UC Cooperative Extension

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Agriculture and Natural Resources

Design and Operation of Resource-efficient Micro-irrigation Systems for Vineyards

UC ANR Wine Grape Irrigation Short Course
May 22, 2019 – Napa, CA

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PRESENTATION OUTLINE

1) Design Considerations for Micro-Irrigation Systems

2) Vineyards' Water and Energy Requirements – Practical Examples

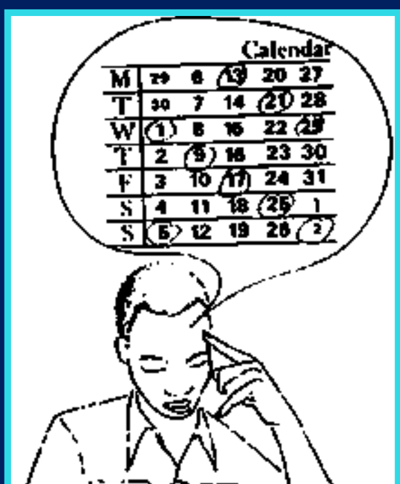
3) Irrigation System Evaluation

4) Some Maintenance Recommendations

WHAT IT TAKES TO BE RESOURCE-EFFICIENT?

Good System Design

✓Accurate & Skilled
✓Flexible Operation



DESIGN

Proper Installation
Regular Maintenance
System Evaluation

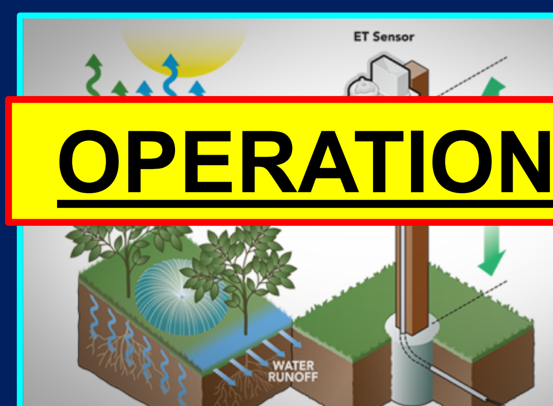
MAINTENANCE

Defined Irrigation Strategy

- Full Irrigation
- Deficit Irrigation (SDI, RDI)
- Homogeneously or VRI

Accurate
Irrigation Scheduling
& Control

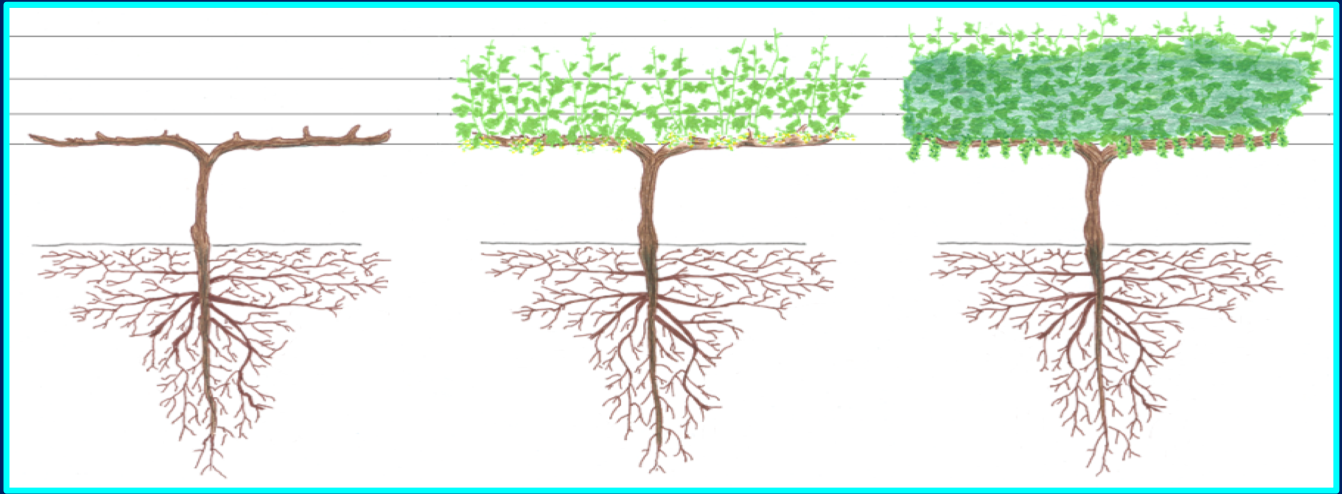
Schedule Implementation
& Feedback



OPERATION

Root system of mature grapevine consists of woody root frame with smaller absorbing roots branching in multiple directions:

- ✓ Mine the soil deeply and horizontally
- ✓ Thrive in soils with good balance between water and air (un-saturated soils)
- ✓ Do not benefit from soil compaction, waterlogging and long wet-dry cycles



Low volume micro-irrigation is mostly used for grapevine, as it allows careful management of amounts and timing of irrigation/nutrient applications

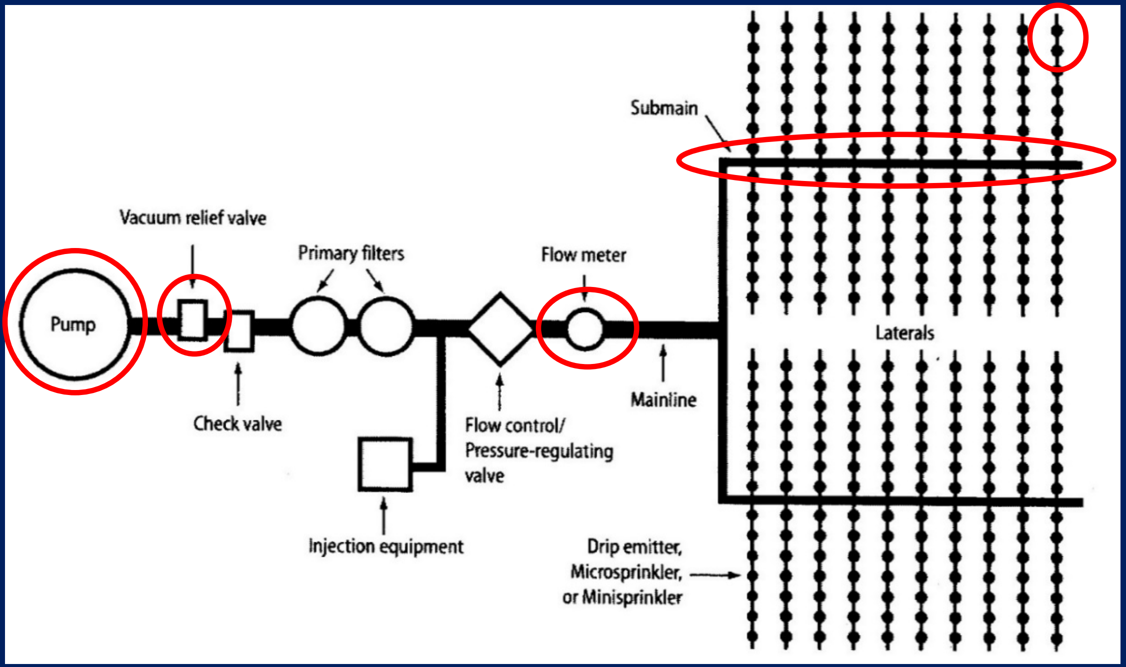
<u>Surface</u> and <u>sprinkler irrigation</u> have been associated with increased incidence of fungal diseases to leaves, canopy and clusters.

