growing season = quality often reduced, even if yields not hurt
- Short periods of 2-3 days of stress can hurt marketable yield
- Irrigation increases size & weight of individual fruit & helps prevent defects like toughness, strong flavor, poor tipfill & podfill, cracking, blossom-end rot and misshapen fruit

Average Annual Precipitation



Legend (in inches)

- Under 36
- 36 to 38
- 38 to 40
- 40 to 42
- 42 to 44
- 44 to 46
- 46 to 48
- 48 to 50
- Above 50

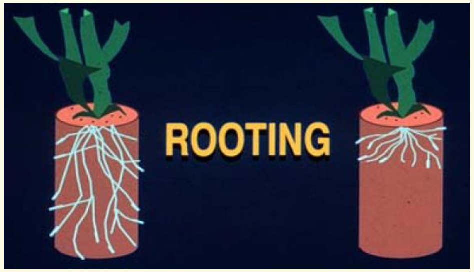
Period: 1961-1990

This map is a plot of 1961-1990 annual average precipitation contours from NOAA Cooperative stations and (where appropriate) NRCS SNOTEL stations. Christopher Daly used the PRISM model to generate the gridded estimates from which this map was derived; the modeled grid was approximately 4x4 km latitude/longitude, and was resampled to 2x2 km using a Gaussian filter. Mapping was performed by Jenny Weisburg. Funding was provided by NRCS Water and Climate Center.

12/7/97

Basic Watering Facts

- Plants need 1”-1.5” of water per week
  - 624-935 gallons (83-125 cu.ft.) per 1,000 sq.ft.
- Can survive drought on half that rate
- Deep infrequent waterings are better than several light waterings



- Deeper roots require less supplemental irrigation
- Taller plants have deeper roots
  - Lowers tendency to wilt
  - Shades soil surface
  - Controls weeds by competition
  - Makes water “go farther”

When to Water

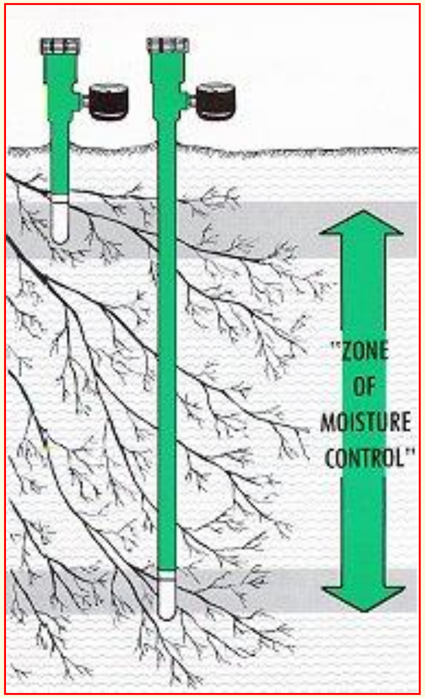
- ✓ Rainfall less than 1” per week
  - – Keep a record of rainfall received
  - – Check soil moisture with long screwdriver
- ✓ It’s getting bad when you see:
  - – Purple-blue wilting leaves
  - – Grass that leaves footprints
  - – Folded or rolled leaves
- ✓ Don’t wait to see wilting before watering

Best Time of Day to Water

- Early morning: 4 a.m. to 8 a.m.
  - Evaporative losses minimized (no sun, calmer winds)
  - Knocks dew and guttation fluid off leaf blades
  - Lets plant leaves dry before evening to discourage fungal growth and infection

Measuring Water Needs [1]

- ✓ "Feel" method - handful of soil
- ✓ Screwdriver method – force into soil
- ✓ Appearance of plants - wilt
- ✓ Calendar method - daily, 3rd day
- ✓ "Checkbook" method
  - Tally total rainfall + irrigation against daily water use of plants
- ✓ Tensiometers
  - Read scale of 0 (wet) to 100 (dry)
- ✓ Moisture resistance blocks
  - Buried at depths in soil, check with meter



Measuring Water Needs 2

Catch cans

4-cycle timer

Rain gauge

Plant Water Requirements [3]

(Estimated design rates for southwest Missouri)

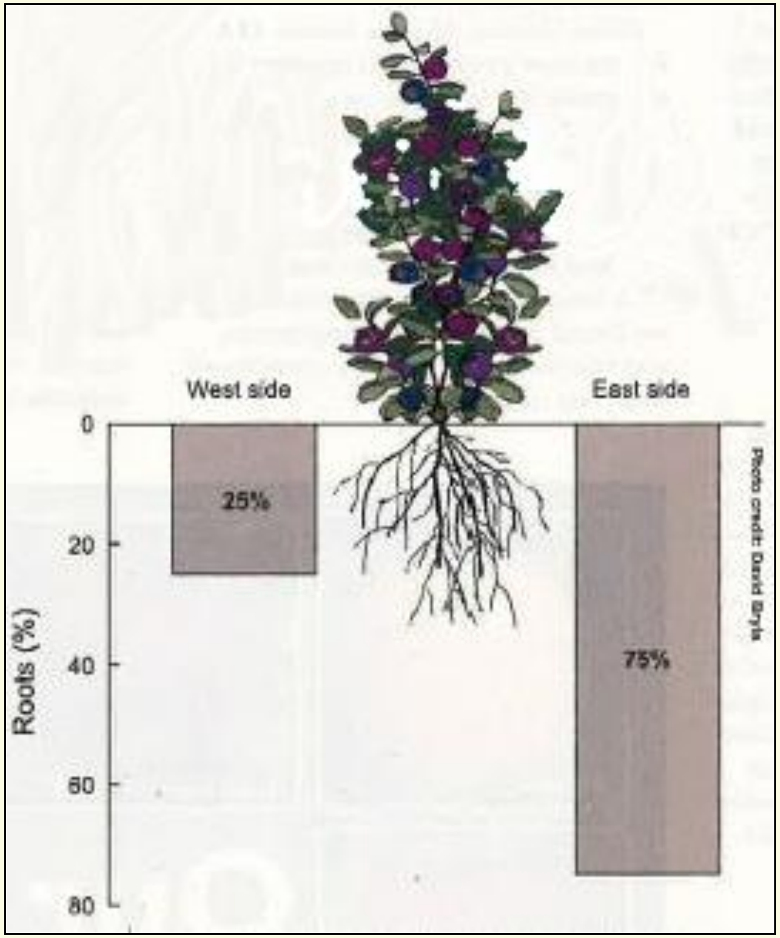
Vegetable Crop (mature)	*Gallons per 100 Feet of Row per Week*
Minimum for plant survival	100
Lettuce, spinach, onions, carrots, radishes, beets	200
Green beans, peas, kale	250
Tomatoes, cabbage, peppers, potatoes, asparagus, pole beans	300
Corn, squash, cucumbers, pumpkins, melons	400-600

Plant Water Requirements [1]

(Design rates for southwest Missouri assuming no effective rainfall for >60 days.)

Fruit Crop	Plant x Row Spacing, Ft.	Sq.Ft./ Plant	Plants/ Acre	Gal/Plant/Day	Gal/Acre/Day
Apples	6 x 14	84	518	8	4144
	18 x 26	468	93	42	3906
Peaches	15 x 20	300	145	28	4060
	18 x 20	360	121	34	4114
Grapes	8 x 10	80	540	10	5440
	8 x 16	128	340	16	5440
Blueberries	4 x 12	48	908	4	3632

Watering Blueberries



- ✓ Blueberries produce 75% of their roots on the east side of the plant
  - – Optimum growth occurs from 57°F to 61°F

