

# Improving the Efficiency of Surface Irrigation Systems in California

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**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**

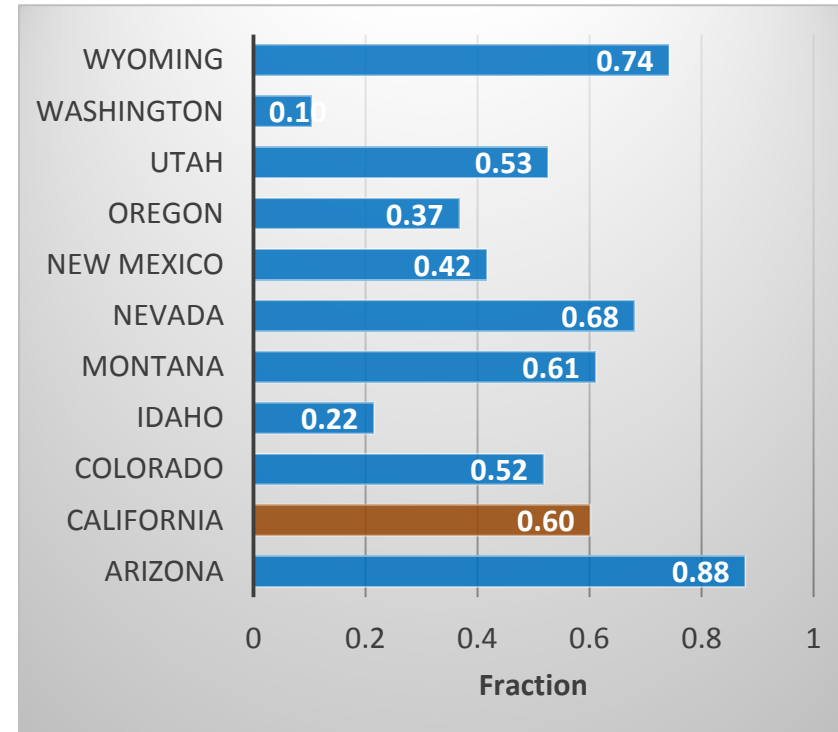


# Surface (flood) irrigation:

- Water application methods where water is applied over the soil surface by gravity (no energy is needed).
- Most common irrigation system throughout the world
- High efficiency possible on medium and heavy soils
- Mostly for field crops in California

**Reduction in field crops in CA from 3,805,800 acres in 2006 to 2,639,200 acres in 2015 (-30%)**

System	Eff. <sub>APP</sub>
Surface	70-85%
Drip	85-90%
Micro-sprinkler	80-90%
Sprinkler	70-90%



2013 Fraction of irrigated land totally or partially irrigated with gravity methods in western states.

Source: USDA Farm and Ranch Irrigation Survey -FRIS, 2013

# How Much Water do I need to Apply?

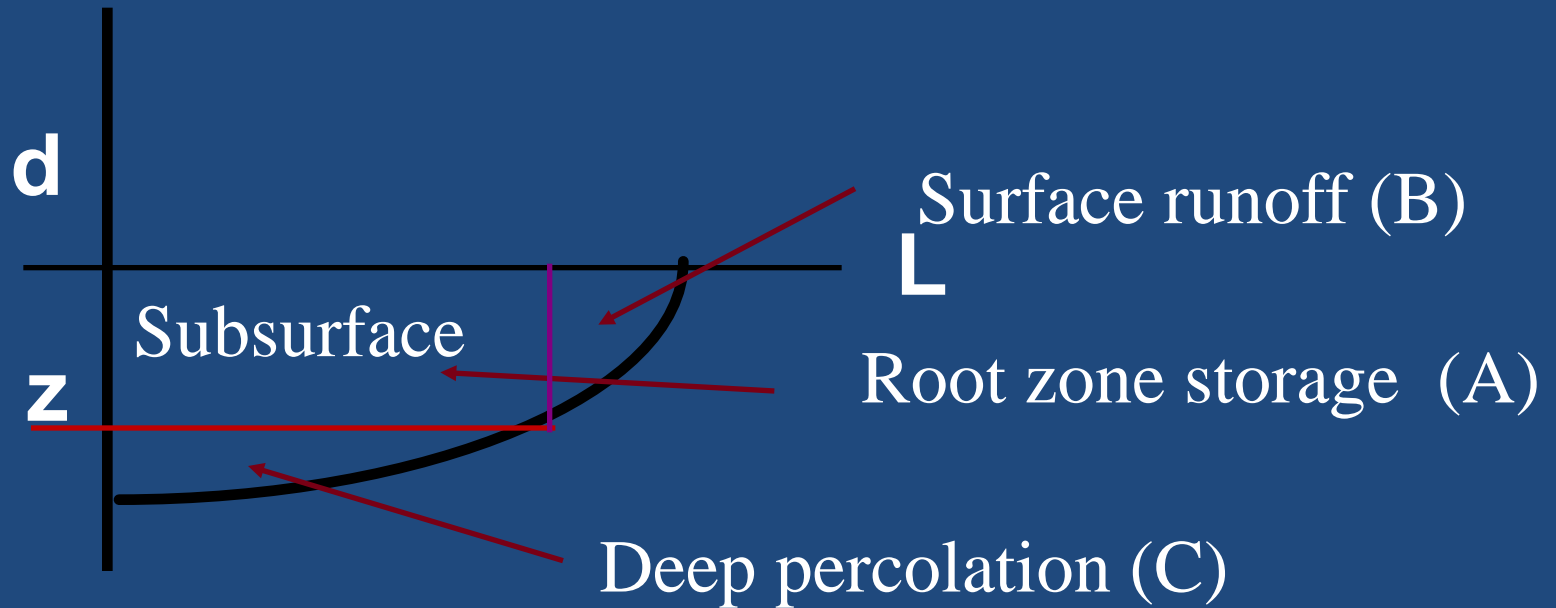
- Need to know crop water use (ET<sub>c</sub>) since last irrigation
- ET<sub>c</sub> from (Reference evapotranspiration and crop coefficient)
- Typical application rates (vary widely depending on soil type, etc):
- Surface: ~ 3-5 in/irrigation (much higher rate for light soils)
- Sprinkler: ~ 0.5-1.2 in/irrigation
- Drip: ~ 0.5 in/irrigation
- Delivery system designed for surface irrigation

