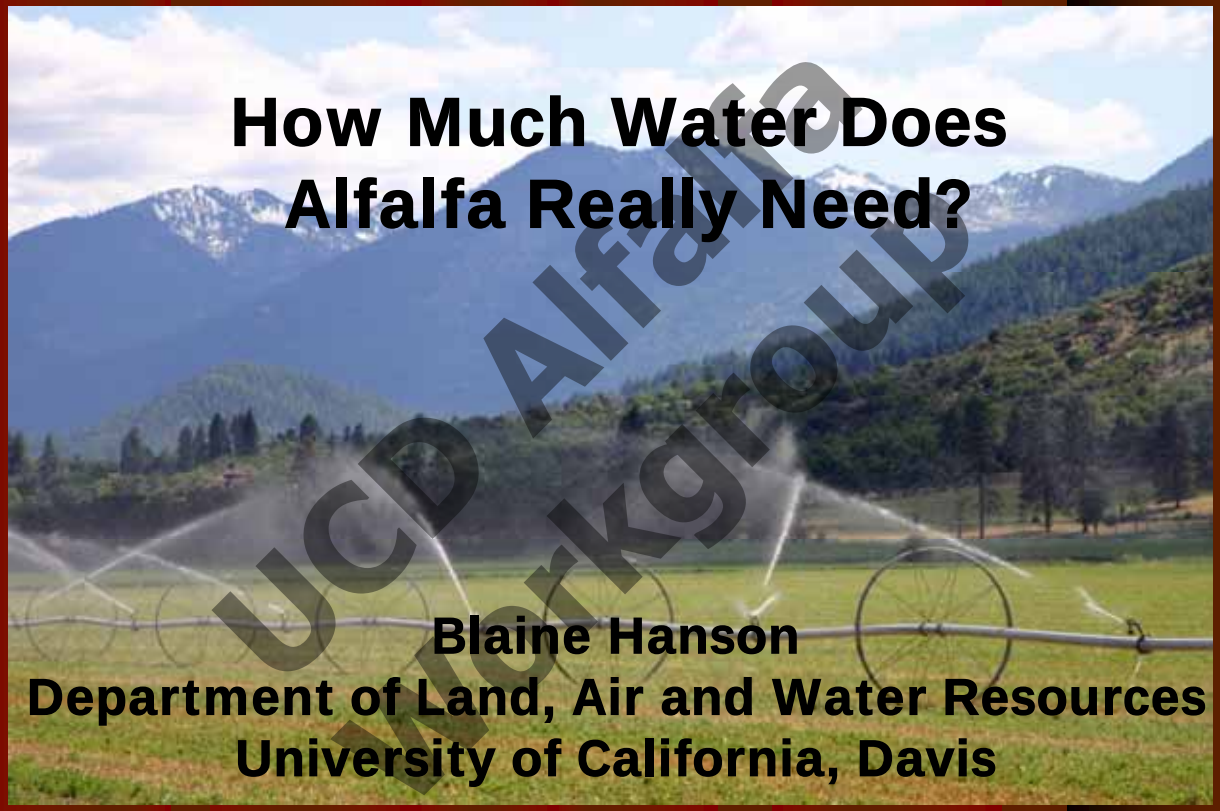

How Much Water Does Alfalfa Really Need?

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Water and Alfalfa in California

- Over 1 million acres in production
- Long growing season
- Seasonal water applications range from 4 million to 5.5 million acre-feet (one acre-foot = 326,000 gallons)
- Questions concerning alfalfa water use
  - What is the seasonal crop water use of alfalfa?
  - Is mid-season deficit irrigation of alfalfa feasible for water transfers to water short areas?

Evapotranspiration (ET)

- Evapotranspiration - crop water use (evaporation from plant leaves or transpiration; evaporation from soil surface)
  - Yield is directly related to evapotranspiration – higher ET = higher yield
  - Maximum ET is controlled by the climatic conditions
  - Insufficient soil moisture is usually the main reason for less-than-maximum ET
- Reference crop ET = ET of grass
  - CIMIS (California Irrigation Management Information System)
  - ET = crop coefficient x reference crop ET
- Depth of water – inches or feet of water
  - Depth = volume ÷ area
  - Standardizes water use (independent of field size)
  - One inch of water = one acre-inch (27,160 gallons) ÷ one acre

Historical seasonal evapotranspiration of alfalfa

- Intermountain area: 33 inches
- Sacramento Valley: 48 inches
- San Joaquin Valley: 49 inches
- Imperial Valley: 76 inches

Note: Source of Sacramento Valley ET is research conducted at UC Davis in the 1960's. Source of the other crop water use values is unknown

Mid-summer deficit irrigation of alfalfa

- Irrigation strategy
  - Full irrigation during early cuttings
  - No irrigation during mid-summer (July, August, September?)
  - Full irrigation in fall
- Advantage
  - Maintain high yields of early cuttings (higher yields and quality)
  - Deficit irrigate during period of lower yields and poorer quality

Why mid-summer deficit irrigation of alfalfa?

- Normally not recommended during periods of adequate water supplies
- Water transfers from agriculture during the mid-summer from water-rich areas (northern California) to water-poor areas (southern California)
  - Amount of water available for transfer: ET difference between fully-irrigated and deficit-irrigated alfalfa (DWR)
- Drought conditions – stretch limited water supplies

Questions

- What is the ET of fully irrigated alfalfa at various locations in California?
- What is the ET of the mid-summer deficit-irrigated alfalfa?
- How much water could be transferred due to mid-summer deficit irrigation?
- How much yield would be lost by mid-summer deficit irrigation?
- Does the mid-summer deficit-irrigation effect on yield carry over to the next year?

Procedure

- Irrigation treatments in commercial fields
  - Full irrigation
  - Deficit irrigation - no irrigations during mid-summer (July, August, September)
- Measurements
  - ET
  - Yield
  - Soil moisture tension

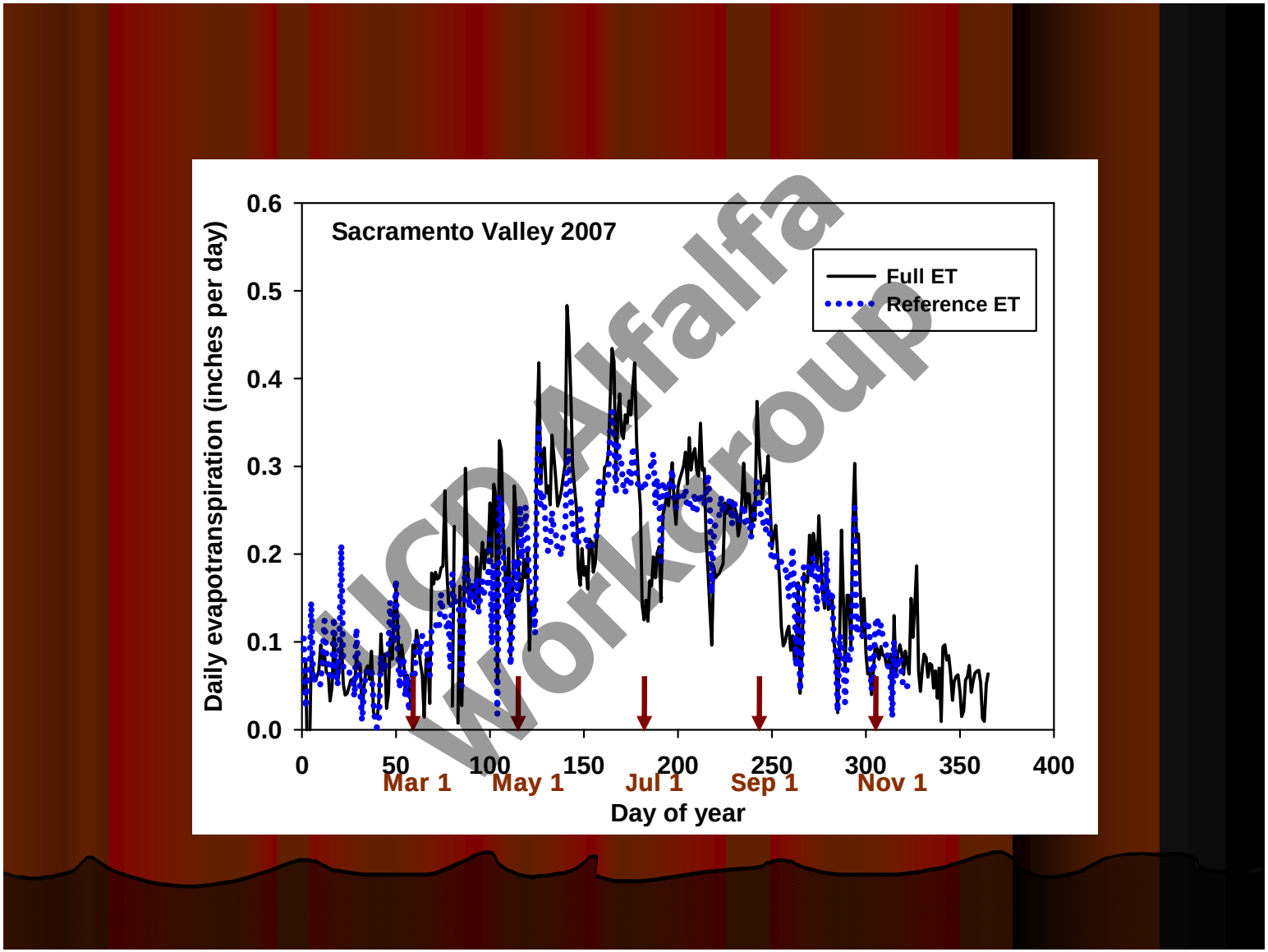
- **2007 sites**
  - **Imperial Valley (Holtville)** – flood irrigation; silt clay; elevation = -7 feet; T_{max} = 104 to 113°F; 7 to 8 harvests
  - **Southern San Joaquin Valley (Buttonwillow, Kern County)** – flood irrigation; clay; elevation = 180 feet; T_{max} = 86 to 104°F; 6 to 7 harvests
  - **Sacramento Valley (Davis)** - flood irrigation; silt clay to clay; elevation = 50 feet; T_{max} = 86 to 35°C; 6 to 7 harvests
  - **Scott Valley (Yreka)** – sprinkle irrigation; loam; elevation = 2,700 feet; T_{max} = 20 to 35°C; 3 harvests
  - **Tulelake (Klamath Basin)** – sprinkle irrigation; mucky silt clay loam; elevation = 4,000 feet; T_{max} = 25 to 35°C; 3 to 4 harvests

