Scheduling Irrigations on Turfgrass Using the New Mexico Climate Center

Dan Smeal

Agricultural Science Center at Farmington

Why Schedule Irrigations ?

- The population of New Mexico is rapidly increasing:

  1,000,000 people in 1960
  2,000,000 people in 2005

- Much of this increase has occurred in urban areas:

Population Figures for Some NM Urban Areas: 1980 & 2003

City or State	Population		% Increase
	1980	2003	
Alamogordo	24,024	35,551	48.0
Albuquerque	331,767	471,856	42.2
Farmington	31,222	41,420	32.7
Las Cruces	45,086	76,990	70.8
Rio Rancho	9,985	58,981	490.7
Roswell	39,676	44,228	11.5
Santa Fe	48,953	66,476	35.8
State	**1,302,894**	**1,874,614**	**43.9**

Meanwhile

- Surface water supplies have remained relatively constant at 1,000,000 acre feet and they are fully appropriated.
- Consequently, demand for NM water will soon exceed the available supply.
- Eventually, the amount of water available for non-essential uses (ie. landscape irrigation) will likely be reduced.

Actions now being taken to decrease landscape water-use include…

- Restrictions on outdoor use
  - Albuquerque
  - Santa Fe
- Rate increases
  - Santa Fe
- Incentives (including cash or rebates for elimination of turfgrass)
  - Albuquerque
  - Flagstaff, AZ
  - Las Vegas, NV

Why target turfgrass?

- "The average homeowner uses about 72 gallons annually to water each square foot of grass, according to the BOR [U.S. Bureau of Reclamation]" (quoted from AP article in Farmington Daily Times, August 10, 2005)
  - This is equal to 116 inches (0.62 gallons = 1 inch/sq.ft.)
- Studies in Farmington and elsewhere indicate that less than 25 gallons of water/square foot (40 inches) are required for acceptable quality of cool season turf, while…
- Warm season turf requires less than 17 gals./sq. ft. (28 inches) for acceptable quality.

Implications

- The volume of water used to irrigate landscapes could be reduced by more than 50% with no detriment to turf quality if irrigations are scheduled appropriately…
  - Provided the irrigation system is properly designed and maintained!

Goal of Turf Irrigation

- Provide the minimum amount of supplemental water required to maintain acceptable landscape quality while minimizing water lost through runoff, deep percolation, and excessive evaporation.

Benefits

- Reduced fertilizer use
  - Less loss of N and K through leaching and P through runoff
- Reduced disease and weed problems
- Enhanced environmental quality
  - Reduced use of pesticides
  - Reduced pollution of ground and surface water
- Reduced operating costs
  - Lower water pumping costs, decreased mowing frequency, etc.
- Increased Bottom Line $$$
- Improved public perception

Turf water-use or evapotranspiration (ET) is a function of…

- Weather
  - Solar Radiation
  - Air Temperature
  - Humidity
  - Wind
- Grass type or species
- Grass height or leaf area
- Secondary factors (turf quality, micro-environment, etc.)

Climate-Based Irrigation Scheduling

- Irrigation depths and frequencies are based on estimates of crop ET using daily weather data (reference or potential ET), correction factors (crop coefficients) to account for plant type, growth stage, irrigation efficiencies, and soil characteristics.

Data availability for estimating turf ET

- Weather data for calculation of reference ET (ETo) or potential ET (PET) are available from a number of weather stations throughout the state.
  - These data are available from the New Mexico Climate Center web-site:

    http://weather.nmsu.edu
- Crop coefficients (Kc) have been formulated for various turfgrasses through research at the Farmington Agricultural Science Center.
- These Kcs, with local calibration, can be used to estimate the water-use (ET) of cool season and warm season turfgrasses throughout New Mexico.

Purpose

- The following slides serve as a guide on how to obtain locally-calibrated estimates of turfgrass water-use (ET) from the New Mexico Climate Center web-site: http://weather.nmsu.edu.
- These estimates, along with knowledge of local soil conditions and irrigation system efficiencies, can be used to schedule irrigations on turfgrass.
- Refer to appendices at the end of the guide for more detailed information.

Step 1

- Enter http://weather.nmsu.edu in web browser.
- Follow directions shown in next several slides…

NMCC Home Page
http://weather.nmsu.edu

new mexico climate center

About Us Contact Us Search

NMCC Climate Station Data ← **Click Here !**

Other NM Climate Station Data

Crop Information

Water Resources

Climate Links

Agricultural Models and Tools

CoCoRaHS
(Community Collaborative Rain, Hail, and Snow Network)




If you cannot find certain data or need help, e-mail webmaster@weather.nmsu.edu. For a mirror of this website, go to weather2.nmsu.edu. For a complete list of all web pages click here.

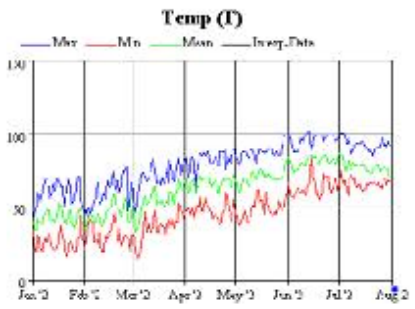
weather.nmsu.edu Statistics

Climate Data Retrieval Page

New Mexico Climate Center

Climate Data Retrieval Pages

Climate Data Graphs



Daily Hourly

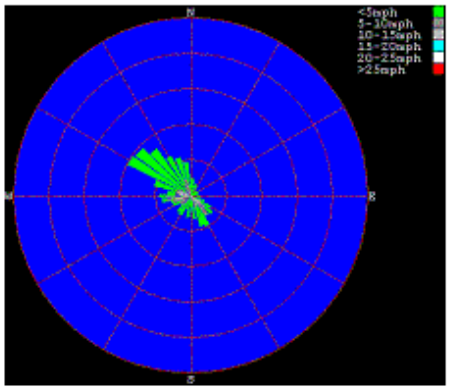
Climate Data Printouts

Report for station Las Cruces
Beginning Date: 01/01/2002
Ending Date: 04/15/2002

Date	Max Temp	Min Temp	Mean Temp	Max
MM/DD/YY	F	F	F	
01/01/02	49.740	34.310	36.234	
01/02/02	48.680	24.620	35.079	
01/03/02	52.290	16.720	31.837	
01/04/02	60.000	31.130	43.339	
01/05/02	54.020	23.290	38.278	
01/06/02	60.340	19.790	38.663	
01/07/02	64.650	24.780	43.870	
01/08/02	69.380	26.830	46.073	
01/09/02	70.700	25.950	46.433	
01/10/02	68.210	33.460	50.455	
01/11/02	55.820	28.950	42.318	
01/12/02	58.770	23.710	40.688	
01/13/02	66.230	22.030	42.301	

Daily Hourly
Raw Daily Raw Hourly

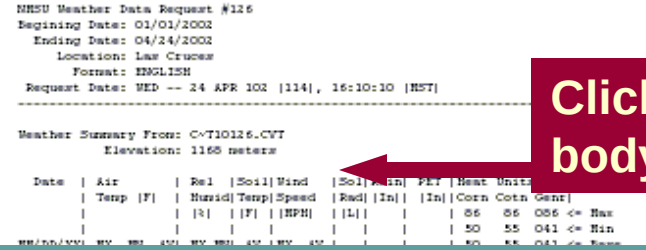
Wind Direction/Speed Graphs



Click Here

Data Interpolation Method

Irrigation Management and GDD Climate Data Retrieval System

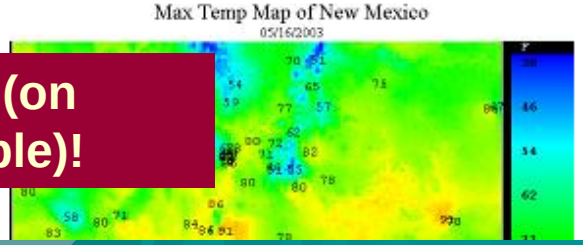


NMSU Weather Data Request #126
Beginning Date: 01/01/2002
Ending Date: 04/24/2002
Location: Las Cruces
Format: ENGLISH
Request Date: WED -- 24 APR 102 |114|, 16:10:10 |MST|

Weather Summary From: C:\T10126.CWT
Elevation: 1166 meters

Date	Air Temp (F)	Rel Humid (%)	Soil Temp (F)	Wind Speed (MPH)	Soil Rad (L)	Precip (In)	PET (In)	Heat Units Corn	Heat Units Cotn	Heat Units Gent	
								86	86	086	<= Max
								50	55	041	<= Min

New Mexico Map of Selected Climate Elements

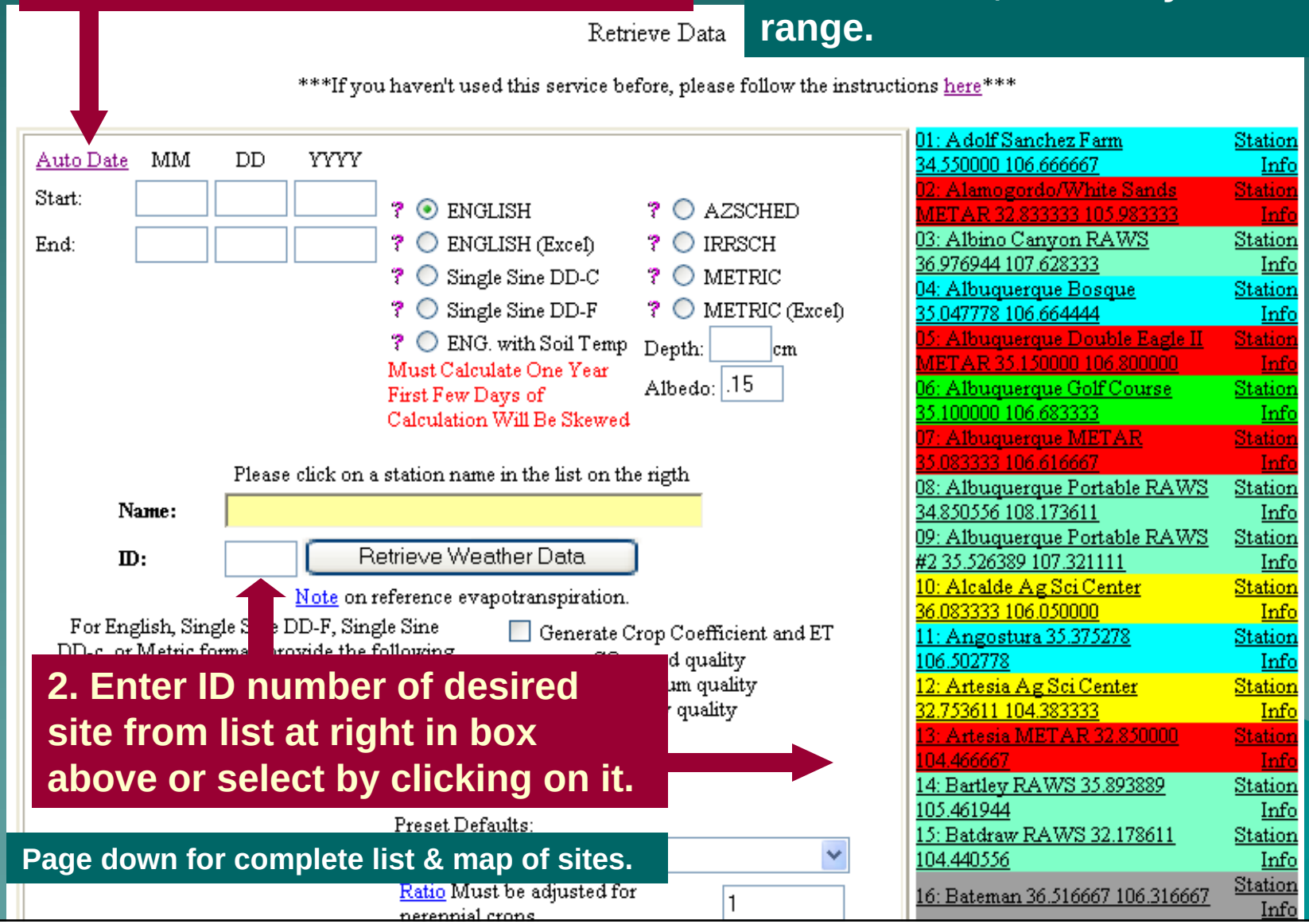


Click Here (on body of table)!

