Efficient Water Management for Sprinkler and Surface Irrigated Forages

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Efficient Water Management for Forage Crops- March 13-14, 2024
Montague and Tulelake

Irrigation: Controlled amount of water is applied to plants at specific intervals

Irrigation Methods:

1- Surface irrigation (flood or gravity):

- **Border strip (flat) irrigation (slope 0.1-0.2%)**
- **Furrow irrigation (slope)**
- **Basin irrigation (zero slope)**

2- Sprinkler Irrigation (various types)

3- Drip Irrigation (various types)

- **Surface drip**
- **Subsurface drip**

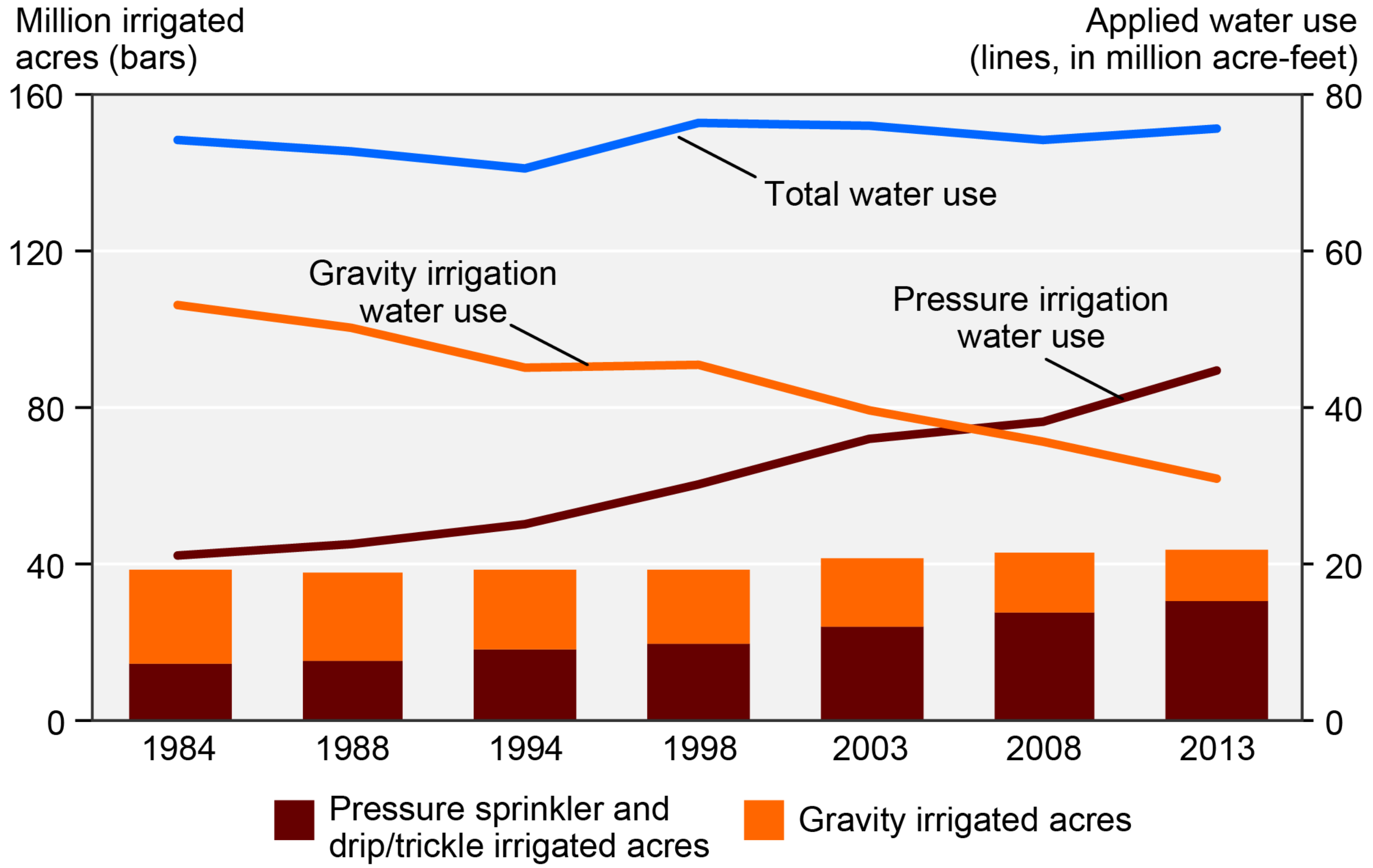



Surface Irrigation: Major improvements since the 1950s

- Land leveling
- Canal lining

Recent improvements: Automation of Surface Irrigation

Irrigated acres and applied water use, 17 Western States, 1984-2013



Source: USDA, Economic Research Service using USDA, National Agricultural Statistics Service, Farm and Ranch Irrigation Survey (FRIS) data. Note that FRIS reports onfarm water applied, not withdrawn; this chart excludes irrigated horticulture crops under protection.

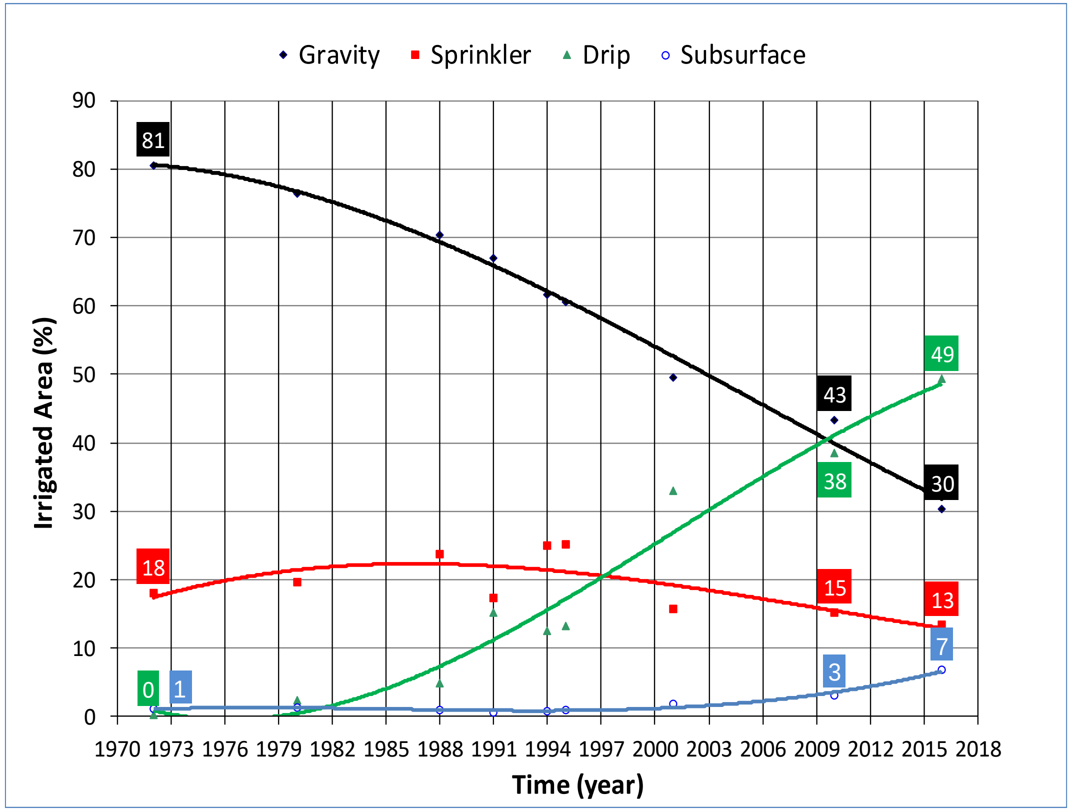
TRENDS IN CALIFORNIA IRRIGATED AGRICULTURE

- Water Agencies and regulators provide financial incentives to growers to shift to micro-irrigation systems (SWEEP, EQIP, CEC)

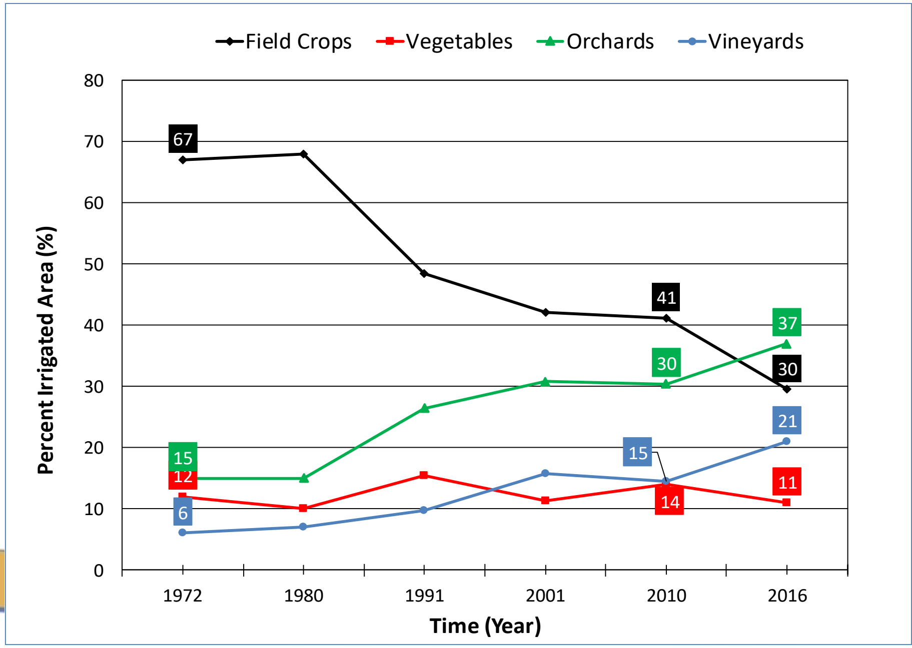
California Agriculture Challenges

Regulations, water, labor, high production costs, etc

Approximately 30% decline in field crops between 2006 and 2017 and increase in permanent crops



Source: Irrigation Survey 2018, *(DWR-UCD)*



Crop Water Use and Irrigation Efficiency

Crop ET = Reference ET x Crop Coefficient

$$ET_C = ET_O \times k_C$$

$$D_{max} = \left[\frac{ETc_{(peak)}}{Eff_{APP}} \right] = in / day$$

ETc is also used in system design: Max irrigation depth to be applied (D_{MAX})

System	Potential Eff.$_{APP}$	Actual Eff.$_{APP}$
Gravity	70-85%	50-90%
Drip	85-90%	50-95%
Micro-sprinkler	80-90%	50-90%
Sprinkler	70-90%	60-90%

Traditional drip (SDI) or sprinkler example:
Peak ETo= 0.40/day Max Kc=1.2 AE=80%

Max application depth=(0.4*1.2/.8)=0.60 in/day
80 acre field with just one zone, need to apply this in

~ 8-20 hr/day (4 ac-ft/day) for drip
~ 4-10 hr/day (4 ac-ft/day) for sprinkler

For flood application rates as high as 10 times the above figures (3-4" per irrigation or more for lighter soils)

How Much Water do I need to Apply?