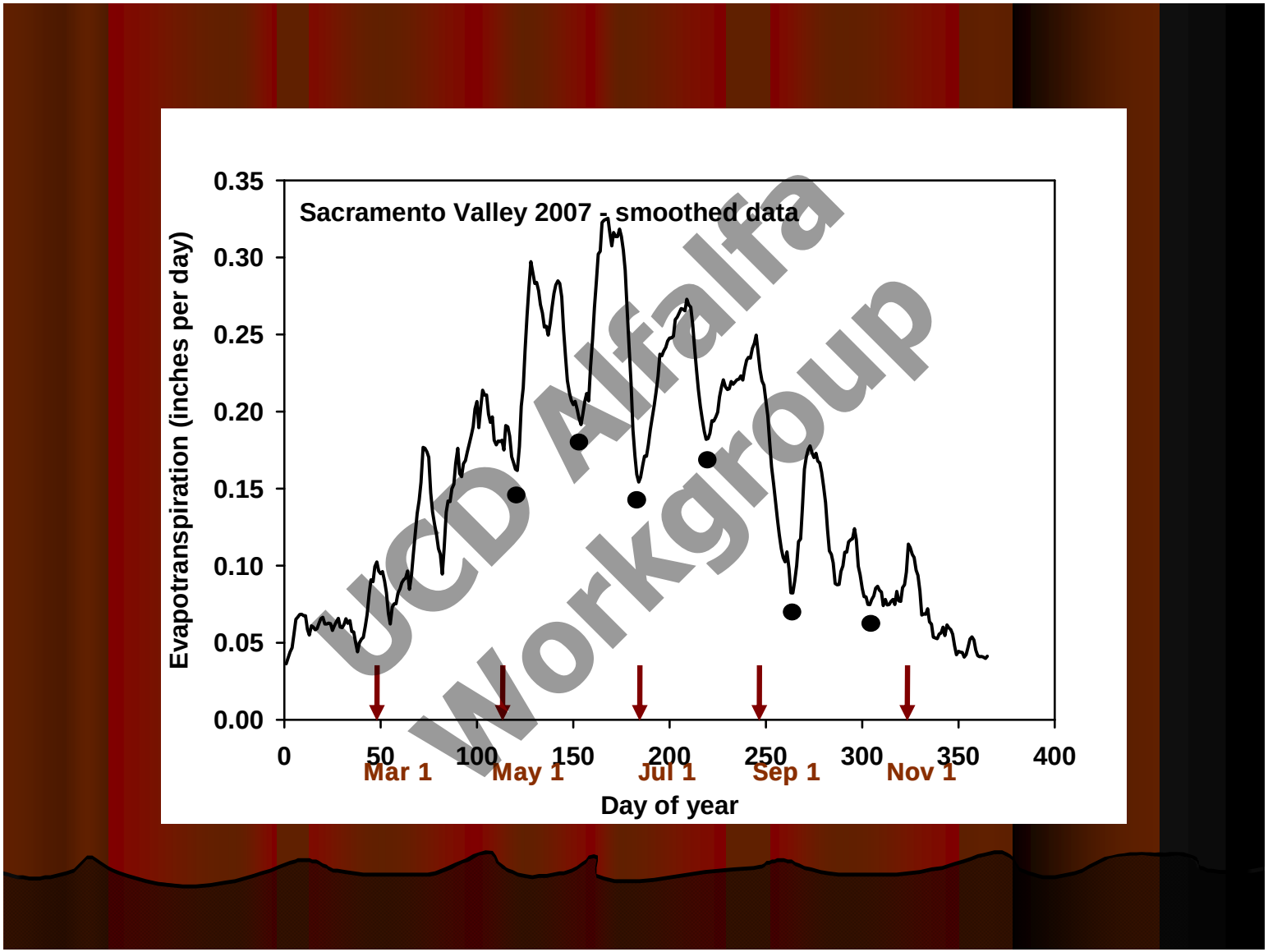
- **Meteorological methods for measuring ET**
  - Fully irrigated ET – eddy covariance, surface renewal
  - Deficit-irrigated ET – Surface renewal
  - Eddy covariance data were used to calibrate the surface renewal method

