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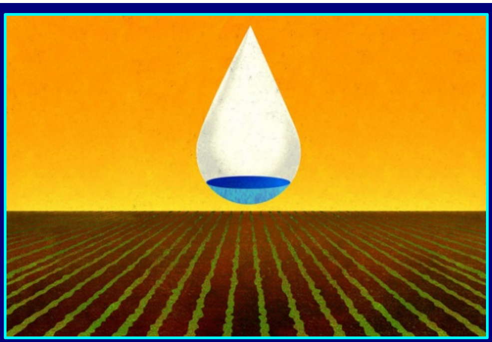

Irrigation Systems and Energy Efficiency

SURFACE IRRIGATION EFFICIENCY WORKSHOP

UC Kearney Agricultural Center - June 3rd, 2016

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OBJECTIVES

1) Background information on Irrigation Systems in California

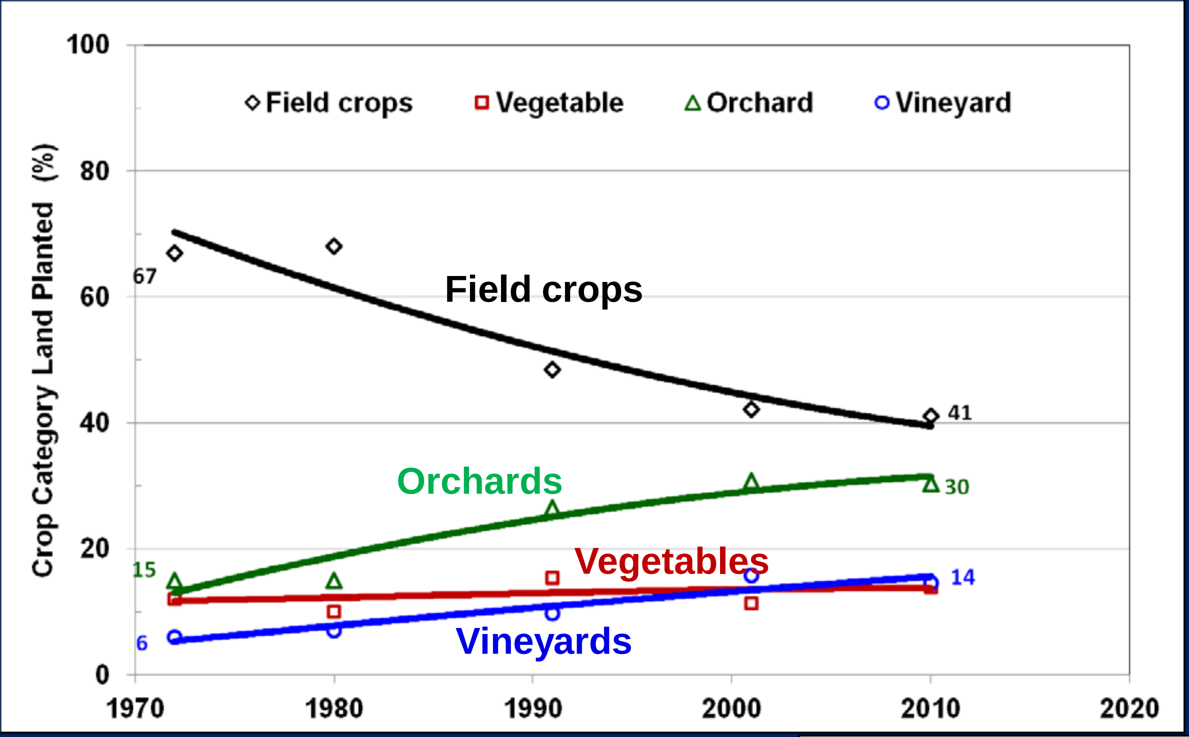
2) Review Pumping Efficiency Concepts

3) Considerations about Different Energy Sources

4) Some Sample Calculations

Survey of Irrigation Methods in California, 2010

(Tindula, Orang & Snyder, 2013)

