ET Toolbox
Evapotranspiration Toolbox for the Middle Rio Grande
A Water Resources Decision Support Tool

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FINAL DRAFT

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2 Introduction - About This Document

This documentation is intended to provide information on the data sources, calculations, and formulations of the many output products of the Agricultural WAter Resources Decision Support (AWARDS) system and the Evapotranspiration Toolbox (ET Toolbox). It also provides user guidance for navigating through these products located on the Internet.

This document was requested primarily by users of the products in New Mexico; therefore it is focused on the operations in the Middle Rio Grande. However, it does contain components that are valid in other AWARDS/ET Toolbox project areas.

This document was written using the LaTeX, pronounced lay-tek, typesetting program operating on a Unix based computer, and saved as a pdf document. Some of the figures were produced by PC Windows software called SmartDraw.

This pdf document is written to more easily accommodate reading and printing, using the Acrobet reader available on personal computers. Using an Internet accessible computer allows access to the numerous website products.

The embedded figures (outlined in red on the computer monitor) are static, dated when aspects of this document were written. Dynamic real-time figures and tables are available by clicking on the W (outlined in blue on the computer monitor) following the figure number. This will activate an Internet link via the users web browser to the AWARDS/ET Toolbox website. The address is: http://www.usbr.gov/pmts/rivers/awards/

However, accessing the website during the winter months may produce limited ET and stream flow results.

The website links to other organizations are outlined in blue on the computer monitor.

Since the AWARDS/ET Toolbox development is an on-going process, this document will be modified as related program changes and additions take place.

3 Purpose of the AWARDS/ET Toolbox

The primary purpose of the AWARDS/ET Toolbox system is to estimate high-resolution daily rainfall and water depletions (crop and riparian vegetation ET, and open water evaporation) within specified river reaches, and to provide these daily values for input into RiverWare, which is the river modeling and water accounting system used by the Upper Rio Grande Water Operations Model (URGWOM). The URGWOM is a multi-agency effort to develop a numerical computer surface water model that will cover the Rio Grande from its headwaters in Colorado to Fort Quitman, Texas. The purpose of the URGWOM is to provide a daily water operations accounting tool that can be used for basin-wide water management and planning.

Other purposes include presentation of near real-time rainfall, ET, and stream flow conditions as frequently as possible within a readily accessible Internet site. These data can be used by water managers, river operations and irrigation district personnel, the scientific and farming communities, and the general public who may be interested in the various levels of water management issues.

The definition of a toolbox is "a case for carrying or storing hand tools". The intent of the AWARDS/ET Toolbox system is to provide tools to the user community that help define the supplies and demands upon the river system. This toolbox is the carrier for the "tools", and a storage medium for historic ET and related products.

4 Overview of the AWARDS and ET Toolbox

The Bureau of Reclamation's Agricultural WAter Resources Decision Support (AWARDS) and Evapotranspiration Toolbox (ET Toolbox) system is used for estimating daily water use requirements at a resolution useful for implementation in the Upper Rio Grande Water Operations Model (URGWOM). The URGWOM is a multi-agency effort to develop a numerical computer surface water model that will cover the Rio Grande from Colorado to Fort Quitman, Texas.

The purpose of the URGWOM is to provide a daily water operations accounting tool that can be used for basin-wide water management and planning. The goal of the ET Toolbox project is to develop a methodology for automatically inputting daily riparian and crop water use estimates, open water evaporation estimates, and rainfall estimates to the URGWOM. The initial development work is focused on the Middle Rio Grande area from Cochiti Dam to Elephant Butte reservoir in New Mexico. ET of riparian vegetation and irrigated crops, and open water evaporation, accounts for about 60 percent of the water depletions over this section of the Rio Grande.

Future expansion may include the area north of Cochiti Dam to the Colorado border, and south of Elephant Butte reservoir to Fort Quitman, TX.

Note that all time related information throughout the AWARDS/ET Toolbox system is on Mountain Standard Time (MST) throughout the year. Therefore, during Mountain Daylight Time temporal scaling will be one hour behind clock time.

The Middle Grande Conservancy District (MRGCD) divisions (diversions) as used within the AWARDS/ET Toolbox system are listed in the following table:

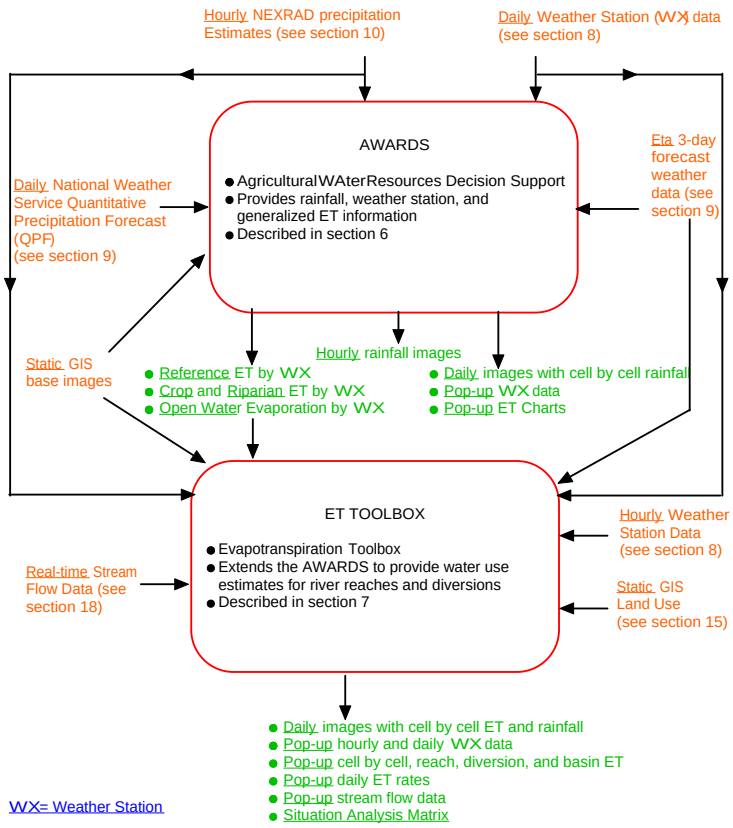
Cochiti
Ansostura (presented in the ET Toolbox as Albuquerque)
Isleta (presented in the ET Toolbox as Belen North and Belen South)
San Acacia (presented in the ET Toolbox as Socorro)

The river reaches boundaries as used within the ET Toolbox system are listed in the following table:

River Reach 1	Cochiti Dam gage to San Felipe gage
River Reach 2	Jemez River above gage below Jemez Canyon Dam
River Reach 3	San Felipe gage to Central Avenue gage
River Reach 4	Central Avenue gage to Bernardo gage
River Reach 5	Bernardo gage to San Acacia gage
River Reach 6	San Acacia gage to San Marcial gage (includes the Bosque Del Apache)
River Reach 7	San Marcial gage to north end of Elephant Butte Reservoir
River Reach 8	North end of Elephant Butte to gage below Elephant Butte Dam (future)

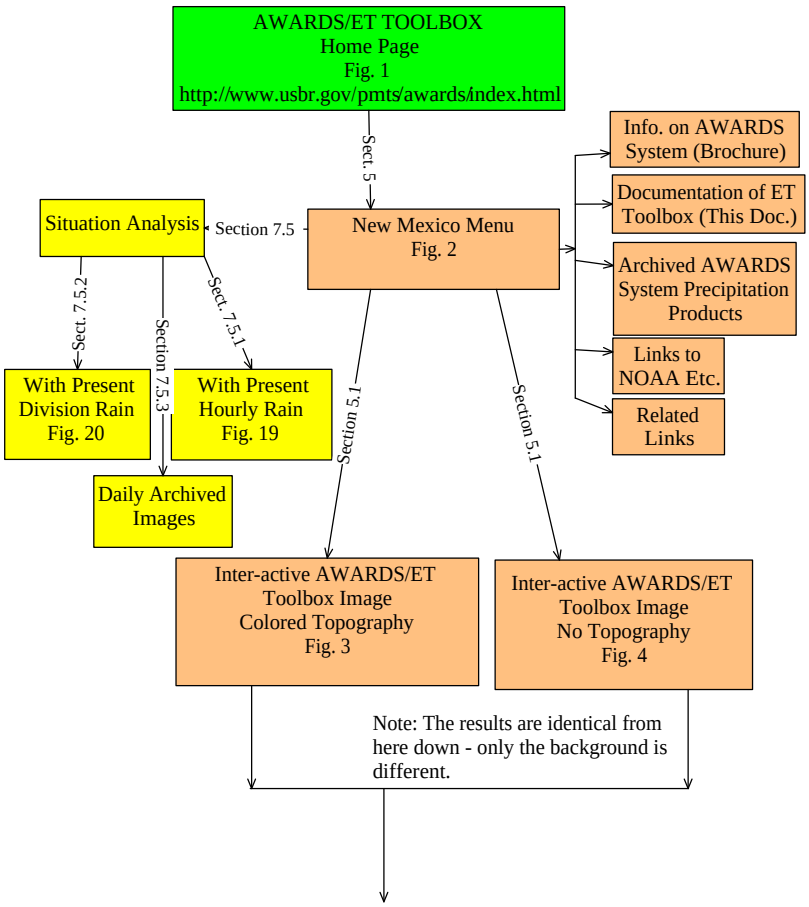
The following diagram shows the overall data flow into and out of the AWARDS and ET Toolbox processes.

This diagram shows the principal data inputs and resulting outputs of the AWARDS and ET Toolbox processes. Note that many of the inputs are shared between them, and outputs from AWARDS are used in the ET Toolbox.

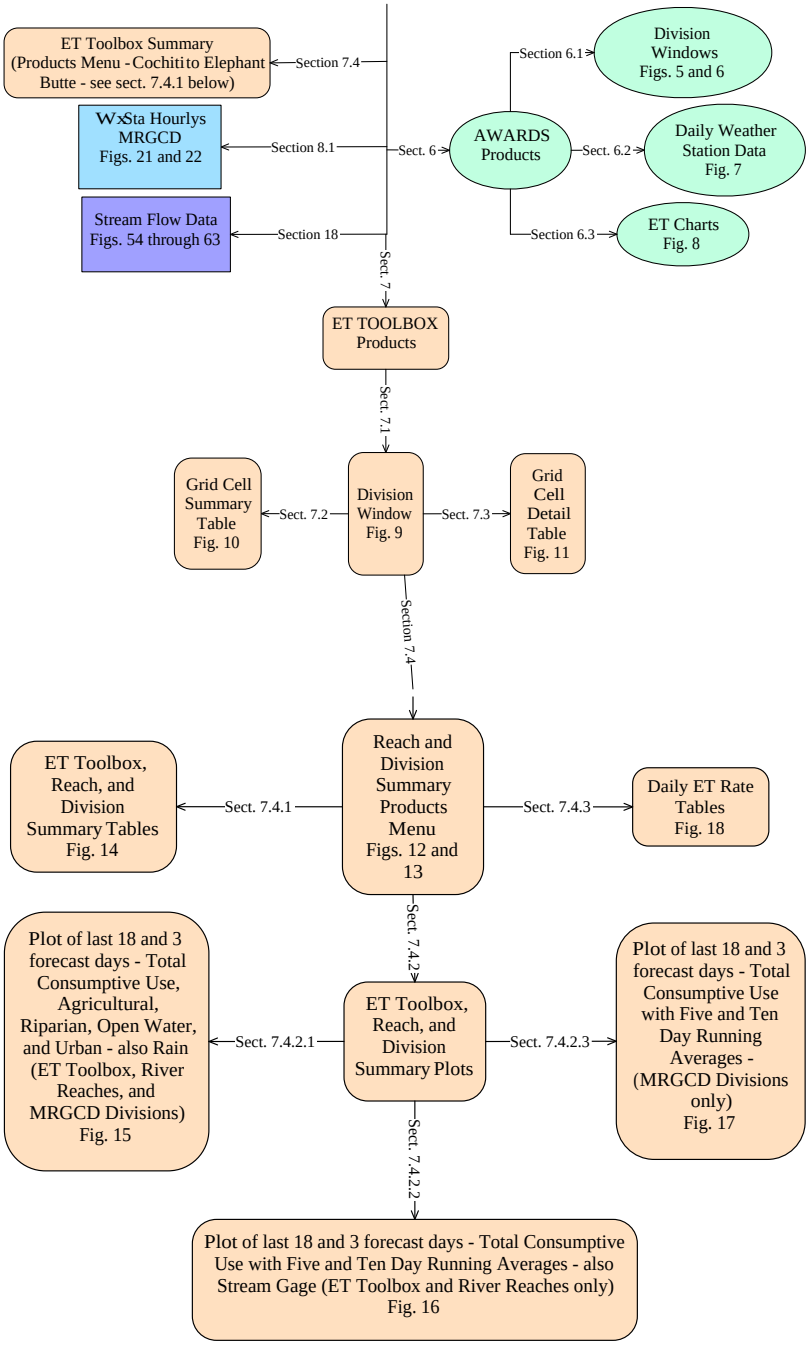


AWARDS and ET Toolbox Data Flow Diagram.

The following is a flow chart of the AWARDS and ET Toolbox, starting at the home page address http://www.usbr.gov/pmts/rivers/awards/index.html, showing the basic structure of the website. The sections and major related figures within this document are noted. The color groupings represent major components. For example, the New Mexico Menu is dark brown, the Situation Analysis is yellow, and the ET Toolbox is light brown. In the future, software may be in place to allow the reader to jump immediately from the elements within this flow chart directly to corresponding sections and figures.



AWARDS and ET Toolbox Website Flow Chart (Continued on next page).



AWARDS and ET Toolbox Website Flow Chart (Continued from previous page).

4.1 AWARDS Overview

In late FY1997, Reclamation's Albuquerque Area Office became aware of a newly developed AWARDS system for the Lugert-Altus Irrigation district in southwest Oklahoma. The AWARDS system is an automated information system on the Internet designed to assist water managers and users by providing easy access to rainfall and crop water use estimates. AWARDS uses rainfall estimates based on data from the NEXRAD (NEXt generation weather surveillance RADar) radar systems and remote automated weather stations. The Albuquerque Area Office requested that the AWARDS system be implemented in the Rio Grande, primarily as the foundation for the development of the desired ET Toolbox.

The primary purpose of the AWARDS system is to improve the efficiency of water management and irrigation scheduling by proving guidance on when and where to deliver water, and how much to apply. The resulting ET charts from AWARDS provide this guidance. AWARDS systems that have been implemented east of the Continental Divide use the NEXRAD Hydroview Multisensor Precipitation Estimation System (MPE) program (radar and gage) hourly product produced by the National Weather Service's (NWS) River Forecast Centers (RFCs) on a 4 km grid scale. (Those west of the Divide use the NEXRAD Level II produced by the National Climate Data Center. Reclamation's Precipitation Accumulation Algorithm is applied to the Level II data to derive the precipitation estimates on a 2 km grid scale.)

The MPE products use the NWS Hydrologic Rainfall Analysis Project (HRAP) 4 km x 4 km resolution grid. Every hour, the MPE data files are automatically collected into the AWARDS/ET Toolbox computer via file transfer protocol (FTP) from the RFCs. These hourly data are then accumulated into daily summations. NWS 24-hour Quantitative Precipitation Forecasts (QPF) are also automatically collected from the RFCs. The National Centers for Environmental Precipitation (NCEP) Eta model data are used for a three-day ET forecast.

Automated weather stations in AWARDS system areas transmit surface weather data via radio signal, phone, or satellite to local computer systems. The daily data are then automatically collected from the local computer systems, via FTP, into the AWARDS/ET Toolbox computer.

Lastly, the Modified-Penman method is used to calculate reference ET for each weather station. Weather data used for calculating reference ET are the maximum and minimum temperatures, average relative humidity, average wind speed, and solar radiation for the previous 24-hour Mountain Standard Time (MST) day.

Coefficients are applied to the reference ET to provide water use estimates for crops, riparian, and open water. These estimates, QPF, ET forecasts, and effective rainfall are integrated into the images via pop-up charts.

Reservoir operators, water managers, and on-farm water users access the AWARDS

system products via the Internet to make their operational decisions.

An AWARDS system brochure is available at: (Agricultural WAter Resources Decision Support (AWARDS)).

The address is: http://www.usbr.gov/pmts/rivers/awards/awards.html

In summary, these are the inputs and outputs of the AWARDS system:

Inputs
1) Hourly NEXRAD precipitation estimates
2) Daily weather station data
3) Static GIS base images
4) Eta 3-Day forecast weather data
5) Daily QPF

Outputs
1) Hourly and daily NEXRAD rainfall images
2) Pop-up daily weather station data
3) Reference ET by weather station
4) Crop and riparian ET by weather station
5) Open water evaporation by weather station
6) ET charts containing past ET, forecast ET, QPF, and effective rainfall

Refer to AWARDS Products (section 6) for more information on the operation of the AWARDS system.

4.2 ET Toolbox Overview

The AWARDS/ET Toolbox computer first operates on the AWARDS system requirements, generating rainfall images and ET charts. It then expands these requirements into the finer resolution ET products to provide detailed water use estimates for the HRAP cells and river reaches and diversions.

The ET Toolbox is an extension of the AWARDS system. The reference ET, crop and riparian ET, and open water evaporation, are input from the AWARDS system. It also uses the following components that are not applied in the AWARDS system:

1) GIS land use
2) Hourly weather station data (from Middle Rio Grande Conservancy District only)
3) Real-time stream flow data

Note that the effective rainfall component that is tabulated in the AWARDS ET charts is not used in the ET Toolbox. Future use depends upon accessing additional data sources and research.

GIS land use is added to specify crop, riparian, and open water acreage within each HRAP grid cell (resolution about 4 km x 4 km) along the Middle Rio Grande. Several GIS vegetation data sets that cover portions of the area were evaluated. The Middle Rio Grande Land Use Trend Analysis GIS Data Base for 1992/93 and aerial photography

taken during a June 1999 ET field study are the current land use resources. Parts of an Ikonos satellite 4-meter multi-spectral resolution land use data set from July 2000 are also used. All of the vegetation data sets are transposed to the HRAP grid cell resolution. GIS methodologies are then used to compare these data sets to determine changes in the vegetation and water depletion over time. The most recent and accurate data sets that cover the areas of interest are chosen for the ET Toolbox. A single land use data set is then assigned to each reach and diversion, thereby providing a means to summarize ET into specific groupings.

Grid cells are assigned to near-by weather stations, and then either a single weather station, or multiple weather stations, are assigned to to each reach and diversion. Grid cells can easily be reassigned whenever new weather stations are installed, land use data sets become available, or groupings are added or modified.

The primary purpose of this effort is to estimate daily rainfall and water depletions for each HRAP grid cell and the specified river reaches and diversions. These daily ET estimates and summary year-to-date cumulative ET estimates are available to users and water managers via the Internet. The daily cumulative river reach ET estimates are provided to the URGWOM by RiverWare, using a Data Storage System developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center.

The products include real-time access to weather station and stream gage data provided by the Middle Rio Grande Conservancy District (MRGCD), radar rainfall estimates, and links to United States Geological Survey (USGS) stream gage data. The AWARDS/ET Toolbox system also receives daily weather data from the New Mexico Climate Center at New Mexico State University (NMSU) for calculating ET and Internet posting. Graphical plots of 5-day and 10-day running averages of daily ET are available to help detect water requirement trends. Other plots include total daily agricultural, riparian, and urban ET, and open water evaporation.

Weather forecasting for the purposes of predicting ET for today and the next two days, and for substituting data for non-reporting weather stations, is accomplished by using the National Centers for Environmental Prediction (NCEP) Eta model weather forecast parameters.

In summary, these are the inputs and outputs of the ET Toolbox system:

Inputs
1) Hourly NEXRAD precipitation estimates
2) Hourly weather station data
3) Daily weather station data
4) Static GIS base images
5) Static GIS land use
6) Eta 3-day weather forecast data
7) Real-time stream flow data

Outputs
1) Hourly and daily NEXRAD rainfall images
2) Pop-up hourly and daily weather station data
3) Pop-up cell by cell, reach, diversion, and basin ET
4) Pop-up daily ET rates
5) Pop-up stream flow data
6) Situation Analysis Matrixes

Refer to ET Toolbox Products (section 7) for more information on the operation of the ET Toolbox.

5 Accessing the AWARDS and ET Toolbox

Access to the AWARDS/ET Toolbox home page is via the Internet at:

http://www.usbr.gov/pmts/rivers/awards/. (figure 1 W).

This page is titled "AWARDS NEXRAD ET TOOLBOX", which shows a map of the AWARDS and ET Toolbox project areas.

Clicking on the Middle Rio Grande provides the "NEXRAD Rainfall, Weather Station, and ET Products for the Rio Grande Basin in New Mexico" menu of available products, important links to National Oceanic and Atmospheric Administration (NOAA), archived precipitation products, and other related links. Henceforth, this menu will be called the New Mexico menu (figure 2 W).

The website has evolved over the years based on the needs and special interests of various users. Therefore, navigating the website may seem rather daunting for the first-time visitor. However, with a little practice the user will learn which pages of information are of interest, and will devise methods, such as bookmarks, to get there with little effort.

5.1 Colored Topography and No-Topography Options

There are two primary options available to the user from the New Mexico menu (figure 2 W).

These options are Colored Topography and No Topography. Clicking on the colored topography option pops-up an inter-active AWARDS/ET Toolbox window (figure 3 W) showing the division windows outlined in black over the topography along the Middle Rio Grande. A colored elevation scale is provided.

Clicking on the no-topography option pops-up an inter-active AWARDS/ET Toolbox window (figure 4 W) showing the division windows outlined in white.

Subsequent windows will maintain the selected version until the version is changed. Each window in both versions generally contains lands that receive water from a diversion dam usually located at the northern most edge of the window. Exceptions are when multiple windows are needed for clarity, or when diversions are not defined. The color scale at the bottom of these inter-active AWARDS/ET Toolbox windows, and subsequent windows, represents the 24-hour rainfall intensities that are mapped into each of the 4 km x 4 km HRAP grid cells.

The ET Toolbox products are generally available by clicking in the small square boxes found throughout the various pop-up windows. Refer to ET Toolbox Products (section 7).

For the AWARDS system ET charts, do not click in these boxes. For these areas, refer to AWARDS Products (section 6).

5.2 Windows and Options Access

Within each window there are small rectangular boxes containing pink lettering. These allow the user to move between windows, go to the AWARDS/ET Toolbox home page, go to the New Mexico home page (menu), go to an all window version, go to the parent window, turn on/off the topography, turn on/off the ET Toolbox vs AWARDS, etc. These options allow quicker movement around the website.

6 AWARDS Products

The purpose of the AWARDS system is to provide generalized ET information for improving water use efficiency. The resulting rainfall estimate images and ET charts were developed to achieve this goal. Refer to the AWARDS/ET Toolbox Calculations (section 13) for information on the calculation of ET as used in the AWARDS system.

Access to the AWARDS products is from the New Mexico menu (figure 2 W) where the user should first choose from either the colored topography or no topography options.

The resulting image (figure 3 W), colored option in this example, shows the NEXRAD rainfall estimates throughout the Rio Grande. Each rainfall pixel is on the 4 km scale. The 4 km rainfall is represented by the color intensity scale at the bottom of the image. These are daily (midnight-midnight) summations of hourly rain. Refer to NEXRAD Precipitation Estimates (section 10) for more information.

This image will henceforth be called the inter-active AWARDS/ET Toolbox image.

The user will first notice the large diversion windows on the image. They are outlined in black for the colored topography version, and white for the no-topography option. For comparison purposes, following is the inter-active AWARDS/ET Toolbox image is a result of the no topography option (figure 4 W).

Do not click into the small square boxes. These are reserved for the ET Toolbox products that are discussed in section 7.

6.1 Division Windows - AWARDS

Clicking within a window in the inter-active AWARDS/ET Toolbox image allows access to the AWARDS products. This is an example image for the MRGCD Albuquerque Division (Angostura Diversion) (figure 5 W). The values printed on each cell, when there is rain, are the daily NEXRAD rainfall estimates, the same as shown on the the inter-active AWARDS/ET Toolbox image. Another example is the no topography image for the MRGCD Belen North Division (Diversion) (figure 6 W).

6.2 Daily Weather Station Data

Daily weather station data are available by clicking on the yellow, green, or blue plus signs (+) shown in many of the windows. Following is an an example showing the daily data at the Candelaria Farms weather station. (figure 7 W) Refer to Automated Weather Station Data (section 8) for more information.

6.3 ET Charts

ET charts are available by clicking into the HRAP cells to pop-up a generalized ET chart showing the ET for all crops, riparian vegetation, and open water that may be

in the area. This example is for the Belen South area served by the Jarales weather station. (figure 8 W).

No acreages or rainfall values are used in these calculations. The heading at the top of each chart shows the name of the weather station data that were used to calculate the daily crop water use for the past four days, using the Modified-Penman Reference ET Equation. Refer to Penman Reference ET Calculation (section 12) for more information.

ET for three forecast days, starting with today, are provided as calculated from the Eta data. Refer to Weather Forecasting (section 9) for more information.

The sum of ET to-date and the sum for the last seven and 14 days is shown. Each weather station is assigned to an array of HRAP cells, therefore the ET portion of the charts may be identical for nearby cells. The start (plant) and terminate (harvest) dates are also given. An example date value of 101 represents January 1. The value 1020 represents October 20.

Near the bottom of each chart is a posting of the NEXRAD rainfall estimates for the HRAP cell. Since the NEXRAD data are collected via FTP from the West Gulf River Forecast Center (WGRFC) on an hourly bases, the number of actual hours received are noted, generally 24. The total rain and calculated effective rain are provided. Refer to Effective Rainfall Estimates (section 11) for more information.

The column headed QPF is the Quantitative Precipitation Estimate that is collected via FTP from the WGRFC eight times per day. Refer to Weather Forecasting (section 9) for more information.

The NEXRAD monthly total rain (since the beginning of the current year) and the HRAP cell number are also provided.

7 ET Toolbox Products

For operational and management purposes, the ET Toolbox provides products for both river reaches and MRGCD divisions (the MRGCD divisions are usually defined at the water diversion points). This versatility allows operation and management entities access to various consumptive use breakouts depending upon their requests and needs. Refer to the AWARDS/ET Toolbox Calculations (section 13) for information on the calculation of ET as used in the ET Toolbox system.

Access to the ET Toolbox products is from the New Mexico menu (figure 2 W) where the user should first choose from either the colored topography or no topography options.

The resulting image (figure 3 W), colored option in this example, shows the NEXRAD rainfall estimates throughout the Rio Grande. Each rainfall pixel is on the 4 km scale. The 4 km rainfall is represented by the color intensity scale at the bottom of the image. These are daily (midnight-midnight) summations of hourly rain. Refer to NEXRAD Precipitation Estimates (section 10) for more information.

This image will henceforth be called the inter-active AWARDS/ET Toolbox image.

The user will first notice the large diversion windows on the image. They are outlined in black for the colored topography version, and white for the no-topography option. For comparison purposes, following is the inter-active AWARDS/ET Toolbox image is a result of the no topography option (figure 4 W).

7.1 Division Windows - ET Toolbox

Clicking in the small white square box attached to the left side of the windows in the inter-active AWARDS/ET Toolbox image (figure 3 W) allows access to the ET Toolbox products. Note that clicking inside a division window allows access to the AWARDS products discussed in section 6.

An example ET Toolbox image for the MRGCD Albuquerque Division (Angostura diversion) (figure 9 W) shows the green line river reach delineations between reaches 2, 3, and 4. The values printed on each cell are daily URGWOM water use in acre-feet for that cell, after adjustments for NEXRAD estimated rainfall.

7.2 Grid Cell Summary Tables

Clicking on a box in the lower-left corner of an HRAP grid cell (figure 9 W), defined by the black dashed lines, will pop up a grid cell summary table. (figure 10 W). This example is for cell number 103x305 in the Albuquerque Division.

The classification source and weather station used for determining the consumptive use are noted. The table shows, for each day, the total consumptive use in cubic feet

per second (cfs) with a breakdown for each type (agricultural, riparian, open water, and urban). The daily rain is the NEXRAD rainfall estimate. The daily URGWOM water use is the consumptive use minus the NEXRAD rain. Five and 10 day running averages of the water use are also provided. In the far right column is the total URGWOM water use to-date in acre-feet since January 1. The forecast method (FM) column next to the date signifies the method used to calculate the consumptive use for three forecast days, starting with today. An E indicates the 12-km grid Eta model weather forecast parameters were used, including Eta model forecast rainfall. In rare cases when the Eta model data were not available, an A indicates that an average of the last three days were used. In this case, the forecast rainfall will be zero. At the bottom of the cell summary is a tabulation of the acres of each type. The fallow and idle types are not included in the consumptive use calculations, but are noted here for information only.

7.3 Grid Cell Detail Tables

Clicking within a grid cell (figure 9 W) will pop up a cell detail table showing the acres of each crop, riparian, open water, and urban species in the cell as defined by the GIS data set. This example is also for cell number 103x305 in the Albuquerque Division (figure 11 W).

The table includes the consumptive use for the last seven days and the next three forecast days, and the totals by type, such as agricultural crops. Today is considered the first of the forecast days. Near the bottom of the table are the daily NEXRAD rainfall estimates for the cell. The URGWOM water use is the consumptive use minus the NEXRAD rain. All quantities are in acre-feet. Those in parentheses are in cfs.

7.4 ET Toolbox, Reach, and Division Summary Products Menus

The ET Toolbox Summary is accessible from the square box at the upper left corner of the inter-active AWARDS/ET Toolbox image (figure 3 W). The menu that pops-up is titled "ET Summary Products To-Date from Cochiti Gage to Elephant Butte Reservoir". This menu provides information similar to that described below for reaches, except there no daily ET rates. It also has some historic discharge tables and plots.

Reach and MRGCD division summary products, including tables and plots, are available by clicking in the appropriate boxes from this example, which is the MRGCD Albuquerque Division (Angostura diversion) (figure 9 W). As an example, clicking in the "River Reach 3 Summary" box from the MRGCD Albuquerque Division image will pop-up this ET Summary Products (To-Date) menu (figure 12 W). The options available are tables, two types of plots, and for river reaches, daily ET rates by vegetative type. These are explained in the following six sub-sections.

Had the user clicked on the "Albuquerque Division Window Summary" box from the

MRGCD Albuquerque Division image, a very similar menu would appear, but it would not contain daily ET rates. These rates were requested for the river reaches only. For comparison, following is an example of an ET Summary Products (To-date) menu for the Albuquerque Division (figure 13 W).

7.4.1 ET Toolbox, Reach, and Division Summary Tables

The details of the reach and division table data are the same as the grid cell summary tables explained above (section 7.2) except a number of weather stations and Eta model cells have been used for the calculations. Clicking on "Table" from the ET Summary Products (To-Date) menu (figure 12 W) provides the following table data for river reach 3 (figure 14 W).

Included in these summary tables are the daily flow differences, with five and 10 day running averages, as reported from real-time gage station data. Refer to Stream Flow Data for gage information (section 18).

Following is a listing of the stream flow gages used to calculate the daily flow differences in the ET Toolbox Summary and reaches 1, 3, 4, 5, and 6 summaries. This is not done in reach 2. The daily flows are an average of all the readings (usually at 30-minute intervals) acquired throughout the day.

ET Toolbox	Cross section at Cochiti Dam minus cross section at San Marcial
River Reach 1	Cross section at Cochiti Dam minus cross section at San Felipe
River Reach 3	Cross section at San Felipe minus cross section at Central Avenue
River Reach 4	Cross section at Central Avenue minus cross section at Bernardo
River Reach 5	Cross section at Bernardo minus cross section at San Acacia
River Reach 6	Cross section at San Acacia minus cross section at San Marcial

7.4.2 ET Toolbox, Reach, and Division Summary Plots

There are also two plots available from the ET Summary Products (To-Date) menu (figure 12 W). Note that the first plot is available from both the reach and division ET Products menu. The second plot is different depending upon whether it was accessed from a reach menu or a division menu.

7.4.2.1 Plot of last 18 and 3 forecast days - Total Consumptive Use, Agricultural, Riparian, Open Water, and Urban - also Rain (ET Toolbox, River Reaches, and MRGCD Divisions) The first plot (figure 15 W) contains a chart (in cfs) of the total daily consumptive use, affected by rain, and traces for each type, unaffected by rain. This is an example of river reach 3. The other river reaches, and the divisions, are similar. A bar chart of the NEXRAD rainfall estimate (in cfs) is also included. These data are plotted for the past 18 days, plus the three forecast days (dashed

traces), starting with today. A break in a trace indicates there were no data available for that period of time.

7.4.2.2 Plot of last 18 and 3 forecast days - Total Consumptive Use with Five and Ten-Day Running Averages - also Stream Gage (ET Toolbox and River Reachs only) The second plot for river reaches contains a chart (in cfs) of the total daily consumptive use, affected by rain, and traces of the five and 10 day running averages of the total (figure 16 W). Also included are similar running average traces of the actual stream flow data from real-time gage stations, an attribute requested by Reclamation personnel.

7.4.2.3 Plot of last 18 and 3 forecast days - Total Consumptive Use with Five and Ten-Day Running Averages - (MRGCD Divisions only) The second plot for MRGCD divisions contains a chart (in cfs) of the total daily consumptive use, affected by rain, and traces of the five and 10 day running averages of the total (figure 17 W). The stream flow traces are not included in the MRGCD division plots, since stream gage data are only compared to river reach depletions, as requested by Reclamation personnel.

7.4.3 Daily ET Rate Table

Another system of tables is available from the ET Summary Products menu for each of the reaches (figure 12 W). These are the daily ET rates. They are not available from the ET Summary Products (To-Date) menu for the divisions. These contain the daily ET rates for each species within each type for the reach, with a notation of the acres and source of the classification. Clicking on a species, such as Alfalfa, pops-up the table containing detailed information about the parameters used to calculate ET (figure 18 W). These include the acres, planting and termination dates (start and stop dates), reference ET, coefficient, ET, total water use, NEXRAD rain, and URGWOM water use, for each day from the planting date through yesterday. These are the data that are accumulated for the ET Toolbox, reach, and division tables.

7.5 Situation Analysis Matrix

The Situation Analysis Matrix is available from the New Mexico menu (figure 2 W). There are two matrixes that show the past, current (today), and predicted (future) status of the stream flow, rainfall, and consumptive use. These matrixes are With Present Hourly Rain (figure 19 W) and With Present Division Rain (figure 20 W). The area of consideration is from the Otowi gage to the San Marcial gage. The period for the past is eight days, and the predicted is three days as determined by the Eta forecast

period. The past rainfall is the summation of NEXRAD over all the HRAP grid cells for the area. The daily consumptive use is the total of agricultural, riparian, open water, and urban for the area. All units are in cfs, except the current (today) rainfall is in inches.

7.5.1 With Present Hourly Rain

The current (today) rainfall, as reported on the With Present Hourly Rain Matrix, is a average of all the reporting MRGCD hourly weather station rainfall quantities since midnight (figure 19 W). Refer to section 8.1 for a listing of the MRGCD weather stations.

7.5.2 With Present Division Rain

The current (today) rainfall, as reported on the With Present Division Rain Matrix, (figure 20 W) is a average of the weather stations located in each division:

Division	ID	Averaged Weather Stations
Cochiti	COC	Pena Blanca and Angostura
Albuquerque	ABQ	Angostura and Candelaria Farms
Belen	BEL	Jarales and Boy's Ranch
Socorro	SOC	San Acacia and Luis Lopez

The Present Division Rain matrix displays a color coded stacked bar when there is rain for each hour in each division.

Currently there are no data available for predicting stream flow at the Otowi and San Marcial gages. The matrixes will be completed when these become available.

7.5.3 Daily Archived Images

Archived matrixes are also available from the New Mexico menu (figure 2 W). Click on Daily Archived Images under the Situation Analysis Matrix heading. The files in the directory are named SAdivrain for present division rain, and SAavgrain for present hourly rain. Each is followed by yymmda01.png.

8 Automated Weather Station Data

Weather data from five sources are used, or presented, within the AWARDS and ET Toolbox products. They are:

Middle Rio Grande Conservancy District (MRGCD)
New Mexico Climate Center (NMCC)
University of New Mexico Sevilleta Long-Term Ecological Research (LTER) Network
Colorado State University Agricultural and Meteorological Network (COAGMET)
Automated Surface Observing System (ASOS)

Example of automated weather station used in the MRGCD network.

8.1 Middle Rio Grande Conservancy District

MRGCD weather station network presently consists of 8 sites; additional weather stations are expected to be added in the near future.

Hourly data are automatically received from this network via File Transfer Protocol (FTP) at 12 minutes past each hour. Clicking on WX Hourlys from the The inter-active AWARDS/ET Toolbox image (figure 4 W) pops-up an image showing the location of the MRGCD weather station network (figure 21 W). Clicking on the plus (+) signs pops-up the hourly weather data for the last 24-hours (figure 22 W). This is an example of the MRGCD Candelaria farms station. These hourly data are converted to the Standard Hydrometeorological Exchange Format (SHEF) shortly after they are received,

and provided, via FTP, to the West Gulf River Forecast Center. Refer to NEXRAD Precipitation Estimates (section 10) for more information.

The 24-hr summaries that are used in estimating ET are received around 1:12 AM MST from the MRGCD. These sites are shown in yellow, preceded by a + sign, on the inter-active AWARDS/ET Toolbox image, and sub-images, on the Internet (figure 4 W). The 24-hr gage precipitation accumulations are shown on the image at the locations. The site ID's are shown if accumulations are not available. The plus (+) signs locate the stations by latitude and longitude. Clicking on a + sign pops-up a table containing the station name, elevation, and location (figure 7 W). Data for the past seven days is shown in the upper part of the table consisting of maximum and minimum temperatures, average wind speed, relative humidity, rain, and solar radiation as measured by the station's sensors. The rain gage monthly totals since the beginning of the year are also tabulated. The bottom part of the table contains all of the data for each day since January 1st with the latest day first. Included in this listing is the calculated Modified-Penman Reference ET. Refer to Penman Reference ET Calculation (section 12) for more information.

If station data are unavailable for a day, alternate weather data from the Eta weather forecast model from the previous day are used. Refer to Weather Forecasting (section 9) for more information. An alternate data key provides information on data that may have been substituted. Example: In the Alternate Weather Data column eta1TS means the Eta model 1st forecast day temperatures and solar radiation were used. In cases when the Eta model data are also unavailable, data from a nearby weather station are used, with the 1st 4 character station ID posted under Alternate Weather Data. If that weather station is also unavailable, a second alternate station is used.

The operational MRGCD weather stations are (from north to south), with the alternate station names:

Site Name	ID	1st Alternate	2nd Alternate	3rd Alternate
Pena Blanca	PBLN	eta12.262.170	ANGN	
Angostura	ANGN	eta12.261.168	PBLN	CFMN
Candelaria Farms	CFMN	eta12.259.166	ANGN	LOSL
Jarales	JRLN	eta12.258.161	LOSL	BOYN
Boys Ranch	BOYN	eta12.258.160	JRLN	IHFN
San Acacia	IHFN	eta12.257.158	BOYN	LLZN
Luis Lopez	LLZN	eta12.257.155	BANN	IHFN
North Bosque	BANN	eta12.257.155	LLZN	IHFN

Note in the above table that the Eta model 12 km cell is always the 1st alternate. The x-y cell identification, like 262.170, is a locater in the 12 km grid.

8.2 New Mexico Climate Center

In addition to the MRGCD network, previous day's meteorological data for ET estimation are also obtained via FTP from the New Mexico Climate Center (NMCC) at New Mexico State University. The 24-hr data are received at 4:30 AM and again at 10:30 AM MST to get missing data. The 24-hr precipitation accumulations from these stations (or site IDs if data are missing) are shown in green, preceded by a + sign, on the inter-active AWARDS/ET Toolbox image, and sub-images, on the Internet (figure 4 W). The same table details, and rules for alternate weather data, apply as described above in section 8.1 for MRGCD data.