Retrieve Data Page

1. For irrigation scheduling, click on 'AutoDate'

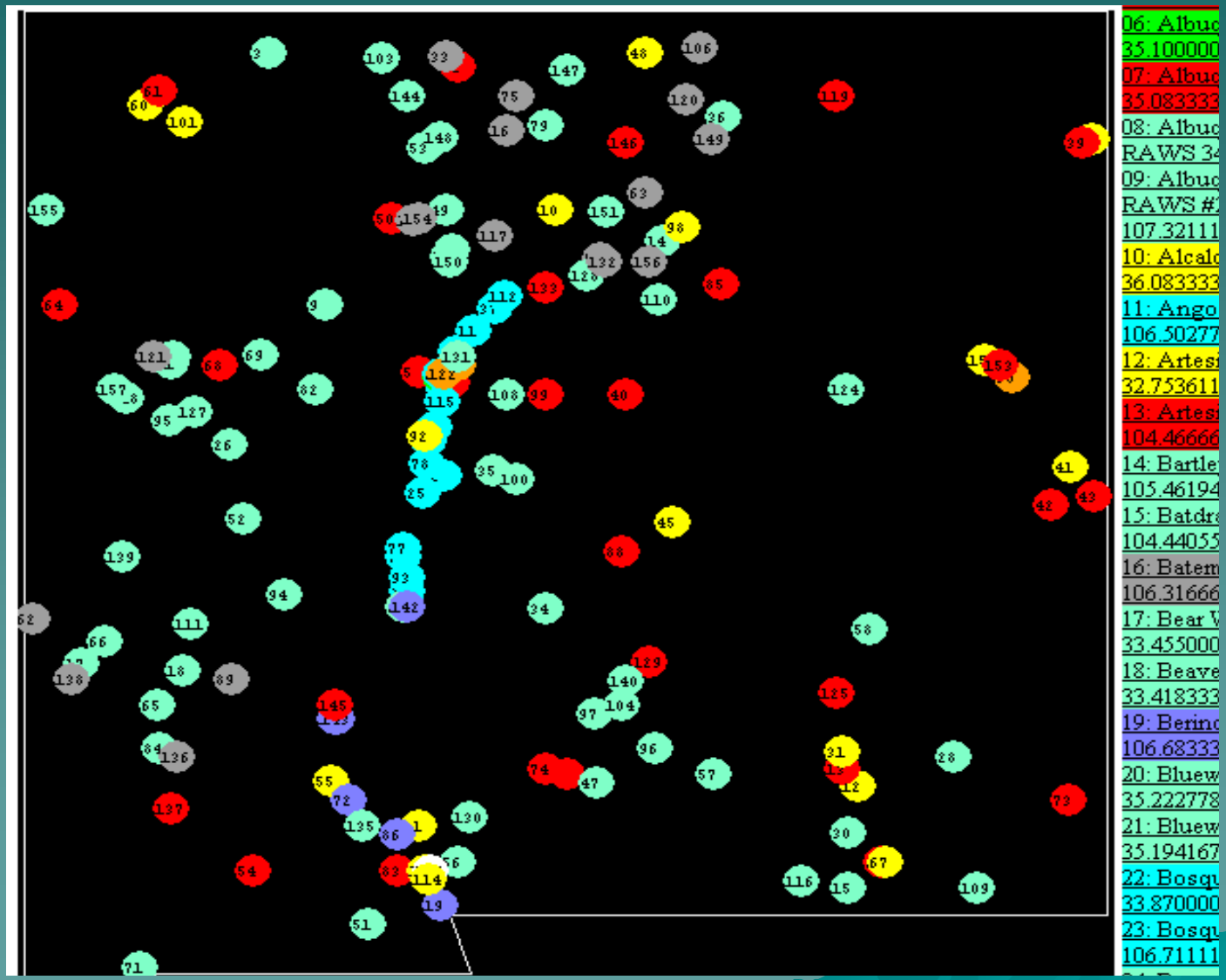
Note: If you just want to view weather data, enter any date range.



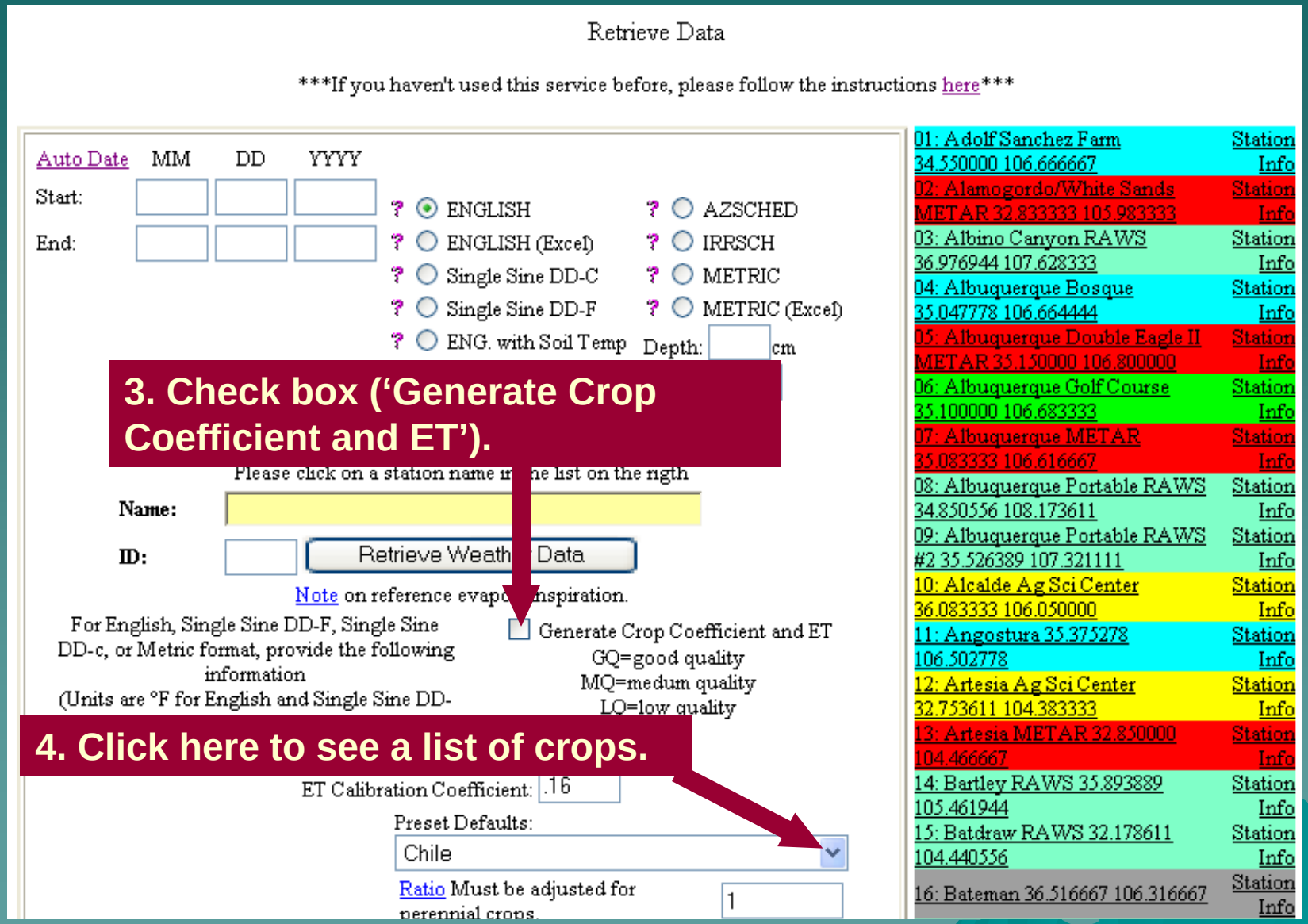
2. Enter ID number of desired site from list at right in box above or select by clicking on it.

Page down for complete list & map of sites.

