This presentation premiered at WaterSmart Innovations

watersmartinnovations.com

watersmart
INNOVATIONS

Crop Coefficients for Scheduling Irrigations on Drought Tolerant Landscapes

Dan Smeal
Mick O'Neill, Rick Arnold, and Kevin Lombard

New Mexico State University
Agricultural Science Center at Farmington

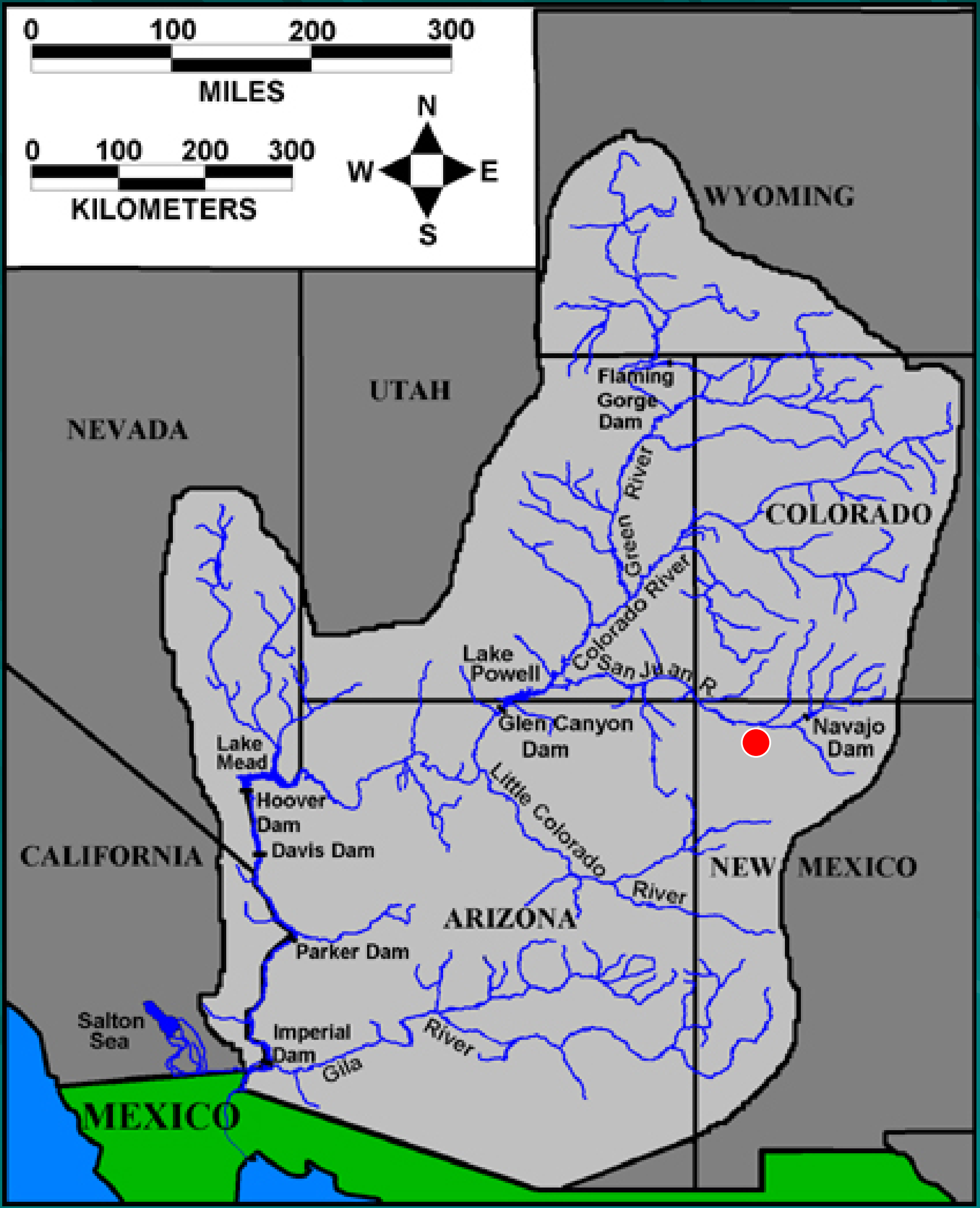
WaterSmart Innovations Conference and Expo

October 8-10, 2008

Las Vegas, NV

Introduction

The southwestern U.S. (particularly those states serviced in part or whole by the Colorado River system) is facing a water crisis!