The NMCC network weather stations are (from north to south), with the alternate station names:

Site Name	ID	Ownership	1st Alternate	2nd Alternate	3rd Alternate
Alcalde Agricultural Science Center	ALCA	NMCC	eta12.265.175	PBLN	
Albuquerque Golf	ABQG	NMCC	eta12.259.166	CFMN	AIRP
Albuquerque Airport	AIRP	NMCC	eta12.260.165	CFMN	ABQG
Los Lunas Agricultural Science Center	LOSL	NMCC	eta12.259.163	JRLN	BOYN
South Bosque	SBOS	MRGCD	eta12.257.154	BANN	LLZN
Elephant Butte	ELFB	USBR	eta12.252.148	SBOS	DERR
Derry Station	DERR	NMCC	eta12.253.145	JORN	ELFB
Jornada Range	JORN	LTER	eta12.256.142	NMSU	HORT
NMSU Golf Course	NMSU	NMCC	eta12.256.140	NWS	HORT
Las Cruces National Weather Service	NWS	NWS	eta12.256.140	HORT	NMSU
Horticultural Experimental Station	HORT	NMCC	eta12.256.140	NMSU	NWS
Leyendecker Plant Science Research Center	LASC	NMCC	eta12.255.139	HORT	NWS
La Union Station	LAUN	NMCC	eta12.257.137	LASC	NWS

8.3 Long-Term Ecological Research

University of New Mexico Long-Term Ecological Research (LTER) Network data are received via FTP at 6:15 AM and again at 10:15 AM MST to get missing data. The 24-hr precipitation accumulations from these stations (or site IDs if data are missing) are shown in blue, preceded by a + sign, on the inter-active AWARDS/ET Toolbox image, and sub-images, on the Internet (figure 4 W). Data from the LTER meteorological stations are not used for the calculation of ET, because the sites generally lie outside the irrigated crop, open water, and the riparian zones. The same table details apply as detailed above in section 8.1 for MRGCD data. However, alternate weather data are not substituted for missing data. Available hourly data are also collected and stored at the above times but are not used or displayed in the AWARDS and ET Toolbox products.

LETR sites (from north to south) are:

Site Name	ID
Bronco Well	45
Red Tank	43
Cerro Montoso Well	42
Deep Well	40
LTER Field Station	01
Rio Salado	44
South Gate Well	41
Blue Springs	48
Five Points	49

8.4 Colorado State University Agricultural and Meteorological Network

Colorado State University Agricultural and Meteorological Network (COAGMET) data are received via FTP at 6:18 AM and again at 10:18 AM MST to get missing data. The 24-hour precipitation accumulations from these stations (or site IDs if data are missing) are shown in blue, preceded by a + sign, on the Upper Rio Grande image accessed from the AWARDS/ET Toolbox home page (figure 1 (W). Data from the COAGMET meteorological stations are not used for the calculation of ET at this time. Expansion of the ET Toolbox into the Upper Rio Grande may occur in the future.

COAGMET sites (from north to south) are:

Site Name	ID
Center, CO	CSU San Luis Valley Res Ctr
Blanca, CO	8 mi SW of Blanca
San Luis, CO	2 mi N of Mesita

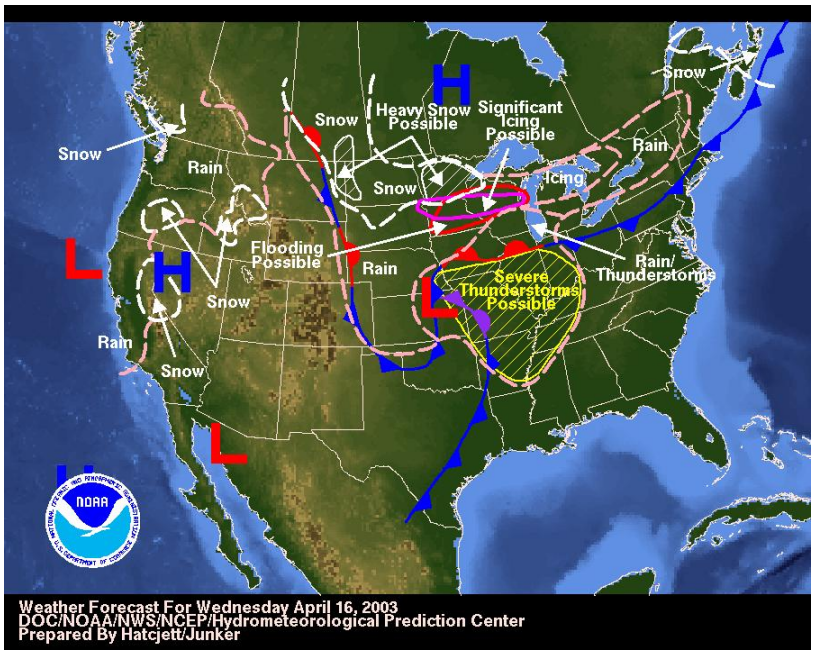
8.5 Automated Surface Observing System

The AWARDS/ET Toolbox system also collects precipitation data from the federal Automated Surface Observing System (ASOS). The 24-hr precipitation accumulations from these stations (or site IDs if data are missing) are shown by pink, preceded by a square, on the inter-active AWARDS/ET Toolbox image and sub-images on the Internet (figure 4 W). An example station name identifier is KGNT. Data from the ASOS sites are not used for the calculation of ET, because these weather stations do not have solar radiation sensors. There are no pop-up data associated with these stations since only precipitation is reported.

ASOS sites (from north to south) are:

Site Name	ID
Santa Fe NM airport	KSAF
Grants-Milan NM airport	KGNT
Albuquerque NM airport	KABQ
Truth Or Consequences NM airport	KTCS
Holloman AFB NM	KHMN
El Paso Tx airport	KELP

9 Weather Forecasting



Example Weather Forecast Map.

9.1 Eta Model

The National Centers for Environmental Prediction (NCEP) Eta model weather forecast parameters at 12-km grid resolution are used for the AWARDS and ET Toolbox ET forecasts for today and the next two days. The Eta model 0600 Universal Time Coordinated (UTC) (11:00 PM MST) run's 3-hr forecasts for temperature, relative humidity, and wind speed, plus the forecast cumulative solar radiation and precipitation for 0600-0600 UTC are used. From the 3-hr forecast values, the computer selects the maximum and minimum temperatures, and calculates the average relative humidity and wind speed. The Eta model-based 24-hr ET forecasts from the previous day are also used when weather station data are unavailable.

The Eta data are collected at 10:00 PM, midnight, and 2:00 AM via FTP. The three attempts are made to assure that missing data are received. These data are acquired for all of the United States west of the Mississippi River, and then clipped for the areas of interest.

An example of the 12-km NCEP grid (Eta cell) for the Middle Rio Grande is shown in figure 23. The x,y numbering system (in red) is used to identify the 12-km grid cells. Each weather station is cross referenced to an Eta cell. In this more detailed example (figure 24) of the Belen North window with topography background, the Los Lunas

(LOSL) weather station is in Eta cell 258,163. However, this is a special case example where Los Lunas is re-assigned to Eta cell 259,163 which has a lower more representative elevation and agricultural/riparian presence. All weather and ET forecasting for the Los Lunas station, and forecast from the previous day if the station data are unavailable for today, are provided by the data from Eta cell 259,163. The Jarales (JRLN) station remains in Eta cell 258,161.

9.2 Quantitative Precipitation Forecasts (QPF)

The NWS 24-hr QPF's are obtained via FTP from the WGRFC eight times a day, and accumulated into a value that is posted onto the ET charts. These QPF values are used nowhere else within the AWARDS/ET Toolbox system.

10 NEXRAD Precipitation Estimates

Radar-based precipitation estimates are used in the AWARDS/ET Toolbox to offset ET demands. Digital data files (in the xmrg format) containing an hourly radar precipitation product are derived from the NEXRAD Hydroview Multisensor Precipitation Estimation System (MPE) program. These (radar and gage) hourly products are produced by the National Weather Service's (NWS) River Forecast Centers (RFCs). For New Mexico, these files are obtained via FTP from the West Gulf River Forecast Center (WGRFC). For additional information, visit the WEB site for the WGRFC at: http://www.srh.noaa.gov/wgrfc/ (W). This (figure 26 W) shows the overlapping radar coverage for NM, TX, OK, and parts of CO and KS. The specific radars used in the AWARDS/ET Toolbox for the Middle Rio Grande are:

KABX	Albuquerque
KFDX	Cannon AFB
KHDX	Holloman AFB
KEPX	El Paso, TX

The location of the Albuquerque radar (KABX) is noted on the west side of the Albuquerque Division (Angostura diversion) (figure 9 W) image.

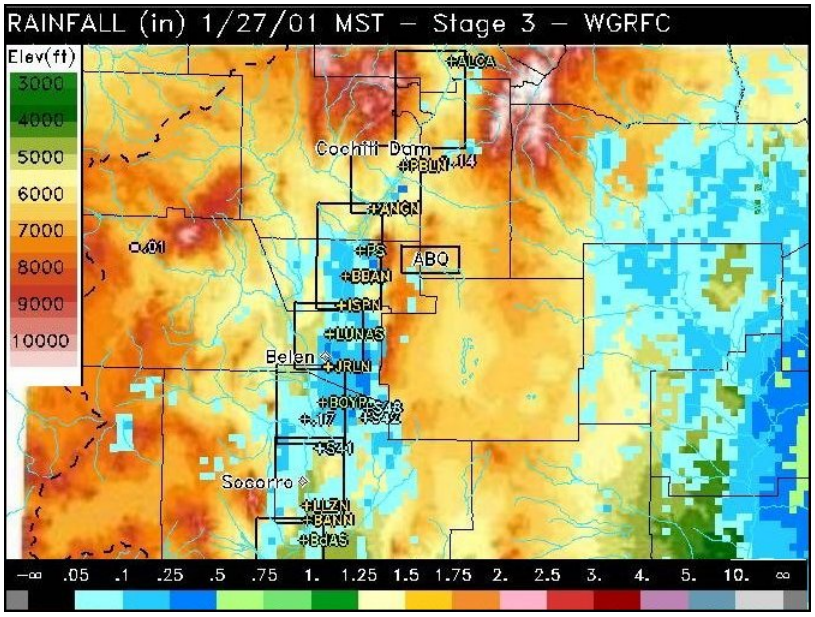
Hourly data from the MRGCD weather stations (section 8.1) are provided to the WGRFC in real-time for their use in developing the MPE product. Radar data obtained from multiple NEXRAD weather surveillance radars that cover the WGRFC's area of responsibility (including the Rio Grande) are quality controlled, adjusted using surface gage measurements, such as those from the MRGCD, and merged into the NWS Hydrologic Rainfall Analysis Project (HRAP) approximate 4 km x 4 km grid.

The AWARDS/ET Toolbox accumulates the hourly MPE developed files (in the xmrg format) into a 24-hr file covering the midnight-midnight MST period. The 24-hr rainfall (average depth) for each HRAP grid cell located over the agricultural, riparian, open water, and urban acreage along the Rio Grande is used in the water use calculations. These precipitation estimates are represented by a color spectrum placed at the bottom of each inter-active ET Toolbox window.

In an AWARDS sub-window, such as this MRGCD Belen North Division (Diversion) AWARDS example (figure 6 W), the non-zero precipitation estimates are posted within each HRAP cell.

These values are not placed into the ET Toolbox windows since they contain consumptive use estimates.

The rainfall in an example ET Toolbox window, (figure 25 W), is represented only by the color spectrum at the bottom of the image. This is an example of the rainfall, represented by the light blue spectrum (.05 inches to .5 inches), on a colored topography image.



Example of radar-based precipitation estimates over the MRGCD area.

11 Effective Rainfall Estimates

The effective precipitation process explained here is not currently used within the ET Toolbox. It is tabulated and appended to the AWARDS ET charts (figure 8 W) for reference only. It is not applied to the ET in the charts. Refer to AWARDS Products (section 6) for more information.

By definition, effective rainfall is that portion of rainfall that contributes to meeting the ET requirement of a crop (ASAE, 1983). Rainfall that neither leaves as surface runoff nor contributes to excess surface drainage may be effective precipitation in the context of irrigation management. Soil types, terrain slope, and soil moisture are not current components of the AWARDS system; therefore this simplified method apparently developed by the Bureau of Reclamation is implemented. The published method bases effective precipitation on increments of monthly rainfall. The AWARDS system uses this monthly process to reduce daily total rainfall into daily effective precipitation (not a scientifically proven assumption). The relationships used are:

Table 1: Effective Rain As A Percent Of Total Rain (r)

Total Rain (in)	Effective Rain (%)
$r < .5$	100
$0.5 \leq r \leq 1.0$	95
$1.0 < r \leq 2.0$	90
$2.0 < r \leq 2.0$	85
$3.0 < r \leq 2.0$	75
$4.0 < r \leq 2.0$	55
$5.0 < r \leq 2.0$	35
$6.0 < r$	5

When future research provides a better method, possibly by using soil types, terrain slope, and remotely sensed soil moisture, then the above will be replaced and used within the ET Toolbox product to more accurately estimate daily water use requirements.

12 Penman Reference ET Calculation

The Modified-Penman Reference ET Equation written in Fortran (figure 27) and most of the crop and riparian coefficients that are used in the ET Toolbox were provided by Dr. Salim Bawazir at the New Mexico State University (NMSU) on March 16, 2000. This is the Penman calculation with evapotranspiration referenced to grass (Eto in inches), as modified by Dr. Ted Sammis at New Mexico State University (1985). This equation requires daily weather data consisting of maximum and minimum temperatures, relative humidity, solar radiation, and wind.

Calculations of Reference ET by other methods, for comparison purposes only, are also done within the AWARDS/ET Toolbox computer, with the results stored in internal files. These methods are:

1. Penman-Monteith Combination
2. 1982 Kimberly-Penman as used in Reclamation's Agrimet Program
3. Modified-Penman referenced to grass, an earlier version (Sammis et al. (1985))
4. American Society of Civil Engineer's (ASCE) Standardized Method based on the ASCE Penman-Monteith Equation - will be in place Spring of 2004

ET

13 AWARDS/ET Toolbox Calculations

13.1 Daily ET

Calculation of daily ET, as applied in the AWARDS system, and Daily Consumptive Use (DCU), as applied in the ET Toolbox, is initially based upon derivation of the Reference ET (Eto) and vegetative or open water coefficient (KC). The coefficient is dependent on either the Growing Degree Days or the Month of the year.

As a general rule, no ET is calculated (it it set to zero) before the start date or after the stop date.

A vegetation or open water coefficient (KC) is applied to the Eto to determine the daily ET in inches using the formula:

$$Daily\ ET = (KC)\ (Daily\ Eto)$$

where Daily Eto is the Reference ET as calculated by the Penman equation. Refer to Penman Reference ET Calculation (section 12). Graphs of coefficients are presented as Growing Degree Days (GDD) or Months. Refer to Veg. and Open Water Coefficients and Related Data (section 14).

13.2 Coefficient (KC)

13.2.1 Coefficient (KC) based on Month

Dr. Jensen (1998) performed a study on open water evaporation for the Lower Colorado River. The monthly coefficients for open water in the Parker Dam to Imperial Dam reach along the Lower Colorado are being used for the Middle Rio Grande. Improved coefficients for open water and wet sands are forthcoming from on-going research studies at Elephant Butte Reservoir. Refer to Open Water Evaporation Estimates (section 16).

Other monthly coefficients from Dr's Jensen's report are used for Marsh, Tree Fruit, Misc. Fruit, Nursery Stock, and Melons.

If coefficients are based on Months, then the KC is interpolated from the curve represented in the graph. For example, a coefficient for open water would be .87 on July 15 (figure 47).

13.2.2 Coefficient (KC) based on Growing Degree Days

If the vegetation or open water coefficient is based on GDD's, then the following is used to find the Growing Degree Days.

The GDD's are accumulated heat that will contribute to plant growth and development from planting to harvest, or bud break to defoliation. The advantage of the GDD method is that the coefficient is dependent on temperature, producing a lower coefficient

in cooler weather and a higher coefficient in warmer weather. The calculated ET is then effected as determined by the above formula (section 13.1).

The average method was chosen in New Mexico (King, et al., 2000) for determination of GDD using:

$$Daily\,GDD = ((daily\,max\,temperature + daily\,min\,temperature)/2) - base\,temperature$$

In the above equation, The daily maximum (max) and minimum (min) temperatures are replaced with cutoff temperatures when the cutoff temperatures are exceeded. An example is Corn with a maximum cutoff temperature of 30 degrees C, and a minimum cutoff temperature of 10 degrees C. If the daily maximum temperature is 32 degrees C, it is reset to the maximum cutoff temperature of 30 degrees C. If the daily minimum temperature is 5 degrees C, it is reset to the minimum cutoff temperature of 10 degrees C.

Refer to the figures in the Veg. and Open Water Coefficients and Related Data (section 14) for the cutoff and base temperatures. If they are not noted in the figures, then they are not applied to the above equation.

A special case exists for riparian vegetation. If the daily maximum temperature is less than the minimum cutoff temperature, then the daily maximum is set to the minimum cutoff. An example is Salt Cedar, with a minimum cutoff of 15.5 degrees C. If the daily maximum is 14 degrees C, it then is reset to 15.5 degrees.

Once the daily GDD is found, this value of GDD is added to the GDD summation to-date. The summation is then applied to the polynominal function, as defined on the graphs, to get the KC.

The daily GDD as calculated above is not allowed to be negative, in which case it is set to zero, thereby rendering the summation of GDD to be static and the KC to be static. The ET will continue to be calculated until the stop date is reached, at which time the ET will be set to zero.

If the stop date is reached before the daily GDD is negative, the ET is set to zero at the stop date.

A further improvement might be to set the ET to zero when the end of the GDD curve is reached, such as 1700 for Corn.

Crop coefficients were taken from King et al. (2000) and Jensen (1998). The coefficients for Salt Cedar and Cottonwood (predominate riparian types) were received from Dr. Salim Bawazir, NMSU (personal correspondence) as a result of extensive field studies in 1999 at the Bosque Del Apache National Wildlife Refuge.

13.3 Daily ET Limits - Special Case

Limits are applied to daily ET calculated at the Luis Lopez weather station. These limits are intended as a short term solution for adjusting high consumptive use in the Socorro,

NM area due to clay soil types, requested by Jim Farmer of the Natural Resources Conservation Center in Socorro. The values (figure 28) are the maximum daily ET in inches allowed at the Luis Lopez weather station, based on month of the year. No limits are applied here for omitted vegetation or when there are no values in the table represented in the figure.

13.4 Vegetative and Open Water Daily Consumptive Use (DCU) - ET Toolbox Only

Computer processes were developed to collect all of the required data sets and calculate the Daily Consumptive Use (DCU) in acre feet for each vegetative type (or open water) within each HRAP grid cell using:

$$Vegetative\,type\,DCU = (Daily\,ET)(Acres)/12$$

where Acres is the vegetative or open water acreage of the grid cell. Refer to GIS Land and Open Water Classification (section 15).

13.5 Total Grid Cell DCU - ET Toolbox Only

All of the acre feet values are summed to arrive at an estimated consumptive use for each grid cell. The NEXRAD estimated daily accumulated rainfall (in acre feet) is then subtracted.

$$Total\,Grid\,Cell\,DCU = Sum\,of\,Vegetative\,type\,DCU's - Rainfall$$

13.6 River Reach and Diversion DCU) - ET Toolbox Only

All of the grid cell totals are summed for each river reach and diversion.

$$River\,Reach\,DCU = Sum\,of\,Total\,Grid\,Cell\,DCU\,values\,within\,the\,river\,reach.$$

$$Diversion\,DCU = Sum\,of\,Total\,Grid\,Cell\,DCU\,values\,within\,the\,diversion.$$

13.7 DCU Values in Cubic Feet Per Second - ET Toolbox Only

The DCU values in acre feet per day are also converted to flow in cubic feet per second (cfs) for use by water managers and in the URGWOM, where:

$$cfs = acre\,feet/1.98347$$

Toolbox.

14 Veg. and Open Water Coefficients and Related Data

The following four tables separate the classifications into Agriculture, Riparian, Open Water, and Urban. The start (plant) and stop (harvest) dates are used as beginning and ending points in the ET calculations. No ET is calculated before the start date or after the stop date. Current classification sources are the 1992/93 Land Use Trend Analysis (LUTA) and 2000 IKONOS (IKONOS). See section 15.

Clicking on a FIG (figure), within the four tables, provides an x-y plot of the coefficients (KC) vs the Growing Degree Days (GDD) or Month, including a tabulation of the data. If a GDD plot, the polynomial function, cutoff temperatures, and base temperature are also provided. The cutoff temperatures are not applied if they are not provided. Refer to ET Toolbox Calculations (section 13) for more information on how these data are used.

The vegetation classifications with "None" dates are currently not used in the ET Toolbox because they were not classified within LUTA or IKONOS. All other classifications with real dates are used in the ET Toolbox. Note that the IKONOS is used only in River Reach 7.

The LUTA classifications of Bosque, Riparian Shrub, and Riparian Woodland use an average of the Cottonwood and Salt Cedar coefficients, except in May, June, and July when the coefficient is set to 1.00. This was suggested by Dr. Salim Bawazir of the New Mexico State University.

Numerous classifications do not have developed coefficients. In these cases, substitute coefficients are used until research is completed. Example: The Corn coefficients are used for Chili Peppers. It is extremely difficult to pick the appropriate substitution especially with the riparian classifications that have mixtures of vegetations. Improvements to these coefficients will greatly enhance the accuracy of water use estimates.

Table 2: Agricultural Classifications

AGRICULTURAL	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Alfalfa	29	-	Jan. 1	Oct. 20	LUTA
Chile Peppers	30	Corn	Apr. 29	Nov. 20	LUTA
Corn	30	-	Apr. 29	Nov. 20	LUTA
Cotton	31	-	None	None	None
Grapes	32	-	Apr. 1	Oct. 20	LUTA
Melons	33	-	Apr. 1	Sep. 1	LUTA
Misc. Fruit	34	-	Jan. 1	Dec. 31	LUTA
Misc. Vegetables	30	Corn	Apr. 29	Nov. 20	LUTA
Nursery Stock	35	-	Jan. 1	Dec. 31	LUTA
Oats	42	Spring Barley	Apr. 10	Aug. 10	LUTA
Pasture Grass	44	Turf-Park	Mar. 15	Oct. 20	LUTA
Pecan 1000*	36	-	None	None	None
Pecan 2000*	37	-	None	None	None
Pecan 3000*	38	-	None	None	None
Pecan 4000*	39	-	None	None	None
Pinto Beans	40	-	None	None	None
Sorghum	41	-	May 17	Dec. 20	LUTA
Spring Barley	42	-	None	None	None
Tree Fruit	43	-	Jan. 1	Dec. 31	LUTA
Wheat†	45	-	Apr. 10	Aug. 10	LUTA
Wheat>1300 GDD†	46	-	Apr. 10	Aug. 10	LUTA

*(1000, 2000, 3000, and 4000 are tree trunk diameter (cm) x number of trees per hectare)
†(when the Growing Degree Days sum exceeds 1300, the Wheat>1300 GDD is used)

Table 3: Riparian Classifications

RIPARIAN	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Bosque*	48	-	Apr. 5	Nov. 21	LUTA
Cottonwood	49	-	Apr. 5	Nov. 21	IKONOS
Cottonwood Bosque	49	Cottonwood	Apr. 5	Nov. 21	IKONOS
Cottonwood/RO/WM†	49	Cottonwood	Apr. 5	Nov. 21	IKONOS
Cottonwood/SC/WM‡	49	Cottonwood	Apr. 5	Nov. 21	IKONOS
Grassland	49	Cottonwood	Mar. 15	Oct. 20	IKONOS
Marsh	51	-	Jan. 1	Dec. 31	LUTA
Misc. Grass	44	Turf-Park	Jan. 1	Dec. 31	LUTA
Riparian Shrub	48	Bosque	Apr. 5	Nov. 21	LUTA
Riparian Woodland	48	Bosque	Apr. 5	Nov. 21	LUTA
Russian Olive/WL¶	49	Cottonwood	Apr. 5	Nov. 21	IKONOS
Salt Cedar	50	-	Apr. 5	Nov. 21	LUTA
Salt Cedar/RO/WM†	50	Salt Cedar	Apr. 5	Nov. 21	IKONOS
Salt Cedar/WL¶	50	Salt Cedar	Apr. 5	Nov. 21	IKONOS
Shrubland	49	Cottonwood	Apr. 5	Nov. 21	IKONOS
Sparce Vegetation	49	Cottonwood	Mar. 15	Oct. 20	IKONOS
Willow	49	Cottonwood	Apr. 5	Nov. 21	IKONOS
Wetland	51	Marsh	Jan. 1	Dec. 31	IKONOS

*(An average of Cottonwood and SaltCedar, except 1.0 in May, June, and July)
†(RO = Russian Olive/WM = Willow Mix)
‡(SC = Salt Cedar/WM = Willow Mix)
¶(WL = Woodland)

Table 4: Open Water Classifications

OPEN WATER	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Open Water	47	-	Jan. 1	Dec. 31	LUTA
Water or Wet Soil	47	Open Water	Jan. 1	Dec. 31	IKONOS

Table 5: Urban Classifications

URBAN	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Turf-Golf	44	Turf-Park	Mar. 15	Oct. 20	None
Turf-Park	44	-	Mar. 15	Oct. 20	LUTA
Urban Irrigation	44	Turf-Park	Mar. 15	Oct. 20	LUTA

15 GIS Land and Open Water Classification

River front near the Bosque riparian research site.

Several Geographic Information System (GIS) vegetation data sets that cover portions of the area were evaluated. The Middle Rio Grande Land Use Trend Analysis (LUTA) GIS data base for 1992/93 is the current land use resource for URGWOM river reaches 1-5 (from Cochiti Dam to the San Acacia Diversion Dam). Data from a 1998 Bureau of Reclamation riparian vegetation classification were used for river reach 6 (from San Acacia to San Marcial). Reach 6 also includes the Middle Rio Grande Conservancy District's Socorro Division, and the Bosque del Apache National Wildlife Refuge. An IKONOS satellite GIS was used for river reach 7, which is the area from San Marcial to Elephant Butte reservoir. The GIS data were transposed to the nominal 4 km x 4 km HRAP grid cell resolution for use in the ET Toolbox with the NEXRAD-based 24-hr rainfall estimates. An important component of the ET Toolbox is determination of the vegetative growth acreage of agricultural crops, riparian vegetation, and open water in each of the 4 km x 4 km HRAP grid cells. These data are then applied to the empirically derived ET to produce a daily volumetric water requirement for each HRAP cell. Refer to ET Toolbox Calculations (section 13).

Additional year 2002 riparian GIS efforts by both the Utah State University (USU) and the Endangered Species (ES) Collaborative Program are now available. Comparisons of the LUTA, IKONOS, USU, and ES have been made and are available from the AWARDS/ET Toolbox staff.

There is a need to develop a methodology for updating the GIS vegetation and open water indexing data to detect changes and update the ET Toolbox at least once during each annual growing season. The constraints are that the technology used must by cost permissive, timely, and sufficiently accurate (e.g. 90%) for use in water resources management.

15.1 River Reaches 1-5 (LUTA)

The Middle Rio Grande Water Assessment - Middle Rio Grande Land Use Trend Analysis Geographic Information System Data Base - Supporting Document Number 13 (1997) - for 1992/93 was chosen for river reaches 1-5. This GIS data base contains the most currently available analysis performed within these upper reaches of the river system from Cochiti Dam to San Acacia Dam.

The purpose of the LUTA was to identify and quantify land use trends in the Albuquerque basin, New Mexico, over the last 58 years on those lands that significantly impact groundwater resources. Historic and current aerial photography and 1992 Landsat Thematic Mapper satellite imagery were used as primary sources for compiling the LUTA GIS database. Reclamation and the City of Albuquerque identified four periods of time for the LUTA: 1935, 1954/55, mid 1970's, and 1992/93. A GIS database was constructed for each of the four time periods, and divided into four segments, one each for the counties of Sandoval, Bernalillo, Valencia, and Socorro.

Coverages from the LUTA GIS were transformed to the 4 km x 4 km HRAP grid cells using GIS tools provided by members of the Civil, Agricultural, and Geological Engineering Department at the New Mexico State University. Results, which were first separated into the four counties, were merged and placed into files acceptable to the ET Toolbox computer programs. Approximately 127 HRAP grid cells from the LUTA are included in the ET Toolbox for reaches 1-5.

15.2 River Reach 6 (USBR, MRGCD, BdA)

River reach 6 includes the area from San Acacia Dam to the San Marcial gage below the Bosque del Apache Wildlife Refuge. A Reclamation aerial photography GIS study completed in 1999 is used to get the riparian growth classification for this reach. Agricultural acreage for San Acacia Dam to the northern edge of the Bosque del Apache is assumed to be 23% of the entire Middle Rio Grande Conservancy District, using a mean of 1985 through 1997, as suggested by district personnel. Personnel at the Refuge provided agricultural acreage for the Refuge. For simplicity, the LUTA portion of Socorro county that extends into reach 6 was ignored. Reach 6 added 31 HRAP grid cells to the study.

The total of 158 HRAP grid cells, at approximately 4,000 acres each, provides ET Toolbox coverage to about 632,000 acres through reach 6.

15.3 River Reach 7 (IKONOS)

The riparian component of an IKONOS satellite 4-metar multi spectral resolution land use data set from July 2000 is used in the ET Toolbox for river reach 7 commencing in 2002. The riparian IKONOS was acquired from the MRGCD and the New Mexico

Interstate Stream Commission. This IKONOS riparian GIS study was limited to areas within the riverside drains; therefore it can not be used throughout the ET Toolbox range from Cochiti Dam to San Marcial gage. (reaches 1 through 6).

16 Open Water Evaporation Estimates

The evaporation from open water and wet sands contributes significantly to the water depletion in the Middle Rio Grande valley. Research is underway to determine and measure the evaporative demand by using LIght Detection And Ranging (LIDAR) and other technologies. A consortium of groups and programs are at work on this research, consisting of the Bureau of Reclamation, Los Alamos National Labs, New Mexico State University, Utah State University, University of Iowa, and others. A year long effort was initiated in 2001 on Elephant Butte reservoir to determine the actual evaporation off the lake surface. A tower was constructed and instrumented, and the Los Alamos Raman LIDAR was on the lake in September 2001 to determine the extent of the measurements by the tower instrumentation. The similar Tamarisk Research Study was accomplished to provide water use planners with long-term evapotranspiration estimates, methods, and models to predict the consumptive use of water by saltcedar and cottonwood.

The results of these research programs should provide a means of determining an evaporative demand. Real-time reservoir area based on height versus surface area tables can then be used in the calculation of daily evaporative use.

Meanwhile, coefficients developed by Dr. Jensen (1998) on open water evaporation for the Lower Colorado River in the Parker Dam to Imperial Dam reach are used for the Middle Rio Grande.

17 Interface with RiverWare

ET Toolbox files for each river reach (currently 7) are available for the URGWOM team to access at around 6:45 AM MST each day. The river reach boundaries are listed in the following table.

River Reach 1	Cochiti Dam gage to San Felipe gage
River Reach 2	Jemez River gage below Jemez Canyon Dam
River Reach 3	San Felipe gage to Central Avenue gage
River Reach 4	Central Avenue gage to Bernardo gage
River Reach 5	Bernardo gage to San Acacia gage
River Reach 6	San Acacia gage to San Marcial gage (includes the Bosque Del Apache)
River Reach 7	San Marcial gage to north end of Elephant Butte Reservoir
River Reach 8	North end of Elephant Butte to gage below Elephant Butte Dam (future)

These ET Toolbox files contain HRAP cell-by-cell daily rainfall (inches), and consumptive use values (acre-feet) for all agricultural, riparian, and urban vegetation classifications, and the open water classification for the day. To get the net water use requirement, the rainfall must be converted to acre-feet and subtracted from the consumptive use. Refer to AWARDS/ET Toolbox Calculations (section 13) for more information.

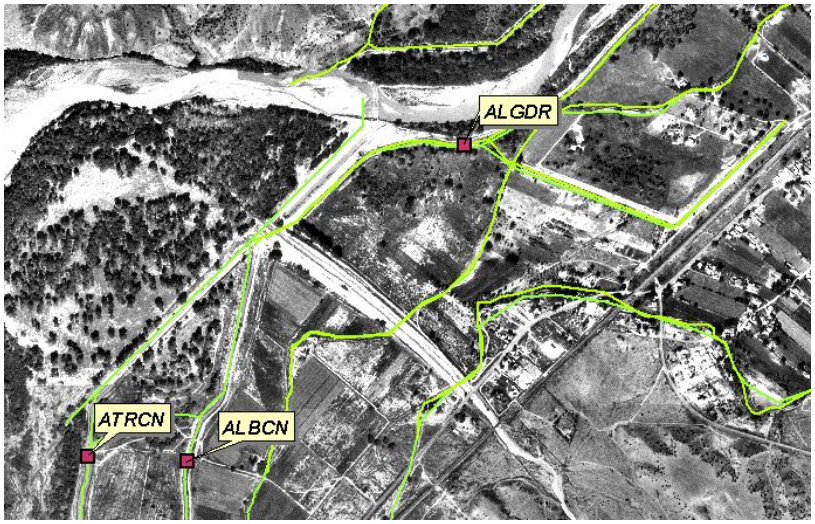
A sample ET Toolbox file (figure 52 W) is shown here. It contains all data for the first HRAP grid cell (108x313) in River Reach 3 for the month of January. (The Internet version shows all data for the current year.) The data for the last three lines under each grid cell are forecast values based on the National Center for Environmental Prediction (NCEP) 12-km grid Eta model.

Here (figure 53 W) is a description of the ET Toolbox file.

These ET Toolbox files are not available from the website, therefore no web address is provided here. They are internal files used in the computer system, and made available daily for use by the URGWOM team. The above two figures exist in this document only for information purposes - they are not intended to be accessed by the casual user of the ET Toolbox.

The tasks of developing the Data Management Interfaces (DMIs) between the ET Toolbox files, the Hydrologic Engineer Center - Data Storage System (HEC-DSS), and RiverWare were accomplished by the URGWOM team. Please contact the URGWOM team for information on how these provided data are used in the RiverWare Model.

18 Stream Flow Data



Gage Station Products in the Angostura Dam Area.

As an enhancement to the ET Toolbox, users at the Middle Rio Grande Conservancy District and USBR requested near real-time graphs and text of stream flow conditions throughout the valley. This allows direct comparison of consumptive use estimates and stream flow, considering an approximate five day lag for water released at Cochiti Dam to arrive at the San Marcial gage. District personnel developed schematics of the diversions and return flows.

The stream flow information is acquired from the MRGCD stream gage network. Two data sets are received.

The first set is MRGCD managed gage station and USBR pumping station data transmitted from the gage to the district office via radio telemetry. These data are for the top of the hour and at 30 minutes after the hour. This set is then automatically received into the ET Toolbox from the MRGCD office via FTP at 15 and 45 minutes past each hour.

The second set is USGS managed gage station data received at the district office via the US Corps of Engineers who get it from the USGS. These USGS data are provided in 15-minute intervals, but to be consistent with the MRGCD data which are in 30-minute intervals, the minute 15 and 45 are ignored. The USGS data is automatically received into the ET Toolbox from the MRGCD office via FTP at 20 minutes after each of the following hours: midnight, 4:00 AM, 8:00 AM, noon, 4:00 PM, and 8:00 PM.

The gage naming criteria differ between the MRGCD, USBR, and USGS managed stations. The following sub sections define these criteria.

18.1 MRGCD Stream Flow Data

The MRGCD uses a three character gage name followed by DV (diversion), CN (canal), DR (drain), WW (waste way), UP (Rio Grande above Isleta Dam), DN (Rio Grande below Isleta Dam), and XC (cross section). An example MRGCD gage is CORCN.

Following is a table of the MRGCD gage stations. Some data are missing because they were not provided by the district or the gages are not yet installed. The type code d+h means that both discharge (d), in cfs, and height or stage (h) in feet, are reported.

Name	Type	Latitude	Longitude	Long Name	Description
ALGDR	d+h	35.379	106.496	Algodones Riverside Drain	Return flow from Cochiti Division along east side, empties into Atrisco Feeder, not in to river
ALBCN	d+h	35.370	106.505	Albuquerque Main Canal	Diversion from river to east side at Angostura Dam
ATFCN	d+h	35.370	106.509	Atrisco Feeder Canal	Diversion from river to east side at Angostura Dam
ANGDV	d+h			Total Angostura Diversion	ALGDR+ALBCN+ATFCN
CORCN	d+h	35.276	106.602	Corrales Main Canal	Flow carried in siphon from Atrisco Feeder on east side to west side, no diversion or return
SANWW	d+h	35.227	106.591	Sandia Lakes Wasteway	Return flow to river, excess bled off east side canals
UCRDR	d+h	35.205	106.641	Upper Corrales Drain Outfal	Return flow to river from Corrales area canals
CORWW	d+h	35.161	106.674	Corrales Main Wasteway	Return flow to river from Corrales area canals
LCRDR	d+h	35.161	106.674	Lower Corrales Drain Outfall	Return flow to river, very minor
ATSCN	d+h				
CENWW	d+h	35.096	106.688	Central Avenue Wasteway	Return flow to river, excess bled off Atrisco Feeder at intake to Atrisco Siphon
ARMCN	d+h	35.088	106.683	Armijo Acequia	Medium sized ditch feeding old Atrisco area
BERCN	d+h				
ATDCN	d+h	35.087	106.683	Atrisco Ditch	Small ditch feeding old Atrisco area
ARECN	d+h	35.088	106.695	Arenal Main Canal	Large canal feeding southwest Albuquerque/Isleta Pueblo
ALBDR	d+h	35.089	106.676	Albuquerque Drain At Tingley	Flow in eastside drain past Central Avenue, no diversion or return
ARSDR	d+h	34.935	106.679	Albuquerque Drain Outfall	Return flow to river from east side of Albuquerque Division
ATRDR	d+h	34.935	106.685	Atrisco Drain Outfall	Return flow to river from west side of Albuquerque Division
BELCN	d+h	34.899	106.701	Belen Highline Canal At HDG	Diversion from river to west side at Isleta Dam
PERCN	d+h	34.895	106.689	Peralta Main Canal At HDG	Diversion from river to east side at Isleta Dam
CHICN	d+h	34.905	106.683	Chical Lateral At HDG	Diversion from river to east side at Isleta Dam
CHACN	d+h	34.904	106.683	Chical Acequia At Heading	Diversion from river to east side at Isleta Dam
CACCN	d+h	34.902	106.683	Cacique Acequia At Heading	Diversion from river to east side at Isleta Dam
ISLUP	d+h				
ISLDV	d+h			Total Isleta Diversion	BELCN+PERCN+CHICN+CHACN+CACCN=ISLDV for total diversion from river at Isleta Dam
ISLDN	d+h	34.904	106.684	Rio Grande Below Isleta Dam	Flow in river just below Isleta Dam, difficult gaging location, so frequent shifts
240WW	d+h				
PERWW	d+h	34.692	106.741	Peralta Main Wasteway	Return flow to river from east side north of Belen
LP1DR	d+h				
BELDR	d+h				
NBLWW	d+h				
LP2DR	d+h				
FD3WW	d+h	34.571	106.771	Feeder 3 Wasteway	Return flow to river from west side south of Belen
STYWW	d+h				
SABDR	d+h				
SFRDR	d+h				
LSJDR	d+h	34.414	106.794	Lower San Juan Drain Outfall	Return flow to river from east side near mouth of Rio Puerco
UN7DR	d+h	34.265	106.877	Unit 7 Drain At San Acacia	Return flow from west side of Belen Division, empties directly into Socorro Main Canal
SNADV	d+h			Total San Acacia Diversion	SOCCN-UN7DR
SOCCN	d+h	34.254	106.897	Socorro Main Canal Heading	Flow in Socorro Main Canal below San Acacia Dam
SADCN	d+h			San Antonio Ditch At BdA Boundary	
SMSCN	d+h			Socorro Main South At BdA Boundary	
ELMDR	d+h			Elmendorf Drain At BdA Boundary	
SOCDR	d+h			Socorro Drain At BdA Boundary	

18.2 USBR Pumping Stations

Pumping stations managed by the USBR use a three character gage name followed by PS (pumping station). An example pumping station is NCPPS.

Following is a table of the pumping stations. The type code d+h means that both discharge (d), in cfs, and height or stage (h) in feet, are reported.

Name	Type	Description
NCPPS	d+h	Neil Cupp Pumping Station - USBR
NBYPS	d+h	North Boundary Pumping Station - USBR
SBYPS	d+h	South Boundary Pumping Station - USBR
FCRPS	d+h	Fort Craig Pumping Station - USBR

18.3 USGS Stream Flow Data

The USGS uses the Standard Hydrometeorological Exchange Format (SHEF) convention. This is a three character gage name followed by the 1st character of the state name, followed by a number representing the state's alphabetical order. New Mexico (N) is the 5th state (5). Therefore all USGS gages in New Mexico are identified by N5 in the 4th and 5th character positions. Colorado is C2. An example USGS gage is OTWN5.