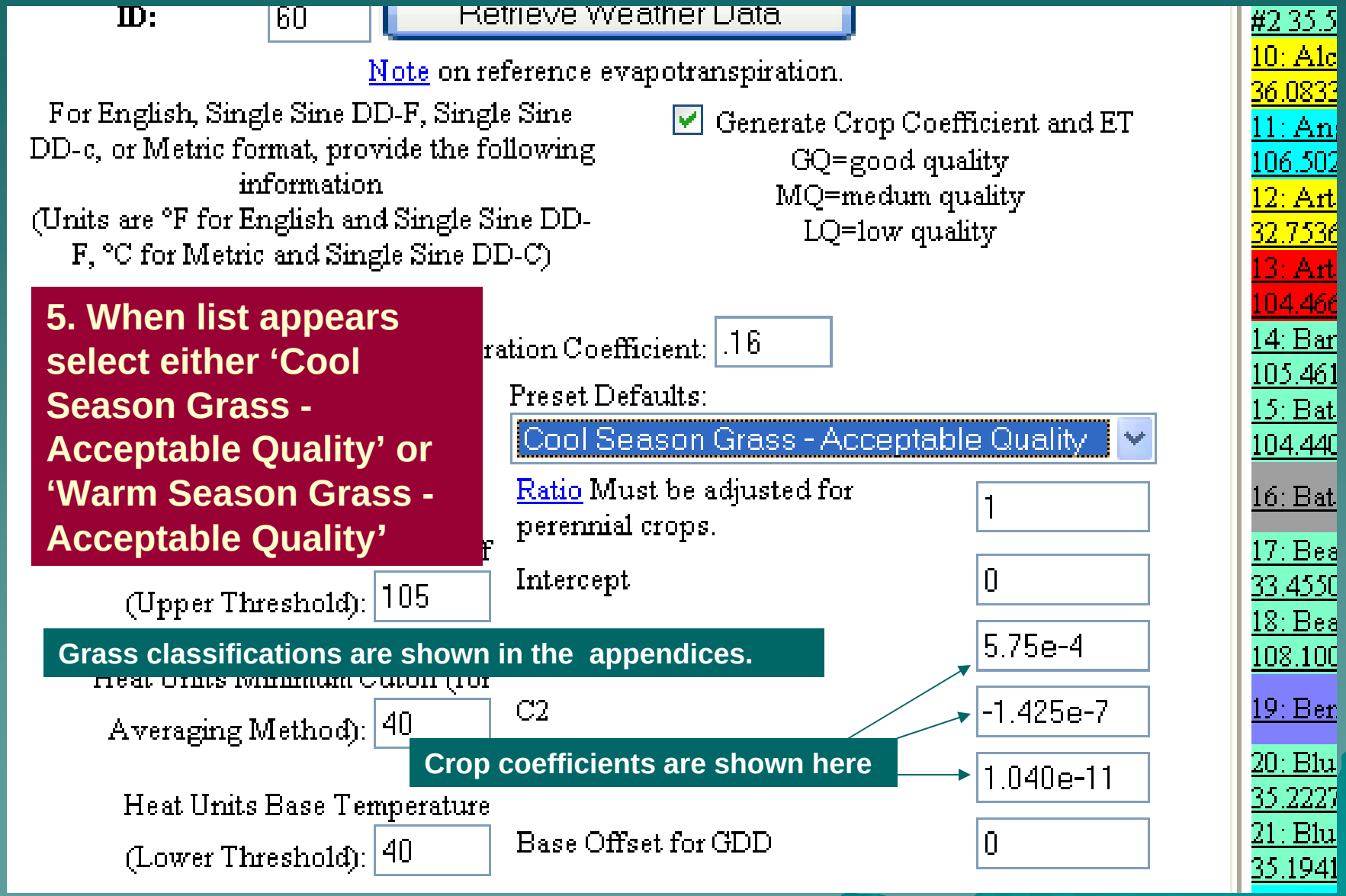
Map of Weather Stations Linked to NMCC



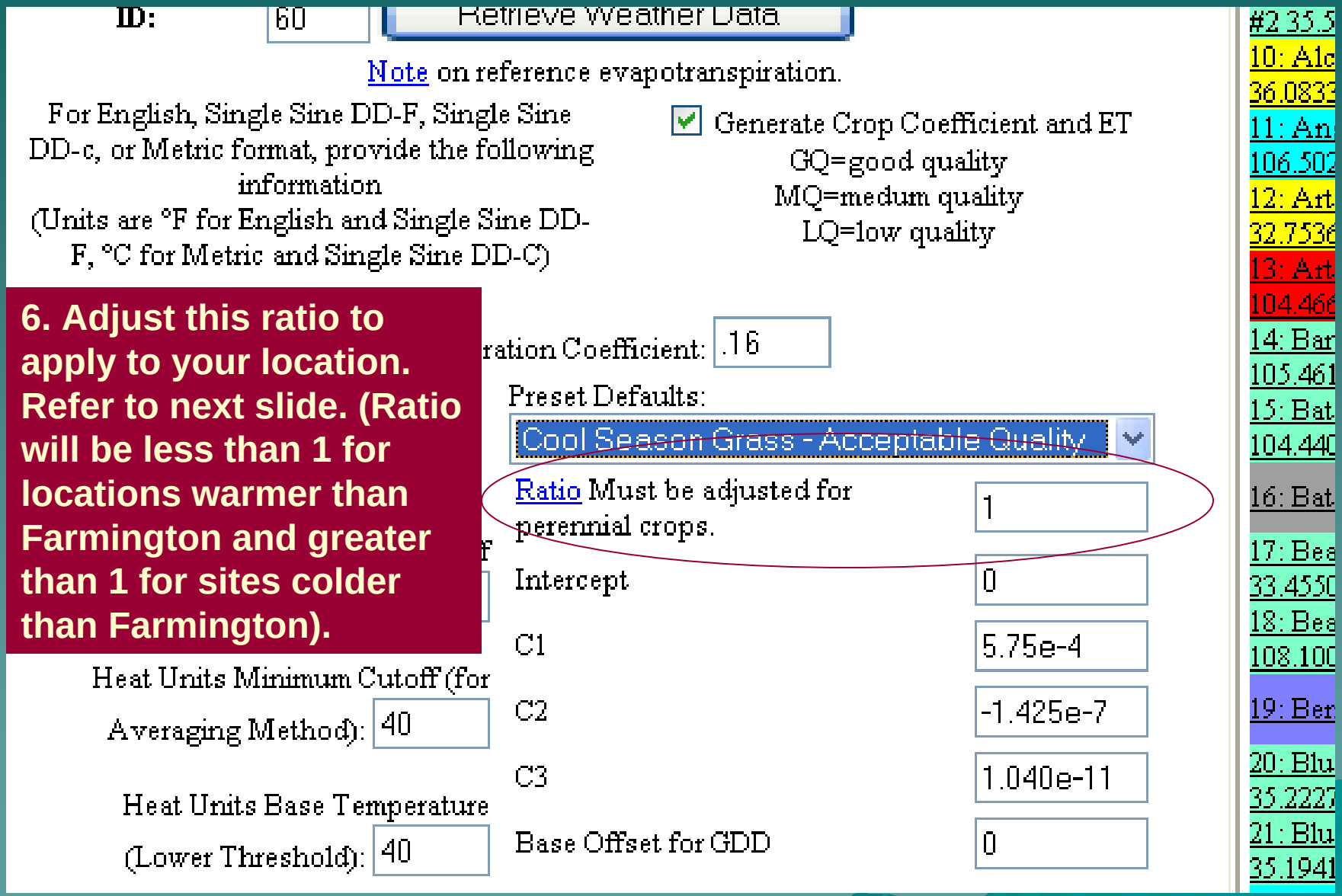
Retrieve Data Page



Obtaining ET Data for Turf



Obtaining ET Data for Turf

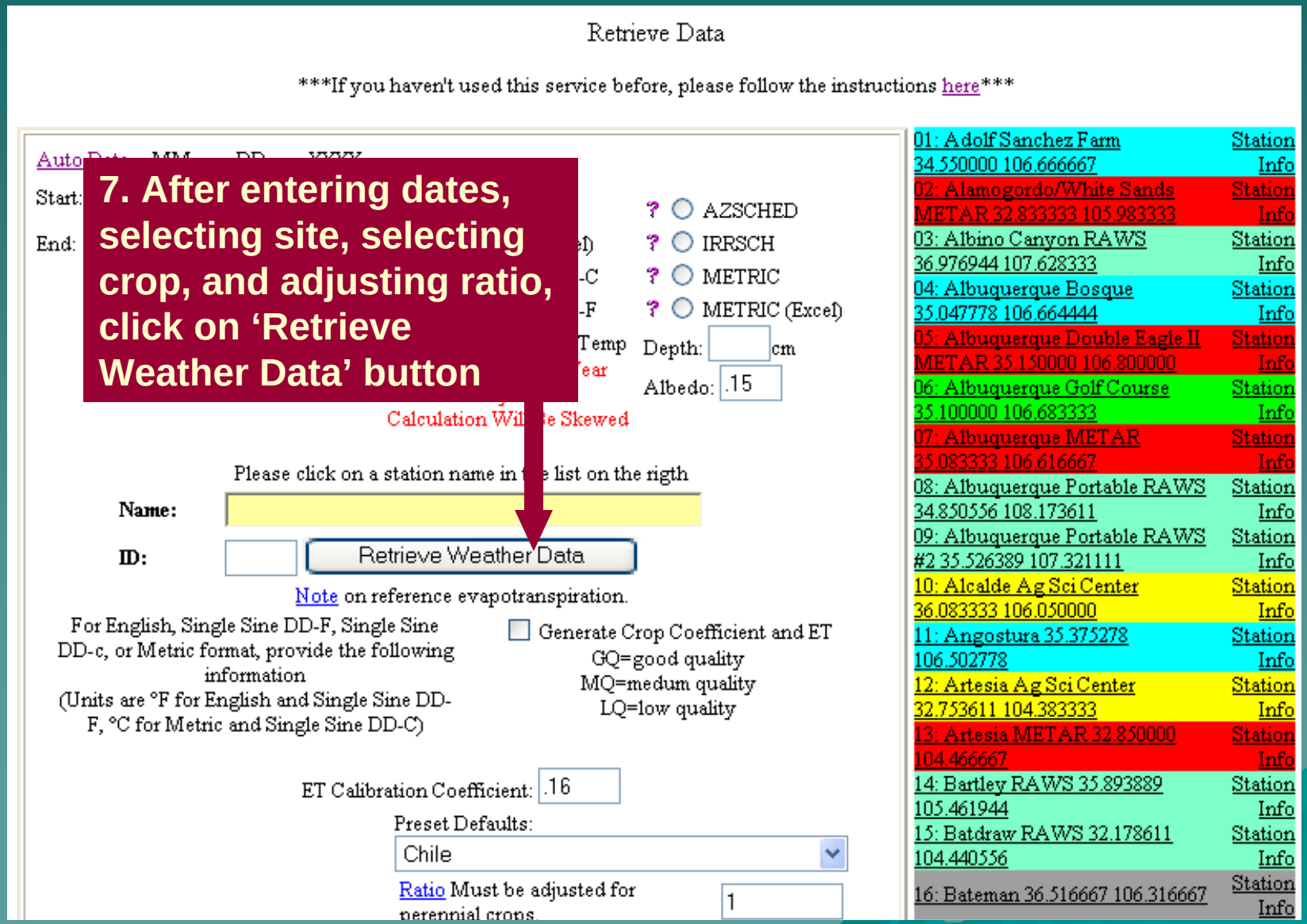


6. Adjust this ratio to apply to your location. Refer to next slide. (Ratio will be less than 1 for locations warmer than Farmington and greater than 1 for sites colder than Farmington).

Ratio Adjustments for Sites

City	Cool Turf	WarmTurf
Clayton, Farmington, Bloomfield, Aztec	1.0	1.0
Albuquerque	0.85	0.75
Artesia, Deming, Las Cruces, Roswell, Alamogordo	0.70	0.60
Clovis, Portales	0.80	0.80
Carlsbad, Hobbs	0.65	0.5
Tucumcari	0.75	0.65
Santa Fe, Gallup, Grants, Las Vegas, Ruidoso	1.20	1.60

Retrieve Data Page



Data File Example (pg. 1)

NMSU Weather Data
Beginning Date: 01/01/2005
Ending Date: 12/31/2005
Location: Farmington Ag Sci Center
Format: ENG
Ratio: 1
Base GDD: 0
X Interept: 0
Coefficients: 5.75e-4, -1.425e-7, 1.040e-11

Elevation: 1700.0[illegible]

Check dates, site, and ratio for accuracy

Note: Crop can be verified by checking coefficients.

Check for completeness and accuracy of temperature data. For irrigation scheduling, temp. data must begin on 1/1.

Date	Air Temp (F)			Rel Humid (%)		Soil Temp (F)	Wind Speed (MPH)	Solar Rad (L)	Rain (In)	PET (In)	Samani PET (In)	GDD		KC	ET (In)		P-M ET (Short Ref.) in	P-M ET (Tall Ref.) in
MM/DD/YY	Max	Min	Avg	Max	Min	Avg	Mx Avg	Tot				Day	Cum		Day	Cum		
01/01/05	050	027	038	083	035	037	15 4.9	218.9	0.00	0.08	0.12	5.3	5.3	0.0030	0.0002	0.0002	0.08	0.11
01/02/05	047	029	037	092	038	036	17 7.9	121.0	0.04	0.06	0.10	3.5	8.8	0.0051	0.0003	0.0005	0.07	0.10
01/03/05	044	034	038	094	078	038	24 5.6	110.1	0.10	0.02	0.08	2.2	11.0	0.0063	0.0001	0.0007	0.04	0.05
01/04/05	049	030	040	094	046	039	27 11.1	135.2	0.15	0.07	0.11	4.9	15.9	0.0091	0.0006	0.0013	0.08	0.12
01/05/05	037	028	032	090	055	038	22 7.9	158.9	0.01	0.05	0.06	0.0	15.9	0.0091	0.0004	0.0017	0.05	0.07
01/06/05	036	021	030	089	039	037	09 4.0	121.9	0.01	0.03	0.07	0.0	15.9	0.0091	0.0003	0.0020	0.05	0.06
01/07/05	036	017	027	094	046	036	13 5.7	192.0	0.00	0.05	0.07	0.0	15.9	0.0091	0.0004	0.0024	0.05	0.07
01/08/05	043	028	034	095	064	036	14 7.2	74.6	0.07	0.02	0.09	1.6	17.5	0.0100	0.0002	0.0027	0.05	0.06
01/09/05	048	037	042	086	056	038	16 7.7	127.2	0.00	0.05	0.09	4.4	21.9	0.0125	0.0006	0.0033	0.07	0.09
01/10/05	056	038	044	095	044	040	15 6.2	144.0	0.20	0.06	0.12	8.2	30.1	0.0172	0.0011	0.0043	0.08	0.11
01/11/05	051	031	043	097	048	041	31 10.1	86.7	0.09	0.05	0.12	5.7	35.8	0.0204	0.0010	0.0054	0.07	0.11