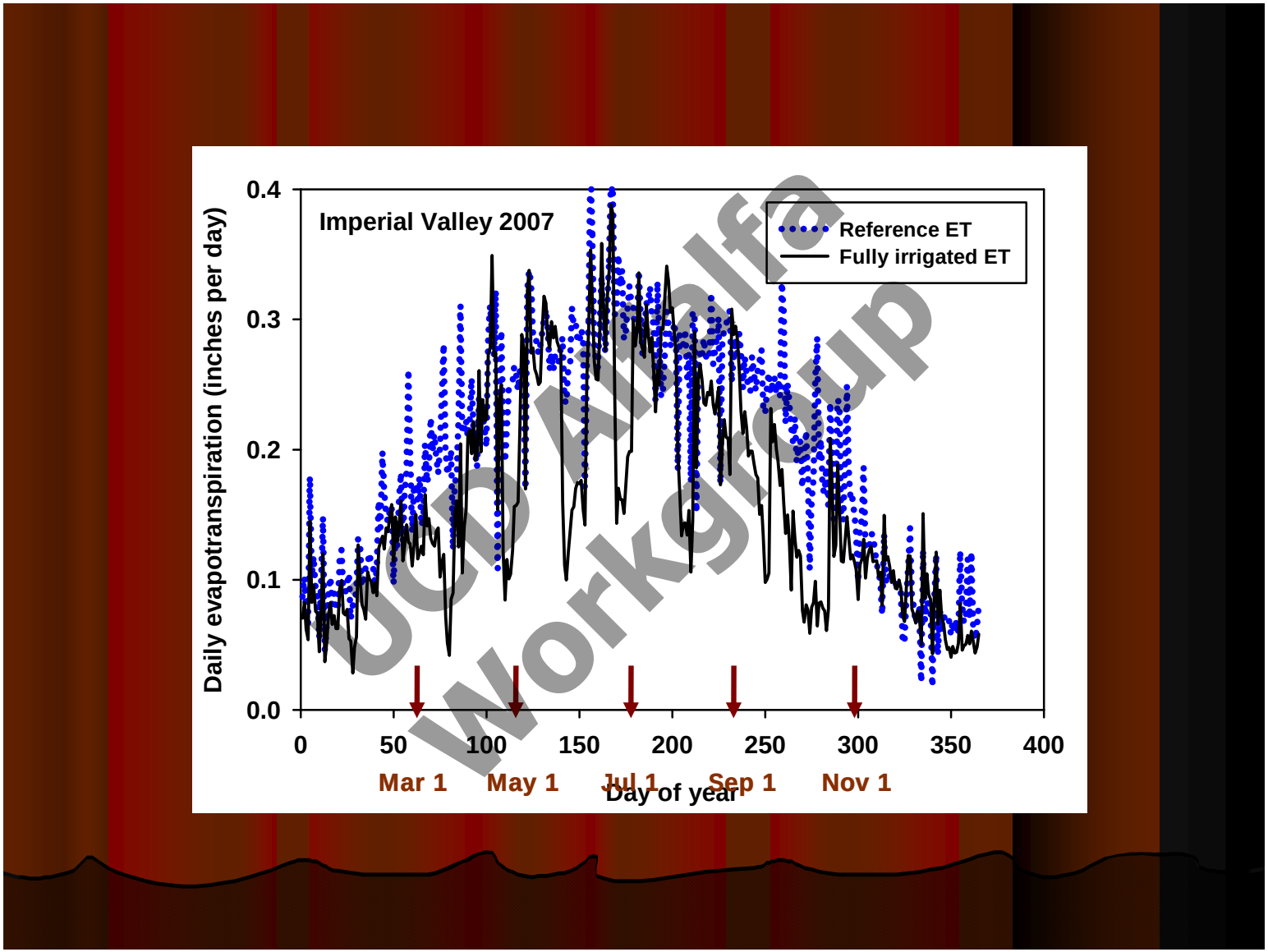
Eddy covariance energy balance

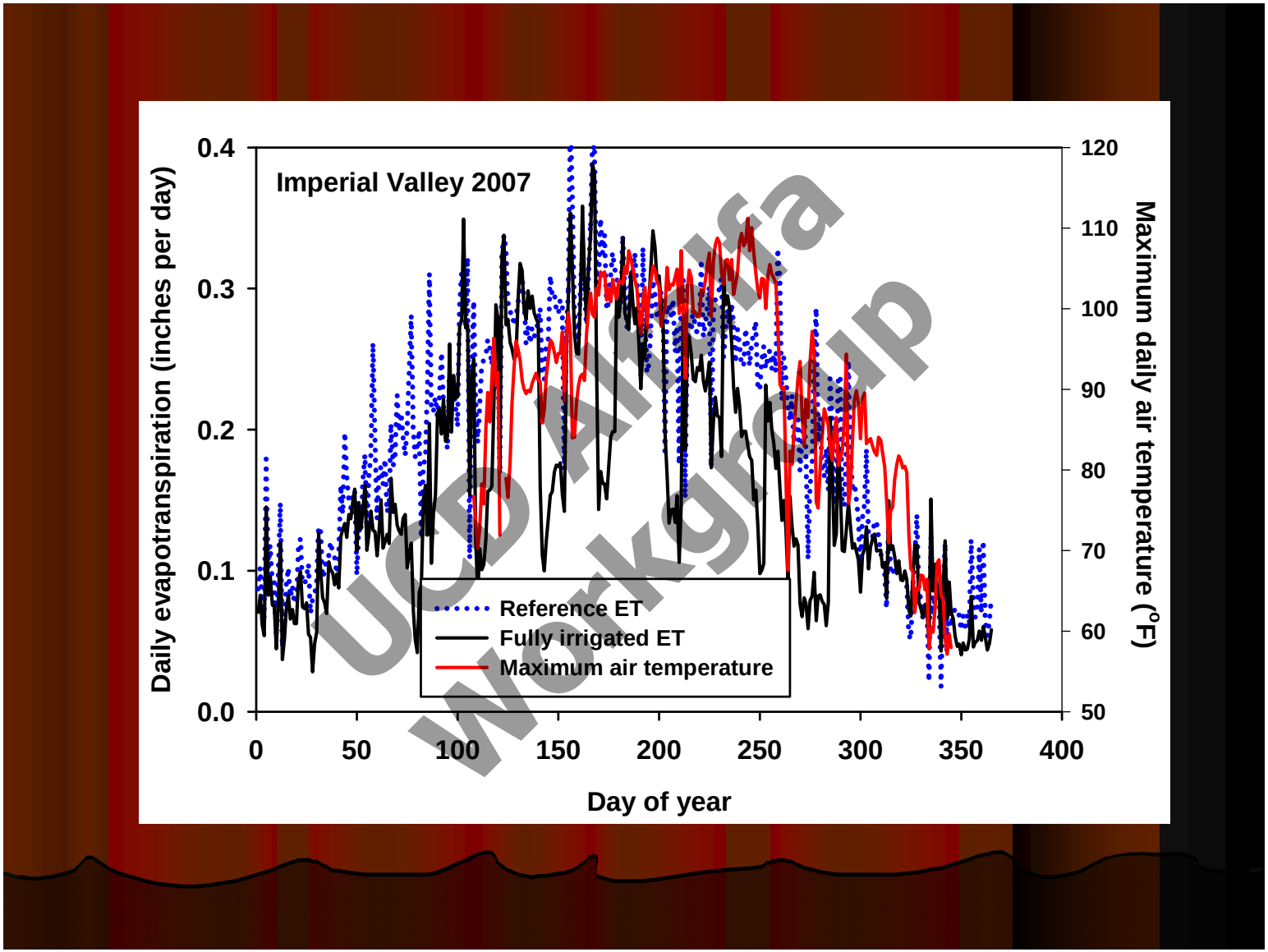
Surface renewal energy balance


Seasonal Evapotranspiration
UCD Alfalfa Workgroup

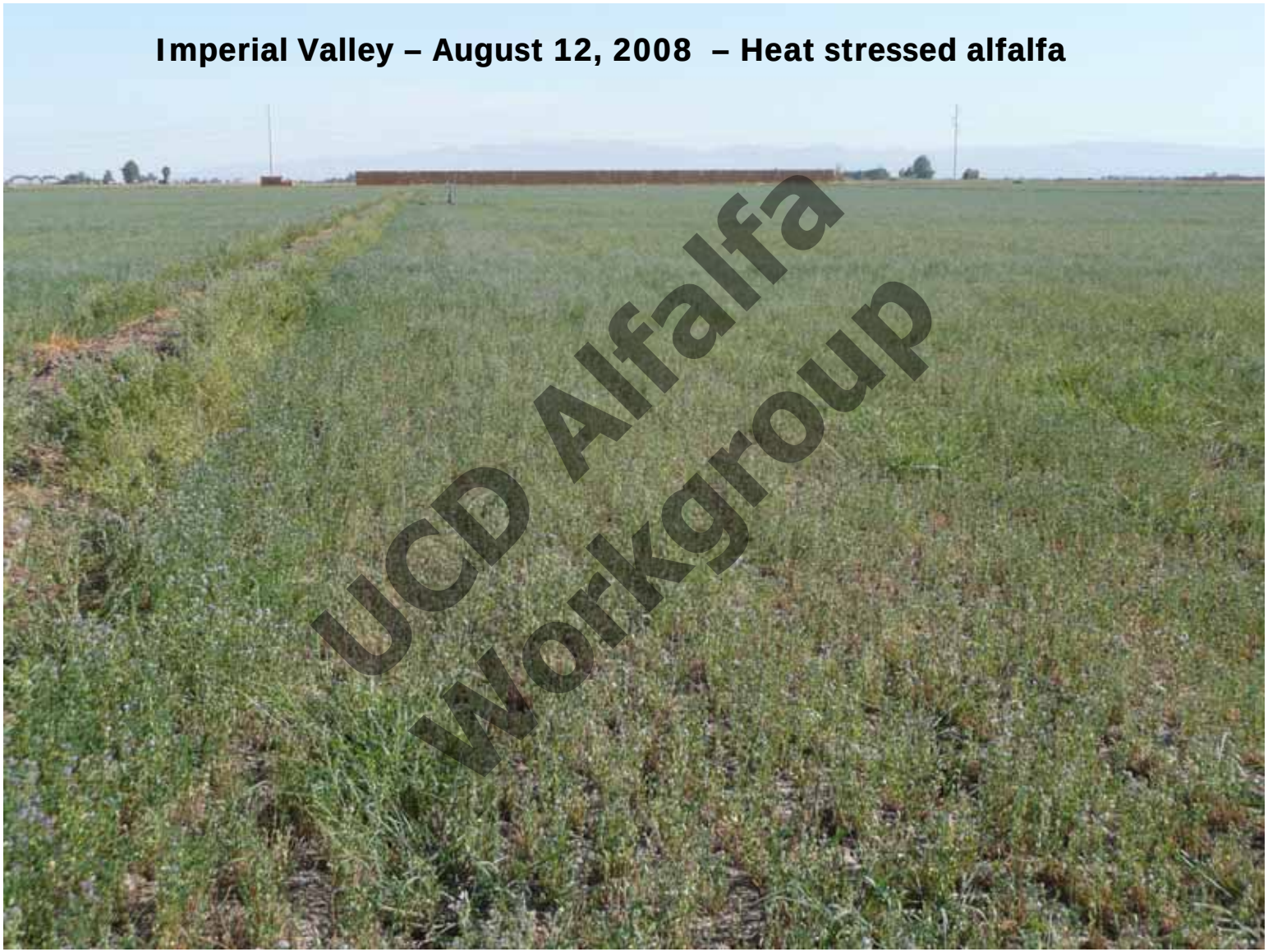

Sacramento Valley 2007
Full ET
Reference ET
Daily evapotranspiration (inches per day)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
ICD Alfalfa Workgroup


Sacramento Valley 2007 - smoothed data
Evapotranspiration (inches per day)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
UCD Alfalfa Workgroup

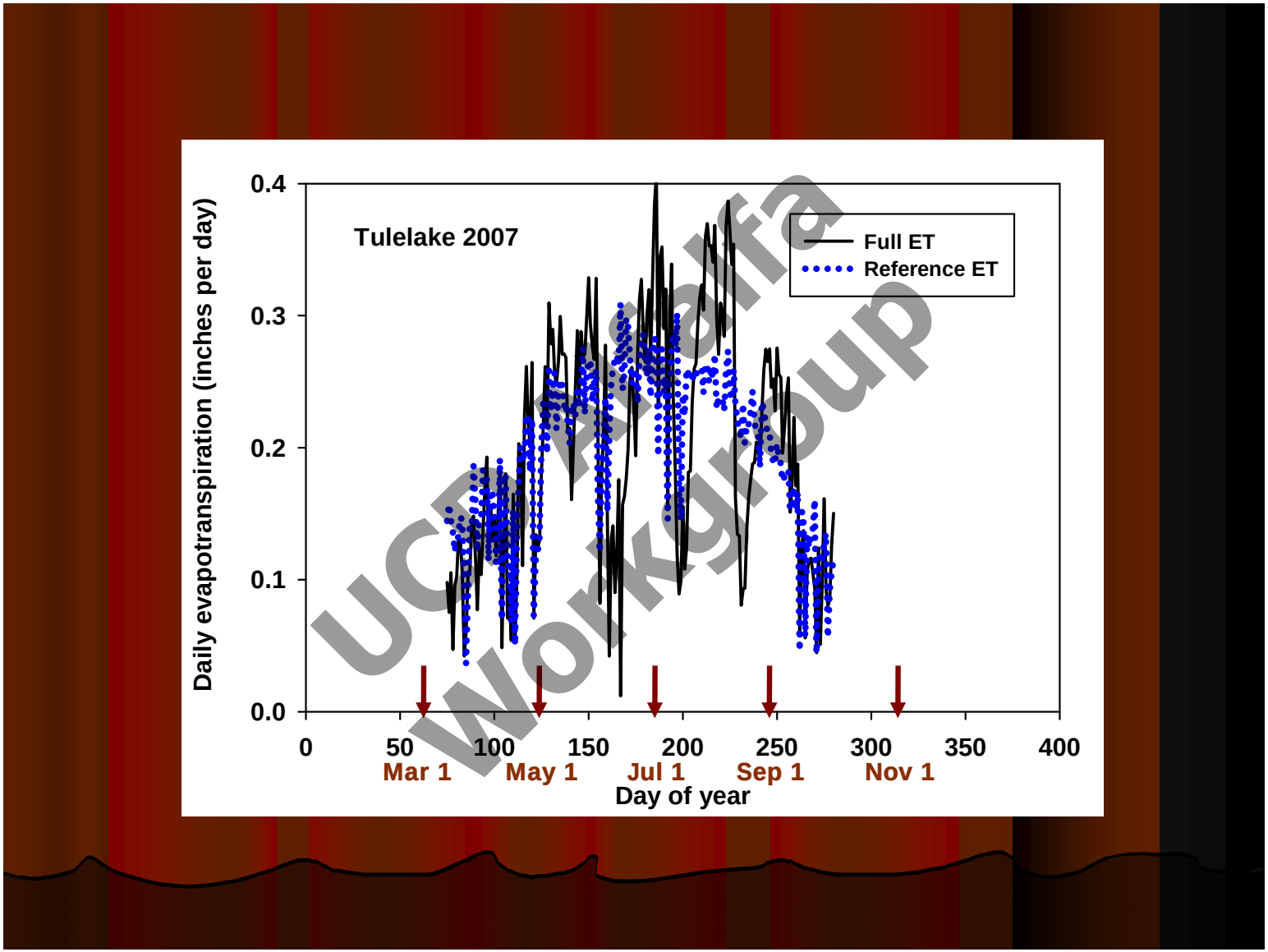

Imperial Valley 2007
Reference ET
Fully irrigated ET
Daily evapotranspiration (inches per day)
0.0
0.1
0.2
0.3
0.4
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
UCD Alfalfa Workgroup