● Study Site

Baumann, P.R. 2001

http://employees.oneonta.edu/baumanpr/geosat2/Lake_Powell/Colorado_River_Basin-Lake_Powell.htm

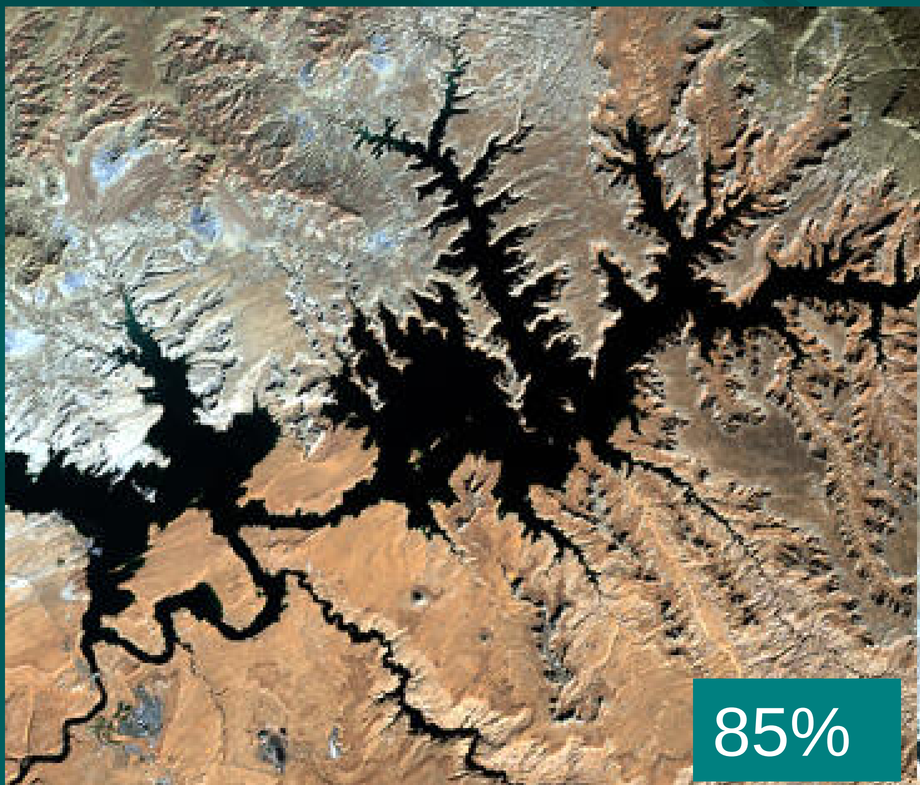
The population is rapidly increasing:

State	Population (millions)		% Increase
	1990	2007 (est.)	
Nevada	1.20	2.57	114.2
Arizona	3.67	6.34	72.8
Utah	1.72	2.65	54.1
Colorado	3.29	4.86	47.7
New Mexico	1.52	1.97	29.6
California	29.8	36.6	22.8
6 State Total	41.2	55.0	33.5

Source: U.S. Census Bureau: http://factfinder.census.gov

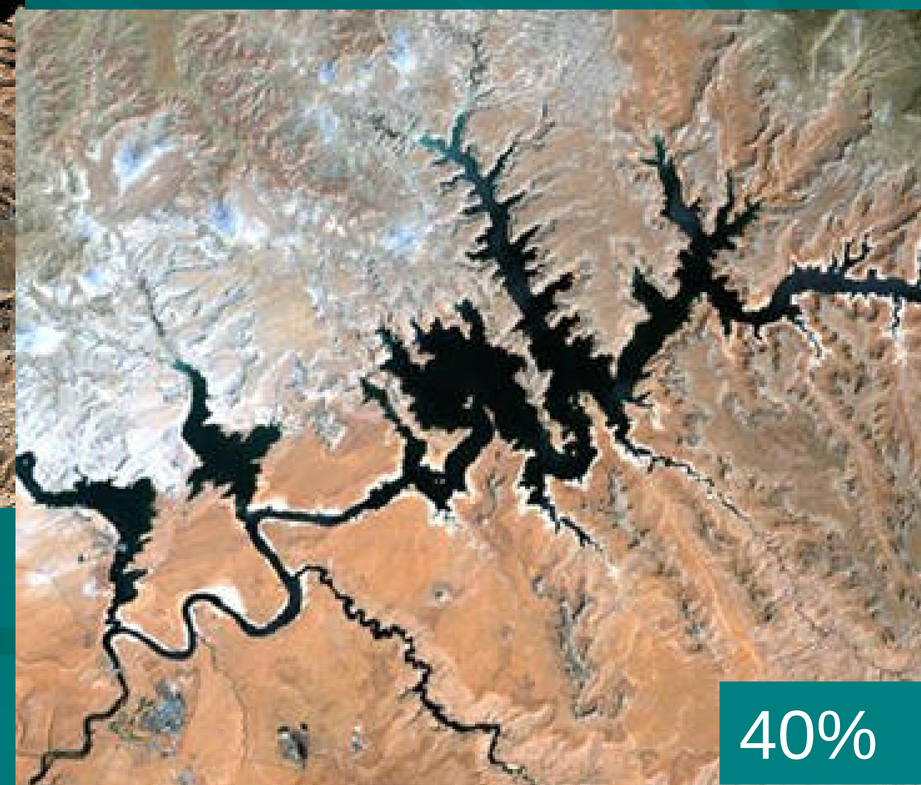
Water resources to satisfy the demand of this increasing population are unstable:

Lake Powell



October 1999

June 2004



July 2008: 62% of capacity

Baumann, P.R., 2001
http://employees.oneonta.edu/baumanpr/geosat2/Lake_Powell/Colorado_River_Basin-Lake_Powell.htm

Lake Mead - 2007

July 2008: 46% of capacity

SNWA: http://www.h2ouniversity.org/html/K2_facts_drought.html

Nat. Geographic News: http://news.nationalgeographic.com/news/2007/08/photogalleries/wip-week40/photo4.html

Consequently…

- The demand for fresh water in the southwest will exceed (or has exceeded) the available supply (allocations).
- The volume of water available for non-essential uses, including landscape irrigation, will be (or has been) restricted.

The Bright Side

- The potential adverse affects of these reduced water quantities on landscape quality can be mitigated through...
  - Efficient irrigation scheduling
  - Appropriate plant selection

Climate-Based Irrigation Scheduling

- Provide quantities of water to plants sufficient to replace estimated crop evapotranspiration (ET).
- Apply this water at a rate that…
  - Minimizes water lost through deep percolation and runoff.
  - Maximizes crop production and quality (agriculture) or aesthetic appeal (landscaping)
- ET estimates are based on weather data or reference ET (ET_R) and correction factors or crop coefficients (K_C) specific to crop and growth stage.