Data File Example (pg. 2)

NMSU Weather Data
Beginning Date: 01/01/2005
Ending Date: 12/31/2005
Location: Farmingtor
Format: ENG
Ratio: 1
Base GDD: 0
X Interept: 0
Coefficients: 5.75e-4, -1.423e-7, 1.040e-11

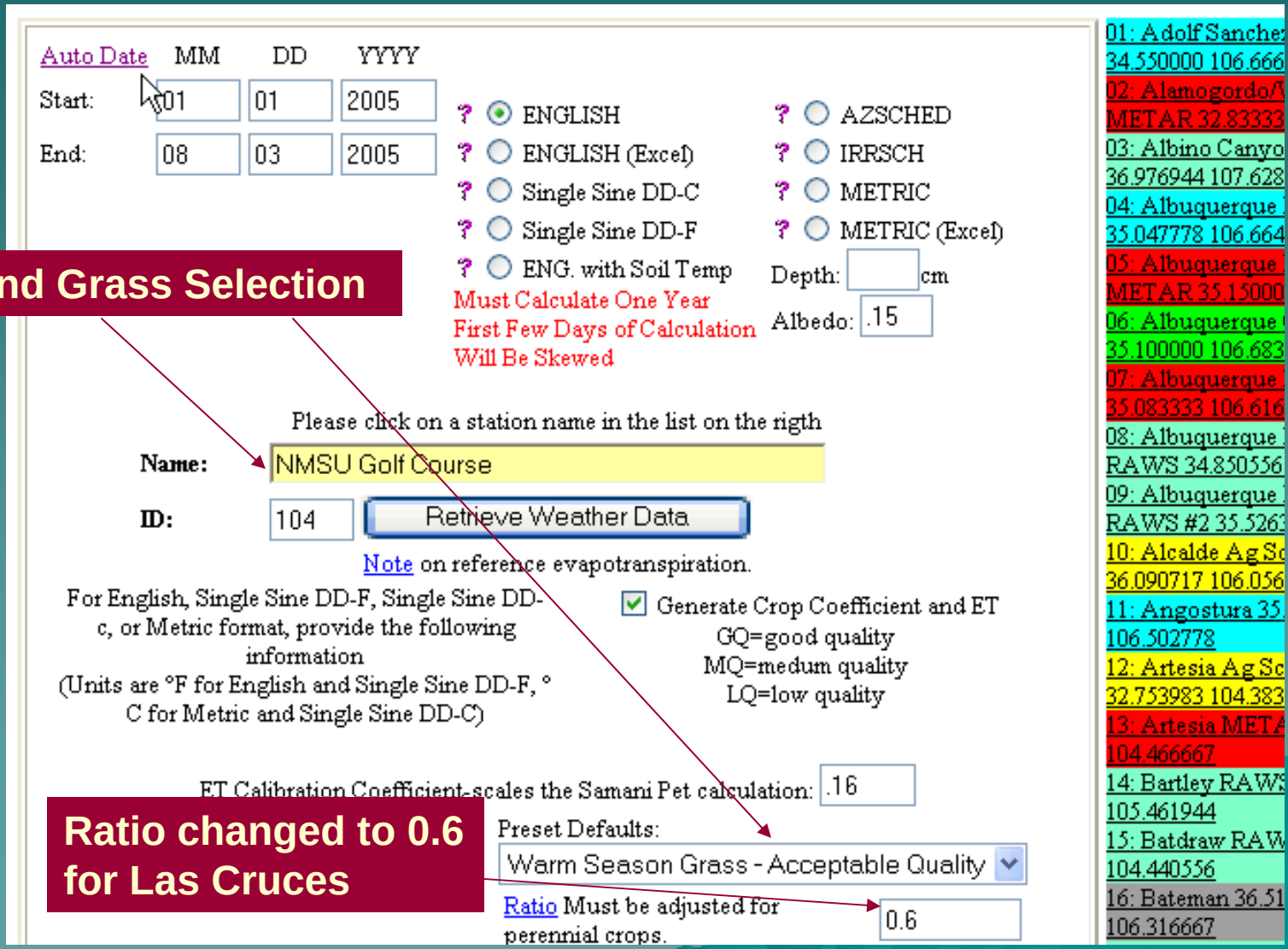
Elevation: 1700.000000 m

If air temperature, humidity, wind speed, and solar radiation data appear to be complete and accurate for dates of interest…

…then estimated daily and cumulative ET is shown here!

Date	Air Temp (F)			Rel Humid (%)		Soil Temp (F)	Wind Speed (MPH)		Solar Rad (L)	Rain (In)	PET (In)	Samani PET (In)	GDD		KC	ET (In)		P-M ET (Short Ref.) in	P-M ET (Tall Ref.) in
MM/DD/YY	Max	Min	Avg	Max	Min	Avg	Mx	Avg	Tot				Day	Cum		Day	Cum		
01/01/05	050	027	038	083	035	037	15	4.9	218.9	0.00	0.08	0.12	5.3	5.3	0.0030	0.0002	0.0002	0.08	0.11
01/02/05	047	029	037	092	038	036	17	7.9	121.0	0.04	0.06	0.10	3.5	8.8	0.0051	0.0003	0.0005	0.07	0.10
01/03/05	044	034	038	094	078	038	24	5.6	110.1	0.10	0.02	0.08	2.2	11.0	0.0063	0.0001	0.0007	0.04	0.05
01/04/05	049	030	040	094	046	039	27	11.1	135.2	0.15	0.07	0.11	4.9	15.9	0.0091	0.0006	0.0013	0.08	0.12
01/05/05	037	028	032	090	055	038	22	7.9	158.9	0.01	0.05	0.06	0.0	15.9	0.0091	0.0004	0.0017	0.05	0.07
01/06/05	036	021	030	089	039	037	09	4.0	121.9	0.01	0.03	0.07	0.0	15.9	0.0091	0.0003	0.0020	0.05	0.06
01/07/05	036	017	027	094	046	036	13	5.7	192.0	0.00	0.05	0.07	0.0	15.9	0.0091	0.0004	0.0024	0.05	0.07
01/08/05	043	028	034	095	064	036	14	7.2	74.6	0.07	0.02	0.09	1.6	17.5	0.0100	0.0002	0.0027	0.05	0.06
01/09/05	048	037	042	086	056	038	16	7.7	127.2	0.00	0.05	0.09	4.4	21.9	0.0125	0.0006	0.0033	0.07	0.09
01/10/05	056	038	044	095	044	040	15	6.2	144.0	0.20	0.06	0.12	8.2	30.1	0.0172	0.0011	0.0043	0.08	0.11
01/11/05	051	031	043	097	048	041	31	10.1	86.7	0.09	0.05	0.12	5.7	35.8	0.0204	0.0010	0.0054	0.07	0.11

Another Example: Warm Season Turf ET in Las Cruces, NM in 2005 (data input)



Site and Grass Selection

Ratio changed to 0.6 for Las Cruces

Another Example: Warm Season Turf ET in Las Cruces, NM in 2005 (data output)

```
NMSU Weather Data
Beginning Date: 01/01/2005
   Ending Date: 08/03/2005
      Location: NMSU Golf Course
        Format: ENG
         Ratio: 0.6
      Base GDD: 0
    X Interept: 0
  Coefficients: 0.00127, -8.399e-7, 1.614e-10
-----------------------------------------------

Elevation: 1265.000000 m
```

Input information check? - OK

Data check? - OK

Warm season turf ET estimate

Date	Air Temp (F)			Rel Humid (%)		Soil Temp (F)	Wind Speed (MPH)	Solar Rad (L)	Rain (In)	PET (In)	Samani PET (In)	GDD		KC	ET (In)		P-M ET (Short Ref.)	P-M ET (Tall Ref.)
MM/DD/YY	Max	Min	Avg	Max	Min	Avg	Mx Avg	Tot				Day	Cum		Day	Cum	in	in
06/11/05	091	054	074	046	010	000	18 6.4	783.0	0.00	0.43	0.26	15.7	1072.9	0.5126	0.2195	10.137	0.30	0.42
06/12/05	089	063	076	039	015	000	16 7.7	778.2	0.00	0.44	0.23	16.6	1089.5	0.5164	0.2259	10.363	0.32	0.46
06/13/05	094	056	076	053	011	000	09 3.7	781.5	0.00	0.39	0.28	17.2	1106.7	0.5202	0.2049	10.568	0.26	0.34
06/14/05	100	060	081	037	008	000	17 7.3	784.1	0.00	0.49	0.30	20.8	1127.5	0.5247	0.2552	10.823	0.35	0.51
06/15/05	100	075	086	033	010	000	21 12.5	720.6	0.00	0.55	0.27	28.0	1155.5	0.5306	0.2908	11.114	0.46	0.70
06/16/05	102	066	086	056	008	000	16 6.7	728.1	0.00	0.45	0.30	24.2	1179.6	0.5354	0.2398	11.354	0.34	0.48
06/17/05	098	060	080	037	008	000	27 8.8	797.5	0.00	0.51	0.29	19.2	1198.8	0.5390	0.2734	11.627	0.38	0.55
06/18/05	098	057	078	031	007	000	25 8.3	794.9	0.00	0.50	0.30	19.1	1217.8	0.5425	0.2736	11.901	0.37	0.54
06/19/05	102	059	081	031	007	000	14 4.5	764.0	0.00	0.44	0.32	21.1	1238.9	0.5463	0.2390	12.140	0.29	0.40
06/20/05	103	064	084	055	010	000	30 10.6	641.0	0.00	0.48	0.31	23.8	1262.7	0.5503	0.2637	12.403	0.40	0.60
06/21/05	096	073	085	046	013	000	20 13.9	747.8	0.00	0.54	0.24	25.3	1288.0	0.5543	0.2994	12.703	0.45	0.67
06/22/05	095	064	083	049	010	000	15 9.2	778.7	0.00	0.49	0.27	20.4	1308.4	0.5575	0.2704	12.973	0.37	0.53
06/23/05	098	065	084	044	009	000	17 8.4	778.7	0.00	0.49	0.29	22.2	1330.6	0.5607	0.2751	13.248	0.37	0.54
										0.42	0.30	21.2	1351.8	0.5637	0.2383	13.486	0.29	0.40
										0.35	0.28	22.0	1373.8	0.5666	0.1998	13.686	0.27	0.38
										0.47	0.26	27.3	1401.2	0.5700	0.2680	13.954	0.38	0.56

Note: Data set began on January 1 but only a small subset is shown !

Notes

- If temperature data are incomplete or inaccurate at your location, refer to the map and enter a site near you that has reasonably similar climatic conditions.
- If humidity, wind, and/or solar radiation data are missing, ET estimates, based on temperature data only, may still be provided but they will not be as accurate as when all data are available.

Using ET to Schedule Irrigations

- Irrigations should be scheduled to replace total ET for a given time period.
- For example, referring to page 27 (column 17) warm season turf ET between June 11 and June 13 in Las Cruces totaled 0.65 inch (0.2195+0.2259+0.2049).
- Assuming 100% irrigation efficiency*, the irrigation requirement (IR) would be 0.65 inch and the system should be run until 0.65 inch of water is applied to the turf.
  - *Refer to next 2 slides.

Corrections to ET

- The ET estimates provided by this technique serve as a baseline only.
- Many micro-climatic factors (shading, slope, reflected radiation, wind screens, etc.) can cause actual ET to be higher or lower than the estimate.
- Variability can be detected by using a soil-sampling probe or other steel rod to evaluate soil moisture in these areas.