# Improving Irrigation System Efficiency

- Reduce losses (nutrients, pesticides, water)
- Limited water supplies and increased demands
- Labor cost (minimum wage in CA from \$10.5 to \$15/hr by 2022)
- What is efficiency?
  - Distribution system efficiency (district level, canals, reservoirs, etc.)
  - On farm or field application efficiency (AE) , distribution uniformity (DU), and other parameters

# Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation



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

IRRIGATION = Root zone storage (ET<sub>c</sub>) + DEEP PERCOLATION + Runoff

A + B + C

$$\text{Application Efficiency (AE)} = A / (A+B+C)$$

To achieve higher efficiency, reduce B and/or C

**BUT**

Need to have a balance,

Deep Percolation sometimes is needed for salinity control

(700 ppm ~ 0.96 tons of salt/ac-ft but NOT with every irrigation)

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

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

$$\text{IRRIGATION} = \text{Root zone storage (ETc)} + \text{DEEP PERCOLATION} + \text{Runoff}$$

A                      +                      B                      +                      C

$$\text{Application Efficiency (AE)} = A / (A+B+C)$$

$$\text{Deep Percolation Ratio} = B / (A+B+C)$$

$$\text{Runoff Ratio} = C / (A+B+C)$$

**Irrigation Water Requirements (IR)**

$$\text{IR} = \text{Crop ET} / \text{AE}$$



# Distribution Uniformity (DU)

**DU= Average depth in low quarter/Average depth infiltrated**

**Many other efficiency parameters  
BUT**

**KEEP IT SIMPLE, AE and DU are all you need**

# Field Crops

## Mostly surface irrigation methods:

- Border (flat) irrigation

Runoff rate: 5-20% (vary)

- Furrow (bed) irrigation

Runoff rate: 15-30% (vary)

Surface runoff:

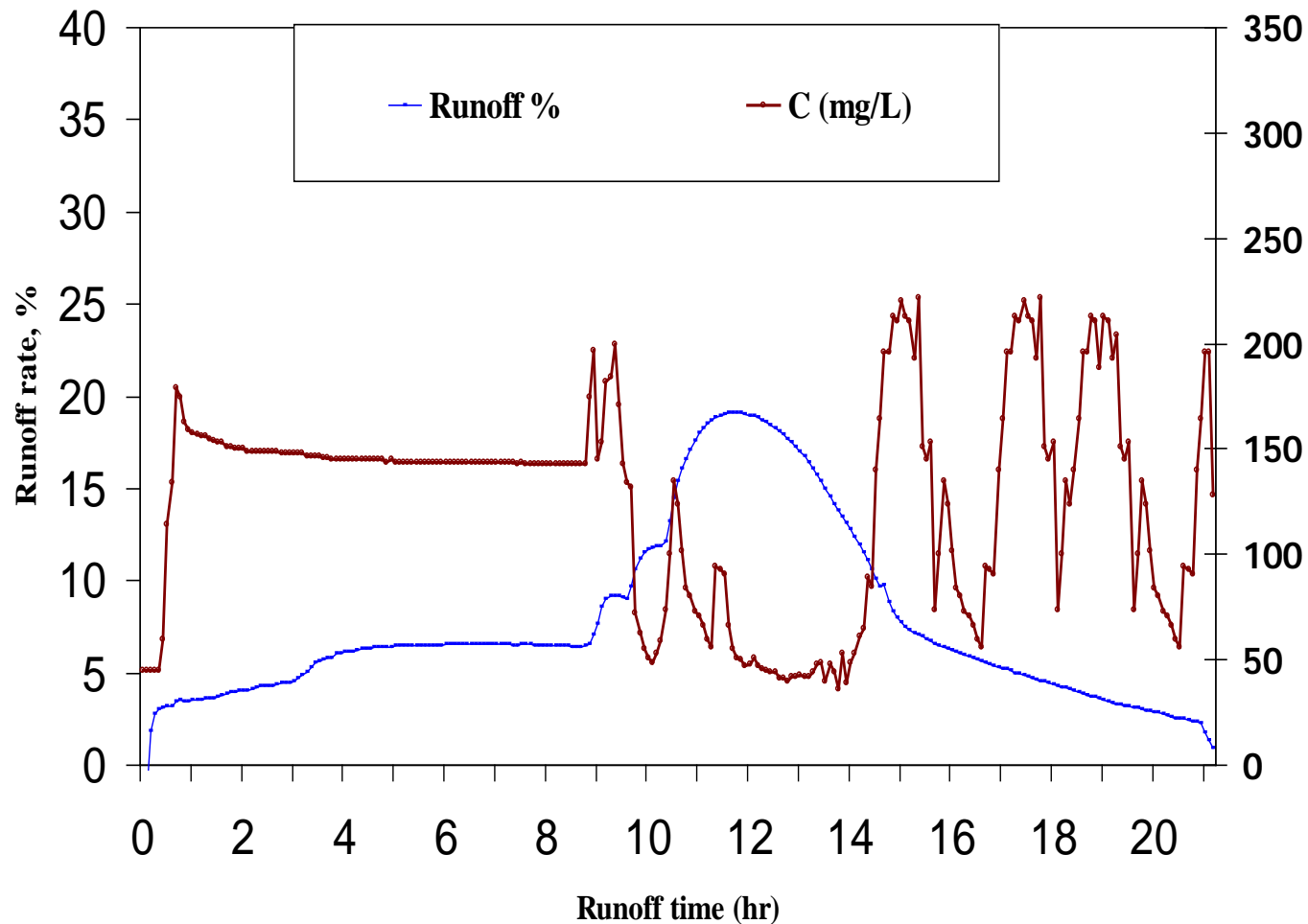
Nutrient losses: surface runoff & deep percolation

Pesticides losses: mostly surface runoff &  
some with deep percolation

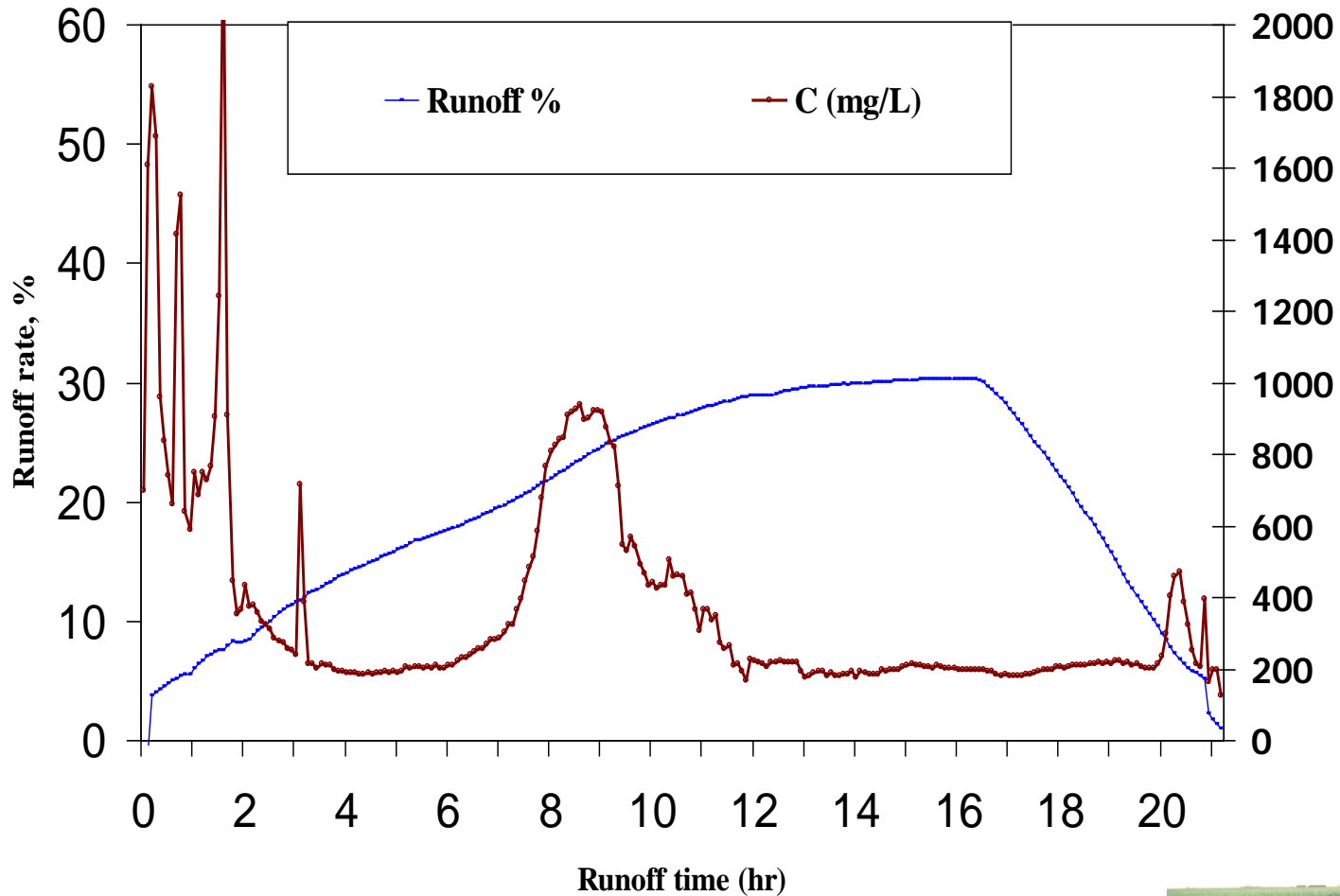
**\* Usually no runoff with basin irrigation**