Source: David Bryla, USDA, Corvallis, OR 2012

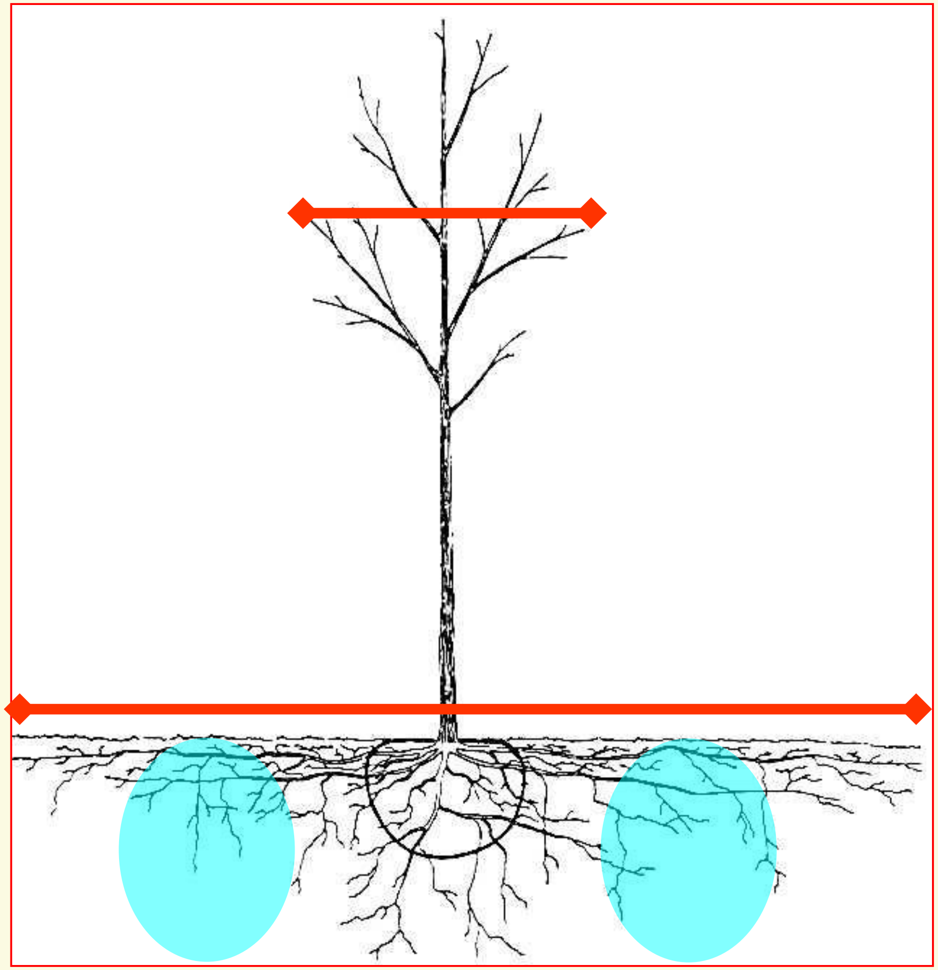
Plant Water Requirements 2

(Design rates for southwest Missouri assuming no effective rainfall for >60 days.)

Fruit Crop	*Gallons per 100 Feet of Row per Day*
Strawberries	50
Raspberries & Blackberries	
With mulch	75
Without mulch	100

Watering Trees

- Most roots in top 12” of soil
- Root spread up to 4X tree crown spread
  - Varies by tree species
- Saturate at least 20% of root zone 12” deep



How Much Water for Trees?

- Gallons needed for 1" water per week =

  $$\frac{\text{Diameter x Diameter}}{2}$$

- Example #1:
  $\frac{\text{6 ft. x 6 ft.}}{2}$ = 18 gal./wk.

- Example #2:
  $\frac{\text{20 ft. x 20 ft.}}{2}$ = 200 gal./wk.

Formula: (Dia.' x Dia.' x 0.7854 ÷ 43,560 sq.ft./ac.) x 27,154 gal./ac.-in.)

Watering Trees

Soaker hose around drip line of tree

"Gender bender" to improve uniformity of water flow

Sizing Horticulture Irrigation Systems

The Two Major Factors in Irrigation System Planning

1. How much <u>water</u> do you need?

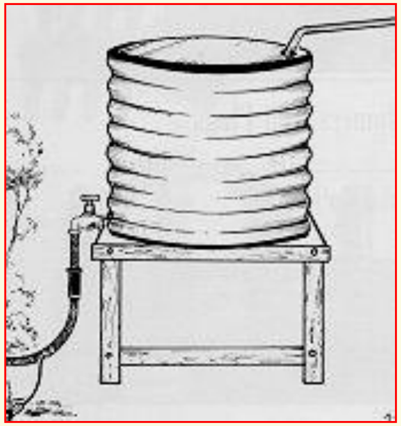
2. How much <u>time</u> do you have?

Water Source Quality

Good

Poor

- ✓ Well = check pH & hardness
- ✓ Municipal = may be expensive
- ✓ Spring = may not be dependable
- ✓ River or stream = depends on runoff
- ✓ Lake or pond water = sand filters
- ✓ Pump to tank on hill
  - Elevation dictates pressure (2.3 feet of head = 1 psi pressure)
  - Watch for tank corrosion



Water Quality Analysis

- ✓ Inorganic solids = sand, silt
- ✓ Organic solids = algae, bacteria, slime
- ✓ Dissolved solids (<500 ppm)
  - – Iron & Manganese
  - – Sulfates & Chlorides
  - – Carbonates (calcium)
- ✓ pH (5.8-6.8 preferred)
- ✓ Hardness (<150 ppm)

Resource: soilplantlab.missouri.edu/soil/water.aspx


PVC Casing


Steel Casing

Plugging Potential of Drip Irrigation Systems

Factor	Moderate (ppm)*	Severe (ppm)*
Physical		
Suspended solids	50-100	>100
Chemical		
pH**	7.0-7.5	>7.5
Dissolved solids	500-2000	>2000
Manganese	0.1-1.5	>1.5
Iron	0.1-1.5	>1.5
Hardness***	150-300	>300
Hydrogen sulfide	0.5-2.0	>2.0

* ppm = mg/L ** pH is unitless *** Hardness: ppm = gpg x 17

Using Ponds for Irrigation

- ✓ Pond 8' deep, 100' dia. holds 280,000 gallons of water.
- ✓ One-half of water volume is usable for irrigation. Rest is seepage & evaporation.
- ✓ 20 GPM demand for 20 hrs/day uses 24,000 gal/day.
- ✓ Pond holds about 6-day water supply.
- ✓ Water is least available when most needed!!

Pond Water Quality

- ✓ Grass filters sediment & nutrients

- ✓ Copper sulfate controls algae & slime

Bucket & Jug Irrigation

- ✓ Labor-intensive
- ✓ Efficient water use
- ✓ Point-source application
- ✓ 0-2 psi system operating pressure
- ✓ Rates:
  - – 2 GPH = 5/64” hole (put in bottom of bucket)
  - – 5 GPH = 1/8” hole

Estimating Water Quantity

- ✓ Household water demand
  - – GPM = Total count of toilets, sinks, tubs, hose bibs, etc. in home
- ✓ Excess is available for irrigation
  - – Contact pump installer for capacity data
- ✓ Is pressure tank large enough?
  - – Stay within cycle limits of pump, OR
  - – Run the pump continuously

Home Water Flow Rates [2]

	Number of Bathrooms in Home			
	1	1.5	2	3
Bedrooms	Flow Rate (Gallons Per Minute)			
2	6	8	10	--
3	8	10	12	--
4	10	12	14	16
5	--	13	15	17
6	--	--	16	18

Source: extension.missouri.edu/p/G1801

Pump Cycling Rate, Max.

Horsepower Rating	Cycles/ Hour
0.25 to 2.0	20
3 to 5	15
7.5, 10, 15	10

Pressure Tank Selection

	Average Pressure, psi*		
Tank Size, gallons	**40**	**50**	**60**
	Pumping Capacity, GPM		
42	5	4	3
82	11	8	6
144	19	14	10
220	29	21	15
315	42	30	22

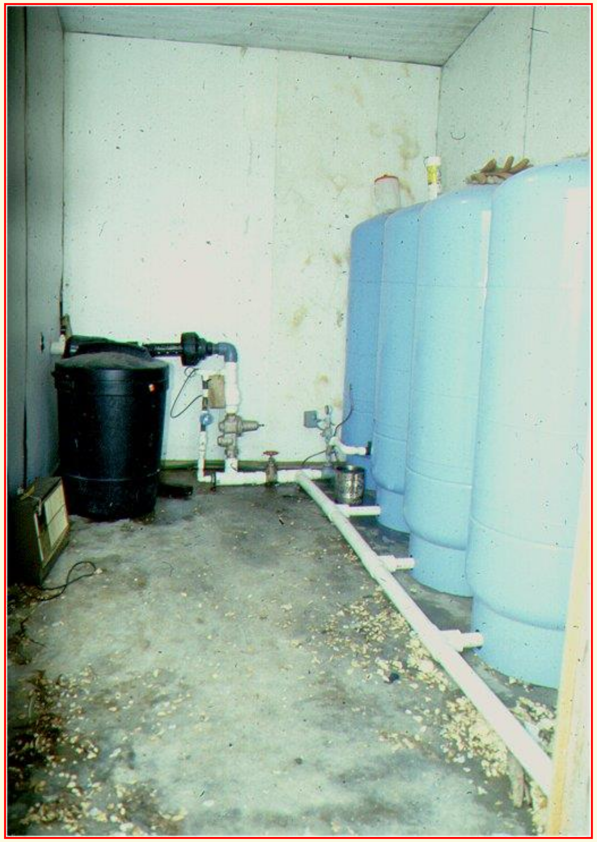
* Cut-in pressure + 10 psi = Avg. Pressure = Cut-out pressure - 10 psi