DESIGN STAGE - Aspects where to focus attention:

- ✓ Preliminary site evaluations (water supplies, soil type and variability, slope, aspect, vine spacing & row orientation, trellis system, projected canopy size)
- ✓ Define the **Water Application Rate** (in/hr) and **Max Irr. Depth** (in.) based on soil properties (**infiltration rate**; **water holding capacity**, slope, etc.) and crop ET

Rule of Thumb: Apply the peak daily ET (in/day) in 16-20-hr set time max

Size the different system's components from downstream to upstream



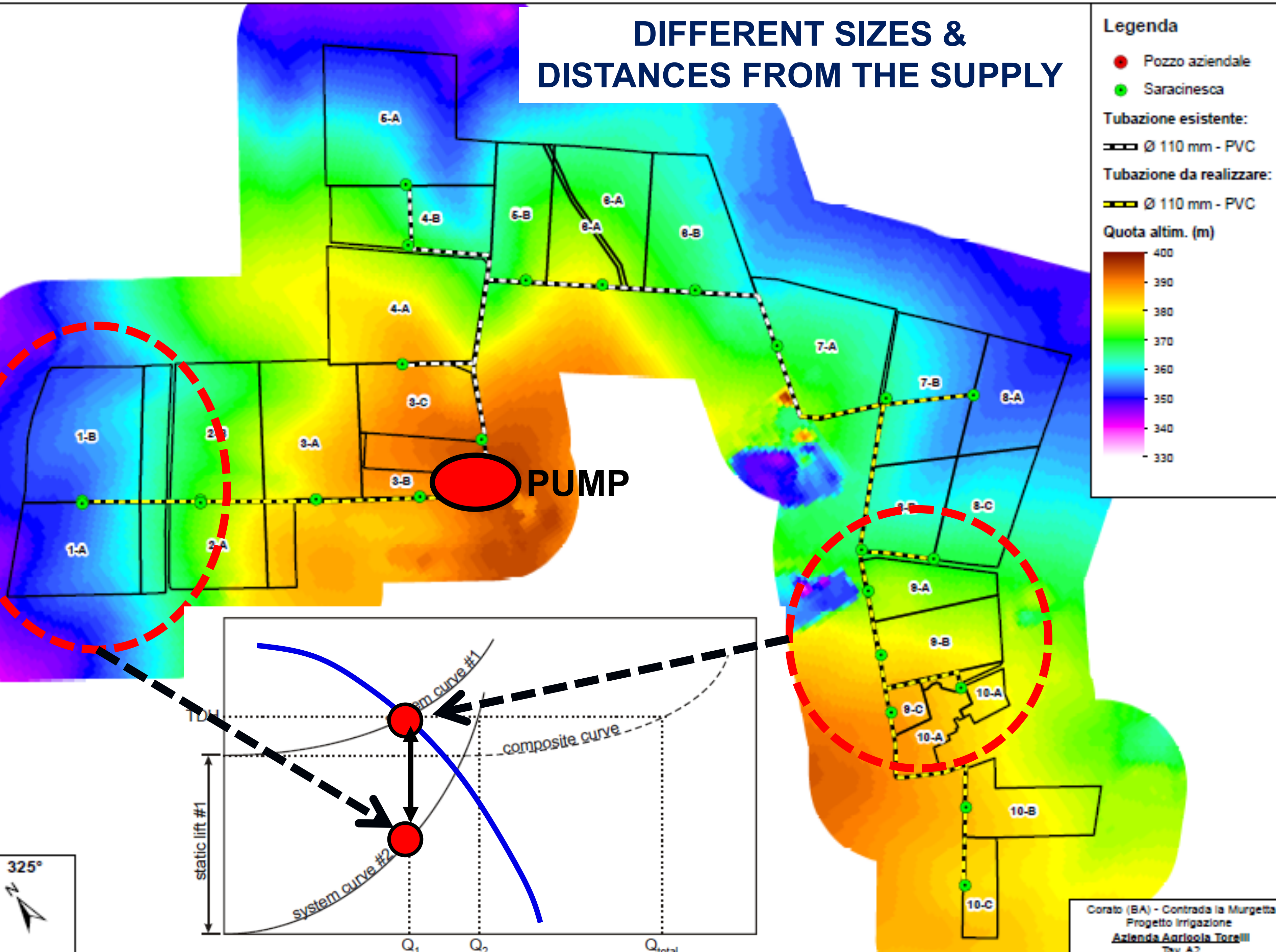
- ✓ Calculate flow and friction losses along the pipe system
- ✓ Size the various parts with sufficient capacity to ensure the routine and max system's load
- ✓ Ensure operational flexibility to the system

Flexibility of Operation => range of operating conditions (Q, P) (adjusting operation to various system's loads)

During its life the irrigation system may be operated under different conditions:

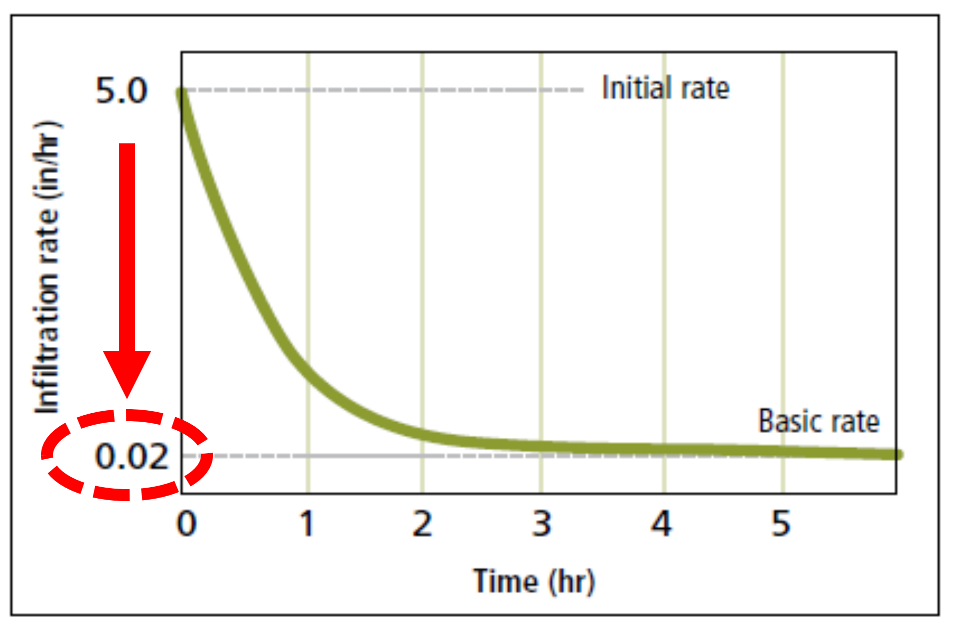
- Water needs of young vines are small, then increase with time (Q)
- Blocks at different elevations and distances from the water supply (P)
- Blocks with different emitters (application rates), due to soil differences (Q, P)
- Composite systems (different flow rate and pressure => drip and micro-sprinkler, single and dual-line, alternating or solid irrigation, etc.) => (Q, F)
- Groundwater level fluctuating or decreasing with time, pump wearing (P)