## Field A (Alfalfa, Border, UCDREC)

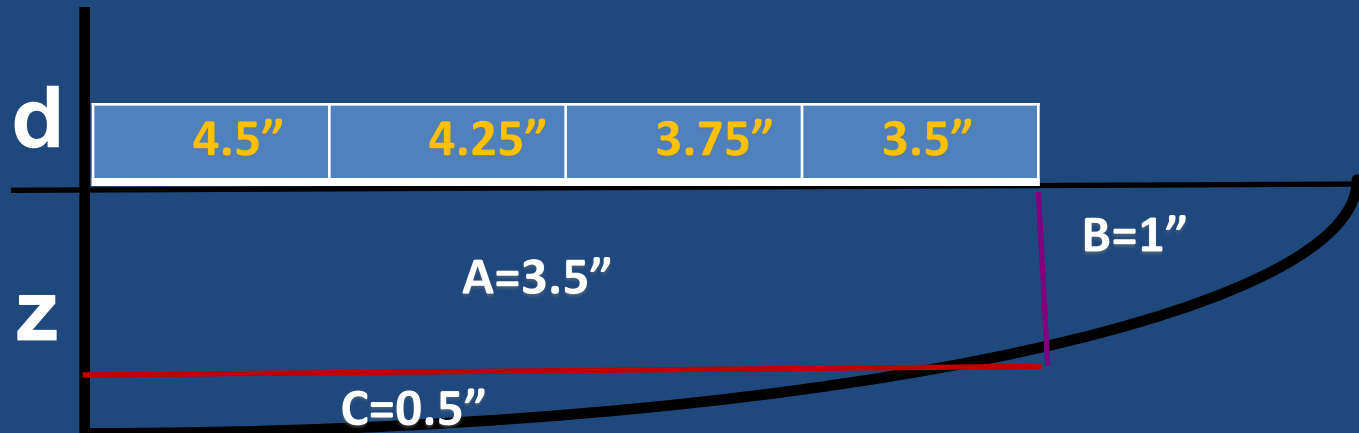


# Field B (Alfalfa, Furrow, UCDREC)



# Surface Irrigation (uniform soil?)

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



$$AE = 3.5/5 = 70\%$$

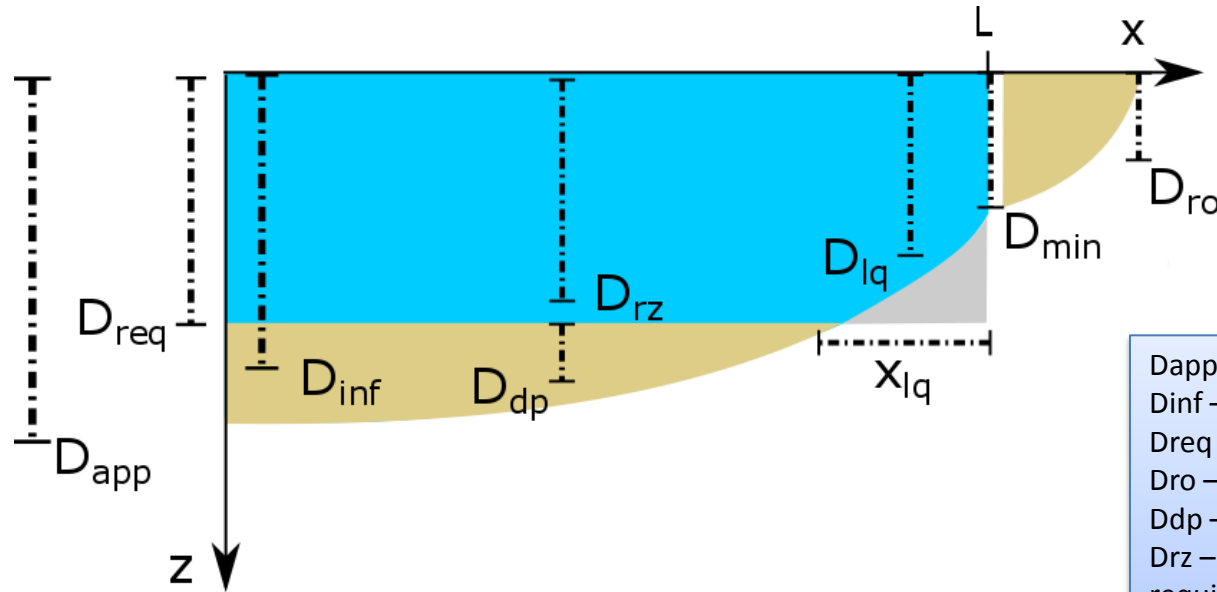
$$ROR = 1/5 = 20\%$$

$$DPR = 0.5/5 = 10\%$$

$$DU = 3.5/4 = 87.5\%$$

# Final infiltration profile and irrigation performance measures

## Application Efficiency (AE) and Distribution Uniformity (DU)



D<sub>app</sub> – applied depth  
 D<sub>inf</sub> – infiltrated depth  
