Variable rate irrigation to manage vineyard variability in California

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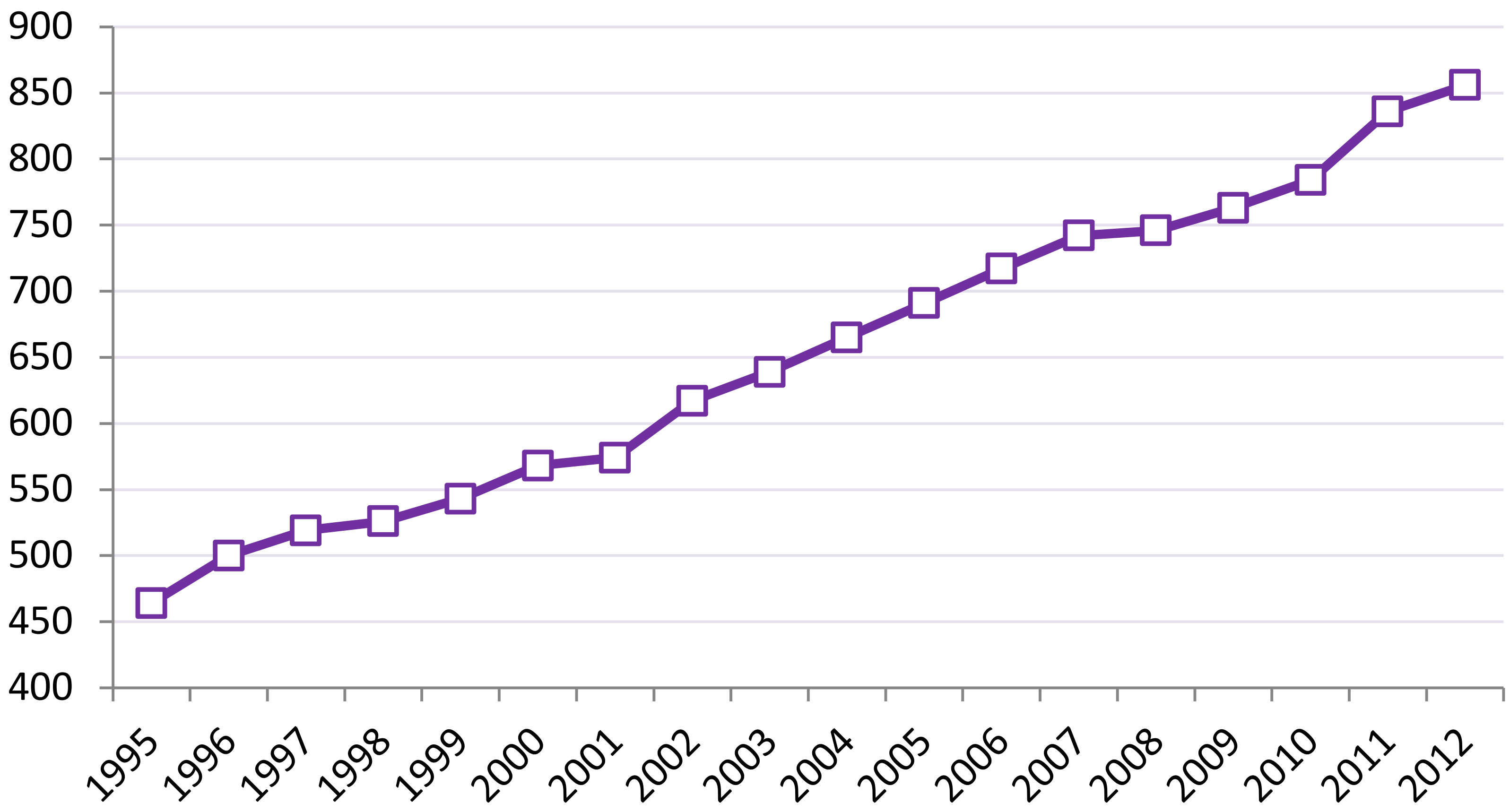
E&J. Gallo Winery

IBM

U.S. wine production (million gallons)



California Wine Institute

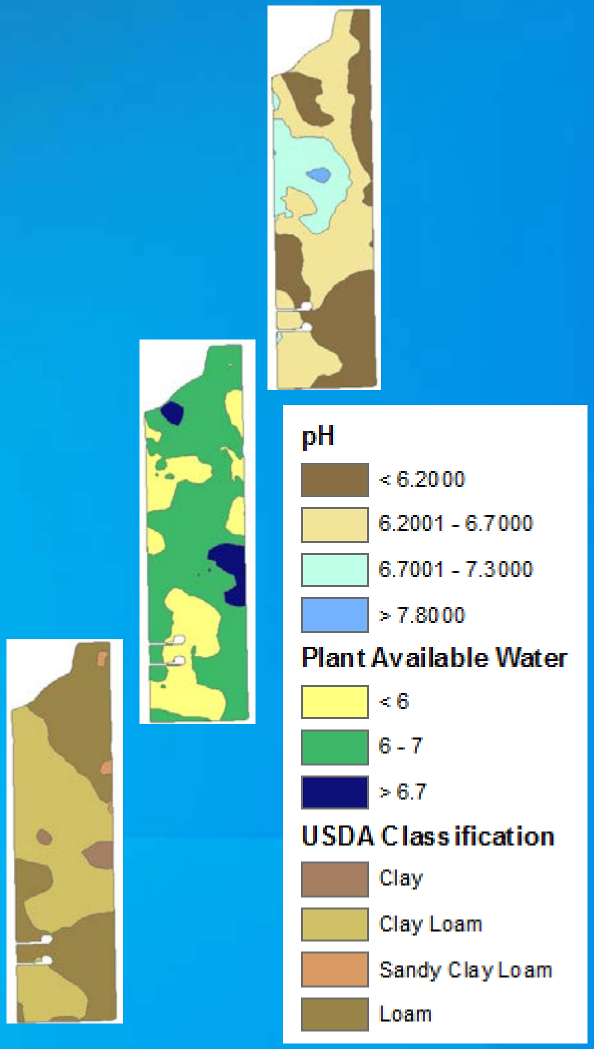
Vineyard development and management

- Vineyards are developed uniformly:
  - Variety
  - Rootstock
  - Planting distances
  - Irrigation layout

- Vineyards are managed uniformly:
  - Pruning
  - Irrigation
  - Fertilization
  - Leaf removal
  - Fruit thinning
  - Harvesting

Vineyard development and management

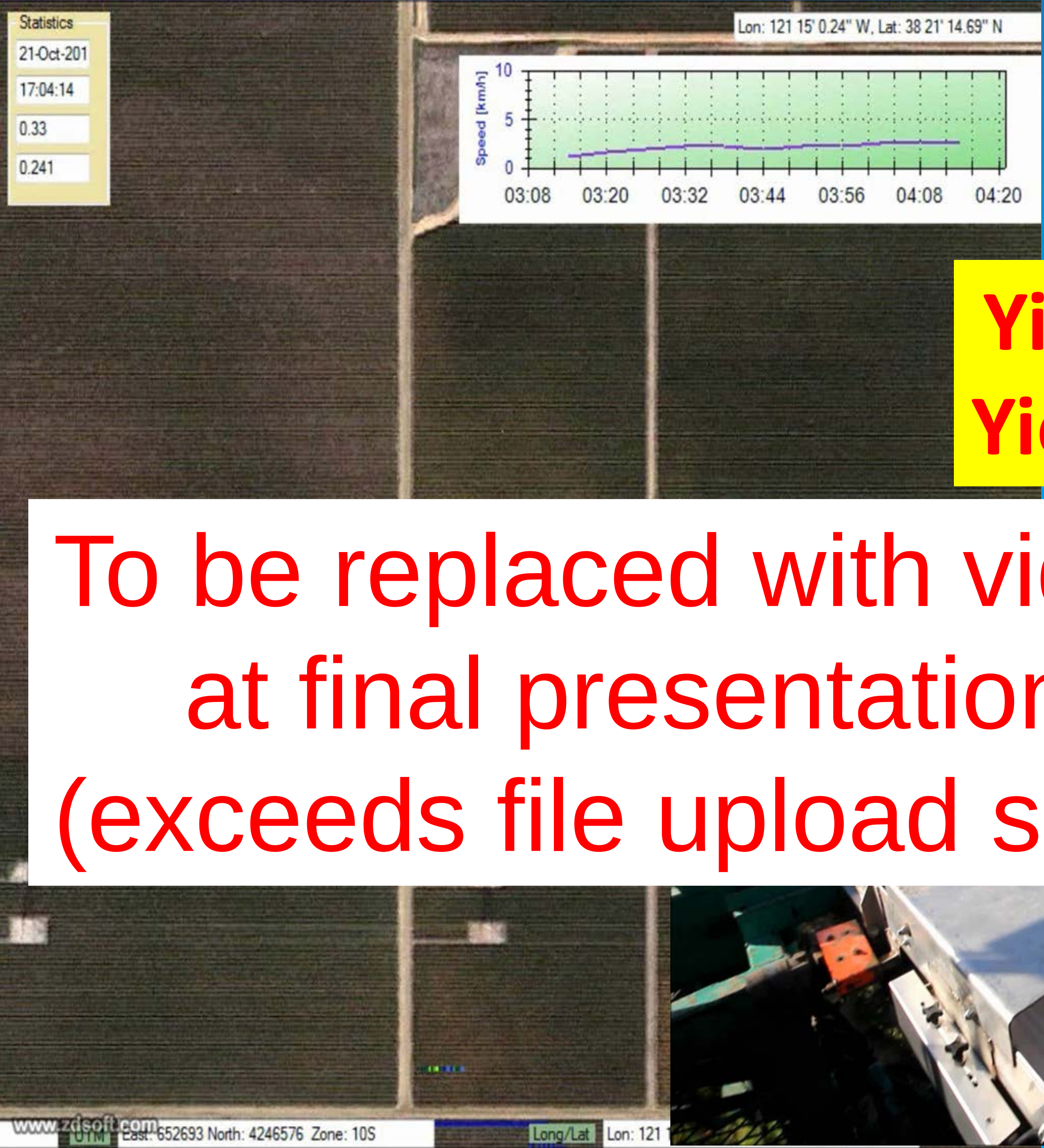
- However soils are variable:
  - Topography
    - Aspect
    - Elevation
    - Slope
  - Chemical and physical properties
    - Texture
    - Water holding capacity
    - pH
    - Nutrient content



How can we manage vineyard variability?

Through Precision Viticulture:

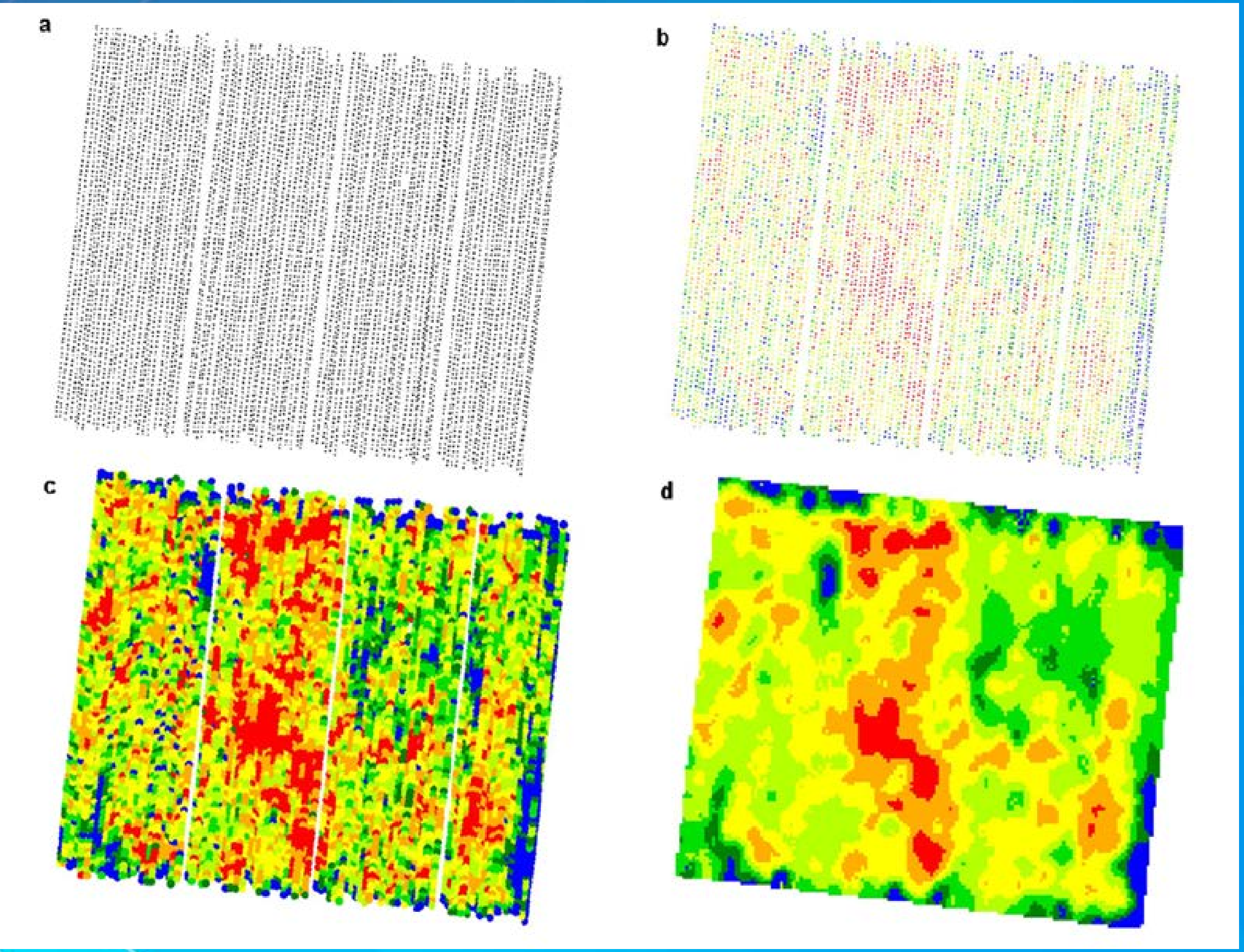
- Management to optimize vineyard performance
  - Responding to intra-field variability
  - Maximizing grape yield and quality
  - Minimizing environmental footprint