- Need to know crop water use (ETc) since last irrigation
- ETc from (Reference evapotranspiration and crop coefficient)

- Typical application rates (vary widely depending on soil type, etc):

- Surface: ~ 3-5 in/irrigation (much higher rate for light soils)

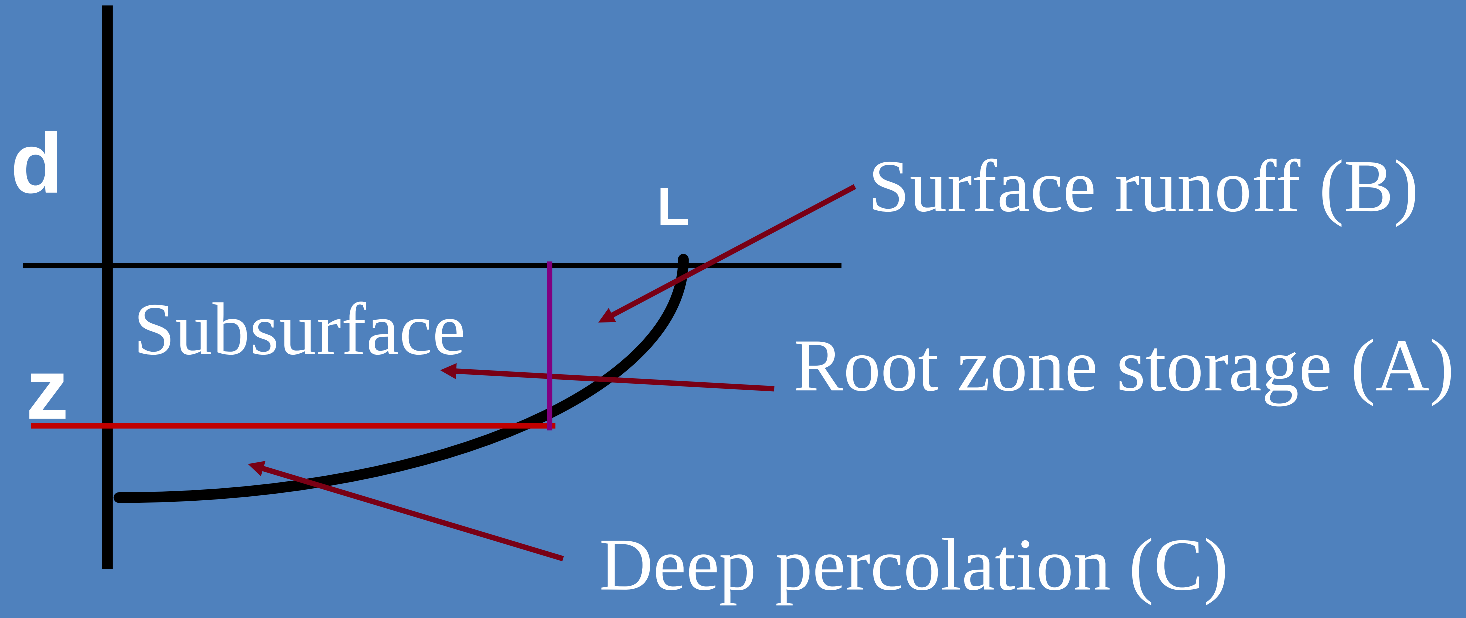
- Sprinkler: ~ 0.5-1.2 in/irrigation

- Drip: ~ 0.5 in/irrigation

- Delivery systems in California were designed for surface irrigation

Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation



On-Farm Water Conservation
=Higher Application Efficiency (AE)

IRRIGATION = Evapotranspiration (ET)+ DEEP PERCOLATION + Runoff

A + B + C

Application Efficiency (AE)= A/(A+B+C)

To achieve higher efficiency, reduce B and/or C

BUT

Need to have a balance,

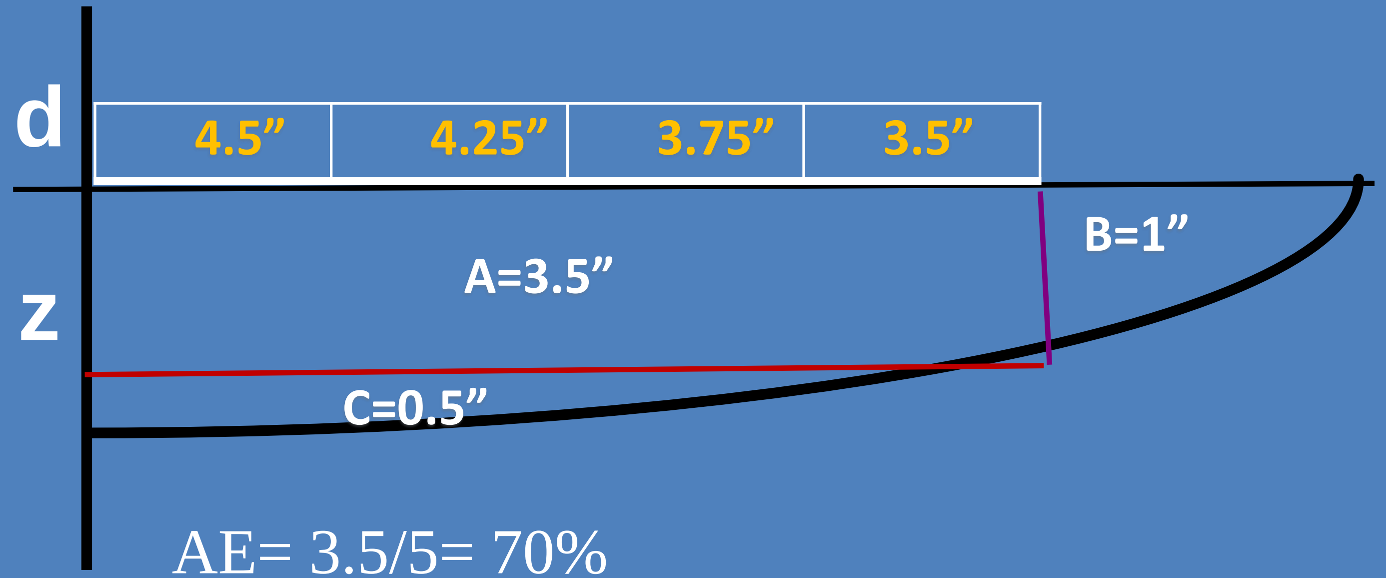
Deep Percolation sometimes is needed for salinity control

(800 ppm ~ 1 ton of salt/ac-ft)

Runoff is needed for Uniformity (100% AE means under irrigation)

Surface Irrigation (uniform soil?)

Applied water = Root zone storage (A) + runoff (B)+ deep percolation (C)



AE= 3.5/5= 70%

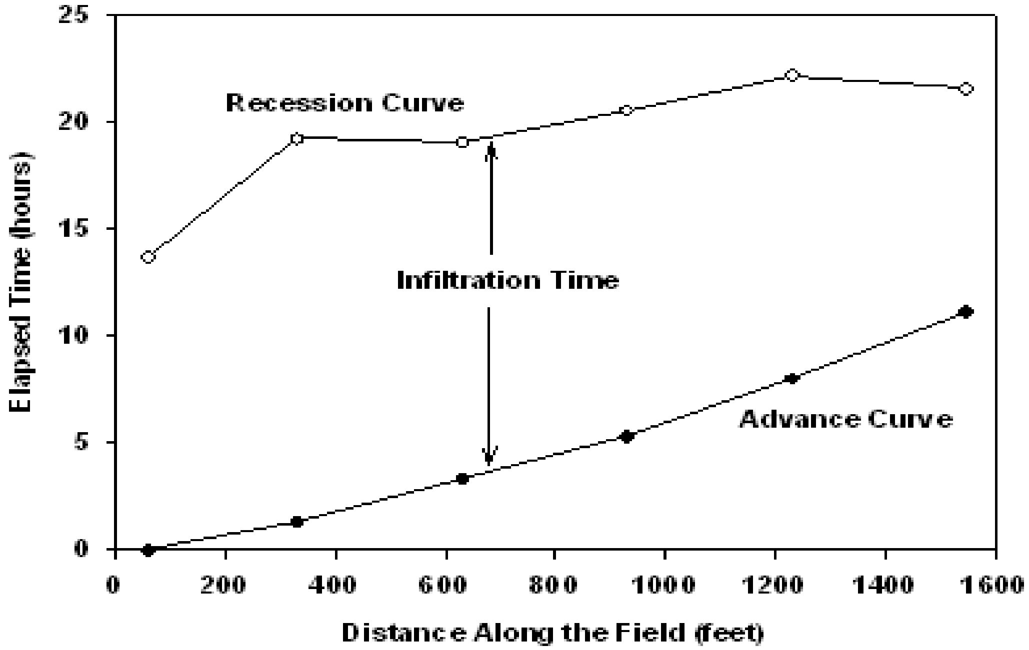
ROR=1/5=20%

DPR=0.5/5=10%

DU=3.5/4= 87.5% (Distribution Uniformity)