Imperial Valley 2007
Daily evapotranspiration (inches per day)
Maximum daily air temperature (°F)
Day of year
Reference ET
Fully irrigated ET
Maximum air temperature
0.0
0.1
0.2
0.3
0.4
50
60
70
80
90
100
110
120
0
50
100
150
200
250
300
350
400
UCD Alfalfa Workgroup

Imperial Valley – August 12, 2008 – Heat stressed alfalfa



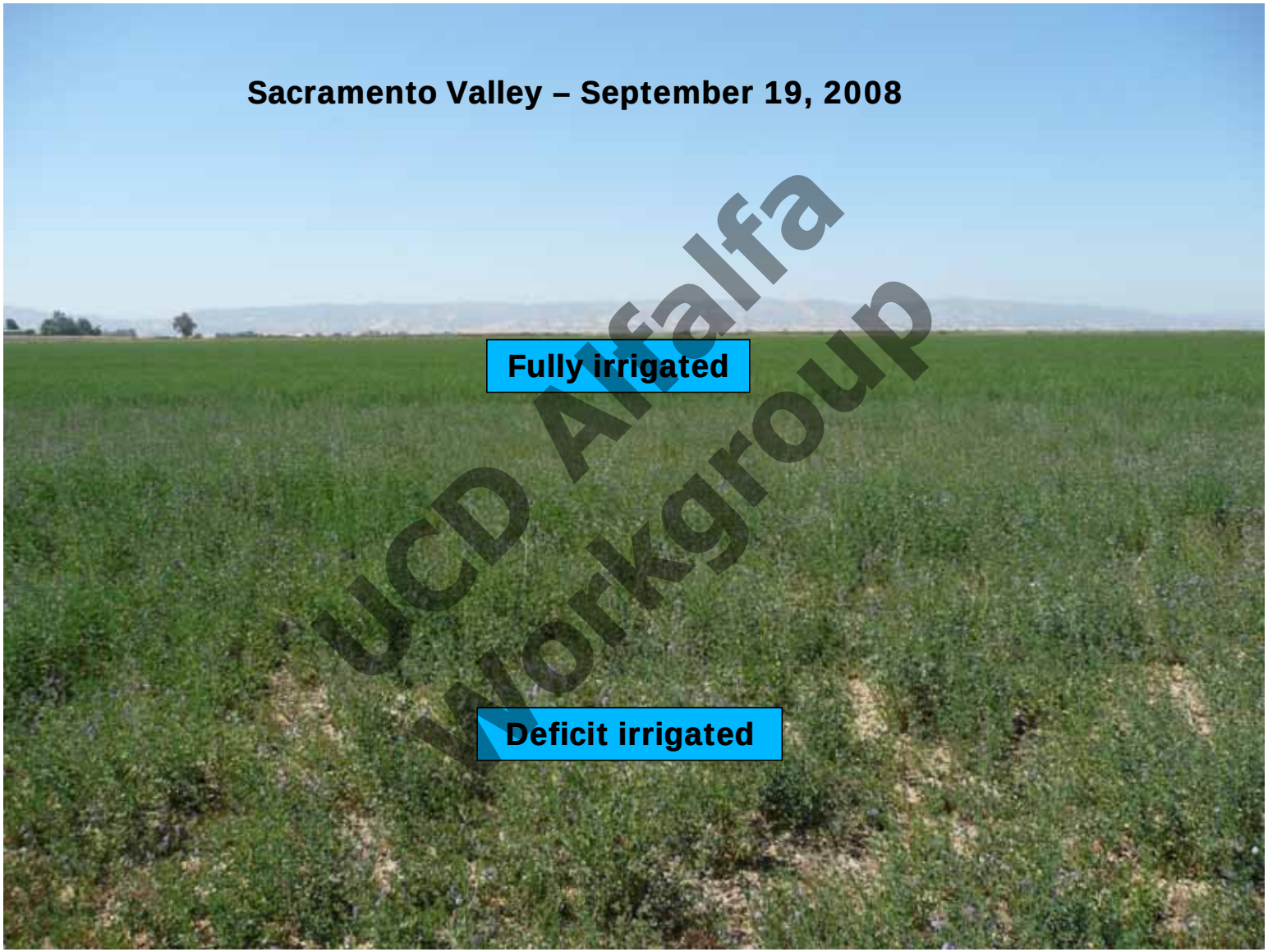

Media
Market

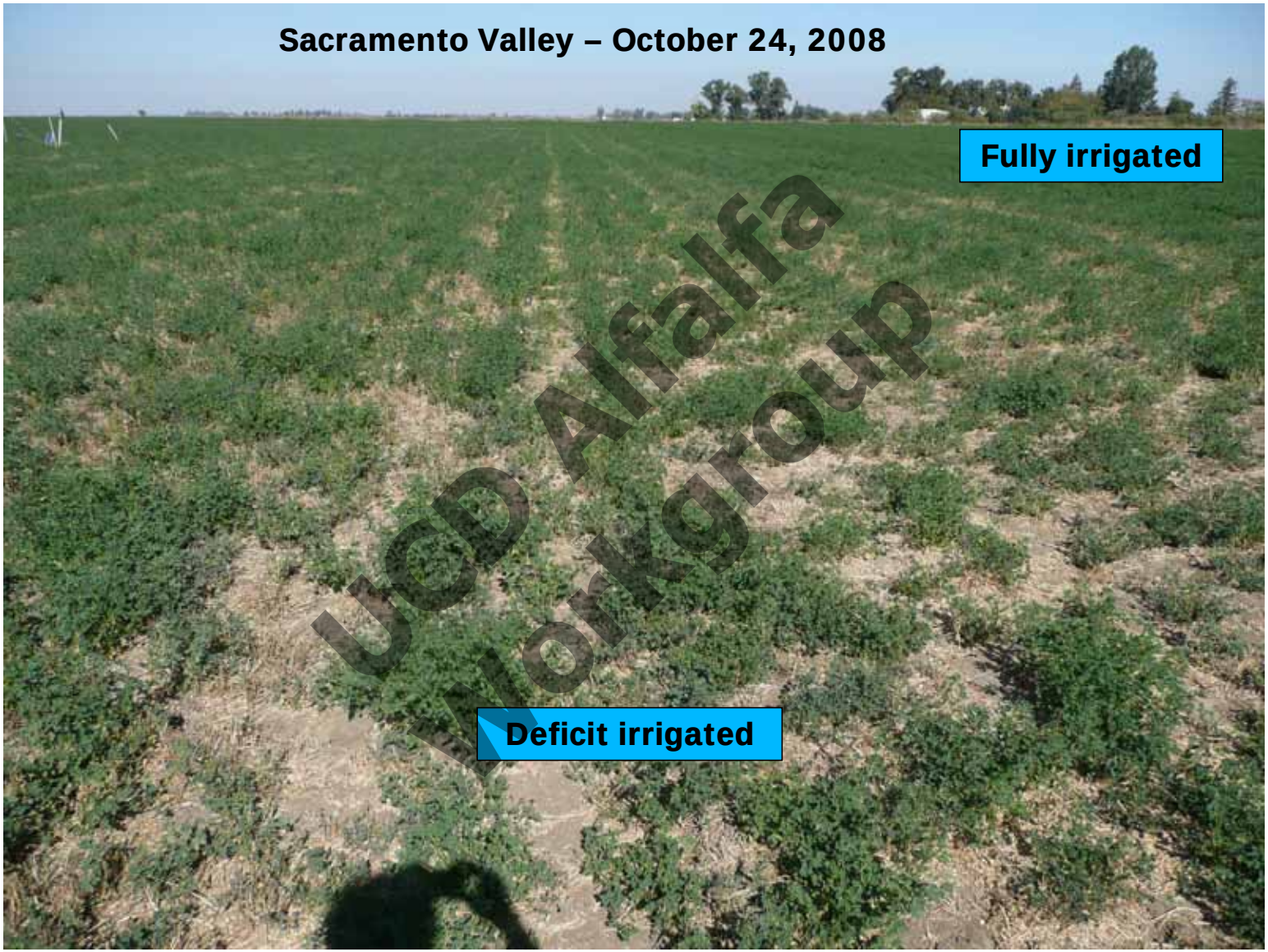

Tulelake 2007
Full ET
Reference ET
Daily evapotranspiration (inches per day)
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
UCD Alfalfa Workgroup