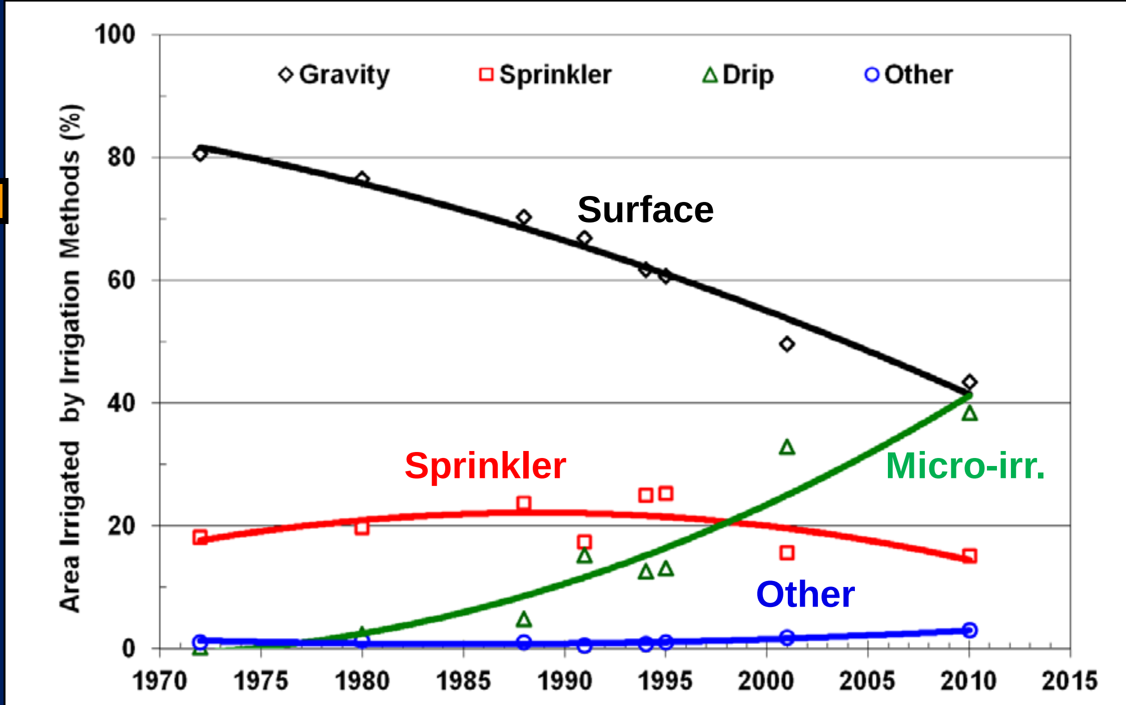


✓Questionnaire to 10,000 growers

✓51% usable return rate

more frequent and flexible delivery schedules are needed by farmers

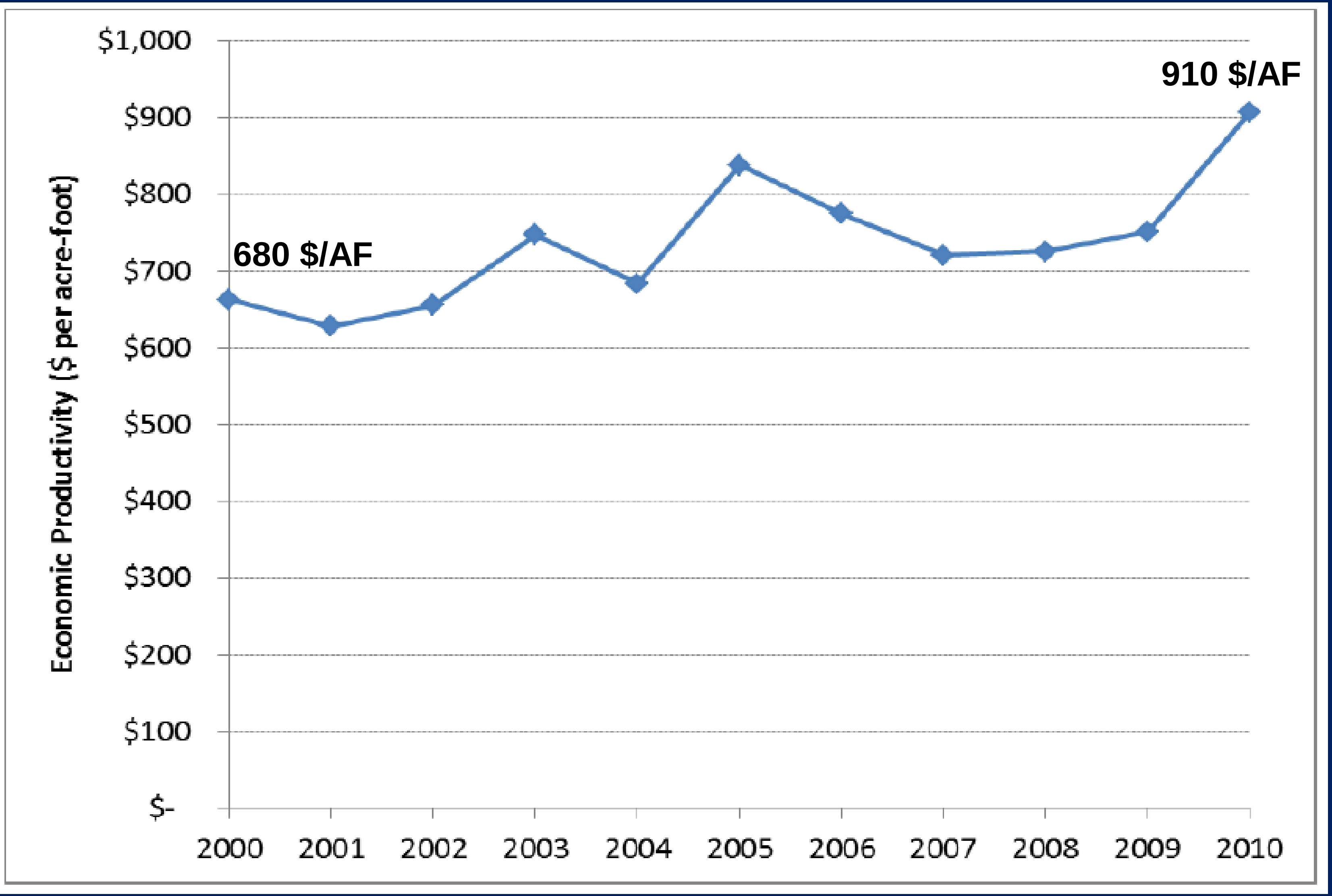