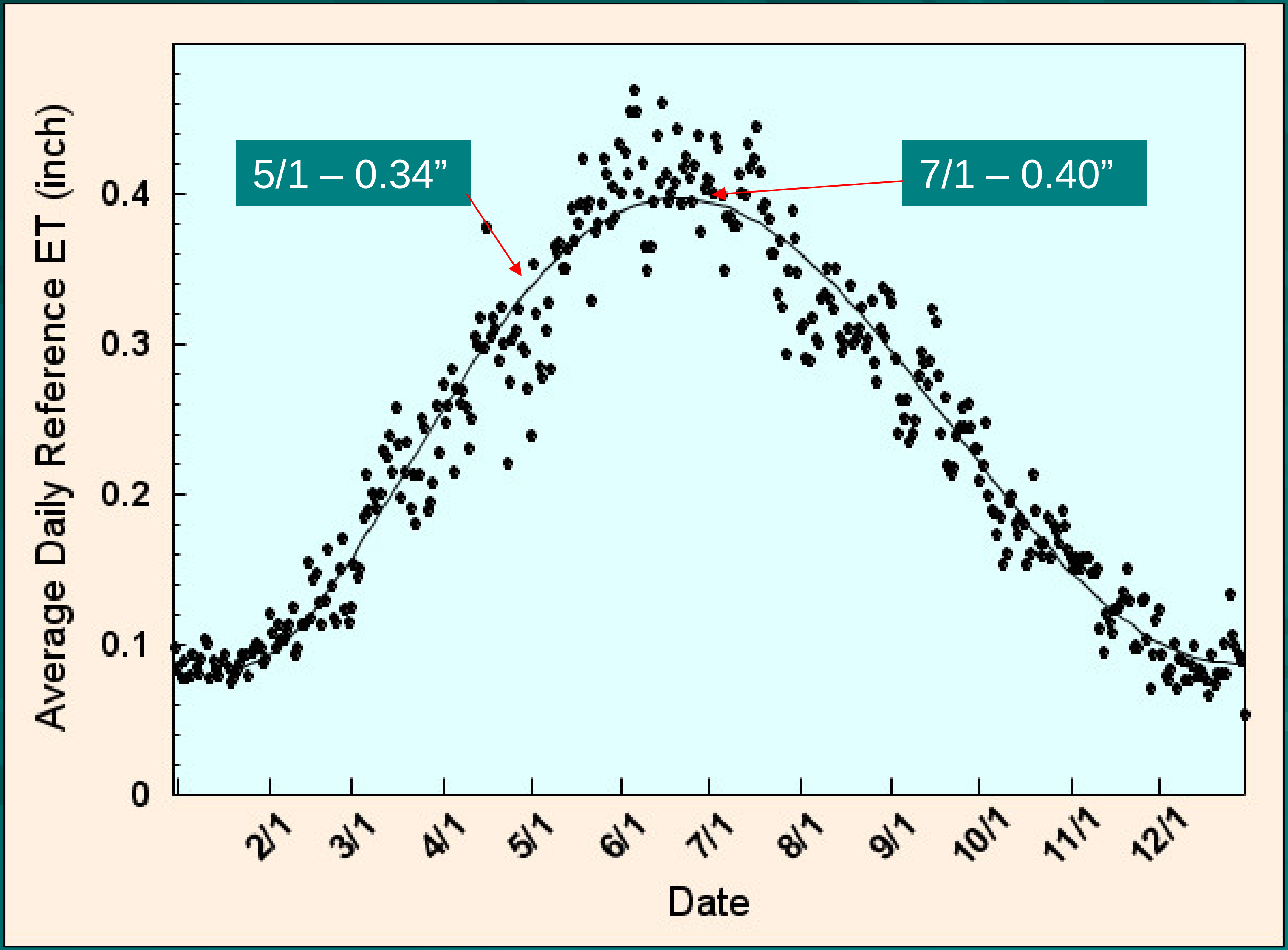
Crop Coefficient (K_c) Concept

- $ET_R \times K_C = ET$
  - Where:
    - ET_R= reference ET (calculated from weather data)
    - K_C = crop coefficient (correction factor for crop and growth stage)*
    - ET = estimate of crop evapotranspiration (ET)

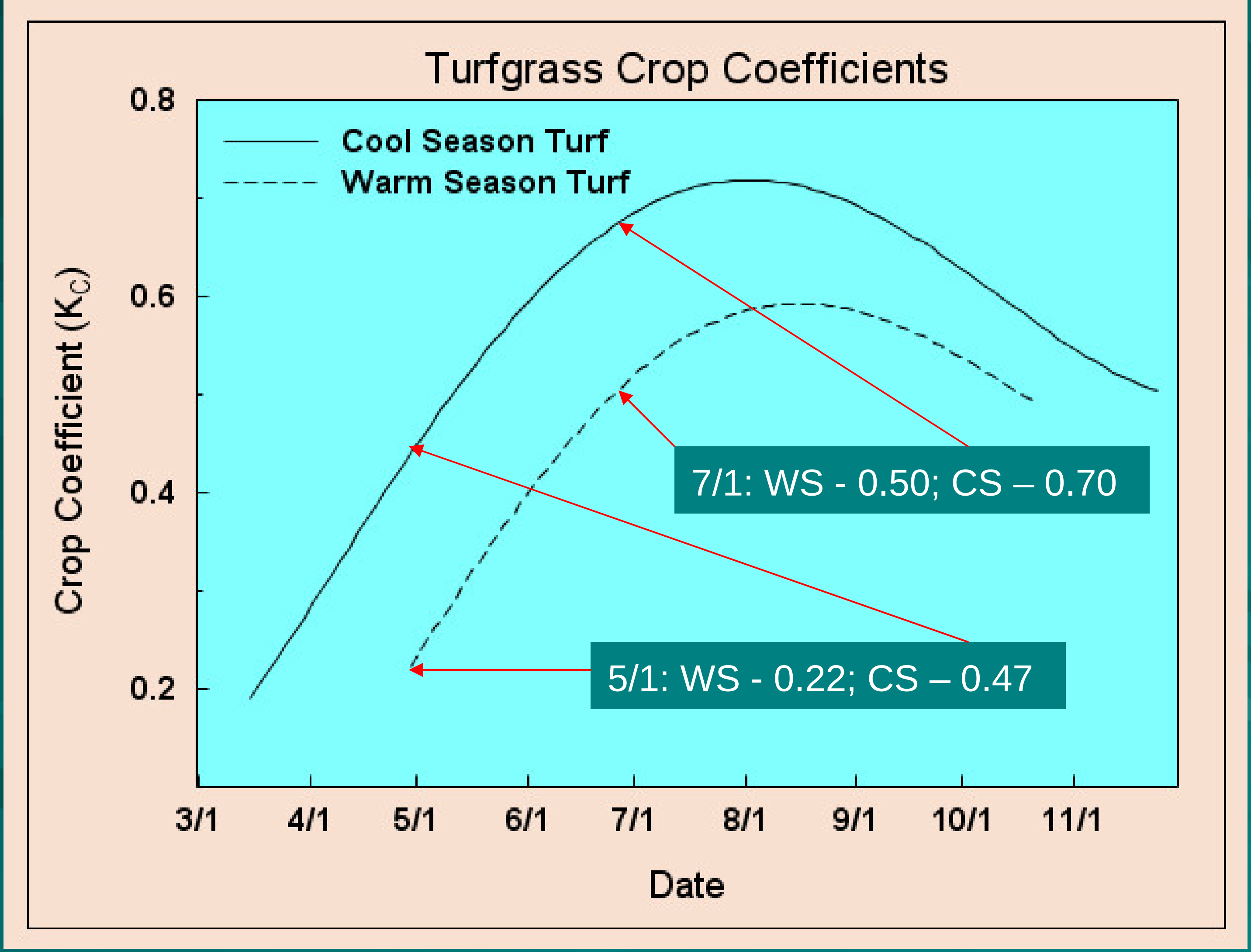
*Determined experimentally for most agricultural crops and available in a number of publications (i.e. FAO 56 Report).