 D<sub>req</sub> – required depth  
 D<sub>ro</sub> – runoff depth  
 D<sub>dp</sub> – deep percolation depth  
 D<sub>rz</sub> – infiltrated depth contributing to the required (D<sub>z</sub> in WinSRFR manual)  
 D<sub>min</sub> = minimum depth  
 D<sub>lq</sub> – low-quarter depth

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

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

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



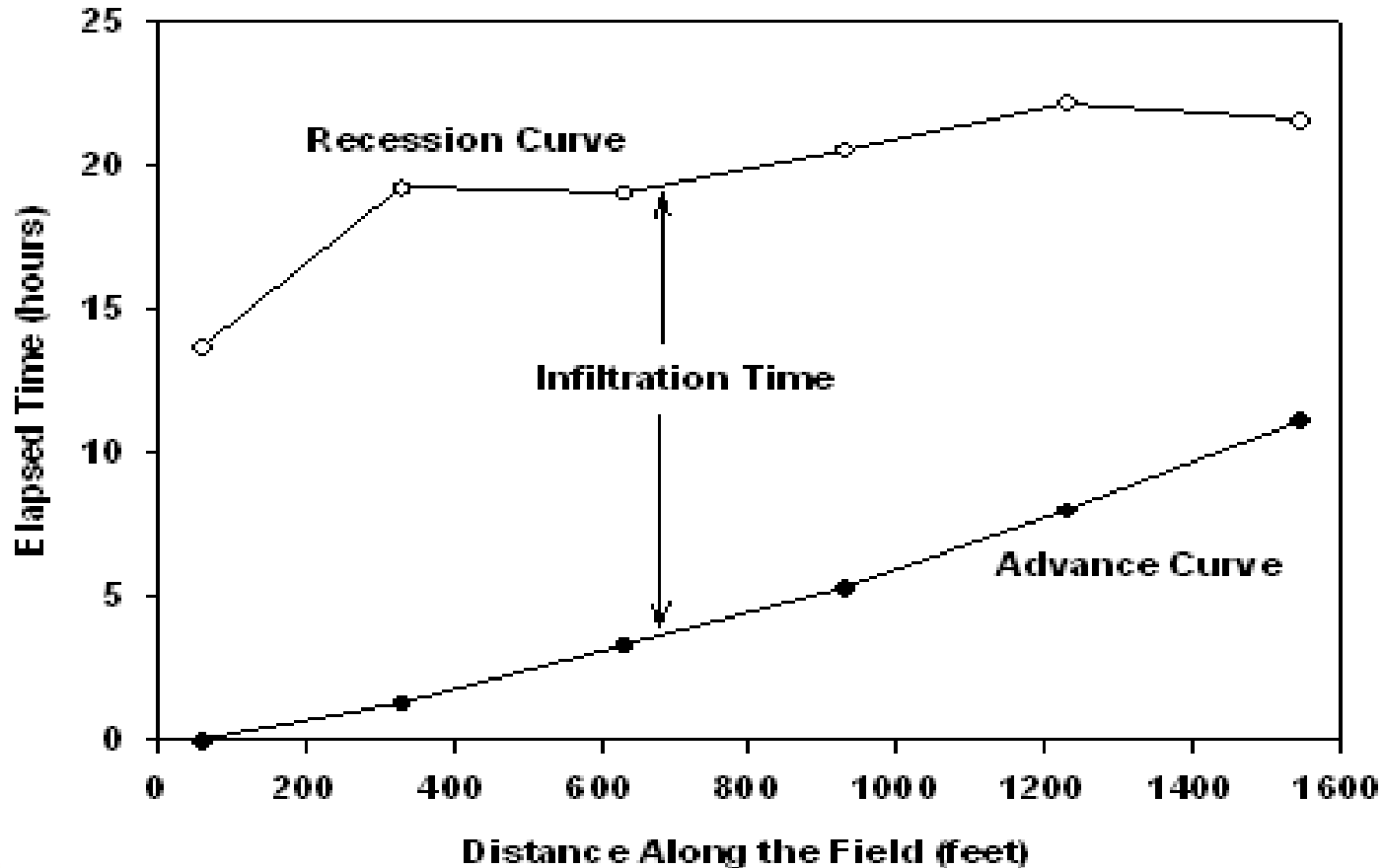
# Flow rate (cfs) and total applied water