WATER DISTRICTS ARE OFTEN NOT CAPABLE TO DELIVER WATER WITH SUCH A FREQUENCY



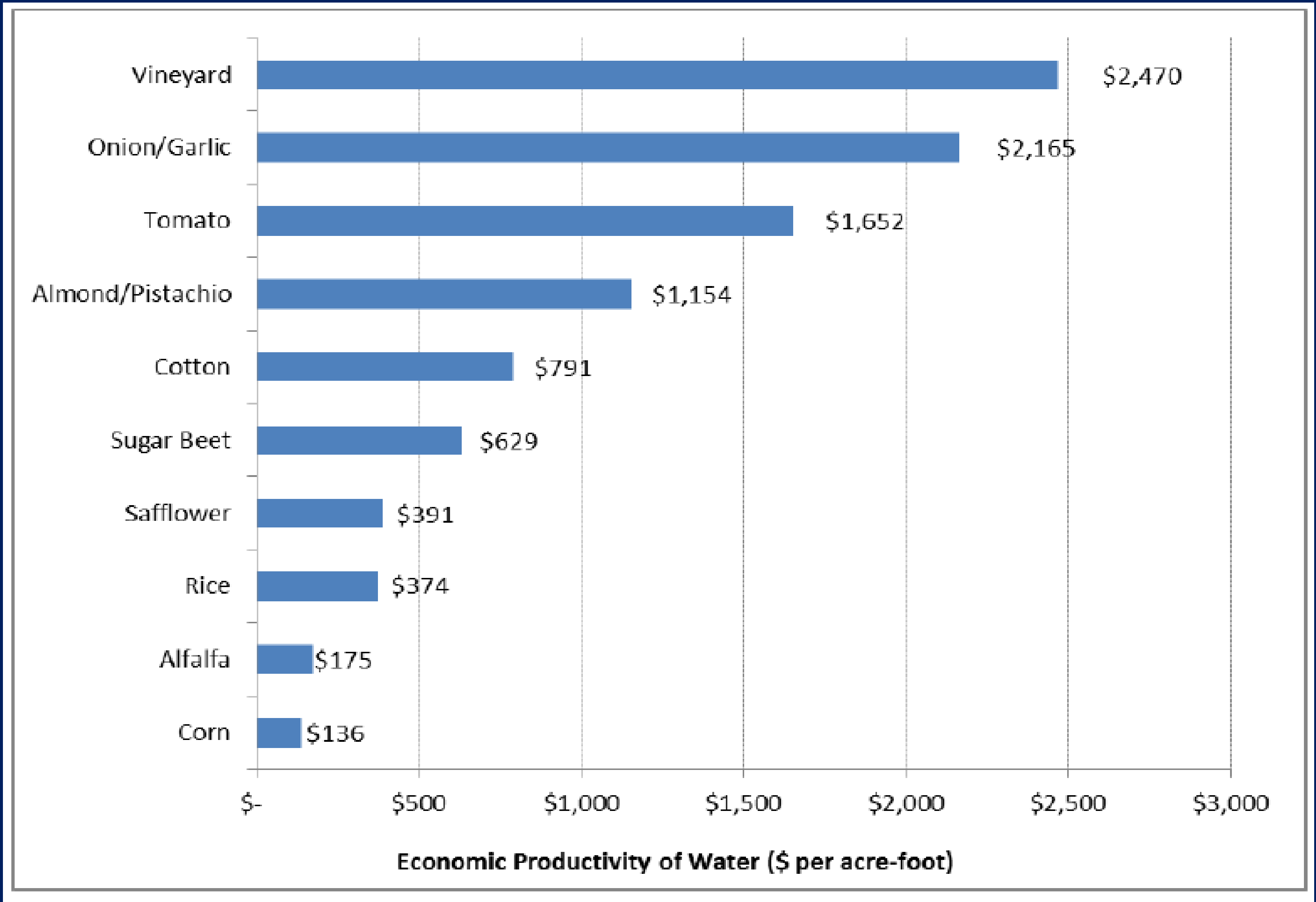
Economic Productivity of Water 2000-2010 (DWR, 2013)