DIFFERENT SIZES & DISTANCES FROM THE SUPPLY



1^{st} RULE OF THUMB:

APPLICATION RATE (in/hr) << SOIL INTAKE RATE (in/hr)



System	Appl. Rate (in./hr)
Surface Irrigation	0.40 – 0.45
Sprinkler Irrigation	0.12
Micro-sprinkler	0.05
Drip Irrigation	0.01 - 0.03

Soil type	Maximum application rate (in/hr) at slope		
	0–5%	5–8%	8–12%
coarse sandy soil	1.5–2.0	1.0–1.5	0.75–1.0
light sandy soil	0.75–1.0	0.5–0.8	0.4–0.6
silt loam	0.3–0.5	0.25–0.4	0.15–0.3
clay loam, clay	0.15	0.10	0.08

2nd RULE OF THUMB:

MAX APPLIED WATER (in) << WATER HOLDING CAPACITY (in)

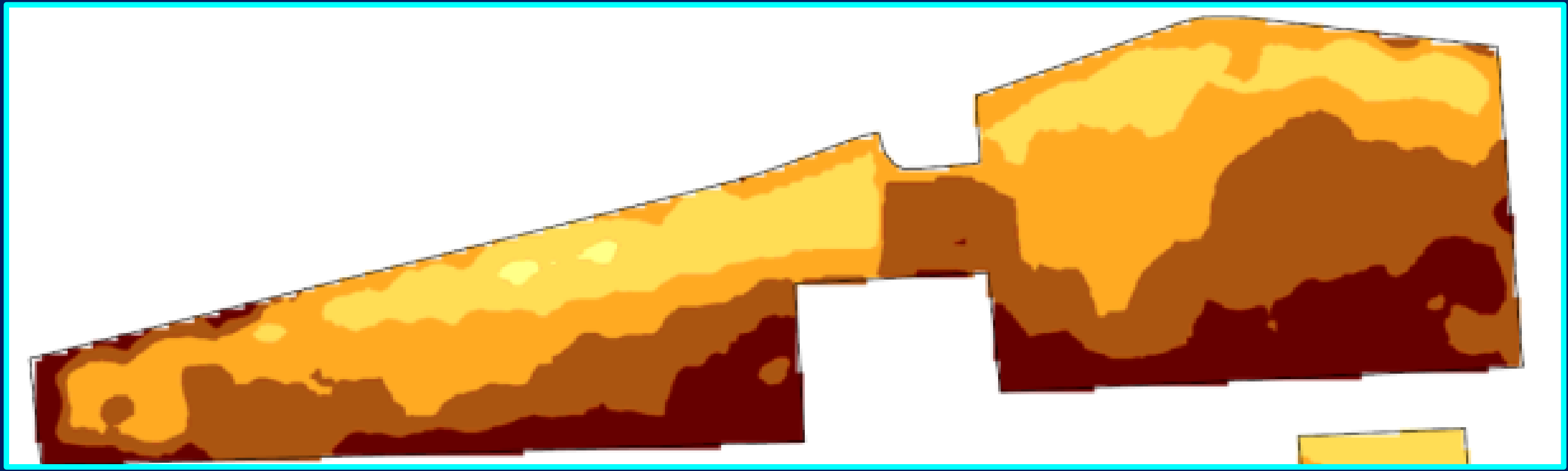
Ranges of Water-Holding Capacities for different soil types

$$(W_A = FC - WP)$$

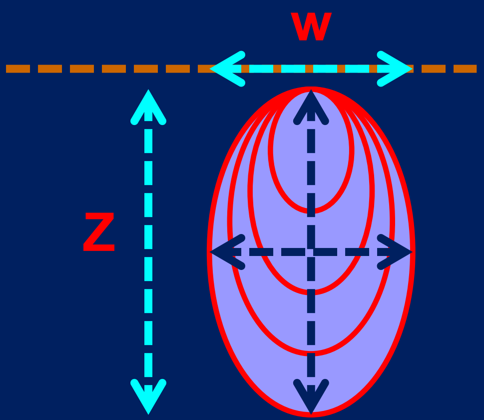
Soil texture	Water-holding capacity Range In./ft	Water-holding capacity Average In./ft
1. Very coarse texture—very coarse sands	0.38-0.75	0.50
2. Coarse texture—coarse sands, fine sands, and loamy sands	0.75-1.25	1.00
3. Moderately coarse texture—sandy loams	1.25-1.75	1.50
4. Medium texture—very fine sandy loams, loams, and silt loams	1.50-2.30	2.00
5. Moderately fine texture—clay loams, silty clay loams, and sandy clay loams	1.75-2.50	2.20
6. Fine texture—sandy clays, silty clays, and clays	1.60-2.50	2.30
7. Peats and mucks	2.00-3.00	2.50

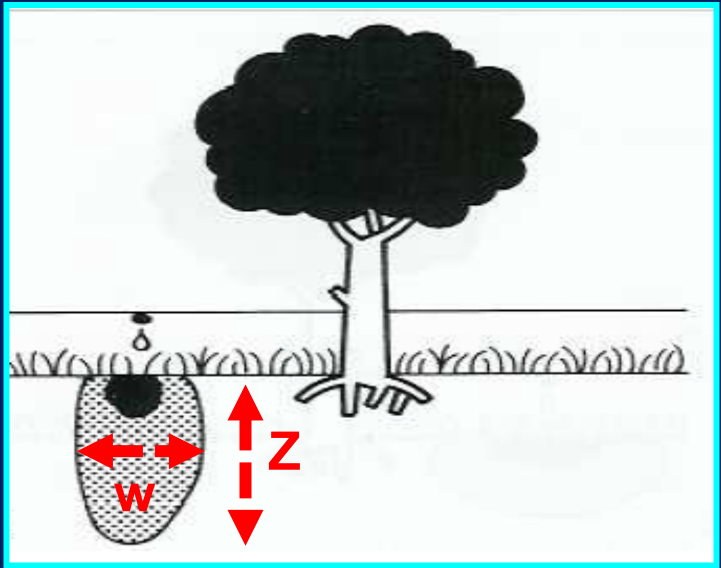
Assessing the spatial variability of soil features

Cost: $40-60 per acre



QUICK METHOD TO ESTIMATE THE HYDRAULIC FEATURES OF YOUR SOIL (k_S)





ET-BASED CALCULATION OF IRRIGATION DEPTH (D_{GMAX})

$$D_{GMAX} = (\text{Max } ET_{Daily} \times \text{Irr. Frequency}) / Eff_{APP}$$

Max ET_{Daily} = 0.25 in => Max $AW_{2\text{-}day}$ = 0.5 in/0.85 = 0.6 in (< 24 hr)

System	Eff_{APP}
Surface Irrigation	**70-85%**
Sprinkler Irrigation	**70-80%**
Micro-sprinkler	**80-90%**
Drip Irrigation	**85-95%**

Micro-irrigation systems are typically designed for the minimal cost => to deliver the peak ET/water needs in 20/24-hr set

$$T_{IRR} = \frac{D_{G\,MAX}}{Appl.\ Rate} = \frac{D_{G\,MAX}}{< Soil\ Intake\ Rate}$$

System	Appl. Rate (in./hr)
Surface Irrigation	**0.40 – 0.45**
Sprinkler Irrigation	**0.12**
Micro-sprinkler	**0.05**
Drip Irrigation	**0.01 - 0.03**