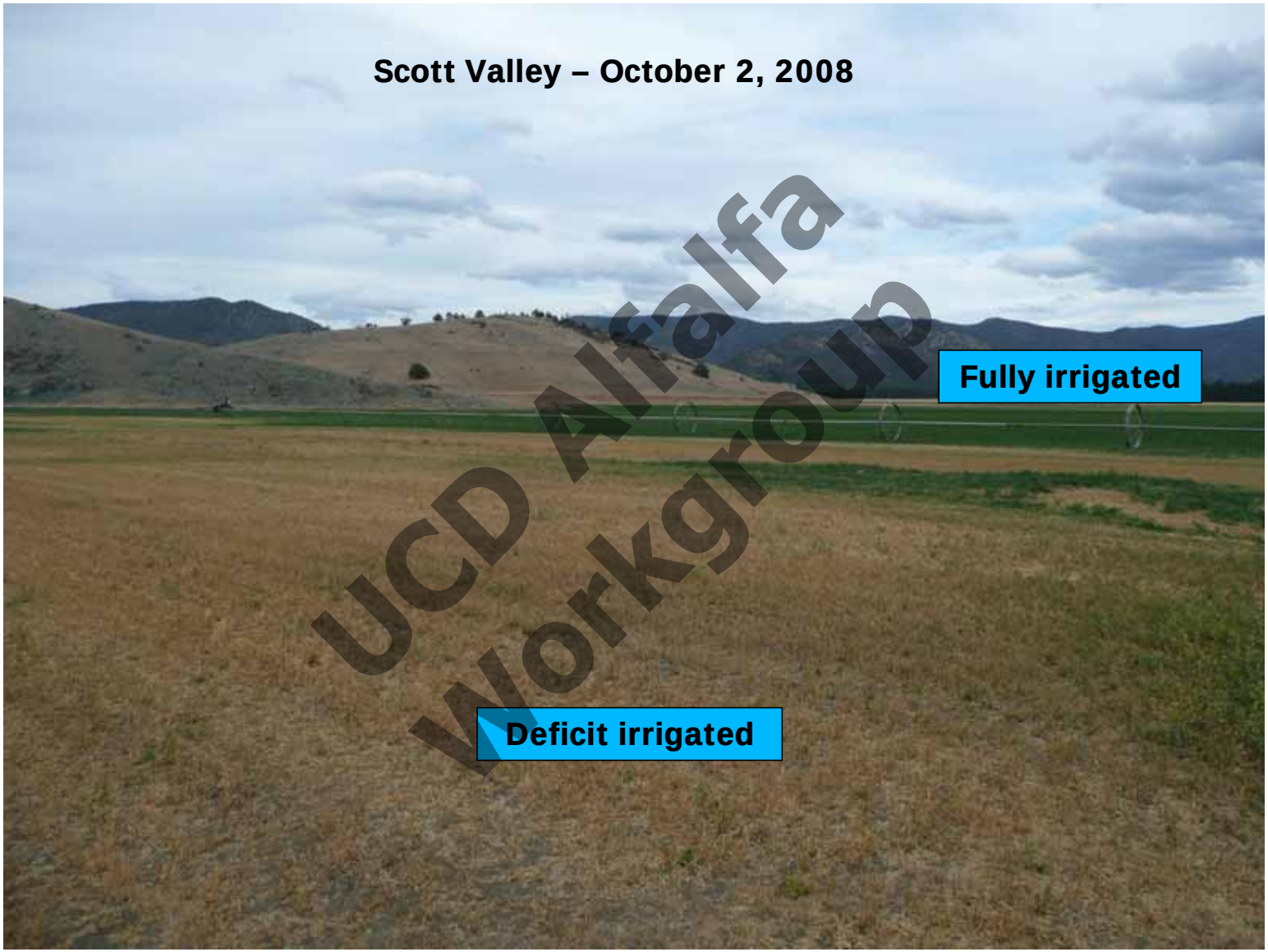
Seasonal ET

Site		Seasonal ET (inches)	Historical ET (inches)
Imperial Valley	(2007)	58	76
	(Dec. 3, 2008)	63	
Kern County	(2007)	56	49
Sacramento Valley	(2005)	50	48
	(2006)	54	
	(2007)	55	
Scott Valley	(2007)	39	33
	(2008)	33	
Tulelake	(2007)	41	33
	(2008)	35	

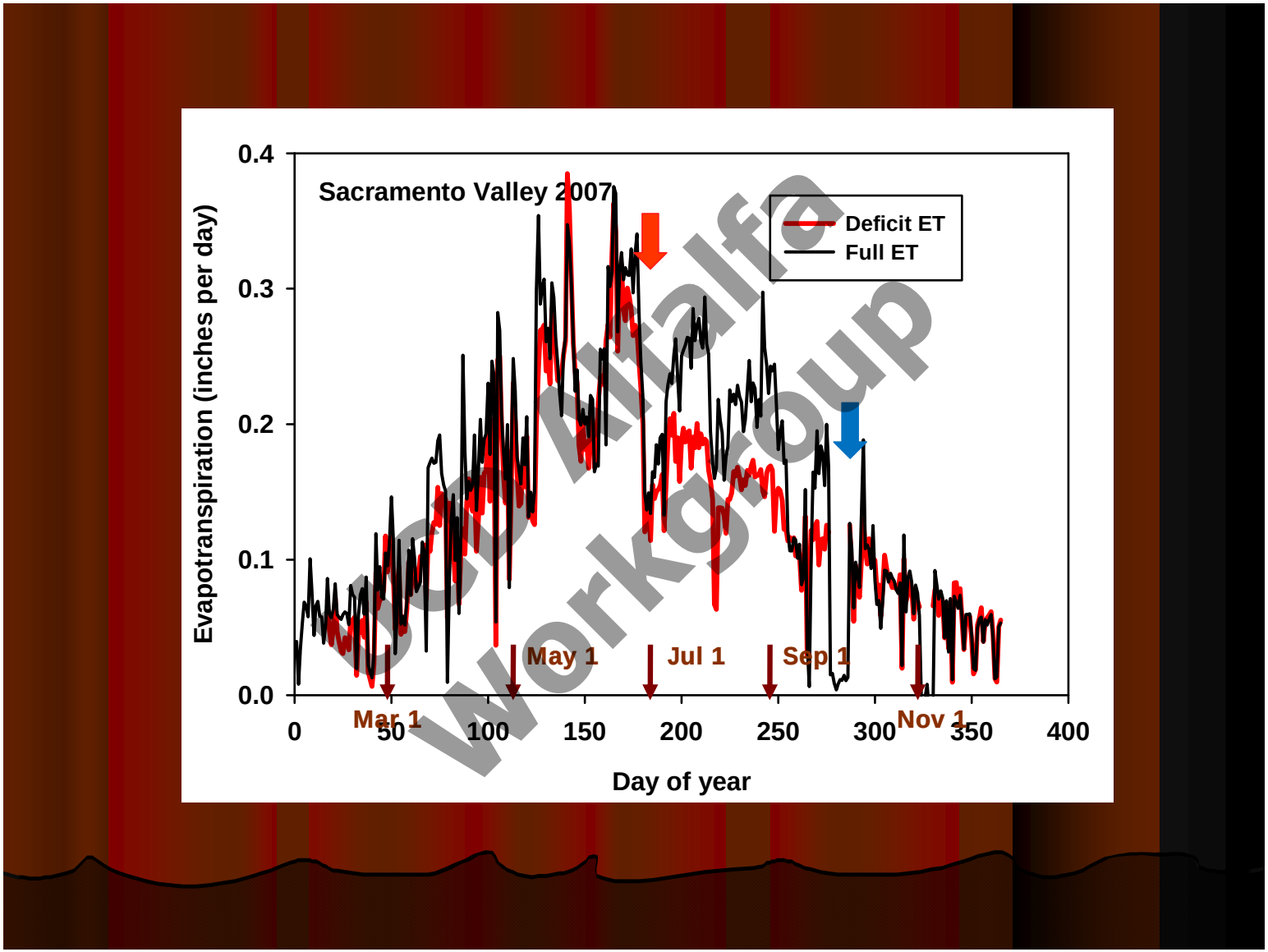
Mid-summer Deficit Irrigation

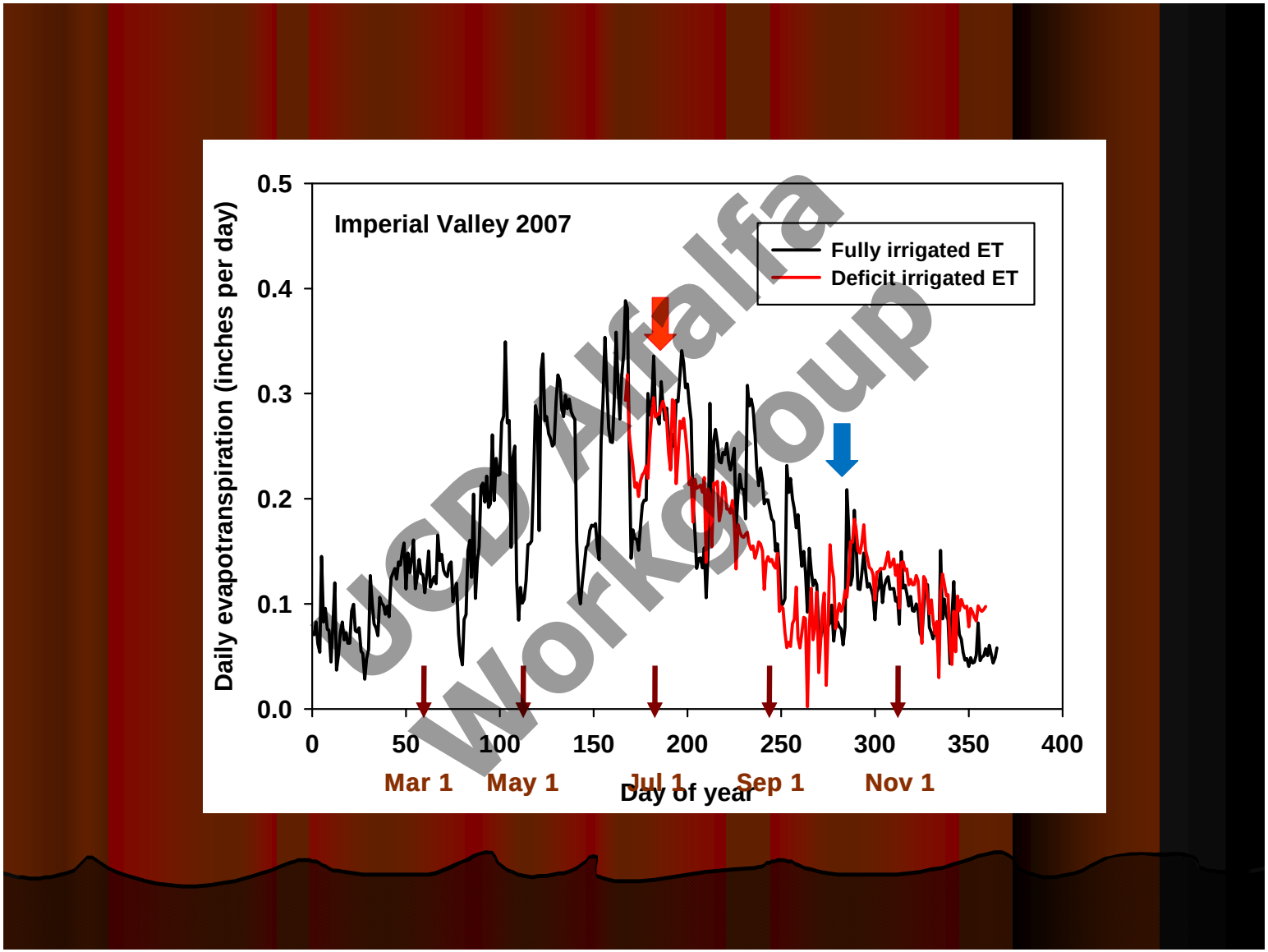

Sacramento Valley – September 19, 2008
Fully irrigated
Deficit irrigated
UCD Alfalfa Workgroup