Corrections to Irrigation Requirement (IR)

- Generally, sprinkler system water application efficiencies are less than 100%.
- To compensate and avoid dry spots in the lawn, the IR must be increased above ET.
- For example: assuming an irrigation efficiency of 80% (0.80), the IR for an ET of 0.65 inch would be 0.81 inch (0.65/0.80)
- Refer to the appendices for more detailed information including links on how to determine irrigation system output (slide 65).

Appendices

- Appendix 1: Terminology
- Appendix 2: Farmington Turfgrass Irrigation Study - Summary.
- Appendix 3: Additional Information and Links

Appendix 1

- Terminology
  - Evapotranspiration (ET)
  - Crop (or Turf) ET (ET_C)
  - Reference (or Potential) ET (ET_O or PET)
  - Crop Coefficient (K_C)
  - Growing Degree-Days (GDD)
  - Irrigation Efficiency (IE)
  - Irrigation Requirement (IR)

Evapotranspiration

- Crop Water-Use or Consumptive-Use
- Consists of two components:
  - Evaporation – loss of water from plant and soil surfaces directly to the atmosphere (not usually beneficial to plant growth)
  - Transpiration – loss of water from the soil through plant tissues (roots, stems, leaves) into the atmosphere through leaf pores (stomates)

Reference or Potential ET (ET_o or PET)

- ET is directly related to atmospheric conditions (temperature, humidity, wind, solar radiation).
- Using healthy, fully transpiring reference crops (4" tall grass, 10" tall alfalfa, etc.), scientists have developed empirical relationships between weather and ET.
- ET_O is a mathematically calculated water volume using only these parameters.
  - Along with appropriate correction factors, it can be used to estimate actual crop ET (ET_C).

Example of one method used to compute ETo (PET)

The Penman-Monteith form of the combination equation is:

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \dfrac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \dfrac{r_s}{r_a}\right)} \quad (3)$$

where R_n is the net radiation, G is the soil heat flux, $(e_s - e_a)$ represents the vapour pressure deficit of the air, ρ_a is the mean air density at constant pressure, c_p is the specific heat of the air, Δ represents the slope of the saturation vapour pressure temperature relationship, γ is the psychrometric constant, and r_s and r_a are the (bulk) surface and aerodynamic resistances. The parameters of the equation are defined in Chapter 3.

For practical irrigation scheduling, the above parameters are extrapolated from daily measurements of air temperature, relative humidity, wind speed, and incoming solar radiation

Factors (other than weather) that affect actual turfgrass ET

- Growth Factors
  - Turfgrass Type (Cool season vs. Warm season), Species (KBG vs. Fescue), Variety (Adelphi vs. Coventry)
  - Height or leaf area
  - Plant health (soil fertility, disease, pests, etc.)
- Environmental factors
  - Soil moisture
  - Irrigation frequency
  - Microclimatic conditions
    - **Slope, shading, reflected radiation, etc.**

Crop coefficient (K_C)

- A correction factor to account for differences between ET_O and actual crop ET (ET_C).
- If you know the reference ET (ET_O) and the crop-coefficient (K_C), you can calculate the crop ET (ET_C)

  *$ET_C = ET_O \times K_C$

Example

- In turf, summer K_C values of about 0.8 (80%) for cool season grass and 0.6 (60%) for warm season grass are common.
- So, if daily PET equals 0.32 inches:
  - Kentucky bluegrass ET = 0.26 in.
    - (0.8 x 0.32) = 0.26
  - Bermudagrass ET = 0.19 in.
    - (0.6 x 0.32) = 0.19

Growing Degree-Days (GDD)

- Since plant development depends on temperature, GDD (or heat units) are used (rather than calendar days) to more accurately define growth stages of crops (ie. spring dormancy break, maturity, growth rate, initiation of winter dormancy, etc.)

- Cool Season Turf Calculation
  - GDD = (Tmax + Tmin)/2 – 40 ^{O}F
    – (between 40 and 105 ^{O}F)
  - Optimum growth temperatures: 60 – 75 ^{O}F

- Warm Season Turf Calculation
  - GDD = (Tmax + Tmin)/2 – 60 ^{O}F
    – (above 60 ^{O}F)
  - Optimum temperatures: 80 – 95 ^{O}F

Irrigation Efficiency (IE)

- IE refers to the percentage of applied irrigation water that actually contributes to plant growth and transpiration.
- Water lost through runoff, deep percolation below the root zone, or excessive evaporation represents a decrease in efficiency.
  - Examples:
    - Water is applied uniformly and it is all transpired through the desired crop: IE = 100%.
    - Application uniformity is poor and 30% of water applied is lost to deep drainage below the root zone: IE = 70% (100% - 30%).

Irrigation Requirement (IR)

- IR is the amount of water that must be applied to satisfy ET.
- If irrigation efficiency is high (ie. irrigation uniformity is good and water losses are minimal) then IR will be nearly equal to ET.
- If application uniformity is low and dry spots are evident, then IR will be greater than ET.
  - This will result in over-irrigation of some areas.

Appendix 2

- The Farmington Turfgrass Irrigation Study (1998-2000 & 2003-2005)
  - Purpose
    - Evaluate the water requirements (ET) of several turfgrasses
    - Develop crop coefficients (K_C) for use in irrigation scheduling of these grasses
      - K_C = ET/PET

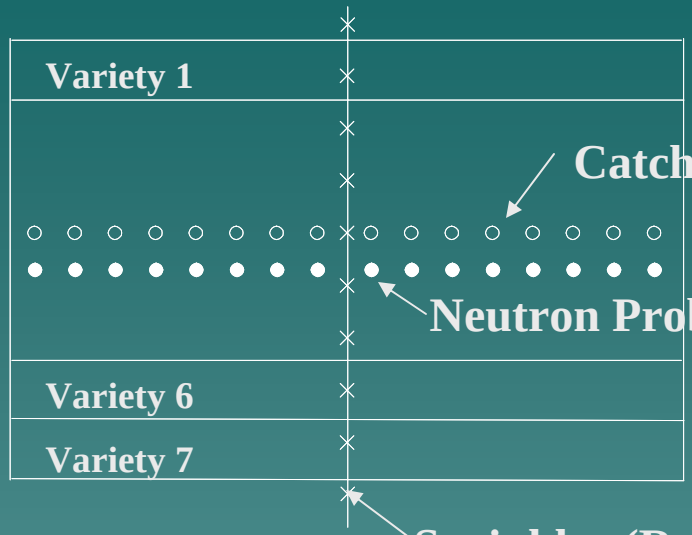
Site Description

- NMSU's Agricultural Science Center at Farmington (about 8 mi. SW of city on Navajo Indian Irrigation Project)
- Elevation: 5640 feet
- Mean Annual Precipitation: 8.2 in.
- Soil Type: Kinnear very fine sandy loam

Materials and Methods

- A single line-source design (refer to next slide) was used to provide irrigation treatments to various turfgrass varieties.
- Applied water (using catch cans) was measured after each irrigation.
- Changes in soil moisture were measured throughout the growing season.
- The grasses were rated for acceptable quality at all irrigation levels.

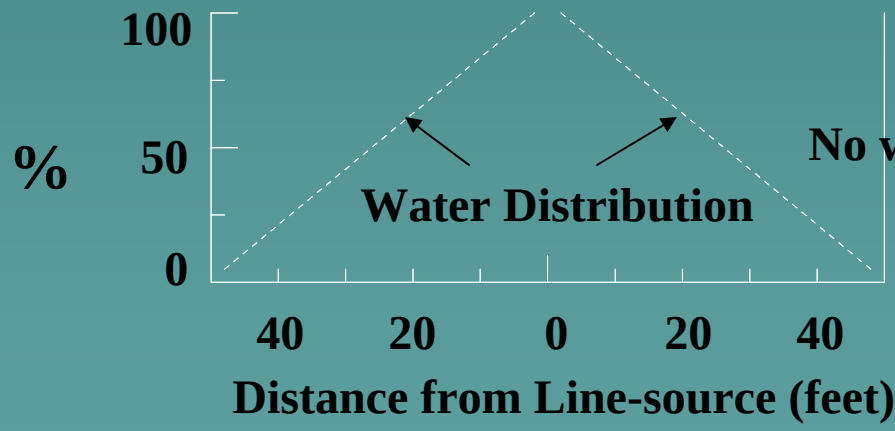
Sprinkler line-source (SLS) Design (Hanks, 1976)



Catch cans (applied water)

Neutron Probe Access Tubes (soil moisture)

Sprinkler (Rainbird 30H, 3/16 x 3/32 in. nozzles) – 20 ft. spacing, 45-50 psi.



No wind conditions

The soil water balance method was used to define ET for each grass at each irrigation level.

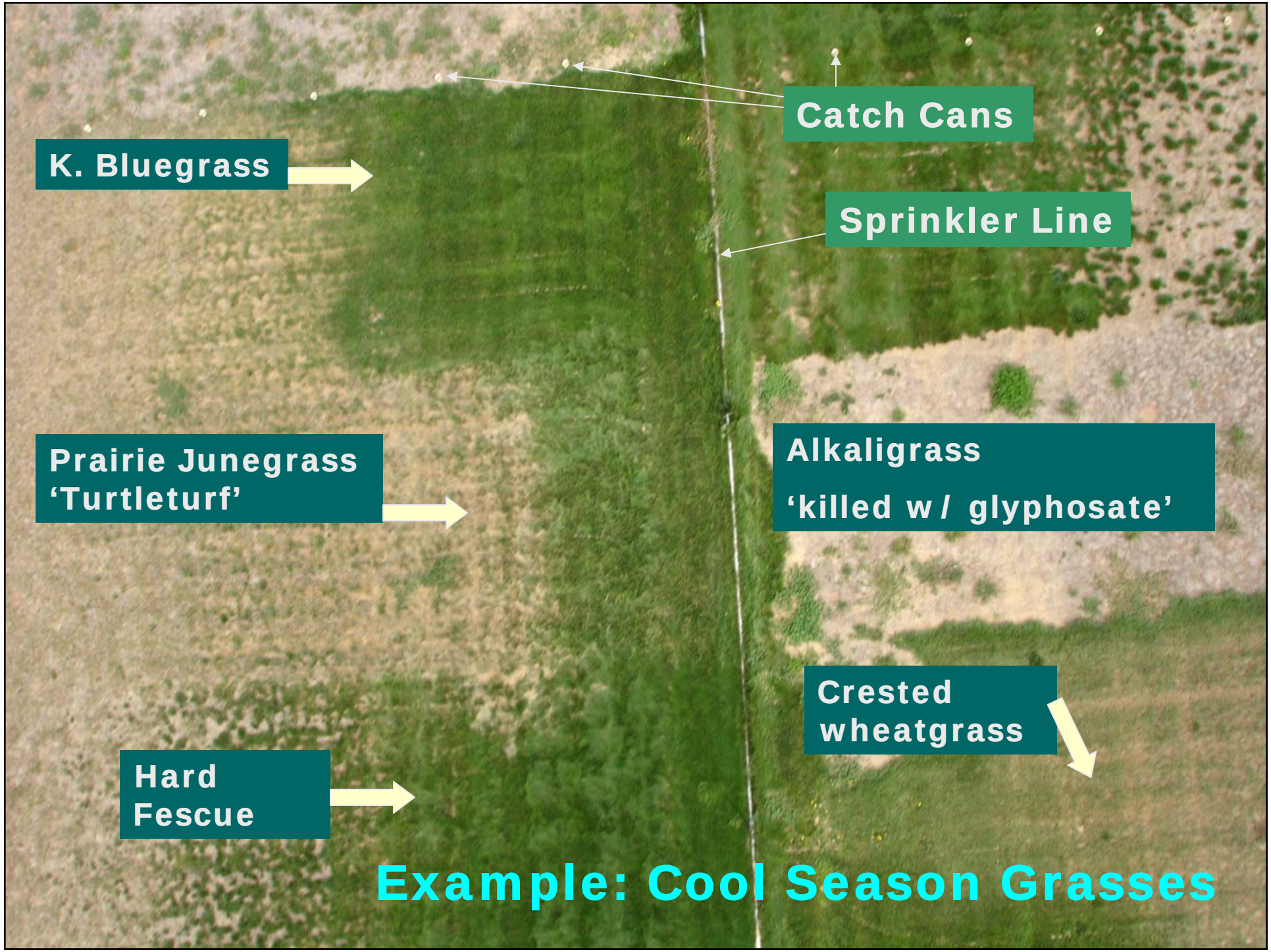
- ET = I + P +/- ΔSW – D, where;
  - I = irrigation (in.)
  - P = precipitation (in.)
  - ΔSW = change in soil water (in.)
  - D = deep drainage (in.)