Yield Monitor
Yield Mapping

To be replaced with video at final presentation (exceeds file upload size)

From point to surface data



Significant Correlations with Yield per Acre

Parameter	Correlation (r^2)
Subsurface K^+	0.903
Soil rooting depth	**0.774**
Subsurface pH	– 0.805
Subsurface P	– 0.805
Subsurface organic matter	– 0.882
Subsurface K/Mg ratio	– 0.890

Significant Correlations with Grape Quality

Parameter	Correlation (r^2)
Soil rooting depth	**– 0.673**
Surface CA	– 0.506
Subsurface CA / Mg ratio	– 0.510
Surface CEC	– 0.554

Variable Rate Irrigation Study

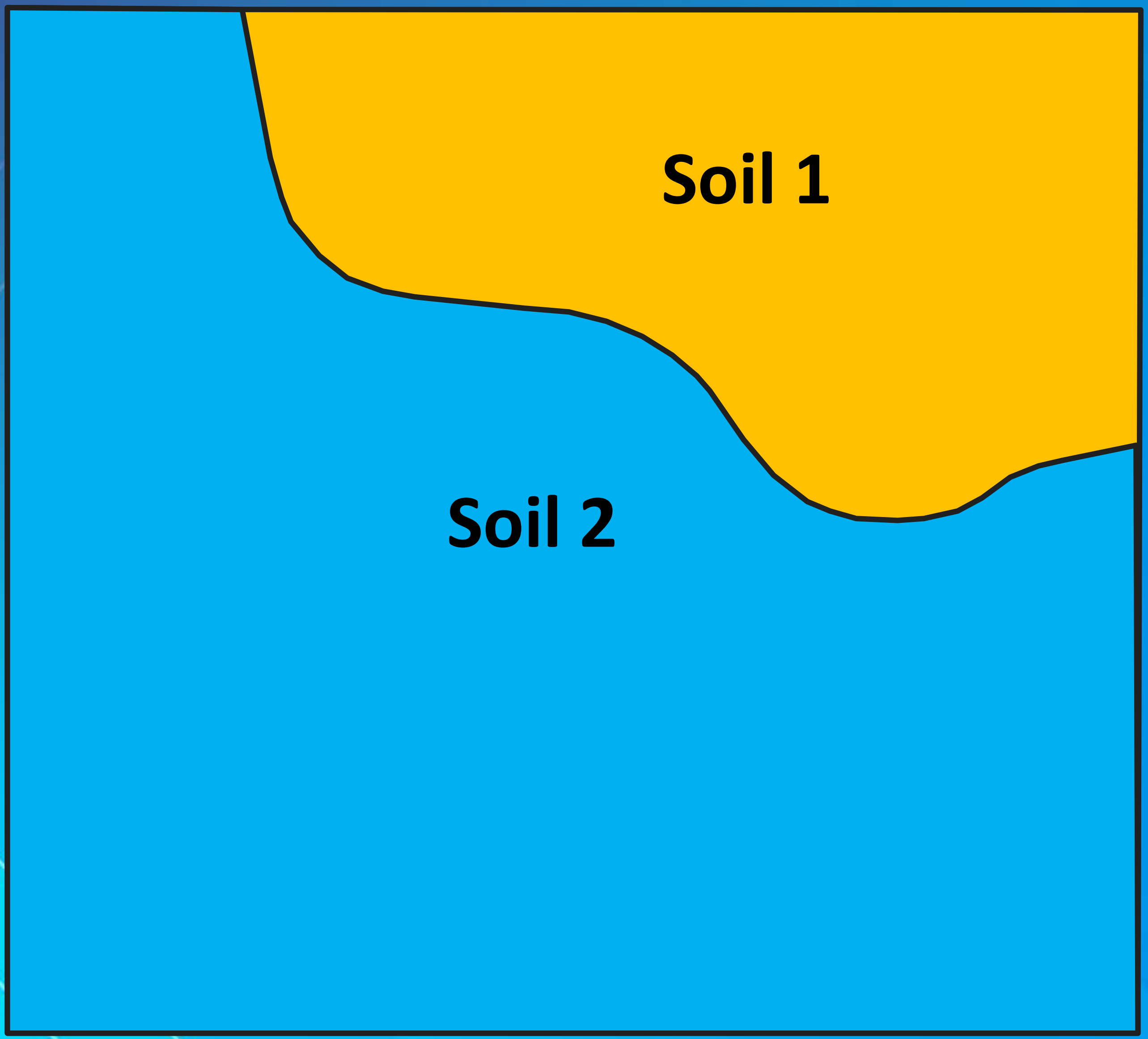
Objective:

Develop and operate a proof-of-concept VRI system prototype and validate it by:

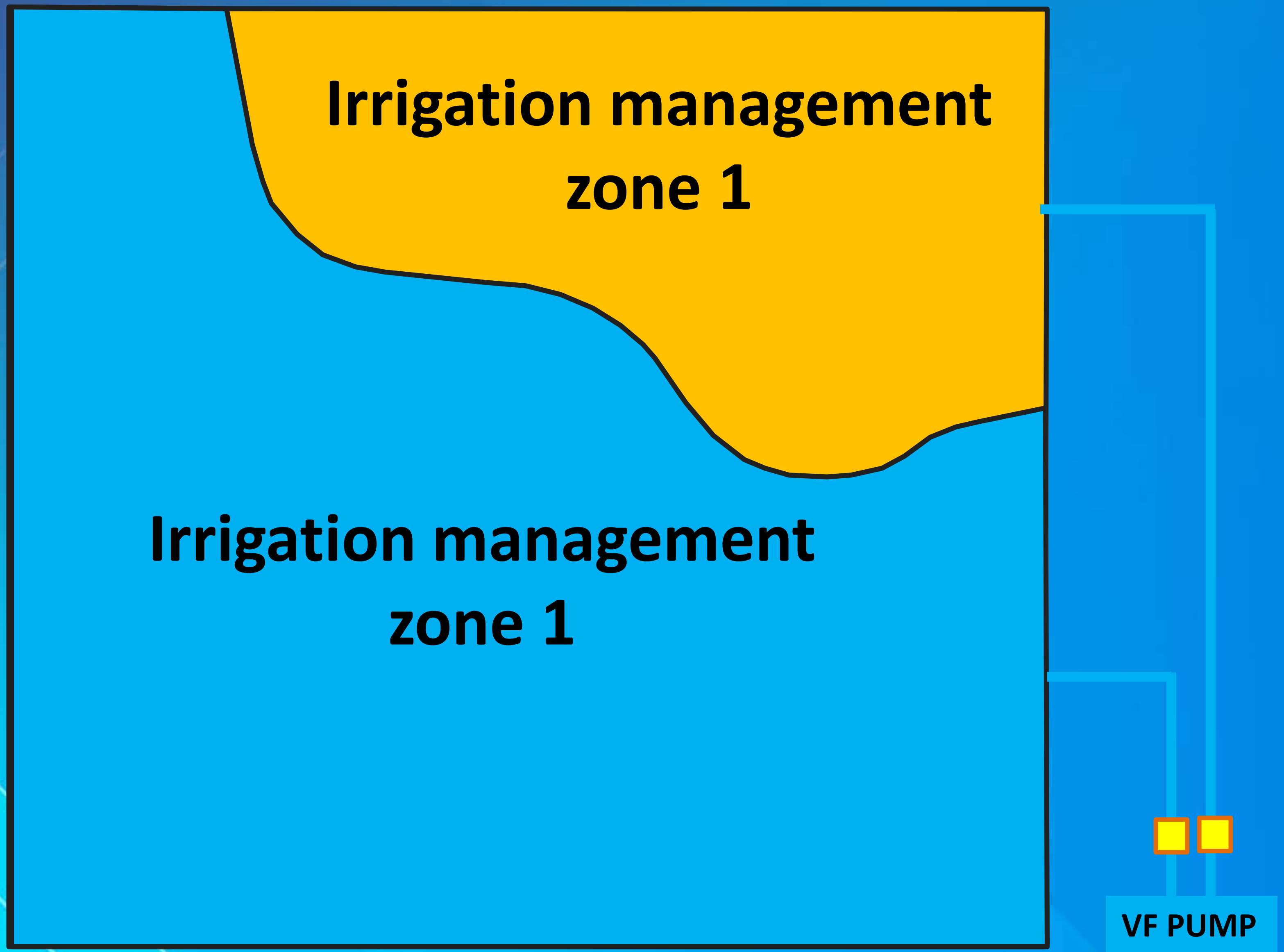
- Decreasing vineyard variability
- Optimizing fruit yield and quality
- Increasing water use efficiency.