680 \$/ac-ft => 910 \$/ac-ft (34%)

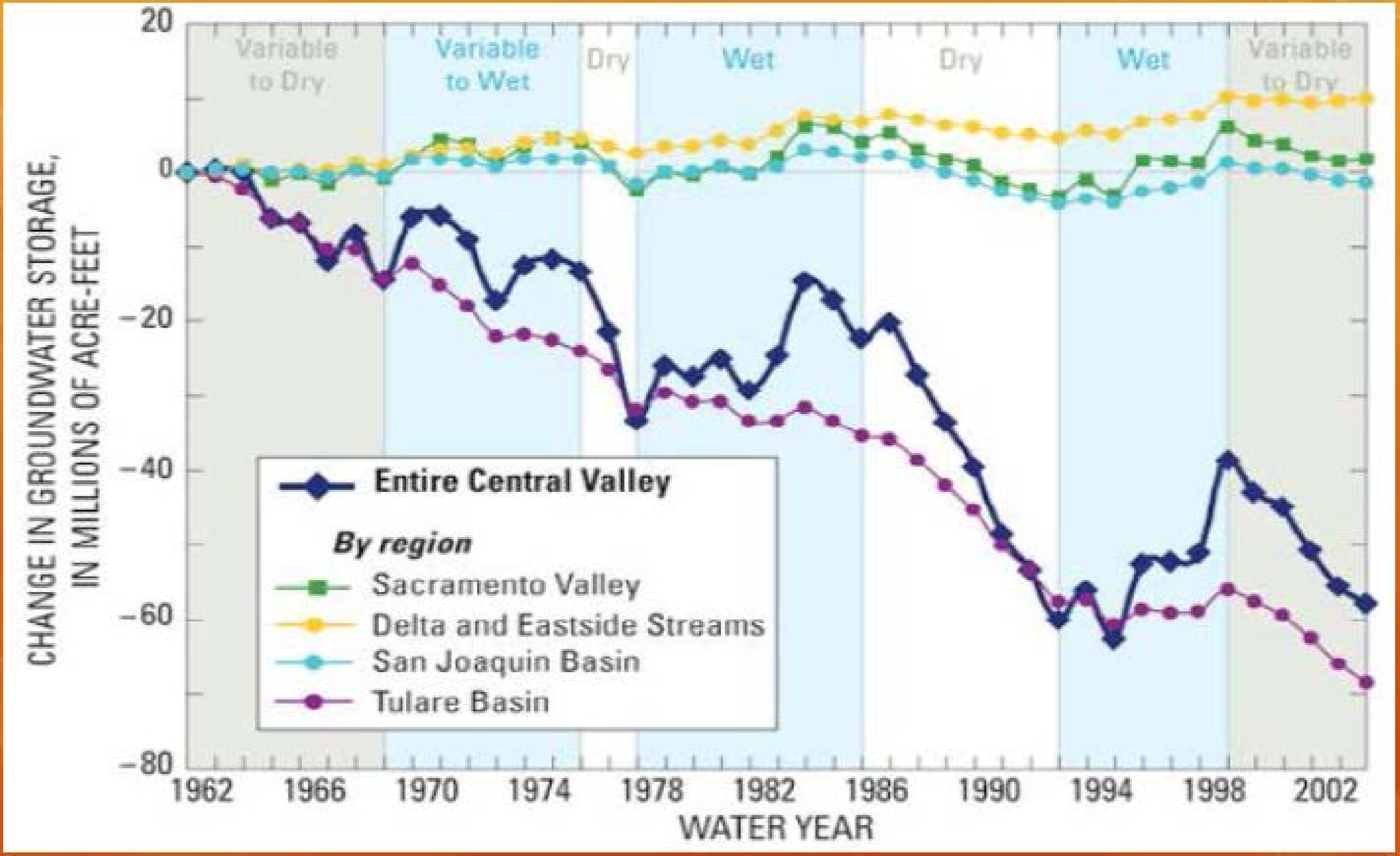
(resulting from more productive crops & more efficient irrigation)



Economic Productivity of Water per crop ($/ac-ft)