SOIL-BASED CALCULATION OF MAX IRRIGATION DEPTH (D_{GMAX})

$$D_{GMAX} = \left[\left(\frac{MAD}{100} * \frac{P_W}{100} * W_a * Z_E \right) / Eff_{APPL.} \right]$$

D_{GMAX} (in.) = Max. Gross Depth of water to apply per irrigation

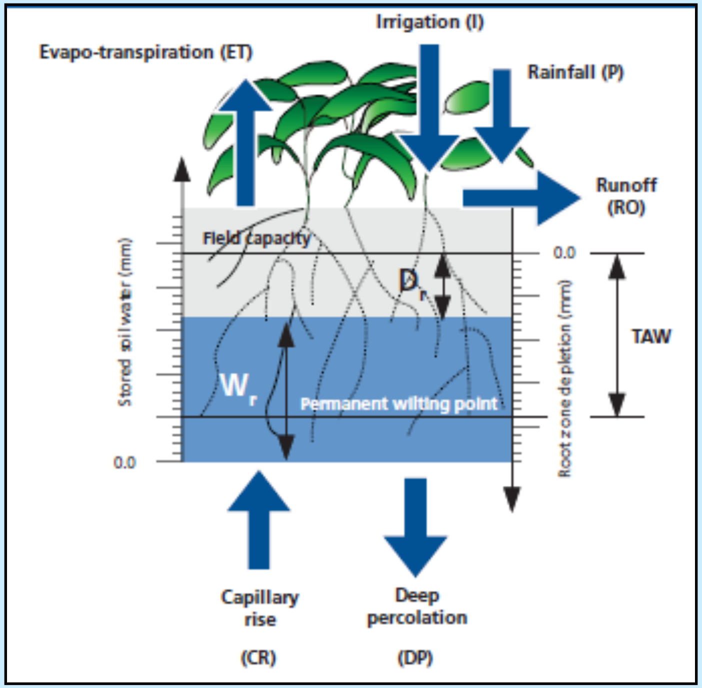
W_a (in./ft.) = Water-holding Capacity of the soil (FC-WP)

MAD = Management Allowable Depletion (moisture depletion threshold for no stress)

P_W (%) = Percent Wetted Area

Z_E (ft.) = Effective Root Depth (60-70% of actual root depth)

$Eff._{APPL.}$ = Application Efficiency of the selected irrigation method



How to convert water depth (in.) to gallons per plant?

$$Water\ volume\left(gals/day\right) = Water\ Depth\ (in/day) * crop\ spacing\ (ft^2) * 0.623$$

Crop Spacing (ft^2) = row spacing × plant spacing	Evapotranspiration (inches per day)							
	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
100	3	6	9	12	16	19	22	25
200	6	12	19	25	31	37	44	50
400	12	25	37	50	62	75	87	100
600	19	37	56	75	93	112	131	150
800	25	50	75	100	125	150	174	199
1000	31	62	93	125	156	187	218	249
1200	37	75	112	150	187	224	262	299
1400	44	87	131	174	218	262	305	349
1600	50	100	150	199	249	299	349	399
1800	56	112	168	224	280	336	392	449
2000	62	125	187	249	311	374	436	498
2200	69	137	206	274	343	411	480	548
2400	75	150	224	299	374	449	523	598

From Larry Schwankl, Blaine Hanson, and Terry Prichard, *Low-Volume Irrigation*. University of California, Davis, 1993.

Calculation Example

<u>Mature vineyard</u>: Cabernet Sauvignon, 5 ft. x 6 ft. spacing, VSP trellis

Irrigation system: Single dripline

Root depth, Z = ~ 5 ft.

Effective rooting depth, Z_E = 70% x 5 ft. = 3.5 ft.

Wetted area, P_W = 25%

<u>Sandy loam soil</u>

F.C. = 3.25 in./ft

P.W.P. = 1.67 in./ft

T.A.W. = 3.25 – 1.67 = 1.60 in/ft

M.A.D. = 50 % of T.A.W. = 0.5 x 1.60 in/ft = 0.80 in/ft

<u>Max gross irrigation depth to apply</u>

$\mathbf{D_G}$ = (MAD * TAW * Pw * Z_E)/Eff_A = (0.5 * 1.60 in/ft * 0.25 * 3.5 ft)/0.85 = **<u>0.8</u> in.**

Vol (gal/plant) = D_G x Spacing x 0.623 = 0.8 in. x 5 ft x 6 ft x 0.623 **= <u>15</u> gals/plant**

Typical Flow Rates and Pressures

Drip & Micro-sprinkler: 0.5-30 gph @ operating pressures of 20-35 psi

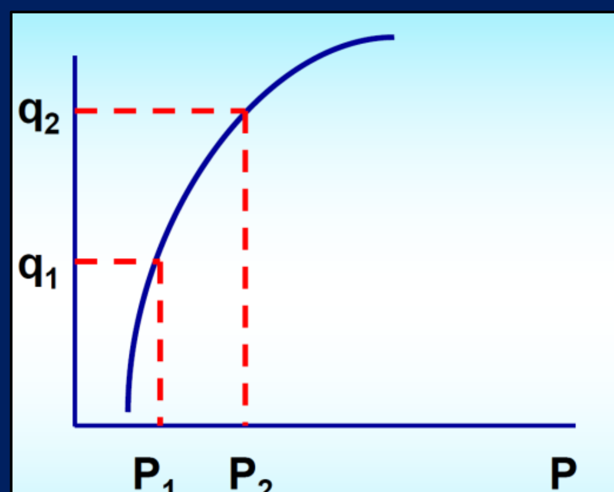
- Micro-irrigation emitters require only 7-12 psi (drippers - fanjets);
- Filtering and delivering water to the emitters on flat grounds typically require additional 15-20 psi;
- Filters are the critical system's components, requiring around 15-25 psi (30-35 psi if of back-flushing type);

Most Relevant System's Components

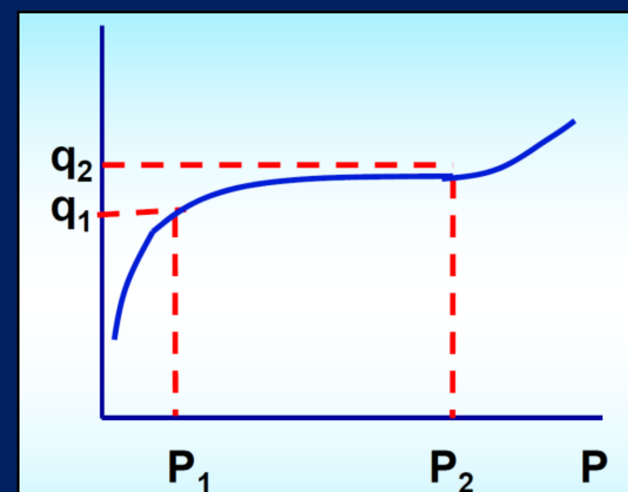
Monitoring Flow and Pressure aims at detecting problems and correcting them in timely manner

$$q = k \cdot P^x$$

NON-PC EMITTERS (x > 0.5)



PC EMITTERS (x < 0.5)



ENERGY REQUIREMENTS FOR IRRIGATION

It takes 1.37 whp-hr/ac-ft per foot of lift

(power the pump must provide to lift 1 ac-foot of water by 1 foot)

FUEL SOURCE	PUMP OUTPUT
ELECTRICITY	0.885 whp-hr/kWh
NATURAL GAS (925 BTU)	61.7 whp-hr/MCF
NATURAL GAS (1000 BTU)	66.7 whp-hr/MCF
DIESEL	12.50 whp-hr/gal
PROPANE	6.89 whp-hr/gal

Source of Energy	Energy Units to Lift Water
Electricity	1.55 kWh/ac-ft per foot of lift
Natural Gas (925 BTU)	0.22 MCF/ac-ft per foot of lift
Natural Gas (1000 BTU)	0.20 MCF/ac-ft per foot of lift
Diesel	0.10 Gal/ac-ft per foot of lift
Propane	0.20 Gal/ac-ft per foot of lift

Source: Nebraska Pumping Plant Performance Criteria (NPPPC)

Mature Vineyard with Micro-Sprinkler vs. Drip Irrigation

Vineyard (ET - R_{EFF})= 18 in. => 1.5 ft. of water per season

Area = 40 acres

Irrigation methods: Micro-Sprinkler (35 psi) vs. Drip Irrig. (25 psi) @ pump out.