Following is a table of the USGS gage stations. The type code d+h means that both discharge (d) in cfs and height or stage (h) in feet, are reported. The type code s+e is used for reservoir status gages. It means that both the storage (s) in acre feet and reservoir elevation (e) in feet above sea level, are reported.

Name	Type	Description
RLPN5	d+h	Rio Chama Near La Puente
ELVN5	s+e	El Vado Dam
RCEN5	d+h	Rio Chama Below El Vado
RCAN5	d+h	Rio Chama Above Abiquiu Dam
ABIN5	s+e	Abiquiu Reservoir
AICN5	d+h	Rio Chama Below Abiquiu Dam
LOBC2	d+h	Rio Grande Near Lobatas, CO
EMBN5	d+h	Rio Grande At Embudo
OTWN5	d+h	Rio Grande At Otowi Bridge, Near San Ildefonso,NM
COCN5	s+e	Cochiti Lake
SILN5	d+h	Rio Grande Below Cochiti, Sile, Cochiti Canal
CCCN5	d+h	Rio Grande Below Cochiti, Sile, Cochiti Canal
CTDN5	d+h	Rio Grande Below Cochiti, Sile, Cochiti Canal
SFPN5	d+h	Rio Grande At San Felipe
JECN5	d+h	Jemez River Below Jemez Dam
ABQN5	d+h	Rio Grande At Albuquerque
RFBN5	d+h	Rio Grande Floodway At Bernardo
BNDN5	d+h	Rio Puerco At Bernardo
SNAN5	d+h	Rio Grande Floodway At San Acacia
SMCN5	d+h	San Marcial Conveyance Channel On Rio Grande
SMFN5	d+h	San Marcial Floodway On Rio Grande

18.4 Schematics

All of the data are assembled into text files and plots; in some instances combining data for valley cross sections and operations. These data are best viewed from the MRGCD North and South Schematics, available by clicking on Stream Flow Data from the interactive ET Toolbox window (figure 4 W). This pops-up a Stream Flow Products window (figure 54 W).

From there, click on either of the boxes labeled MRGCD North Schematic (figure 55 W) or MRGCD South Schematic (figure 56 W).

The schematics are updated every 30-minutes, as noted by the posted date and time at the bottom. All times are Mountain Standard Time (MST) throughout the year. The schematics show the inflows and outflows throughout the MRGCD. Green boxes are MRGCD gages, yellow boxes are USGS gages, and orange boxes are USBR pumping stations.

Values posted in the boxes are the latest discharges in cfs. No value in a box means the stream flow gage network has not been established. Clicking on a box with a value, or N/A (Not Available), pops-up a graph containing two charts. This is an example of the Corrales Main Canal (figure 57 W). The bottom chart shows the height (stage) of the gage in feet and the top shows the discharge (stream flow) in cfs. A table to the right of the graph provides the year-to-date gage information (figure 58).

18.4.1 Valley Cross Sections

Valley Cross Sections on the left of the north schematic (figure 55 W) represent river reaches 1,3,4,5,and 6 from Cochiti to San Marcial. An example valley cross section is SFPXC.

Following is a table of the Valley Cross Sections. Note the gages that are totaled for each of the cross sections.

Name	Description	Gages Totaled
CTDXC	Cross Section at Cochiti	SILN5 CCCN5 CTDN5
SFPXC	Cross Section at San Felipe	SFPN5 CMCCN
ABQXC	Cross Section at Albuquerque	ABQN5 ALBDR ATSCN
RFBXC	Cross Section at Bernardo	RFBN5 SFRDR LSJDR
SNAXC	Cross Section at San Acacia	SNAN5 SOCCN
SMCXC	Cross Section at San Marcial	SMFN5 SMCN5

This is an example cross section at San Felipe (figure 59 W).

These cross sections contain summations of individual gages (in some cases both MRGCD and USGS) with a trace for each. The gage information table on the upper right (figure 60) shows the data for each gage, the total, and the daily average. An M means the data for the chart are missing.

The daily consumptive use chart at the bottom allows comparison of stream flow and consumptive use with the forecast consumptive use shown with dashed lines. This is done for all cross sections except San Marcial. The comparable reach summary report is also shown on the right. (figure 14)

18.4.2 Irrigation Diversions

Irrigation diversions on the right of the north schematic (figure 55 W) represent the four district diversion points. This is an example of the Cochiti diversion, named COCDV, (figure 61 W), with a summation of USGS gages at the two canals, SILN5 and CCCN5, below Cochiti Dam.

The gage information table on the right (figure 62) shows the data for each gage, the total, and the daily average.

18.5 Area-Wide Stream Flow Information

Clicking on the upside-down white triangles from the Stream Flow Products window (figure 54 W) pops-up area-wide gage station products. This example (figure 63 W) is of the Alcalde, NM area available by clicking on the top-most upside-down white triangle.

These products were developed before implementation of the schematics. Included in these are plots and tables of some of the same data that are on the schematics, and some reservoir storage and elevation data from the USGS.

Also available from these area-wide images are combinations of stream data for the Rio Chama Operations (RCOPS), Middle Valley Operations (MVOPS), and Middle Valley Flows (MVFLO).

Following is a table of these combinations. Note the gages that are totaled for each of the cross sections.

Name	Description	Gages Totaled
RCOPS	Rio Chama Operations	RLPN5 RCEN5 AICN5 EMBN5 OTWN5
MVOPS	Middle Valley Operations	OTWN5 CTDN5 CCCN5 SILN5 JECN5
MVFLO	Middle Valley Flows	CTDN5 ABQN5 ISLDN RFBN5 SNAN5 SMFN5

Some images of gage locations are also shown.

18.6 Direct Links to USGS Gage Information

Clicking on the correct side-up white triangles found on many of the pop-up windows throughout the AWARDS/ET Toolbox system provides real-time Internet links to USGS gage graphs and text data. An example is available through the Internet at http://waterdata.usgs.gov/nm/nwis/uv/gen_stn_pg?station=08313000 (Rio Grande at Otowi Bridge).

19 Historic ET Toolbox Processing - 1975 to 1998

At the request of the URGWOM team, historic consumptive use values were processed to satisfy a requirement of determining agricultural and riparian water depletions in each of the river reaches. The results of this study were used to calibrate the URGWOM.

Years 1984 through 1998 were processed using a combination of the Alcalde and Los Lunas weather stations. Temperature and relative humidity from the Los Lunas station and solar radiation and wind from the Alcalde station were used to calculate the Penman Reference ET.

Years 1975 through 1983 were processed differently. For these years there were no data from Alcalde, and only temperature and precipitation data were available at Los Lunas. Therefore, a monthly comparison of temperature and precipitation was made with years 1984 through 2000. Daily relative humidity, solar radiation, and wind data from the closest matched month in the period 1984 through 2000 were then used to calculate the Penman Reference ET. An Excel spread sheet has been developed that shows the Los Lunas precipitation and temperature data, and a comparison of monthly precipitation and average temperatures for each year 1975 through 1983, with 1984 through 2000.

Access to the spread sheet is available through the Internet at:

http://www.usbr.gov/pmts/rivers/awards/Nm/NM_LosLunasCOOPdata.htm (W).

Page seven of the spread sheet contains documentation of the procedures used.

Years 1999 through the last most current year used temperature, relative humidity, solar radiation, and wind data from various weather stations for calculating the Penman Reference ET. The stations were assigned to specific 4 km x 4 km HRAP grid cells within each reach:

1999	Reaches 1 and 2	Alcalde
	Reach 3	Rio Grande Nursery (NMCC)
	Reach 4	Los Lunas
	Reach 5	Boy's Ranch
	Reach 6	North Bosque
2000	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura, Rio Grande Nursery, and Albuquerque Golf Course (NMCC)
	Reach 4	Bosque Bar (MRGCD), Rio Grande Nursery, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch
	Reach 6	Luis Lopez, North Bosque, and South Bosque
2001	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura, Rio Grande Nursery, and Albuquerque Golf Course (NMCC)
	Reach 4	Bosque Bar (MRGCD - through Dec 6), Rio Grande Nursery, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch and San Acacia
	Reach 6	San Acacia, Luis Lopez, North Bosque, and South Bosque
2002	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura, Rio Grande Nursery, and Albuquerque Golf Course (NMCC)
	Reach 4	Rio Grande Nursery, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch and San Acacia
	Reach 6	San Acacia, Luis Lopez, North Bosque, and South Bosque
	Reach 7	South Bosque
2003	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura and Candelaria Farms
	Reach 4	Candelaria Farms, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch and San Acacia
	Reach 6	San Acacia, Luis Lopez, North Bosque, and South Bosque
	Reach 7	South Bosque

Occasionally data from weather stations were not available. In these cases interim substitutions were made while repairs were underway, or permanent replacements were made if new or nearby stations were available.

In all historic processing through 1998, only weather station precipitation data were used since NEXRAD data were not collected for the ET Toolbox until 1999. The historic data posted on the website for 1999 through the last most complete year uses NEXRAD precipitation. This is an important item to note when comparing 1975 through 1998 precipitation data with 1999 through current year precipitation data.

Numerous reruns of the historic ET Toolbox processing for 1975 through 1998 have occurred. The more recent was in February 2003 to correct problems with the agricultural acreage and precipitation in reach 6.

For these historic calculations, the vegetative acreage from the 1992/93 LUTA for

reaches 1 through 5 were used, as well as the combinations of data sources for reach 6. Refer to GIS Land and Open Water Classification (section 15).

The same crop coefficients and Penman Reference ET Equation were used. The only variance from year-to-year was the weather data.

The year 2001 ends on December 6 due to the Department of the Interior shutdown of Internet communications.

Access to these historic data is via the inter-active AWARDS/ET Toolbox image (figure 4 W). From there click a small white square box attached to the left side of a window. An example is the MRGCD Albuquerque Division (Angostura diversion) (figure 9 W). From there, as an example, click on "Historic River Reach 3 Summary", which will pop-up a directory of historic ET Toolbox files. The user can select any year from 1975 to present.

20 Data Flow - Computer Processing

There are many data sets used in the ET Toolbox that are acquired either hourly or daily through the use of C-SHELL scripts. These scripts are run on a Sun Sunblade 2000 Computer Workstation using the Solaris 9 UNIX operating system. The computer is located in the Bureau of Reclamation's Technical Service Center, Water Resources Services Division, at the Denver Federal Center, Lakewood, Colorado. The scripts call various computer programs written mostly in FORTRAN, although some C and Python programming is also used. The data acquisition and management of the NEXRAD data is not documented here (possibly in the future).

Abbreviations used in the flow diagrams are:

WX	Weather Station
Web	World-Wide Web (Internet)
FTP	File Transfer Protocal
SHEF	Standard Hydrologic Exchange Format
WGRFC	West Gulf River Forecast Center
Eta	A weather forecast model run from the National Center for Environmental Prediction
ET	Evapotranspiration
NEXRAD	NEXt generation RADar
DOS	Disk Operating System

Click on the following subjects to access flow diagrams of the function of each major script, called program, and related data flow. These figures are not available on the website.

Weather (Forecast and Real-Time)
(figure 64 figure 65 figure 66 figure 67 figure 68 figure 69)

Gage (Real-Time Stream Flow and Reservoir Status)
(figure 70 figure 71)

ET Toolbox (Reference ET, Crop ET, ET Charts, ET Toolbox, Plotting)
(figure 72 figure 73 figure 74 figure 75 figure 76 figure 77 figure 78)

Miscellaneous (Acres Processing and Reporting, and other processing)
(figure 79 figure 80 figure 81 figure 82 figure 83 figure 84 figure 85 figure 86 figure 87 figure 88)

A more detailed document is being developed for the ET Toolbox program developers and managers to help guide them through the complex operation of the computer system.

21 ET Toolbox Research

Future ET Toolbox research could include studies to:

1. Implement daily open water calculations with actual daily areal extent updates (the FLO-2D model is under consideration).
2. Revise evaporation demands based on results of open water field studies.
3. Improve the riparian vegetation ET coefficients and make other equation changes based on the results of the ET field studies.
4. Determine if adding soil moisture fields from Land Surface Models and observations, and soil types and slope, can be used in the ET Toolbox to improve the efficiency of water management.
5. Improve estimates of effective precipitation using soil types and slope, and soil moisture.
6. Improve the situation analysis matrix with predicted stream flow data.
7. Install additional weather stations in critical ET demand areas.
8. Implement a field scheduling component based on real-time soil moisture monitoring, soil types, and plant growth, to improve irrigation delivery demands.
9. Access and use real-time ground water level information for integration into a system-wide water balance feature.
10. Improve the Stream Flow Schematics to include greater datail and missing data.

AWARDS/ET Toolbox Computer

22 References

1. American Society of Agricultural Engineers (ASAE), 1983:
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2. Jensen, M.E., 1998:
   Coefficients for Vegetative Evapotranspiration and Open Water Evaporation for the Lower Colorado River Accounting System. Report prepared for the U.S. Bureau of Reclamation, Boulder City, Nevada.
3. King, J.P., A.S. Bawazir, and T.W. Sammis, 2000:
   Evapotranspiration Crop Coefficients as a Function of Heat
   Units for Some Agricultural Crops in New Mexico. Technical Completion Report for Project No. 01-4-23955, New Mexico State University
4. Sammis, T.W., C.L. Mapel, D.G. Lugg, R.R. Lansford, J.T. McGuckin, 1985:
   Evapotranspiration Crop Coefficients
5. Predicted Using Growing Degree Days. Transactions of the ASAE (American Society of Agricultural Engineers) 28(3), pp. 773-780.

23 FIGURES

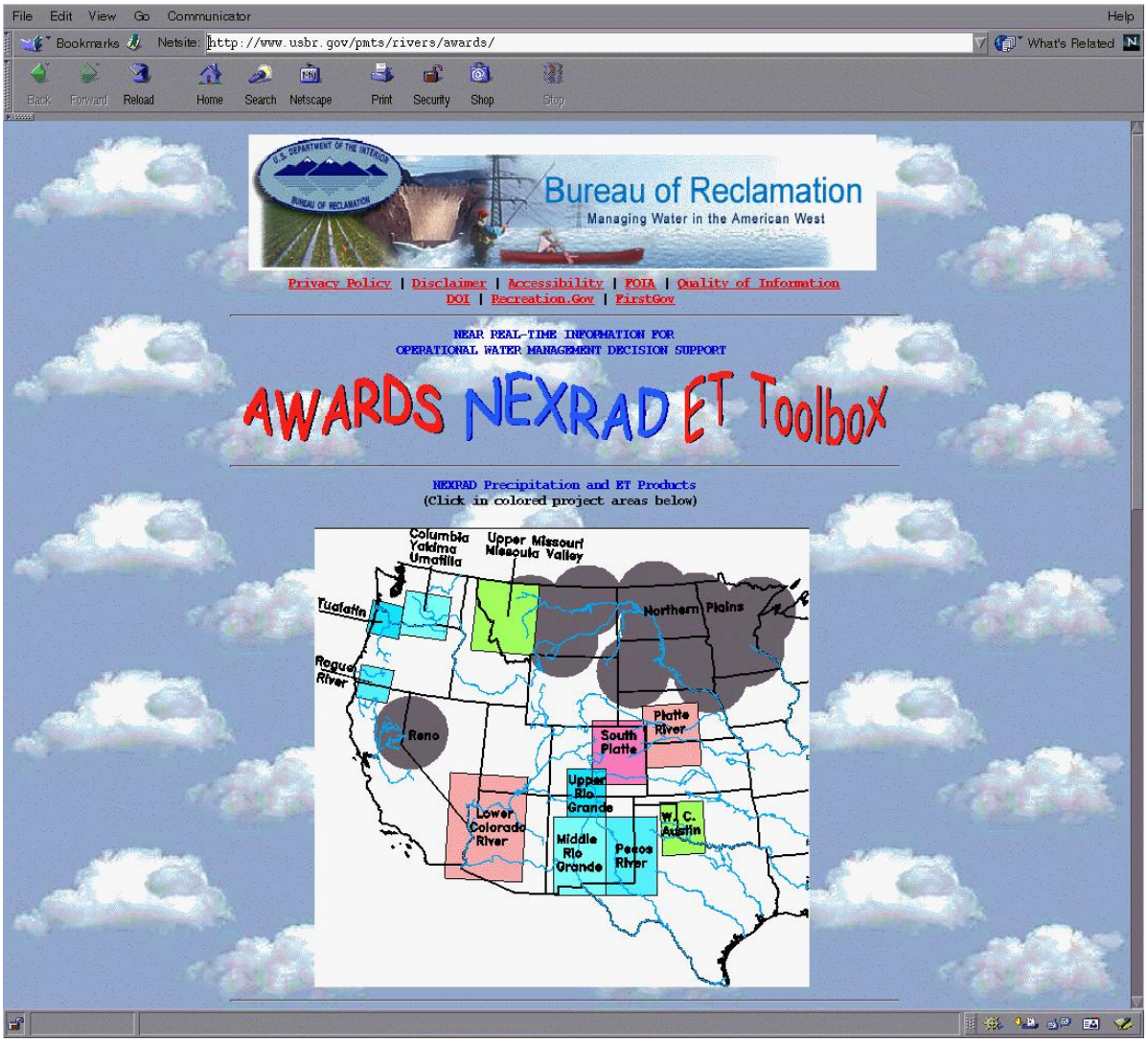

Figure 1: ET Toolbox Home Page

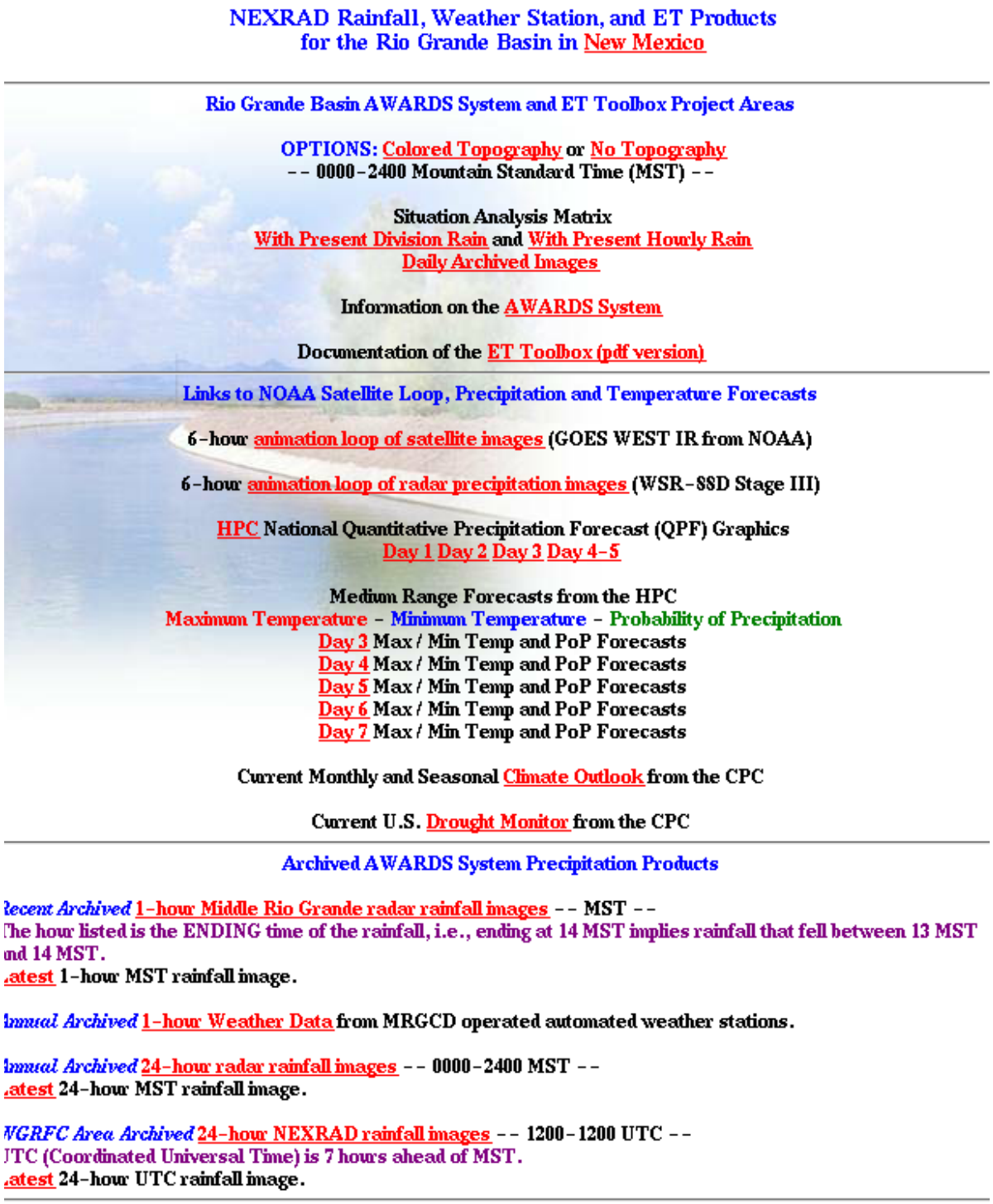

Figure 2: New Mexico ET Products Menu

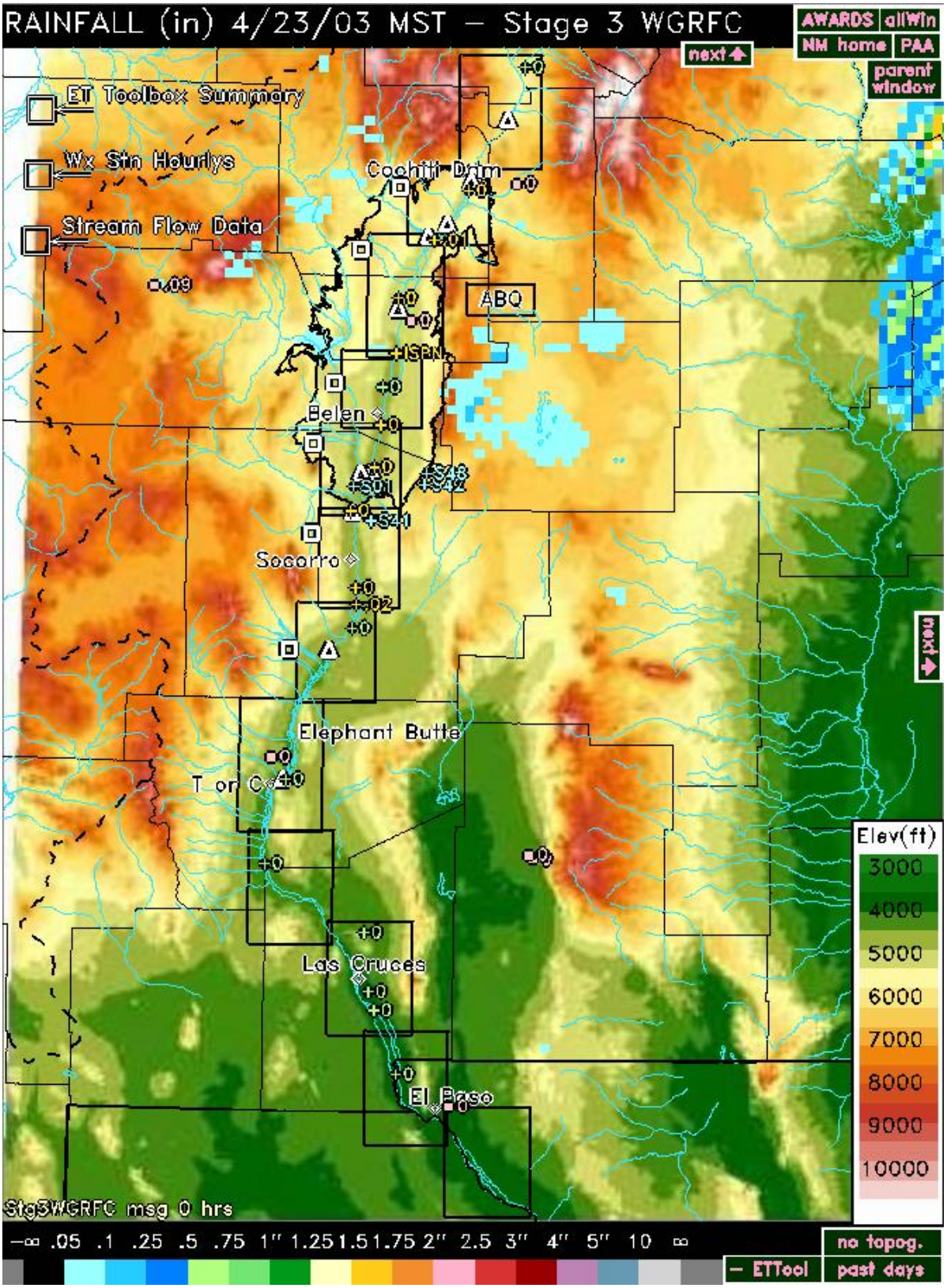

Figure 3: Colored Topography Inter-active AWARDS/ET Toolbox Image

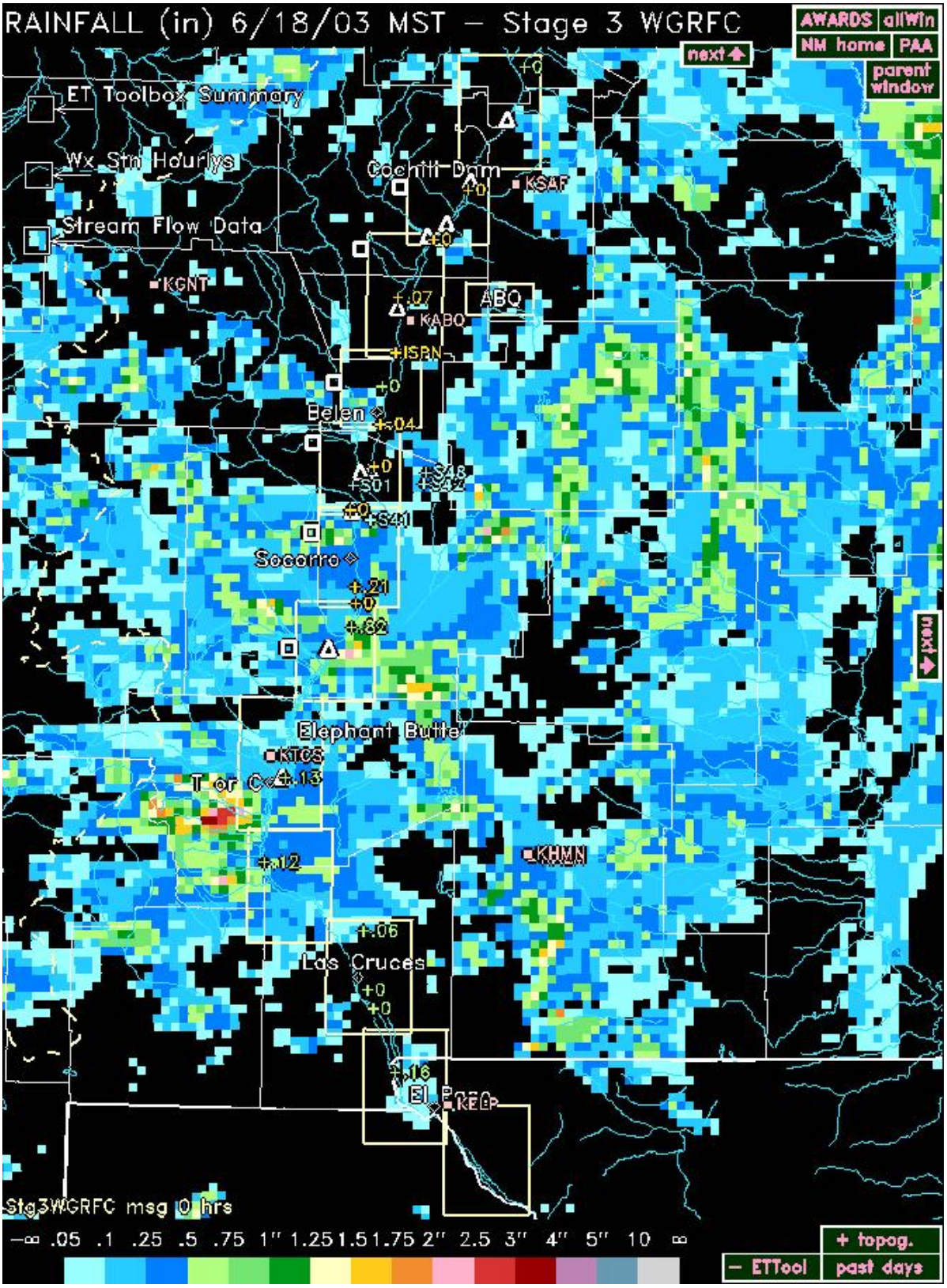

Figure 4: No Topography Inter-active AWARDS/ET Toolbox Image

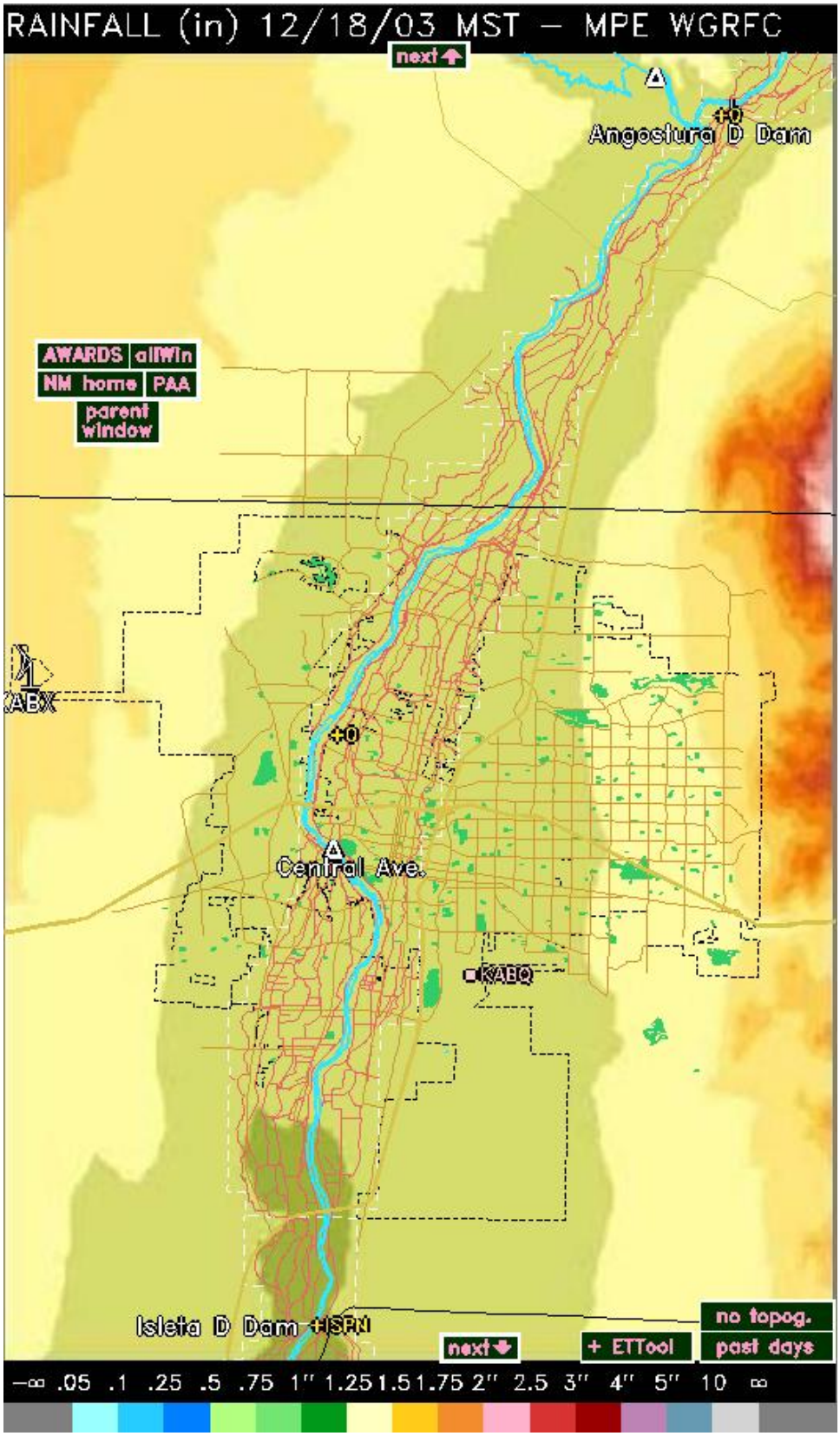

Figure 5: MRGCD Albuquerque Division (Diversion) - AWARDS

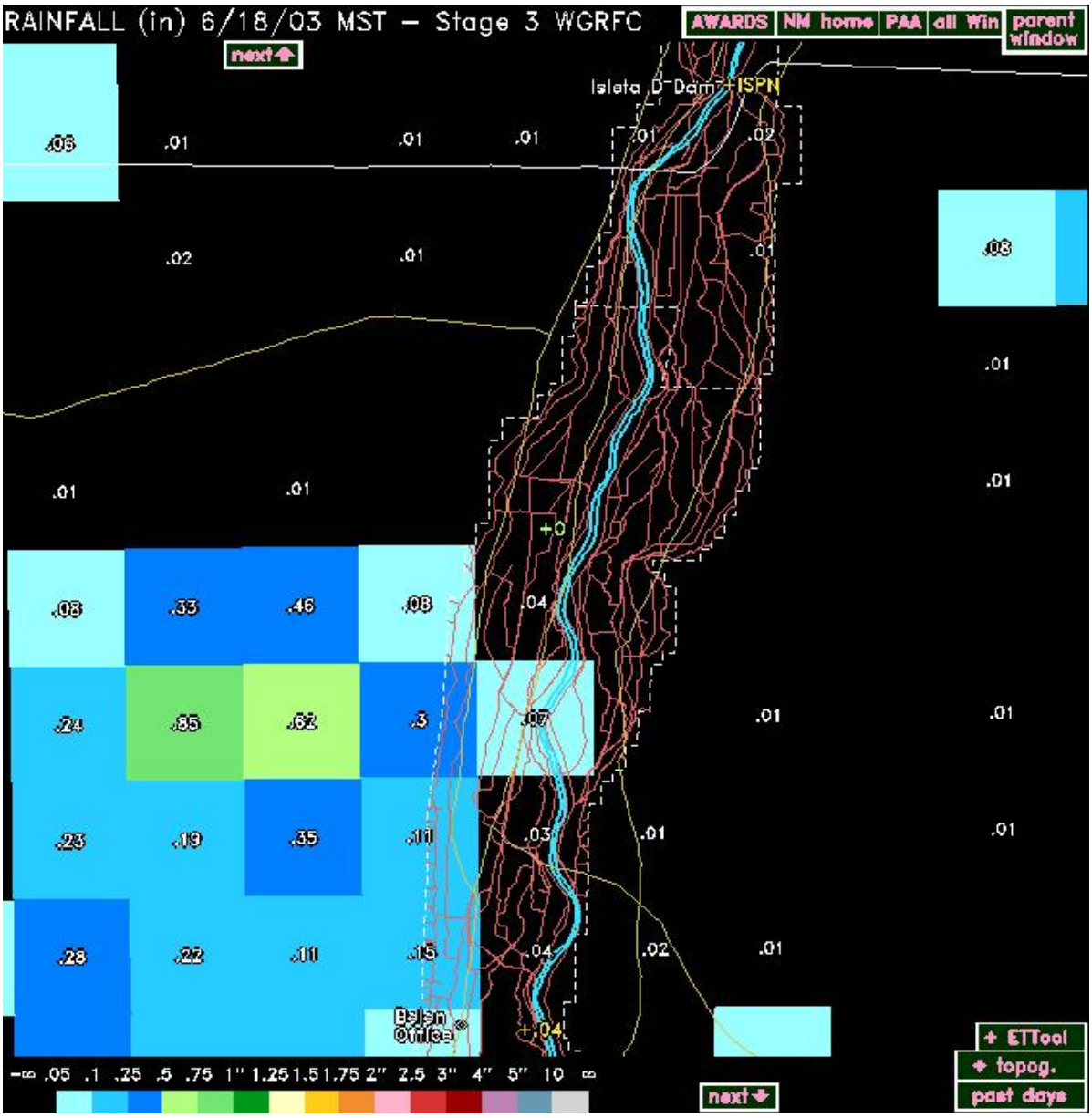

Figure 6: MRGCD Belen North Division (Diversion) - AWARDS

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Oct 15, 03 13:05 **CFMN.txt** Page 1/1

```
Candelaria Farms Station - MRGCD                    - Weather Data - 2003
 Name: CFMN
 Elev. 4971 ft                 Oct    Oct    Oct    Oct    Oct    Oct    Oct
 Lat.  35.134                    8      9     10     11     12     13     14
 Lon. 106.679                  ----   ----   ----   ----   ----   ----   ----
    Max. Temp. (F)             66.0   82.0   78.0   78.0   74.0   77.0   70.0
    Min. Temp. (F)             57.0   44.0   55.0   49.0   41.0   41.0   31.0
    Avg. Wind  (Mi/Hr)          2.3    1.3    1.9    1.9    0.5    3.8    1.1
    Rel. Hum.  (%)             77.0   62.5   70.0   65.0   67.0   57.5   55.5
    Rain       (In)            0.08   0.00   0.10   0.00   0.00   0.00   0.00
    Solar Rad. (Mj/Sq m)       4.70  13.40  13.70  17.20  17.00  17.10  16.90

     ============================
     | Gage Monthly Total Rain: |                    Alternate Data Key
     |    January    0.02       |                    ---------------------
     |    February   0.86       |                    eta == 12 km eta model
     |    March      1.71       |                    [123] == eta forecast day
     |    April      0.04       |                    T == eta Temperature
     |    May        0.07       |                    W == eta Wind
     |    June       0.12       |                    H == eta Humidity
     |    July       0.09       |                    R == eta Rain
     |    August     0.43       |                    r == nexrad radar Rain
     |    September  0.34       |                    S == eta Solar Radiation
     |    October    1.02       |                    ???? == weather station
     ============================


                         Daily Weather Data and Reference ET
    Month  Day  Max.  Min.    Avg.   Rel.  Rain    Solar      Penman    Alternate
                Temp  Temp    Wind   Hum.          Radiation  Ref. ET   Weather
                (F)   (F)   (Mi/Hr)  (%)   (In)    (Mj/Sq m)   (In)     Data
                |--[T]---|    [W]    [H]   [Rr]       [S]
    -----  ---  ----  ----  --------  ----  ----    ---------  -------   ---------
    Oct     14  70.0  31.0    1.1    55.5  0.00     16.90      0.15
    Oct     13  77.0  41.0    3.8    57.5  0.00     17.10      0.19
    Oct     12  74.0  41.0    0.5    67.0  0.00     17.00      0.14
    Oct     11  78.0  49.0    1.9    65.0  0.00     17.20      0.17
    Oct     10  78.0  55.0    1.9    70.0  0.10     13.70      0.13
    Oct      9  82.0  44.0    1.3    62.5  0.00     13.40      0.14
    Oct      8  66.0  57.0    2.3    77.0  0.08      4.70      0.03     eta1TWHrS
    Oct      7  72.0  47.0    1.8    74.0  0.77      6.20      0.05
    Oct      6  82.0  41.0    0.5    60.5  0.00     18.50      0.18
    Oct      5  80.0  59.0    2.5    39.5  0.00     21.30      0.23     eta1TWHrS
    Oct      4  66.0  57.0    3.2    60.0  0.00      8.00      0.08     eta1TWHrS
    Oct      3  72.0  60.0    2.6    27.5  0.07      8.60      0.12     eta1TWHrS
    Oct      2  82.0  55.0    3.9    49.5  0.00     15.00      0.19
    Oct      1  83.0  48.0    1.6    58.0  0.00     19.40      0.20
    Sep     30  89.0  65.0    4.3    16.0  0.00     23.40      0.32     eta1TWHrS
    Sep     29  91.0  44.0    0.9    56.0  0.00     19.90      0.22
    Sep     28  85.0  46.0    1.1    59.0  0.00     20.50      0.21
    Sep     27  85.0  42.0    1.3    52.5  0.00     20.90      0.22
    Sep     26  87.0  42.0    0.7    56.5  0.00     21.40      0.22
    Sep     25  80.0  51.0    2.6    61.0  0.00     18.60      0.19
    Sep     24  86.0  46.0    1.4    56.5  0.00     17.50      0.19
    Sep     23  83.0  45.0    2.0    55.5  0.00     19.30      0.20
    Sep     22  84.0  36.0    1.3    51.5  0.00     21.20      0.22
    Sep     21  85.0  62.0    2.1    24.5  0.00     25.50      0.29     eta1TWHrS
    Sep     20  85.0  58.0    4.9    27.0  0.00     24.00      0.31     eta1TWHrS
    Sep     19  79.0  50.0    3.4    31.5  0.00     25.40      0.28     eta1TWHrS
    Sep     18  79.0  58.0    5.2    25.0  0.00     25.70      0.31     eta1TWHrS
    Sep     17  86.0  58.0    7.4    20.5  0.00     25.80      0.37     eta1TWHrS
    Sep     16  88.0  63.0    5.9    23.0  0.00     26.00      0.36     eta1TWHrS
    Sep     15  86.0  58.0    5.5    35.0  0.00     24.60      0.31     eta1TWHrS
    Sep     14  76.0  57.0    4.9    47.0  0.00     25.70      0.27     eta3TWHrS
    Sep     13  85.0  62.0    2.6    25.0  0.00     26.30      0.30     eta2TWHrS
    Sep     12  80.0  42.0    2.1    61.5  0.00     23.40      0.23
    Sep     11  74.0  51.0    3.1    64.5  0.00     22.20      0.21
    Sep     10  76.0  52.0    3.1    71.5  0.15     10.90      0.11
```