Pressure Tanks

Larger tank

OR

variable pump speed controller



Multiple tanks

Soaker Hose

- "Sweaty" hose
- Low pressure
- 1/2" - 5/8" dia.
- 0.1 - 1.0 GPH per foot (not engineered)
- Lasts 7-10 years
- Good for gardens, shrub beds
- Expensive on large areas

Micro-Sprinkler

- ✓ Good for landscape beds
- ✓ Uses more water than soaker hose
- ✓ More evaporation
- ✓ Wide range of spray patterns
  - – Spray range is 1.5-6 ft.
- ✓ Not effective for frost control

Sprinkler Irrigation 1

- 1.5-8.5 GPM flow rate
- 4-7 GPM water supply/acre for irrigation
- 45-60 GPM/acre for frost control from 25°F-20°F.
- 25-45 psi system operating pressure
- Equipment & labor tradeoff
- Cost = $500-$700/acre (?)

Sprinkler Irrigation 2

Oscillating sprinkler covers 3,500 sq.ft. rectangle

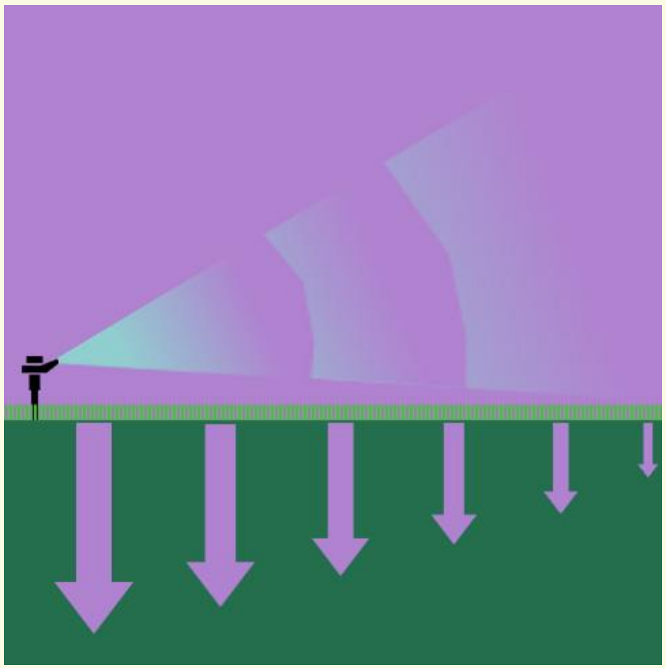
Traveling sprinkler covers 16,500 sq.ft. variable path

Sprinkler Irrigation 3

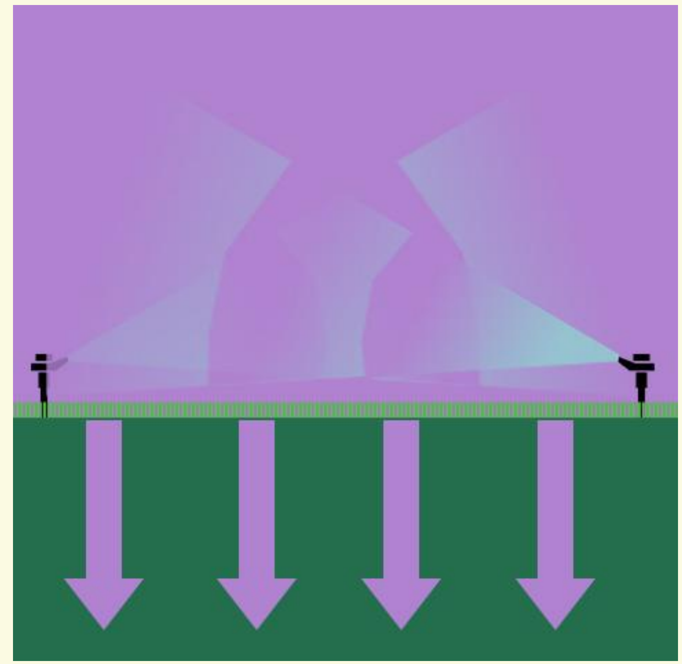
Whirling-head sprinkler covers 5 to 50 ft. diameter

Rotary or impulse sprinkler covers partial to full circles

How a Sprinkler Waters

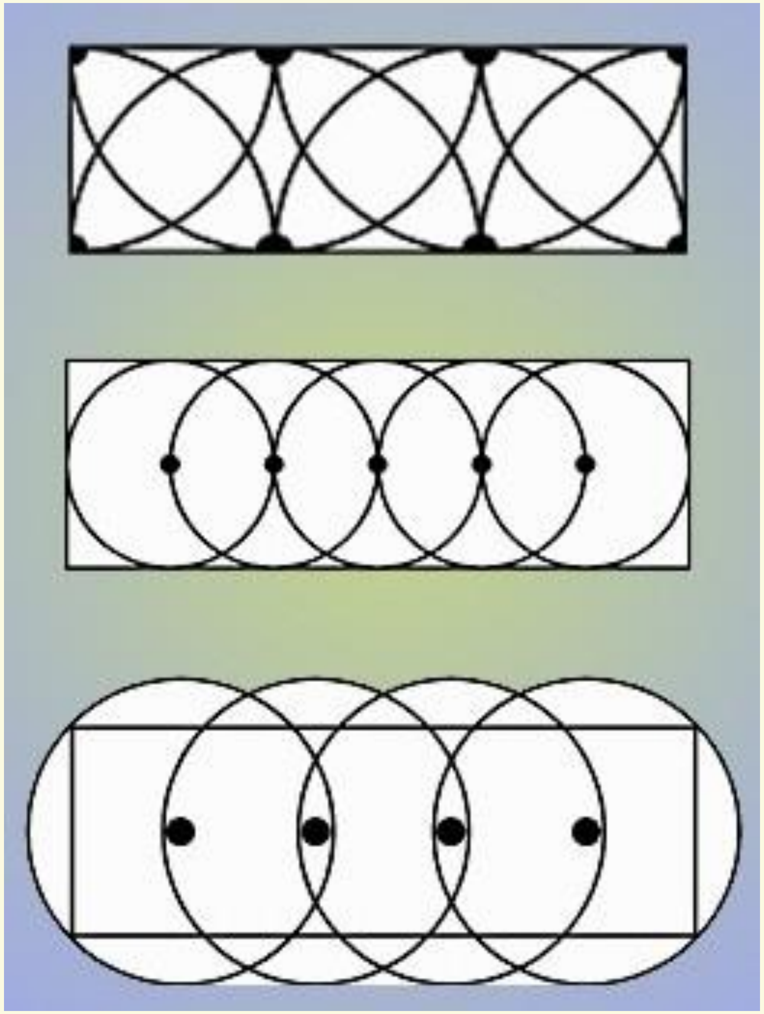


One sprinkler applies a lot of water close in and less water farther away, so watering is uneven.



When sprinklers are set so that patterns overlap, the entire area gets an even amount of water.