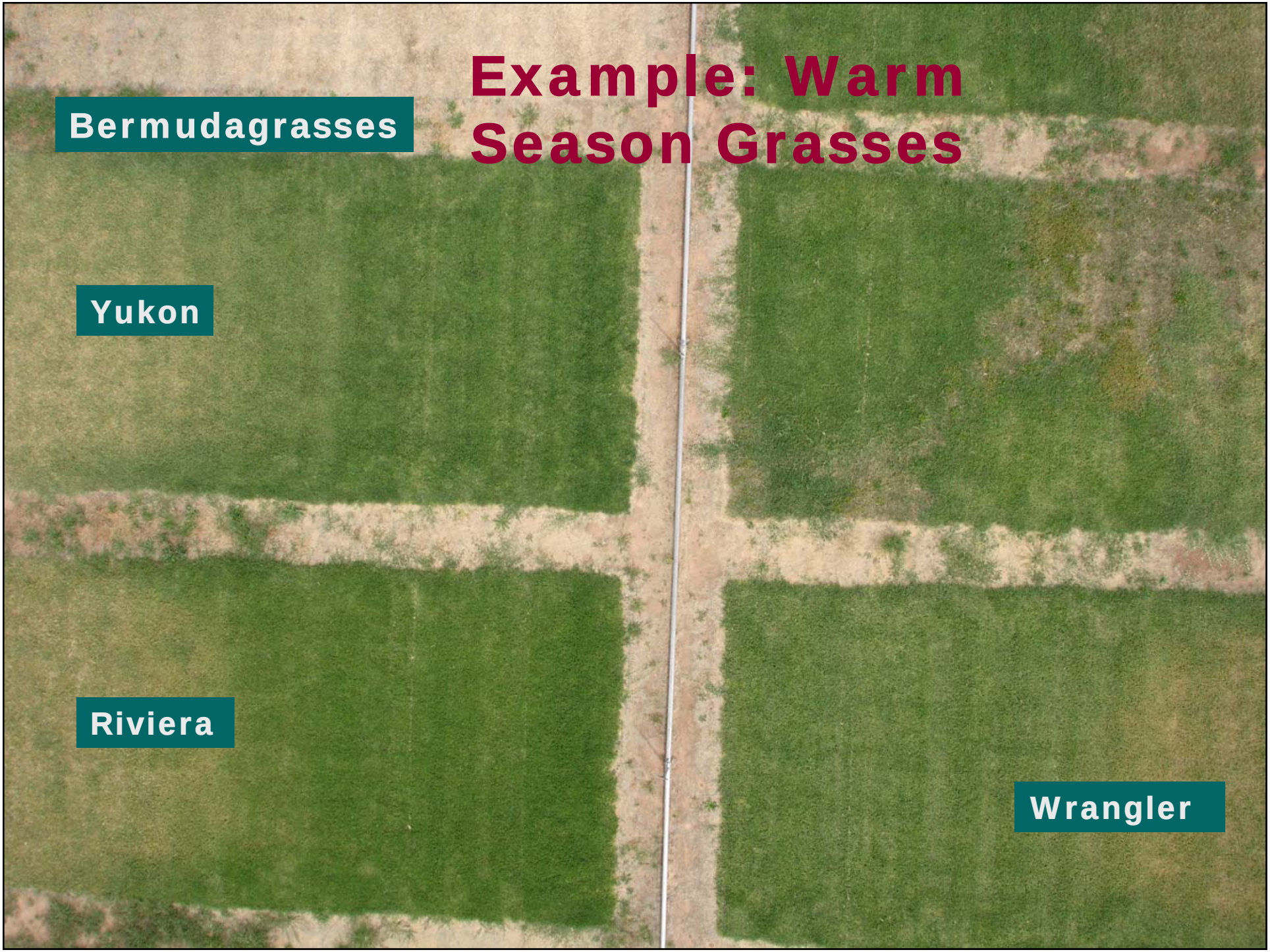
Turfgrasses Evaluated

- Cool Season Grasses
  - Kentucky Bluegrass (7)
  - Tall Fescue (1)
  - Fine or Hard Fescue (2)
  - Perennial Ryegrass (1)
  - Prairie Junegrass (1)
  - Alkali grass (1)
  - Wheatgrass (2)

Turfgrasses Evaluated

- Warm Season Grasses
  - Bermudagrass (5)
  - Buffalograss (5)
  - Blue Grama (2)
  - Zoysia (1)

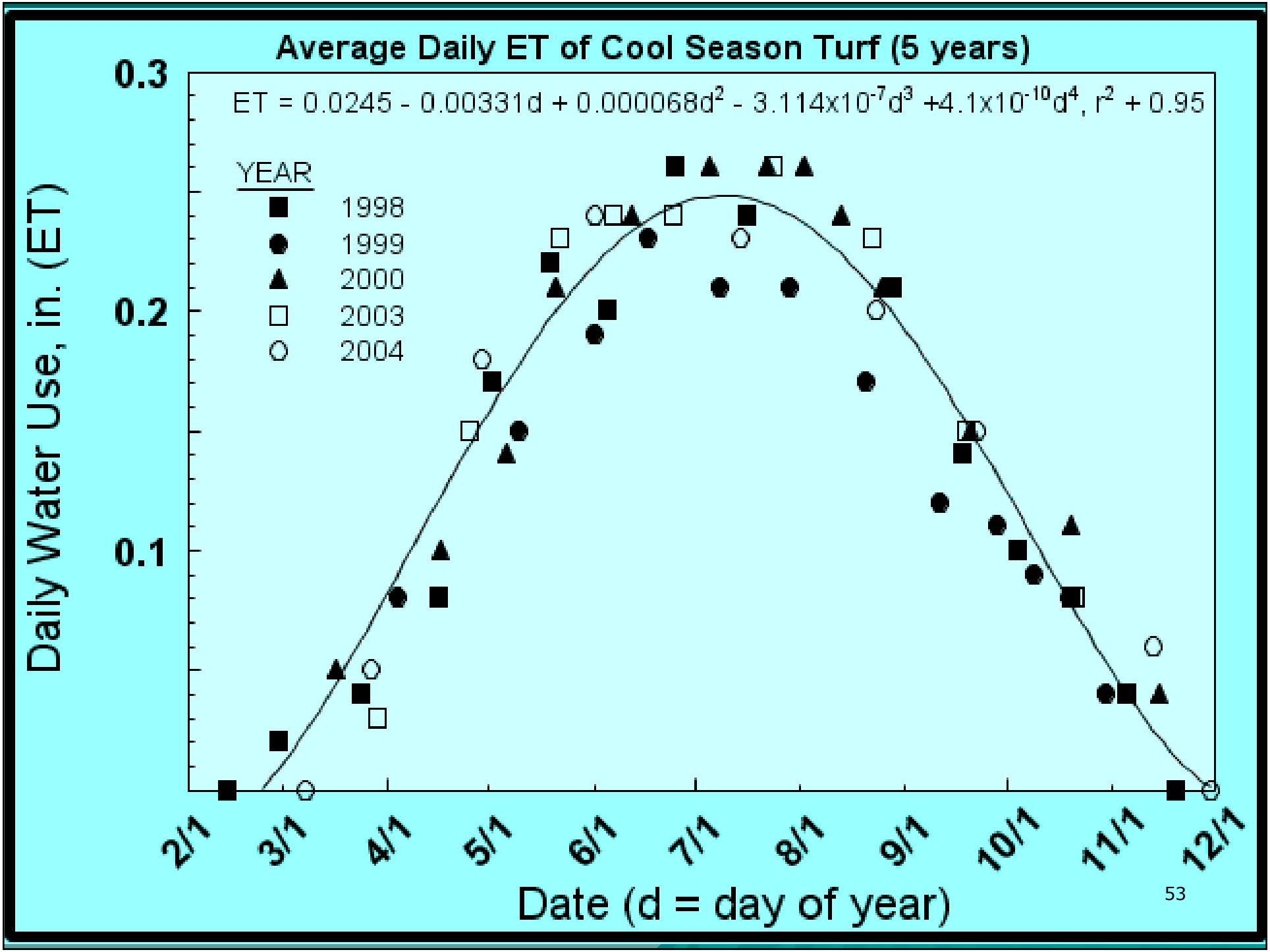

Catch Cans
K. Bluegrass
Sprinkler Line
Prairie Junegrass
'Turtleturf'
Alkaligrass
'killed w/ glyphosate'
Crested
wheatgrass
Hard
Fescue
Example: Cool Season Grasses