Example

Average Daily Reference ET (ET_R) at Farmington, NM



K_C (K_L) for Turfgrasses



Example: ET Estimation of cool and warm season turfgrass on given days at Farmington, NM

DATE	ET_R	K_C		ET (in.)*	
	inch	CS Turf	WS Turf	CS Turf	WS Turf
5/1	0.34	0.47	0.22	0.16	0.07
7/1	0.40	0.70	0.50	0.28	0.20

$*ET = ET_R \times K_C$

What’s the Point of a K_C ?

- Plant ET is directly related to weather (humidity temperature, solar radiation, and wind).
- These weather parameters may differ significantly from site to site.
- Since the K_C is indexed to weather data it provides a means of estimating ET at any given site using data from a nearby weather station or one located at a site having very similar weather conditions.
- This techniques is used by most ‘smart controllers’.

Example: Comparison of Estimated Average Daily ET for Warm Season Turf in May and July between Farmington, NM and Boulder City, NV using the K_C developed at Farmington

Month	K_C†		ET_R		ET (in.)	
	B.C.	Farm.	B.C.‡	Farm.	B.C.	Farm.
May	0.49	0.21	0.38	0.36	0.19	0.08
July	0.58	0.58	0.53	0.40	0.31	0.23

† Using a cumulative Growing Degree timescale (not day of year).

‡ Shevennell, L. 1996. Statewide potential evapotranspiration maps for Nevada.

- Item
  - To help reduce urban water use in the west, homeowners, businesses, developers, etc. have been encouraged to replace turfgrass with drought tolerant landscape plants (i.e. xeriscapes).
- Problems
  - Due to insufficient knowledge or experience, recommendations and/or availability of plant species suitable for western, drought-tolerant landscapes are quite limited.
  - Landscape coefficients (K_L) for developing climate-based irrigation scheduling recommendations for these plant species are lacking.
  - Consequently, even xeriscapes are oftentimes grossly watered!

Our Project Objectives

- Establish and maintain a live exhibit of various native or drought-tolerant plants that have potential for use in urban landscapes of the western U.S.
- Evaluate the growth and quality of each species under variable levels of irrigation in an effort to formulate (crop) coefficients (K_L)* for these landscapes.
- *$K_L = K_C$

Materials and Methods

Description of Site

- Located in northwestern NM on the Colorado Plateau (36^{O} 41’ N, 180^{O} 18’ W) at an elevation of ~ 5600 feet.
- Sandy loam soil (calcareous, pH ~ 8).
- Average annual precipitation = 8.2 inches.
- USDA Plant Hardiness Zone 6B (-5 to 0 ^{o}F)
- Average annual ET_R = 87 inches
  - ET_O = 62 inches

Plot Description

- Garden dimensions: 160 feet x 80 feet (0.3 acre)
  - Split into 4, 80’ x 40’ quadrants
- 100 different perennial species
  - At least 1 individual of each species in each quadrant
- Planted in 2002 (April thru September)
- Most were small transplants (2 to 4 inch pots).
- Irrigation for establishment (2002 – 2003)
  - 0.25 to 3.0 gallons per plant per week

Drip Irrigation Treatments (2004 – present)

- Once per week irrigations at 0, 20, 40, and 60% of reference ET (ET_R).
- Adjusted for a mean canopy area of a reference plant.
- Irrigation (volume) calculations:

$$I = ET_R \times TF \times 0.623 \times A_C$$

Where:

I = irrigation volume (gallons)