Check Sprinkler Overlap



CORRECT
- High uniformity
- No waste

INCORRECT
- Poor uniformity
- Inadequate irrigation

INCORRECT
- Poor uniformity
- Wasted water

Drip Irrigation 1

- Also known as:
  - Trickle irrigation
  - Micro-irrigation
  - Low-volume irrigation

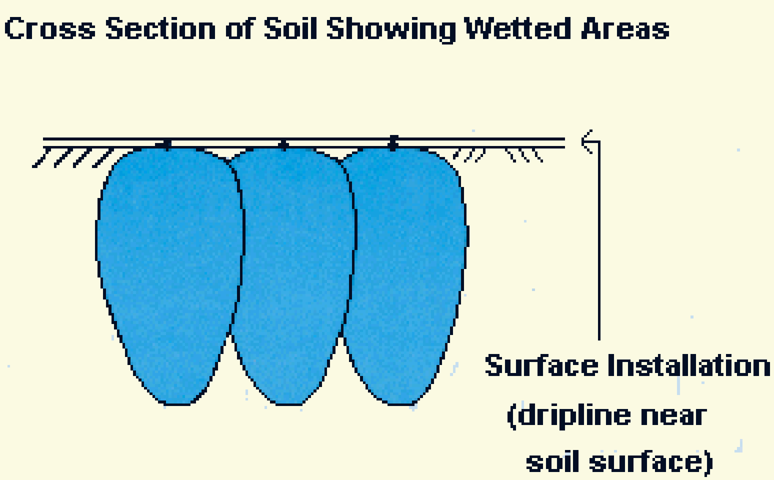
Drip Irrigation 2

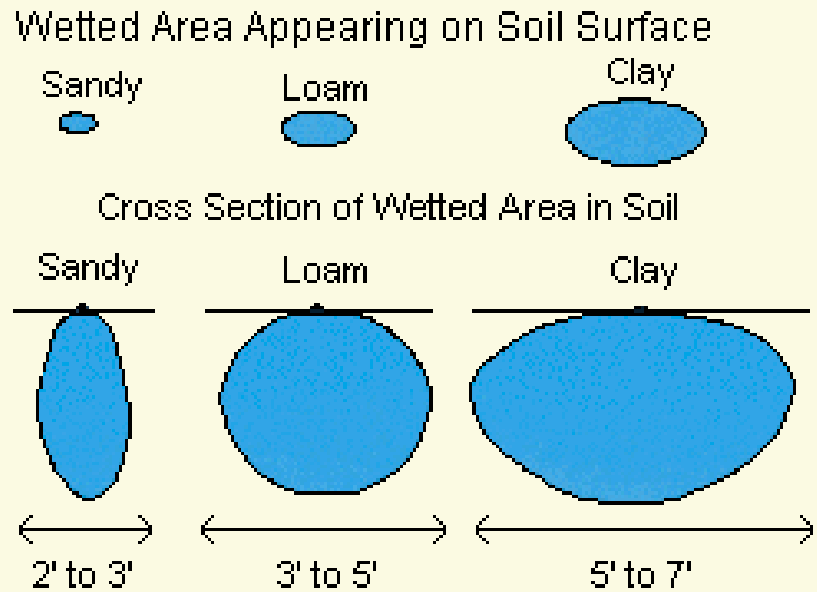
- 0.5-2.0 GPH flow rate per emitter
- 2-5 GPM/acre for water supply
- Point use gives less runoff, less evaporation, easier weed control,
  saves 30%-50% water
- Low pressure of 6-20 psi means smaller pumps & pipes
- Can fertilize through system
- Do field work while irrigating

Drip Irrigation 3

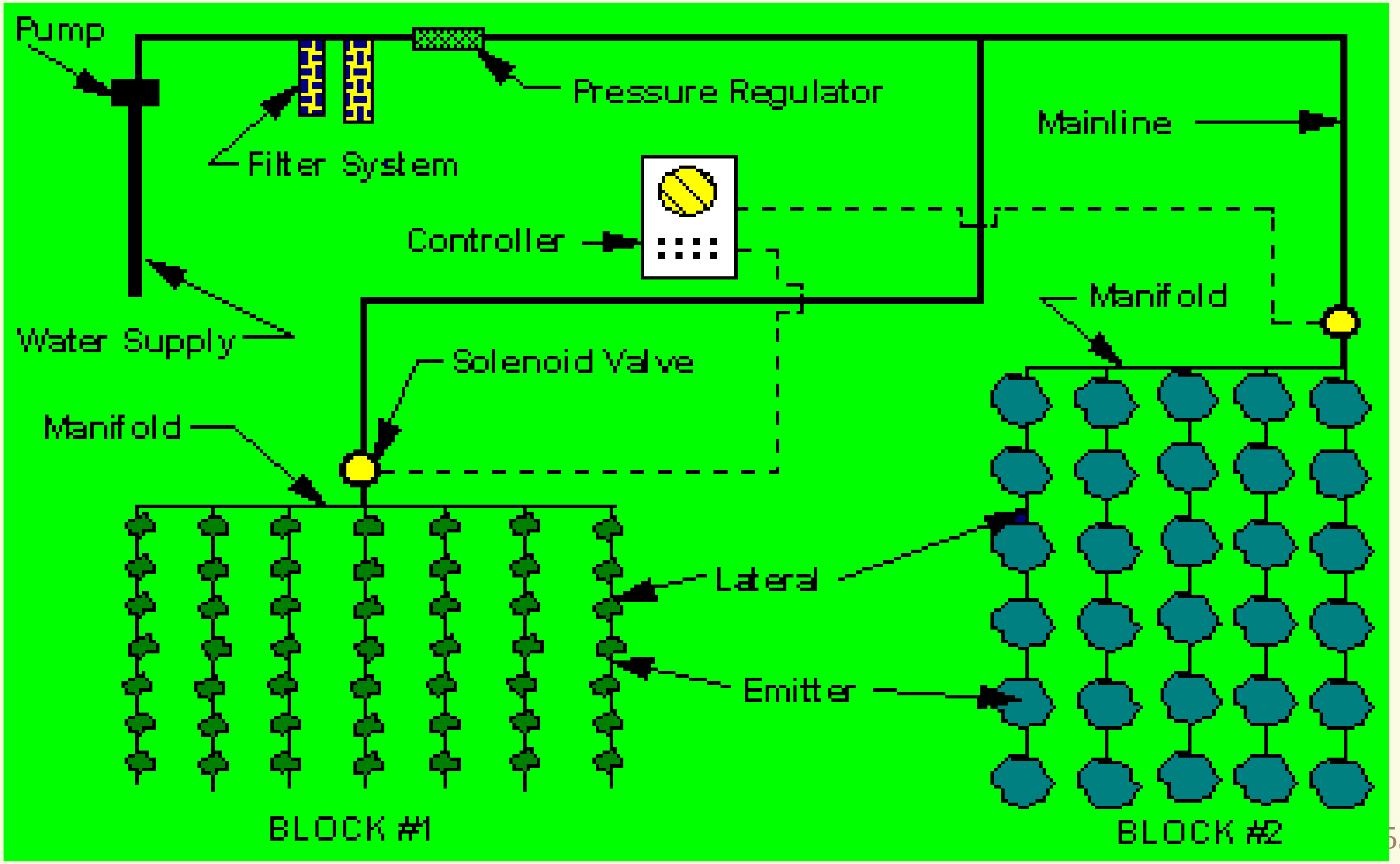
- Can automatically control
- Susceptible to clogging
- Must design system to carefully match equipment to elevation
- Requires diligent management
- Cost = $900 - $1200 for 1st acre;
  $600 - $800/acre for rest

Wetting Patterns (Drip)





Example Layout of Drip Irrigation System



Drip Irrigation Components 1

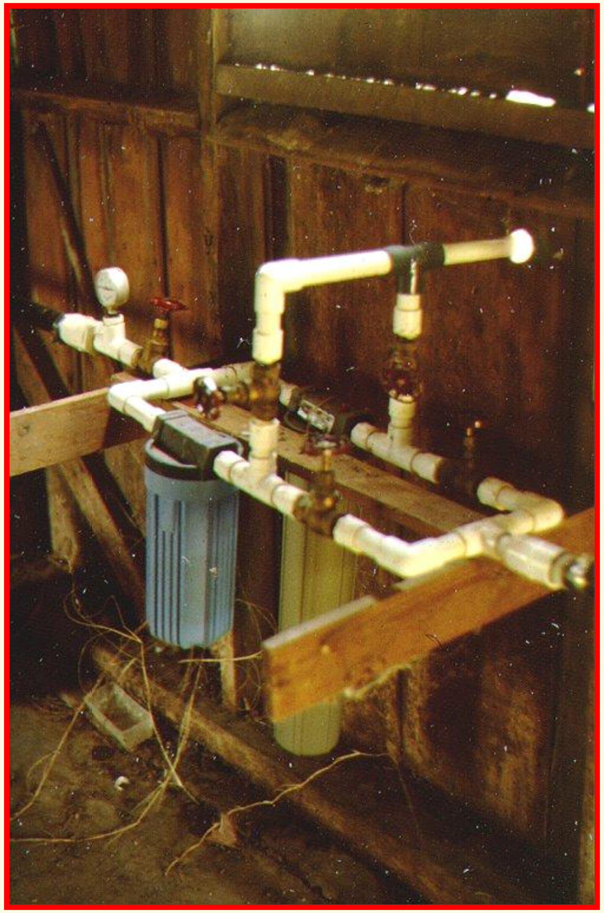
- Power Supply
  - Electric = 1st choice
  - Gas, diesel, propane = 2nd choice
  - Gravity = ram pumps
- Pump system
  - Higher elevation = lower horsepower
  - Size to elevation & system pressure
  - Pressure tank vs. throttling valve control