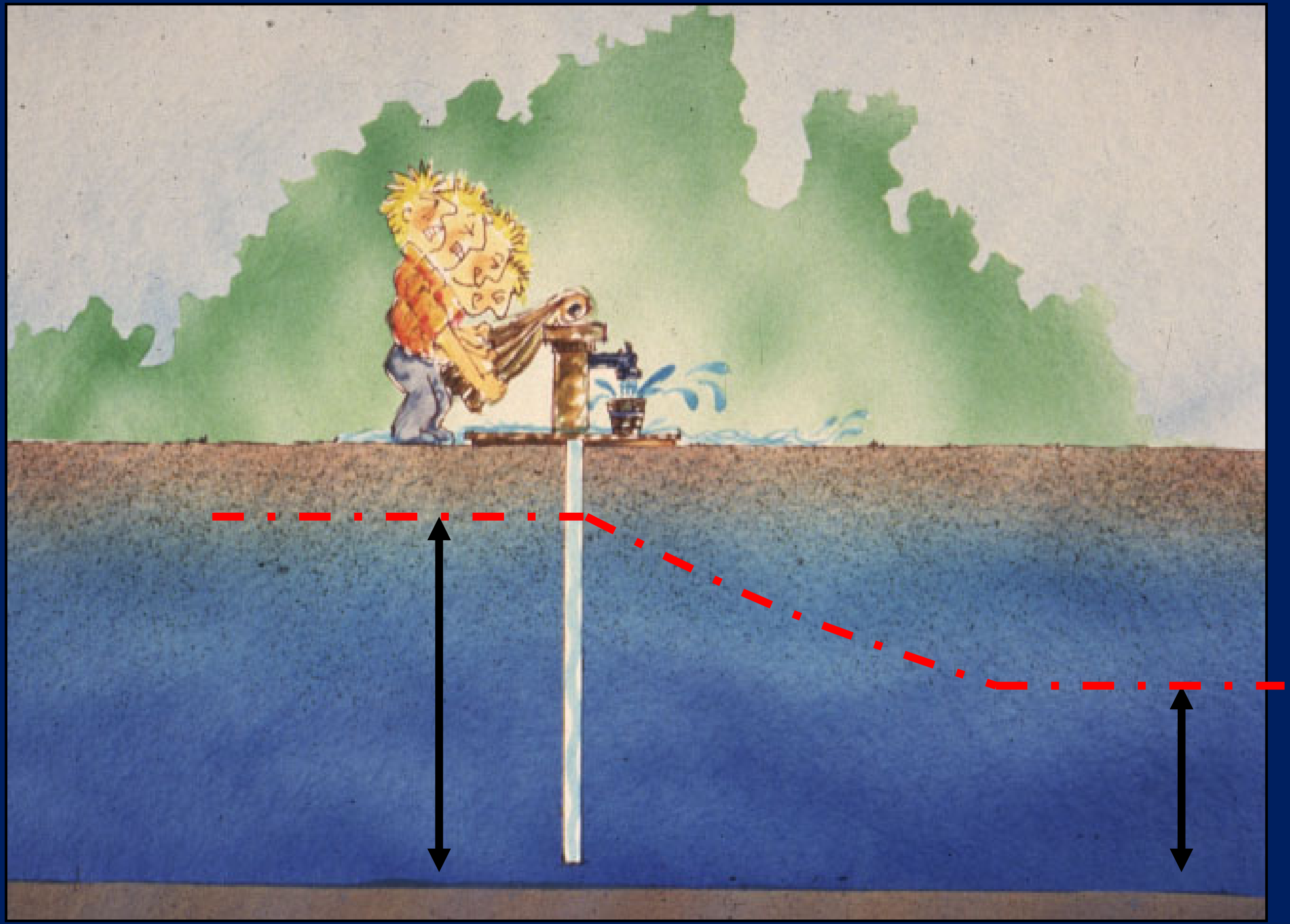
HOW ABOUT THE DROUGHT IMPACTS?



Source: Faunt, C.C., ed., (2009) as cited in Christian-Smith (2011)

California's farmers in 2014-2015 reacted quickly, by pumping enough ground water to stay competitive

~ 5% prices increase in 2013-2015



Power and Energy terms

Power (kW, Hp) = Head x Flowrate = H x Q

Energy (kWh) = Head x Volume Water Lifted = Power x Operating Time

Pumping Plant Efficiency

is the overall energy efficiency of the pump and motor considered together

$$E_{PUMP} = \frac{Power\ Out}{Power\ In} = \frac{Water\ \ Horsepower\ (WHP)}{Electric\ \ Horsepower\ (EHP)} = \frac{output\ power\ provided\ to\ water\ by\ the\ pump}{input\ power\ required\ at\ pump\ shaft}$$