Modular vs. Zonal Irrigation

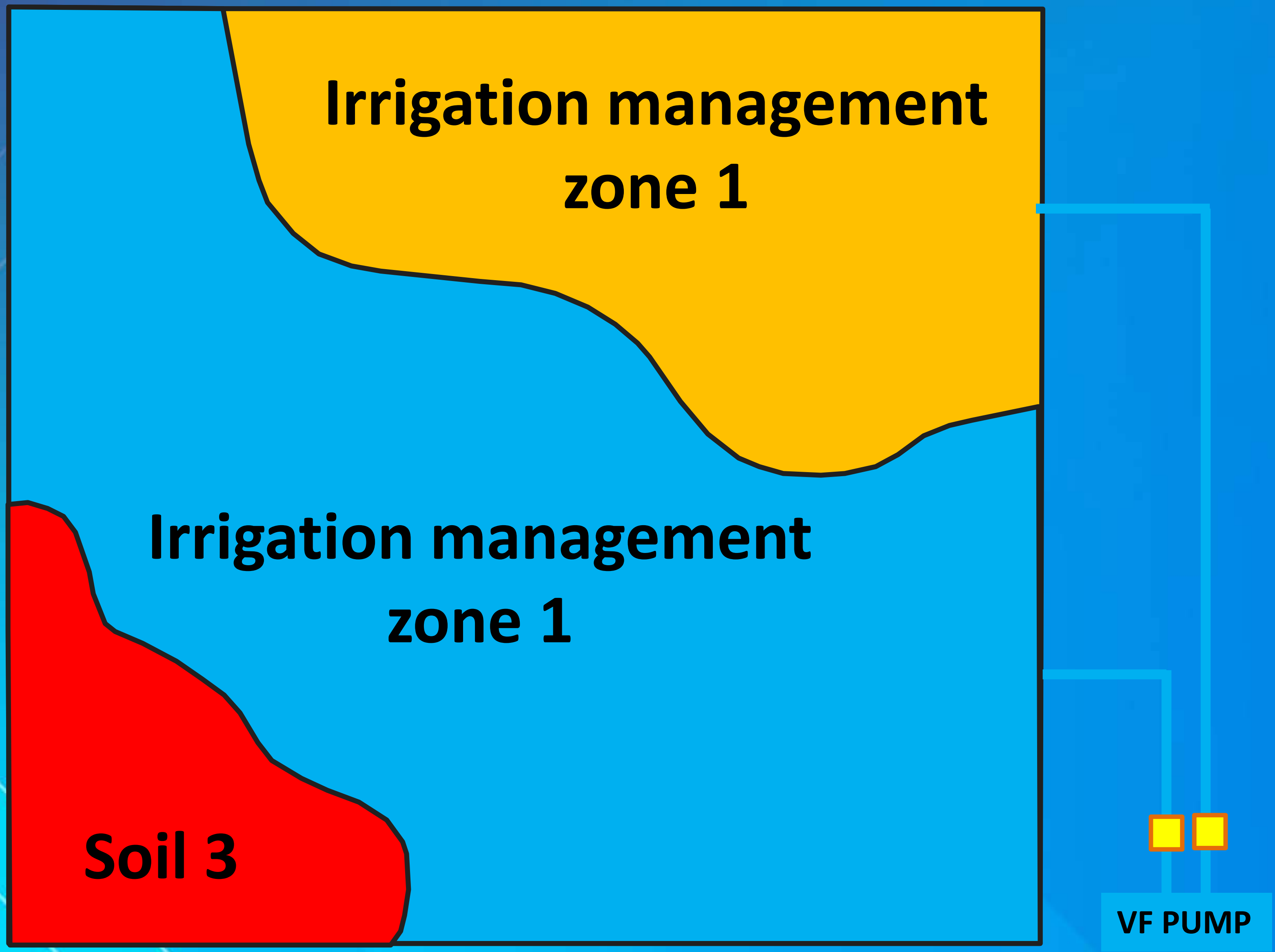
Zonal Irrigation



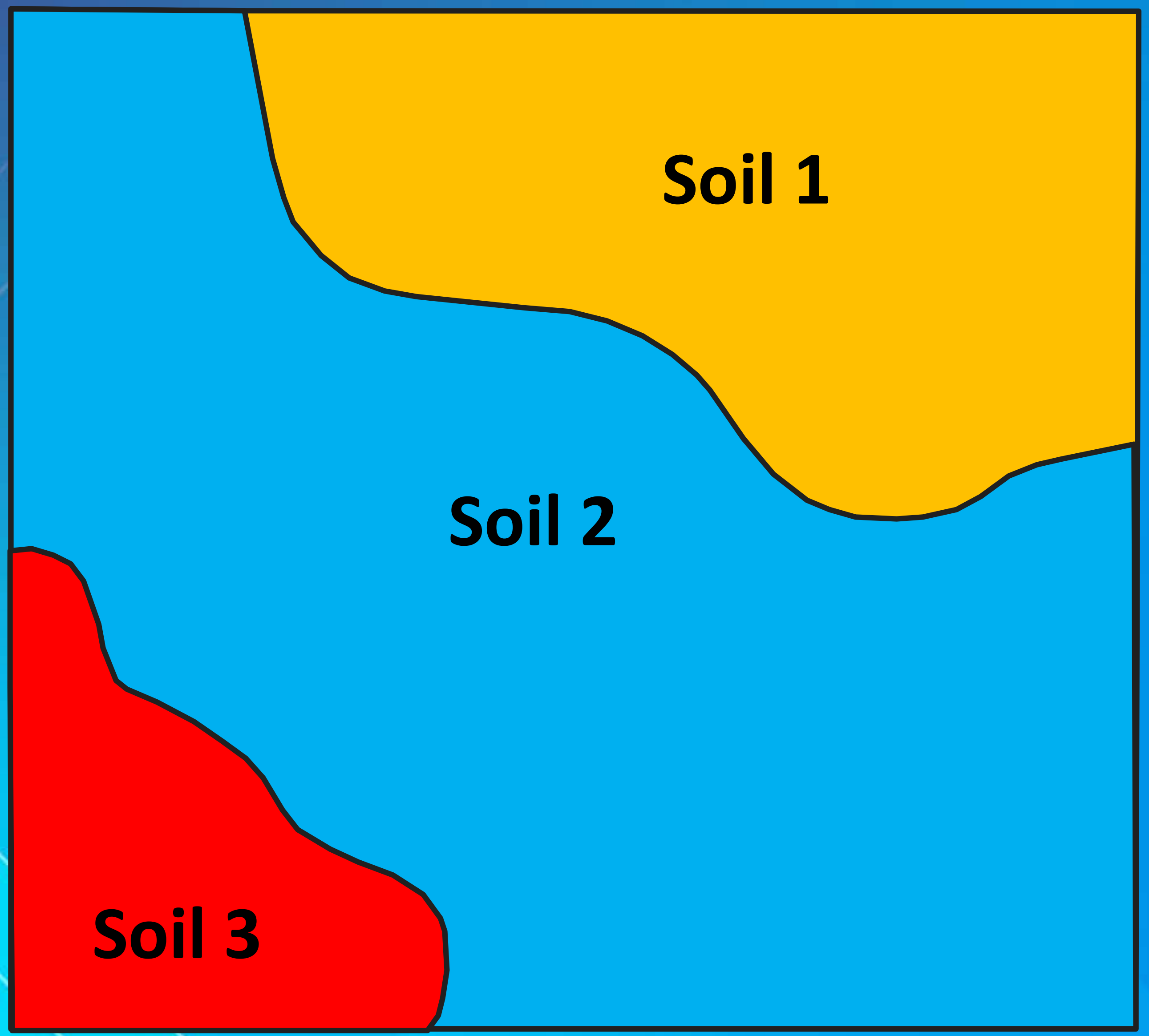
Zonal Irrigation



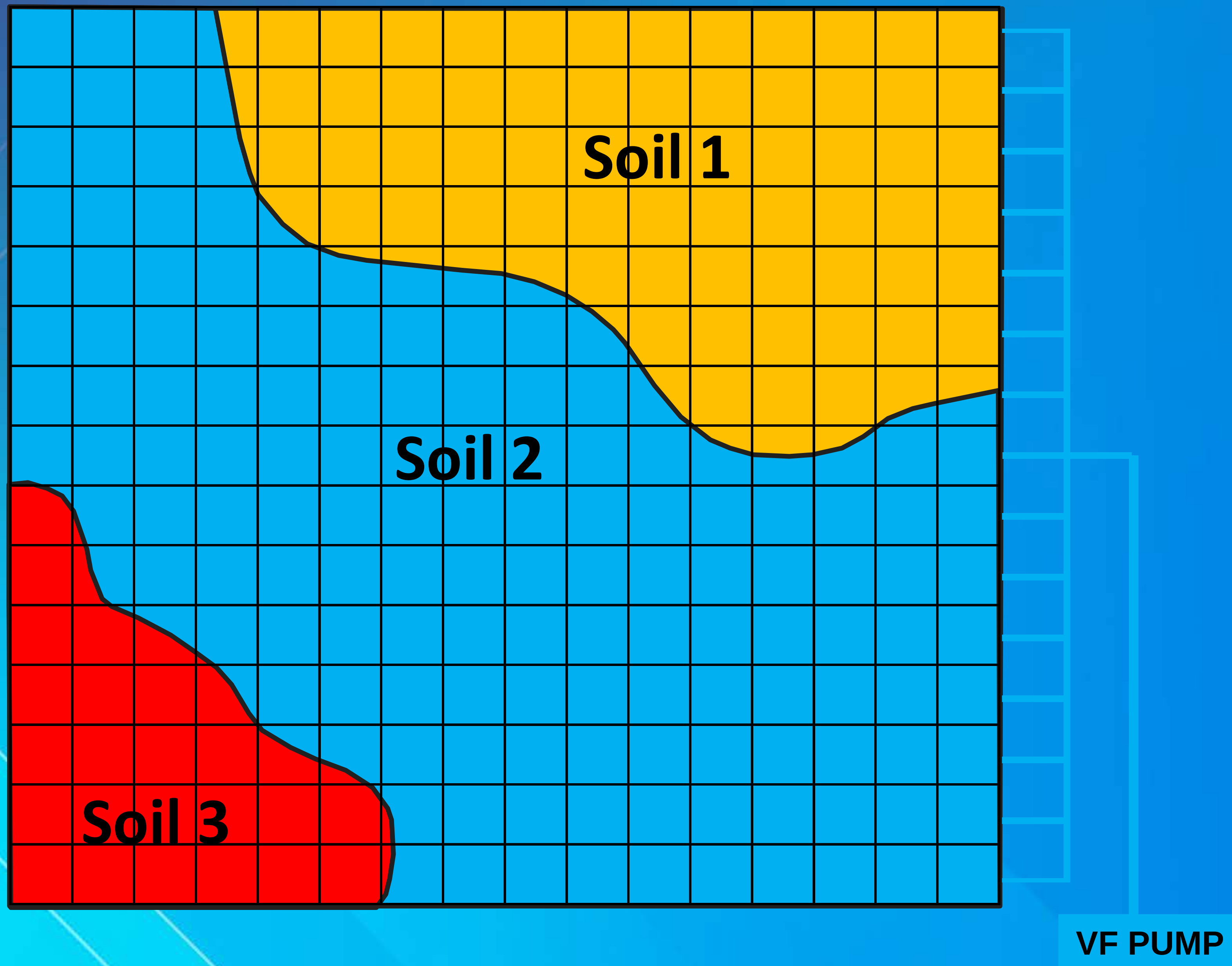
Zonal Irrigation



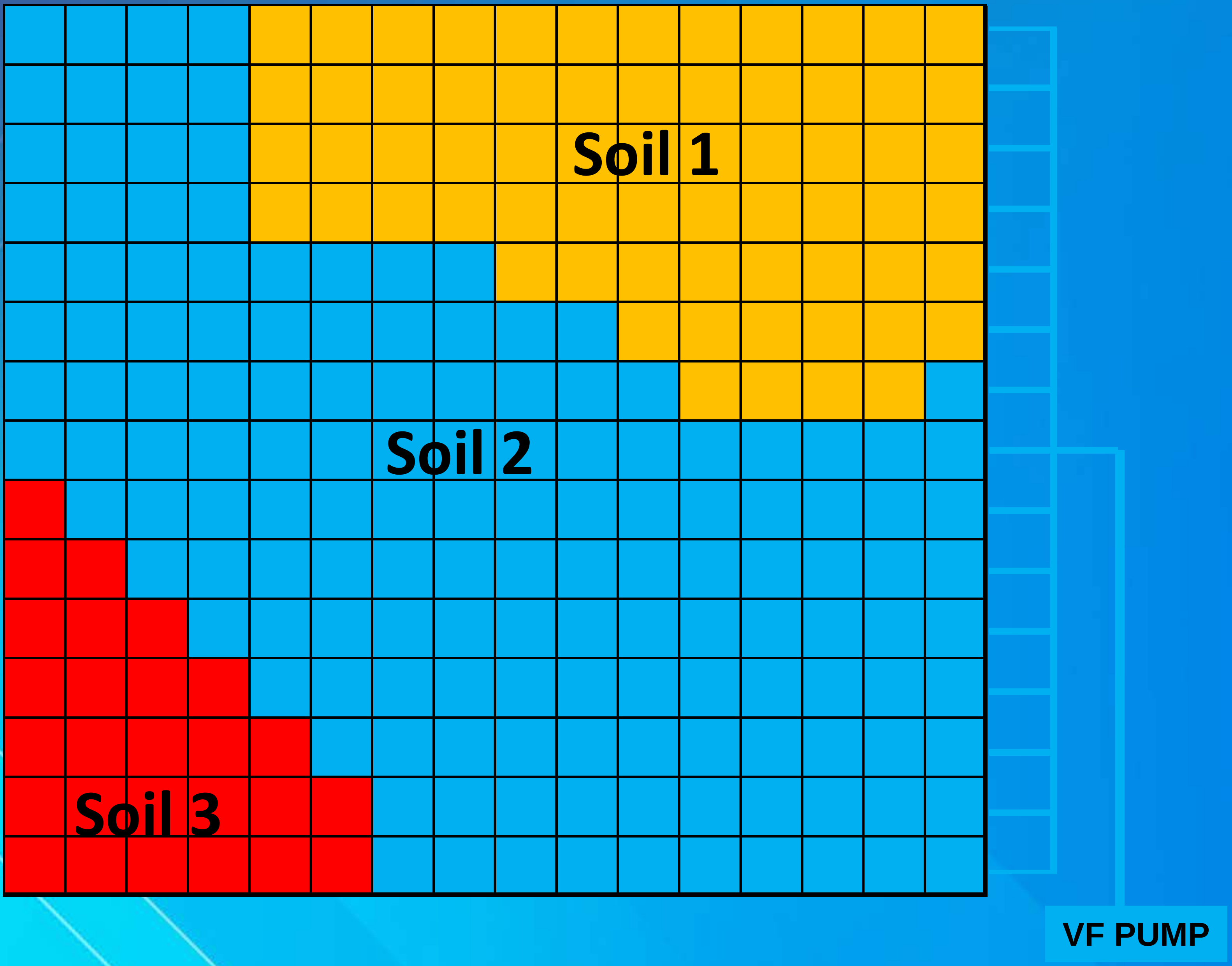
Modular Irrigation



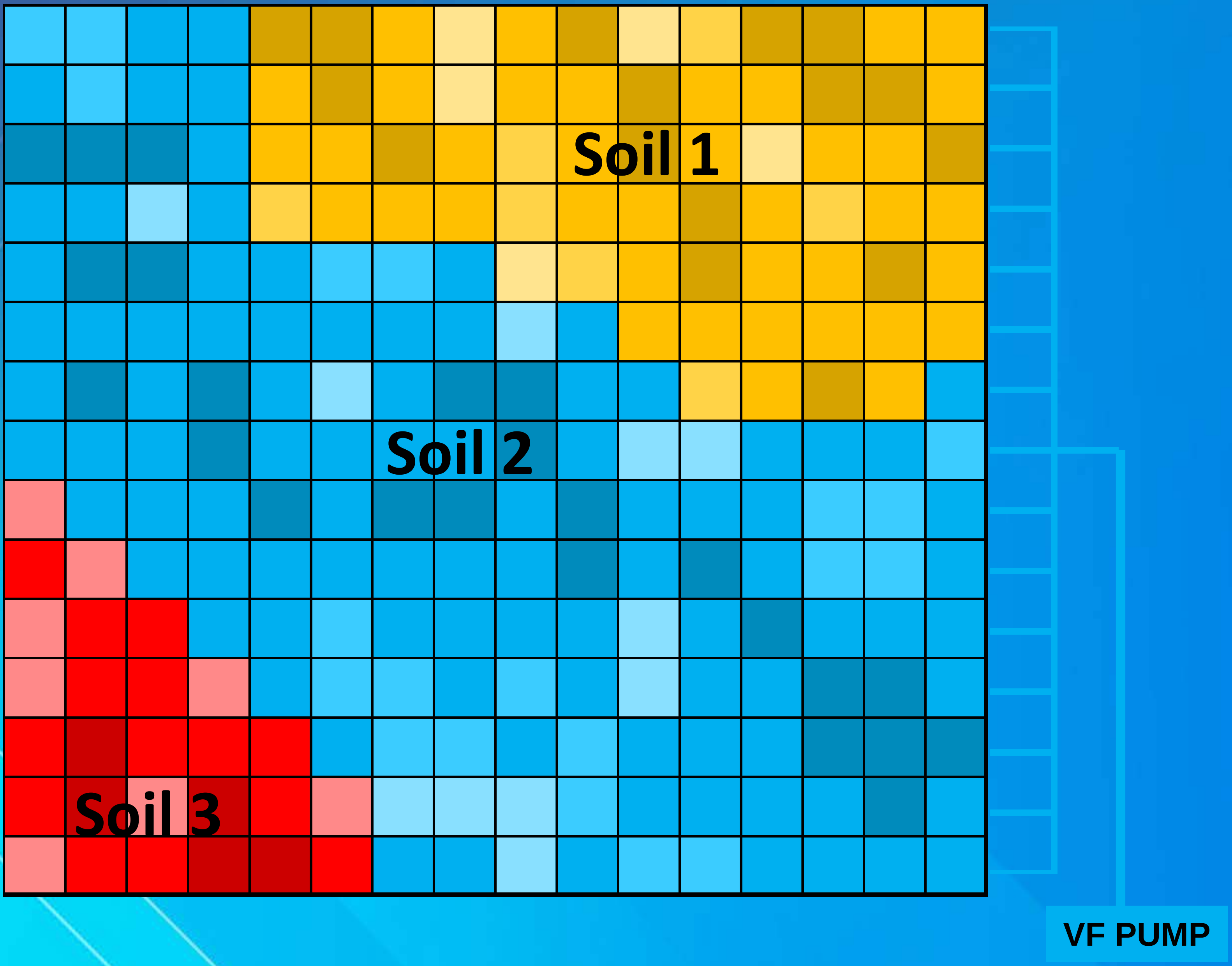
Modular Irrigation

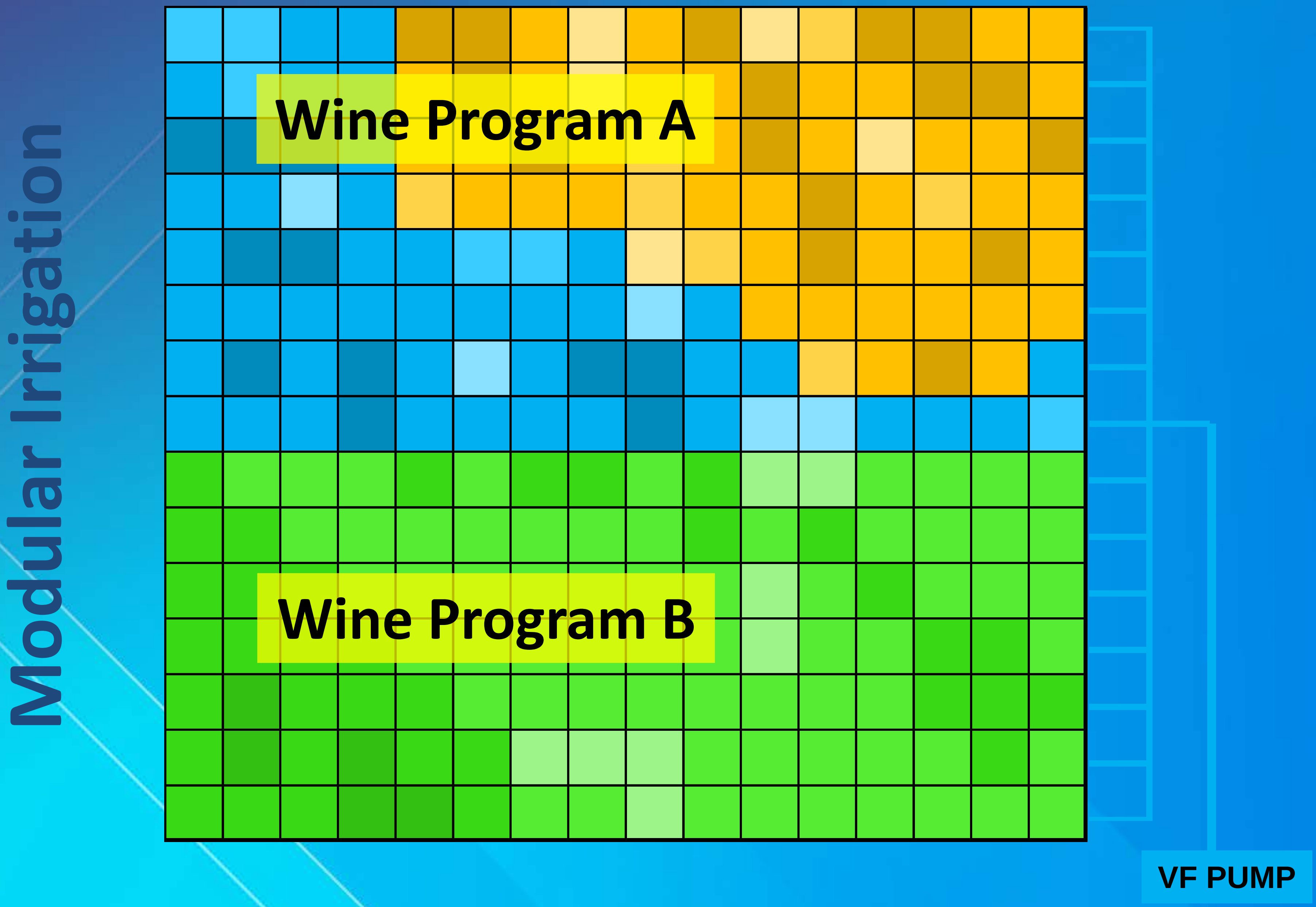


Modular Irrigation



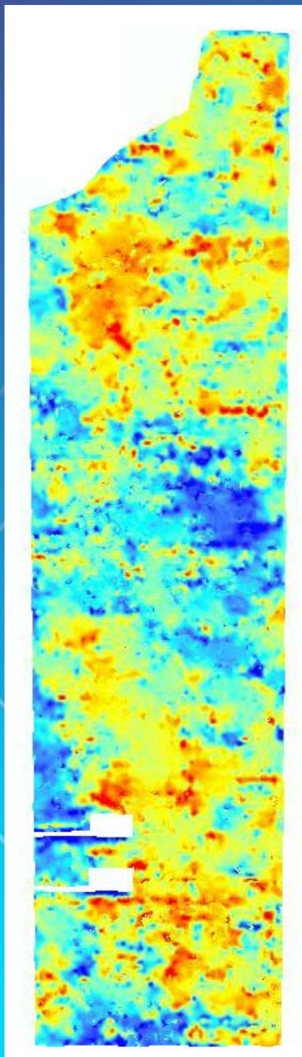
Modular Irrigation




Modular Irrigation
Wine Program A
Wine Program B
VF PUMP

Experiment location

2012 yield map



Colony 2A Cabernet Sauvignon

- **Wilton, California**