Drip Irrigation Components 2

- Check valve(s)
  - Stop backflow into water source
  - Critical if fertigating
- Filter system
  - 150-200 mesh screen
  - Manual or automatic backflushing
  - If you can see particles, the system can plug

Filter Selection 1

- Cartridge filter
  - Best with well water on very small systems
  - Made of paper or spun fiber
  - Disposable or washable
  - Install in pairs to avoid service downtime
  - Clean when pressure loss exceeds 5-7 psi



Filter Selection 2

- ✓ Screen filter
  - 150-200 mesh, 3/4” to 6” dia.
  - Slotted PVC, perf. or mesh stainless steel or nylon mesh
  - Manual or automatic flush
- ✓ Disc filter
  - Stack of grooved wafers
  - Provides more filter area than screen of same size
  - Cannot handle sand well

Filter Selection 3

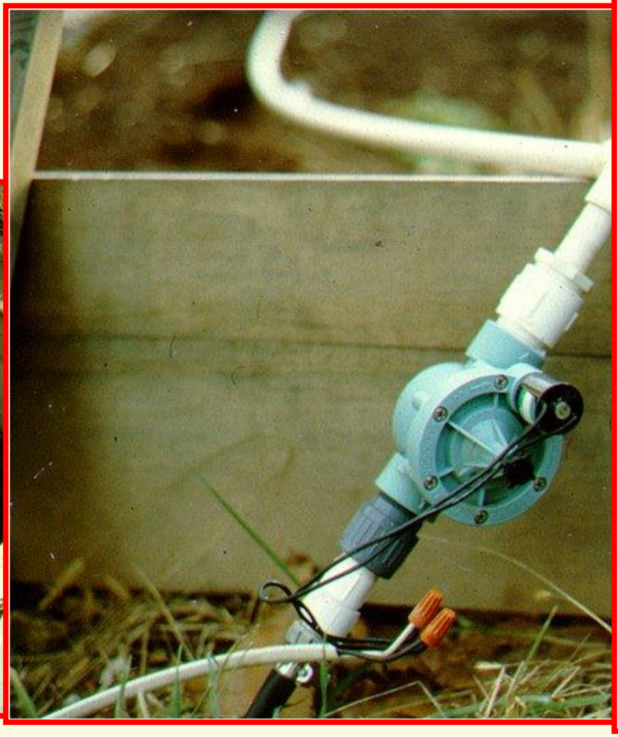
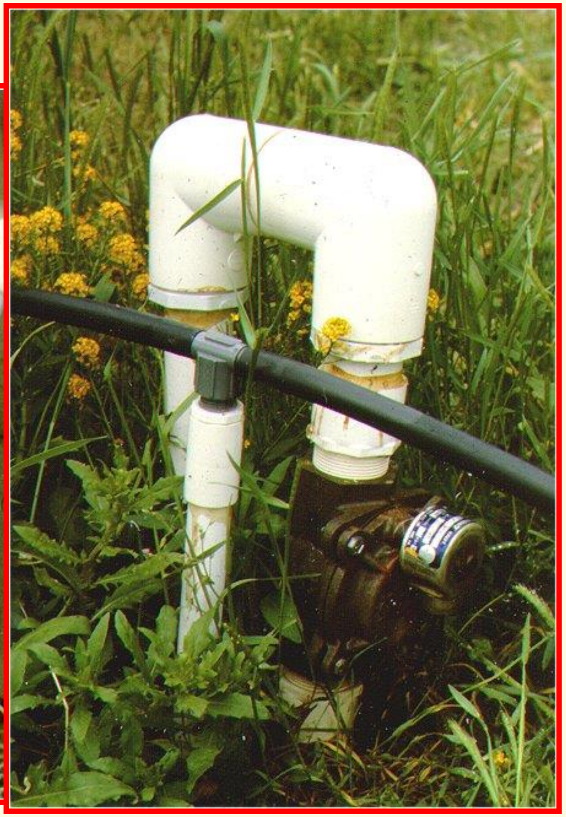
- Sand media
  - 14” to 48” diameter
  - Use swimming pool filter for smaller systems
  - Use pairs of canisters for larger systems
  - #16 silica sand = 150-200 mesh screen
  - Work best at < 20 GPM flow per square foot of media
  - Follow with screen filters
  - Backflush to clean

Drip Irrigation Components 3

- Pressure regulation
  - Depends on field slope & pipe layout
  - In-line regulators
  - Pressure tank(s) = match to pump cycle rate to avoid pump burnout
- Solenoid valves
  - Low-voltage water control valves
  - Mount above ground for easy service

Solenoid Valves

- Low-voltage water control valves
- Mount above ground for easy service

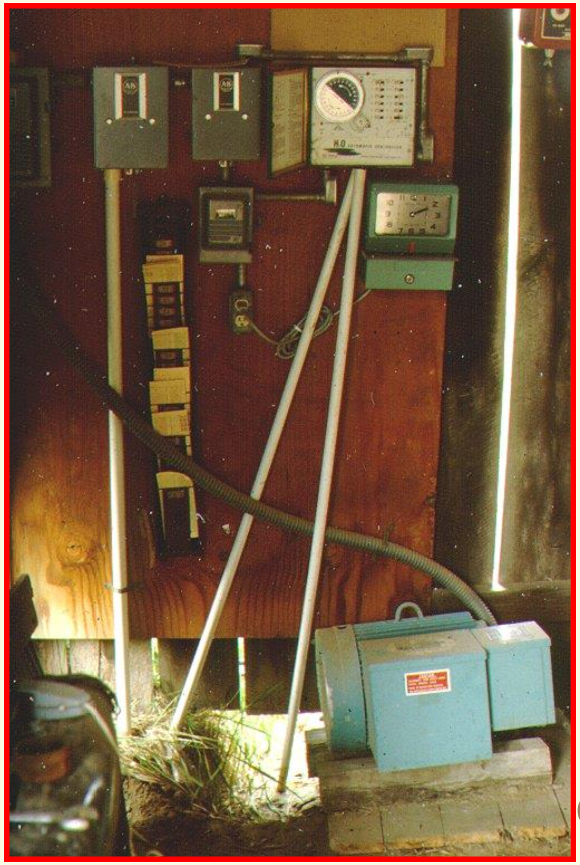




Drip Irrigation Components 4

- Controller
  - Time clock switches solenoid valves
- Mainline
  - Carry water to each irrigation block
  - Buried 1.5" - 3" dia. PVC pipe
- Manifolds
  - Meter water from mainlines to laterals
  - Buried 3/4" - 2" PVC or PE pipes

Controller

- ✓ Protect controllers from weather & pests
- ✓ Use proper wiring (Type UF or USE)



Drip Irrigation Components 5

- ✓ Laterals
  - Carry water down rows to the plants
  - Surface or buried 3/8" - 3/4" PE pipe
  - Thin-wall "tape" for close-growing crops

- ✓ Emitters
  - Deliver water to the plants
  - 0.5 - 2 GPH "in-line" or "on-line" units
  - Pressure-compensating or not

Laterals & Emitters 1

- Operating pressure in laterals
  - Thin-wall “tape” = 4-8 psi
  - Non-P.C. emitters = 8-15 psi
  - P.C. emitters = 10-60 psi
- Max. pressure variation in plant block = 20 psi (+/- 10 psi)