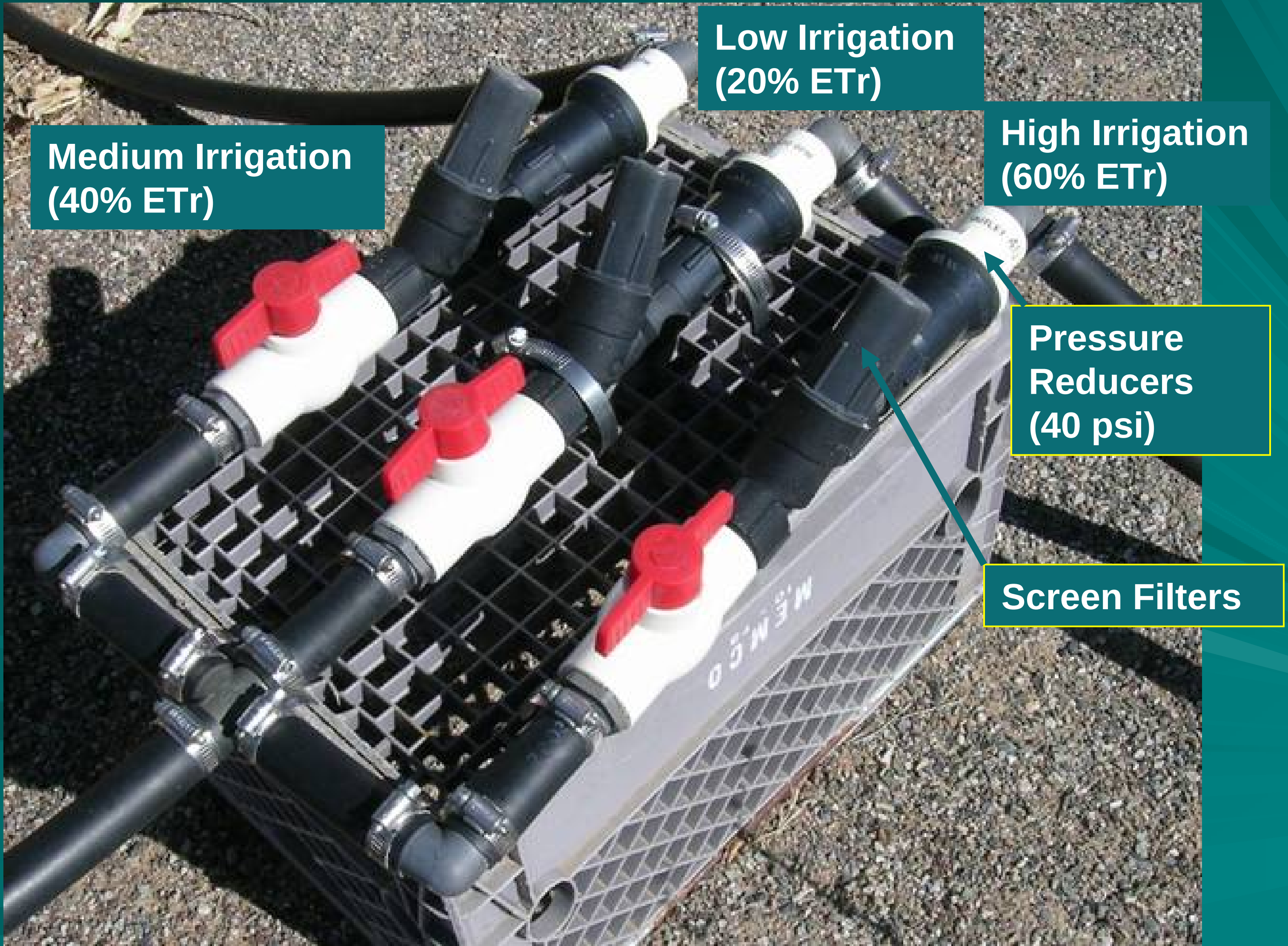
ET_R = FAO-24 modified Penman ref. ET (inches)

TF = treatment factor (0, 0.2, 0.4, or 0.6)

A_C = reference plant canopy area (square ft)