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Figure 7: MRGCD Daily Weather Data

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Oct 21, 03 11:10 **BELS.JRLN.100.288.txt** Page 1/1

Jarales – So. of Belen, NM – MRGCD
ESTIMATED CROP WATER USE – OCTOBER 21, 2003

CROP	START DATE	DAILY CROP WATER USE-(IN) PENMAN ET – OCT 17	18	19	20	FORECAST PENMAN ET OCT 21	OCT 22	OCT 23	TERM DATE	SUM ET	7 DAY USE	14 DAY USE
Alfalfa	101	0.14	0.13	0.15	0.14	0.00	0.00	0.00	1020	64.4	1.0	1.8
PastGrass	315	0.12	0.11	0.13	0.12	0.00	0.00	0.00	1020	40.0	0.9	1.5
Sorghum	517	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1220	25.9	0.0	0.0
Wheat	410	0.00	0.00	0.00	0.00	0.00	0.00	0.00	810	13.0	0.0	0.0
Corn	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1120	34.7	0.0	0.0
Chili Pep	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1020	34.7	0.0	0.0
Grapes	401	0.15	0.14	0.16	0.16	0.00	0.00	0.00	1020	28.2	1.1	1.9
Urban Irr	315	0.12	0.11	0.13	0.12	0.00	0.00	0.00	1020	40.0	0.9	1.5
Park/Golf	315	0.12	0.11	0.13	0.12	0.00	0.00	0.00	1020	40.0	0.9	1.5
Rip. Wood	405	0.08	0.07	0.08	0.07	0.09	0.09	0.09	1121	46.9	0.6	1.1
Salt Cedar	405	0.09	0.08	0.09	0.08	0.11	0.10	0.10	1121	42.0	0.7	1.3
Rip. Shrub	405	0.08	0.07	0.08	0.07	0.09	0.09	0.09	1121	46.9	0.6	1.1
Marsh	101	0.11	0.10	0.11	0.10	0.12	0.12	0.12	1231	71.2	0.8	1.5
Open Water	101	0.16	0.15	0.17	0.16	0.21	0.20	0.20	1231	58.5	1.1	2.0
Misc Grass	315	0.14	0.13	0.15	0.14	0.00	0.00	0.00	1020	46.2	1.0	1.8
Melons	401	0.00	0.00	0.00	0.00	0.00	0.00	0.00	901	37.8	0.0	0.0
Tree Fruit	101	0.15	0.15	0.17	0.16	0.21	0.20	0.20	1231	54.4	1.1	2.0
Nursery St	101	0.15	0.15	0.17	0.16	0.21	0.20	0.20	1231	54.4	1.1	2.0
Oats	410	0.00	0.00	0.00	0.00	0.00	0.00	0.00	810	19.9	0.0	0.0
Misc Fruit	101	0.15	0.15	0.17	0.16	0.21	0.20	0.20	1231	54.4	1.1	2.0
Misc Vegs	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1020	34.7	0.0	0.0
Bosque	405	0.08	0.07	0.08	0.07	0.09	0.09	0.09	1121	46.9	0.6	1.1
Cottonwood	405	0.07	0.06	0.07	0.06	0.08	0.07	0.07	1121	29.6	0.5	0.9

					QPF	
NEXRAD HRS AVAIL	24	24	24	24		QPF valid until:
TOTAL RAIN	0.00	0.00	0.00	0.00	0.00	5am MST OCT 22
EFFECTIVE RAIN	0.00	0.00	0.00	0.00	0.00	

NEXRAD MONTHLY TOTAL RAIN:

JANUARY	0.00
FEBRUARY	0.25
MARCH	0.17
APRIL	0.04
MAY	0.00
JUNE	0.29
JULY	0.14
AUGUST	1.05
SEPTEMBER	1.00
OCTOBER	1.42

(100x288)

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Figure 8: ET Chart

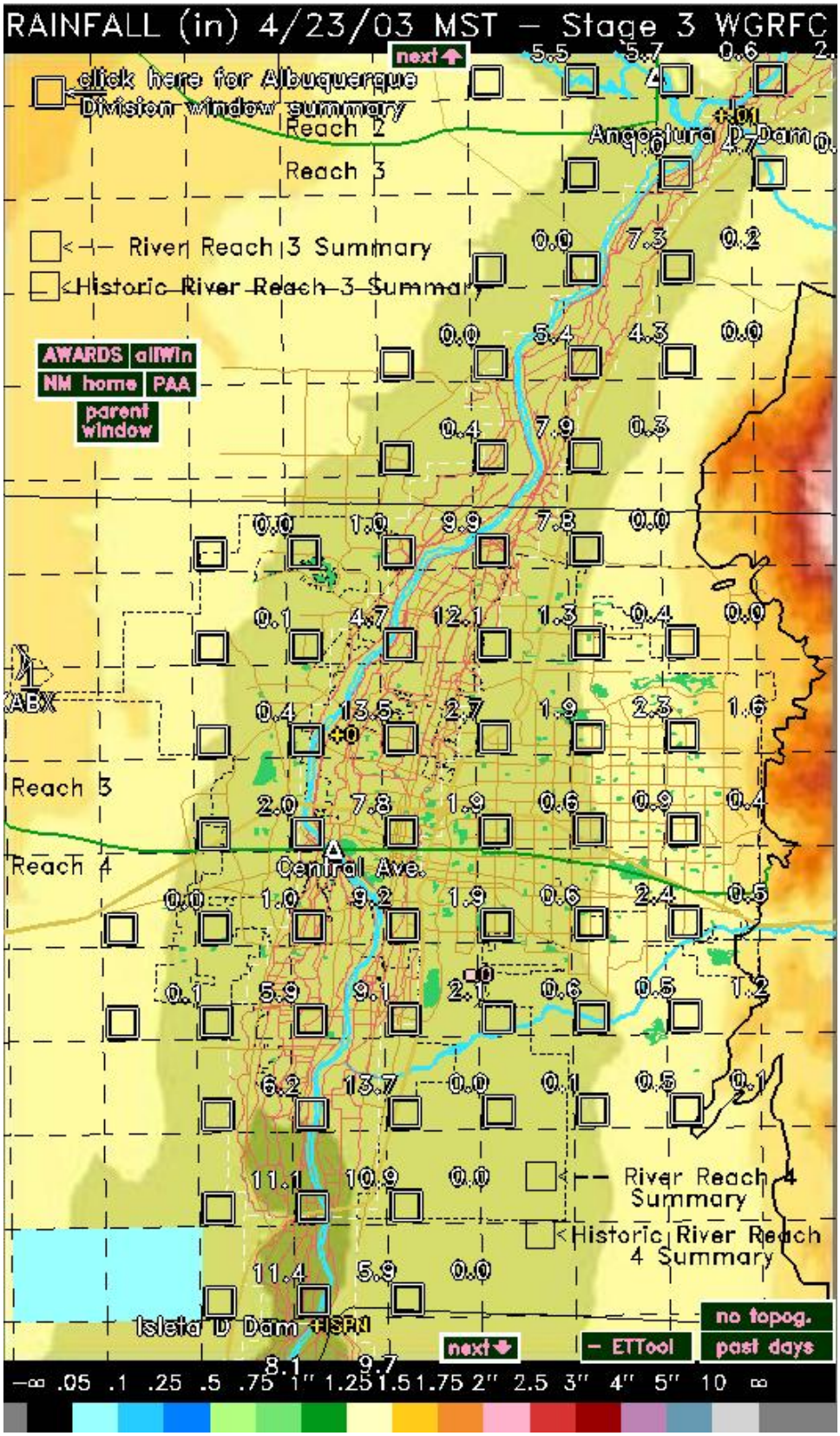

Figure 9: MRGCD Albuquerque Division (Diversion) - ET Toolbox - Numbers in cells are the daily URGWOM water use in acre-feet.

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Apr 24, 03 10:24 **GABQ.etsum.103.305.txt** Page 1/1

ET TOOLBOX CELL SUMMARY (UNDER DEVELOPMENT)

Window named: Greater Albuquerque

Cell number: 103x305

Vegetation classification: LUTA 1992/93

Weather station: Candelaria Farms Station - MRGCD

ET TOOLBOX classes (ag. + rip. + open water + urb.): 1803.0 acres

(Daily URGWOM Water Use = Daily Consumptive Use Total - Rain)

2003 Month	Day	F M	Daily Consumptive Use Total CFS	Agriculture CFS	Riparian CFS	Open Water CFS	Urban CFS	Daily Rain CFS	Daily URGWOM Water Use Total CFS	5-Day Avg. CFS	10-Day Avg. CFS	Total URGWOM Water Use To-Date Since Jan. 1, 2003 AC-FT
Apr.	26	E	15.4	7.1	3.2	3.1	1.9	0.0	15.4	12.3	11.5	568.5
Apr.	25	E	14.3	6.6	3.1	2.8	1.8	0.0	14.3	11.2	10.9	537.9
Apr.	24	E	12.2	5.6	2.6	2.5	1.5	0.0	12.2	10.7	10.2	509.6
Apr.	23		6.8	3.2	1.4	1.4	0.8	0.0	6.8	10.4	9.9	485.4
Apr.	22		12.6	5.8	2.7	2.6	1.5	0.0	12.6	10.8	10.3	471.9
Apr.	21		10.0	4.5	2.2	2.1	1.2	0.0	10.0	10.7	10.0	447.1
Apr.	20		12.0	5.6	2.4	2.5	1.5	0.0	12.0	10.6	9.9	427.2
Apr.	19		10.7	4.9	2.3	2.2	1.4	0.0	10.7	9.7	9.4	403.5
Apr.	18		8.6	4.0	1.8	1.8	1.1	0.0	8.6	9.5	9.1	382.3
Apr.	17		12.0	5.6	2.4	2.5	1.5	0.0	12.0	9.8	9.1	365.2
Apr.	16		9.5	4.4	1.9	2.0	1.2	0.0	9.5	9.2	8.6	341.3
Apr.	15		7.6	3.5	1.5	1.6	1.0	0.0	7.6	9.1	8.4	322.6
Apr.	14		9.5	4.4	1.9	2.0	1.2	0.0	9.5	9.2	8.6	307.5
Apr.	13		10.6	4.9	2.1	2.3	1.4	0.0	10.6	8.8	8.4	288.7
Apr.	12		9.0	4.2	1.7	1.9	1.2	0.0	9.0	8.3	8.2	267.7
Apr.	11		9.0	4.2	1.7	1.9	1.2	0.0	9.0	8.0	8.0	249.9
Apr.	10		7.8	3.7	1.3	1.8	1.1	0.0	7.8	7.6	8.1	232.2
Apr.	9		7.8	3.7	1.3	1.8	1.1	0.0	7.8	8.0	8.0	216.7
Apr.	8		7.7	3.7	1.3	1.7	1.1	0.0	7.7	8.0	8.1	201.2
Apr.	7		7.7	3.7	1.3	1.7	1.1	0.0	7.7	8.2	8.0	186.0
Apr.	6		7.2	3.4	1.3	1.6	1.0	0.0	7.2	8.1	7.6	170.7
Apr.	5		9.7	4.6	1.5	2.2	1.4	0.0	9.7	8.5	7.5	156.4
Apr.	4		7.7	3.9	0.9	1.8	1.2	0.0	7.7	8.1	7.3	137.3
Apr.	3		8.7	4.3	1.0	2.1	1.3	0.0	8.7	8.2	7.3	122.1
Apr.	2		7.2	3.7	0.8	1.7	1.1	0.0	7.2	7.8	7.1	104.9
Apr.	1		9.2	4.6	1.1	2.2	1.4	0.0	9.2	7.2	7.1	90.6
Mar.	31		7.6	3.8	0.9	1.8	1.2	0.0	7.6	6.5	6.9	72.4
Mar.	30		8.2	4.0	0.9	2.0	1.2	0.0	8.2	6.5	6.1	57.5
Mar.	29		6.9	3.5	0.8	1.6	1.1	0.0	6.9	6.4	0.4	41.3
Mar.	28		3.9	2.0	0.4	0.9	0.6	0.0	3.9	6.5	-0.6	27.6
Mar.	27		5.9	2.9	0.6	1.4	0.9	0.0	5.9	7.0	-6.3	19.8
Mar.	26		7.5	3.8	0.8	1.8	1.2	0.0	7.5	7.2	-6.4	8.2
Mar.	25		7.7	3.9	0.8	1.8	1.2	0.0	7.7	5.7	-7.2	-6.6
Mar.	24		7.4	3.8	0.8	1.8	1.2	0.0	7.4	-5.7	-7.4	-21.9
Mar.	23		6.6	3.3	0.7	1.6	1.1	0.0	6.6	-7.7	-7.8	-36.6
Mar.	22		6.9	3.5	0.7	1.7	1.1	0.0	6.9	-19.7	-8.0	-49.7
Mar.	21		2.9	1.5	0.3	0.7	0.5	3.0	-0.1	-20.1	-8.3	-63.4
Mar.	20		4.0	2.0	0.4	1.0	0.6	53.1	-49.1	-20.1	-8.0	-63.2
Mar.	19		1.0	0.6	0.1	0.2	0.2	3.8	-2.8	-9.1	-2.8	34.1
Mar.	18		2.9	1.5	0.3	0.7	0.5	56.2	-53.2	-7.9	-2.2	39.7
Mar.	17		4.8	2.4	0.4	1.2	0.8	0.0	4.8	3.7	3.5	145.1
Mar.	16		2.4	1.2	0.2	0.6	0.4	2.3	0.1	3.4	3.3	135.6
Mar.	15		5.7	2.9	0.5	1.4	0.9	0.0	5.7	4.0	3.5	135.4
Mar.	14		3.3	1.6	0.3	1.4	0.0	0.0	3.3	3.6	3.2	124.0
Mar.	13		4.4	2.1	0.4	1.9	0.0	0.0	4.4	3.5	3.0	117.4
Mar.	12		3.4	1.6	0.3	1.5	0.0	0.0	3.4	3.3	2.8	108.7
Mar.	11		3.3	1.6	0.3	1.4	0.0	0.0	3.3	3.1	2.7	101.8
Mar.	10		3.4	1.6	0.3	1.5	0.0	0.0	3.4	3.0	2.5	95.3
Mar.	9		3.0	1.5	0.3	1.3	0.0	0.0	3.0	2.8	2.2	88.5
Mar.	8		3.1	1.5	0.3	1.4	0.0	0.0	3.1	2.5	2.0	82.6
Mar.	7		2.7	1.3	0.2	1.2	0.0	0.0	2.7	2.4	0.4	76.5
Mar.	6		3.0	1.5	0.2	1.3	0.0	0.0	3.0	2.2	0.1	71.1
Mar.	5		2.1	1.0	0.2	1.0	0.0	0.0	2.1	1.9	-1.3	65.3
Mar.	4		1.9	1.0	0.1	0.8	0.0	0.0	1.9	1.5	-1.3	61.1
Mar.	3		2.2	1.1	0.1	1.0	0.0	0.0	2.2	1.5	-1.2	57.3
Mar.	2		2.0	1.0	0.1	0.9	0.0	0.0	2.0	-1.5	-1.2	52.9
Mar.	1		1.3	0.6	0.1	0.6	0.0	0.0	1.3	-2.1	-3.5	49.0

Irrigated Ag acreage = 705.5
Riparian acreage = 681.4 (Includes Bosque)
Open Water acreage = 233.3
Urban acreage = 182.8
Total (ag. + rip. + open water + urb.) = 1803.0 acres

Fallow acreage = 2.7
Idle acreage = 70.5

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Figure 10: Grid Cell Summary

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ET TOOLBOX CELL DETAILS (UNDER DEVELOPMENT)

Greater Albuquerque

Vegetation classification: LUTA 1992/93

Cell number: 103x305

Weather station: Candelaria Farms Station − MRGCD

Last 7 and 3 Forecast Day's URGWOM Water Use in Acre−Feet (CFS)

Consumptive Use

Crop	Acres	2003 Apr. 23	Apr. 24	Apr. 25	Apr. 26	Apr. 27	Apr. 28	Apr. 29	Forecast Apr. 30	May 1	May 2
Alfalfa	377.4	3.8	5.3	6.0	6.6	6.3	5.7	6.9	8.8	8.5	9.1
PastGrass	262.6	2.4	3.5	3.9	4.2	3.9	3.5	4.4	5.5	5.0	5.5
Sorghum	40.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grapes	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban Irr	141.4	1.3	1.9	2.1	2.2	2.1	1.9	2.4	3.0	2.7	3.0
Park/Golf	41.4	0.4	0.6	0.6	0.6	0.6	0.6	0.7	0.9	0.8	0.9
Rip. Wood	24.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
Rip. Shrub	20.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
Marsh	62.7	1.0	1.5	1.6	1.7	1.6	1.5	1.8	2.3	2.1	2.3
Open Water	233.3	2.7	3.9	4.3	4.7	4.5	3.9	4.9	6.2	5.8	6.4
Misc Grass	24.5	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.6	0.6
Tree Fruit	3.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nursery St	3.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Oats	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc Vegs	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosque	549.8	1.4	2.3	2.8	2.8	2.8	2.8	3.2	4.1	4.1	4.6
Totals	1803.0	13.5	19.6	22.1	23.6	22.6	20.4	25.1	31.8	30.2	32.9
		(6.8)	(9.9)	(11.2)	(11.9)	(11.4)	(10.3)	(12.7)	(16.1)	(15.3)	(16.6)
Agricul.	705.5	6.3	9.0	10.1	10.9	10.4	9.3	11.5	14.5	13.7	14.8
		(3.2)	(4.5)	(5.1)	(5.5)	(5.2)	(4.7)	(5.8)	(7.3)	(6.9)	(7.5)
Riparian	681.4	2.8	4.3	5.0	5.1	5.0	4.8	5.7	7.3	7.1	7.9
		(1.4)	(2.2)	(2.5)	(2.6)	(2.5)	(2.4)	(2.9)	(3.7)	(3.6)	(4.0)
Open Water	233.3	2.7	3.9	4.3	4.7	4.5	3.9	4.9	6.2	5.8	6.4
		(1.4)	(2.0)	(2.2)	(2.4)	(2.3)	(2.0)	(2.5)	(3.1)	(2.9)	(3.2)
Urban	182.8	1.7	2.4	2.7	2.9	2.7	2.4	3.0	3.8	3.5	3.8
		(0.8)	(1.2)	(1.4)	(1.5)	(1.4)	(1.2)	(1.5)	(1.9)	(1.8)	(1.9)
NEXRAD											
Rainfall Est.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
URGWOM											
Water Use		13.5	19.6	22.1	23.6	22.6	20.4	25.1	31.8	30.2	32.9
		(6.8)	(9.9)	(11.2)	(11.9)	(11.4)	(10.3)	(12.7)	(16.1)	(15.3)	(16.6)

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Figure 11: Grid Cell Detail

ET Summary Products (To–Date)
Reach 3

OPTIONS:

Table

Plot of last 18 and 3 forecast days – Total, Agriculture, Riparian, Open Water, and Urban – also Rain

Plot of last 18 and 3 forecast days – Total and Running Averages – also Stream gage

Click on red for Daily Agricultural Crop ET Rates – Total 7085 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Alfalfa	2819	Chili Peppers	34	Corn	252	Grapes	13
Melons	18	Misc. Fruit	5	Misc. Vegetables	124	Nursery Stock	167
Oats	19	Pasture grass	3246	Sorghum	129	Tree Fruit	259

Click on red for Daily Riparian ET Rates – Total 6747 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Bosque	5922	Marsh	86	Misc. Grass	311	Rip. Shrub	276
Rip. Woodland	152	-----	-----	-----	-----	-----	-----

Click on red for Daily Open Water ET Rates – Total 1952 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Open Water	1952	-----	-----	-----	-----	-----	-----

Click on red for Daily Urban ET Rates – Total 2502 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Parks and Golf Irrigation	1883	Urban Irrigation	619	-----	-----	-----	-----

Figure 12: ET Summary Products Menu - Reach 3

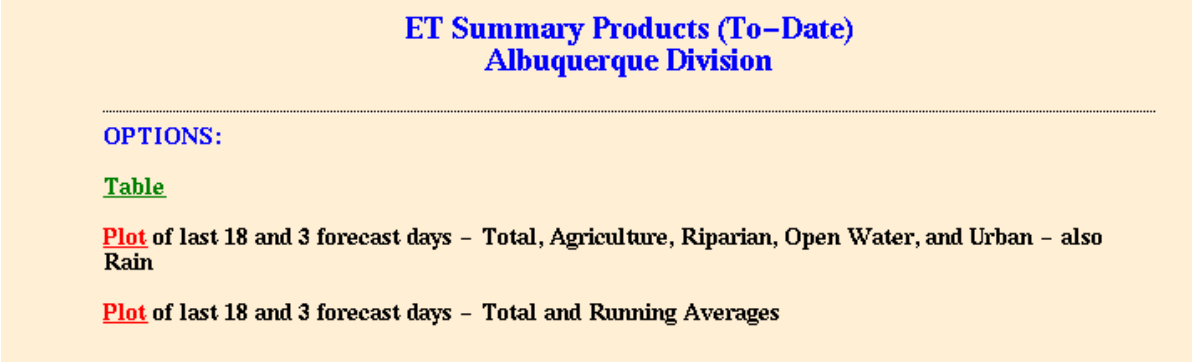

Figure 13: ET Summary Products Menu - Albuquerque Division

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ET TOOLBOX REACH SUMMARY (UNDER DEVELOPMENT)

Summary for: URGWOM Reach 3 (San Felipe to Cent. Ave. gage)

Vegetation classification: LUTA 1992/93

ET TOOLBOX classes (ag. + rip. + open water + urb.): 18286.1 acres

(Daily URGWOM Water Use = Daily Consumptive Use Total − Rain)

2003 Month	Day	F M	Daily Consumptive Use Total CFS	Agriculture CFS	Riparian CFS	Open Water CFS	Urban CFS	Daily Rain CFS	Daily URGWOM Water Use Total CFS	5-Day Avg. CFS	10-Day Avg. CFS	Total URGWOM Water Use To-Date Since Jan. 1, 2003 AC-FT	Daily Flow Difference Total CFS	5-Day Avg. CFS	10-Day Avg. CFS
Sep.	20	E	183.9	70.5	70.2	22.2	21.1	0.0	183.9	196.4	183.0	60033.7	None	None	None
Sep.	19	E	169.4	64.9	65.3	20.1	19.1	0.0	169.4	197.4	162.7	59669.6	None	None	None
Sep.	18	E	183.9	70.5	70.2	22.2	21.1	0.0	183.9	193.8	141.2	59334.1	240	157	160
Sep.	17		224.6	85.9	86.2	27.1	25.4	0.0	224.6	194.9	134.4	58970.0	161	109	159
Sep.	16		220.4	84.6	85.2	26.3	24.4	0.0	220.4	186.5	121.5	58525.3	181	99	167
Sep.	15		188.5	72.7	71.9	22.6	21.2	0.0	188.5	169.5	111.1	58088.8	205	111	165
Sep.	14		151.7	58.7	56.3	18.1	18.7	0.0	151.7	128.0	104.1	57715.7	None	114	163
Sep.	13		189.3	73.2	72.8	22.2	21.2	0.1	189.3	88.6	102.7	57415.3	None	162	188
Sep.	12		182.8	70.5	70.9	21.4	20.1	0.0	182.8	73.9	98.7	57040.6	112	209	214
Sep.	11		135.5	52.2	52.8	15.6	14.8	0.4	135.1	56.5	96.2	56678.7	239	234	225
Sep.	10		70.7	27.2	27.3	8.6	7.5	89.3	−18.6	52.7	99.8	56411.2	219	219	213
Sep.	9		70.9	27.3	26.6	8.6	8.3	116.5	−45.6	80.1	118.5	56448.1	244	212	193
Sep.	8		141.5	54.5	55.5	16.4	14.9	25.9	115.6	116.7	133.1	56538.4	231	214	192
Sep.	7		128.7	49.7	50.0	15.2	13.8	32.5	96.1	123.5	130.5	56309.5	239	219	181
Sep.	6		117.5	45.6	46.1	14.0	11.9	1.5	116.0	135.8	124.4	56119.1	163	216	190
Sep.	5		120.9	47.3	47.8	14.0	11.9	2.6	118.3	147.0	127.4	55889.4	184	208	199
Sep.	4		137.7	54.1	53.6	16.0	14.0	0.1	137.7	157.0	134.0	55655.2	255	174	205
Sep.	3		153.1	59.8	58.8	17.7	16.8	3.7	149.4	149.4	130.7	55382.6	257	170	204
Sep.	2		157.7	61.4	61.2	18.1	16.9	0.0	157.7	137.4	132.3	55086.8	223	143	204
Sep.	1		171.8	67.2	66.8	19.7	18.0	0.0	171.8	113.0	132.8	54774.6	123	164	210
Aug.	31		168.3	66.1	65.9	19.3	17.0	0.0	168.3	107.8	133.9	54434.5	15	190	225
Aug.	30		143.0	57.0	54.6	16.4	14.9	43.1	99.9	111.0	137.0	54101.2	234	236	247
Aug.	29		129.0	50.7	50.7	14.8	12.8	39.6	89.4	111.9	145.1	53903.4	123	239	241
Aug.	28		122.2	48.4	47.2	14.0	12.7	86.6	35.6	127.2	150.4	53726.3	329	266	246
Aug.	27		153.2	60.4	58.8	17.2	16.7	7.4	145.8	152.6	160.5	53655.9	253	255	226
Aug.	26		184.3	73.7	70.5	21.0	19.1	0.0	184.3	159.9	160.6	53367.2	242	259	217
Aug.	25		126.3	50.1	48.9	14.4	12.8	21.9	104.4	163.0	157.3	53002.3	249	258	209
Aug.	24		167.8	67.0	64.8	18.9	17.0	1.8	166.0	178.3	158.6	52795.5	257	243	195
Aug.	23		165.3	65.7	63.3	18.5	17.8	3.0	162.2	173.5	154.1	52466.9	276	226	181
Aug.	22		190.6	76.9	72.6	21.0	20.1	7.9	182.7	168.5	158.2	52145.6	272	197	162
Aug.	21		200.3	80.6	76.5	22.2	21.1	0.5	199.9	161.4	158.5	51783.9	240	175	141
Aug.	20		182.4	73.7	70.4	20.1	18.2	1.6	180.8	151.6	156.0	51388.2	174	160	120
Aug.	19		149.1	60.3	57.3	16.4	14.9	7.0	142.0	138.8	161.6	51030.1	168	146	115
Aug.	18		190.8	77.3	73.4	21.0	19.1	53.6	137.3	134.6	161.2	50748.9	132	136	112
Aug.	17		146.8	59.7	57.1	16.0	14.0	0.0	146.8	147.8	167.1	50477.1	165	126	113
Aug.	16		151.1	61.7	58.9	16.4	14.1	0.0	151.1	155.6	171.8	50186.4	165	107	113
Aug.	15		146.1	59.7	55.5	16.0	14.8	29.4	116.7	160.4	175.6	49887.2	102	79	112
Aug.	14		148.2	60.8	56.4	16.0	14.9	26.9	121.3	184.3	185.5	49656.1	117	83	115
Aug.	13		203.0	83.2	78.7	21.8	19.3	0.0	203.0	187.7	194.0	49415.9	85	88	114
Aug.	12		186.7	76.7	72.0	20.6	17.3	0.6	186.1	186.4	189.2	49014.0	70	100	115
Aug.	11		192.2	78.7	73.4	21.0	19.1	17.6	174.6	188.0	185.1	48645.5	24	118	121
Aug.	10		237.9	97.9	89.0	25.9	25.2	1.2	236.7	190.8	189.8	48299.7	123	145	132
Aug.	9		194.0	80.3	72.6	21.0	20.1	55.9	138.1	186.6	187.7	47831.1	141	147	135
Aug.	8		197.4	81.5	74.4	21.4	20.1	1.0	196.4	200.4	189.0	47557.6	145	139	138
Aug.	7		197.0	81.7	75.1	21.0	19.2	3.0	194.0	192.1	187.5	47168.7	160	130	145
Aug.	6		197.0	81.7	75.1	21.0	19.2	8.2	188.8	182.2	184.8	46784.6	159	124	141
Aug.	5		215.8	90.4	80.2	23.0	22.2	0.0	215.8	188.8	181.4	46410.7	130	120	143
Aug.	4		206.9	86.6	78.7	22.2	19.4	0.0	206.9	188.8	184.4	45983.4	104	123	148
Aug.	3		174.7	73.4	65.7	18.5	17.1	19.9	154.8	177.7	188.5	45573.7	99	136	156
Aug.	2		205.1	86.4	74.9	21.8	22.0	60.4	144.8	182.9	197.8	45267.2	128	160	163
Aug.	1		221.5	94.0	82.7	23.4	21.5	0.0	221.5	187.4	201.6	44980.5	139	159	162
July	31		215.8	85.3	89.4	21.8	19.3	0.0	215.8	173.9	198.7	44541.9	149	167	159
July	30		151.4	60.5	63.1	14.8	13.0	0.0	151.4	179.9	199.6	44114.7	168	172	157
July	29		180.8	71.7	73.1	18.1	17.9	0.0	180.8	199.3	205.6	43814.9	217	176	150
July	28		167.4	66.7	67.5	16.4	16.8	0.0	167.4	212.7	211.0	43456.9	126	167	140
July	27		154.3	61.2	62.6	15.6	14.8	0.0	154.3	215.9	217.7	43125.3	175	165	141
July	26		248.1	98.8	101.7	25.1	22.5	2.3	245.8	223.4	227.2	42819.9	178	151	135
July	25		248.1	98.8	101.7	25.1	22.5	0.0	248.1	219.2	224.7	42333.2	184	141	128
July	24		247.9	98.5	100.9	25.1	23.4	0.0	247.9	211.9	224.3	41841.9	172	124	123

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Figure 14: Reach 3 Summary

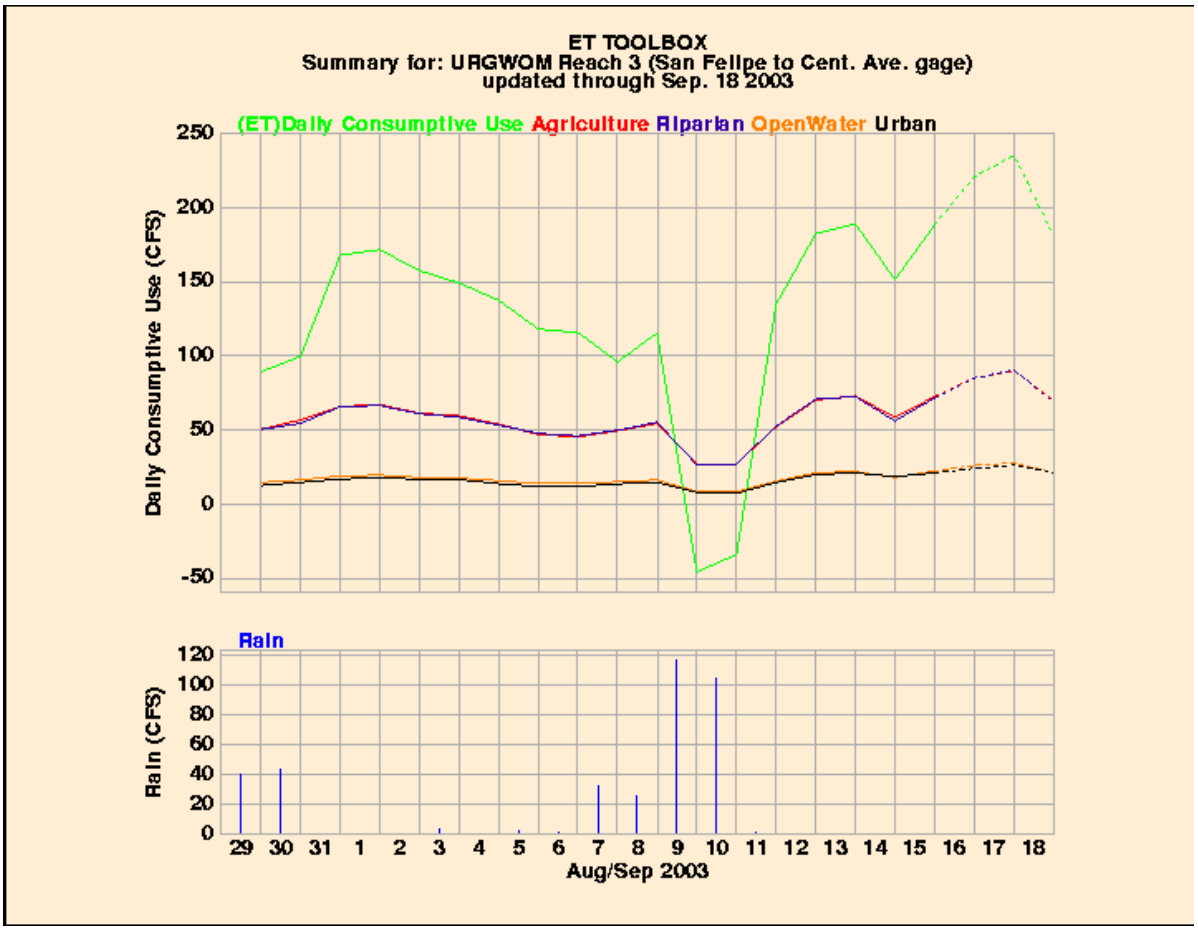

Figure 15: Reach 3 Daily Consumptive Use And Rainfall

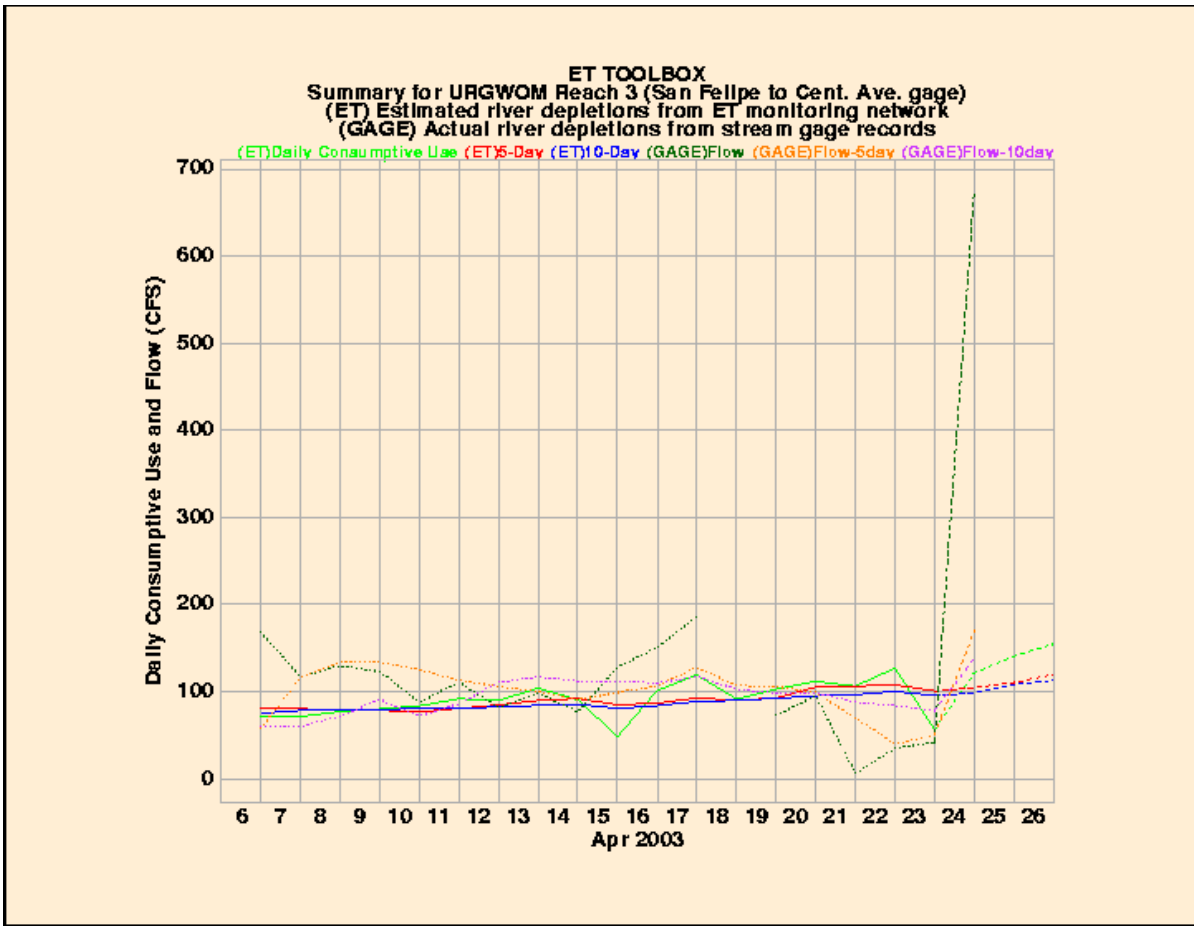

Figure 16: Reach 3 Daily Consumptive Use With Stream Flow And Running Averages

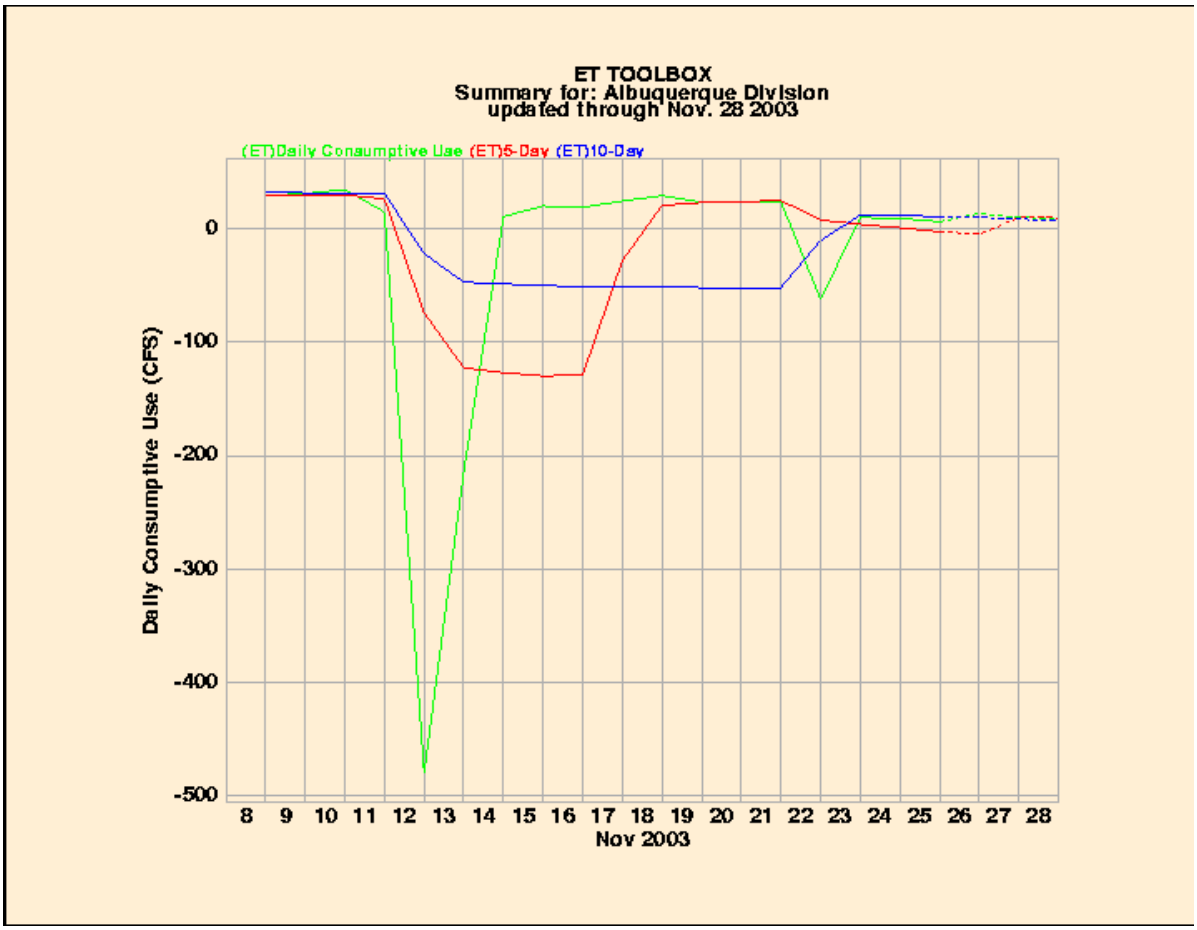

Figure 17: Greater Albuquerque Division (MRGCD) Daily Consumptive Used And Running Averages