Water Lift = 100 ft (from aquifer level to ground)

$TDH_{MICRO\text{-}SPR.}$: 100 ft + (35 psi x 2.31 ft/psi) = **180 ft.**

TDH_{DI}: 100 ft + (25 psi x 2.31 ft/psi) = **158 ft.**

Total ac-ft $_{MICRO\text{-}SPR.}$ = 1.5/0.80 = 1.9 ac-ft.

Total ac-ft $_{DI}$ = 1.5/0.90 = 1.7 ac-ft

Diesel => 0.10 gal/ac-ft per foot of lift

Ave. Price of Diesel for Ag.= $3.50 per gallon

System	$Eff._A$
Gravity (surface)	0.70
Drip & SDI	0.90
Micro-sprinkler	0.80
Sprinkler	0.75

Vol. Dies. Micro-Sprinkler: 40 ac x 1.9 ac-ft x 180 ft x 0.10 gal/ac-ft = **1,368 gal**

Cost for Micro-Sprinkler irrigation: 1,368 gal x $3.50 per gallon = **$4,790**

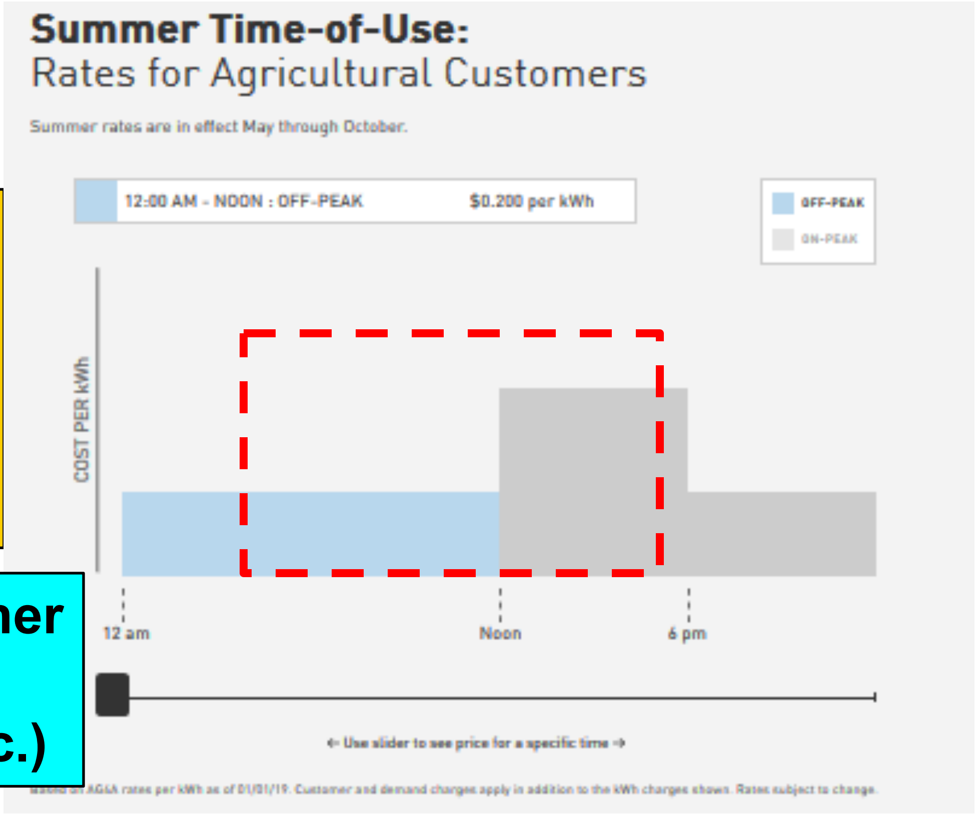
Vol. Dies. Drip Irrigation = 40 ac x 1.7 ac-ft x 158 ft x 0.10 gal/ac-ft = **1,075 gal**

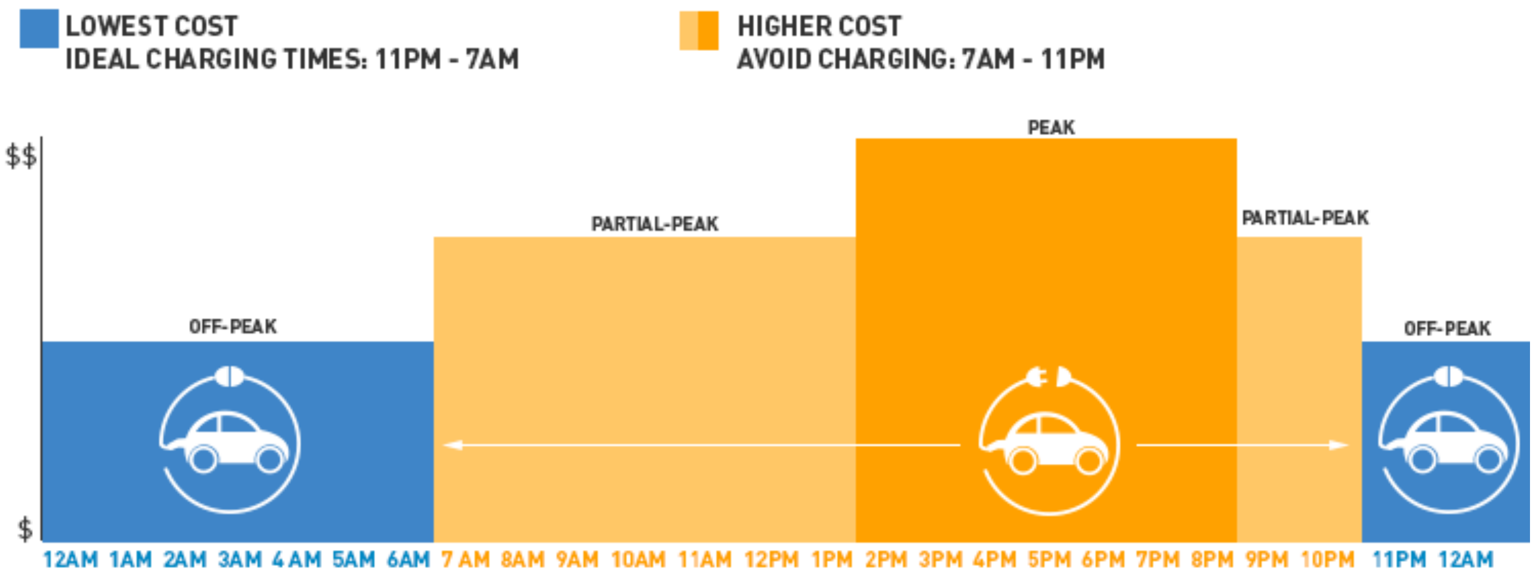
Cost for Drip Irrigation: 1,075 gal x $3.50 per gallon = **$3,760**

SOME ENERGY-RELATED CONSIDERATIONS

If soil intake rate and water holding capacity allow, appl. rate can be increased to reduce irrigation set time and benefit from tiered energy rates or DR

There are a few ways to pursue higher application rates (system retrofit, higher operating pressure, VFD, etc.)