- **31.5 acres**
- **5 x 11 feet**
- **17-year old**
- **Teleki 5C**
- **Hand-pruned**
- **Drip-irrigated**

- **San Joaquin silt loam (~ 75%)**
- **San Joaquin-Galt complex (~ 25%)**
- **20 inches annual rainfall**
- **Highly variable**

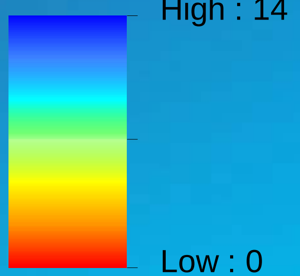
Yield (t/ac)

High : 14

Low : 0

Field layout

Yield (t/ac)

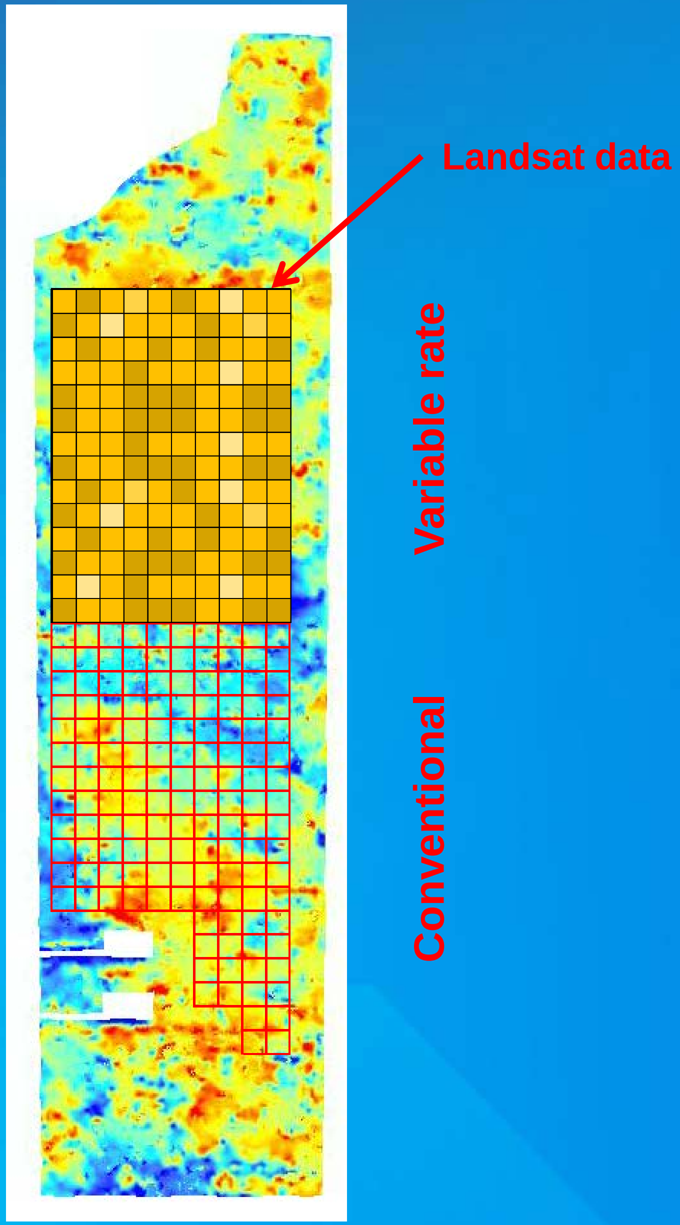


Block area: 31.5 acres
VRI & CI: 10.0 acres
Field average: 9.17 tons/acre

<u>For each high density variable:</u>

140 data points in VR Irrigation

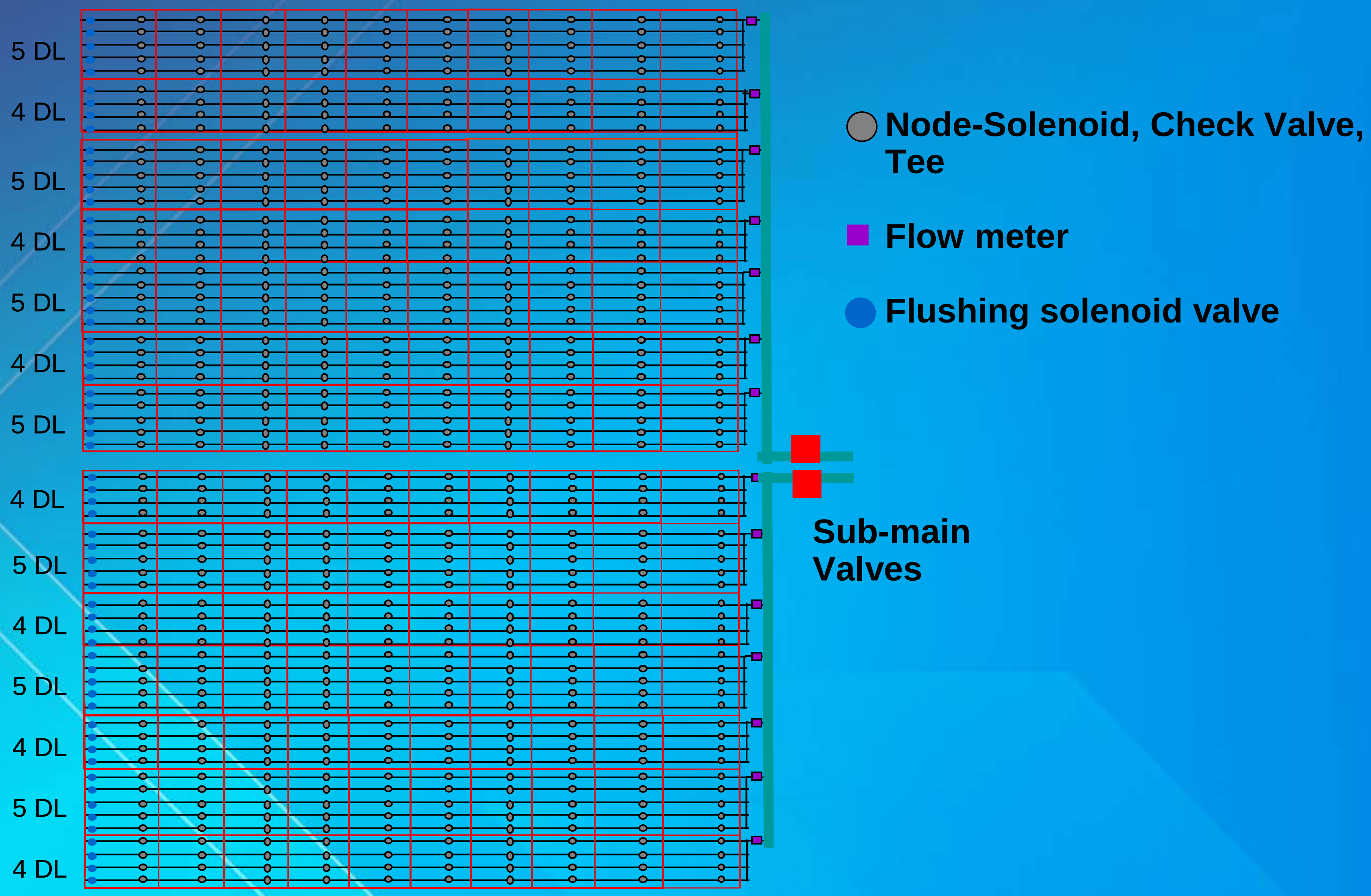
140 data points in Conventional Irrigation