Laterals & Emitters 2

- Extend laterals 10-20 ft. past row end to serve as debris trap

- Use air relief valve at high point of each plant block to stop shutoff suction

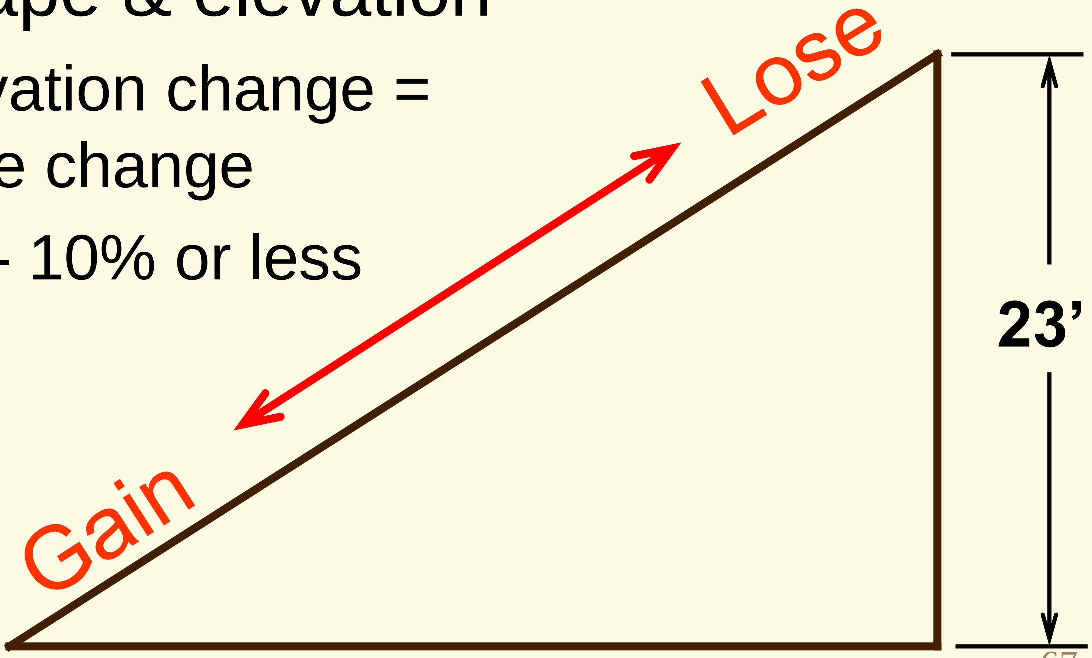
Laterals & Emitters 3

Split water flow for
low-use plants

Roll up & store laterals
at end of season

Design Considerations 1

- ✓ Water supply capacity
- ✓ Hours of operation per day
- ✓ Field size, shape & elevation
  - 2.31 feet elevation change = 1 psi pressure change
  - Design for +/- 10% or less flow variation
- ✓ Plant spacing
- ✓ Row spacing



Design Considerations 2

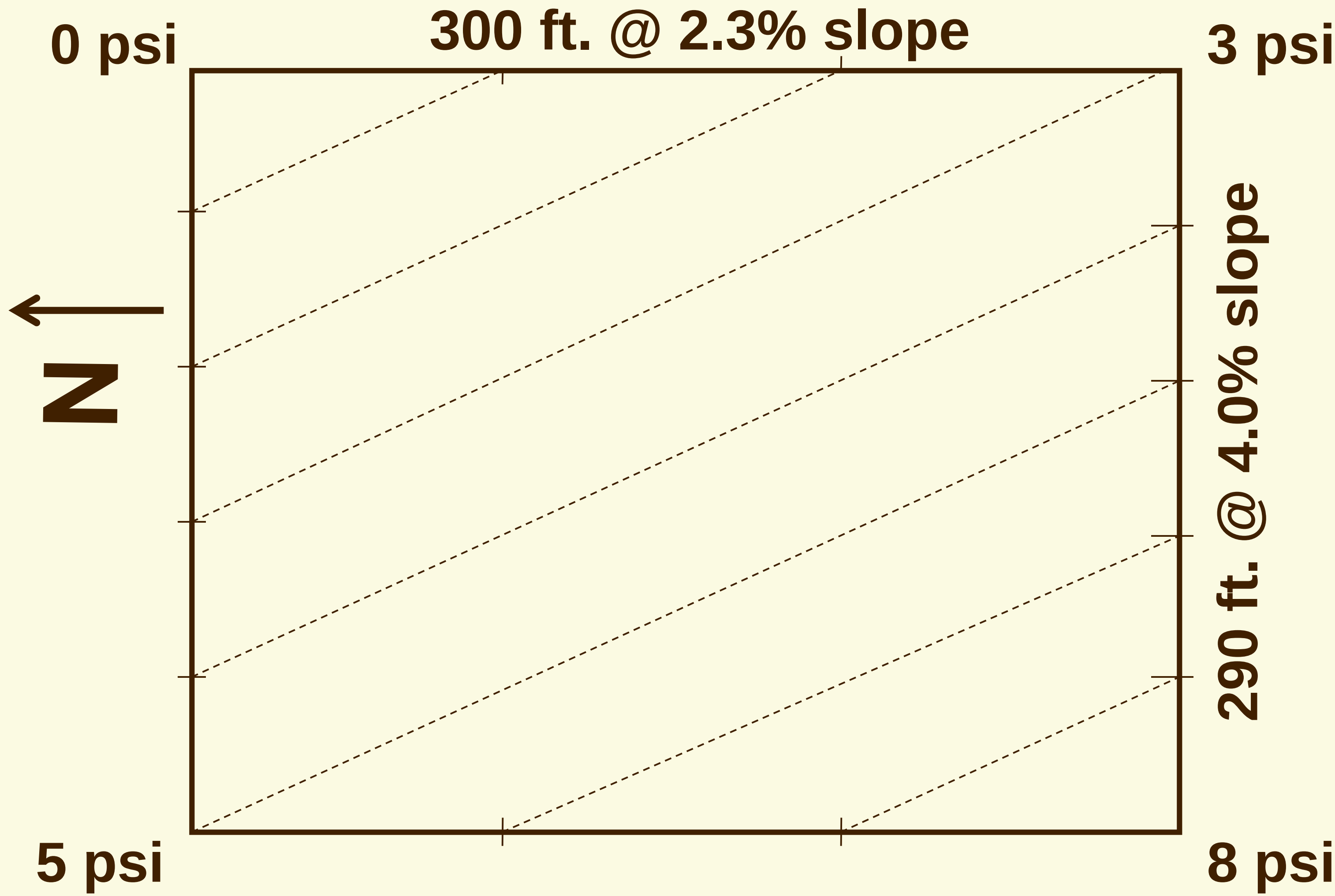
- ✓ Emitter selection & location
- ✓ Clogging control - air relief valve
- ✓ Burial and draining
  - – Frostline depth = 24"- 30"
  - – Flush with air
- ✓ Pipe protection under roadways
- ✓ Animal damage
- ✓ Expansion

Planning Your System [1]

✓ **Make a field plan**

– Show field size, shape, elevation contours
– Show distance to water source, electricity
– Note soil type, climate, air drainage
– Example: Two acres grapes
a. 290' x 300' field, 4.0% slope across rows, 2.3% along row
b. **37 plants per row** 8' o.c., **28 rows** 10' o.c.,
c. Irrigate up to 20 hrs./day