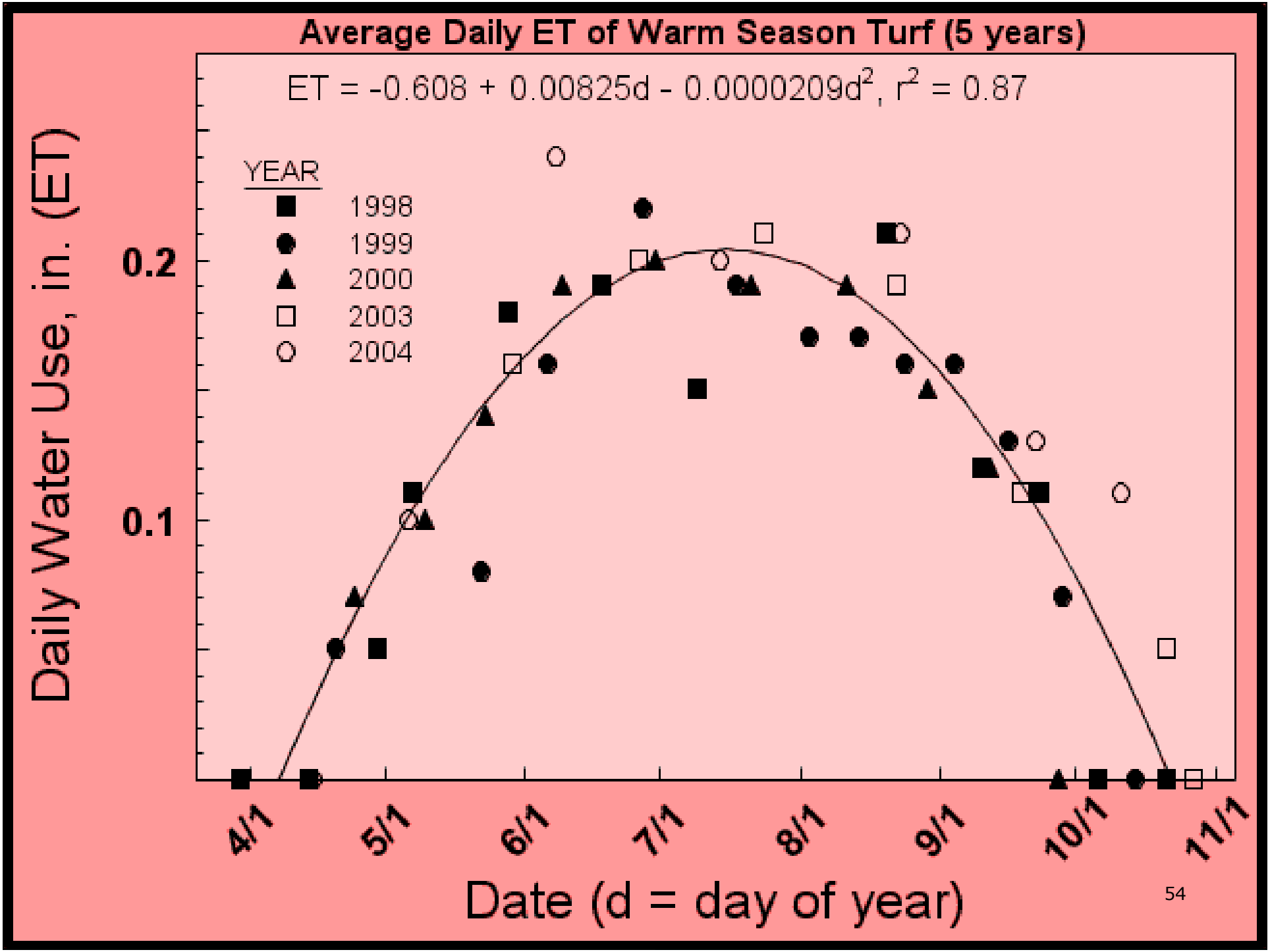

Example: Warm Season Grasses
Bermudagrasses
Yukon
Riviera
Wrangler

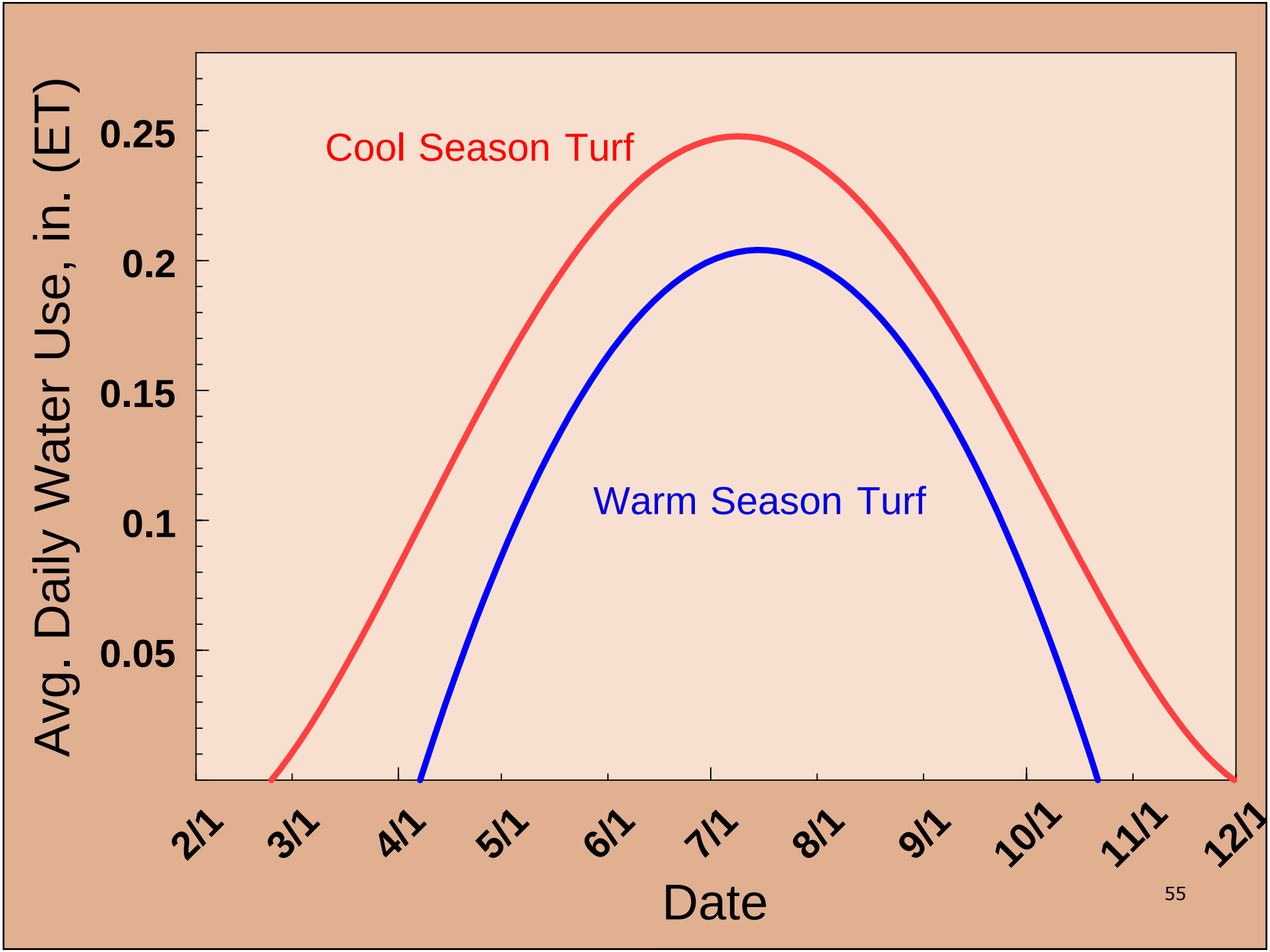
Summary of Results

- Total Seasonal ET for Acceptable Quality
  - Cool Season Grasses 35-40 inches (March – November)
  - Warm season grasses: 25-30 inches (May – mid-October)
- Peak Daily Summer ET at Acceptable Quality
  - Cool Season Grasses: 0.23-0.28”/day
  - Warm Season Grasses: 0.17-0.22”/day

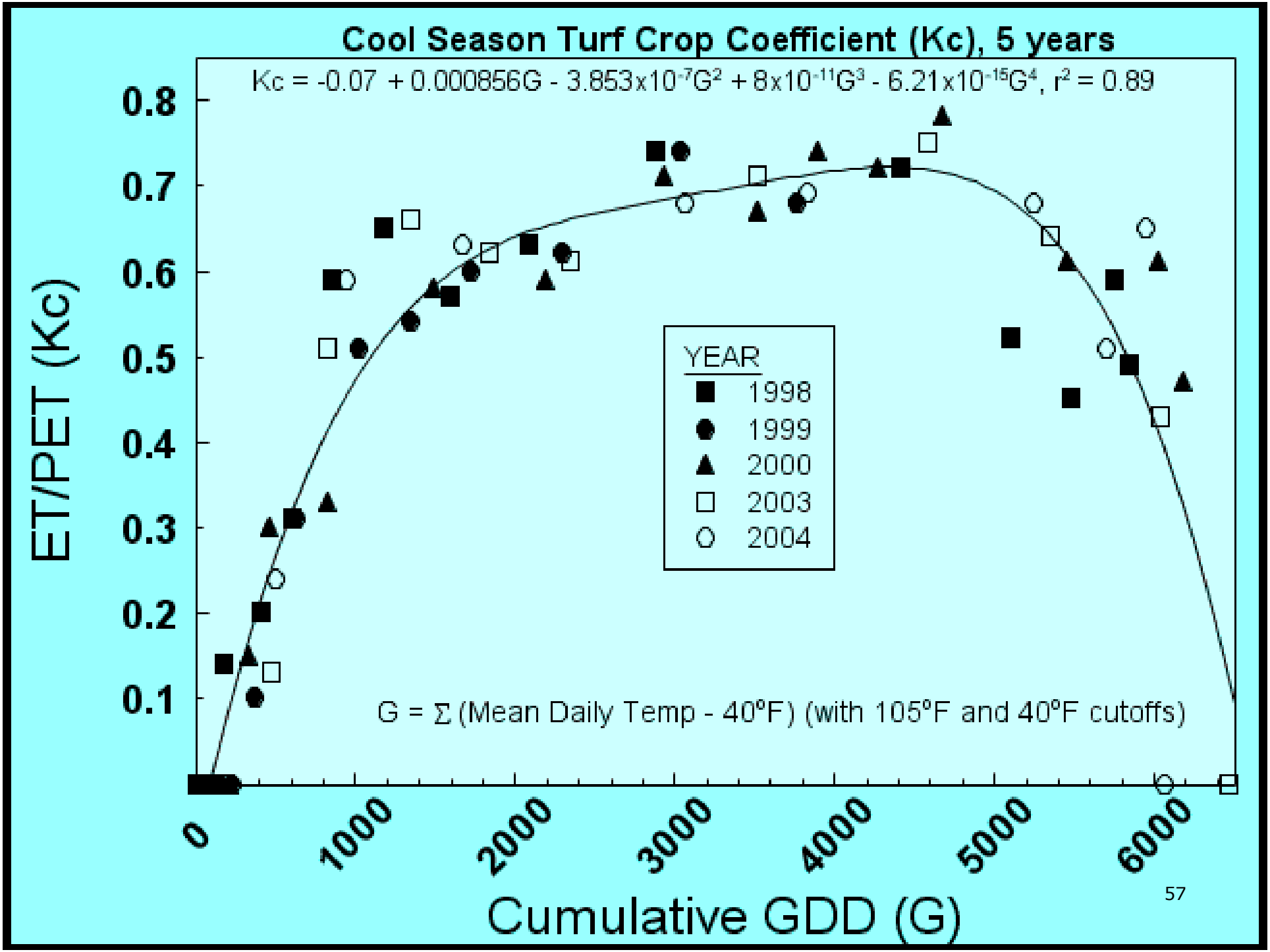
- The next three graphs show the average daily water-use (consumptive-use curves) of cool season and warm season turfgrasses at Farmington.
- These 'average curves' can be used to successfully schedule irrigations in Farmington and other locations having similar climatic conditions (ie. Santa Fe)