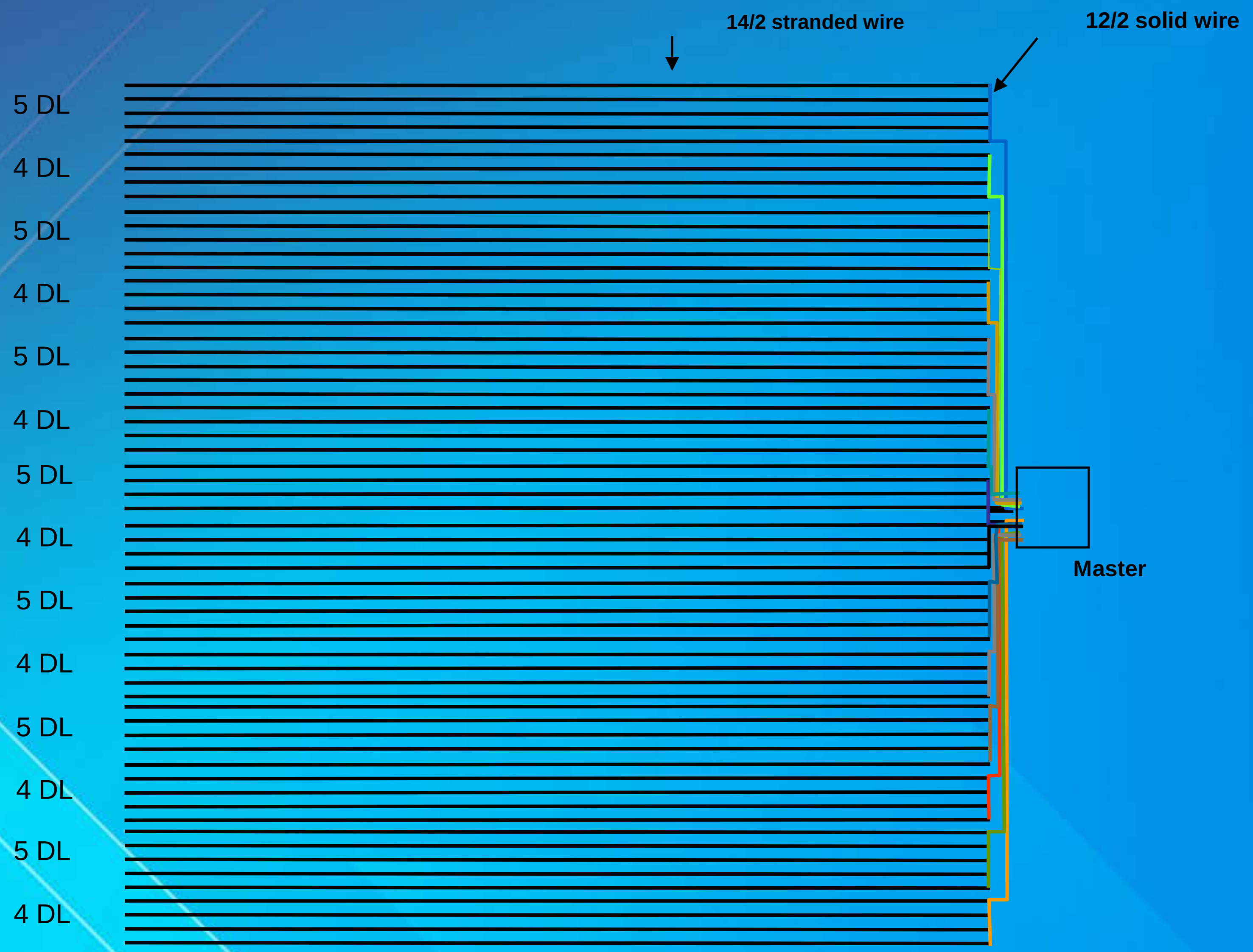
System design

- IBM First Of A Kind (FOAK) program
- Variable flow submersible pump
- Underground piping to experiment
- Main and sub-main valves
- Flow meters
- Power/electronics/central computer
- Double-hose irrigation tubing
- Solenoid and check valves