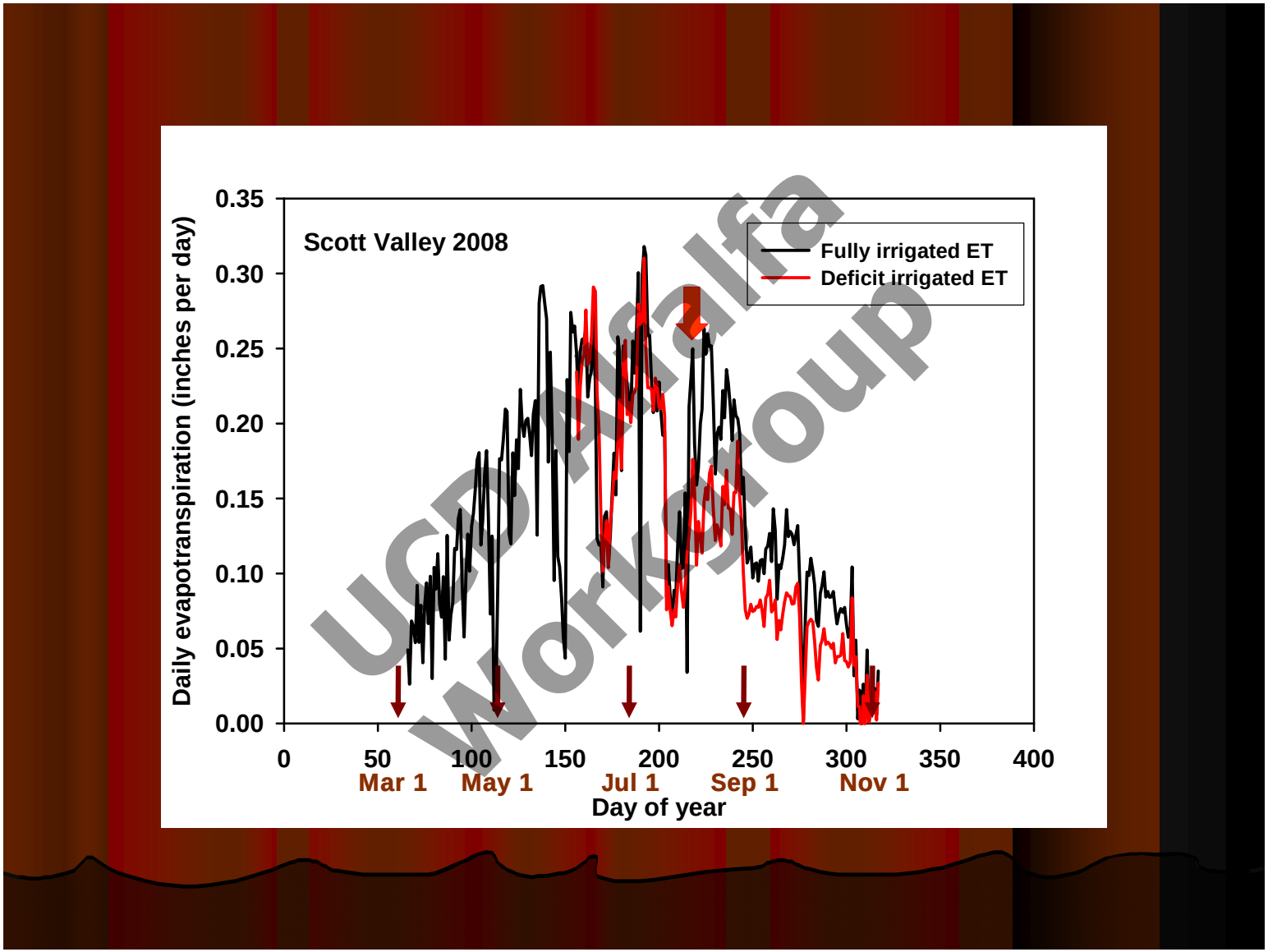

Sacramento Valley – October 24, 2008
Fully irrigated
UCD Alfalfa Workgroup
Deficit irrigated

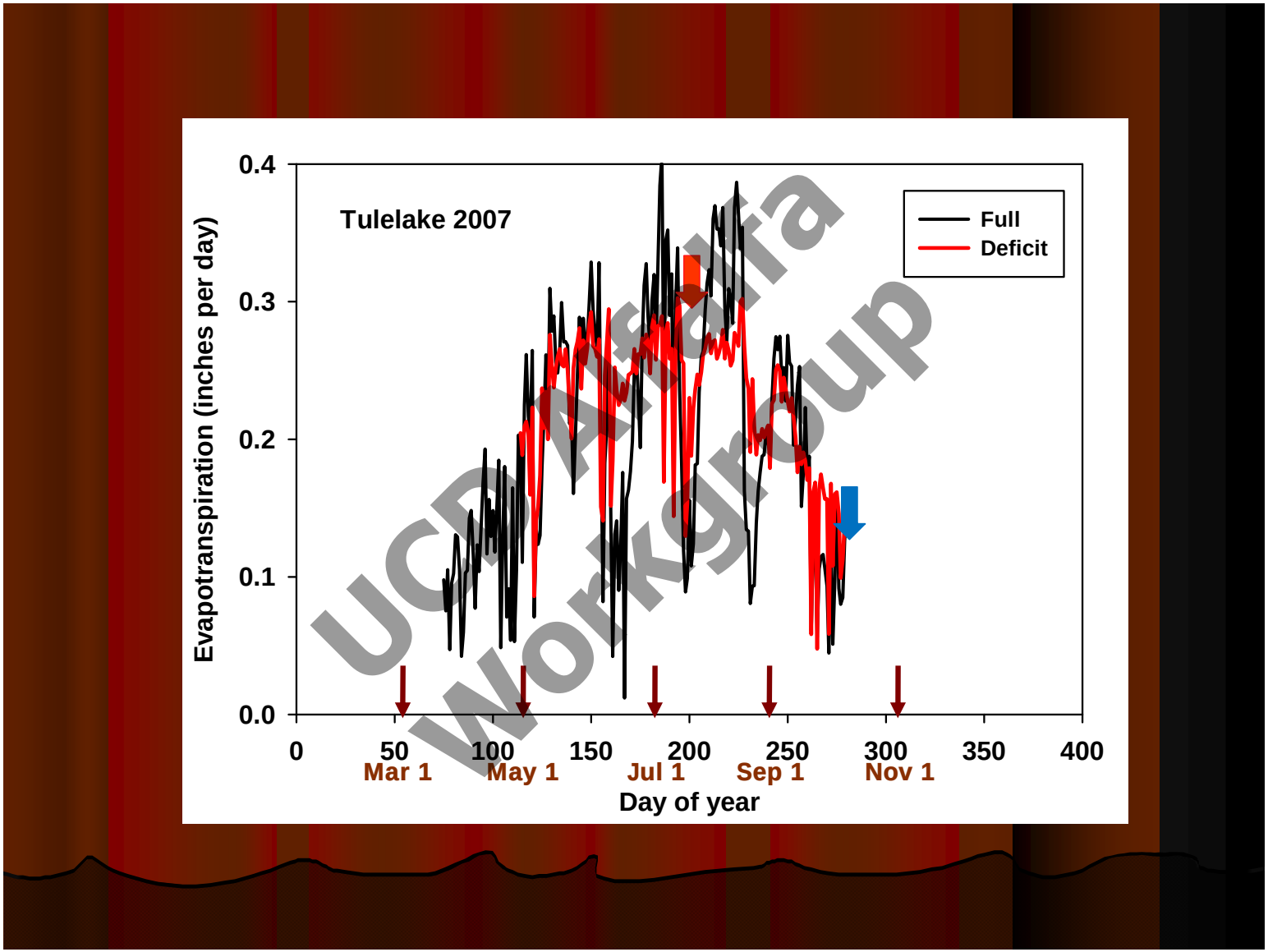

Scott Valley – October 2, 2008
UCD Alfalfa Workgroup
Fully irrigated
Deficit irrigated


Imperial Valley – November 7, 2008
Deficit-irrigated part of the field fully irrigated in October
UCD Alfalfa Workgroup


Sacramento Valley 2007
Deficit ET
Full ET
Evapotranspiration (inches per day)
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
Day of year
Mar 1
May 1
Jul 1
Sep 1
Nov 1
UC Alfalfa Workgroup