# Advance and Recession Curves

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



# Tools to Improve Efficiency

- Increasing check flow rate (to increase advance rate, avoid erosion, time of the year)
- Reducing field length: to improve DU and reduce DP (good option for light soils, not effective on heavy ground)
- Tailwater recovery systems: to reduce RO (good option for heavy soils, not effective for light soils)
- Selecting an appropriate irrigation water cutoff time (good option for heavy soils to reduce or eliminate runoff)
- Automation of surface irrigation

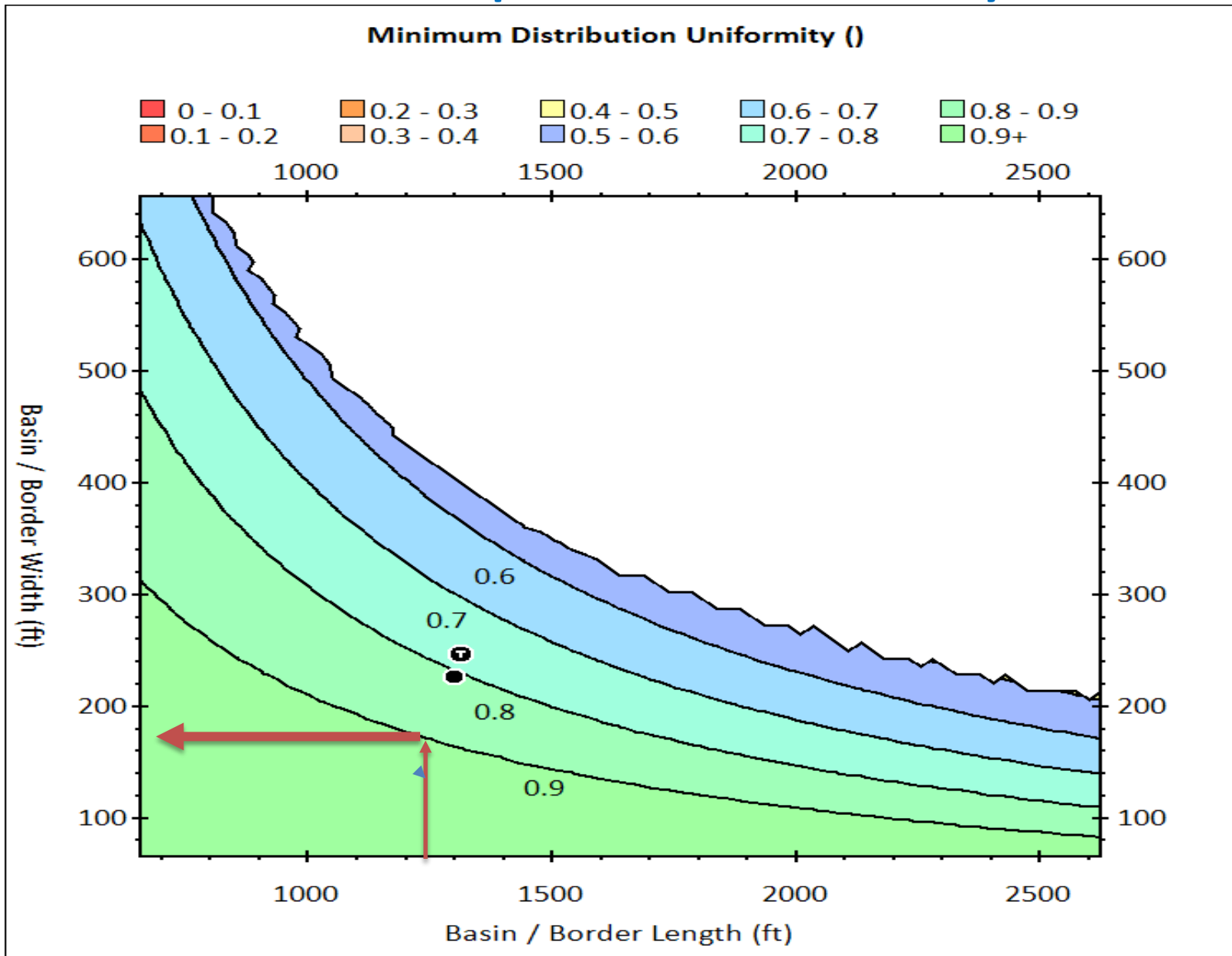
# Tools to Improve Efficiency

- Evaluation of current irrigation system (AE and DU)
- Inflow rate, outflow rates (runoff and tile water)
- Advance rate (and recession rate)
- WinSRFR (surface irrigation design and simulation model)

The screenshot displays the WinSRFR 4.1.3 Project Management software interface. The window title is "WinSRFR 4.1.3 Project Management - Barley 4-02-10.srfr (Farm: Farm 1)". The interface is divided into several sections:

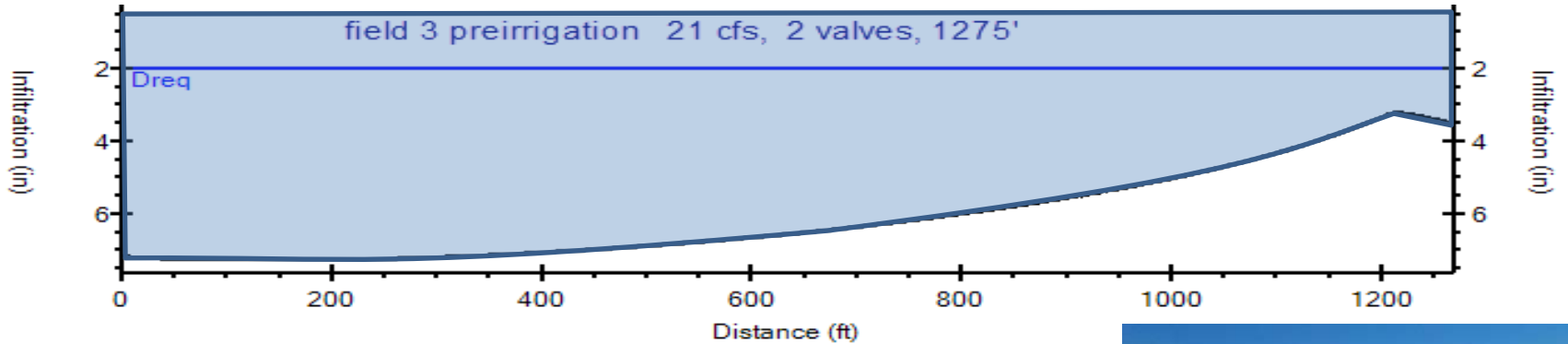
- Analysis Explorer:** A tree view on the left showing the project structure for "Farm: Farm 1" and "Field: Field1". It includes folders for "Event Folder 1", "Design: Folder 1", "Operations: Folder 1", and "Simulation: Folder 1". Under "Simulation: Folder 1", there are several simulation entries with parameters like "NRCS=2.0", "Simulation 1 (2)", "t50=32 B=40", "t100=28 min", "tc = 30 min b = 30 mm/h", "tc = 30 min b = 50 mm/h", and "Hydrus generated function Ks= 4 cm/h".
- WinSRFR Worlds:** A central area with four buttons: "Event Analysis" (cyan), "Simulation" (grey), "Physical Design" (yellow), and "Operations Analysis" (pink). Below the buttons is the text "Press button to enter WinSRFR World".
- Details - Farm: Farm 1:** A section at the bottom left with input fields for "ID", "Notes", "Name" (containing "Farm 1"), "Created" (containing "Fri, Apr 02, 2010 3:25 PM"), and "Owner".
- Logos:** The USDA logo and the ARID-LAND AGRICULTURAL RESEARCH CENTER logo are displayed at the bottom.
- Status Bar:** The bottom right corner shows "User Level: Advanced" and the time "3:31 PM".

# Tools to Improve Efficiency

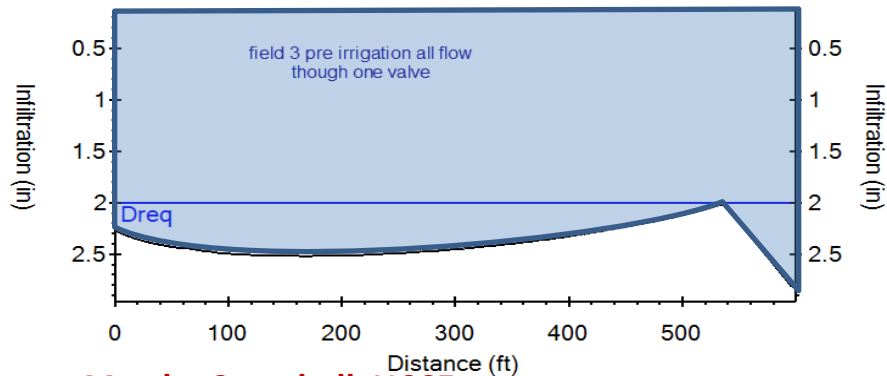


**Reducing field length:** to improve DU and reduce DP  
 (good option for light soils, not effective on heavy ground)

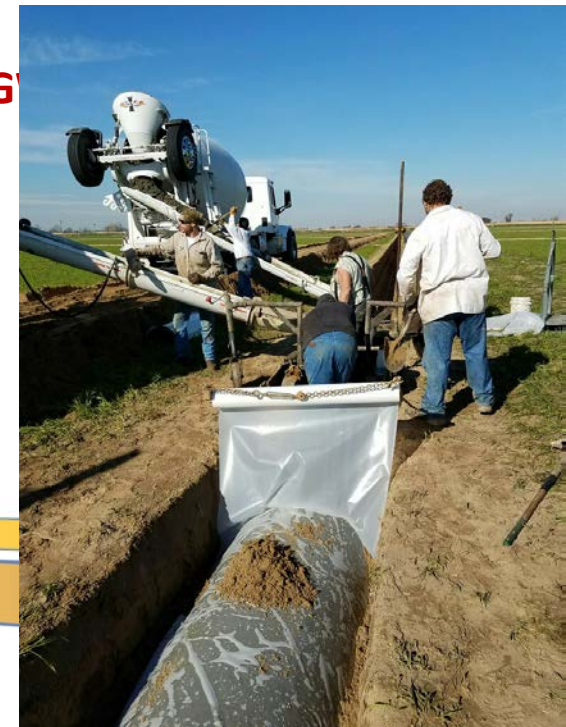
**1275 ft, 2 valves, 21.4 cfs      6.1 inches applied**