Advance and Recession Curves

(also other parameters are need for system evaluation, flow rates, slope, n, soil type, etc)



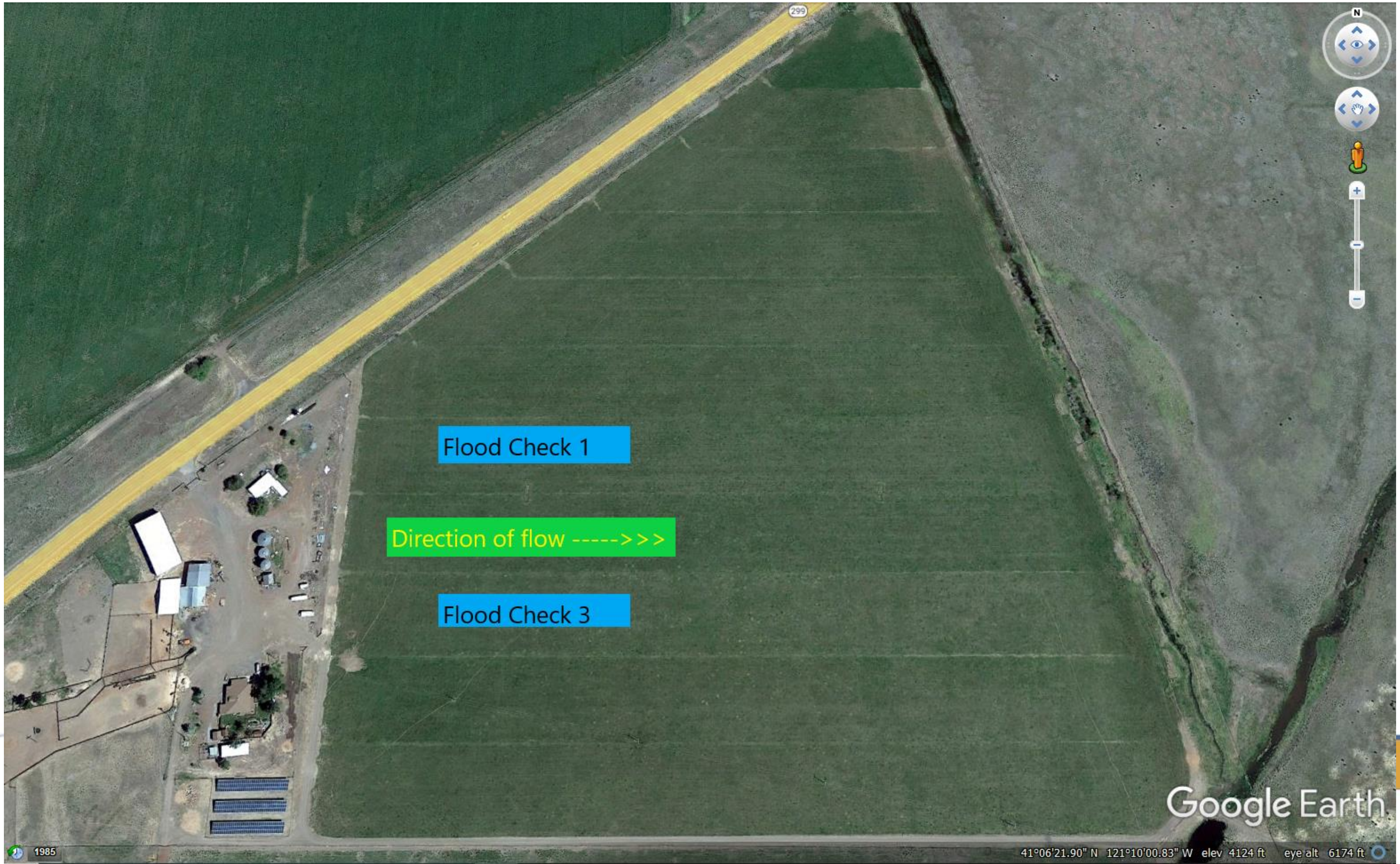
Advance and Recession Curves

(also other parameters are need for system evaluation, flow rates, slope, n, soil type, etc)

Surface Irrigation Systems and GW Recharge

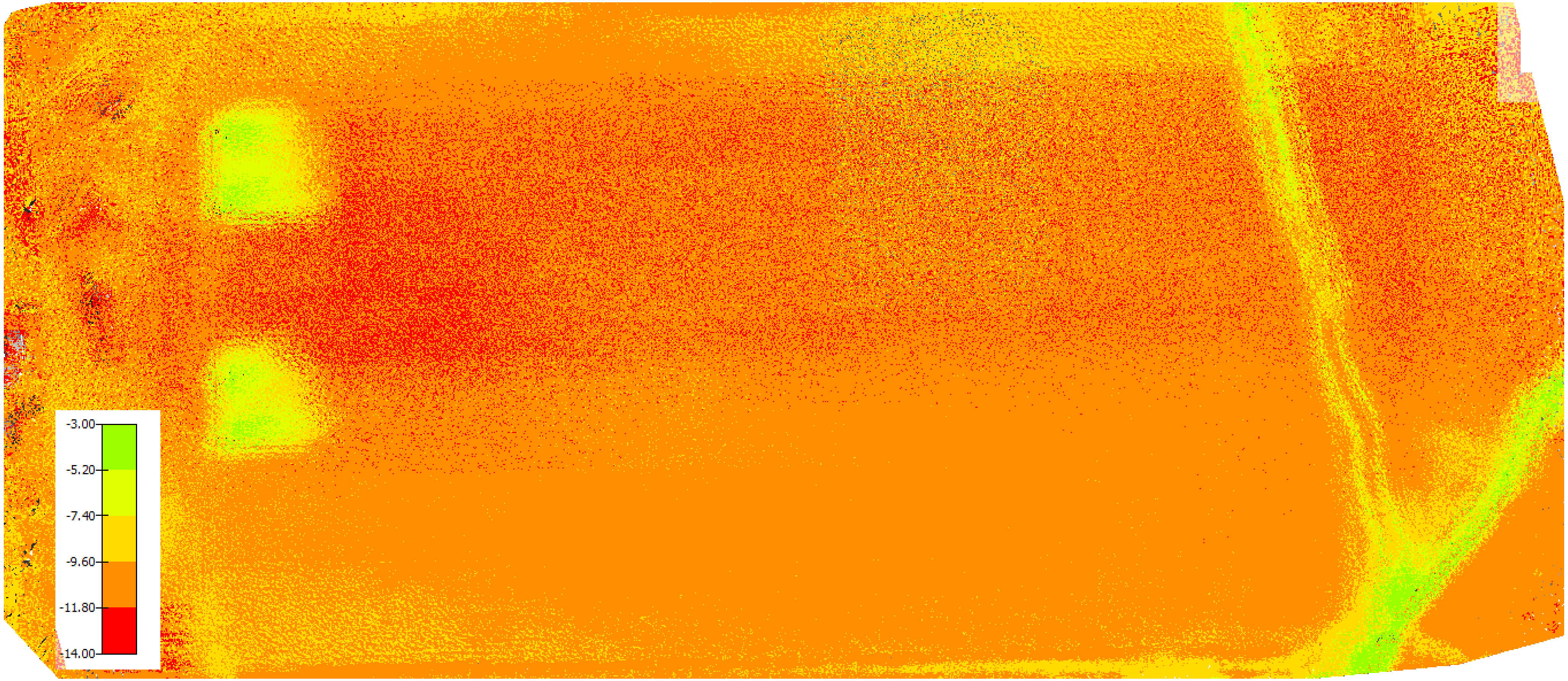
Map of McArthur site- Big Valley, CA

(From Google Earth)