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Apr 24, 03 14:42 **REA3.Alfalfa.txt** Page 1/1

```
URGWOM Reach 3 (San Felipe to Cent. Ave. gage)
----------------------------------------------------------------
 Daily ET Rates for Alfalfa              Today is: Apr. 24, 2003
----------------------------------------------------------------
 Vegetation Classification: LUTA  1992/93
   Number of 4x4 km cells =  41    Number with Alfalfa =  20
   Weather station(s) used:
      1) ANGN Angostura, NM - MRGCD
      2) CFMN Candelaria Farms Station - MRGCD
      3) CFMN Candelaria Farms Station - MRGCD
   Reference (Ref.) ET is averaged from above weather station(s)
   Crop Coef. is averaged from above weather station(s)
   Crop ET = Ref. ET x Crop Coef.
   Total Water Use = Sum of cell water use
   NEXRAD Rain = Sum of (cell rain x cell crop acres/12)
   URGWOM Water Use = Total Water Use - NEXRAD Rain
----------------------------------------------------------------
  Acres:    2819  Plant Date: Jan.  1  Termination Date: Oct. 20

      Month Day  Ref.  Crop  Crop    Total    NEXRAD    URGWOM
       (2003)     ET   Coef.  ET   Water Use   Rain    Water Use
                 (IN)        (IN)   (AC-FT)   (AC-FT)   (AC-FT)
      ----- ---  ----  ----  ----  ---------  -------  ---------
       Jan.  1   0.10  0.41  0.04     9.41      0.00      9.41
       Jan.  2   0.09  0.41  0.04     8.01      0.00      8.01
       Jan.  3   0.10  0.41  0.04     9.41      0.00      9.41
       Jan.  4   0.11  0.41  0.05     9.41      0.00      9.41
       Jan.  5   0.10  0.41  0.04     9.41      0.00      9.41
       Jan.  6   0.12  0.41  0.05    10.79      0.00     10.79
       Jan.  7   0.09  0.41  0.04     9.41      0.00      9.41
       Jan.  8   0.09  0.41  0.04     9.41      0.00      9.41
       Jan.  9   0.06  0.41  0.03     6.10      0.00      6.10
       Jan. 10   0.08  0.41  0.03     8.43      0.00      8.43
       Jan. 11   0.05  0.41  0.02     4.69      0.00      4.69
       Jan. 12   0.11  0.41  0.04     9.41      0.00      9.41
       Jan. 13   0.11  0.41  0.05    10.36      0.00     10.36
       Jan. 14   0.10  0.41  0.04     9.41      0.00      9.41
       Jan. 15   0.13  0.41  0.05    11.74      0.00     11.74
       Jan. 16   0.12  0.41  0.05    10.79      0.00     10.79
       Jan. 17   0.12  0.41  0.05    10.79      0.00     10.79
       Jan. 18   0.11  0.41  0.05    10.79      0.00     10.79
       Jan. 19   0.12  0.41  0.05    11.74      0.00     11.74
       Jan. 20   0.12  0.41  0.05    10.79      0.00     10.79
       Jan. 21   0.12  0.41  0.05    10.79      0.00     10.79
       Jan. 22   0.13  0.41  0.05    11.74      0.00     11.74
       Jan. 23   0.12  0.41  0.05    11.74      0.00     11.74
       Jan. 24   0.11  0.41  0.04    10.79      0.00     10.79
       Jan. 25   0.11  0.42  0.05    11.74      0.00     11.74
       Jan. 26   0.12  0.42  0.05    11.74      0.00     11.74
       Jan. 27   0.13  0.42  0.05    13.14      0.00     13.14
       Jan. 28   0.15  0.42  0.06    15.49      0.00     15.49
       Jan. 29   0.13  0.42  0.05    11.74      0.00     11.74
       Jan. 30   0.15  0.42  0.06    15.49      0.00     15.49
       Jan. 31   0.15  0.43  0.06    15.49      0.00     15.49
                ------        ----    -----    ------  --------
  Jan. Totals    3.46         1.43   330.19      0.00    330.19

       Feb.  1   0.12  0.43  0.05    11.74      0.00     11.74
       Feb.  2   0.19  0.43  0.08    20.18      0.00     20.18
       Feb.  3   0.10  0.43  0.04    10.79      0.00     10.79
       Feb.  4   0.12  0.43  0.05    11.74      0.00     11.74
       Feb.  5   0.12  0.43  0.05    12.69      0.00     12.69
       Feb.  6   0.12  0.43  0.05    13.14      0.00     13.14
       Feb.  7   0.09  0.43  0.04     9.41      0.00      9.41
       Feb.  8   0.06  0.43  0.03     7.03      0.44      6.59
       Feb.  9   0.11  0.43  0.05    12.19      0.00     12.19
       Feb. 10   0.12  0.43  0.05    13.14      0.00     13.14
       Feb. 11   0.11  0.43  0.05    10.79      0.00     10.79
       Feb. 12   0.13  0.43  0.06    14.09      0.00     14.09
       Feb. 13   0.07  0.44  0.03     7.03     52.90    -45.87
       Feb. 14   0.07  0.44  0.03     8.43      4.86      3.57
       Feb. 15   0.10  0.45  0.04     9.41      0.00      9.41
       Feb. 16   0.10  0.45  0.04     9.41      0.00      9.41
       Feb. 17   0.15  0.45  0.07    16.44      0.00     16.44
       Feb. 18   0.05  0.45  0.02     5.62      0.77      4.85
       Feb. 19   0.13  0.45  0.06    14.09      0.00     14.09
       Feb. 20   0.02  0.45  0.01     2.34     62.26    -59.92
       Feb. 21   0.16  0.45  0.07    17.85      0.00     17.85
       Feb. 22   0.20  0.45  0.09    21.13      0.00     21.13
       Feb. 23   0.16  0.45  0.07    17.85      0.00     17.85
       Feb. 24   0.07  0.45  0.03     7.03      7.43     -0.40
       Feb. 25   0.13  0.45  0.06    12.69     15.23     -2.54
       Feb. 26   0.07  0.45  0.03     8.43     24.14    -15.71
       Feb. 27   0.11  0.46  0.05    10.36      0.01     10.35
       Feb. 28   0.08  0.46  0.04     8.43      0.76      7.67
                ------        ----    -----    ------  --------
  Feb. Totals    3.08         1.36   323.47    168.80    154.67

                ------        ----    -----    ------  --------
  Total To-Date 17.71         9.14  2151.61    530.11   1621.50
```

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Figure 18: Daily ET Rates

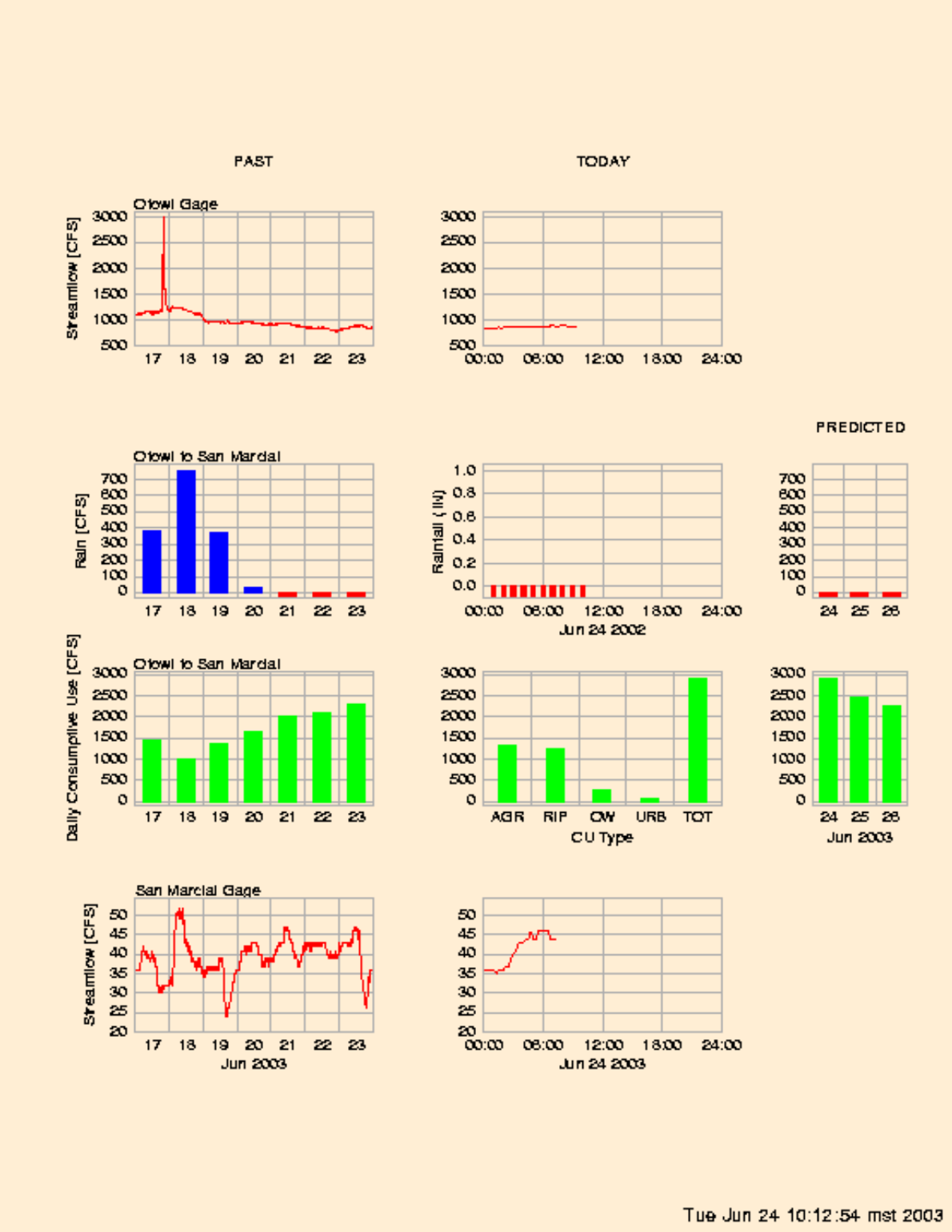

Figure 19: With Present Hourly Rain Matrix

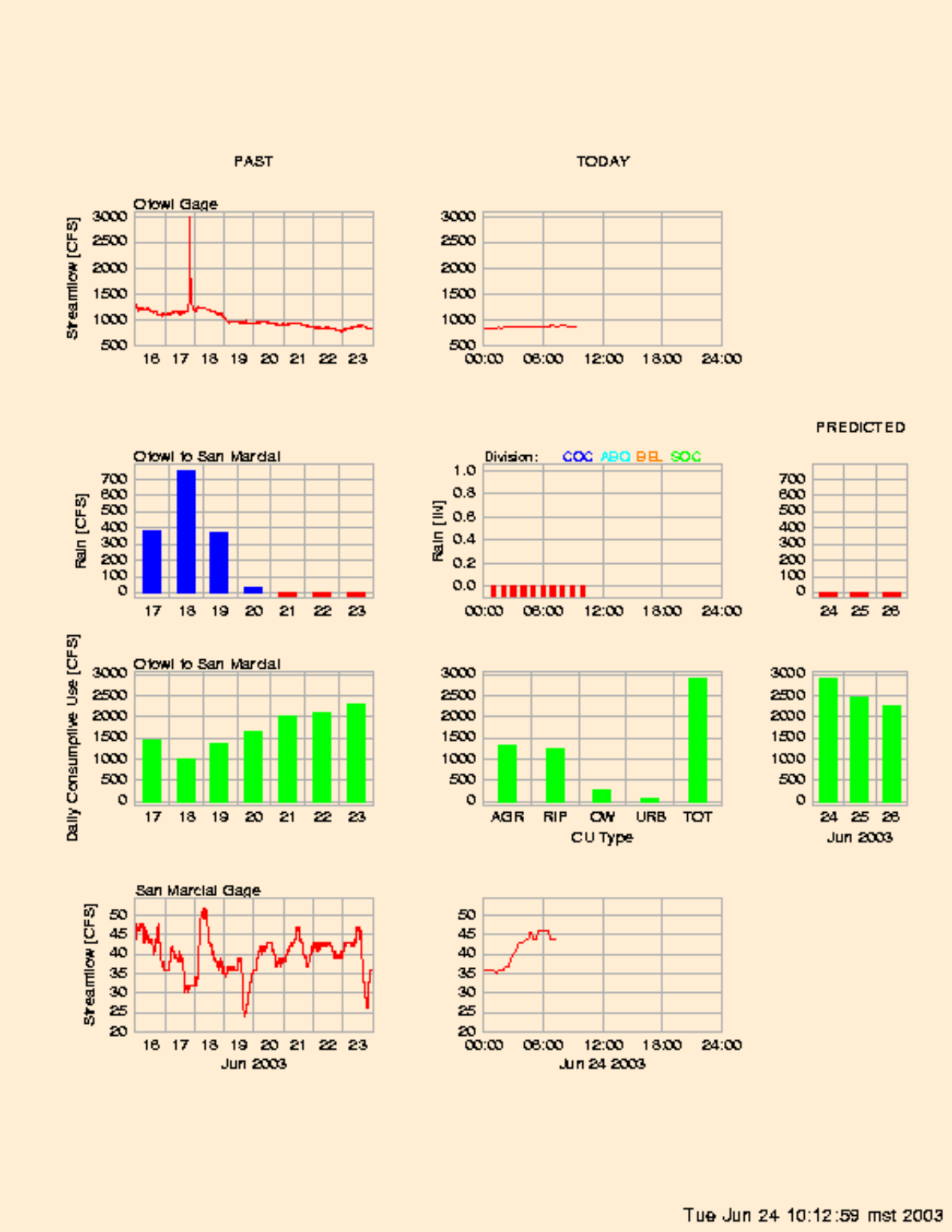

Figure 20: With Present Division Rain Matrix

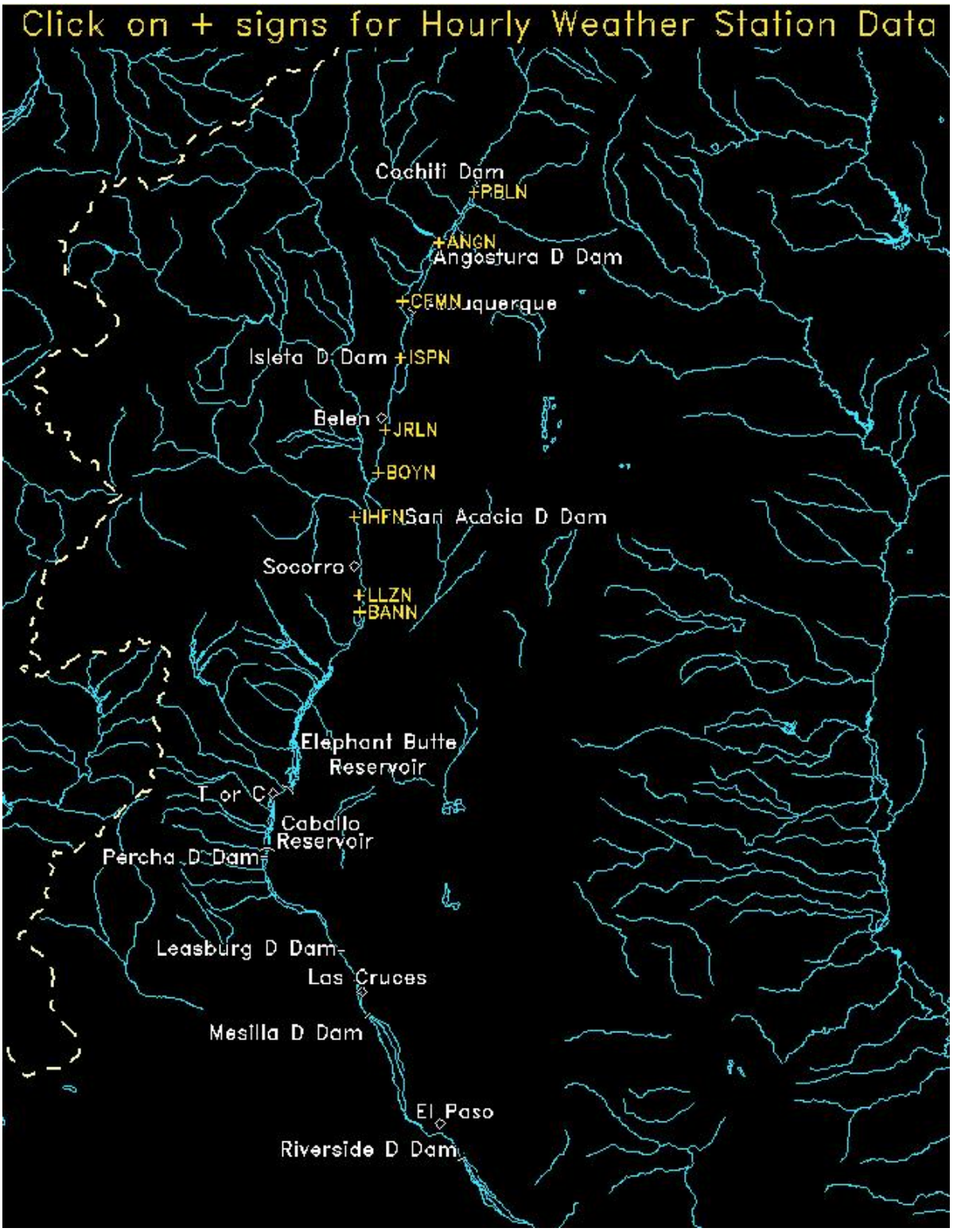

Figure 21: MRGCD Weather Station Network

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Candelaria Farms – MRGCD CFMN

Hourly Weather Data for Last 24–Hours – 2003

Month	Day	Time (MST)	Temp. (F)	Wind (Mi/Hr)	Wind Dir. (Deg)	Rel. Hum. (%)	Rain (in)	Solar Radiation (Mj/Sq m)	Soil Temp. (F)
June	05	10AM	75.2	0.5	166	45	0.00	2.74	69.0
June	05	9AM	71.2	0.7	208	52	0.00	1.97	69.0
June	05	8AM	67.8	0.9	240	62	0.00	1.05	69.1
June	05	7AM	65.0	3.8	240	64	0.00	0.84	69.3
June	05	6AM	60.7	2.5	245	71	0.00	0.25	69.6
June	05	5AM	61.9	2.6	259	67	0.00	0.01	69.9
June	05	4AM	62.1	1.4	289	64	0.00	0.00	70.2
June	05	3AM	66.5	4.8	116	52	0.00	0.00	70.5
June	05	2AM	67.3	5.7	133	53	0.00	0.00	70.8
June	05	1AM	68.6	6.9	103	51	0.00	0.00	71.0
June	04	12PM	70.2	5.1	123	48	0.00	0.01	71.4
June	04	11PM	70.9	9.1	105	48	0.00	0.01	71.7
June	04	10PM	68.3	3.2	186	39	0.00	0.01	72.1
June	04	9PM	67.5	1.2	217	36	0.00	0.01	72.5
June	04	8PM	70.4	0.3	226	35	0.00	0.01	72.7
June	04	7PM	78.9	1.3	216	21	0.00	0.16	72.9
June	04	6PM	83.6	6.6	188	17	0.00	0.82	72.9
June	04	5PM	83.9	11.2	248	13	0.00	0.37	72.7
June	04	4PM	86.9	6.8	284	16	0.00	1.60	72.3
June	04	3PM	86.1	5.6	246	16	0.00	1.50	71.4
June	04	2PM	86.9	6.2	273	18	0.00	2.77	70.2
June	04	1PM	86.0	4.2	209	23	0.00	3.44	69.1
June	04	12AM	83.2	2.6	163	29	0.00	3.41	68.2
June	04	11AM	81.0	0.4	187	32	0.00	3.24	67.5

Thursday June 05, 2003 1/1

Figure 22: MRGCD Hourly Weather Data

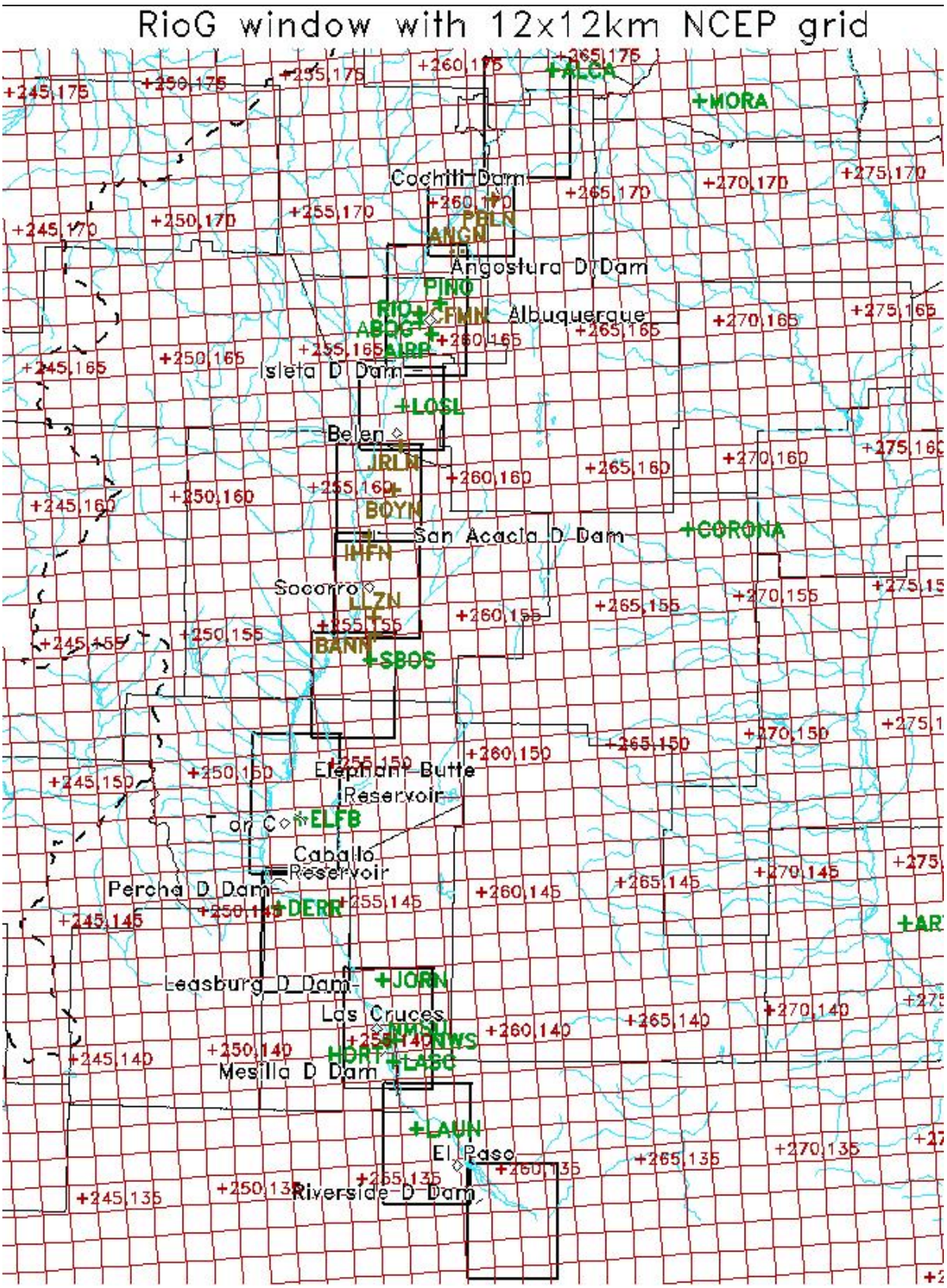

Figure 23: 12-km NCEP Grid (Eta Cell) For The Middle Rio Grande

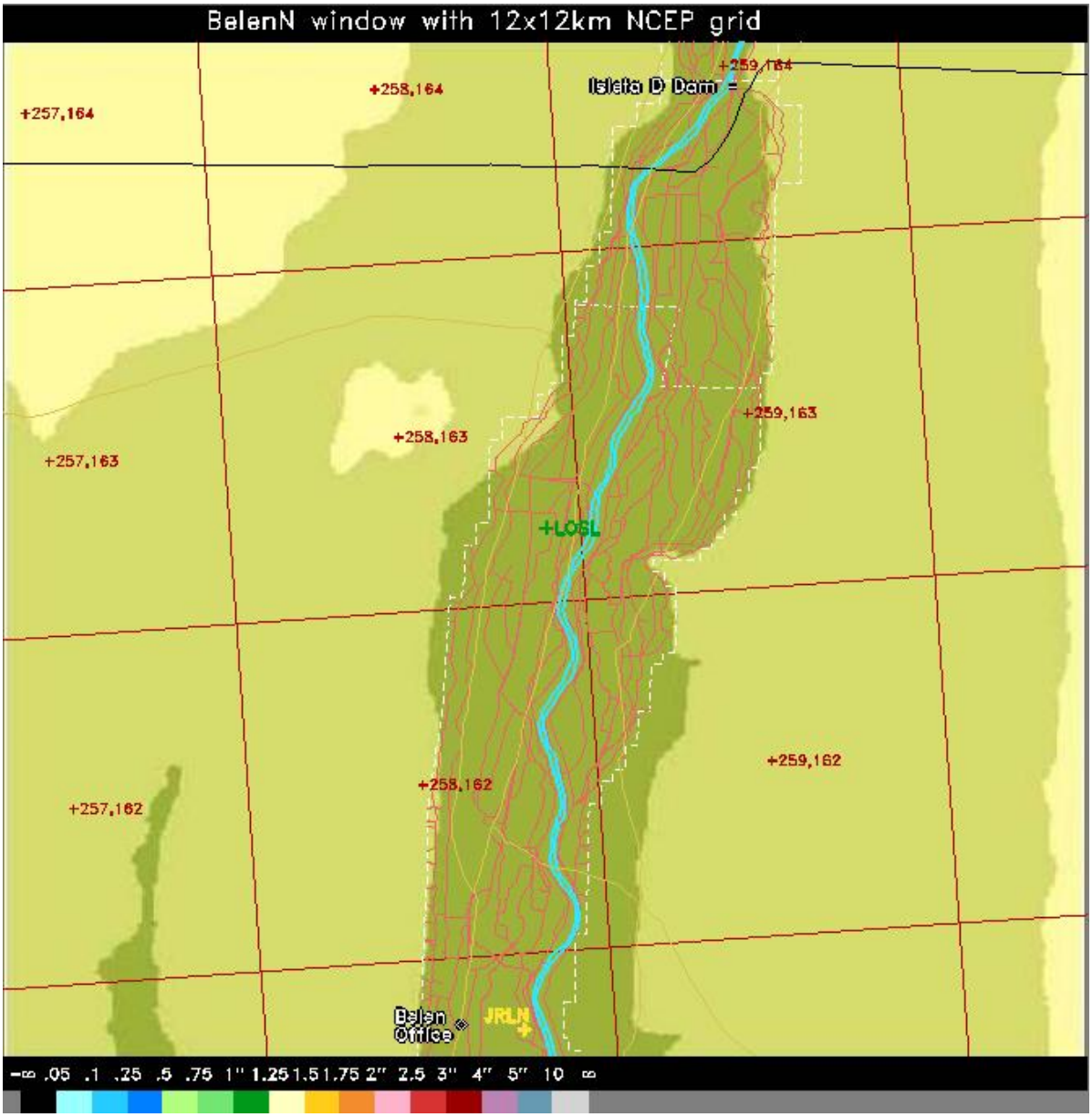

Figure 24: 12-km NCEP Grid For Belen North

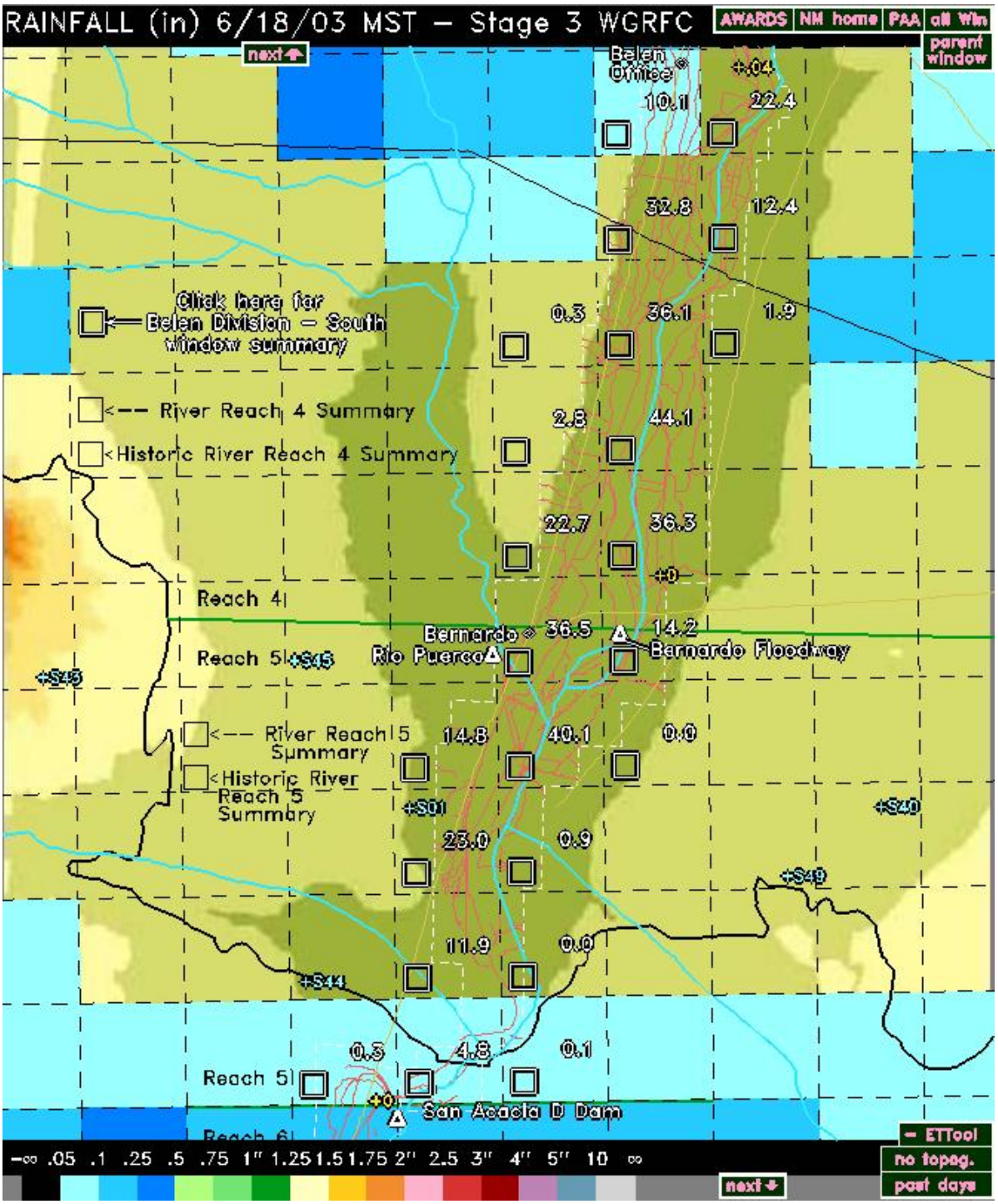

Figure 25: MRGCD Belen South Division (Diversion) - AWARDS

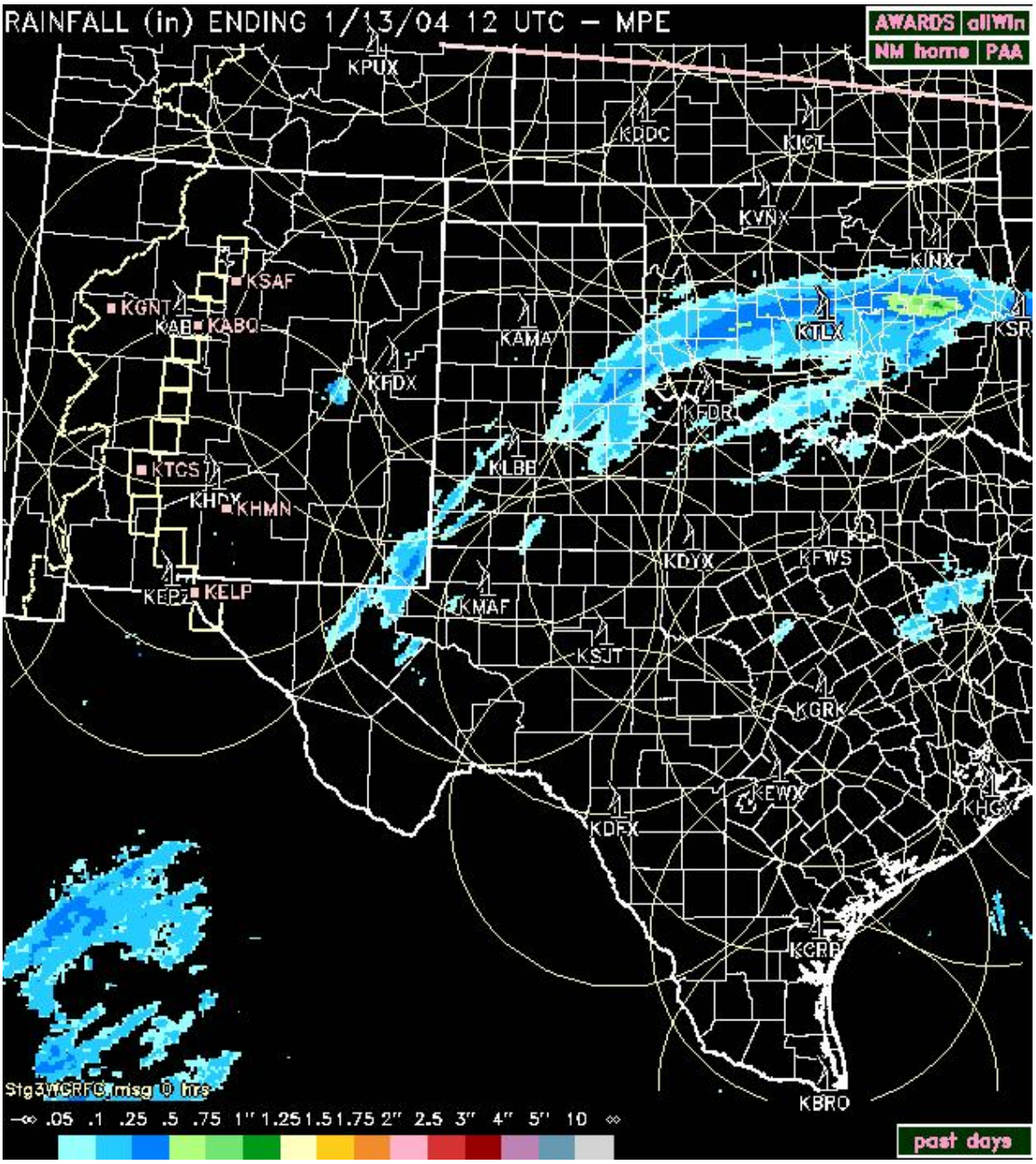

Figure 26: New Mexico, Texas, and Oklahoma Radar Coverage

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```
      subroutine etpbyts
c
c Penman's equation for reference et (ETr), referenced to grass
c  This is the modified Penman equation as modified by Dr. Ted Sammis
c  at the New Mexico State University, as provided by Salim Bawazir
c  on March 16, 2000.
c
c List of Input Values
c
c Name      Value  Units               Description
c  elev     Input  m                     elevation
c  tmax     Input  deg.C                 maximum temperature
c  tmin     Input  deg.C                 minimum temperature
c  rhmax    Input  %                     maximum relative humidity
c  rhmin    Input  %                     minimum relative humidity
c  wr_value Input  m/sec                 wind speed
c  sr_value Input  megajoules/m^2.day    solar radiation
c
      integer errors2
      include 'refet.common'
c
c Initalize
c
c Reflection coefficient, 0.07+0.053*LAI
      albedo=.21
c Specific heat of air (cal/deg.C/cm^3)
      cp=.242
c Long wave radiation (cal/cm^2/day)
      rl=-64.
c
c Perform calculations
c
c Find maximum saturated vapor pressure (mb)
      svpma = 6.108*exp((17.27*tmax)/(tmax+237.3))
c Find minimum saturated vapor pressure (mb)
      svpmi = 6.108*exp((17.27*tmin)/(tmin+237.3))
c Find saturated vapor pressure at mean temperature (mb)
      vps1 = (svpmi+svpma)/2.0
c Find actual vapor pressure at mean temperature (mb)
      vpa1 = ((svpma*rhmin/100.) + (svpmi*rhmax/100.))/2.
c Find difference between saturated vapor pressure at mean temperature
c  and actual vapor pressure at mean temperature (mb)
      vpdiff = vps1-vpa1
c Find average temperature
      tavg=(tmax+tmin)/2.
c Find slope of the saturated vapor pressure curve (mb/deg C)
      delta = 33.8639*(0.05904*(0.00739*tavg+0.8072)**7 - 0.0000342)
c Find latent heat of vaporization (cal/g)
      hl = 595.0-(0.51*tavg)
c Find pressure when elevation is in meters (mb)
      pr = 1013.0-(0.1055*elev)
c Find psychrometric constant
      gamma = (cp*pr)/(0.622*hl)
c Convert average wind speed from meters/second to km/hr
      windkm = wr_value*86400.*.001/24.
c Find wind speed at 2 meters - assumes instrument is at 3.75 meters
c  (km/day)
      wind2m = (windkm*24.)*((2/3.75)**.2)
c Find wind function (km/day)
      windf = 15.36*(1.0+(0.0062*wind2m))
c Find net solar radiation where sr_value is in mj/m^2/day
c  (cal/cm^2/day
      rn=(.95*(1.0-albedo)*sr_value/0.041868)+rl
c Find reference et (cal/cm**2/day)
```

Jan 31, 02 8:13 **Penmanequation.txt** Page 2/2