Overhead View of Xeric Garden - 2006

Primary Distribution Manifold



Secondary (8-outlet) Manifolds

1 gph emitters

Spaghetti tubing outlet at base of plant

NM Climate Center Weather Station

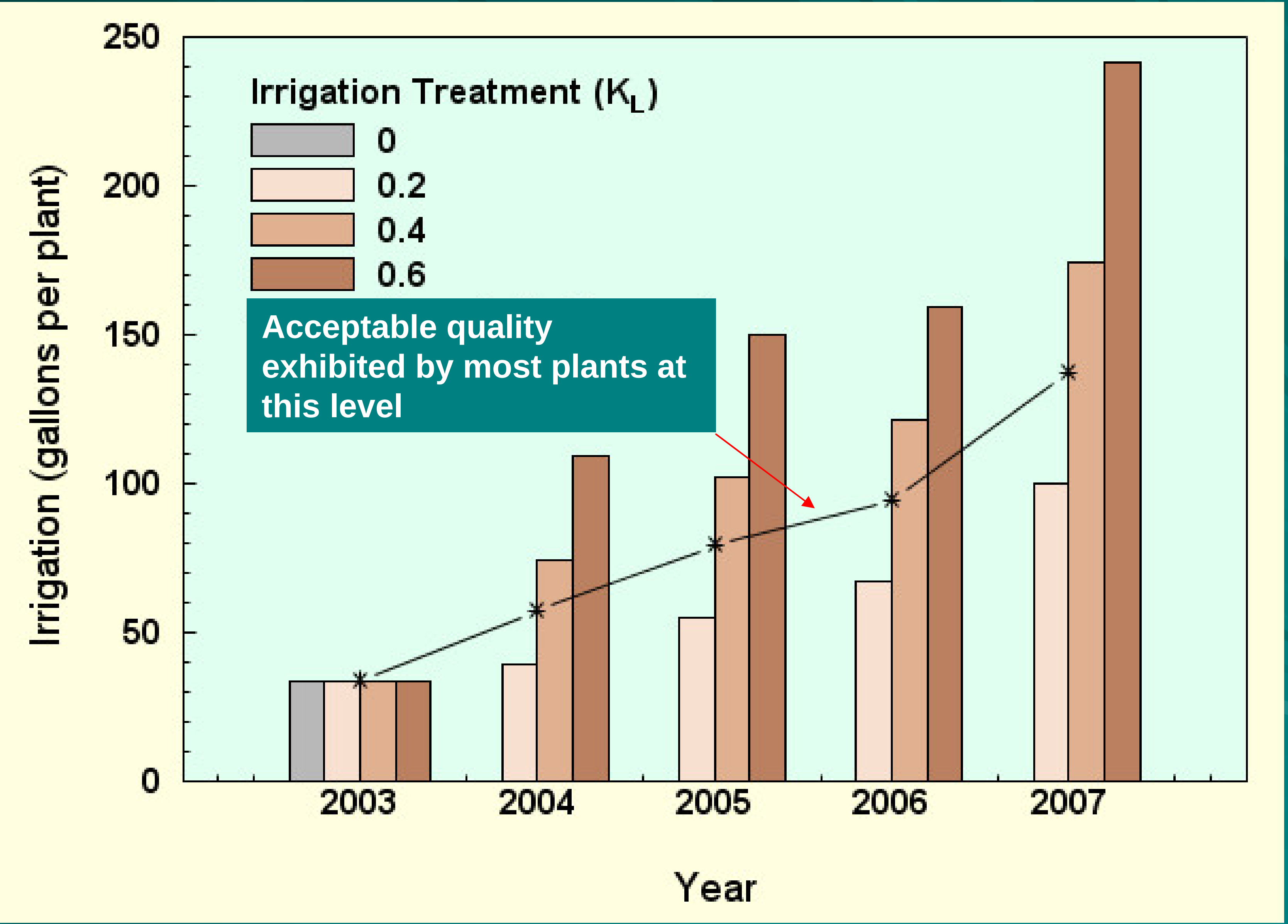
Data available from: http://weather.nmsu.edu

Plant Evaluations

- Subjective quality ratings
  - Assistance from public including Native Plant Society, master gardeners, xeriscaping class students, and other visitors
- Measurements of height and canopy area were taken but were not necessarily indicative of aesthetic quality.
  - They were used to make adjustments to the treatment factor for estimating the K_L.

Results

Total Season Irrigation Applied per Plant



Annual Total and Effective Precipitation

Year	Precipitation (in.)		%
	Total	Effective†	Effective
2003	6.32	2.27	35.9
2004	8.74	3.03	34.7
2005	8.69	3.21	36.9
2006	8.76	3.88	44.2
2007	8.27	3.06	37.0
Mean	8.16	3.09	37.9

†60% of per event amounts > 0.2 inch.

Some[†] suggested K_L values

Species	**Common Name**	**K_L**
Berlandiera lyrata	Chocolate flower	0
Buddleia davidii	Butterfly bush	0.3
Centranthus ruber	Jupiter's beard	0.3
Chilopsis linearis	Desert willow	0.1
Fallugia paradoxa	Apache plume	0
Gaillardia aristata	Blanket flower	0.4
Helianthus maximiliani	Maximilian sunflower	0.6
Perovskia atriplicifolia	Russian sage	0.3
Salvia greggii	Cherry sage	0.5
Sporobolis wrightii	Big sacaton	0.2

[†]Complete list available from website: http://farmingtonsc.nmsu.edu

Simplified Equation for Irrigation Scheduling

- Gallons per plant per irrigation

  $I = ET_R \times K_L \times d \times D^2 \times 0.49$

  where;

  I = irrigation volume (gallons)

  ET_R = average daily reference ET (inch)

  K_L = landscape coefficient for species

  d = days since last irrigation

  D = plant diameter (feet)

  0.49 constant (conversion of water depth to volume and plant diameter to area: 0.623 x 0.785)

Reference ET at Farmington and weekly irrigation required per sq. ft. at two K_L levels