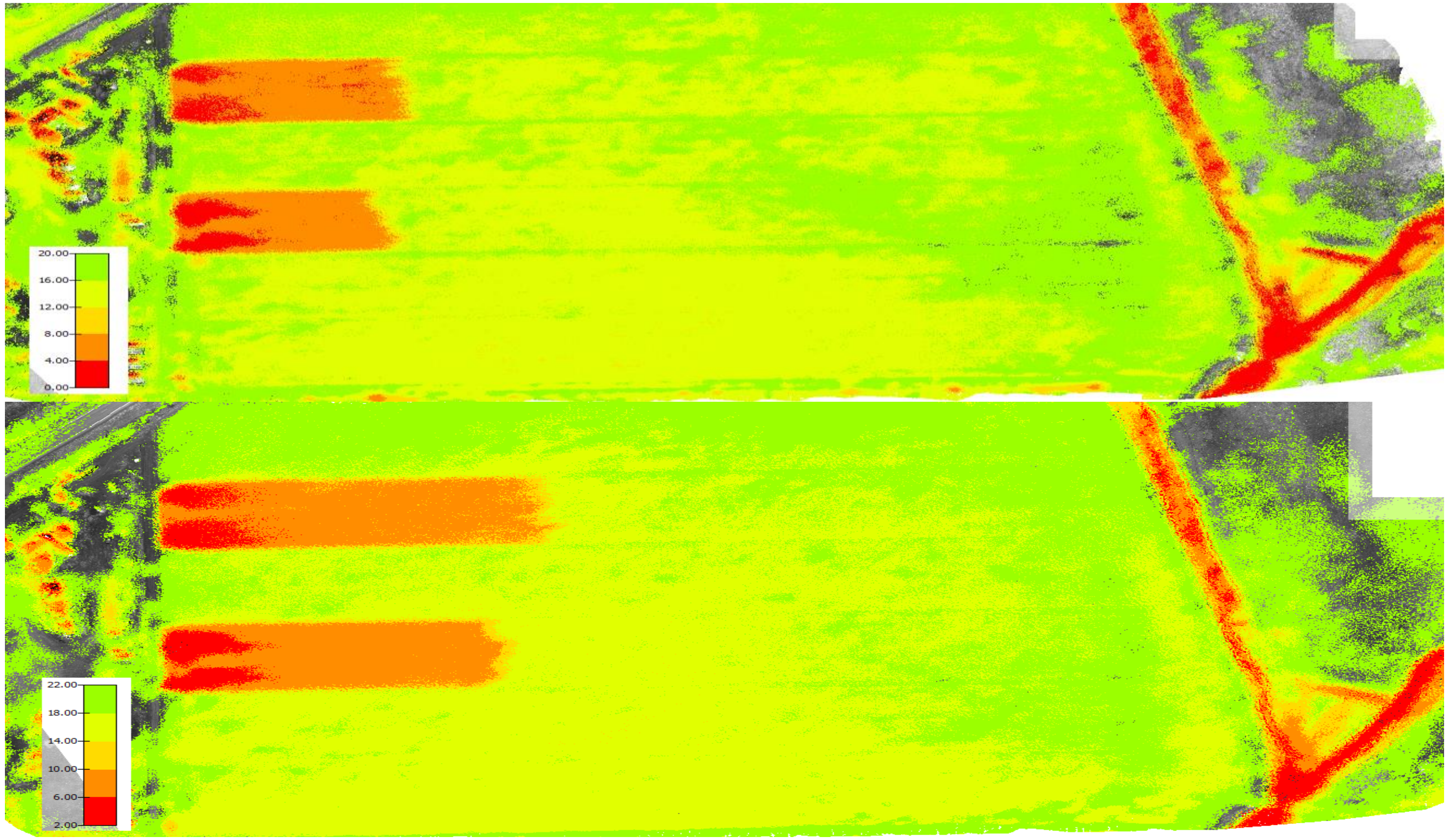


Thermal Images showing advance

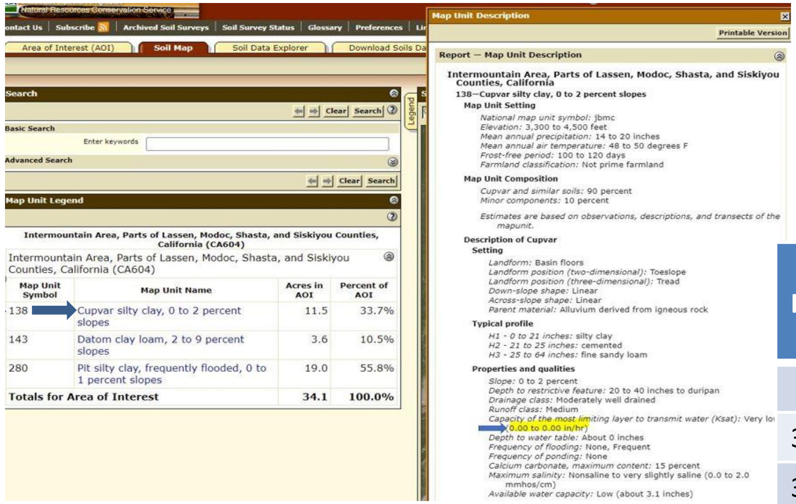
(taken with drone ~8 am 3/4/2021)



More thermal images (~10:30 and 12:30)



McArthur
Big Valley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Map Unit Legend

Intermountain Area, Parts of Lassen, Modoc, Shasta, and Siskiyou Counties, California (CA604)

Intermountain Area, Parts of Lassen, Modoc, Shasta, and Siskiyou Counties, California (CA604)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
138	Cupvar silty clay, 0 to 2 percent slopes	11.5	33.7%
143	Datom clay loam, 2 to 9 percent slopes	3.6	10.5%
280	Pit silty clay, frequently flooded, 0 to 1 percent slopes	19.0	55.8%
Totals for Area of Interest		34.1	100.0%

Legend

Map Unit Description

Printable Version

Report — Map Unit Description

Intermountain Area, Parts of Lassen, Modoc, Shasta, and Siskiyou Counties, California

138—Cupvar silty clay, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: jbmc
Elevation: 3,300 to 4,500 feet
Mean annual precipitation: 14 to 20 inches
Mean annual air temperature: 48 to 50 degrees F
Frost-free period: 100 to 120 days
Farmland classification: Not prime farmland

Map Unit Composition

Cupvar and similar soils: 90 percent
Minor components: 10 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Cupvar

Setting

Landform: Basin floors
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from igneous rock

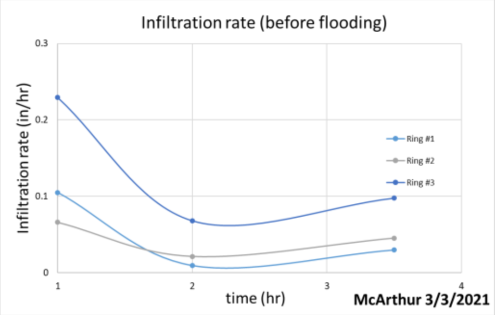
Typical profile

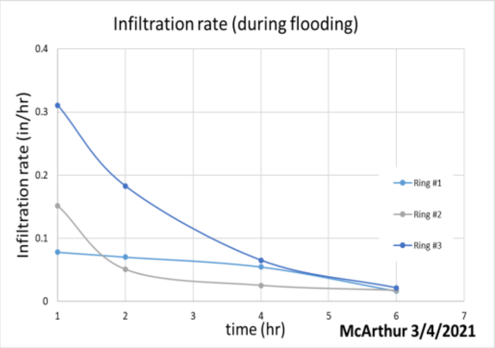
H1 - 0 to 21 inches: silty clay
H2 - 21 to 25 inches: cemented
H3 - 25 to 64 inches: fine sandy loam

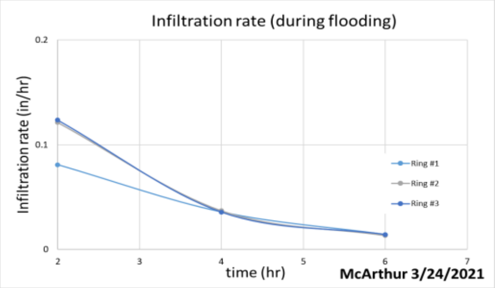
Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 20 to 40 inches to duripan
Drainage class: Moderately well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very lo (0.00 to 0.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None, Frequent
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Low (about 3.1 inches)

Date	Irrigated checks	Avg. Applied depth (in)
McArthur		
3/4/2021	1 & 3	1.82
3/24/2021	1 & 3	2.34
4/7/2021	1 & 4	2.16