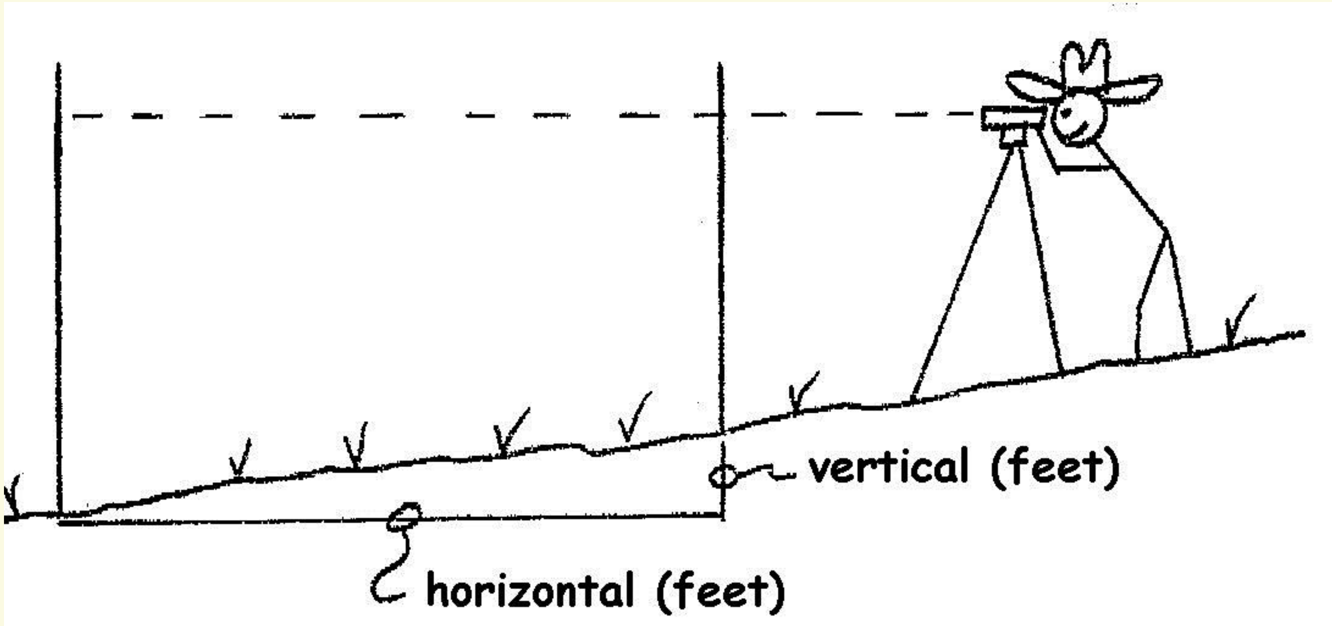
Sample Field Plan 1



Slope Measurement by Elevation Change

Two types of instruments

- Builder's level and measuring rod
- Line level + string + tape measure + stake

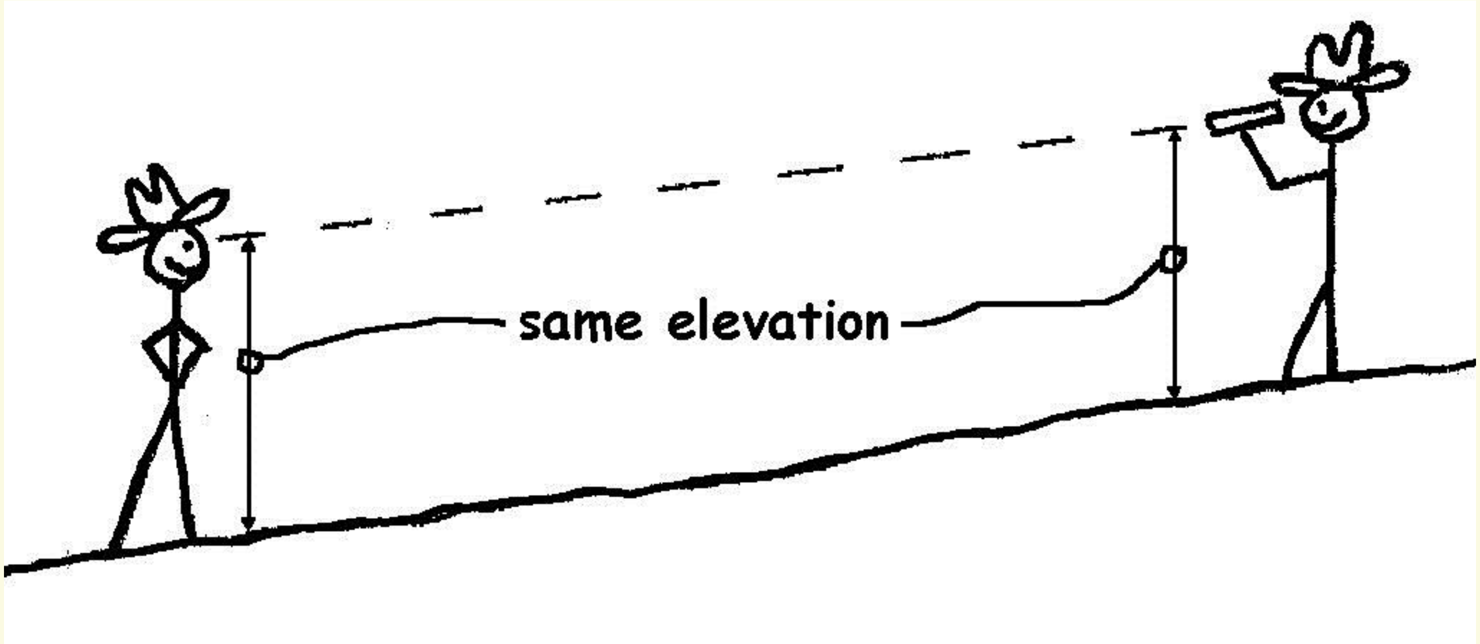


Slope in % = (vertical / horizontal) x 100

Slope Measurement by Direct Reading

Two types of instruments

- Clinometer (Abney level)
- “Smart” level (electronic)



Plant Water Requirements

(Design rates for southwest Missouri assuming no effective rainfall for >60 days.)

Fruit Crop	Plant x Row Spacing, Ft.	Sq.Ft./ Plant	Plants/ Acre	Gal/Plant/Day Gal/Acre/Day
Apples	6 x 14	84	518	8 4144
	18 x 26	468	93	42 3906
Peaches	15 x 20	300	145	28 4060
	18 x 20	360	121	34 4114
Grapes	8 x 10	80	540	10 5440
	8 x 16	128	340	16 5440
Blueberries	4 x 12	48	908	4 3632

Planning Your System 2

- **Calculate minimum pumping capacity needed & compare to water source**
  - GPD = Gallon/plant/day x # of plants
    Example: Two acres 8' x 10' grapes
    10 GPD x 1,080 plants = 10,800 gal.
    per 20 hr. day = 540 GPH
    = **9.0 GPM**

Planning Your System 3

- **Calculate area irrigated at once**
  - # of plants = Well capacity / GPH applic. rate
  - Allow for home water demand
  - Balance well cap. to row length & block size
  - Example: 3 BR, 1 1/2 bath home & 19 GPM well
    a. Home needs 10 GPM , so field gets 9 GPM
    b. (9 GPM well cap. x 60 min/hr) ÷ **1 GPH/plant** = 540 plants
    c. 540 plants / 37 plants/row ≈ **14 rows at once**
    d. 28 total rows / 14 rows/block = **2 blocks**
    e. 2 blocks x 10 GPD/plant ÷ 1 GPH/em. = **20 hrs.**

Pumping Head Calculations

- Total head in feet is the sum of:
  - Elevation from water source to high point
  - Pipe friction loss
  - Discharge pressure
  - Miscellaneous friction loss of elbows, risers, valves, etc.
- Remember conversion of:

  2.31 feet = 1 psi

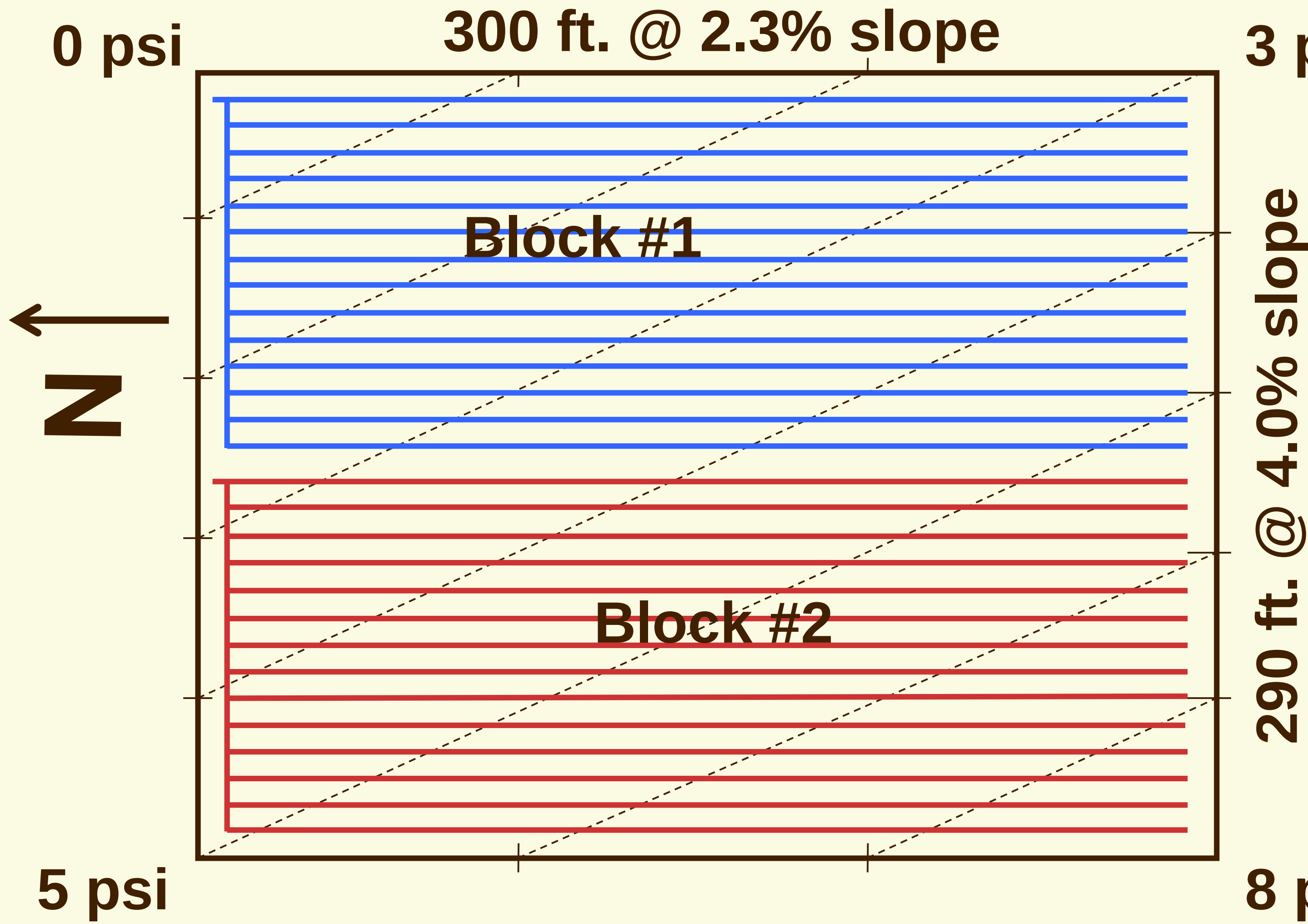
Friction Loss Design

- Size piping for 1 psi or less pressure loss per 100 feet
- Pipe friction may replace pressure regulators on downhill runs
- Vary flowrate no more than 20% (+/- 10%) within each block of plants
- Manifolds attached to mainline...
  - at center if < 3% slope
  - at high point if 3+% slope

Plastic Pipe Friction Loss

	Pipe Diameter, inches			
	0.75"	**1"**	**1.5"**	**2"**
GPM	**PSI Loss per 100 ft. of pipe**			
5	2.8	0.8	0.1	--
10	11.3	3.0	0.4	0.1
15	21.6	6.4	0.8	0.2
20	37.8	10.9	1.3	0.4
25	--	16.7	1.9	0.6
30	--	--	2.7	0.8

Sample Field Plan 2

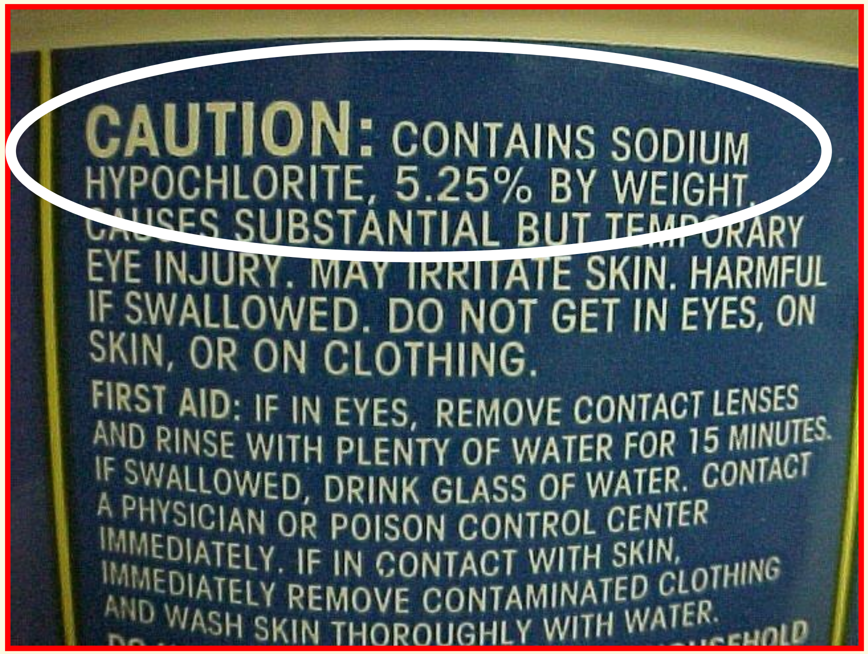


Troubleshooting Guide

Symptom	Possible Causes
Reddish-brown slime or particles near emitters	Bacteria feeding on iron
White stringy masses of slime near emitters	Bacteria feeding on sulfur
Green or slimy matter in surface water	Algae or fungi
White film on tape or around emitters	Calcium salts or carbonates
Presence of silt or clay	Inadequate filtration

Chemical Injection 1

- Kill bacteria & slime
  - Chlorine needs "contact time"
  - Powdered HTH can plug emitters

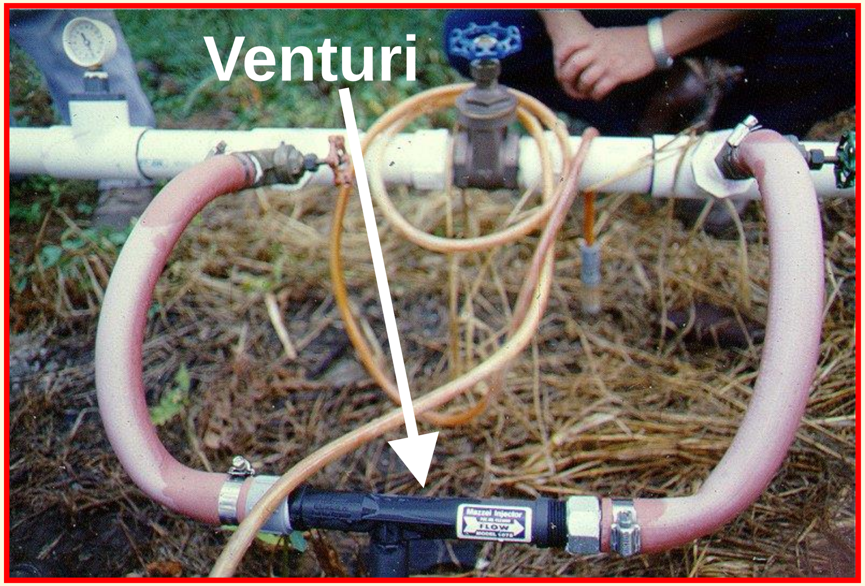


Chemical Injection 2

- Control pH with acid
  - Help acidify soil for plants (blueberries)
  - Dissolve Mn, Fe, Ca precipitates
  - Make chemicals work better

Chemical Injection 3

- Apply fertilizer
  - Be sure it's 100% water-soluble
  - Always inject it two elbows before the filter for good mixing



Horticulture Irrigation Exercise

Design a Drip System for Tomatoes

Irrigation Resources on the Web

- Irrigation System Planning & Management Links
  extension.missouri.edu/webster/irrigation/

- Missouri Digital Soil Survey
  soils.missouri.edu/

Questions??

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UNIVERSITY OF MISSOURI Extension

Program Complaint Information

To file a program complaint you may contact any of the following:

University of Missouri

- MU Extension AA/EEO Office
  109 F. Whitten Hall, Columbia, MO 65211
- MU Human Resources Office
  130 Heinkel Bldg, Columbia, MO 65211

USDA

- Office of Civil Rights, Director
  Room 326-W, Whitten Building
  14th and Independence Ave., SW
  Washington, DC 20250-9410