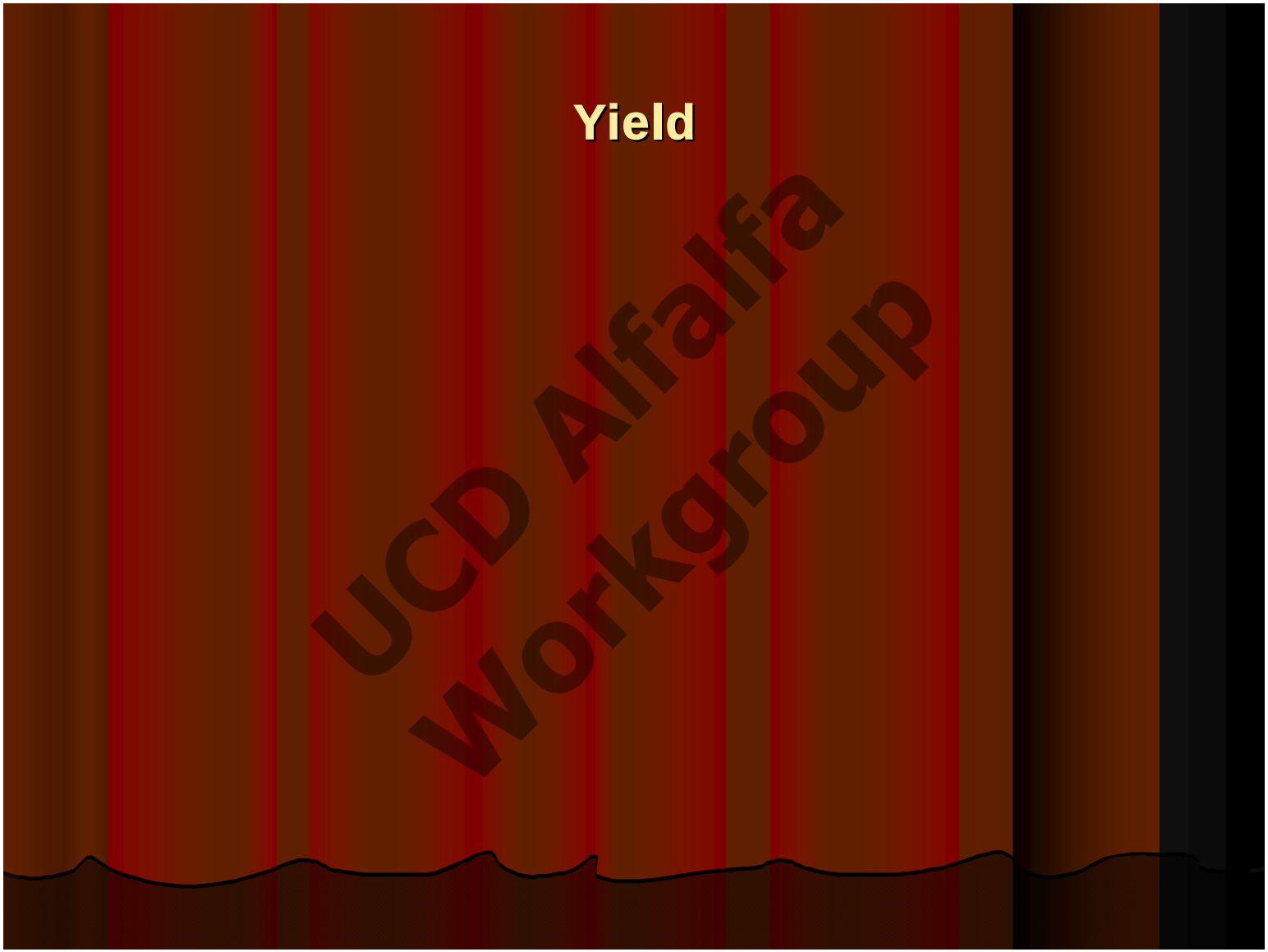

Imperial Valley 2007
Fully irrigated ET
Deficit irrigated ET
Daily evapotranspiration (inches per day)
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
UCD Alfalfa Workgroup

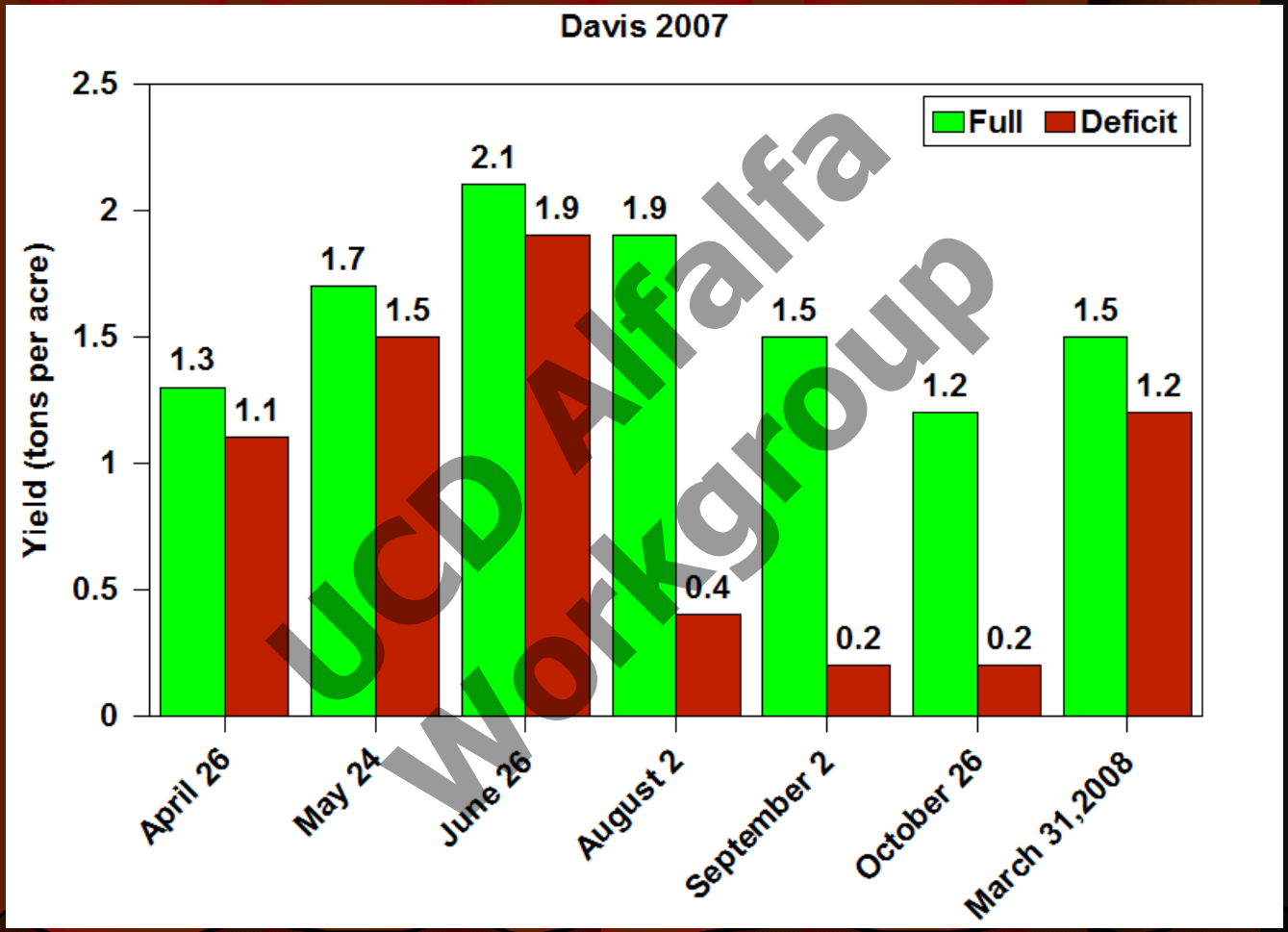

Scott Valley 2008
Fully irrigated ET
Deficit irrigated ET
Daily evapotranspiration (inches per day)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
UCD Alfalfa Workgroup


Tulelake 2007
Full
Deficit
Evapotranspiration (inches per day)
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
Mar 1
May 1
Jul 1
Sep 1
Nov 1
Day of year
UCD ATrain Workgroup