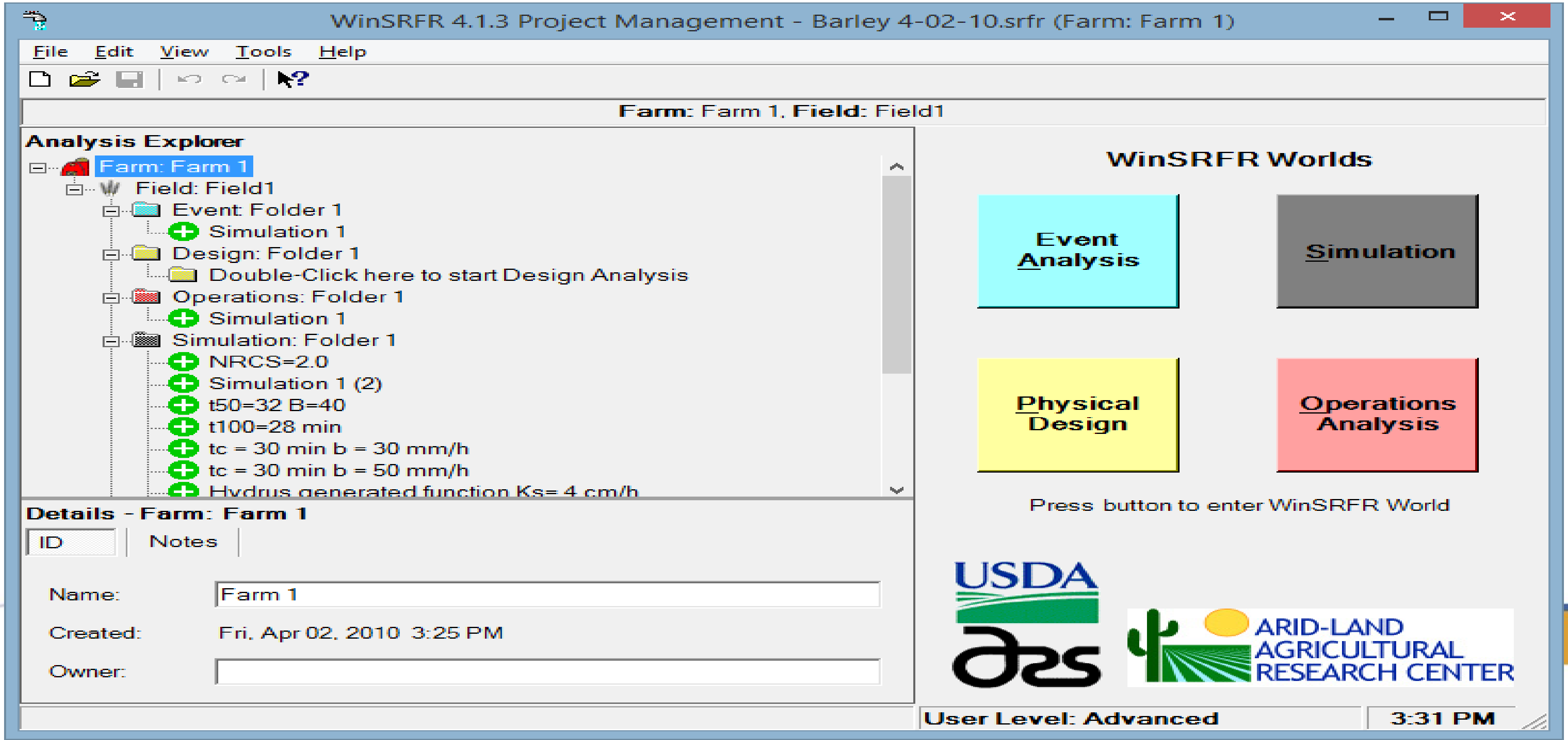






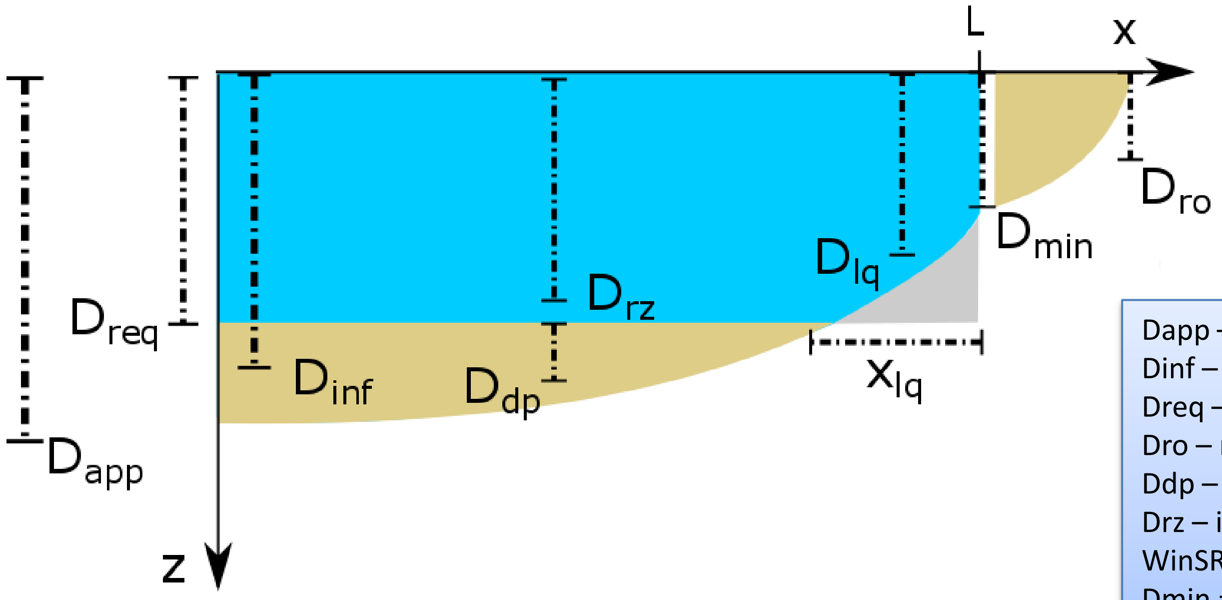
Tools to Improve Surface Irrigation Efficiency

- Evaluation of current irrigation system (AE and DU)-Application Efficiency and Distribution Uniformity
- Inflow rate, outflow rates (runoff and tile water)
- Advance rate (and recession rate) using wireless advance sensors
- WinSRFR (surface irrigation design and simulation model)



Final infiltration profile and irrigation performance measures

Application Efficiency (AE) and Distribution Uniformity (DU)



- Dapp – applied depth
- Dinf – infiltrated depth
- Dreq – required depth
- Dro – runoff depth
- Ddp – deep percolation depth
- Drz – infiltrated depth contributing to the required (Dz in WinSRFR manual)
- Dmin = minimum depth
- Dlq – low-quarter depth

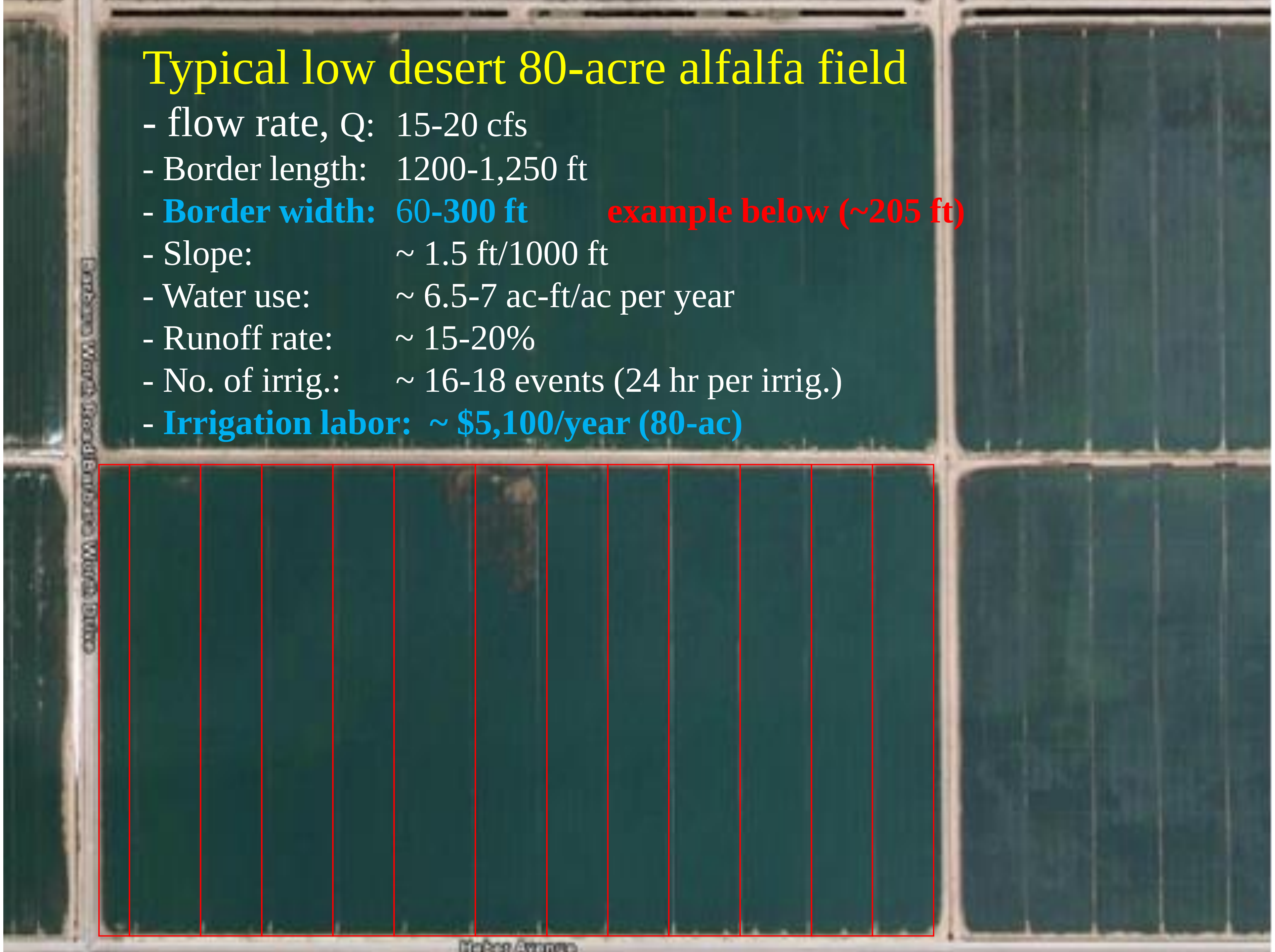
$$AE(\%) = \frac{D_{rz}}{D_{app}} \times 100$$