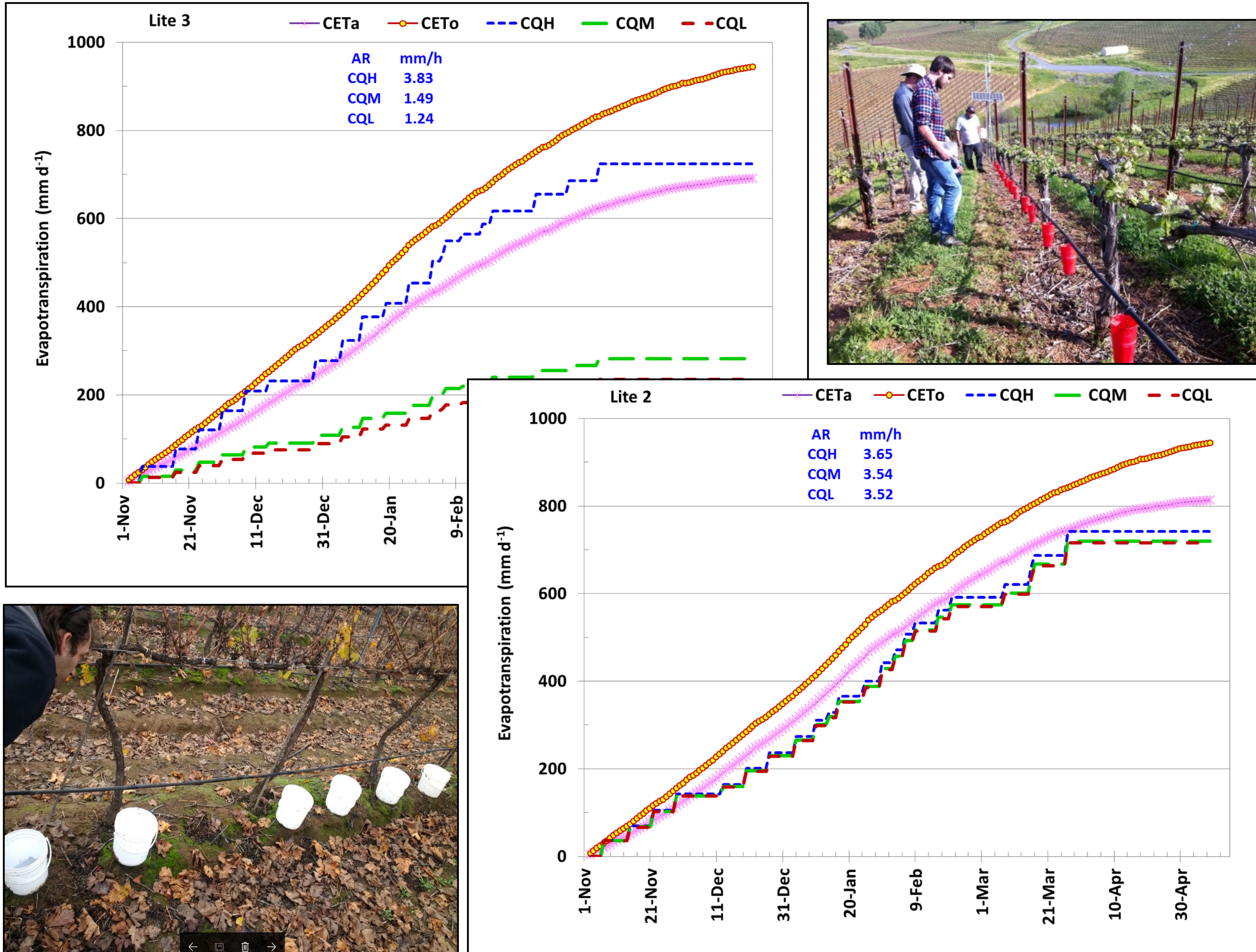


IRRIGATION SYSTEM EVALUATION

OBJECTIVES:

- ✓ Average Application Rate (in/hr)
- ✓ System Distribution Uniformity, D.U. (%)
- ✓ Identify main problems & corrections

STANDARDIZED SYSTEM EVALUATION PROCEDURE


Lite 3
CETa CETo CQH CQM CQL
AR mm/h
CQH 3.83
CQM 1.49
CQL 1.24
Evapotranspiration (mm d-1)
1000
800
600
400
200
0
1-Nov
21-Nov
11-Dec
31-Dec
20-Jan
9-Feb
Lite 2
CETa CETo CQH CQM CQL
AR mm/h
CQH 3.65
CQM 3.54
CQL 3.52
Evapotranspiration (mm d-1)
1000
800
600
400
200
0
1-Nov
21-Nov
11-Dec
31-Dec
20-Jan
9-Feb
1-Mar
21-Mar
10-Apr
30-Apr

WHAT PARAMETERS ARE MEASURED IN THE FIELD?

FLOWRATE

PRESSURE

CALCULATING DISTRIBUTION UNIFORMITY

$$D.U. = \frac{average\ flow\ of\ lowest\ 25\%\ emitters\ measured}{average\ flow\ of\ all\ emitters\ measured}$$

EXAMPLE OF D.U. CALCULATION IN A VINEYARD

0.98 gph	0.89 gph	0.95 gph	0.94 gph
0.99 gph	1.05 gph	0.99 gph	1.00 gph
1.15 gph	0.70 gph	1.05 gph	1.01 gph
0.98 gph	0.97 gph	0.96 gph	0.94 gph

The total number of emitters measured: 16
(=> 25% * 16 emitters = 4 emitters)

The average flow of all emitters measured: 0.97 gph

The average flow of the lowest 4 emitters measured (25%): 0.87 gph

The Distribution Uniformity = 0.87/0.97 = 90%

Collection time:	0.5	minutes
Hose pressure at emitters:	24.5	psi
	Collected volume:	
#1	258	mL
#2	304	mL
#3	290	mL
#4	320	mL
#5	288	mL
#6	305	mL
#7	312	mL
#8	220	mL
#9	310	mL
#10	320	mL
#11	315	mL
#12	307	mL
#13	305	
#14	312	
#15	297	
#16	304	

The average flow rate was	8.9101	gph.
The average application rate was	0.0357	in/hr.
The Flow DU for this location was	87.7764	%

Distribution Uniformity.. 85%

How your system rates:

Poor	Fair	Good	Very Good	Excellent
			X	
74 or below	75-79	80-84	85-89	90 and up

ADDITIONAL INFORMATION FROM SYSTEM EVALUATION

DRIP/MICRO EVALUATION: PROBLEMS NOTED

Ref. #

5 The field DU is considered poor

Pressure problems

Manifold inlet pressure variation is a significant problem

Possible causes of manifold inlet pressure variation include:

6 -Lack of pressure regulation;

consider installing manifold pressure regulators

Hose inlet pressure variation is a significant problem

Possible causes of hose inlet pressure variation include:

9 -Defective regulators

10 -Inlet pressure lower than pressure regulator's operating range

12 Some pressures found in the field were very low

Other problems noted

27 Fertilizer injector located downstream of filter

31 High pressure losses at pump station

34 Small wetted soil area

DRIP/MICRO EVALUATION: PROBLEMS NOTED

Ref. #

3 The field DU is considered OK

Pressure problems

Hose inlet pressure variation is a significant problem

Possible causes of hose inlet pressure variation include:

8 -Lack of pressure regulation;

consider installing hose pressure regulators

Other problems noted

27 Fertilizer injector located downstream of filter

30 No flow meter

CLOGGING IS THE MAIN CAUSE OF POOR SYSTEM D.U.