The Water Horsepower (WHP) is given by:

$$WHP = \frac{TDH\ (ft) * Q\ (gpm)}{3960}$$

The Energy Horsepower (EHP) is given by:

$$EHP = \frac{TDH\ (ft) * Q\ (gpm)}{3960 * E_{PUMP}(\%)} = \frac{WHP}{E_{PUMP}\ (\%)}$$

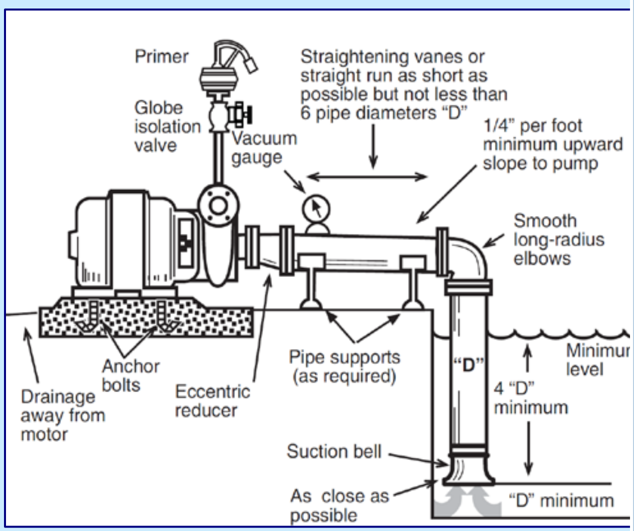
Common Causes of Poor Pumping Plant Performance

- Wear (sand)
- Improperly matched pump
- Changed pumping conditions
  - Irrigation system changes
  - Drop in ground water levels
- Clogged impeller
- Poor suction conditions
- Throttling the pump

Usually the E_{PUMP} is provided by the pump manufacturer. However, it should be evaluated every several years

1. A good quality pressure gauge (oil-filled) mounted on the discharge side of the pump
2. Flow meter installed at least 5-8 pipe diameters downstream the pump, (or a 5-gallon bucket + garden hose)
3. A stopwatch and a calculator

STEP 1 – Find the Total Dynamic Head



Reading pressure from gauge ________ psi × 2.31 (a conversion factor) = **feet**

Add height* if pump is **above** water surface + **feet**

OR

Subtract height* if pump is **below** water surface – ________ **feet**

To get total dynamic head (feet). ________ **TDH**

** Height is defined as distance from the water surface to the centerline of the discharge pipe.*

STEP 2 – Find the Flow Rate in GPM

If your system has a flow meter, read the gallons per minute (gpm). If the meter reads in cubic feet per second (cfs), multiply cfs times 448.8 to get gpm.

_______ **gpm**

STEP 3 – Find the Input kW and Energy Horsepower (EHP)

$3.6 \times$ _______(revs) $\times$ _______(Kh) $\div$ _______(secs) $=$ _______ **Input kW**

_______ (KW) $\times$ 1.34 $=$ _______ **EHP**

Seconds the disk takes to make 10 revolutions

STEP 4 – Find the Water Horsepower (WHP)

______ (TDH) × ______ (gpm) ÷ 3,960 = ______ **WHP**

STEP 5 – Determine the Pumping Plant Efficiency

______ (WHP) × 100 ÷ ______ (EHP) = ______ **% Efficiency**

Expected Pumping Plant Efficiency

Rated Motor Size (HP)	Expected Efficiency (%)
3 to 5	66%
7.5 to 10	68%
15 to 30	69%
40 to 60	72%
75+	75%

Note: *These efficiencies are for older pumps in excellent condition. New pumps and used pumps under mild conditions or improved design will have higher efficiencies.*

Recommended Corrective Actions

- ☺ E_{pump} greater than 60% - no corrective action
- 😐 55% to 60% - consider adjusting impeller
- 😐 50% to 55% - consider adjusting impeller; consider repairing or replacing pump if adjustment has no effect
- ☹ Less than 50% - consider repairing or replacing pump


Efficiencies of Standard and Energy-efficient Electric Motors

Horsepower	Standard	Energy Efficient
10	86.5	91.7
20	86.5	93.0
50	90.2	94.5
75	90.2	95.0
100	91.7	95.8
125	91.7	96.2

COMPARISONS BETWEEN DIFFERENT ENERGY SOURCES

FUEL SOURCE	PUMP OUTPUT	RELATIVE OUTPUT
ELECTRICITY	0.885 whp-hr/kWh	1
NATURAL GAS (925 BTU)	61.7 whp-hr/MCF	69.72 times as Electricity
NATURAL GAS (1000 BTU)	66.7 whp-hr/MCF	75.36 times as Electricity
DIESEL	12.50 whp-hr/gal	14.2 times as Electricity
PROPANE	6.89 whp-hr/gal	7.70 times as Electricity

1 MCF of Natural Gas (925 BTU) produces 69.72 times the water horsepower as 1 kW of Electricity.

1 gal of Diesel produces 14.2 times the water horsepower as 1 kWh of Electricity.