$$DU_{lq} = \frac{D_{lq}}{D_{\inf}}$$

$$DU_{\min} = \frac{D_{\min}}{D_{\inf}}$$

Typical low desert 80-acre alfalfa field

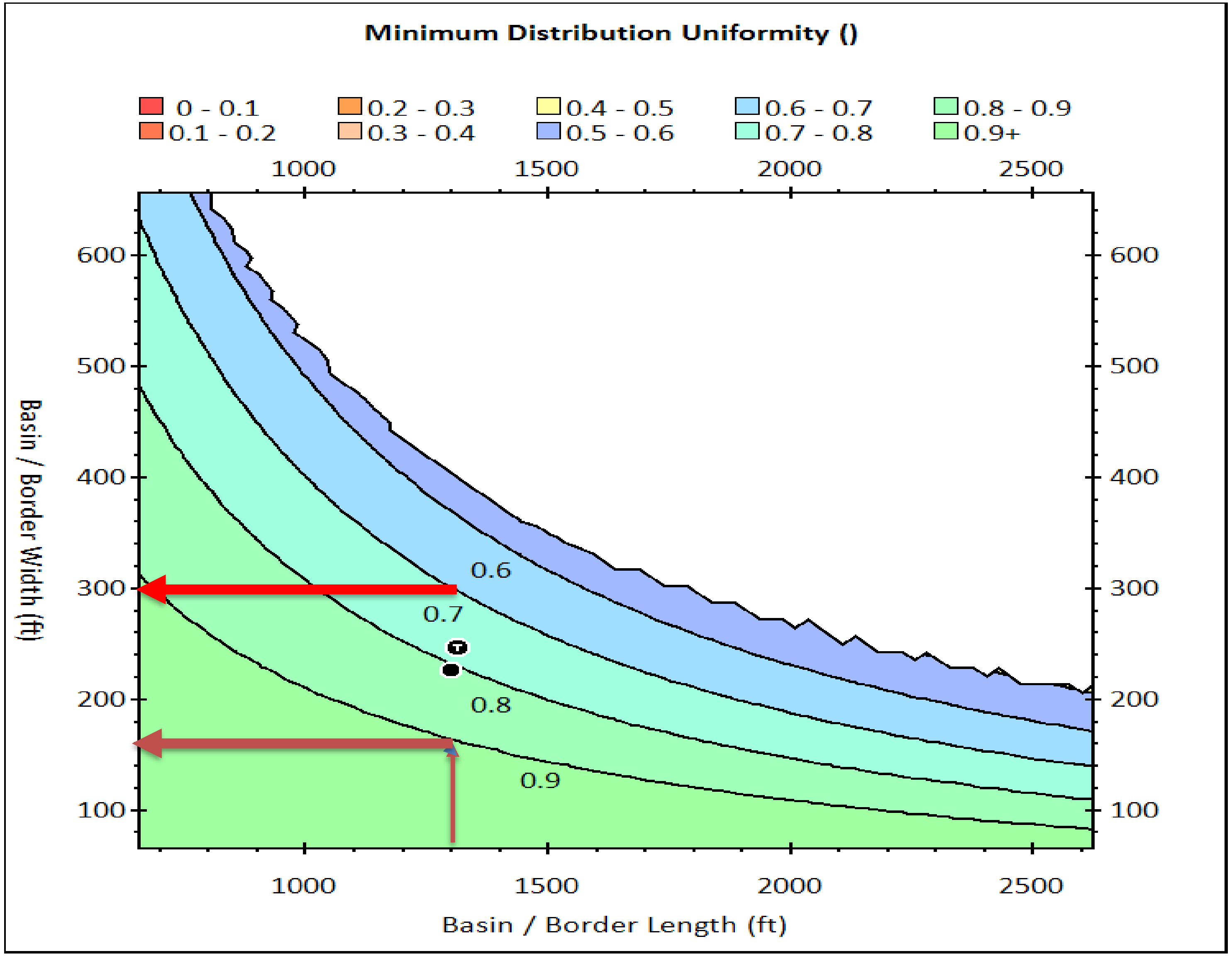
- flow rate, Q: 15-20 cfs
- Border length: 1200-1,250 ft
- **Border width: 60-300 ft** **example below (~205 ft)**
- Slope: ~ 1.5 ft/1000 ft
- Water use: ~ 6.5-7 ac-ft/ac per year
- Runoff rate: ~ 15-20%
- No. of irrig.: ~ 16-18 events (24 hr per irrig.)
- **Irrigation labor: ~ $5,100/year (80-ac)**



Results: Tools and practical charts to help growers design efficient surface irrigation system to meet their needs and maximize water use efficiency

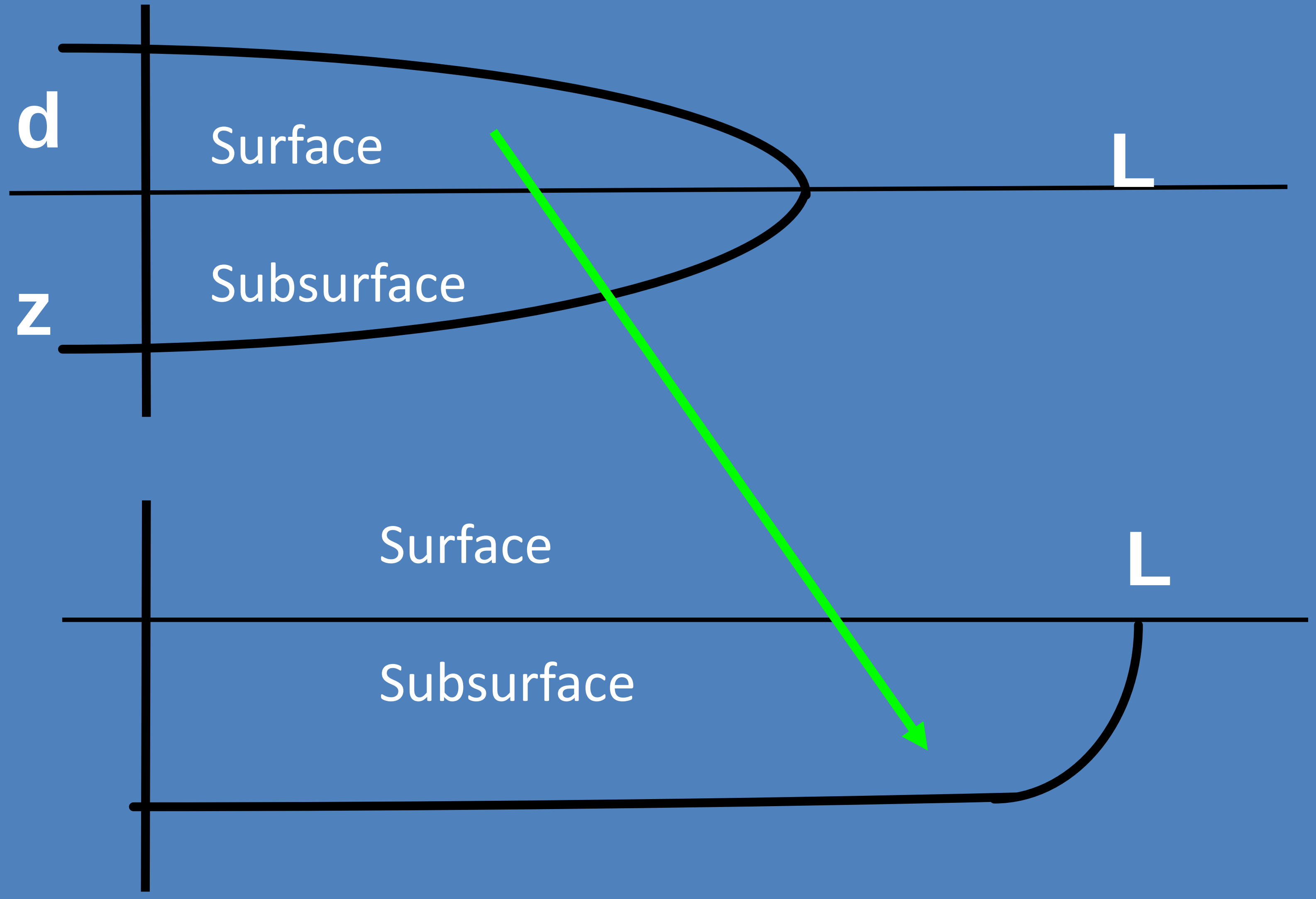
Example: Fixed flow rate (district water or GW), fixed border length, fixed slope, Alfalfa

What is the best border width to get the maximum efficiency (DU)?



Volume applied= Surface storage +Subsurface storage

flow rate*time= **d***L + **z***L



Optimization to achieve higher efficiency

(Automation of surface irrigation systems)

- The process of considering all flood irrigation variables to improve on-farm irrigation efficiency

- Adjust irrigation time to allow for changing crop roughness (height and density of the crop)

- Adjusting border/set length to allow for variable soil type across the field

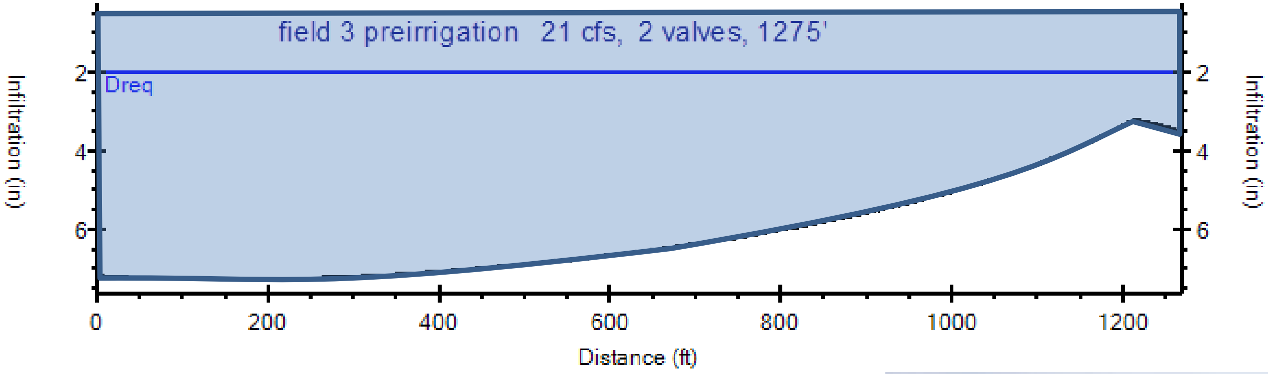
- Adjusting flow rate to an irrigation set (one or more border/land) to improve efficiency

- Computer simulation models are needed

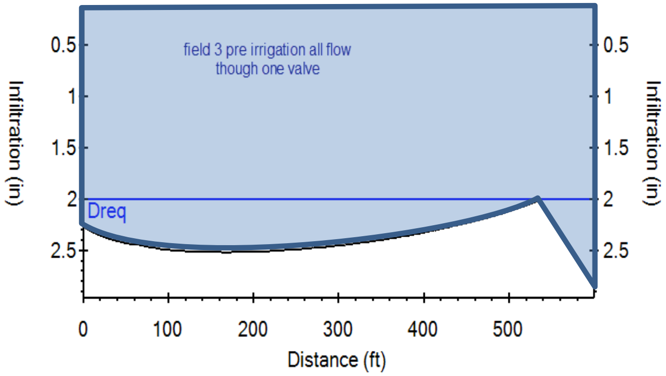
- Accurate measurements are needed during irrigation events (flow rate and advance rate)

SWEEP funding: (Reducing field length (light soil): to improve DU and reduce DP (and nitrate into GW).
(good option for light soils, not effective on heavy ground)-SWEEP
Good option if you can control water application rates