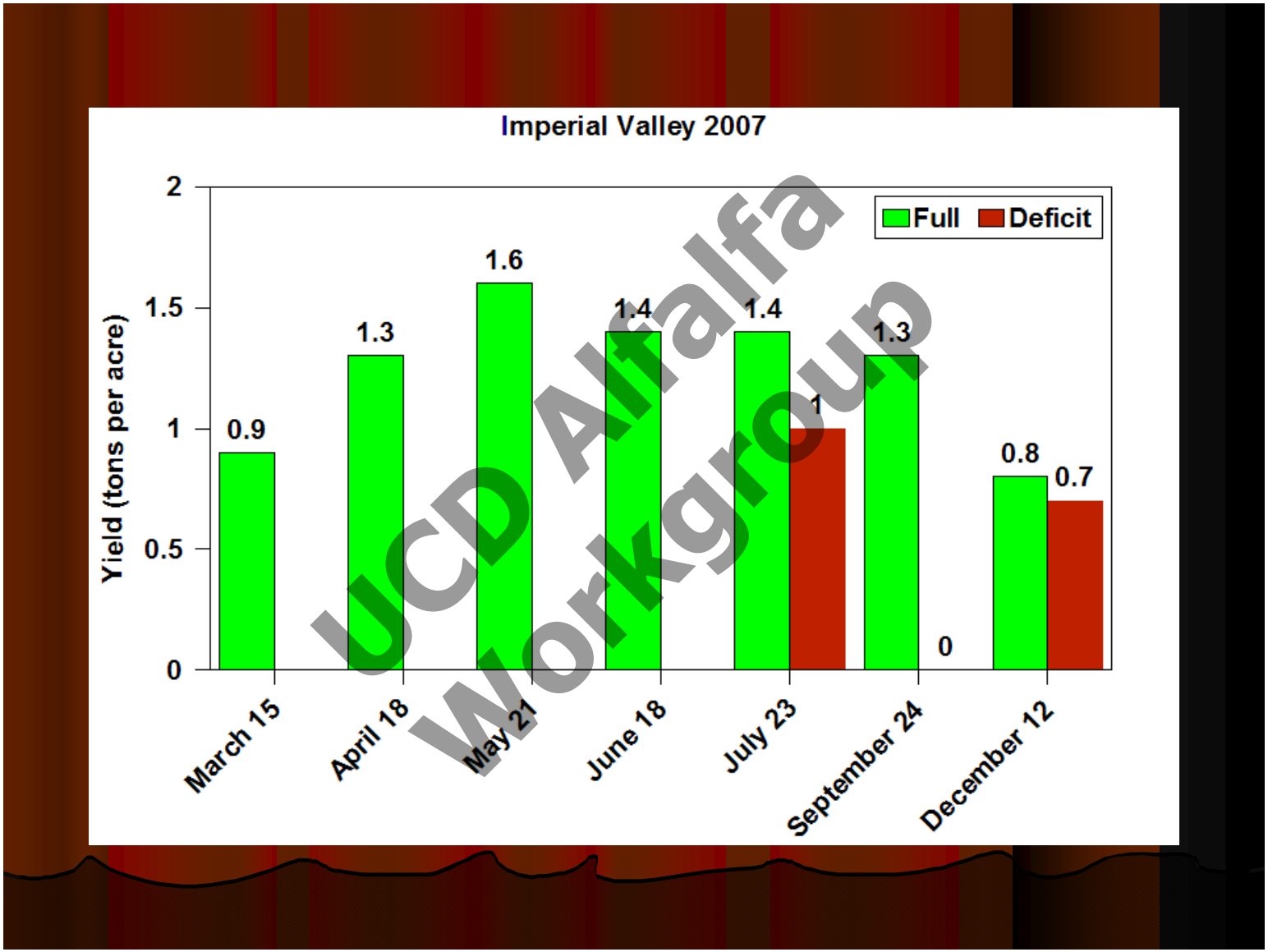
Deficit irrigation

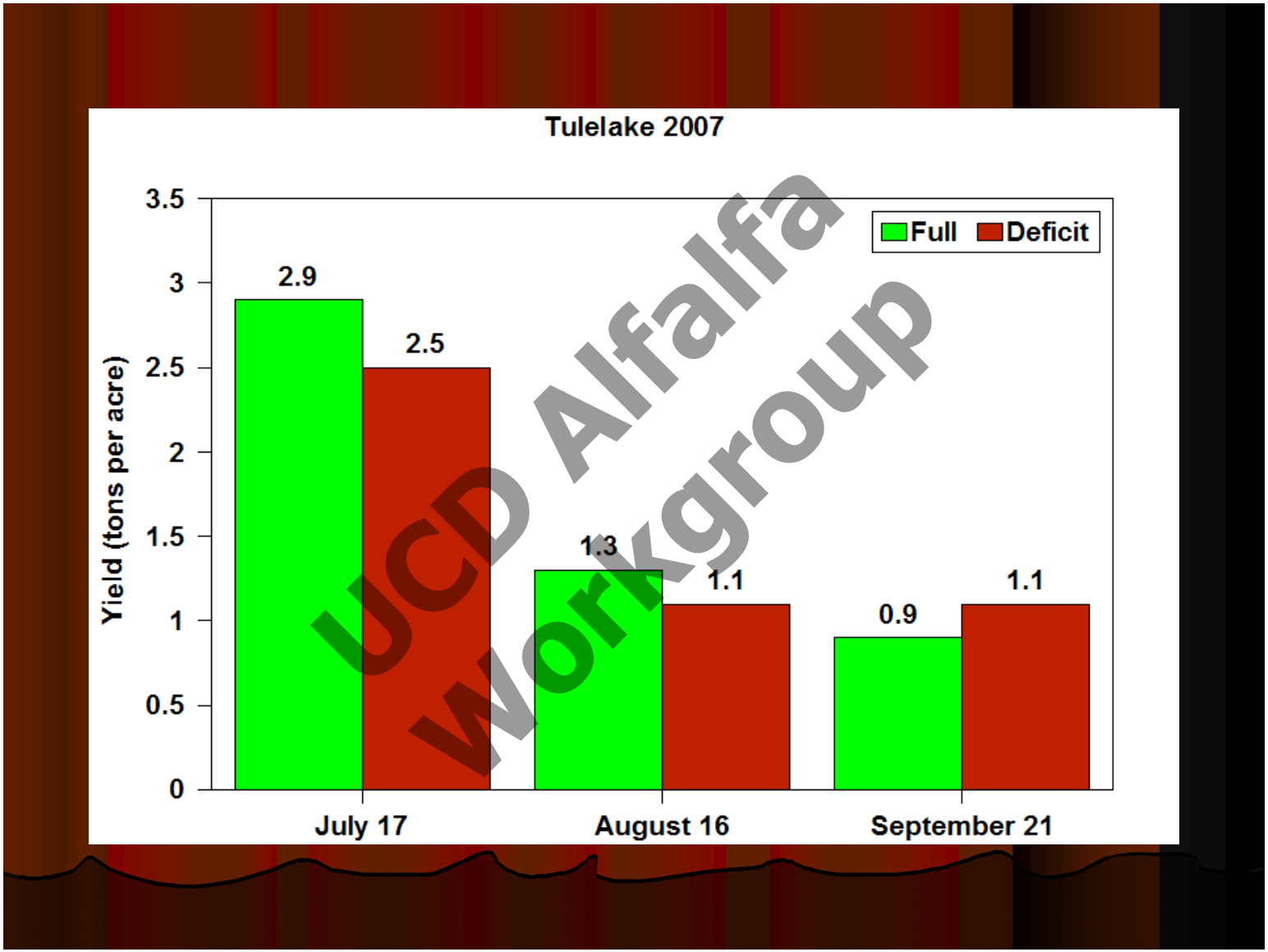
Site		ET differences (inches)	Full ET during period of deficit irrigation (inches)
Imperial Valley	2007	2.4	22.5
Kern County	2006	1.8	8.9
	2007	1.7	14.0
Sacramento Valley	2005	9.4	23.4
	2006	7.4	21.2
	2007	4.7	18.7
Scott Valley	2007	2.0	10.6
	2008	3.1	12.6
Tulelake	2007	0.2	18.6
	2008	4.3	24.7


Yield
UCD Alfalfa Workgroup



*Yields smaller than 0.5 tons per acre are not economical to harvest


Imperial Valley 2007
Yield (tons per acre)
2
1.5
1
0.5
0
Full
Deficit
0.9
1.3
1.6
1.4
1.4
1
1.3
0
0.8
0.7
March 15
April 18
May 21
June 18
July 23
September 24
December 12
UCD Alfalfa Workgroup


Tulelake 2007
Yield (tons per acre)
3.5
3
2.5
2
1.5
1
0.5
0
Full
Deficit
2.9
2.5
1.3
1.1
0.9
1.1
July 17
August 16
September 21
UCD Alfalfa Workgroup

Seasonal yield reductions

Site		Actual yield difference (tons per acre)	Practical yield difference* (tons per acre)
Imperial Valley	2007	1.66	1.66
Kern County	2006	0.66	1.03
	2007	0.85	1.16
Sacramento Valley	2005	1.37	
	2006	2.78	3.95
	2007	3.74	4.59
Scott Valley	2007	0.82	1.38
Tulelake	2007	0.4	0.4

* adjusted for yields smaller than 0.5 tons per acre (not considered economical to harvest)

Conclusions

- Seasonal ET of alfalfa differed from historical ET
- Mid-summer deficit irrigation reduced ET and yield
  - Effect of mid-summer deficit irrigation was site specific
- Water transfer amounts should be based on ET of fully irrigated alfalfa during period of deficit irrigation
- Water transfer amounts based on ET differences is not practical because of the site specific responses
  - Penalizes growers because ET of deficit-irrigated field results from stored soil moisture from previous irrigations
  - Mid-summer yields were not economical to harvest
- Compensation for yield losses should be based on yield of fully irrigated alfalfa, not on yield differences

Irrigating alfalfa with limited water supplies

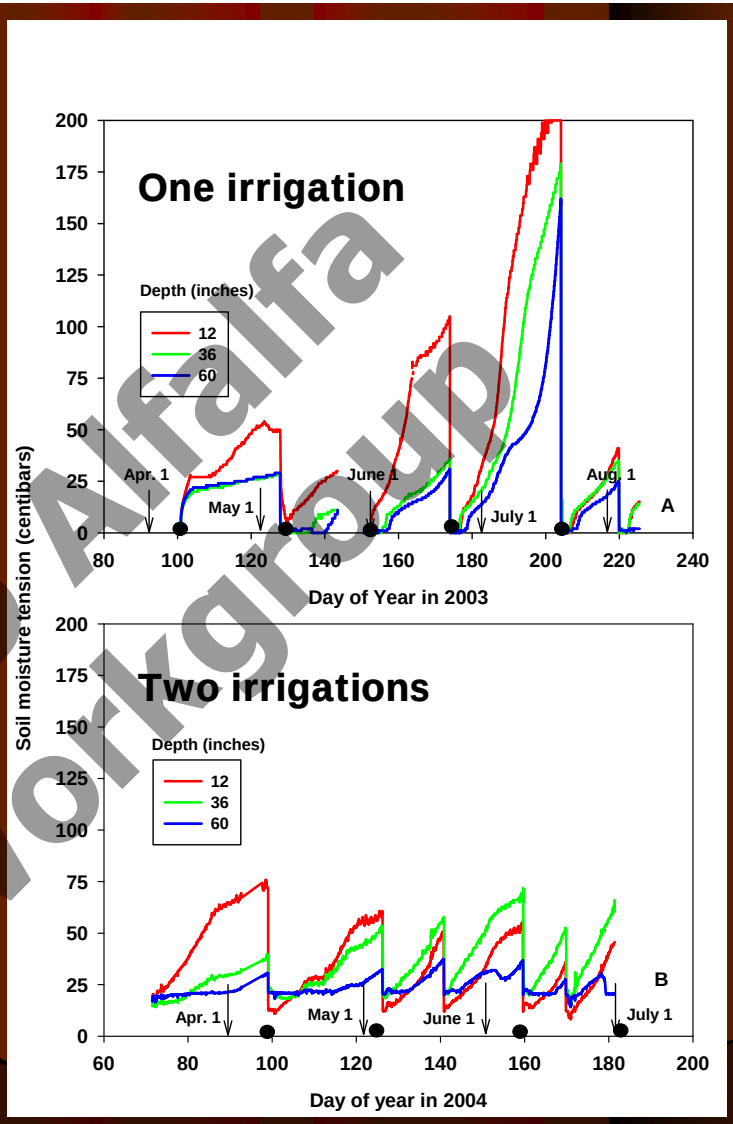
- Options
  - Reduce irrigated acres
    - Fully irrigate reduced acres
    - No irrigation on remaining acres
  - Reduce water applications between harvests – irrigate entire field
    - Distribute the limited water supply throughout the crop season
    - Reduce the number of irrigations between harvests – flood irrigation, sprinkle irrigation
    - Reduce the amount of applied water per irrigation – sprinkle irrigation
    - Combination of both
  - Mid-summer deficit irrigation
- Critical irrigation – first irrigation just after harvest

Irrigation system considerations

- **Sprinkle irrigation**
  - Can apply small amounts of water to the entire field
  - Reduced irrigation set time - inconvenience factor
- **Flood irrigation**
  - Reduce the number of flood irrigations between harvests
  - Reduced set time – water may not reach the end of the field; inconvenience factor
  - Eliminate surface runoff – cut off irrigation water before water reaches the end of the field
  - Cracked soil – infiltration time of 2 to 3 hours

Effect of reducing the number of flood irrigations between harvests on the soil moisture tension

Note: the higher the soil moisture tension, the drier the soil



Which option is the best?

- Best option – provides the most revenue or maximizes profit
- May be site specific
- Sacramento Valley
  - 50 % water supply
  - Mid-summer deficit irrigation resulted in the most revenue
    - Full irrigation for the first three harvests; no irrigation thereafter
- Considerations
  - Salinity – no leaching under limited water supplies