Cost of Electricity per Agricultural Use in California (PG&E, 2016)

	RATE A (< 35 HP)	RATE B (> 35 HP)
SUMMER	0.278 $/kWh	0.236 $/kWh
WINTER	0.213 $/kWh	0.182 $/kWh

Assuming an average cost of electricity of \$0.227 per kWh, we could afford to pay:

\$15.82 per MCF of Natural Gas (925 BTU)

\$17.10 per MCF of Natural Gas (1000 BTU)

\$3.22 per gal of Diesel

\$1.75 per gal of Propane

ENERGY REQUIRED TO LIFT THE WATER OF 1 FOOT

1 Acre-Foot Water = 43,560 Cubic Feet

1 Cubic Foot = 62.4 pounds

Energy required for 1 ft = 43,560 ft^3 x 62.40 lbs/ft^3 = 2,718,144 ft-lbs

1 hp = 33,000 ft-lbs/min

1 hp-hr = 33,000 ft-lbs/min x 60 min/hr = 1,980,000 ft-lbs/hr

Energy needed to pump 1 ac-ft of water at head of 1 foot

2,718,144 ft-lbs/1,980,000 ft-lbs/whp-hr = **1,373 whp-hr/ac-ft per foot of lift**

ELECTRICITY

$$\frac{1.373\ whp-hr/ac-ft}{0.885\ whp-hr/kWh}=1.55\ kWh/ac-ft\ per\ foot\ of\ lift$$

NATURAL GAS (925 BTU)

$$\frac{1.373\ whp-hr/ac-ft}{61.7\ whp-hr/kWh}=0.022\ MCF/ac-ft\ per\ foot\ of\ lift$$

NATURAL GAS (1000 BTU)

$$\frac{1.373\ whp-hr/ac-ft}{66.7\ whp-hr/kWh}=0.020\ MCF/ac-ft\ per\ foot\ of\ lift$$

DIESEL

$$\frac{1.373\ whp-hr/ac-ft}{12.50\ whp-hr/kWh}=0.10\ gal/ac-ft\ per\ foot\ of\ lift$$

PROPANE

$$\frac{1.373\ whp-hr/ac-ft}{12.50\ whp-hr/kWh}=0.20\ gal/ac-ft\ per\ foot\ of\ lift$$

Multiply these numbers by the total head in ft to obtain the **AMOUNT OF FUEL NECESSARY PER ACRE-FT OF WATER FOR A PARTICULAR LIFT**

Multiply these numbers by the total acre-ft of water to fulfil the crop water requirements (+ leaching, flushing, etc.) to obtain the **TOTAL FUEL NECESSARY TO PUMP WATER (kWh, gal, MCF, etc.)**

If we multiply the total fuel required by the unit fuel price, we obtain the **TOTAL COST TO PUMP WATER ($$)**

EXAMPLE 1

Alfalfa ET = 50 inches = 4.2 ft of water per season (SJV)

Area = 130 acres

Irrigation methods: Sprinkler (50 psi) Vs. SDI (20 psi)

Lift of water = 50 ft (from well to ground)

$TDH_{SPRINKLER}$: 50 ft + 50 psi x 2.31 ft/psi = 165 ft

TDH_{SDI}: 50 ft + 20 psi x 2.31 ft/psi = 96 ft

Total ac-ft $_{SPRINKLER}$ = 4.2/0.75 = 5.6 ac-ft

Total ac-ft $_{SDI}$ = 4.2/0.90 = 4.6 ac-ft

Diesel : 0.10 gal/ac-ft per foot of lift

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

Sprinkler: 130 ac x 5.6 ac-ft x 165 ft x 0.10 gal/ac-ft = 12,012 gal

SDI = 130 ac x 4.6 ac-ft x 96 ft x 0.10 gal/ac-ft = 5,740 gal

Difference in fuel amount = 12,012 – 5,740 = 6,272 gal

Cost of Diesel = $ 2.6 per gallon

Total saving = 6,272 gal x $2.6/gal = $16,307

EXAMPLE 2

Almond ET = 48 inches = 4.0 ft of water per season (SJV)

Area = 130 acres

Irrigation methods: Surface Irr. (5 psi) Vs. Drip (20 psi)

Lift of water = 150 ft (from well to ground)