```
      eto = ((delta/(delta+gamma))*rn)+
     2 ((gamma/(delta+gamma))*windf*vpdiff)
c Find reference et (mm/day)
      eto = (eto/hl)*10.
c Find reference et (in/day)
      Eto = eto*.03937
      return
      end
```

Thursday June 26, 2003 Penmanequation.txt 1/1

Figure 27: Penman Reference ET Equation

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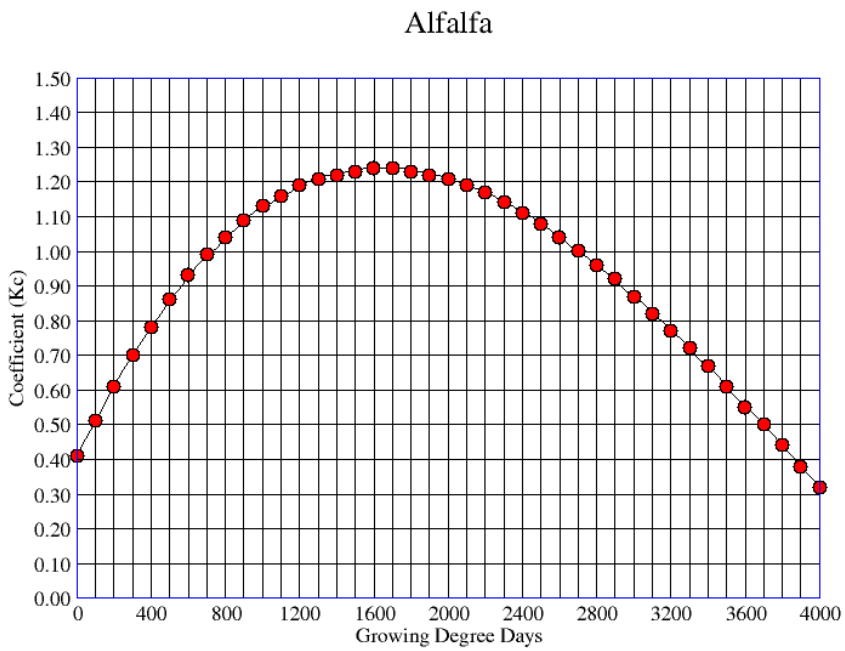
Jun 22, 00 13:20 **limits** Page 1/1

Station	Crop num.	Crop name	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
LLZN	1	Alfalfa				.11	.19	.27	.30	.24	.15	.09		
LLZN	2	PastGrass				.10	.16	.22	.25	.21	.14	.08		
LLZN	3	Sorghum					.06	.14	.26	.20	.10			
LLZN	4	Wheat			.04	.12	.26	.11						
LLZN	5	Corn					.09	.13	.25	.24	.16			
LLZN	6	Chili Pep						.01	.09	.23	.18	.01		
LLZN	7	Grapes				.06	.13	.20	.21	.17	.10	.05		
LLZN	33	Misc Vegs				.05	.08	.14	.27	.26	.15	.08		

Wednesday June 11, 2003 1/1

Figure 28: Limited ET As Calculated At The Luis Lopez Station

Figure 29: Alfalfa Curve

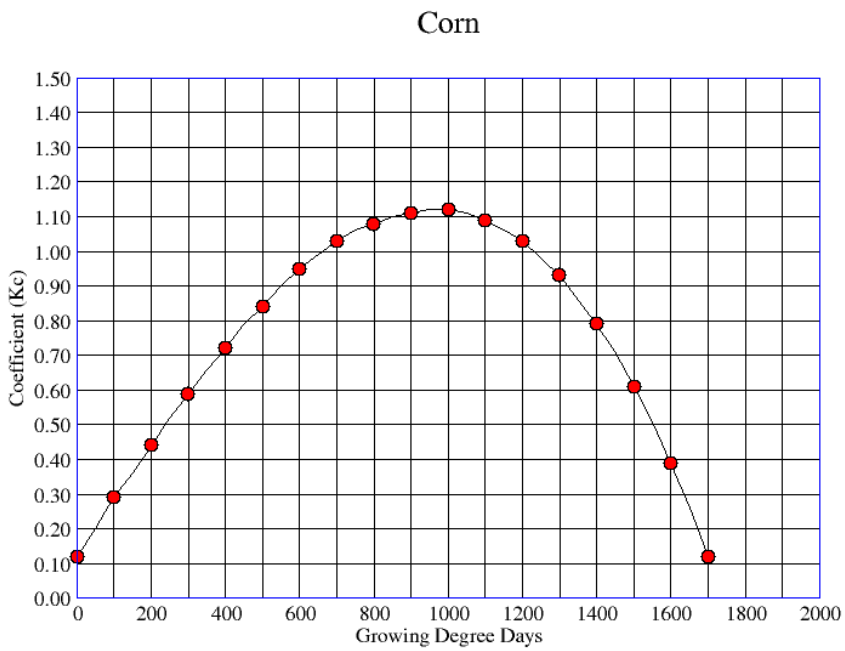



```
                Polynominal Function for Alfalfa

 Kc  =    0.41E+00 +   0.111E-02(GDD) +  -0.425E-06(GDD)**2 +
                     0.356E-10(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

 Base Temperature (deg. C) =   5.0
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.41	600	0.93	1200	1.19	1800	1.23	2400	1.11	3000	0.87	3600	0.55
50	0.46	650	0.96	1250	1.20	1850	1.23	2450	1.10	3050	0.85	3650	0.53
100	0.51	700	0.99	1300	1.21	1900	1.22	2500	1.08	3100	0.82	3700	0.50
150	0.56	750	1.01	1350	1.22	1950	1.22	2550	1.06	3150	0.80	3750	0.47
200	0.61	800	1.04	1400	1.22	2000	1.21	2600	1.04	3200	0.77	3800	0.44
250	0.66	850	1.06	1450	1.23	2050	1.20	2650	1.02	3250	0.75	3850	0.41
300	0.70	900	1.09	1500	1.23	2100	1.19	2700	1.00	3300	0.72	3900	0.38
350	0.74	950	1.11	1550	1.24	2150	1.18	2750	0.98	3350	0.69	3950	0.35
400	0.78	1000	1.13	1600	1.24	2200	1.17	2800	0.96	3400	0.67	4000	0.32
450	0.82	1050	1.14	1650	1.24	2250	1.16	2850	0.94	3450	0.64		
500	0.86	1100	1.16	1700	1.24	2300	1.14	2900	0.92	3500	0.61		
550	0.89	1150	1.17	1750	1.24	2350	1.13	2950	0.89	3550	0.58		

Curve developed by New Mexico State University

Figure 30: Corn Curve

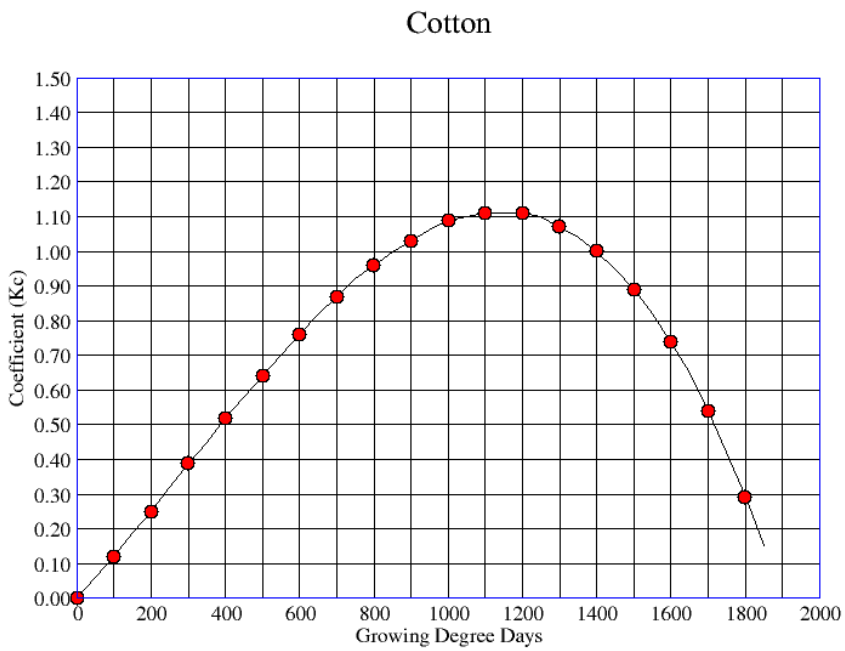



```
                Polynominal Function for Corn

 Kc  =    0.12E+00 +   0.168E-02(GDD) +  -0.246E-06(GDD)**2 +
                     -0.437E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

 Max. Cutoff Temperature (deg. C) =  30.0
 Min. Cutoff Temperature (deg. C) =  10.0
 Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.12	600	0.95	1200	1.03
50	0.20	650	0.99	1250	0.98
100	0.29	700	1.03	1300	0.93
150	0.36	750	1.06	1350	0.86
200	0.44	800	1.08	1400	0.79
250	0.52	850	1.10	1450	0.71
300	0.59	900	1.11	1500	0.61
350	0.66	950	1.12	1550	0.51
400	0.72	1000	1.12	1600	0.39
450	0.79	1050	1.11	1650	0.26
500	0.84	1100	1.09	1700	0.12
550	0.90	1150	1.06		

Curve developed by New Mexico State University

Figure 31: Cotton Curve

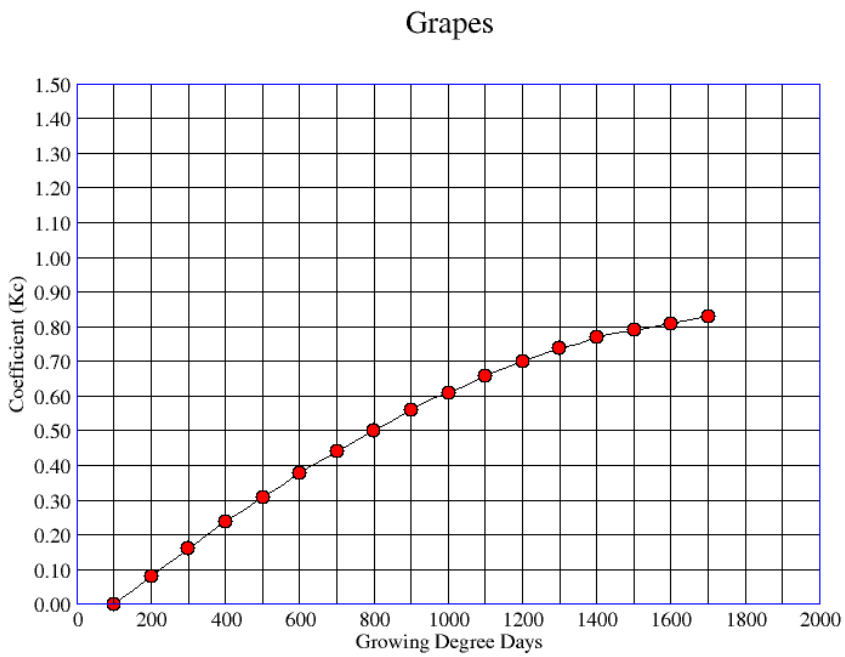



```
                Polynominal Function for Cotton

 Kc  =    0.42E-03 +   0.120E-02(GDD) +   0.462E-06(GDD)**2 +
                     -0.577E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

 Max. Cutoff Temperature (deg. C) =  30.0
 Min. Cutoff Temperature (deg. C) =  12.0
 Base Temperature (deg. C) =  12.0
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.00	600	0.76	1200	1.11	1800	0.29
50	0.06	650	0.82	1250	1.10	1850	0.15
100	0.12	700	0.87	1300	1.07		
150	0.19	750	0.92	1350	1.04		
200	0.25	800	0.96	1400	1.00		
250	0.32	850	1.00	1450	0.95		
300	0.39	900	1.03	1500	0.89		
350	0.45	950	1.06	1550	0.82		
400	0.52	1000	1.09	1600	0.74		
450	0.58	1050	1.10	1650	0.65		
500	0.64	1100	1.11	1700	0.54		
550	0.70	1150	1.11	1750	0.42		

Curve developed by New Mexico State University

Figure 32: Grape Curve

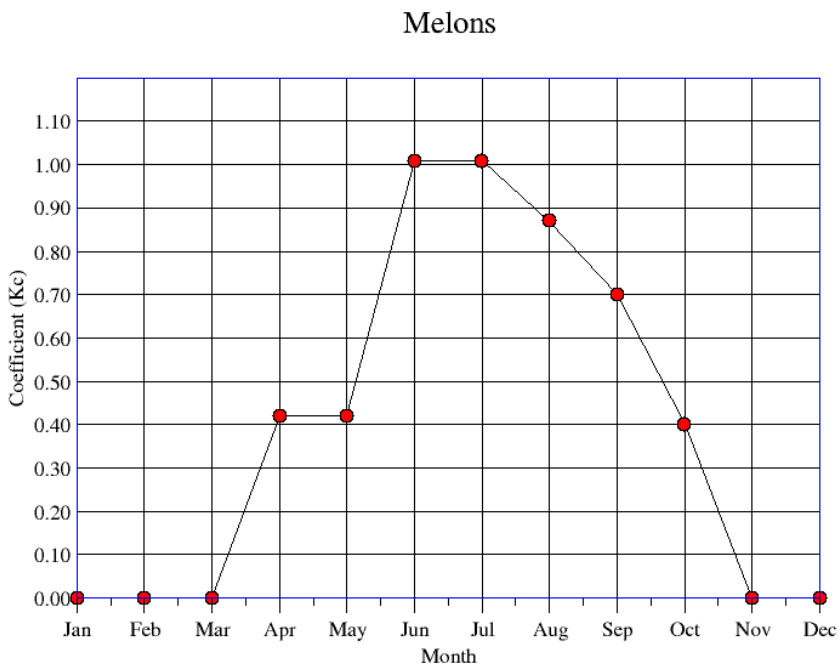



```
                Polynominal Function for Grapes

 Kc  =   -0.91E-01 +   0.881E-03(GDD) +  -0.150E-06(GDD)**2 +
                    -0.300E-10(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

 Max. Cutoff Temperature (deg. C) =  30.0
 Min. Cutoff Temperature (deg. C) =  10.0
 Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
150	0.04	750	0.47	1350	0.75
200	0.08	800	0.50	1400	0.77
250	0.12	850	0.53	1450	0.78
300	0.16	900	0.56	1500	0.79
350	0.20	950	0.59	1550	0.80
400	0.24	1000	0.61	1600	0.81
450	0.27	1050	0.63	1650	0.82
500	0.31	1100	0.66	1700	0.83
550	0.34	1150	0.68		
600	0.38	1200	0.70		
650	0.41	1250	0.72		
700	0.44	1300	0.74		

Curve developed by New Mexico State University

Figure 33: Melon Curve

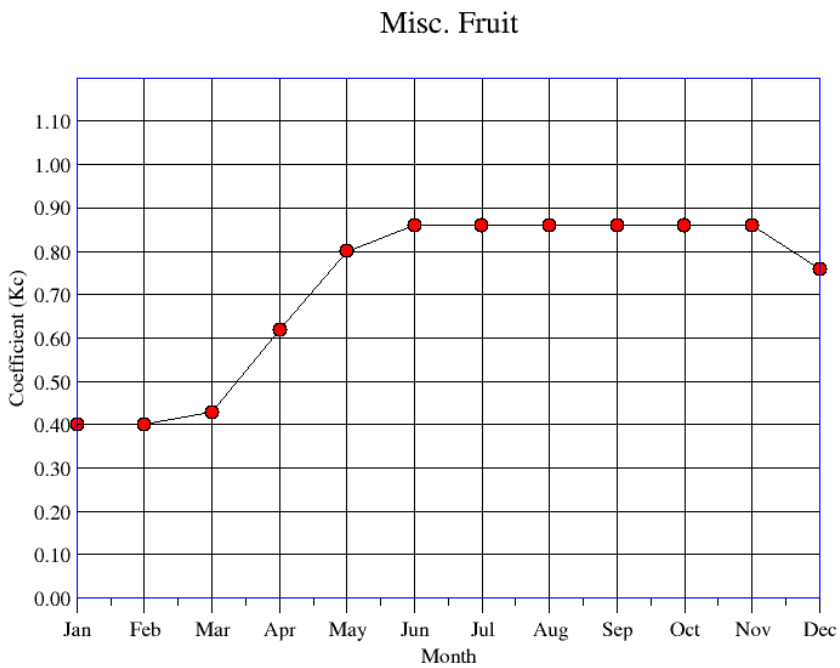


Monthly Coefficients for Melons

Month	Crop Coefficient (Kc)
January	0.00
February	0.00
March	0.00
April	0.42
May	0.42
June	1.01
July	1.01
August	0.87
September	0.70
October	0.40
November	0.00
December	0.00

Data from Jensen,M.E., (1998)

Figure 34: Misc. Fruit Curve

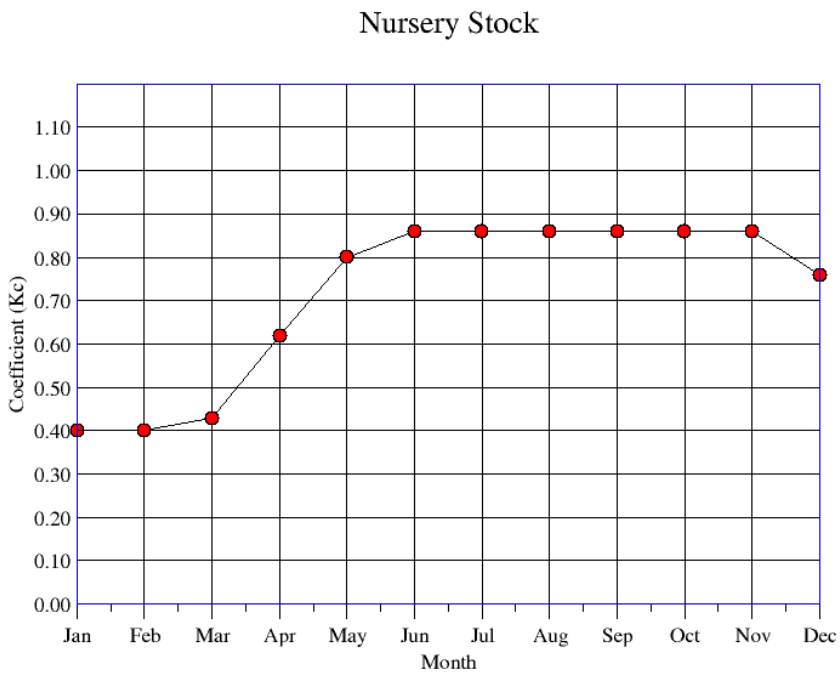


Monthly Coefficients for Misc Fruit

Month	Crop Coefficient (Kc)
January	0.40
February	0.40
March	0.43
April	0.62
May	0.80
June	0.86
July	0.86
August	0.86
September	0.86
October	0.86
November	0.86
December	0.76

Data from Jensen,M.E., (1998)

Figure 35: Nursery Stock Curve

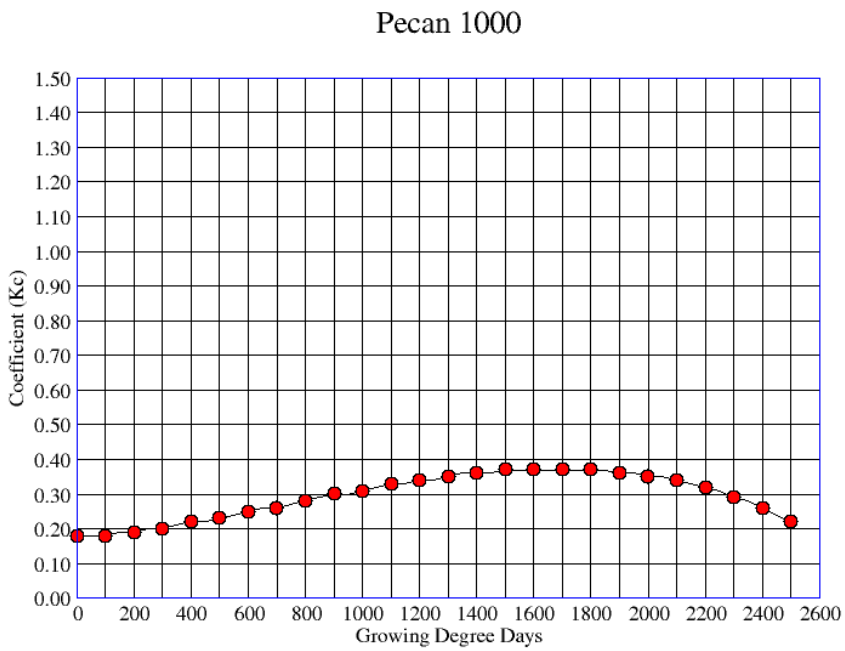


Monthly Coefficients for Nursery Stock

Month	Crop Coefficient (Kc)
January	0.40
February	0.40
March	0.43
April	0.62
May	0.80
June	0.86
July	0.86
August	0.86
September	0.86
October	0.86
November	0.86
December	0.76

Data from Jensen,M.E., (1998)

Figure 36: Pecan 1000 Curve

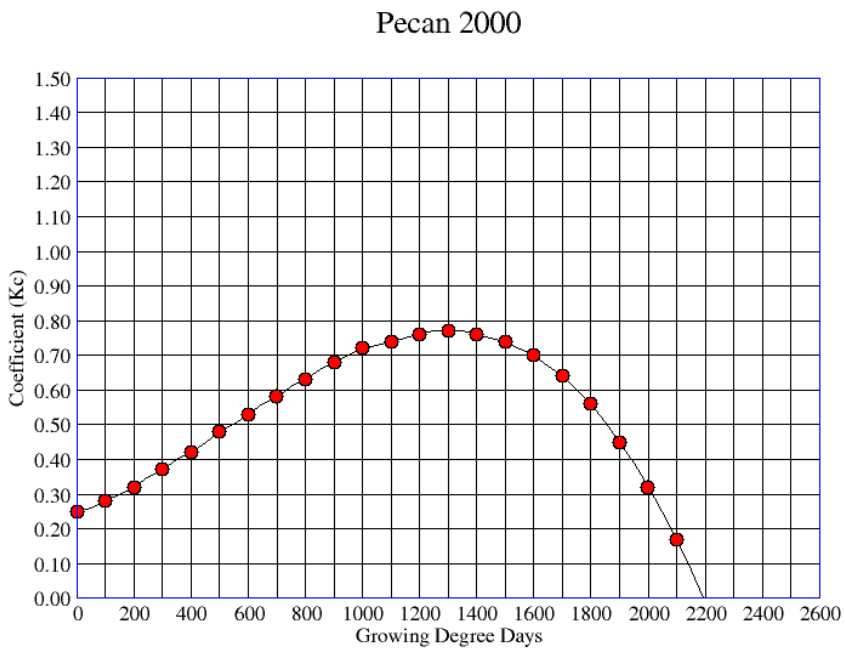



```
                Polynominal Function for Pecan 1000

Kc  =    0.18E+00 +   0.569E-04(GDD) +   0.140E-06(GDD)**2 +
                    -0.621E-10(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Min. Cutoff Temperature (deg. C) =  -4.0
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.18	600	0.25	1200	0.34	1800	0.37	2400	0.26
50	0.18	650	0.26	1250	0.34	1850	0.37	2450	0.24
100	0.18	700	0.26	1300	0.35	1900	0.36	2500	0.22
150	0.19	750	0.27	1350	0.36	1950	0.36		
200	0.19	800	0.28	1400	0.36	2000	0.35		
250	0.20	850	0.29	1450	0.36	2050	0.35		
300	0.20	900	0.30	1500	0.37	2100	0.34		
350	0.21	950	0.30	1550	0.37	2150	0.33		
400	0.22	1000	0.31	1600	0.37	2200	0.32		
450	0.22	1050	0.32	1650	0.37	2250	0.31		
500	0.23	1100	0.33	1700	0.37	2300	0.29		
550	0.24	1150	0.33	1750	0.37	2350	0.28		

Curve developed by New Mexico State University

Figure 37: Pecan 2000 Curve



Polynominal Function for Pecan 2000

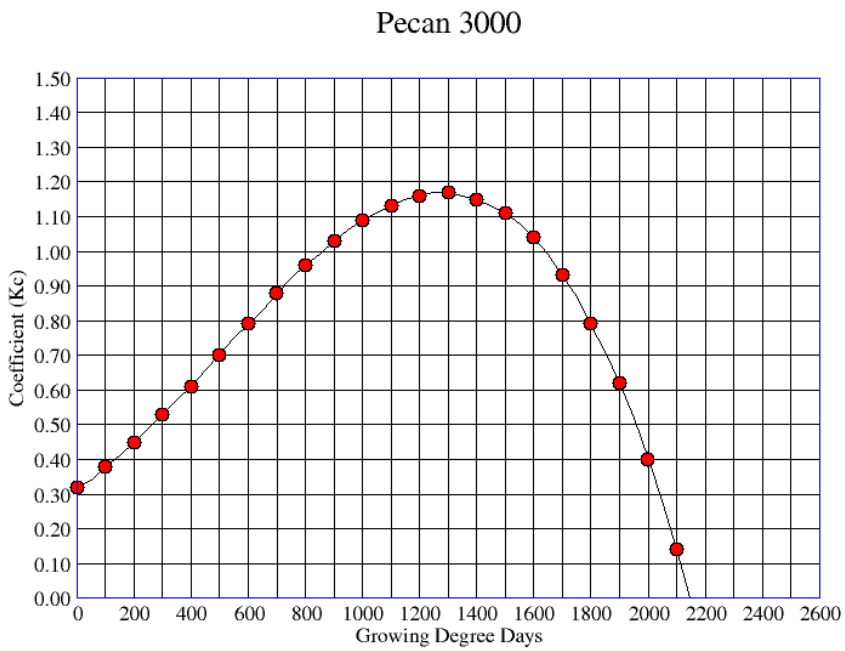
```
Kc  =    0.25E+00 +   0.305E-03(GDD) +   0.461E-06(GDD)**2 +
                     -0.297E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5
```

Min. Cutoff Temperature (deg. C) = -4.0
Base Temperature (deg. C) = 15.5

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.25	600	0.53	1200	0.76	1800	0.56
50	0.26	650	0.56	1250	0.77	1850	0.51
100	0.28	700	0.58	1300	0.77	1900	0.45
150	0.30	750	0.61	1350	0.77	1950	0.39
200	0.32	800	0.63	1400	0.76	2000	0.32
250	0.35	850	0.66	1450	0.75	2050	0.25
300	0.37	900	0.68	1500	0.74	2100	0.17
350	0.40	950	0.70	1550	0.72	2150	0.08
400	0.42	1000	0.72	1600	0.70		
450	0.45	1050	0.73	1650	0.67		
500	0.48	1100	0.74	1700	0.64		
550	0.50	1150	0.75	1750	0.60		

Curve developed by New Mexico State University

Figure 38: Pecan 3000 Curve



Polynominal Function for Pecan 3000

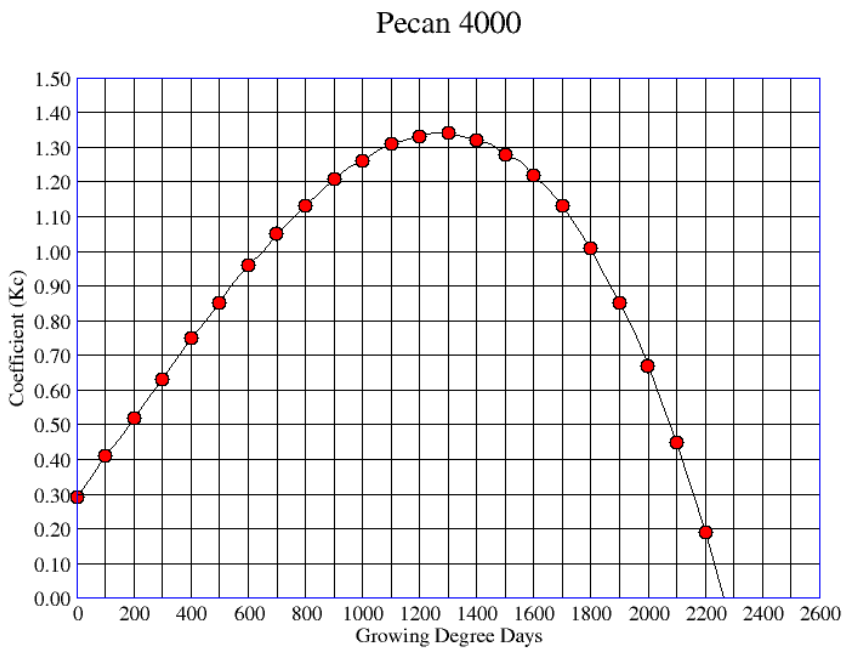
```
Kc  =    0.32E+00 +   0.531E-03(GDD) +   0.724E-06(GDD)**2 +
                     -0.484E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5
```

Min. Cutoff Temperature (deg. C) = -4.0
Base Temperature (deg. C) = 15.5

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.32	600	0.79	1200	1.16	1800	0.79
50	0.34	650	0.83	1250	1.17	1850	0.71
100	0.38	700	0.88	1300	1.17	1900	0.62
150	0.41	750	0.92	1350	1.16	1950	0.52
200	0.45	800	0.96	1400	1.15	2000	0.40
250	0.49	850	0.99	1450	1.13	2050	0.28
300	0.53	900	1.03	1500	1.11	2100	0.14
350	0.57	950	1.06	1550	1.08		
400	0.61	1000	1.09	1600	1.04		
450	0.66	1050	1.11	1650	0.99		
500	0.70	1100	1.13	1700	0.93		
550	0.75	1150	1.15	1750	0.87		

Curve developed by New Mexico State University

Figure 39: Pecan 4000 Curve



Polynominal Function for Pecan 4000

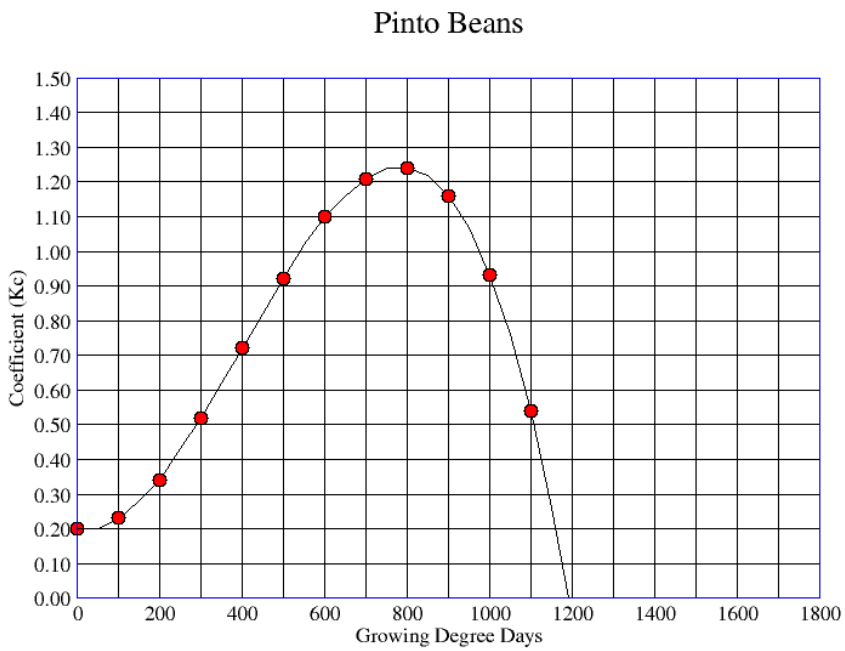
```
Kc  =    0.29E+00 +   0.111E-02(GDD) +   0.185E-06(GDD)**2 +
                 -0.323E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                  0.000E+00(GDD)**5
```

Min. Cutoff Temperature (deg. C) = -4.0
Base Temperature (deg. C) = 15.5

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.29	600	0.96	1200	1.33	1800	1.01
50	0.35	650	1.00	1250	1.34	1850	0.93
100	0.41	700	1.05	1300	1.34	1900	0.85
150	0.46	750	1.09	1350	1.33	1950	0.77
200	0.52	800	1.13	1400	1.32	2000	0.67
250	0.58	850	1.17	1450	1.31	2050	0.56
300	0.63	900	1.21	1500	1.28	2100	0.45
350	0.69	950	1.24	1550	1.26	2150	0.32
400	0.75	1000	1.26	1600	1.22	2200	0.19
450	0.80	1050	1.29	1650	1.18	2250	0.05
500	0.85	1100	1.31	1700	1.13		
550	0.91	1150	1.32	1750	1.07		

Curve developed by New Mexico State University

Figure 40: Pinto Beans Curve

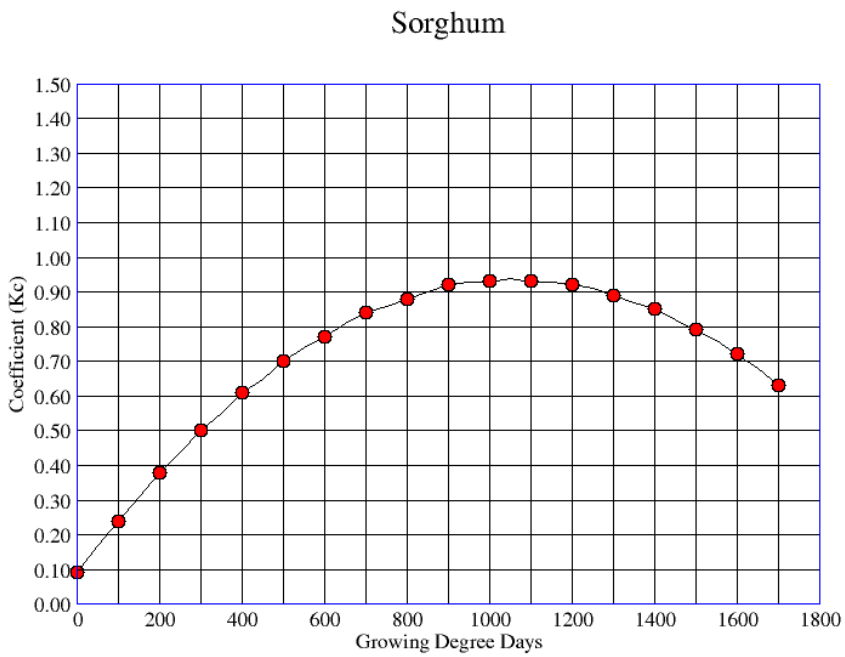



```
                Polynominal Function for Pinto Beans

 Kc  =    0.20E+00 +  -0.212E-03(GDD) +   0.572E-05(GDD)**2 +
                     -0.477E-08(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

 Max. Cutoff Temperature (deg. C) =  30.0
 Min. Cutoff Temperature (deg. C) =  10.0
 Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.20	600	1.10		
50	0.20	650	1.16		
100	0.23	700	1.21		
150	0.28	750	1.24		
200	0.34	800	1.24		
250	0.43	850	1.22		
300	0.52	900	1.16		
350	0.62	950	1.07		
400	0.72	1000	0.93		
450	0.82	1050	0.76		
500	0.92	1100	0.54		
550	1.02	1150	0.26		

Curve developed by New Mexico State University

Figure 41: Sorghum Curve

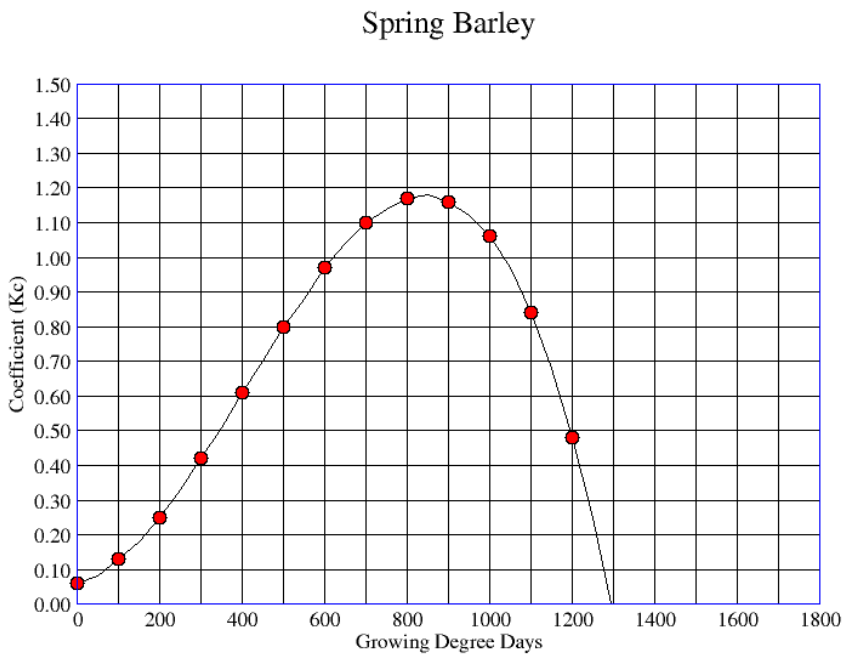



```
                Polynominal Function for Sorghum

 Kc  =    0.89E-01 +   0.159E-02(GDD) +  -0.746E-06(GDD)**2 +
                     -0.836E-12(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

 Base Temperature (deg. C) =   7.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.09	600	0.77	1200	0.92
50	0.17	650	0.81	1250	0.91
100	0.24	700	0.84	1300	0.89
150	0.31	750	0.86	1350	0.87
200	0.38	800	0.88	1400	0.85
250	0.44	850	0.90	1450	0.82
300	0.50	900	0.92	1500	0.79
350	0.55	950	0.93	1550	0.76
400	0.61	1000	0.93	1600	0.72
450	0.65	1050	0.94	1650	0.68
500	0.70	1100	0.93	1700	0.63
550	0.74	1150	0.93		

Curve developed by New Mexico State University

Figure 42: Spring Barley Curve

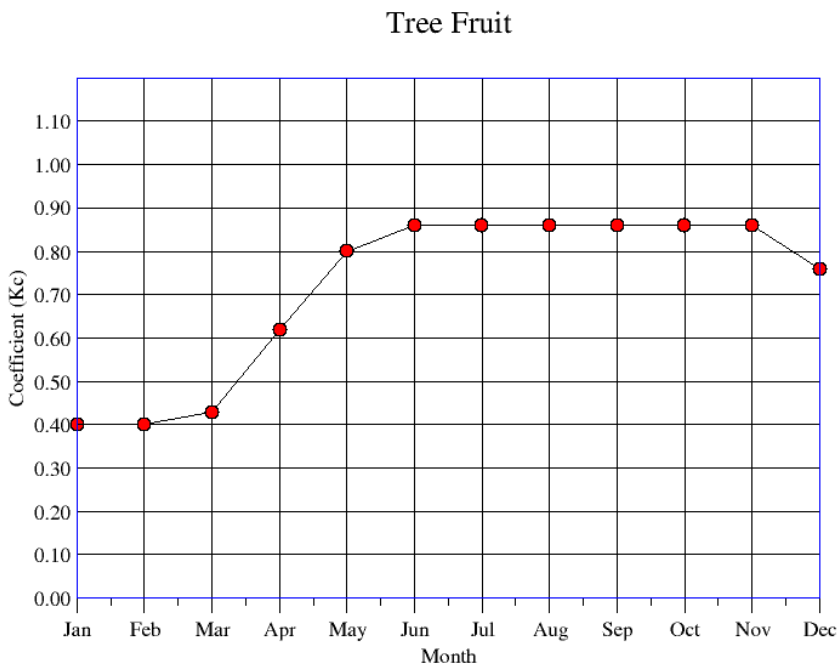



```
                Polynominal Function for Spring Barley

 Kc  =    0.57E-01 +   0.323E-03(GDD) +   0.394E-05(GDD)**2 +
                     -0.326E-08(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

 Max. Cutoff Temperature (deg. C) =  30.0
 Min. Cutoff Temperature (deg. C) =   5.0
 Base Temperature (deg. C) =   5.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.06	600	0.97	1200	0.48
50	0.08	650	1.04	1250	0.25
100	0.13	700	1.10		
150	0.18	750	1.14		
200	0.25	800	1.17		
250	0.33	850	1.18		
300	0.42	900	1.16		
350	0.51	950	1.12		
400	0.61	1000	1.06		
450	0.70	1050	0.97		
500	0.80	1100	0.84		
550	0.88	1150	0.68		

Curve developed by New Mexico State University

Figure 43: Tree Fruit Curve

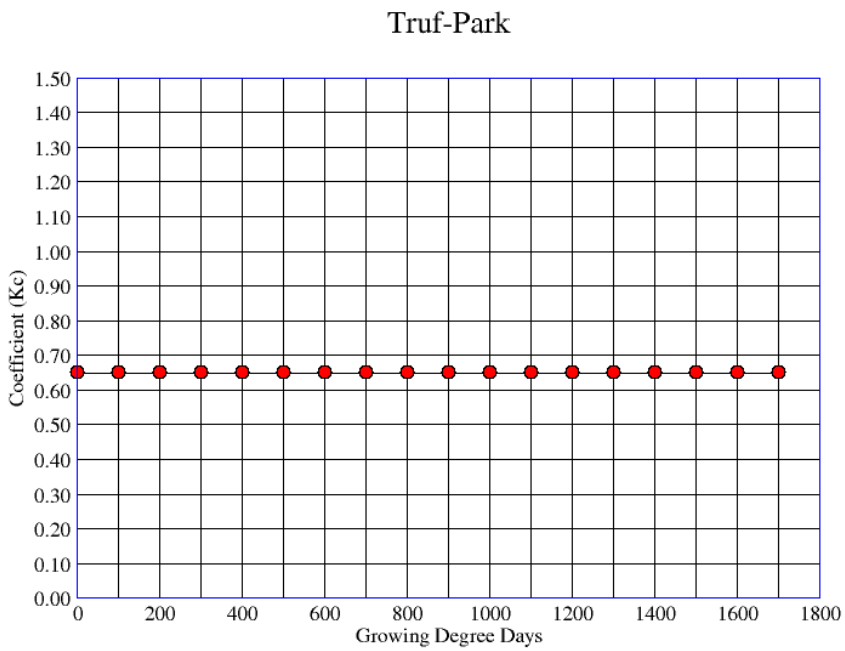


Monthly Coefficients for Tree Fruit

Month	Crop Coefficient (Kc)
January	0.40
February	0.40
March	0.43
April	0.62
May	0.80
June	0.86
July	0.86
August	0.86
September	0.86
October	0.86
November	0.86
December	0.76

Data from Jensen,M.E., (1998)

Figure 44: Turf-Park Curve

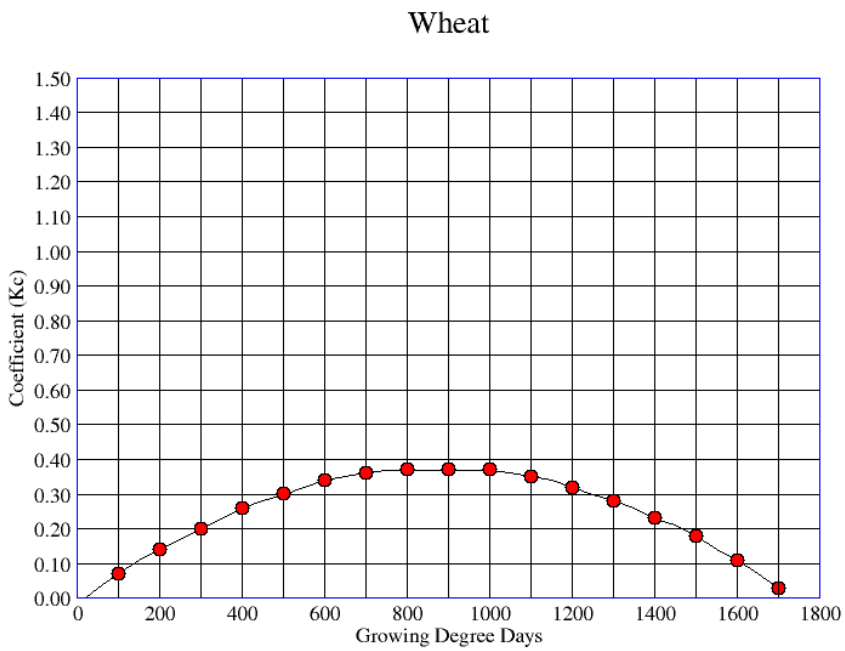