1275 ft, 2 valves, 21.4 cfs **6.1 inches applied**



600 ft, 1 valve, 21.5 cfs **2.5 inches applied (NO3 in**



Source: Marsha Campbell and Khaled Bali, UCCE

Automation of Surface Irrigation Systems

- Irrigators typically work in 12-24-hr shifts (labor)
- Make decisions on when to turn the water off based on several variables (flow rate, advance rate, crop height, etc)
- Automation: smart decisions based on accurate and real-time data (flow rate, advance rate, automated gates, ETc , and other variables)
- Water conservation and labor savings (CA min. wage $16/hr in 2024)

Automation of Surface Irrigation Systems
UC Desert Research and Extension Center






Automation Systems in CA

Commercial fields and UC ANR Research Centers



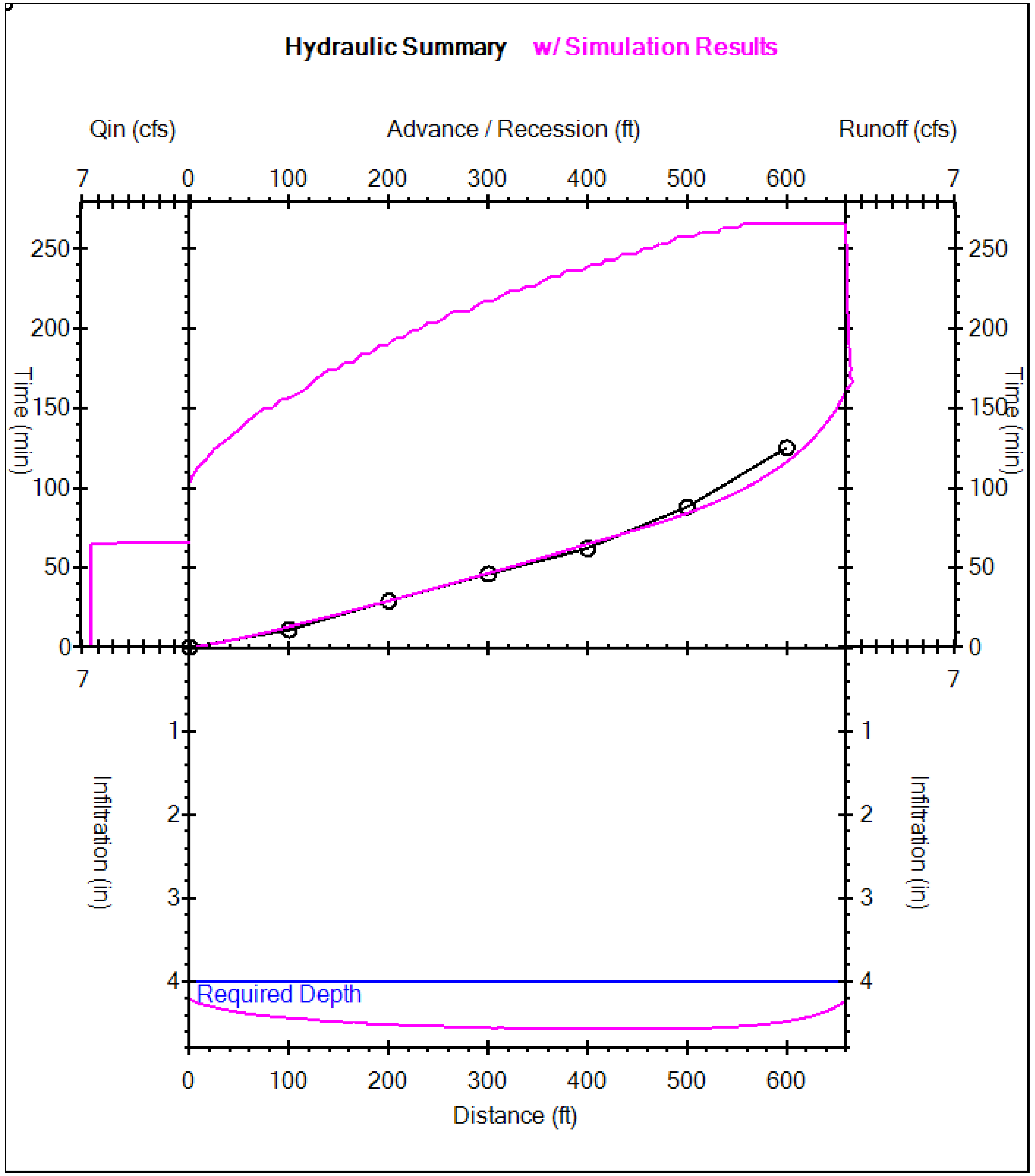


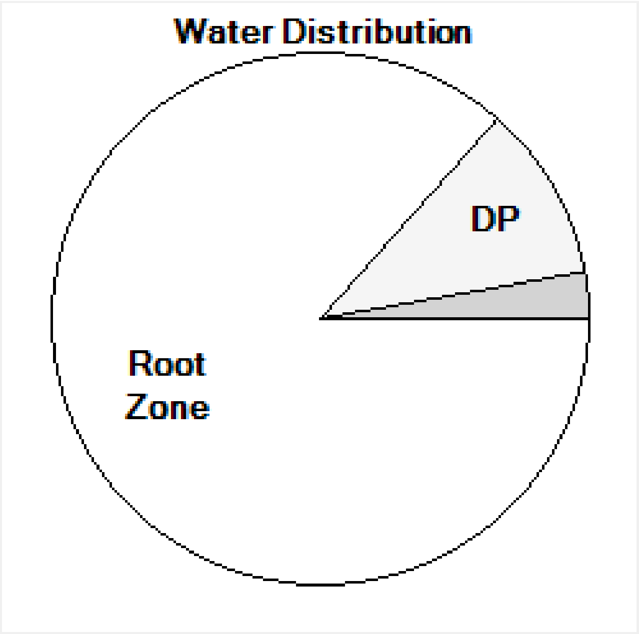

Rubicon Water

https://www.rubiconwater.com/

Watch Technologies

https://watchtechnologies.com/





Efficiency & Uniformity Indicators

AE = 87 %

DUmin = 0.94 DUlq = 0.97

DP% = 11 %

RO% = 3 %

Warning(s)

-- None --

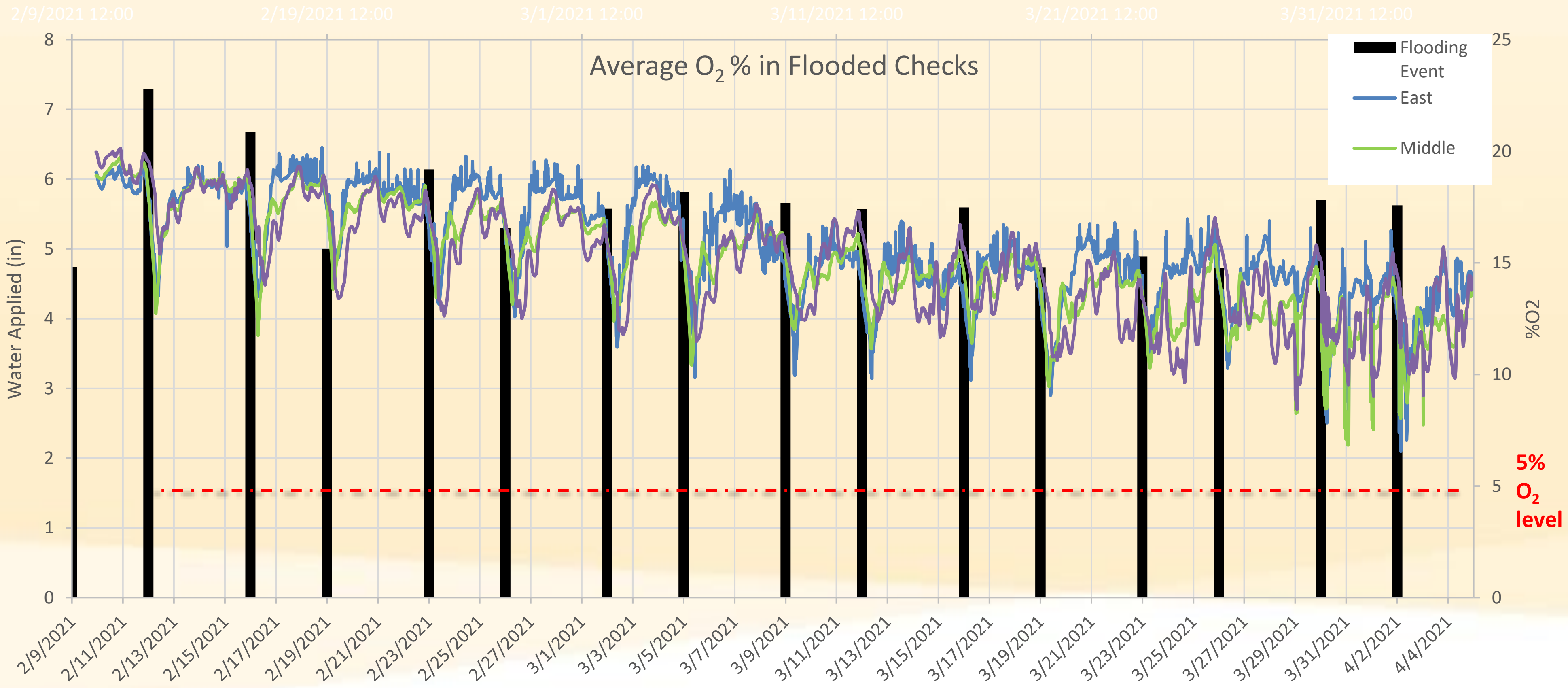
Performance Indicators (from Simulation) Hydraulic Summary

Dapp = 4.61 in Dinf = 4.5 in Dro = 0.13 in
Ddp = 0.5 in Dmin = 4.2 in Dlq = 4.37 in
Tco = 65 min TL = 161.1 min XR = 0.61
Xmax = 660 ft Ymax = 4.84 in Verr% = -0.01 %

Surface Irrigation and Groundwater Recharge on alfalfa (2021- two flooding events/week)