<u>Main causes of clogging include:</u>

- ✓ Suspended material in irrigation water
- ✓ Chemical precipitation in emitters
- ✓ Biological growths in emitters
- ✓ Root intrusion
- ✓ Soil ingestion

Types of clogging that can be managed through injection of chemicals

Types of clogging	Action	Remedial
Slimy bacteria	grow inside pipes & emitters	chlorine, ozone, citric acid
Iron & Manganese oxides	bacteria oxidize iron and manganese	chlorine, phosphate, aeration in ponds
Iron & Manganese sulfides	toxic to plants even in small concentrations	aeration, chlorination and acid injection
Calcium & Magnesium Carbonates	clogging emitters	lowering pH to 7, sulphuric and phosphoric acid injection
Plant roots entry into underground emitters	clogging emitter from outside	acid injection, embedded herbicides

An average pipe flow velocity of 1 ft/s can be assumed. Divide this velocity into the longest pipe distance in the system (from pump to farthest emitter) and determine the adequate injection time

This is the time to wait after starting the pump and the time to allow for flushing before turning the pump off

Typical recommended chlorine dosages for different organic growth and precipitation problems

For algae:

Use 0.5 to 1.0 ppm continuously or 20 ppm for 20 min at the end of each irrigation cycle

For hydrogen sulfide

Use chlorine at 3.5 to 8.5 times the hydrogen sulfide content

For iron bacteria

Use 1.0 ppm of chlorine over the number of ppm of iron content

For iron precipitation

Use 0.65 times the Fe^{2+} content to maintain 1.0 ppm free residual chloride at the end of laterals

For manganese precipitation

Use chlorine at 1.3 times the Mn content

For slimes

Maintain 1.0 ppm free chlorine residual at the end of laterals

SOME RECOMMENDATIONS

Have a professional system evaluation at least every 2-3 years

DU and application rate tend to change over time

Know your system application rate & DU

⇒ Key elements for irrigation scheduling

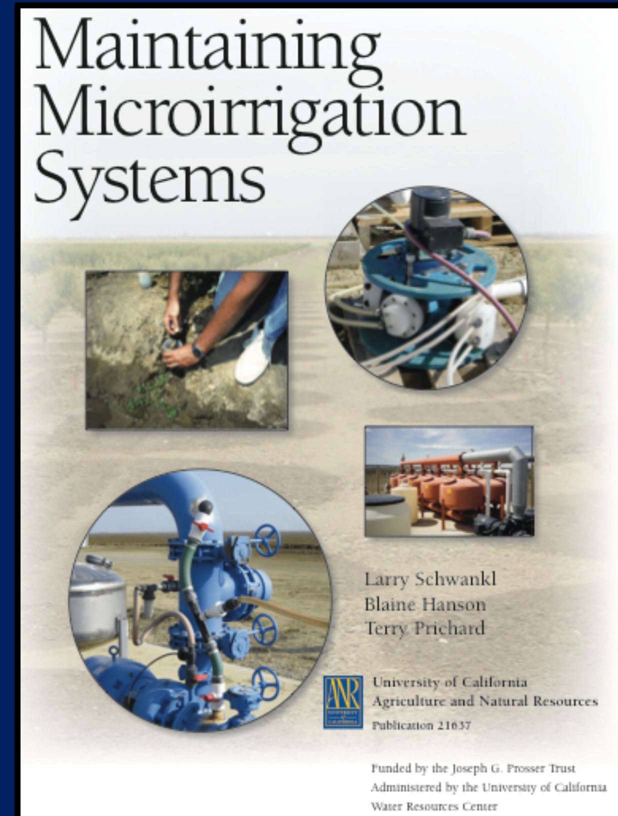
(time to run the system = water to be applied/application rate)

Monitor the system periodically to spot and correct problems

(check mainly flowrate and pressure at critical points)

HIGH EFFICIENCY REQUIRES SIGNIFICANT EFFORTS IN ROUTINE MAINTENANCE

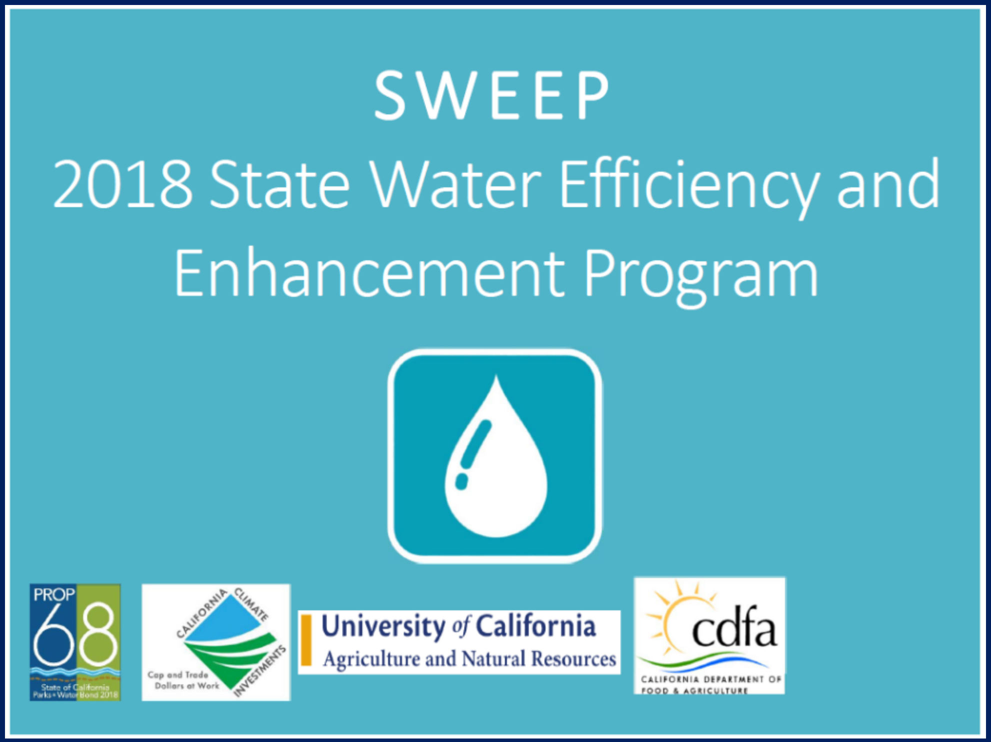
- ✓ Checking for leaks (farm equipment & animals)
- ✓ Back-flushing filters (manually or automatically)
- ✓ Periodically flushing main, submain and laterals (in that order)
- ✓ Chlorinating for organic material: continuous (1-2 ppm) or periodic (10-50 ppm)
- ✓ Acidifying (lowering Ph. < 7-5) to avoid/remove precipitates
- ✓ Cleaning or replacing clogged emitters and other components