```
                Polynominal Function for Turf-Park

 Kc  =    0.65E+00 +   0.000E+00(GDD) +   0.000E+00(GDD)**2 +
                     0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

 Base Temperature (deg. C) =   5.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.65	600	0.65	1200	0.65
50	0.65	650	0.65	1250	0.65
100	0.65	700	0.65	1300	0.65
150	0.65	750	0.65	1350	0.65
200	0.65	800	0.65	1400	0.65
250	0.65	850	0.65	1450	0.65
300	0.65	900	0.65	1500	0.65
350	0.65	950	0.65	1550	0.65
400	0.65	1000	0.65	1600	0.65
450	0.65	1050	0.65	1650	0.65
500	0.65	1100	0.65	1700	0.65
550	0.65	1150	0.65		

Curve developed by New Mexico State University

Figure 45: Wheat Curve



Polynominal Function for Wheat

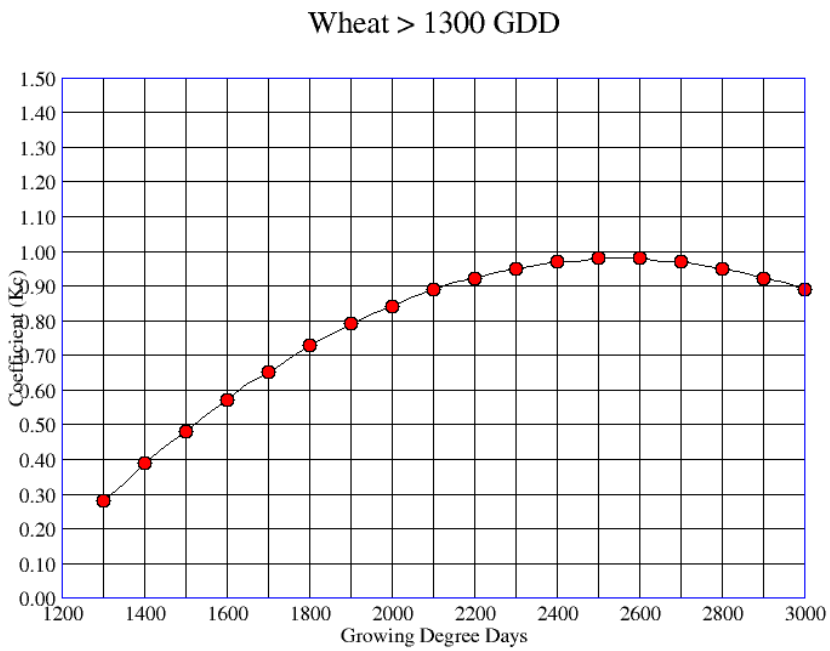
```
Kc  =   -0.17E-01 +   0.894E-03(GDD) +  -0.510E-06(GDD)**2 +
                    0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                    0.000E+00(GDD)**5
```

Max. Cutoff Temperature (deg. C) = 27.0
Min. Cutoff Temperature (deg. C) = 4.0
Base Temperature (deg. C) = 4.0

GDD	Kc	GDD	Kc	GDD	Kc
50	0.03	650	0.35	1250	0.30
100	0.07	700	0.36	1300	0.28
150	0.11	750	0.37	1350	0.26
200	0.14	800	0.37	1400	0.23
250	0.17	850	0.37	1450	0.21
300	0.20	900	0.37	1500	0.18
350	0.23	950	0.37	1550	0.14
400	0.26	1000	0.37	1600	0.11
450	0.28	1050	0.36	1650	0.07
500	0.30	1100	0.35	1700	0.03
550	0.32	1150	0.34		
600	0.34	1200	0.32		

Curve developed by New Mexico State University

Figure 46: Wheat>1300 GDD Curve

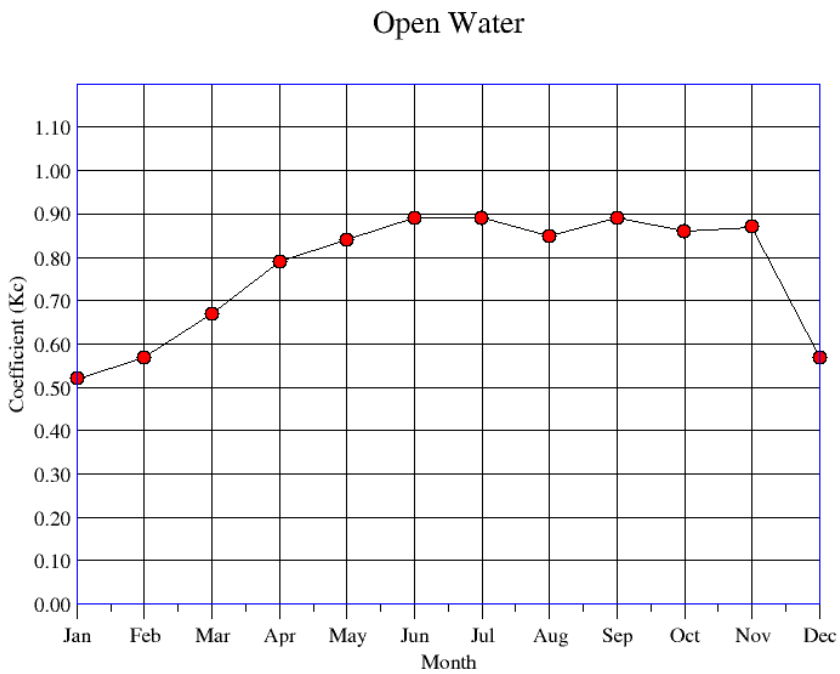



```
                Polynominal Function for Wheat > 1300 GDD

 Kc  =   -0.19E+01 +   0.228E-02(GDD) +  -0.447E-06(GDD)**2 +
                    0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                    0.000E+00(GDD)**5

 Max. Cutoff Temperature (deg. C) =  27.0
 Min. Cutoff Temperature (deg. C) =   4.0
 Base Temperature (deg. C) =   4.0
```

GDD	Kc	GDD	Kc	GDD	Kc
1300	0.28	1900	0.79	2500	0.98
1350	0.33	1950	0.82	2550	0.98
1400	0.39	2000	0.84	2600	0.98
1450	0.44	2050	0.87	2650	0.97
1500	0.48	2100	0.89	2700	0.97
1550	0.53	2150	0.91	2750	0.96
1600	0.57	2200	0.92	2800	0.95
1650	0.62	2250	0.94	2850	0.94
1700	0.65	2300	0.95	2900	0.92
1750	0.69	2350	0.96	2950	0.91
1800	0.73	2400	0.97	3000	0.89
1850	0.76	2450	0.97		

Curve developed by New Mexico State University

Figure 47: Open Water Curve

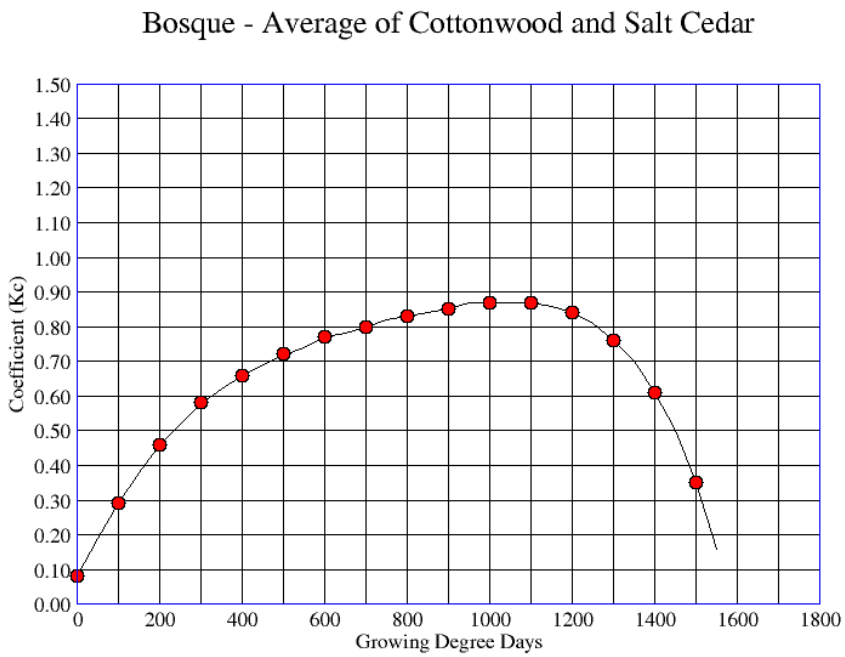


Monthly Coefficients for Open Water

Month	Crop Coefficient (Kc)
January	0.52
February	0.57
March	0.67
April	0.79
May	0.84
June	0.89
July	0.89
August	0.85
September	0.89
October	0.86
November	0.87
December	0.57

Data from Jensen,M.E., (1998)

Figure 48: Bosque Average Curve



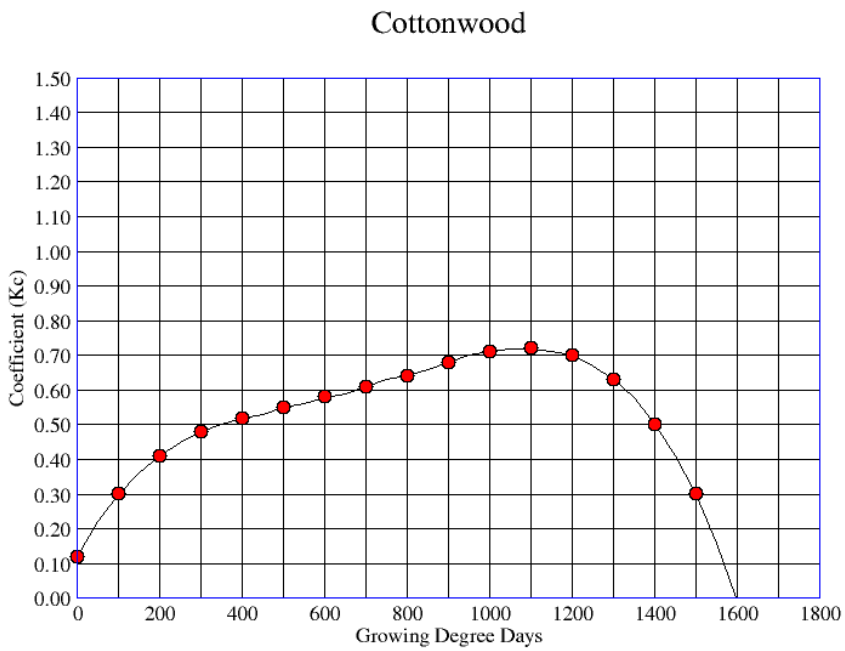
Polynominal Function for Bosque

The Bosque uses an average of the Kc calculated from the Cottonwood and Salt Cedar polynominal functions. Refer to them. In May, June, and July, the Kc is set to 1.00

GDD	Kc	GDD	Kc	GDD	Kc
0	0.08	600	0.77	1200	0.84
50	0.19	650	0.78	1250	0.81
100	0.29	700	0.80	1300	0.76
150	0.38	750	0.82	1350	0.70
200	0.46	800	0.83	1400	0.61
250	0.52	850	0.84	1450	0.50
300	0.58	900	0.85	1500	0.35
350	0.62	950	0.87	1550	0.16
400	0.66	1000	0.87		
450	0.66	1050	0.87		
500	0.72	1100	0.87		
550	0.74	1150	0.86		

Curve developed by New Mexico State University

Figure 49: Cottonwood Curve

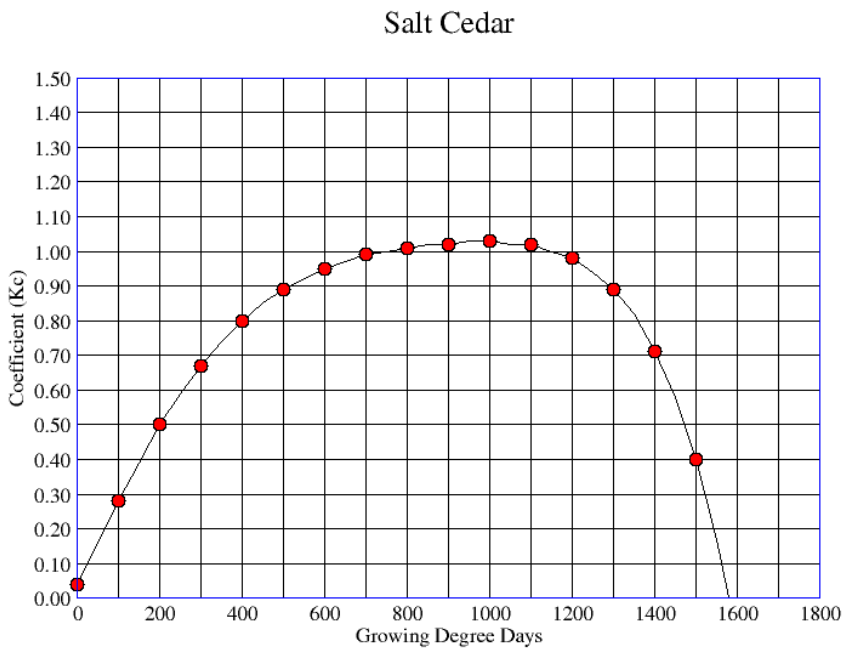



```
                Polynominal Function for Cottonwood

 Kc  =    0.12E+00 +   0.225E-02(GDD) +  -0.506E-05(GDD)**2 +
                     0.585E-08(GDD)**3 +  -0.279E-11(GDD)**4 +
                     0.338E-15(GDD)**5

 Min. Cutoff Temperature (deg. C) =  15.5
 Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.12	600	0.58	1200	0.70
50	0.22	650	0.59	1250	0.67
100	0.30	700	0.61	1300	0.63
150	0.36	750	0.63	1350	0.58
200	0.41	800	0.64	1400	0.50
250	0.45	850	0.66	1450	0.41
300	0.48	900	0.68	1500	0.30
350	0.50	950	0.70	1550	0.16
400	0.52	1000	0.71		
450	0.53	1050	0.72		
500	0.55	1100	0.72		
550	0.56	1150	0.71		

Curve developed by New Mexico State University

Figure 50: Salt Cedar Curve



Polynominal Function for Salt Cedar

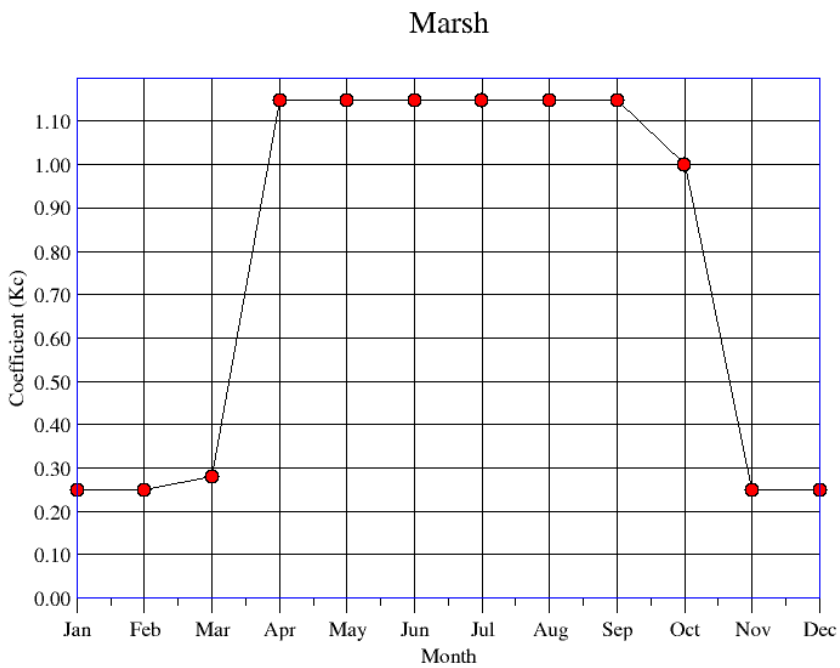
```
Kc  =    0.40E-01 +   0.253E-02(GDD) +  -0.653E-06(GDD)**2 +
                  -0.395E-08(GDD)**3 +   0.469E-11(GDD)**4 +
                  -0.163E-14(GDD)**5
```

Min. Cutoff Temperature (deg. C) = 15.5
Base Temperature (deg. C) = 15.5

GDD	Kc	GDD	Kc	GDD	Kc
0	0.04	600	0.95	1200	0.98
50	0.16	650	0.97	1250	0.94
100	0.28	700	0.99	1300	0.89
150	0.39	750	1.00	1350	0.82
200	0.50	800	1.01	1400	0.71
250	0.59	850	1.02	1450	0.58
300	0.67	900	1.02	1500	0.40
350	0.74	950	1.03	1550	0.17
400	0.80	1000	1.03		
450	0.85	1050	1.02		
500	0.89	1100	1.02		
550	0.92	1150	1.00		

Curve developed by New Mexico State University

Figure 51: Marsh Curve



Monthly Coefficients for Marsh

Month	Crop Coefficient (Kc)
January	0.25
February	0.25
March	0.28
April	1.15
May	1.15
June	1.15
July	1.15
August	1.15
September	1.15
October	1.00
November	0.25
December	0.25

Data from Jensen,M.E., (1998)

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REA3 URGWOM Reach 3 (San Felipe to Cent. Ave. gage) LUTA 1992/93
ANGN Angostura, NM – MRGCD 101 2003

108x313			12	1 2.5	3 1.1	8 3.8	9 24.5	10 14.9	20 625.8	21 317.8	23 49.4	26 7.1	28 1.6	33 14.2	34 32.9
101	0.00	53.4	0.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.01	0.00	0.00
102	0.00	53.4	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
103	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
104	0.00	53.4	0.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.01	0.00	0.00
105	0.00	53.4	0.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.01	0.00	0.00
106	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
107	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
108	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
109	0.00	53.4	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
110	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
111	0.00	53.4	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
112	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
113	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
114	0.00	53.4	0.22	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.00	0.00
115	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
116	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
117	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
118	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
119	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
120	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
121	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
122	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
123	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
124	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
125	0.00	53.4	0.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.01	0.00	0.00
126	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
127	0.00	53.4	0.35	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.01	0.00	0.00
128	0.00	53.4	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.01	0.00	0.00
E 129	0.00	53.4	0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01	0.00	0.00
E 130	0.00	53.4	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.01	0.00	0.00
E 131	0.00	53.4	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.01	0.00	0.00

Wednesday February 18, 2004 REA3.ettool 1/1

Figure 52: ET Toolbox File

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```
Description of contents of the ET TOOLBOX file - Sample file name = REA1.ettool
--------------------------------------------------------------------------------

   The fortran format is included for clarity and can be used by a
   fortran program to read the file.

1. First record:    format = a4,1x,a48,10x,a4,2x,a10
     Reach short name
     Reach long name
     Vegetation classification source
     Vegetation classification year

2. Second record:   format = 1x,a4,1x,a48,5x,i4,1x,i4
     Weather station short name
     Weather station long name
     Start day (month-day - generally Jan 1.)  example: 101 = January 1
     Start year

3. Third record:    format =  2x,i3,1hx,i3,18x,i3,2h |,<inum>(1x,i3,f8.1,2h |)
     Cell number (x value)
     Cell number (y value)
     Number of land use classifications in this cell (inum)
      The following are repeated for the number of land use classifications:
        Land use classification
        Acres

4. Fourth record:   format = 3x,i4,f7.2,f8.1,f8.2,2h |,<inum>(f8.2,4x,2h |)
     Month-day
     Nexrad estimated rainfall for this day in this cell - inches
     Active acres - For water use classifications (those that are active based
                    on plant and terminate dates, riparian, and open water)
     Total consumptive use for this day - acre-feet
     Consumptive use for each land use classification for this day - acre-feet

           These fourth records are repeated for each day

5. 7777 record:     format = 3x,4h7777,f7.2,8x,f8.2,2h |,<inum>(f8.2,4x,2h |)
     7777
     Total nexrad estimated rainfall to-date for this cell - inches
     Total consumptive use to-date for this cell - acre-feet
     Total consumptive use to-date for each land use classification for
       this cell - acre-feet

6. 8888 record:     format = 3x,4h8888,f7.2,8x,f8.2,2h |
     8888
     Total nexrad estimated rainfall to-date for this weather station - inches
     Total consumptive use to-date for this weather station - acre-feet

7. 9999 record:     format = 3x,4h9999,f7.2,8x,f8.2,2h |
     9999
     Total nexrad estimated rainfall to-date for this reach - inches
     Total consumptive use to-date for this reach - acre-feet

LUTA 1992/93 Land Use Classes

No.     Class description
 1      Alfalfa
 2      Pasture grasses
 3      Sorghum/Sudex
 4      Wheat
 5      Corn
 6      Chile peppers
 7      Grapes
 8      Fallow agriculture
 9      Idle agriculture
10      Residential
11      Residential-dense
12      Urban irrigated
13      Parks/golf courses
14      Urban vacant
15      Commercial/industrial
16      Riparian woodland
17      Salt Cedar
18      Riparian shrub
```

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```
19      Marsh
20      Desert scrub
21      Pinon/Juniper
22      Arroyo
23      Open water
24      Miscellaneous grass
25      Quarry/borrow pit
26      Agricultural complex
27      Melons
28      Tree fruit
29      Nursery stock
30      Oats
31      not in the 4 LUTA 1992/93 counties
32      Miscellaneous fruit
33      Miscellaneous vegetables
34      Bosque
35      Cochiti Dam
36      Jemez river channel