- Utilization of existing surface irrigation systems on alfalfa for GW recharge.
- Up to 7”/week recharge with intermittent flooding with no significant impact on alfalfa yield
- Data from UC Kearney Research and Extension Center:

2021; **~89 inches** of recharge in 16 irrigation events over a 7.5 week period (~12”/week)



Irrigation with sprinkler Systems

Source: A. Daccache, UCD

Irrigation with sprinkler Systems

Advantages

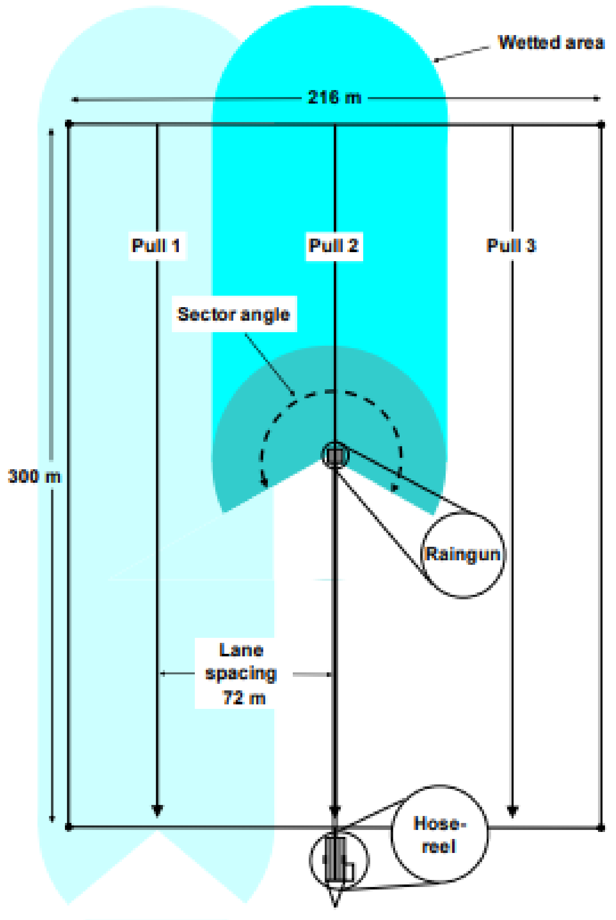
- Suitable for most soil types when application rates are matched to soil infiltration capacity
- Ability to adequately irrigate steep or undulating topographies
- Suitable for light and frequent irrigation
- Automation is readily available for most sprinklers systems
- Can be effective for frost control
- With proper drainage, sprinklers can be used efficiently to leach accumulated salts

Source: A. Daccache, UCD

Irrigation with sprinkler Systems

Uniformity

Overhead irrigation relies on overlapping to achieve good uniformity



Source: A. Daccache, UCD

Use 'coefficients' to assess irrigation uniformity from the system

Christiansen Coefficient of Uniformity (CU)

Tells us the 'average' error

Distribution Uniformity (DU)

Tells us how badly the 'worst quarter' is irrigated

UCDAVIS

Irrigation with sprinkler Systems

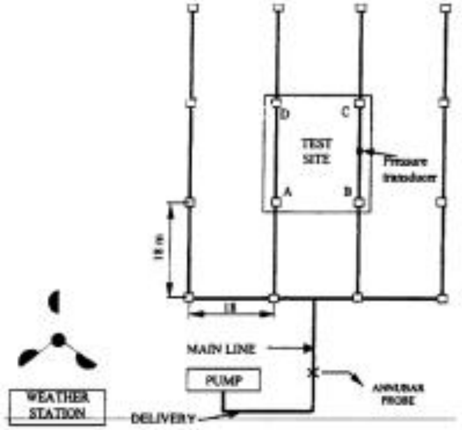
Field test and data collection

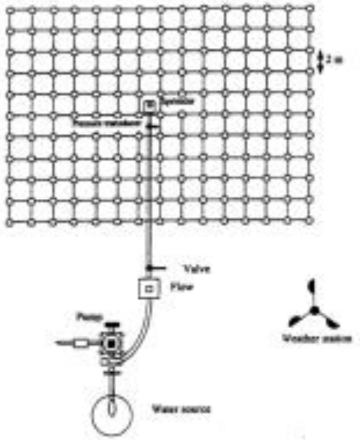
- Rigid
- Sharp edged
- Deeper than wide (stability)
- Lot of them

Source: A. Daccache, UCD

Irrigation with sprinkler Systems

Field test and data collection





Source: A. Daccache, UCD

Irrigation with sprinkler Systems

Distribution uniformity (DU)

$$DU = 100\% \left(\frac{m^*}{m} \right)$$

Where:

m* is the mean application depth in the lowest quartile (mm or ml), and

m is the mean application depth (mm or ml)

Source: A. Daccache, UCD

Irrigation with sprinkler Systems

Example

Catch can measurements (any unit)
20, 25, 20, 15, 18, 22, 21, 19

CU calculation

Average = 20

Absolute deviations:

0, 5, 0, 5, 2, 2, 1, 1

Sum of absolute deviations = 16

CU = 100(1- $\Sigma x/mn$) = 100 (1 – 16/(8x20))
= **90%**

DU calculation

Ordered:

25, 22, 21, 20, 20, 19, *18, 15*

Average = 20

Average of lowest quarter = 16.5

DU = 16.5 / 20 x 100 = **82.5%**

Source: A. Daccache, UCD

Sprinkler Irrigation Systems

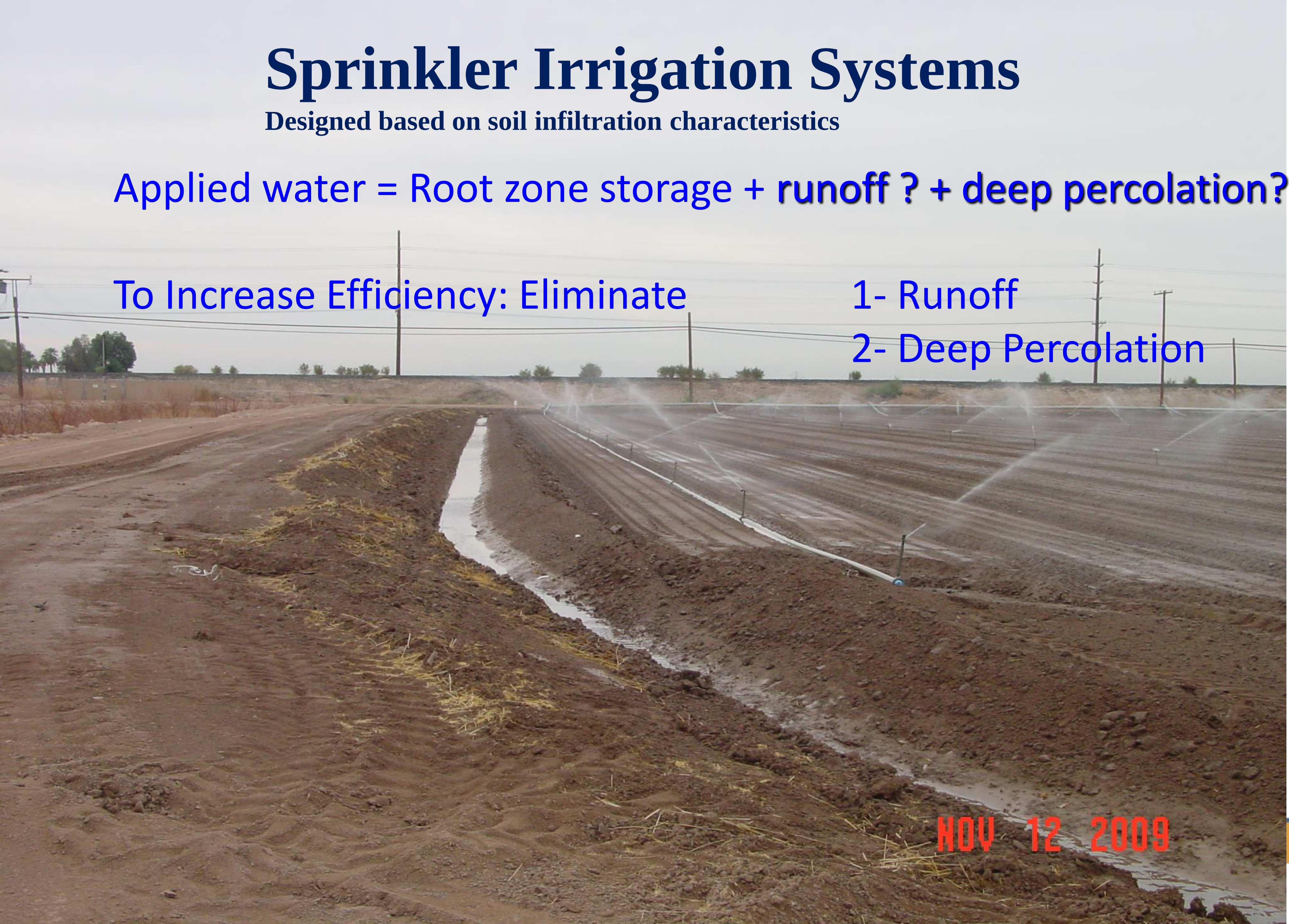
Designed based on soil infiltration characteristics

Applied water = Root zone storage + **runoff ? + deep percolation?**

To Increase Efficiency: Eliminate

1- Runoff

2- Deep Percolation



Summary

- Need more emphasis on evaluation of surface irrigation systems

- Room for improvement but you cannot improve what you do not measure

- New tools to analyze and improve the design and management of surface irrigation (technology, modeling, automation)

- Higher surface irrigation efficiency is possible at a reasonable cost

- Higher labor costs will be a key factor in increasing efficiency ($16 plus benefits in 2024)

- Potential for utilizing existing surface irrigation infrastructure for groundwater recharge (SIGMA)

- Energy and GHG emissions savings (production costs)

Thank You