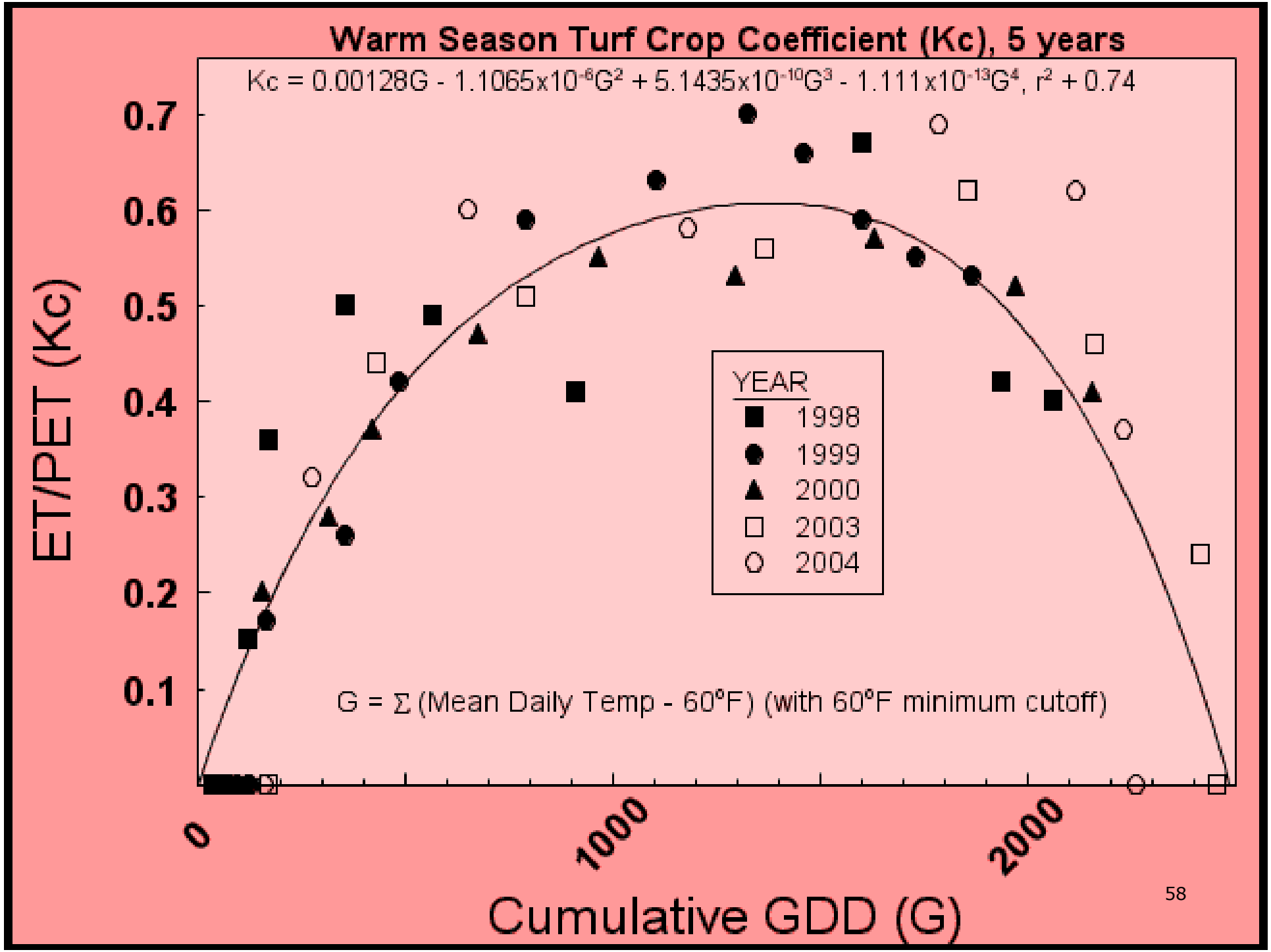

Average Daily ET of Cool Season Turf (5 years)
ET = 0.0245 - 0.00331d + 0.000068d2 - 3.114x10-7d3 +4.1x10-10d4, r2 + 0.95
YEAR
1998
1999
2000
2003
2004
Daily Water Use, in. (ET)
0.3
0.2
0.1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Date (d = day of year)


Average Daily ET of Warm Season Turf (5 years)
ET = -0.608 + 0.00825d - 0.0000209d², r² = 0.87
YEAR
1998
1999
2000
2003
2004
Daily Water Use, in. (ET)
0.2
0.1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
Date (d = day of year)

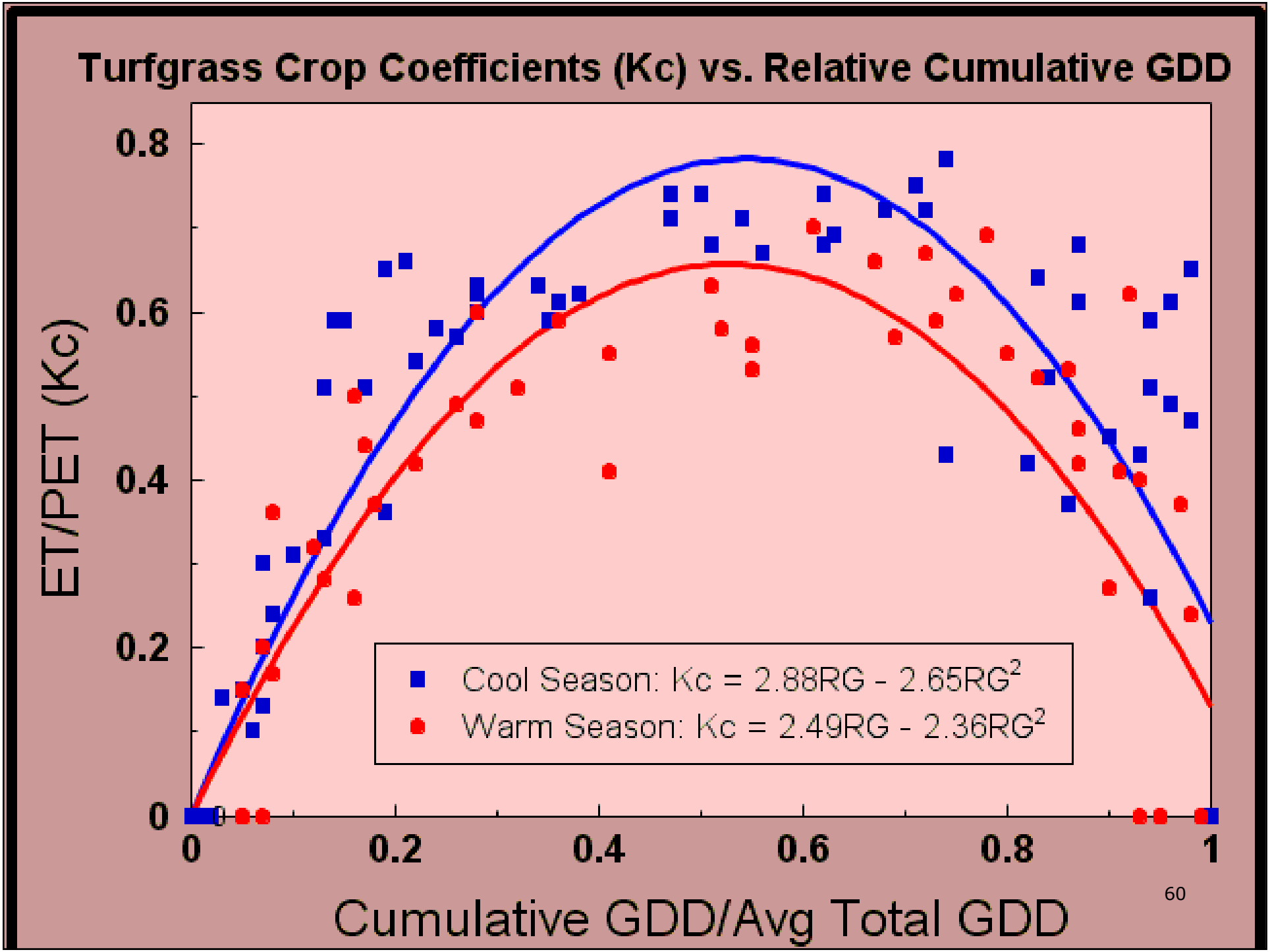

Avg. Daily Water Use, in. (ET)
0.25
0.2
0.15
0.1
0.05
Cool Season Turf
Warm Season Turf
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Date

- The next few graphs show the crop coefficients (K_C) of the two types of grasses.
- The K_C is simply the ratio of measured turf ET to the reference ET (ET_O) calculated using local weather data.
- Temperature-based growing degree-days (gdd) are used as the time scale (rather than days) to provide a more accurate indication of turf development.


Cool Season Turf Crop Coefficient (Kc), 5 years
Kc = -0.07 + 0.000856G - 3.853x10-7G2 + 8x10-11G3 - 6.21x10-15G4, r2 = 0.89
ET/PET (Kc)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
YEAR
1998
1999
2000
2003
2004
G = Σ (Mean Daily Temp - 40°F) (with 105°F and 40°F cutoffs)
0
1000
2000
3000
4000
5000
6000
Cumulative GDD (G)


Warm Season Turf Crop Coefficient (Kc), 5 years
Kc = 0.00128G - 1.1065x10-6G2 + 5.1435x10-10G3 - 1.111x10-13G4, r2 + 0.74
ET/PET (Kc)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
YEAR
1998
1999
2000
2003
2004
G = Σ (Mean Daily Temp - 60°F) (with 60°F minimum cutoff)
0
1000
2000
Cumulative GDD (G)

- To increase the transferability of the crop coefficient from place to place, the next graph shows the relationship between Kc and 'relative' growing degree-days (RGDD).
- RGDD is the ratio of the cumulative GDD on a given day (from January 1) to the total average GDD at the location.


Turfgrass Crop Coefficients (Kc) vs. Relative Cumulative GDD
ET/PET (Kc)
0
0.2
0.4
0.6
0.8
0
0.2
0.4
0.6
0.8
1
Cumulative GDD/Avg Total GDD
Cool Season: Kc = 2.88RG - 2.65RG2
Warm Season: Kc = 2.49RG - 2.36RG2

- The RGDD functions formulated during the Farmington study serve as the basis for the turfgrass ET estimates found on the NMCC web-site for various sites.

Appendix 3

- Additional Information
  - Prerequisites for irrigation scheduling
  - Irrigation system auditing
  - Soil information
  - Example

Prerequisites for Irrigation Scheduling

- Must know the output and efficiency (application uniformity) of the irrigation system!
- Knowledge of soil characteristics
  - Water holding capacity
  - Water intake rate
- Maximum Allowable Depletion (MAD)
  - 50% for cool season grass
  - 60% for warm season grass
- Root (or soil water-management) depth
  - For turf, between 18 and 24 inches

Determining Irrigation System Output

- Gross output can be determined by this formula:
  - Precipitation Rate (in/hr) = (flow rate in gallons per minute x 96.3)/area irrigated in square feet
- To determine irrigation system uniformity an audit is required:
  - See
    - http://aggie-horticulture.tamu.edu/greenhouse/hortgardens/conservation/agentdemo1.pdf
    - http://www.ncwcd.org/ims/ims_info/responsi.pdf
    - Irrigation Audit Manual (City of Albuquerque) www.cabq.gov/waterconservation

Approximate Available Water Holding Capacities of Different Soils

Soil Texture	Inches per Foot
Coarse sand and gravel	0.5
Sands	0.8
Loamy sands	1.1
Sandy loams	1.5
Fine sandy loams	1.9
Loams and silt loams	2.4
Clay loams & silty clay loams	2.1
Silty clays and clays	1.9

Approximate Water Intake Rates of Different Soils

Basic Intake Rates*

Coarse sand	**0.75 – 1.00 in/hr**
Fine sands	**0.5 – 0.75 in/hr**
Fine sandy loams	**0.35 – 0.50 in/hr**
Silt loams	**0.25 – 0.40 in/hr**
Clay loams	**0.10 – 0.30 in/hr**

*Water intake rates of soils can vary substantially from the basic rates due to compaction, tillage or aeration, thatch, etc.

Scenario (Irrigation Frequency)

- Soil Type = Sandy loam
- Available soil water = 1.6 inches/foot
- Intake rate = 0.6 inches/hour
- Root (or management) depth = 18”
- Total available water = 2.40” (1.6 x 1.5)
- MAD = 50% or 1.20”
- ET = 0.30 inches/day
- Irrigation Frequency = 4 days*
    - 1.20” / 0.30” = 4

*Assuming 100% irrigation efficiency.

Following this management technique, 1.2” of irrigation would be applied every 4 days at a rate not to exceed 0.6 inches/hour.

Other Valuable Irrigation Links

- http://www.jessstryker.com/index.html (Irrigation Tutorials)
- http://aggie-horticulture.tamu.edu/greenhouse/hortgardens/conservation/agentdemo1.pdf (Irrigation Auditing Worksheet)
- http://www.aquaconserve.com/resources/article1.php (ET)
- http://texaset.tamu.edu/whatis.php (Texas ET Network)
- http://www.waterright.org/ (ET Tutorials)
- http://cati.csufresno.edu/cit/rese/index.html (Center for Irrigation Technology)

Irrigation Links (pg. 2)

- http://ag.arizona.edu/pubs/garden/mg/irrigation/index.html (Arizona Master Gardener's - Irrigation)
- http://www.owue.water.ca.gov/docs/wucols00.pdf (California - Irrigation of Landscapes)
- http://extension.usu.edu/drought/landscape.cfm (Utah - Landscape Irrigation)
- http://mwm.bz/drip_irrigation.htm (Drip Irrigation - Landscapes)
- http://www.irrigation.org/SWAT/ (Irrigation Association – Smart Water Application Technology)


The End…
for now