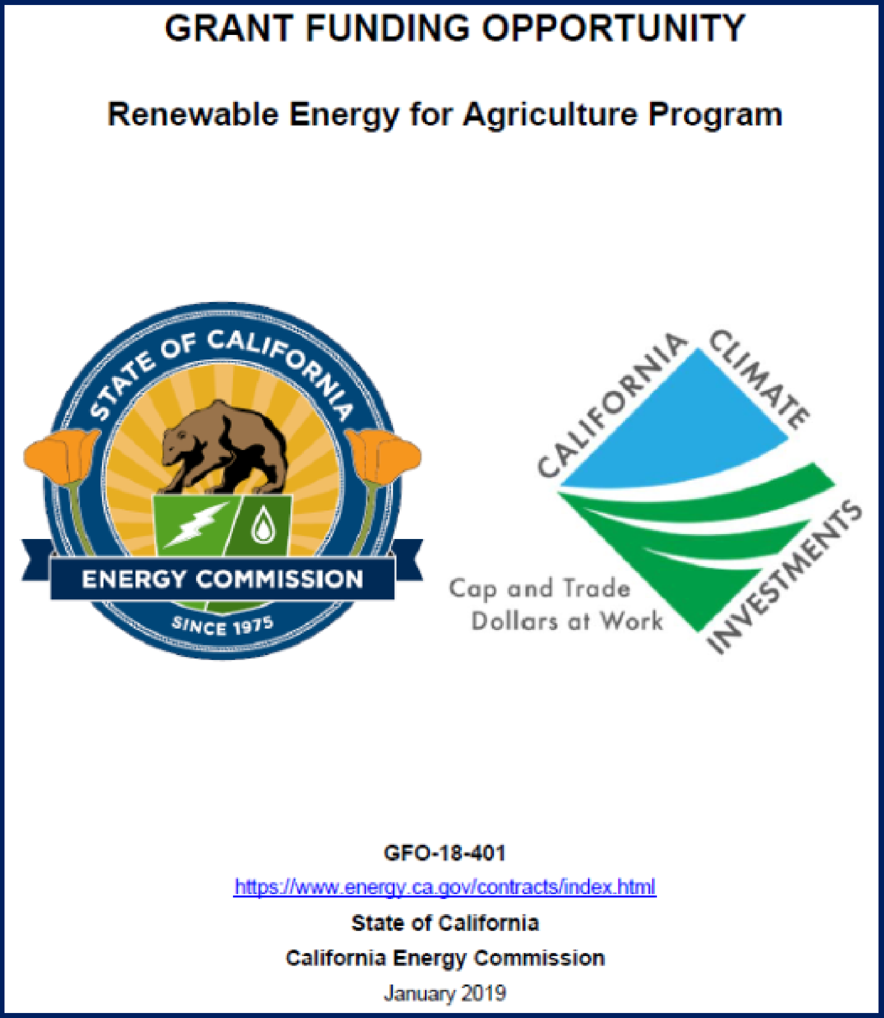
Publication available at:

http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=21637

AVAILABLE FINANCIAL INCENTIVES FOR IRRIGATION AND ENERGY IMPROVEMENTS



MARCH 8, 2019


GRANT FUNDING OPPORTUNITY

Renewable Energy for Agriculture Program

STATE OF CALIFORNIA
ENERGY COMMISSION
SINCE 1975

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

GFO-18-401

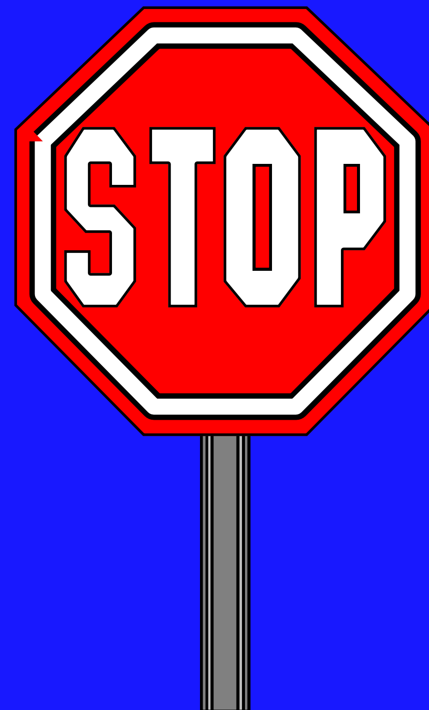
https://www.energy.ca.gov/contracts/index.html

State of California

California Energy Commission

January 2019

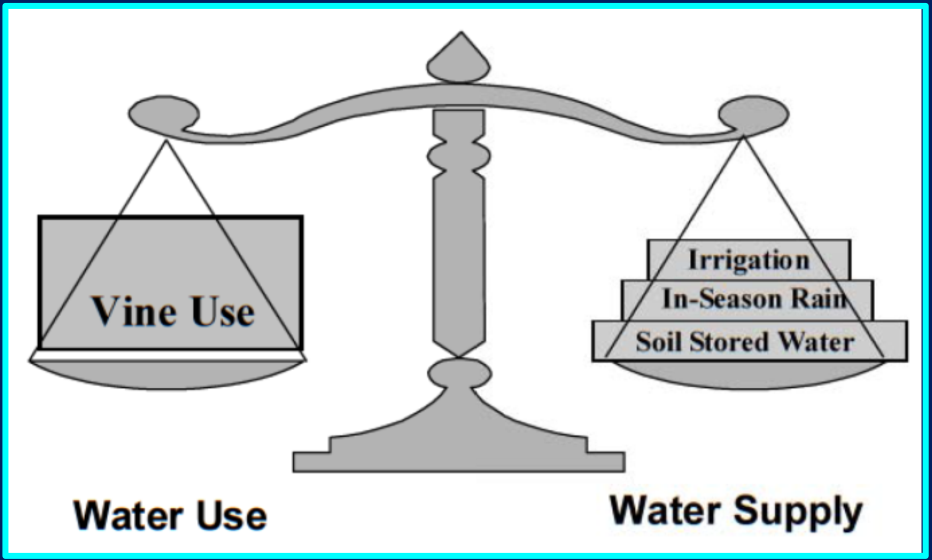
MARCH 15, 2019


STOP

WATER REQUIREMENTS OF GRAPEVINE

In California, mature grapevine needs anywhere from **16 to 28** inches of irrigation water per season to grow and produce at economic yield, depending on the seasonal rainfall, training system, canopy size, row orientation, wind conditions

Grapevine can uptake and use water from various sources:



Moisture stored in the soil profile

In-season effective rainfall

Water applied and infiltrated from irrigation

Fog and Dew

To determine the irrigation water to apply, one must account for actual ET, residual soil moisture, rainfall, and the target level of water deficit

Cumulative ET (mm/day) and cumulative precipitation + irrigation (mm/day) on North and South facing slopes at Safari Vineyards (April 8-Oct 18, 2016)

(D. Zaccaria, L. Wunderlich, R. Snyder, K. Shackel)