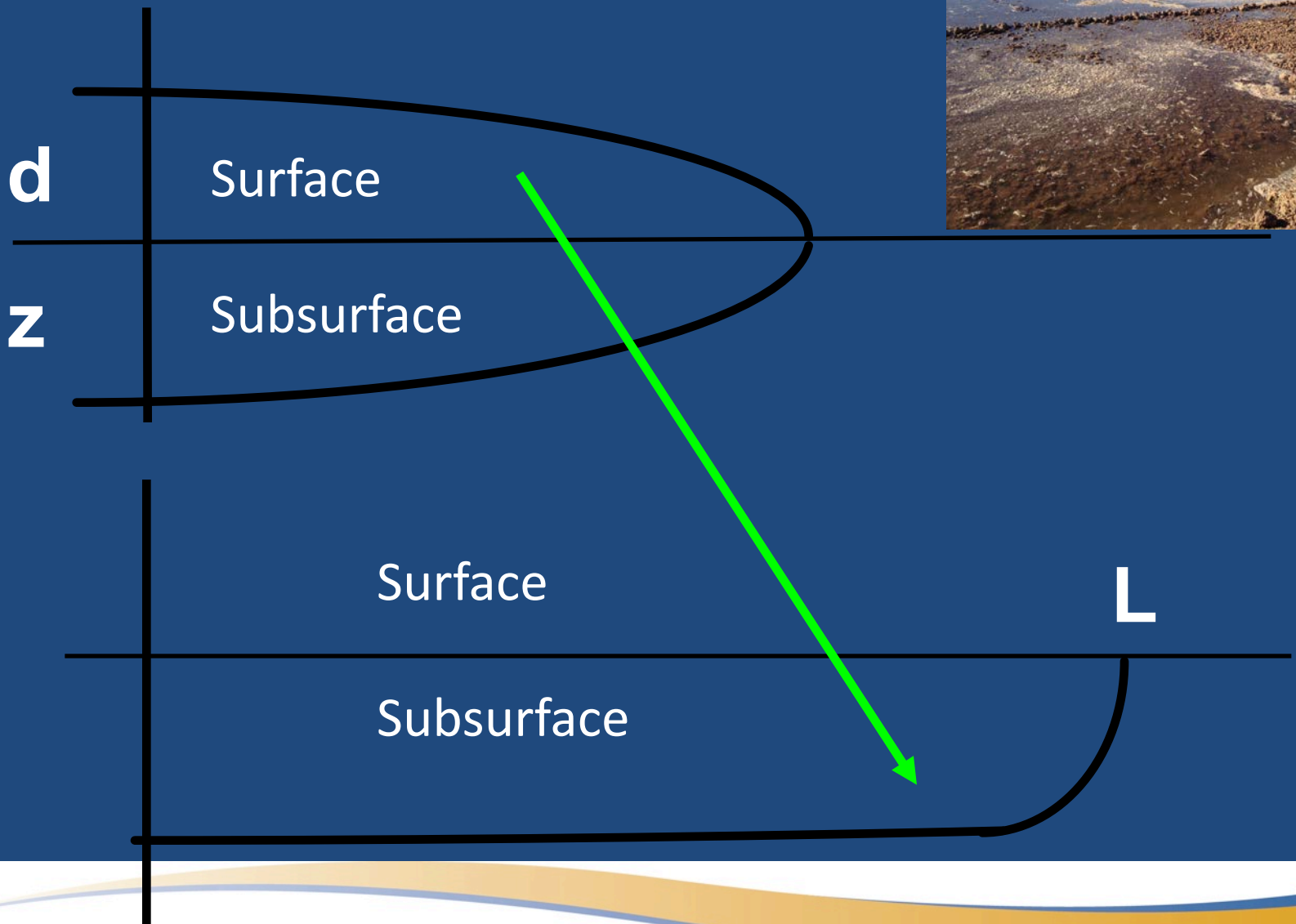
**600 ft, 1 valve, 21.5 cfs      2.5 inches applied (NO3 in G)**



Source: Marsha Campbell, UCCE



# Irrigation management – applying the right amount of water



# Tailwater Recovery Systems

- For water conservation
- Improving the quality of drainage water (TMDL)



# Automation of Surface Irrigation Systems





# 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 efficiency is possible at a reasonable cost
- Higher labor costs will be a key factor in increasing efficiency

# Thank You