$TDH_{SURFACE}$: 150 ft + 5 psi x 2.31 ft/psi = 161 ft

TDH_{DI}: 150 ft + 20 psi x 2.31 ft/psi = 196 ft

Total ac-ft $_{SURFACE}$ = 4.0/0.70 = 5.7 ac-ft

Total ac-ft $_{DI}$ = 4.0/0.90 = 4.4 ac-ft

Natural Gas_{925} : 0.022 MCF/ac-ft per foot of lift

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

Surface Irr: 130 ac x 5.7 ac-ft x 161 ft x 0.022 MCF/ac-ft = 2,624 MCF

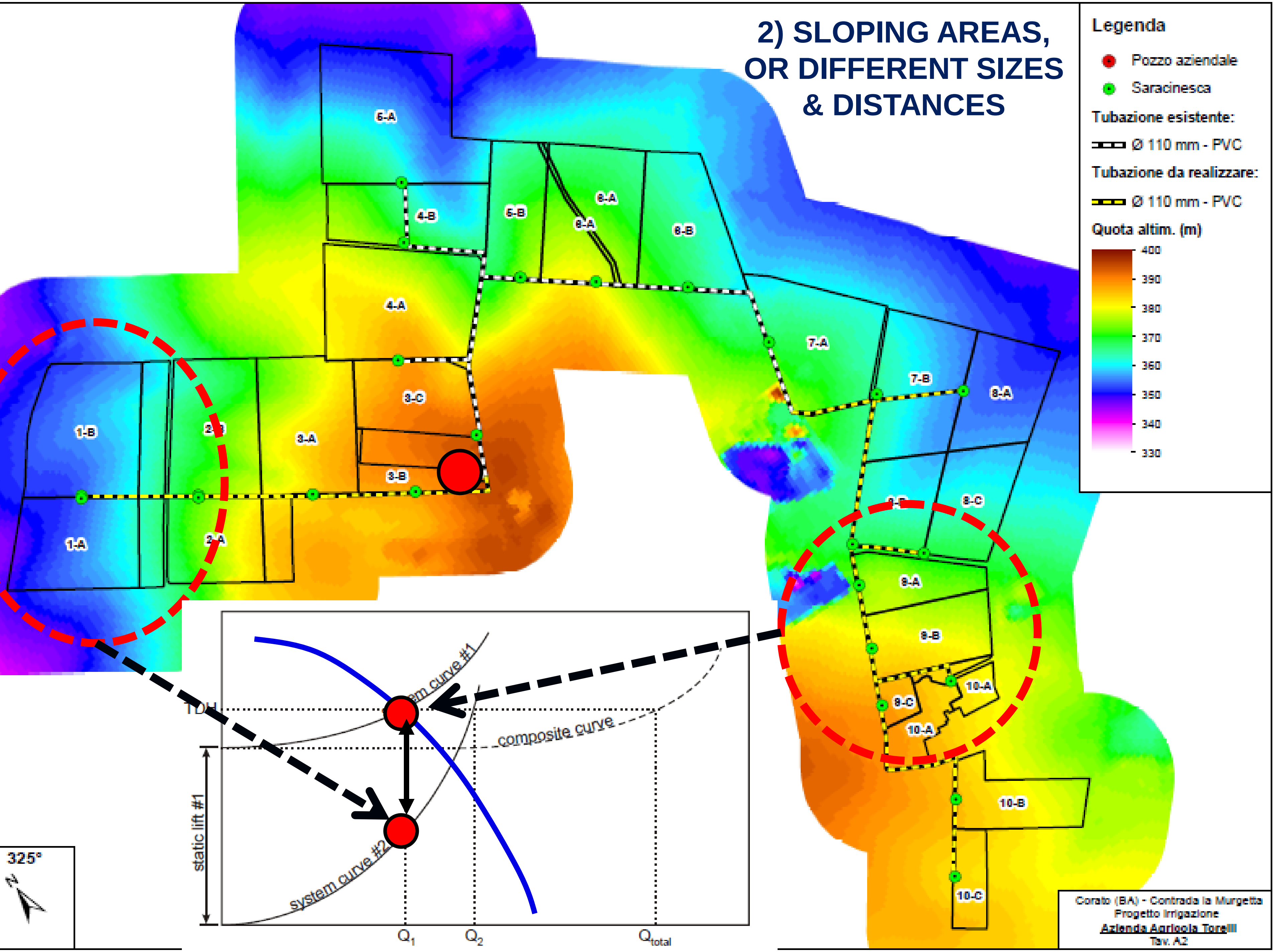
DI = 130 ac x 4.4 ac-ft x 196 ft x 0.022 MCF/ac-ft = 2,466 MCF

Difference in fuel amount = 2,624 – 2,466 = 158 MCF

Price of Natural Gas = $ 3.39 per MCF

Total saving = 158 MCF x $3.39/MCF = $535.6

2) SLOPING AREAS, OR DIFFERENT SIZES & DISTANCES



THANK YOU!