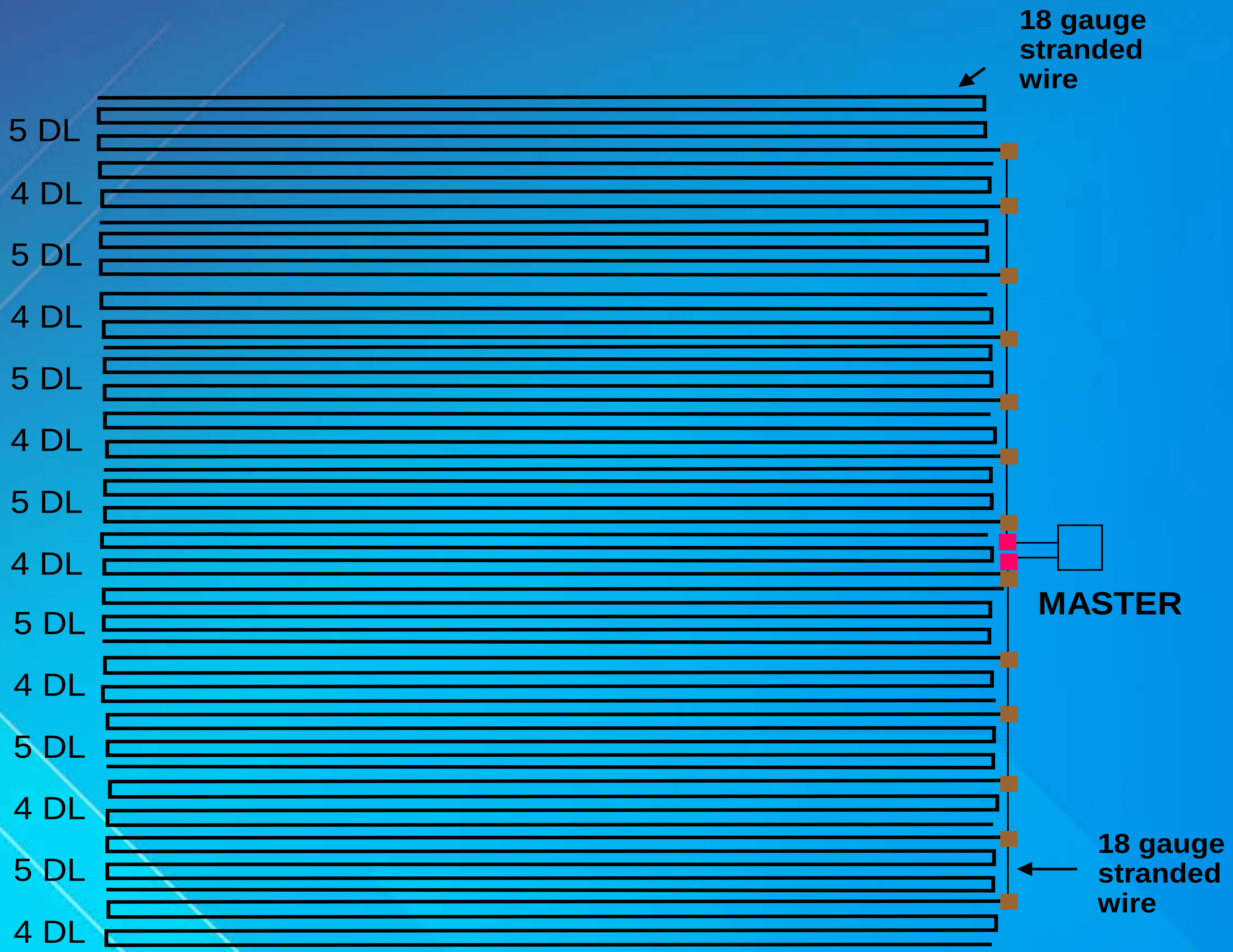
General layout



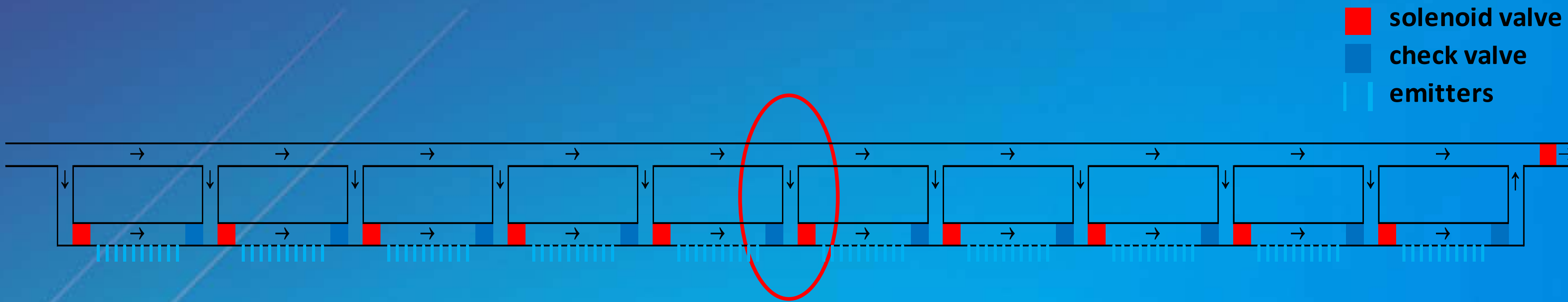
Power layout

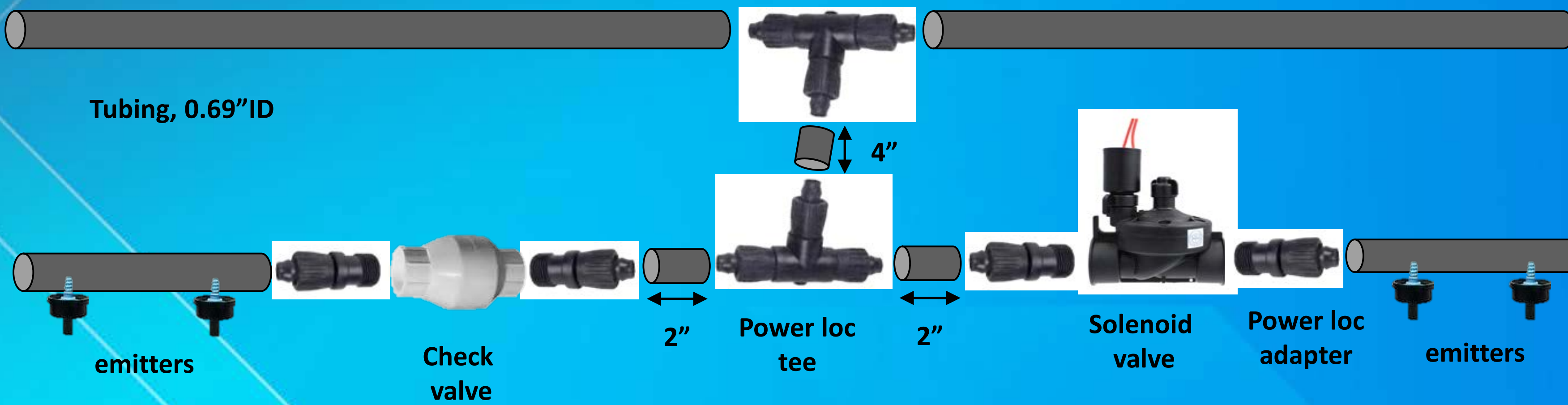


Communication layout



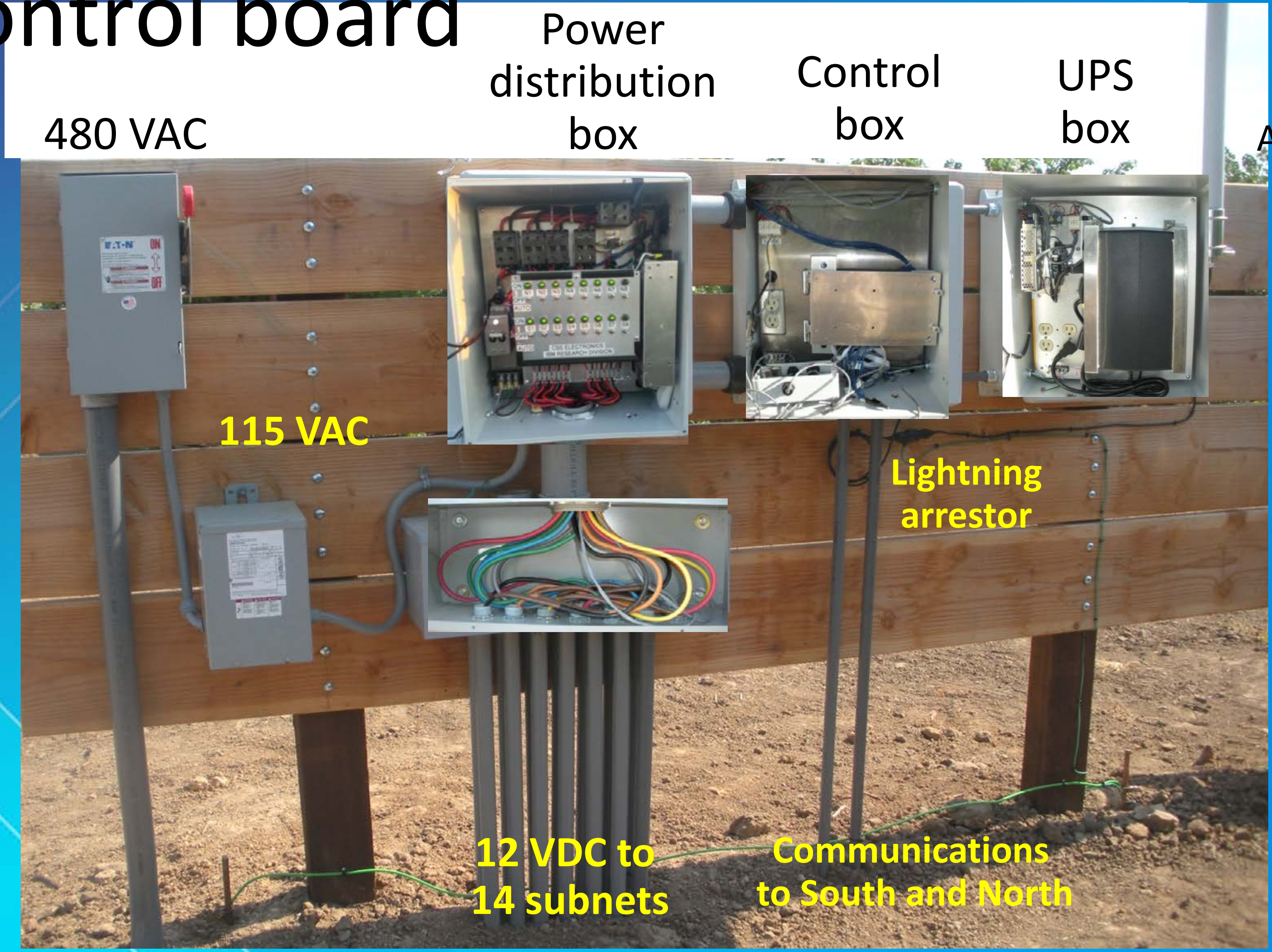
System design





System design

Control board



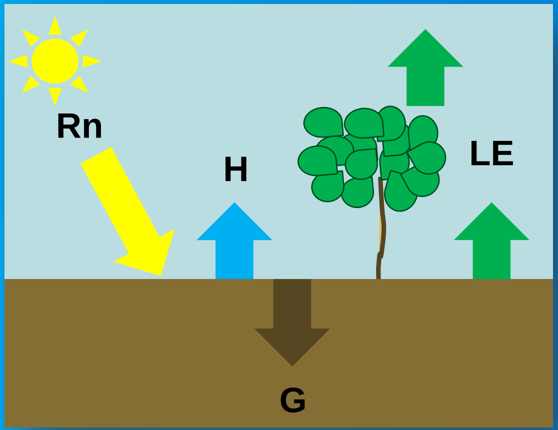
Irrigation zone control

- Computer network with single master coordinating operation
- Master-slave messaging protocol based on MODBUS
- High speed over the 3,000+ feet cable
- PC and master control are accessed remotely through cell link to load irrigation schedules

Irrigation scheduling

- METRIC (Mapping evapotranspiration at high resolution and internalized calibration)
- ET residual of surface energy balance

$$Rn + LE + G + H = 0$$



- Inputs
  - Landsat (visible & infrared)
  - CIMIS weather data
- Outputs
  - ETc
  - Kc (f/NDVI)
- Watering of each zone:

$$ETc = ETref * Kc * Km$$

2013 irrigation management

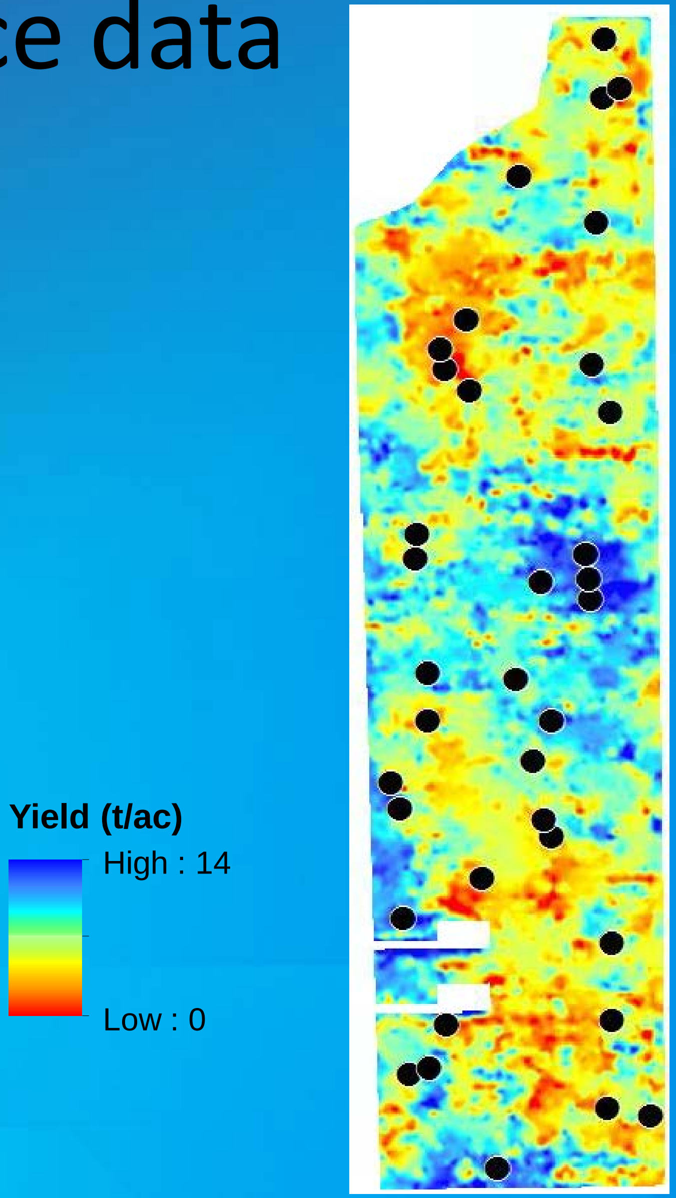
2012 yield tons/acre *(average = 8.9)*	# of irrigation zones	Irrigation management factor		
		May **4 weeks**	June **4 weeks**	July - Oct **16 weeks**
< 8.9	76	1.2	0.5	0.7
> 8.9	64	no irrigation	0.5	0.7

2014 irrigation management

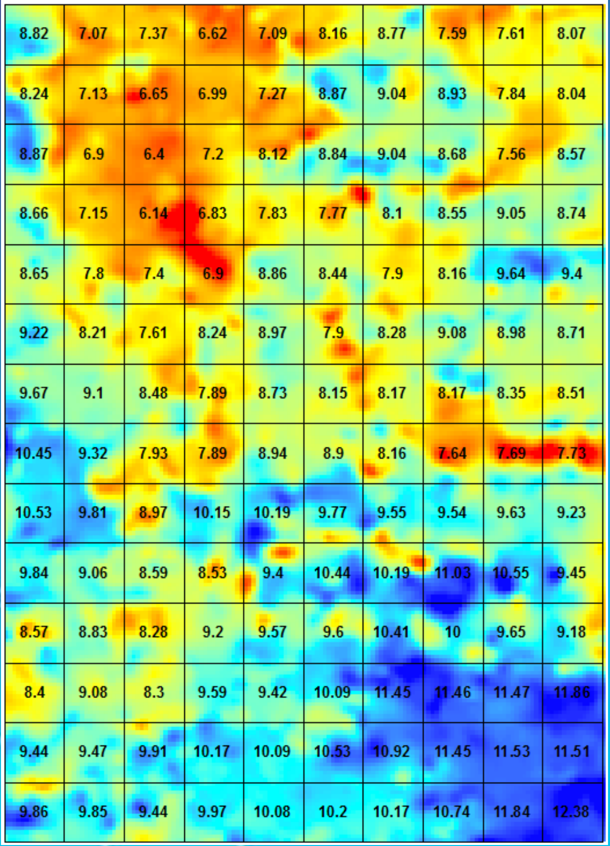
# of irrigation zones	Irrigation management factor		
	May **4 weeks**	June **4 weeks**	July - Oct **16 weeks**
140	0.0 - 0.7	0.5 – 0.8	0.6 – 1.0

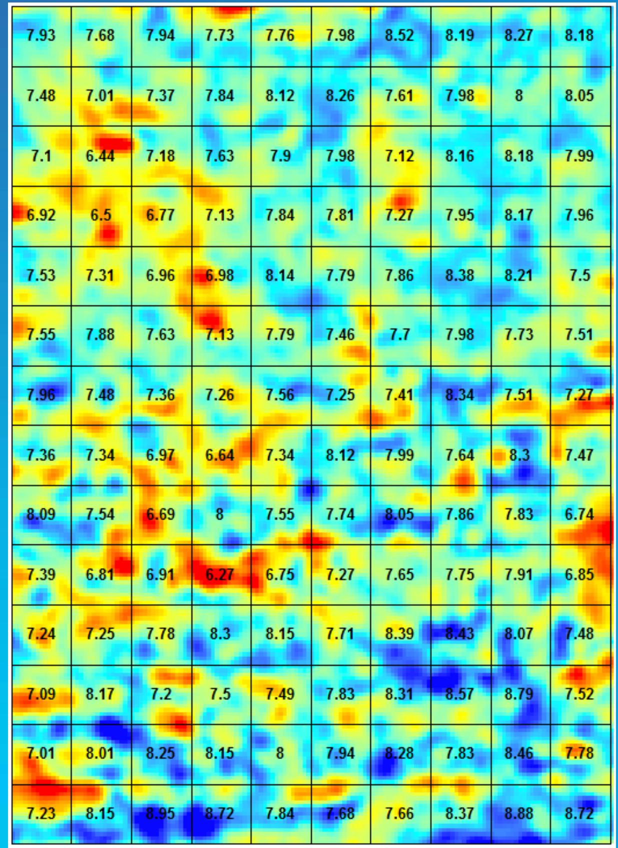
Vine performance data

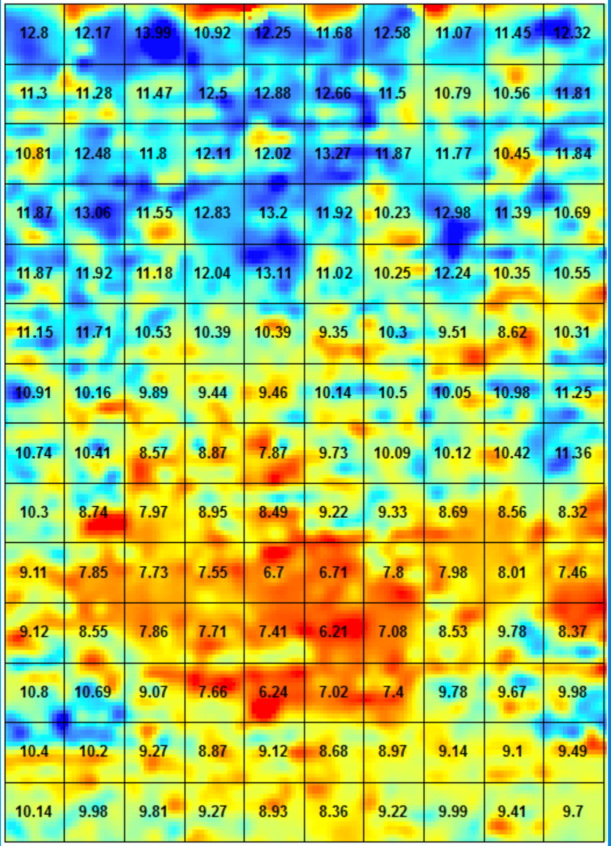
- High density:
  - Yield
  - NDVI
- Fruit composition
  - 43 analytes
  - GQI
- Wine composition
  - 45 analytes
  - Sensory