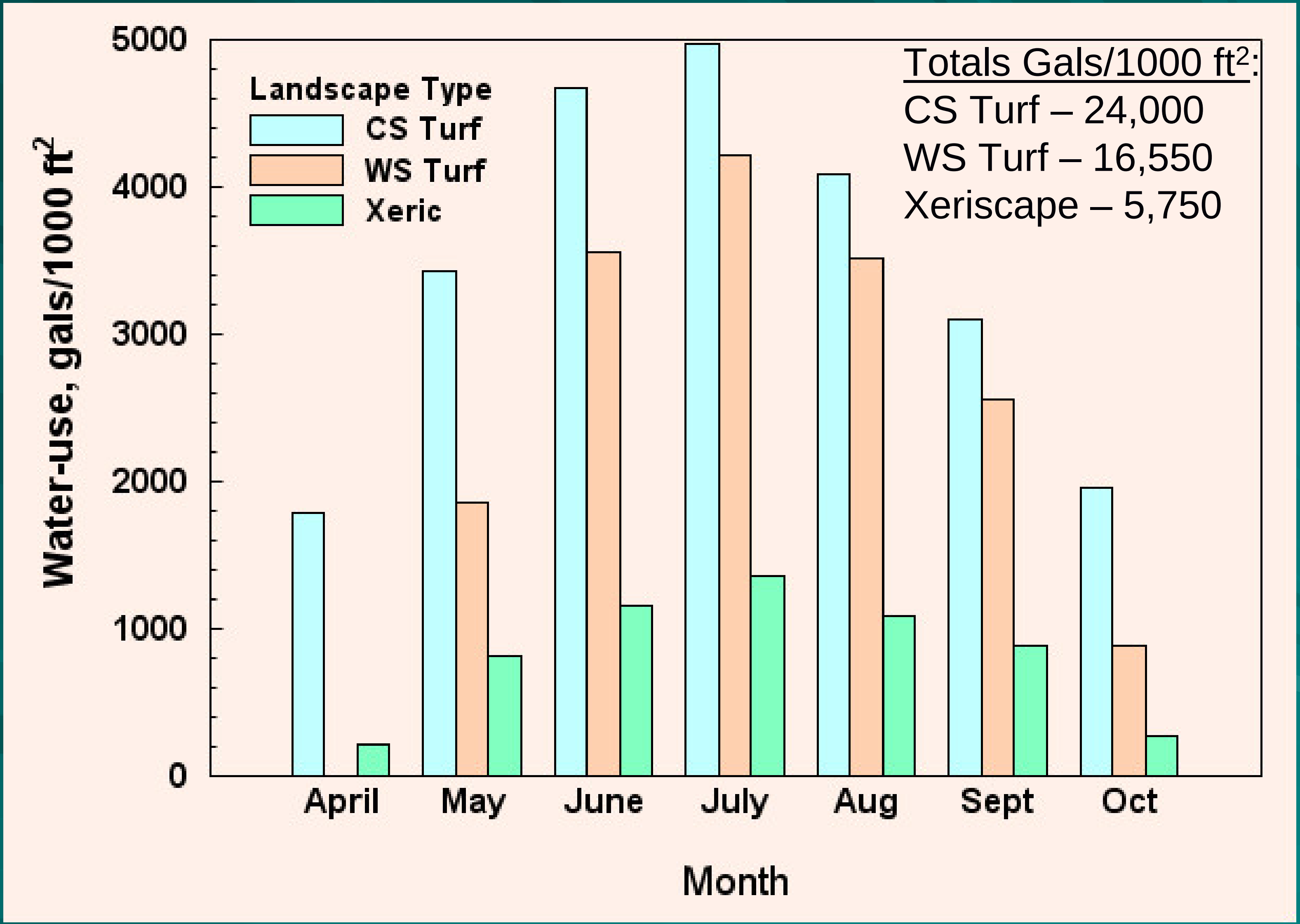
Period	Avg. Daily ET_R	gals/ft²/week at...	
	inch	K_L = 0.2	K_L = 0.5
April 16-30	0.30	0.26	0.65
May 1-15	0.32	0.28	0.70
May 16-31	0.39	0.34	0.85
June	0.41	0.36	0.89
July	0.39	0.34	0.85
August	0.31	0.27	0.68
Sept. 1-15	0.27	0.24	0.59
Sept. 16-30	0.25	0.22	0.55
Oct. 1-15	0.19	0.17	0.41

Adjustments to ET_R

- For precipitation:
  - Subtract $\sum (P_E)$
  - P_E = 0.6 x daily precipitation greater than 0.2 inch
- For microclimate:
  - Decrease by 10 – 20% if in partial shade, north slope, sheltered from wind, mulched, etc.
  - Increase by 10 – 20% if on south slope, close to south side of structure, in isolated, open area, etc.

Water-Use: Xeriscape Compared to Turf

Xeriscape live cover: 25% in April, 40% in May, 50% in June and October, 60% in July – September; K_L = 0.3



Summary

- This demonstration project provided…
  - A valuable exhibit of drought-tolerant species that have potential for western, semi-arid urban landscapes
  - Some valuable insight into the water requirements of xeric adapted species including estimates of baseline K_Ls that can be used for efficient irrigation scheduling

Acknowledgements

- U.S. Bureau of Reclamation
  - Water Conservation Field Services Program
    - Provided seed funding.
- Project Aides, Technicians, etc.
    - Rachel Sawyer
    - Zach Williams
    - Joe Ward
    - Others
- Rainbird

Thank You!

http://farmingtonsc.nmsu,edu
dsmeal@nmsu.edu