VRI Yield - Normalized





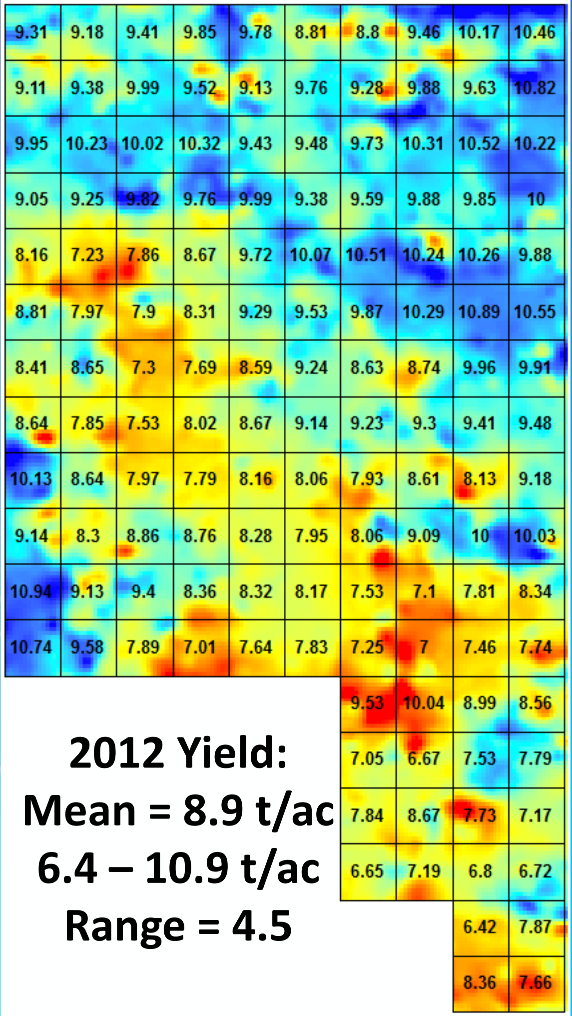


2012 Yield:
Mean = 8.9 t/ac
6.1 – 12.4 t/ac
Range = 6.3

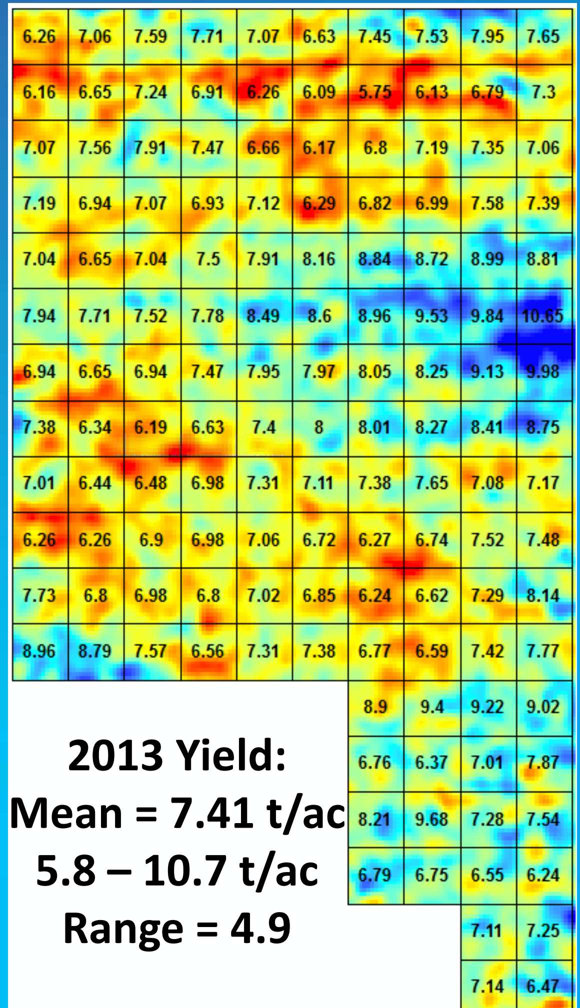
2013 Yield:
Mean = 7.7 t/ac
6.3 – 8.9 t/ac
Range = 2.6

2014 Yield:
Mean = 10.2 t/ac
6.2 – 14.0 t/ac
Range = 7.8

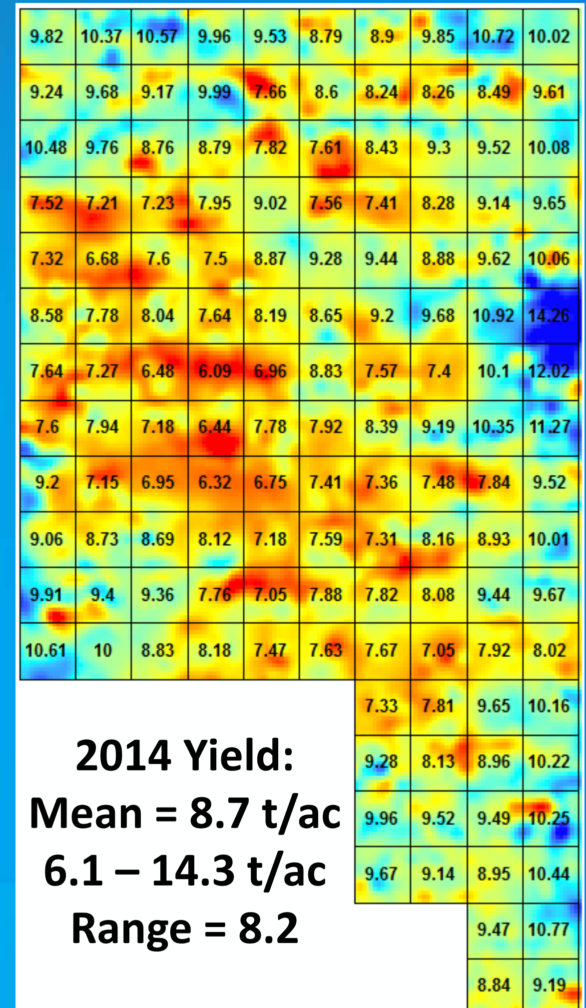
CI Yield - Normalized



2012 Yield:
Mean = 8.9 t/ac
6.4 – 10.9 t/ac
Range = 4.5

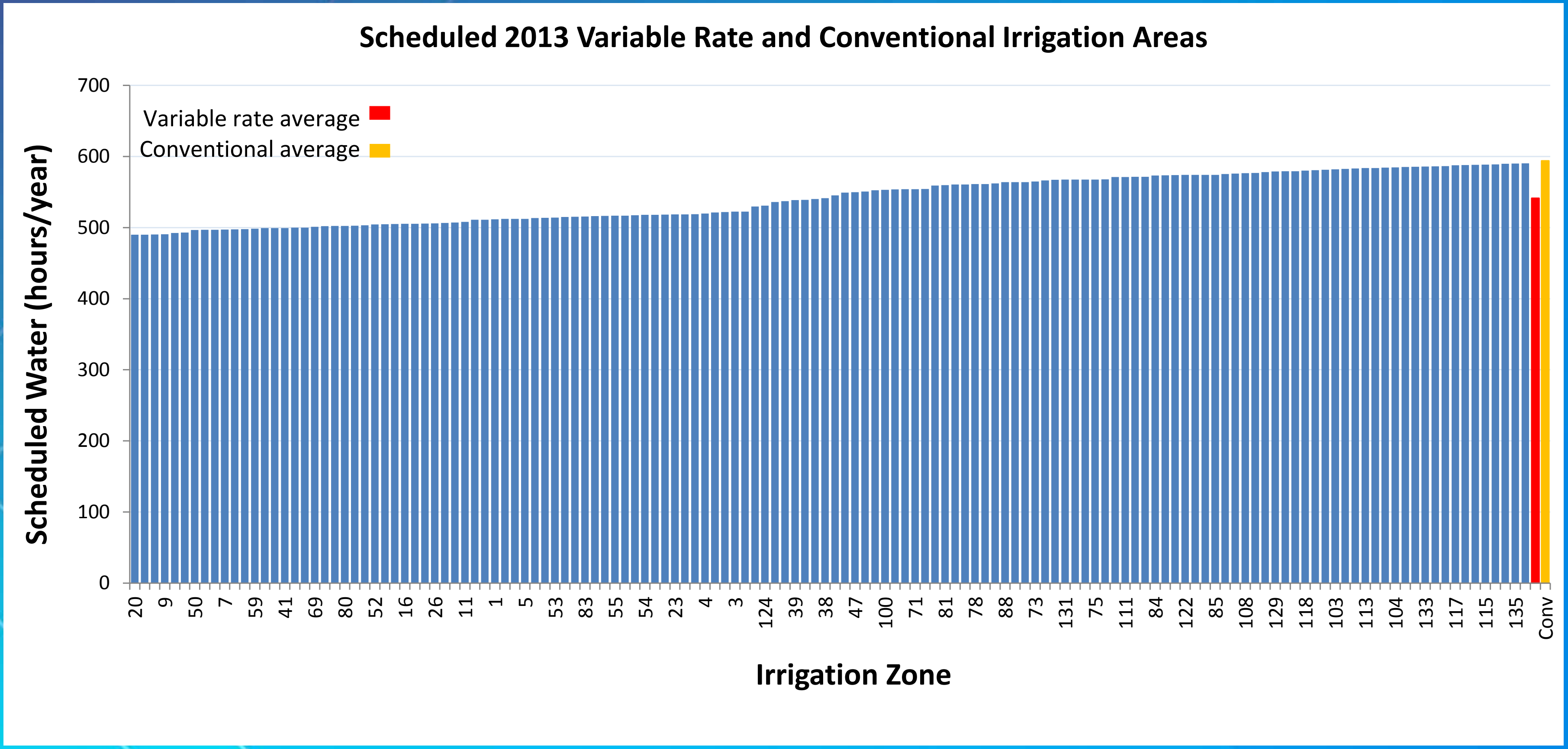


2013 Yield:
Mean = 7.41 t/ac
5.8 – 10.7 t/ac
Range = 4.9

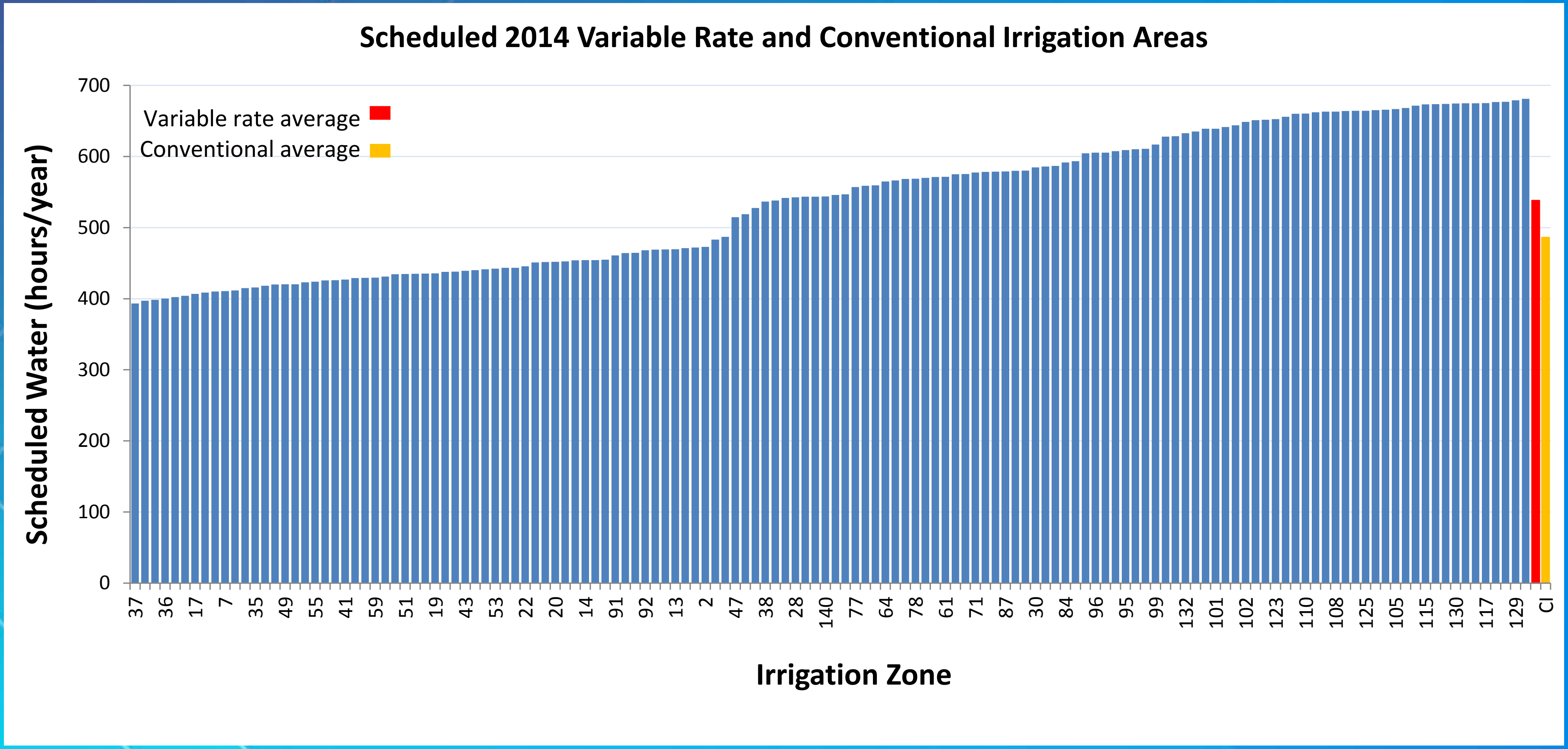


2014 Yield:
Mean = 8.7 t/ac
6.1 – 14.3 t/ac
Range = 8.2

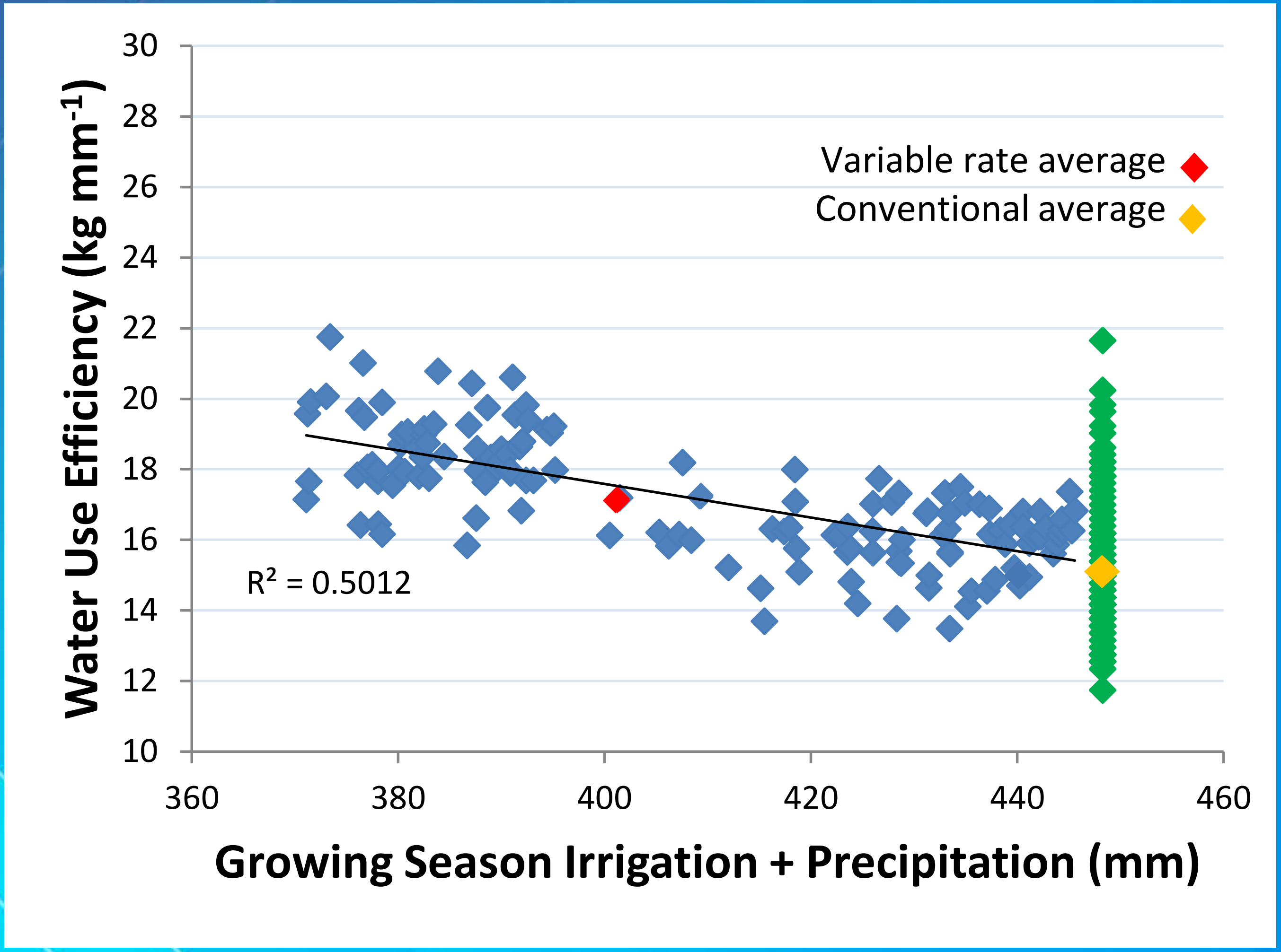
2013 applied water



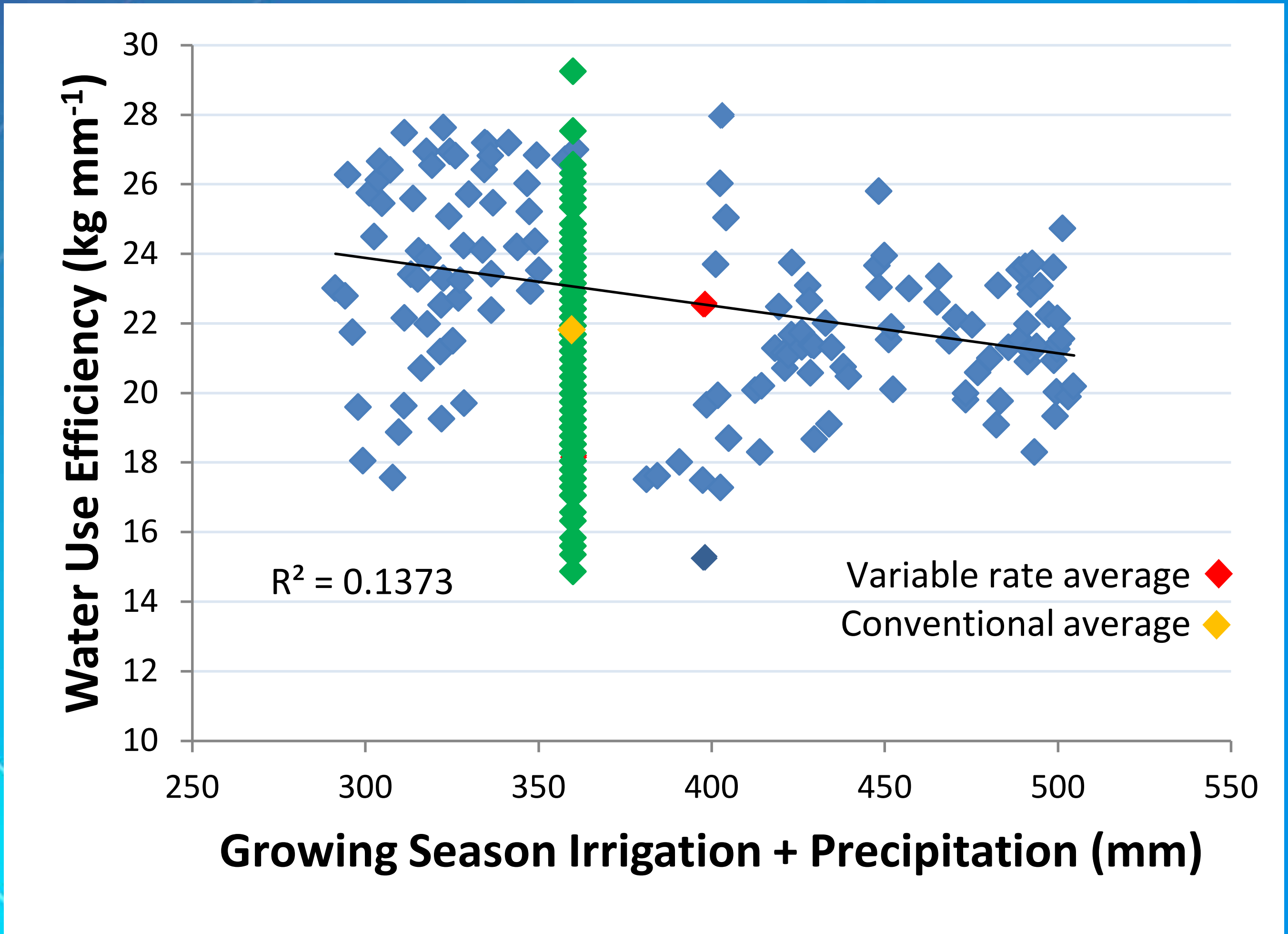
2014 applied water



2013 water use efficiency



2014 water use efficiency



Non-spatial statistics

Irrigation	Yield class	Leaf Area Index	clusters per vine	cluster weight (g)	berry weight (g)
Variable rate	high	6.0 a	147.7 a	76.0 a	0.9 ab
	medium	5.3 a	127.7 a	84.7 a	0.8 b
	low	5.2 a	127.7 a	71.6 a	0.7 c
Conventional	high	6.1 a	151.6 a	81.9 a	1.0 a
	medium	6.1 a	155.6 a	75.7 a	0.8 b
	low	6.1 a	130.2 a	66.1 a	0.7 bc

Different letters are significantly different at $p<0.05$

Spatial statistics

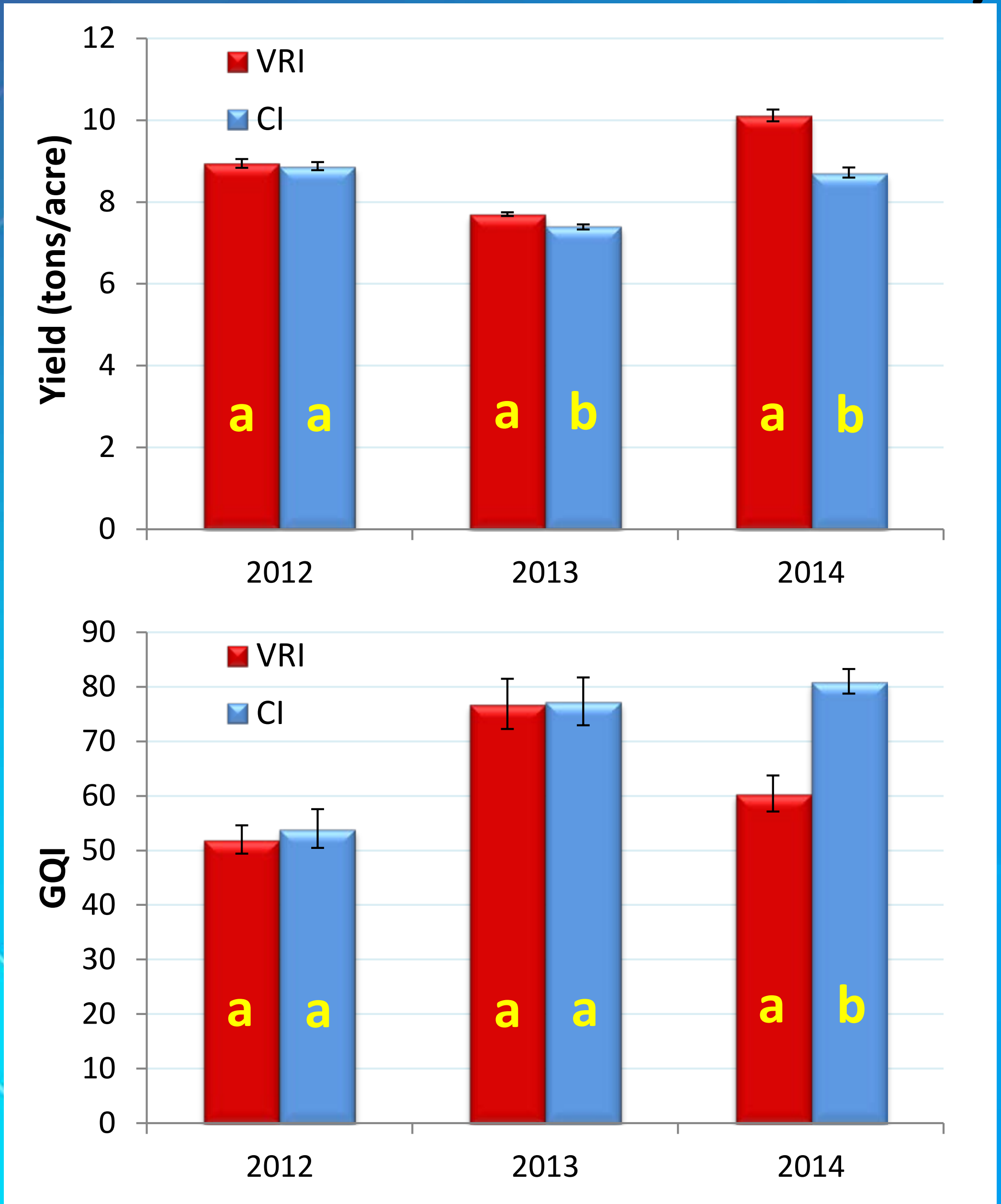
1. MCD, Mean Correlation Distance
2. Cambardella Index

Measures of spatial dependence and structure

Variable Rate Irrigation:

- Decreased spatial structure in 2013
- Increased spatial structure in 2014

Fruit Yield and Quality



2013 Wine Composition

	Irrigation	
	Conventional	**Variable rate**
A420	4.2 b	4.7 a
A520	8.0 b	9.3 a
MALC	14.4 b	15.1 a
Malic acid	2,062.8 a	1,806.5 b
IBMP	1.8 a	1.2 b
Pigmented_polymers	27.8 b	33.5 a
Polymeric_tannins	611.6 b	761.5 a
Quercetin glycosides	2.7 b	4.1 a
Dimethyl_sulfide	12.8 a	11.3 b

Conclusions

- First season:
  - Successful VRI system prototype implementation
  - VRI decreased vineyard variability
  - VRI increased water use efficiency
- Second season:
  - Increased yield in low yielding vines
  - Maintained high water use efficiency
- Opportunity for commercial development

Acknowledgments

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  - Viticulture Lab: Luis Sanchez, Maegan Salinas, Erin Troxell, Shijian Zhuang, Nona Ebisuda
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  - GIS-CE: Martin Mendez, Andrew Morgan
  - Nick Dokoozlian
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