40      Cottonwood
```

Wednesday October 15, 2003 README.ettool 1/1

Figure 53: ET Toolbox File Description

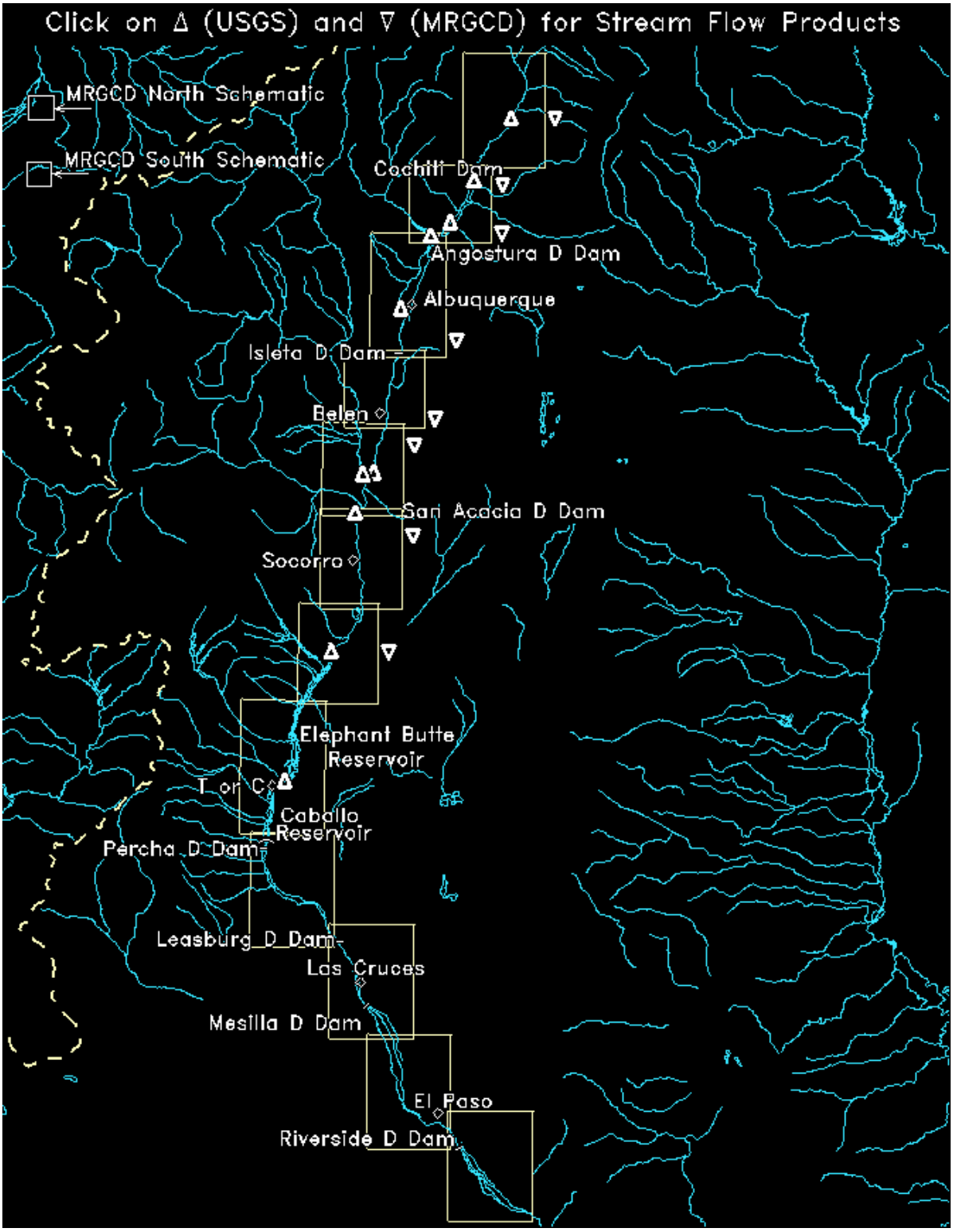

Figure 54: Stream Flow Products

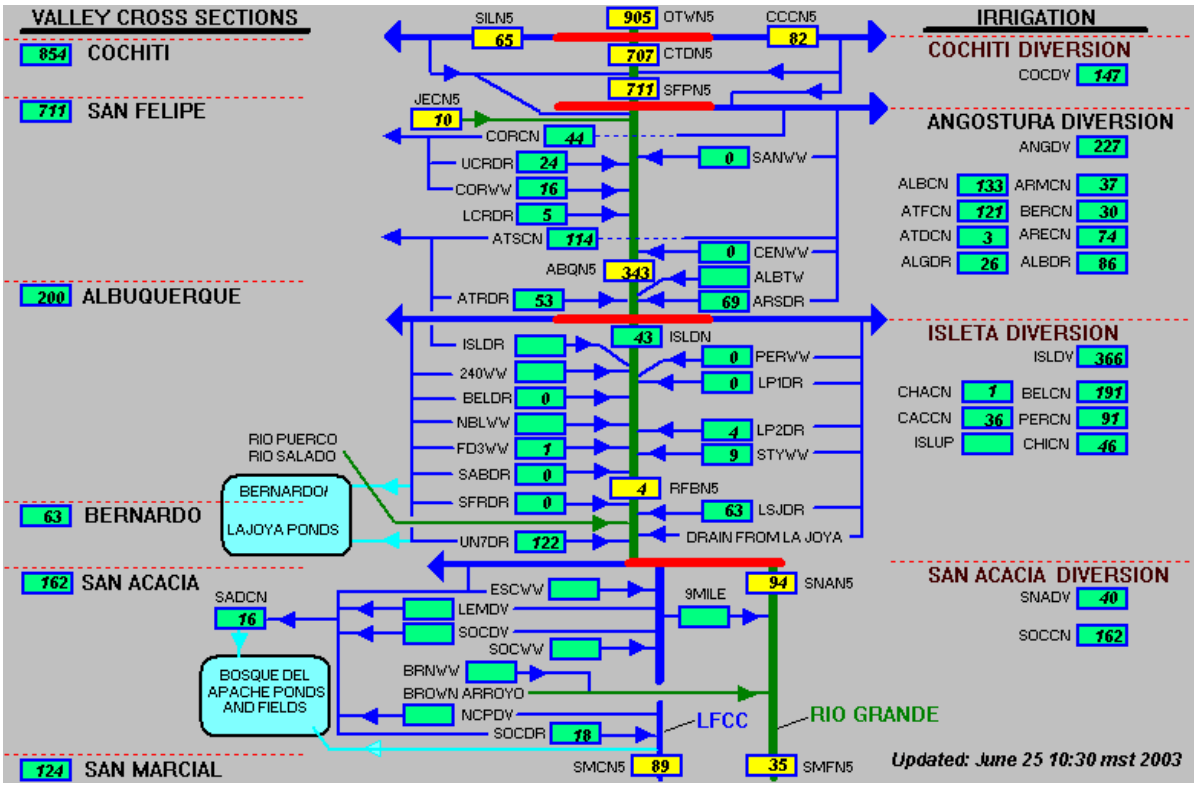

Figure 55: MRGCD North Schematic

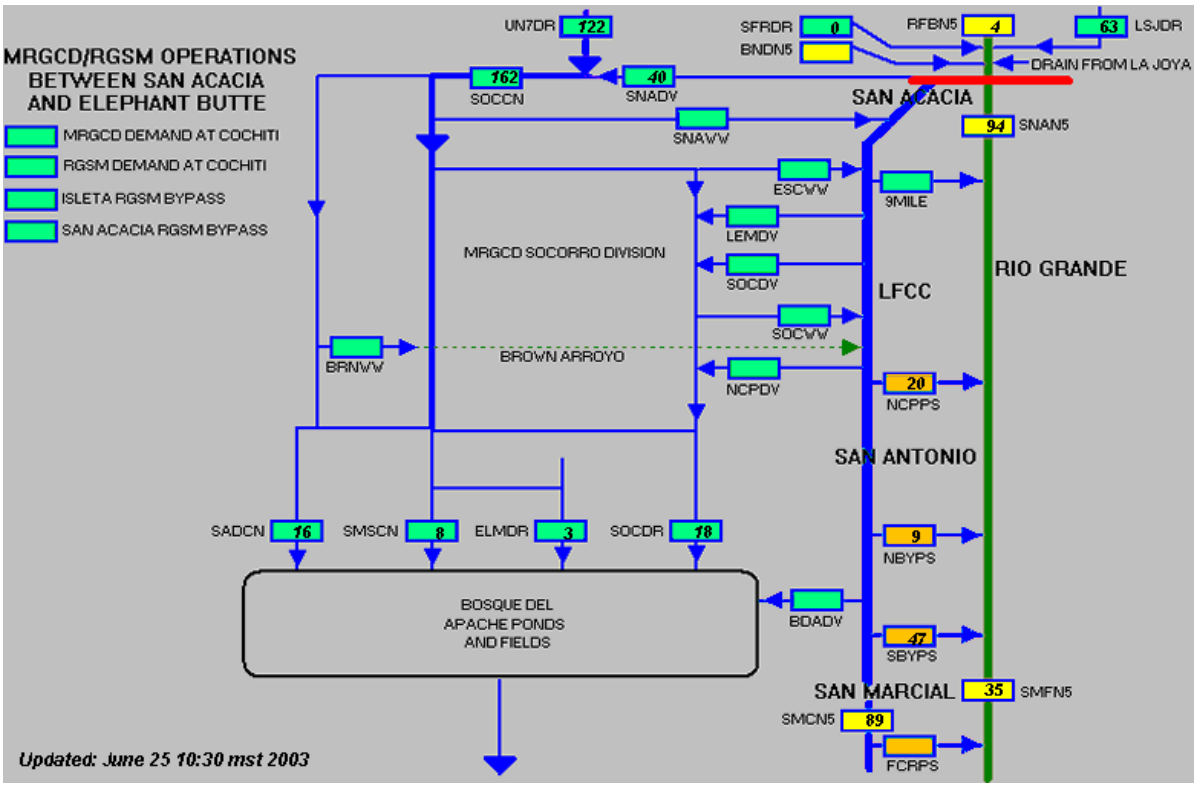

Figure 56: MRGCD South Schematic

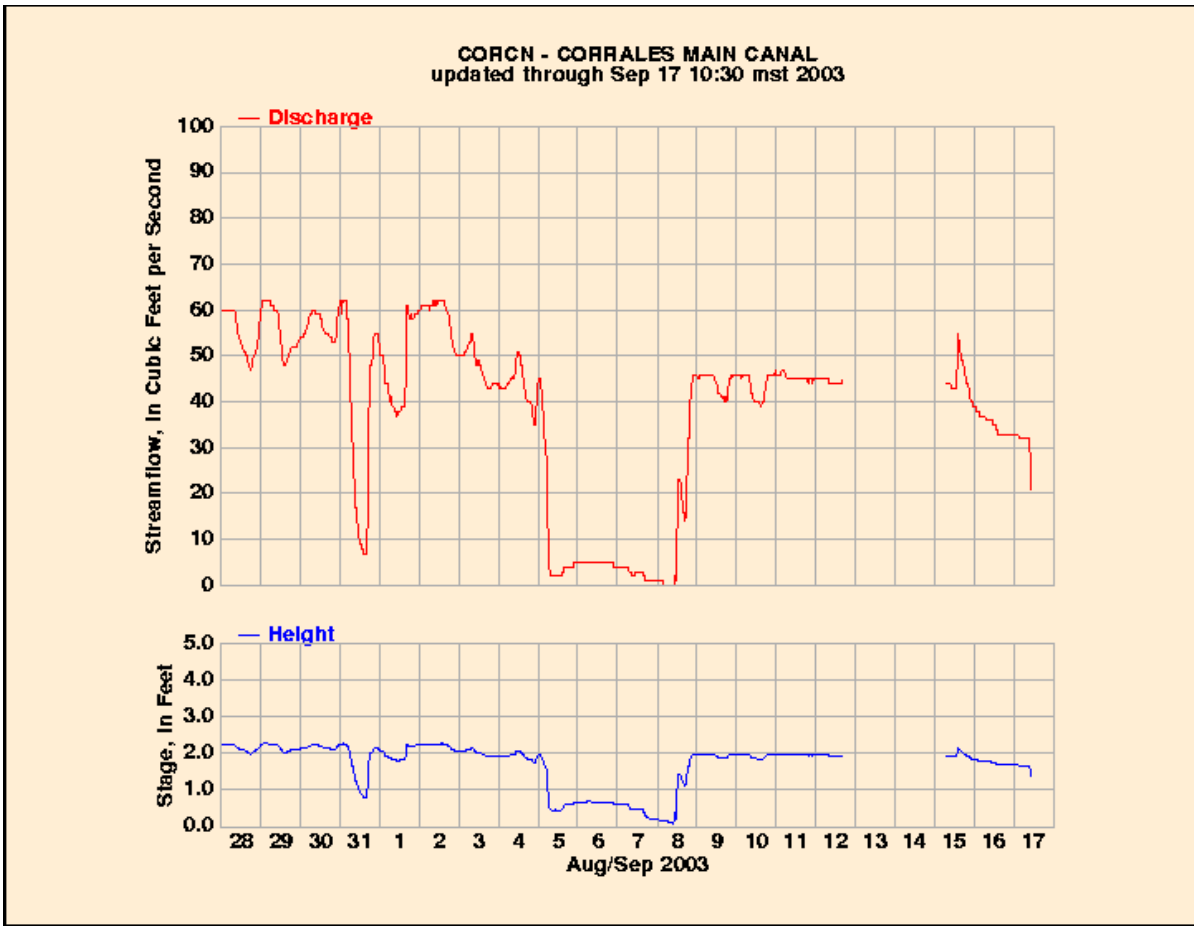

Figure 57: Corrales Main Canal Gage Station

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Sep 17, 03 12:19 **CORCN.gage** Page 1/1

Gage Information – CORCN – CORRALES MAIN CANAL
Year 2003

Month	Day	Time (mst)	Height (ft)	Discharge (cfs)
Sep	9	1030	1.95	45
Sep	9	1000	1.97	46
Sep	9	930	1.97	46
Sep	9	900	1.97	46
Sep	9	830	1.98	46
Sep	9	800	1.97	46
Sep	9	730	1.98	46
Sep	9	700	1.97	46
Sep	9	630	1.97	46
Sep	9	600	1.98	46
Sep	9	530	1.97	46
Sep	9	500	1.98	46
Sep	9	430	1.98	46
Sep	9	400	1.98	46
Sep	9	330	1.97	46
Sep	9	300	1.97	46
Sep	9	230	1.97	46
Sep	9	200	1.97	46
Sep	9	130	1.95	45
Sep	9	100	1.95	45
Sep	9	30	1.96	45
Sep	9	0	1.98	46
Sep	8	2330	1.97	46
Sep	8	2300	1.97	46
Sep	8	2230	1.97	46
Sep	8	2200	1.97	46
Sep	8	2130	1.96	45
Sep	8	2100	1.94	44
Sep	8	2030	1.90	42
Sep	8	2000	1.84	40
Sep	8	1930	1.67	32
Sep	8	1900	1.67	32
Sep	8	1830	1.58	29
Sep	8	1800	1.44	23
Sep	8	1730	1.25	17
Sep	8	1700	1.12	14
Sep	8	1630	1.15	15
Sep	8	1600	1.20	16
Sep	8	1530	1.22	17
Sep	8	1500	1.29	19
Sep	8	1430	1.36	21
Sep	8	1400	1.42	23
Sep	8	1330	1.44	23
Sep	8	1300	1.43	23
Sep	8	1230	1.36	21
Sep	8	1200	1.01	11
Sep	8	1130	0.22	1
Sep	8	1100	0.29	1
Sep	8	1030	0.37	2
Sep	8	1000	0.09	0
Sep	8	930	0.09	0
Sep	8	900	0.10	0
Sep	8	830	0.11	0
Sep	8	800	0.11	0
Sep	8	730	0.13	0
Sep	8	700	0.13	0
Sep	8	630	0.14	0
Sep	8	600	0.15	0
Sep	8	530	0.15	0
Sep	8	500	0.16	0
Sep	8	430	0.16	0
Sep	8	400	0.16	0
Sep	8	330	0.17	1

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Figure 58: Corrales Main Canal Gage Information

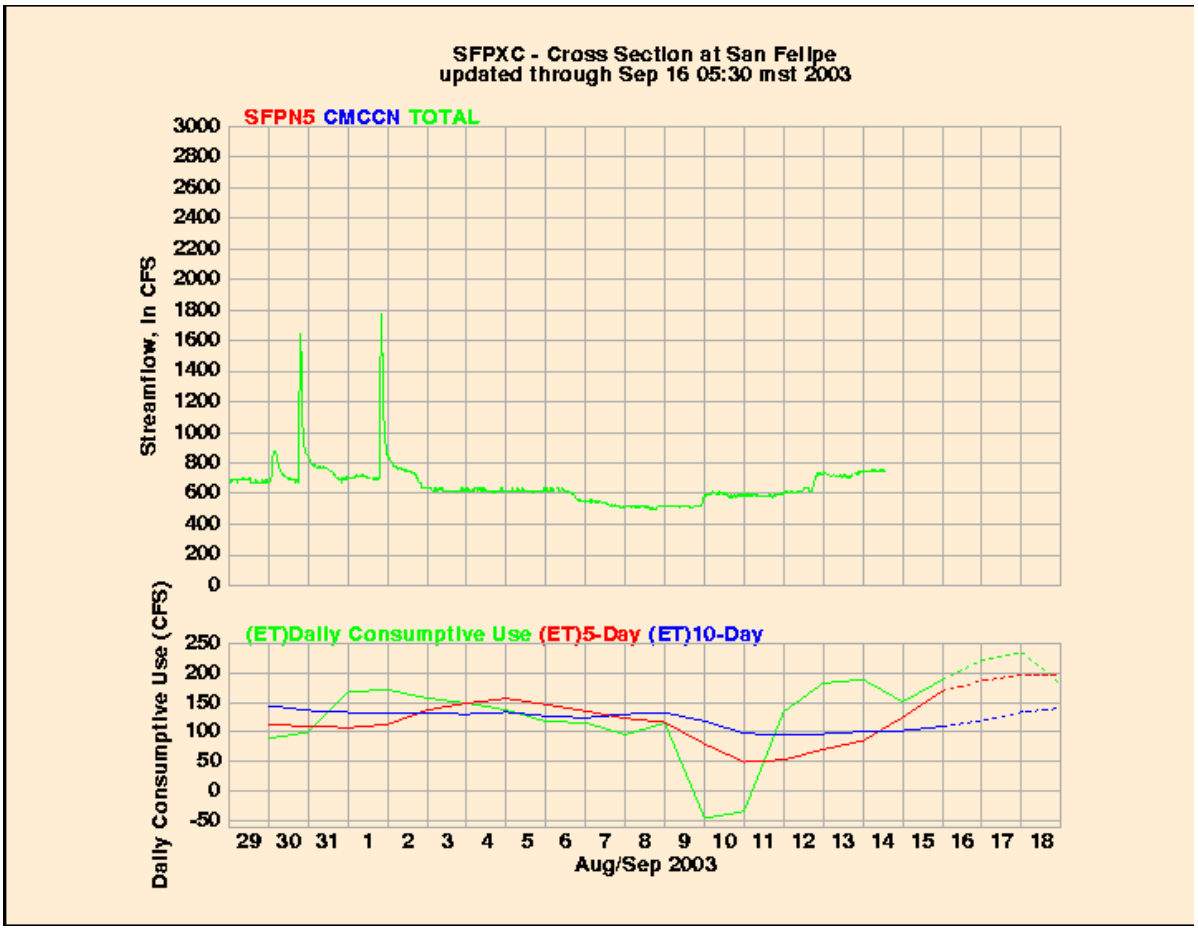

Figure 59: Valley Cross Section

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Sep 17, 03 12:20 **SFPXC.gage** Page 1/1

Gage Information – SFPXC – Cross Section at San Felipe
Year 2003

Month	Day	Time (mst)	SFPN5 (cfs)	CMCCN (cfs)	TOTAL (cfs)	DaAvg (cfs)
Sep	9	530	592	M	592	588
Sep	9	500	582	M	582	
Sep	9	430	592	M	592	
Sep	9	400	582	M	582	
Sep	9	330	592	M	592	
Sep	9	300	582	M	582	
Sep	9	230	582	M	582	
Sep	9	200	602	M	602	
Sep	9	130	582	M	582	
Sep	9	100	592	M	592	
Sep	9	30	592	M	592	
Sep	9	0	592	M	592	
Sep	8	2330	582	M	582	591
Sep	8	2300	592	M	592	
Sep	8	2230	592	M	592	
Sep	8	2200	592	M	592	
Sep	8	2130	582	M	582	
Sep	8	2100	592	M	592	
Sep	8	2030	592	M	592	
Sep	8	2000	582	M	582	
Sep	8	1930	582	M	582	
Sep	8	1900	572	M	572	
Sep	8	1830	582	M	582	
Sep	8	1800	592	M	592	
Sep	8	1730	582	M	582	
Sep	8	1700	572	M	572	
Sep	8	1630	592	M	592	
Sep	8	1600	582	M	582	
Sep	8	1530	572	M	572	
Sep	8	1500	582	M	582	
Sep	8	1430	582	M	582	
Sep	8	1400	592	M	592	
Sep	8	1330	602	M	602	
Sep	8	1300	592	M	592	
Sep	8	1230	602	M	602	
Sep	8	1200	602	M	602	
Sep	8	1130	592	M	592	
Sep	8	1100	602	M	602	
Sep	8	1030	602	M	602	
Sep	8	1000	602	M	602	
Sep	8	930	613	M	613	
Sep	8	900	602	M	602	
Sep	8	830	592	M	592	
Sep	8	800	592	M	592	
Sep	8	730	602	M	602	
Sep	8	700	592	M	592	
Sep	8	630	602	M	602	
Sep	8	600	602	M	602	
Sep	8	530	613	M	613	
Sep	8	500	602	M	602	
Sep	8	430	602	M	602	
Sep	8	400	602	M	602	
Sep	8	330	592	M	592	
Sep	8	300	592	M	592	
Sep	8	230	592	M	592	
Sep	8	200	592	M	592	
Sep	8	130	592	M	592	
Sep	8	100	582	M	582	
Sep	8	30	592	M	592	
Sep	8	0	572	M	572	
Sep	7	2330	582	M	582	518

Thursday September 18, 2003 1/1

Figure 60: Gage Information - Valley Cross Section at San Felipe

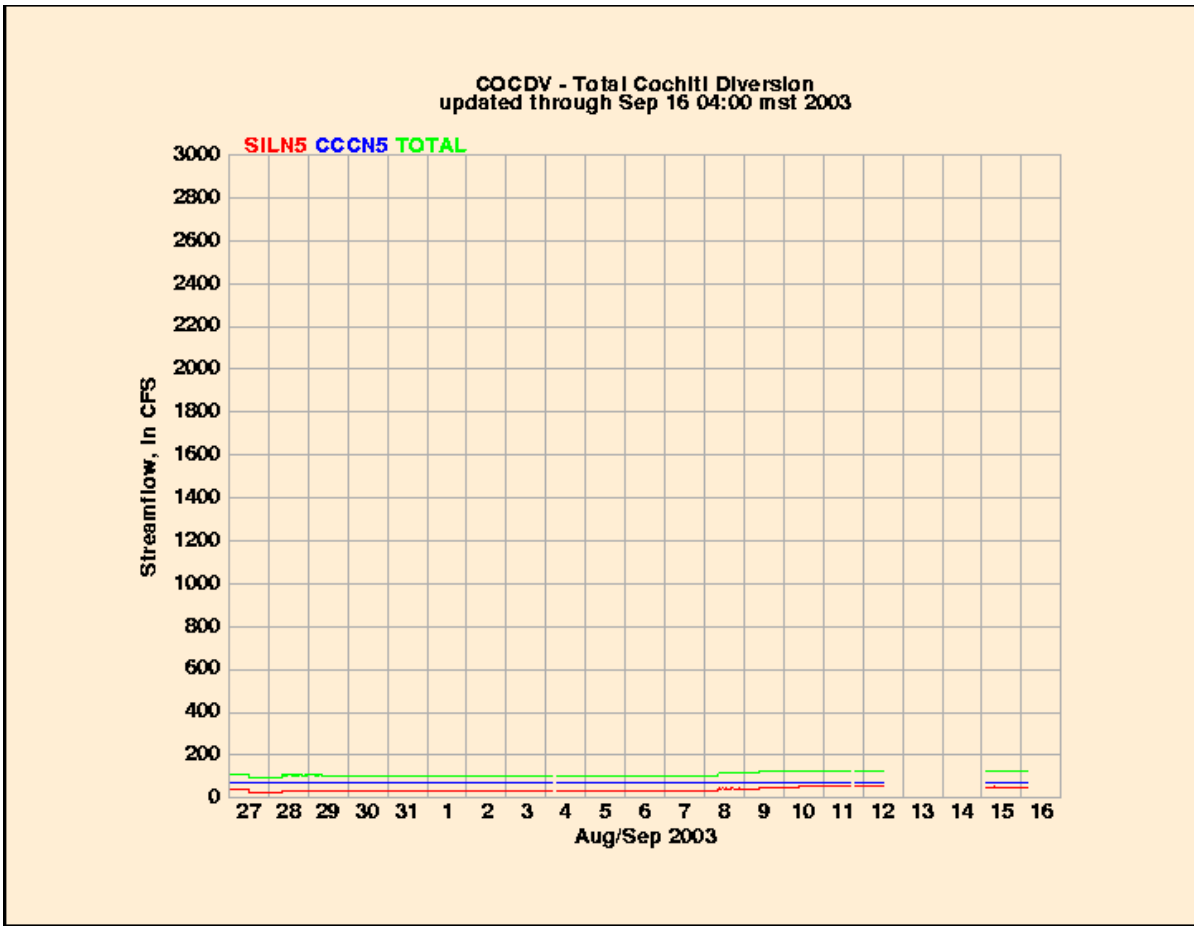

Figure 61: Total Cochiti Diversion

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Sep 09, 03 13:51 **COCDV.gage** Page 1/1

Gageing Information – COCDV – Total Cochiti Diversion
Year 2003

Month	Day	Time (mst)	SILN5 (cfs)	CCCN5 (cfs)	TOTAL (cfs)	DaAvg (cfs)
Sep	9	800	44	71	115	115
Sep	9	730	44	71	115	
Sep	9	700	44	71	115	
Sep	9	630	44	71	115	
Sep	9	600	44	71	115	
Sep	9	530	44	71	115	
Sep	9	500	44	71	115	
Sep	9	430	44	71	115	
Sep	9	400	44	71	115	
Sep	9	330	44	71	115	
Sep	9	300	44	71	115	
Sep	9	230	44	71	115	
Sep	9	200	44	72	116	
Sep	9	130	44	71	115	
Sep	9	100	44	71	115	
Sep	9	30	44	71	115	
Sep	9	0	44	71	115	
Sep	8	2330	44	71	115	111
Sep	8	2300	44	71	115	
Sep	8	2230	44	71	115	
Sep	8	2200	44	71	115	
Sep	8	2130	44	71	115	
Sep	8	2100	45	71	116	
Sep	8	2030	44	71	115	
Sep	8	2000	44	71	115	
Sep	8	1930	44	71	115	
Sep	8	1900	44	71	115	
Sep	8	1830	44	71	115	
Sep	8	1800	44	71	115	
Sep	8	1730	44	72	116	
Sep	8	1700	45	72	117	
Sep	8	1630	44	72	116	
Sep	8	1600	45	72	117	
Sep	8	1530	44	72	116	
Sep	8	1500	44	72	116	
Sep	8	1430	44	72	116	
Sep	8	1400	44	72	116	
Sep	8	1330	45	72	117	
Sep	8	1300	44	72	116	
Sep	8	1230	44	72	116	
Sep	8	1200	44	72	116	
Sep	8	1130	45	72	117	
Sep	8	1100	45	72	117	
Sep	8	1030	44	72	116	
Sep	8	1000	44	71	115	
Sep	8	930	44	71	115	
Sep	8	900	45	72	117	
Sep	8	830	44	72	116	
Sep	8	800	31	72	103	
Sep	8	730	31	72	103	
Sep	8	700	31	72	103	
Sep	8	630	31	72	103	
Sep	8	600	31	72	103	
Sep	8	530	31	72	103	
Sep	8	500	31	72	103	
Sep	8	430	31	72	103	
Sep	8	400	31	72	103	
Sep	8	330	31	72	103	
Sep	8	300	31	72	103	
Sep	8	230	31	71	102	
Sep	8	200	31	72	103	
Sep	8	130	31	72	103	
Sep	8	100	31	71	102	

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Figure 62: Cochiti Diversion Gage Information

Gage Station Products in Northern New Mexico

OPTIONS (Under Development Prototypes):

LOBC2 – Rio Grande near Lobatas, CO: Plots and Table

RLPN5 – Rio Chama near La Puente: Plots and Table

ELVN5 – El Vado Dam Storage & Elevation: Plots and Table

RCEN5 – Rio Grande below El Vado: Plots and Table

RCAN5 – Rio Chama above Abiquiu Dam: Plots and Table

ABIN5 – Abiquiu Reservoir Storage & Elevation: Plots and Table

AICN5 – Rio Chama below Abiquiu Dam: Plots and Table

RCOPS – Rio Chama Operations: Plots and Table

EMBN5 – Rio Grande at Embudo: Plots and Table

OTWN5 – Rio Grande below Otowi Bridge, near San Idlefonso: Plots and Table

Figure 63: Stream Products Menu

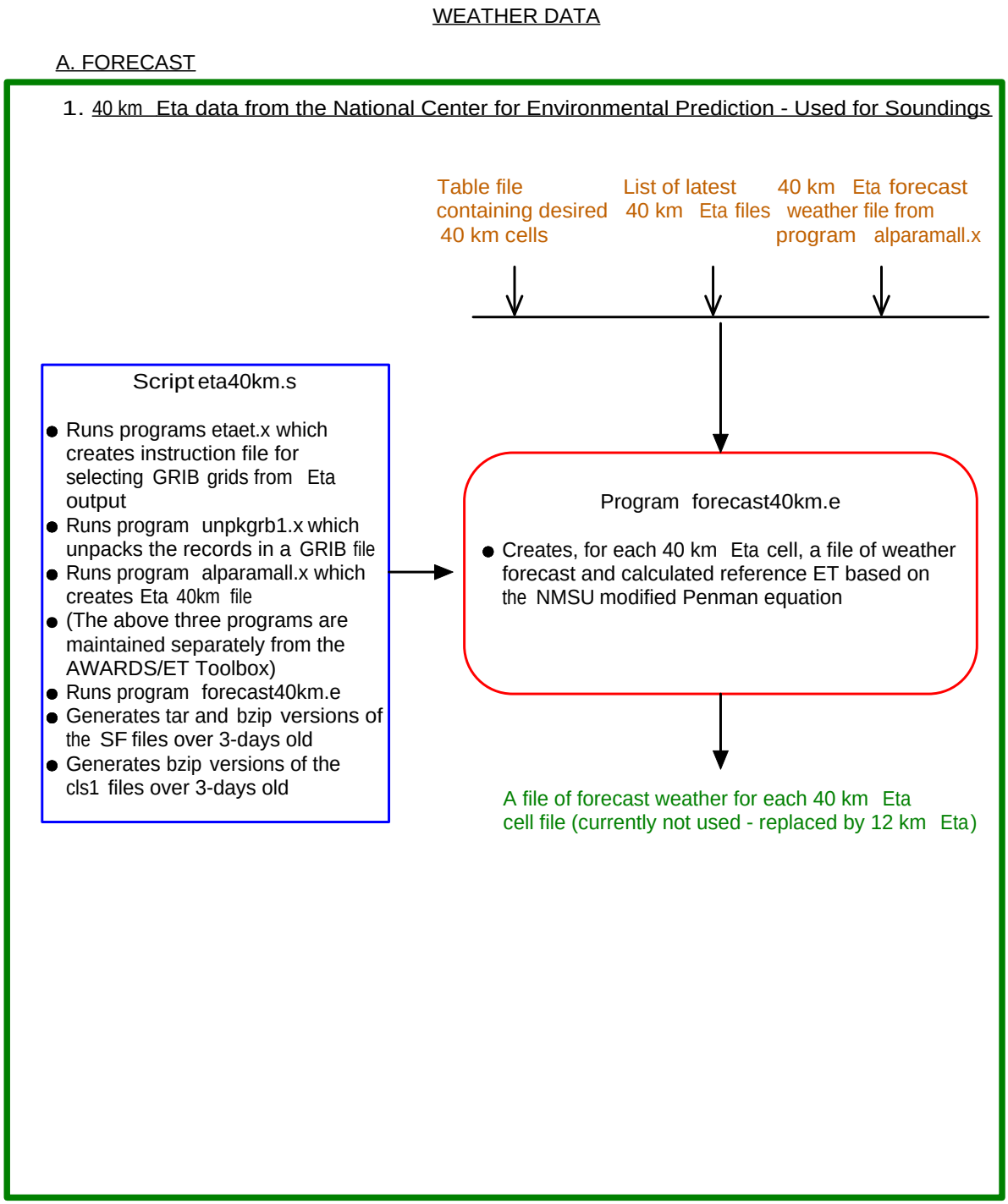

Figure 64: Flow Diagram of Weather Data, Page 1 - Forecast 40 km Eta data from the National Center for Environmental Prediction - Used for Soundings

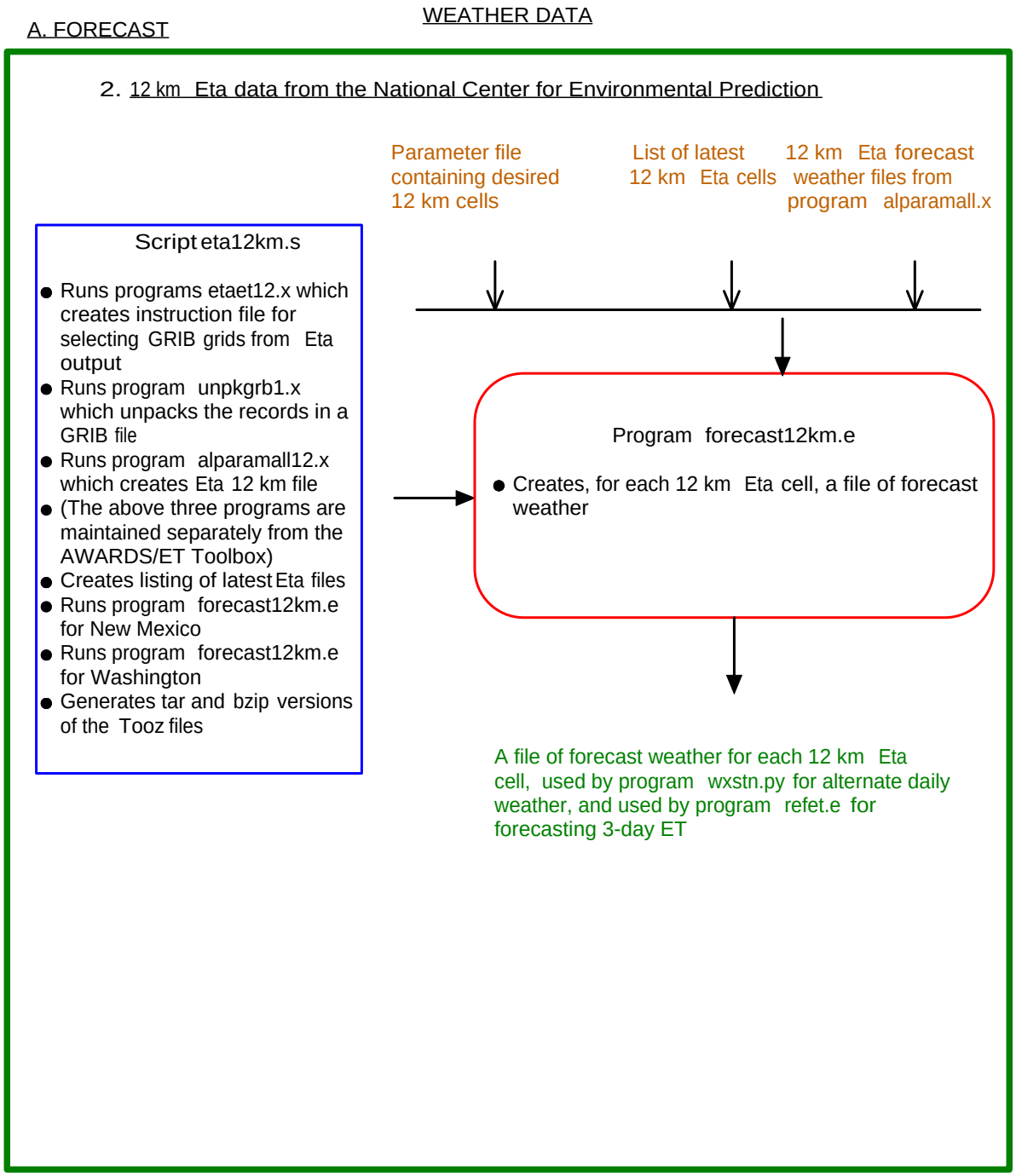

Figure 65: Flow Diagram of Weather Data, Page 2 - Forecast 12 km Eta data from the National Center for Environmental Prediction

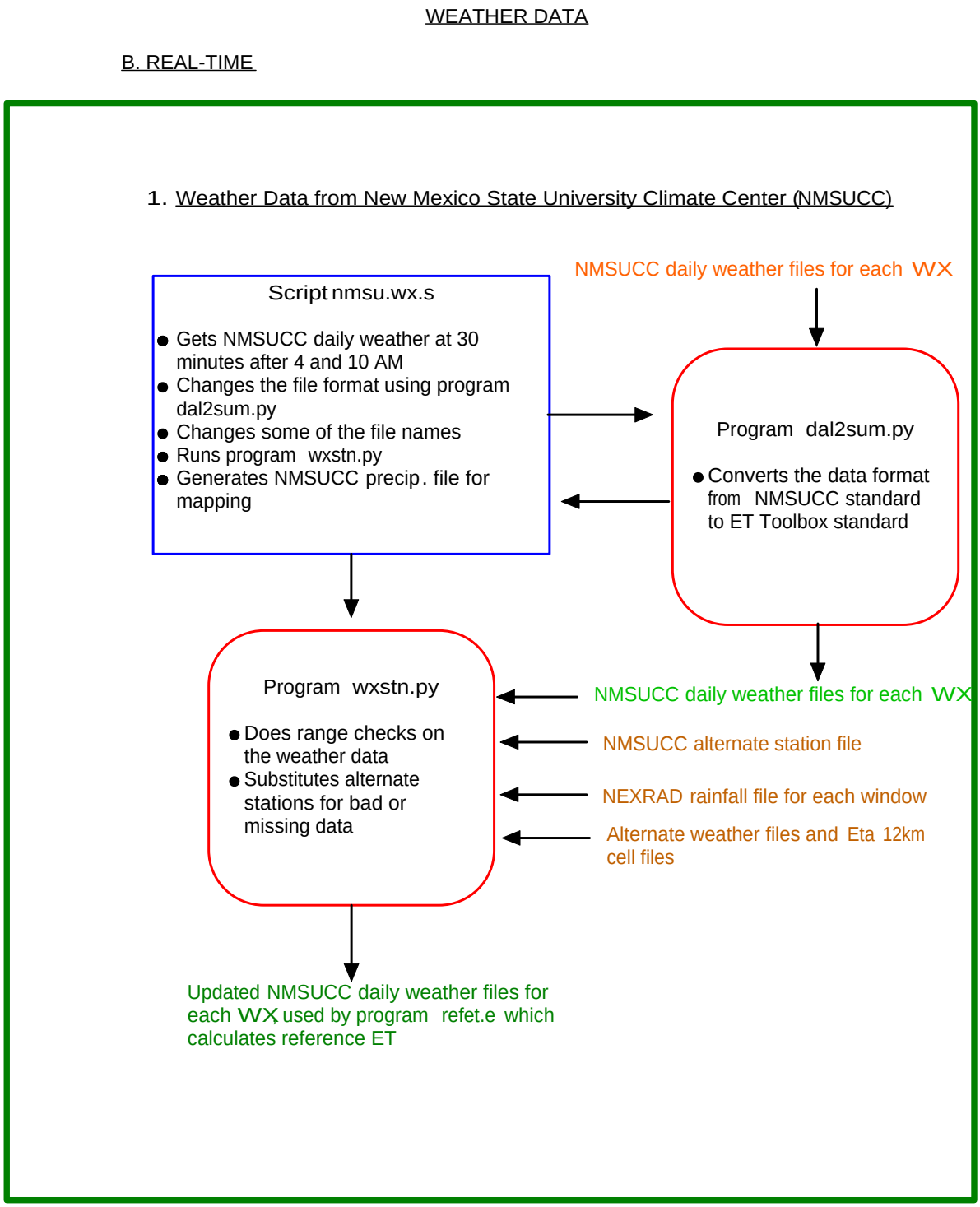

Figure 66: Flow Diagram of Weather Data, Page 3 - Real-Time from the New Mexico State University Climate Center (NMSUCC)

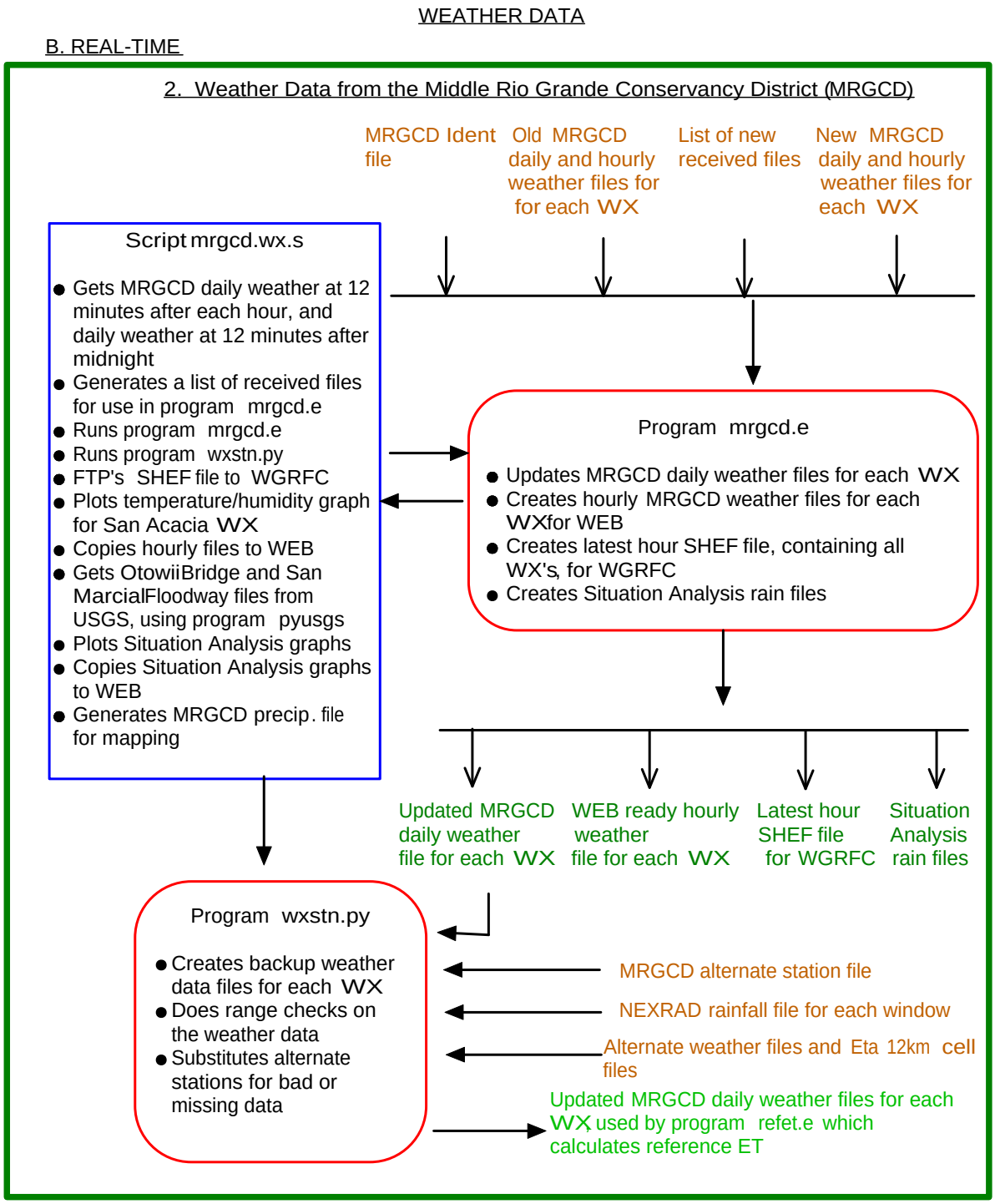

Figure 67: Flow Diagram of Weather Data, Page 4 - Real-Time from the Middle Rio Grande Conservancy District (MRGCD)

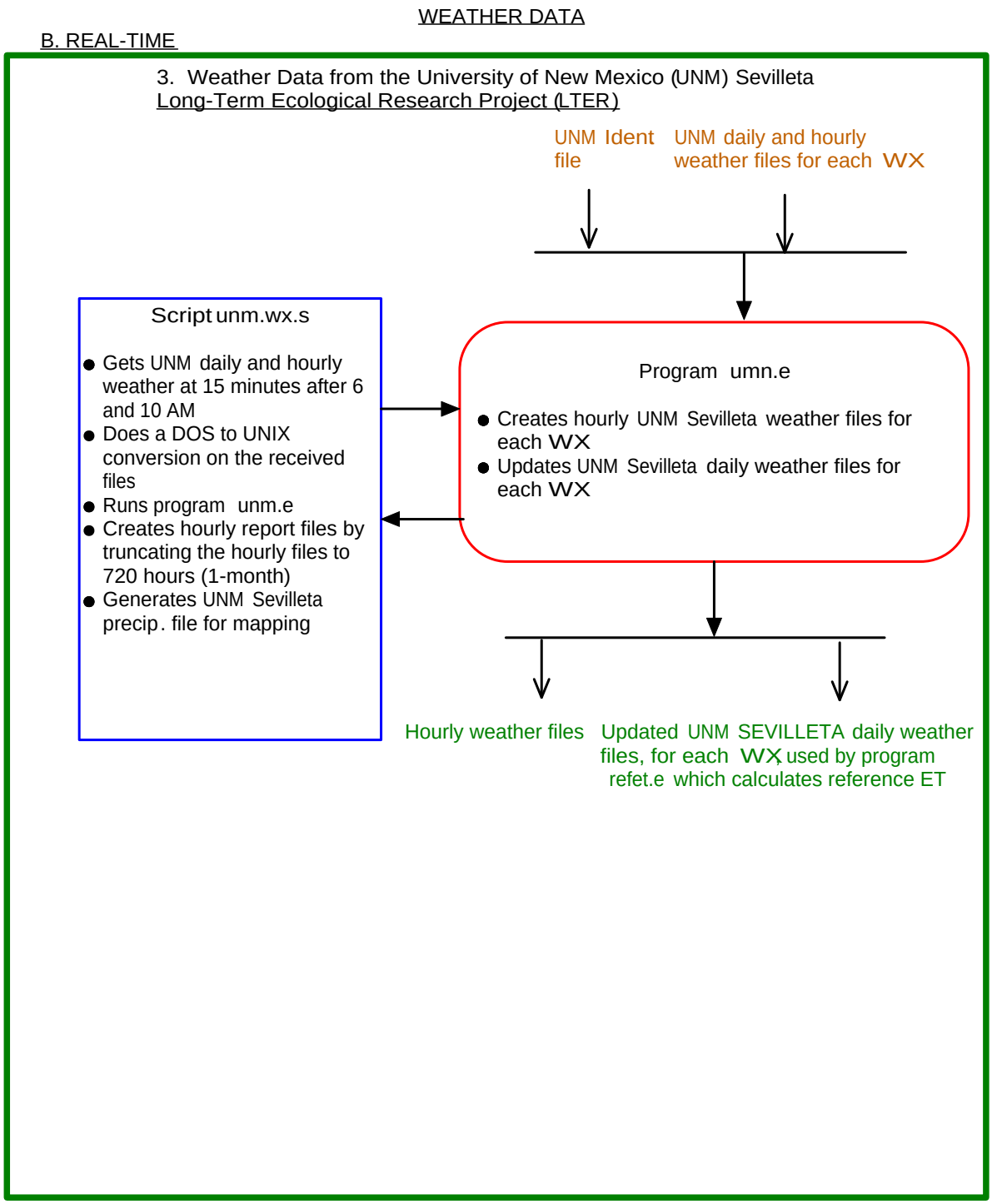

Figure 68: Flow Diagram of Weather Data, Page 5 - Real-Time from the University of New Mexico (UNM) Sevilleta Long-Term Ecological Research Project (LTER)

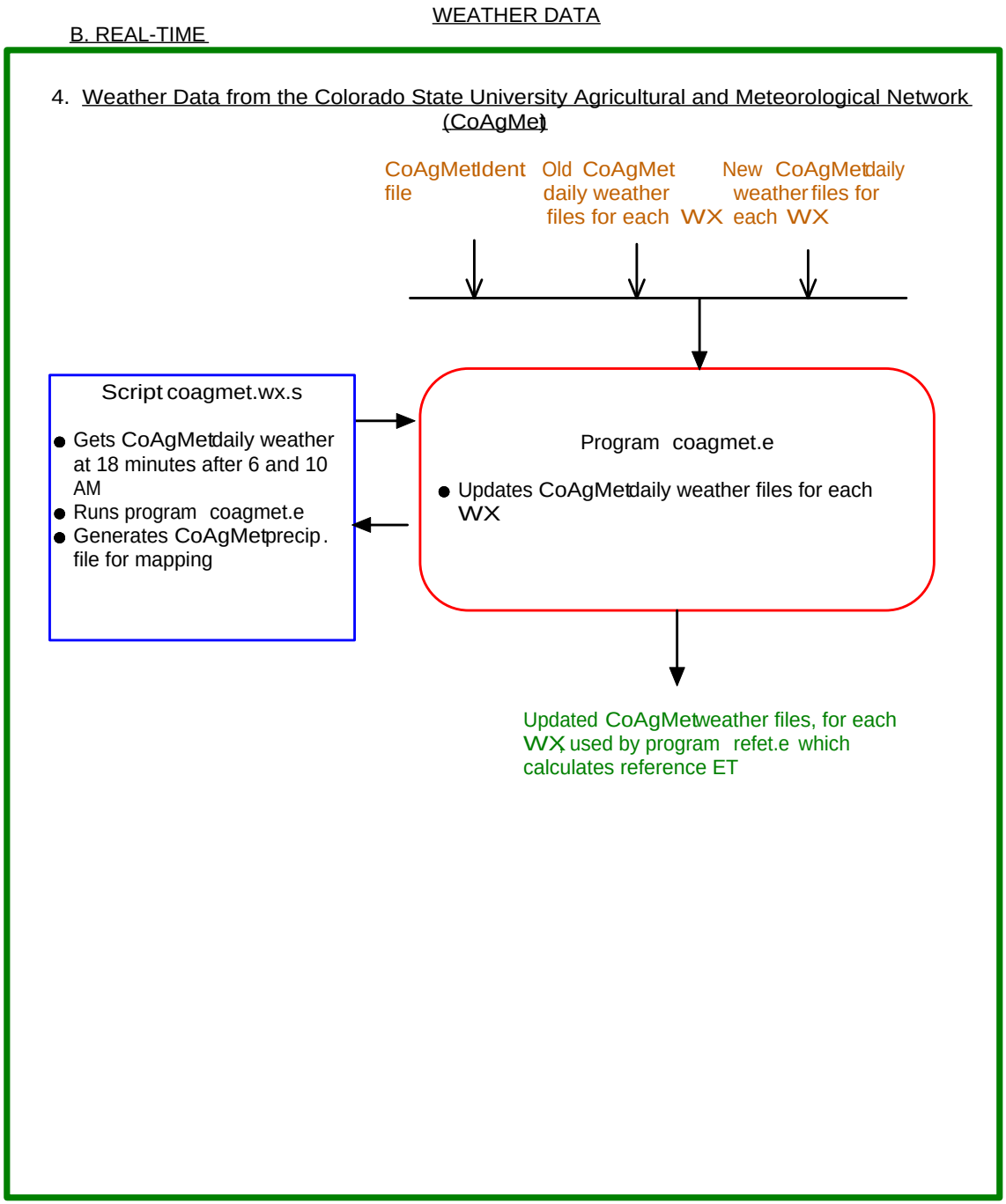

Figure 69: Flow Diagram of Weather Data, Page 6 - Real-Time from the Colorado State University Agricultural and Meteorological Network (CoAgMet)

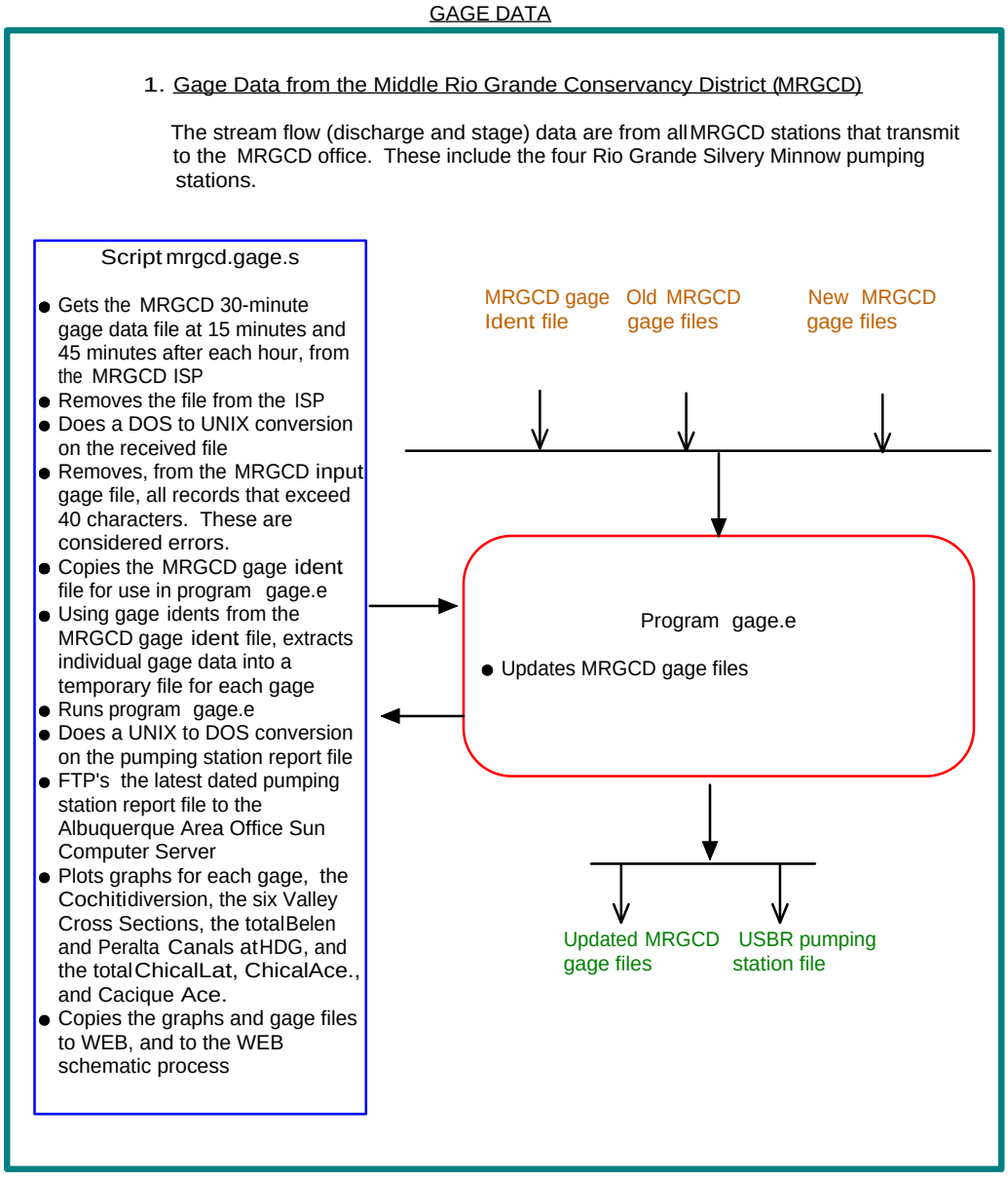

Figure 70: Flow Diagram of Gage Data, Page 1 - Gage Data from the Middle Rio Grande Conservancy District (MRGCD)

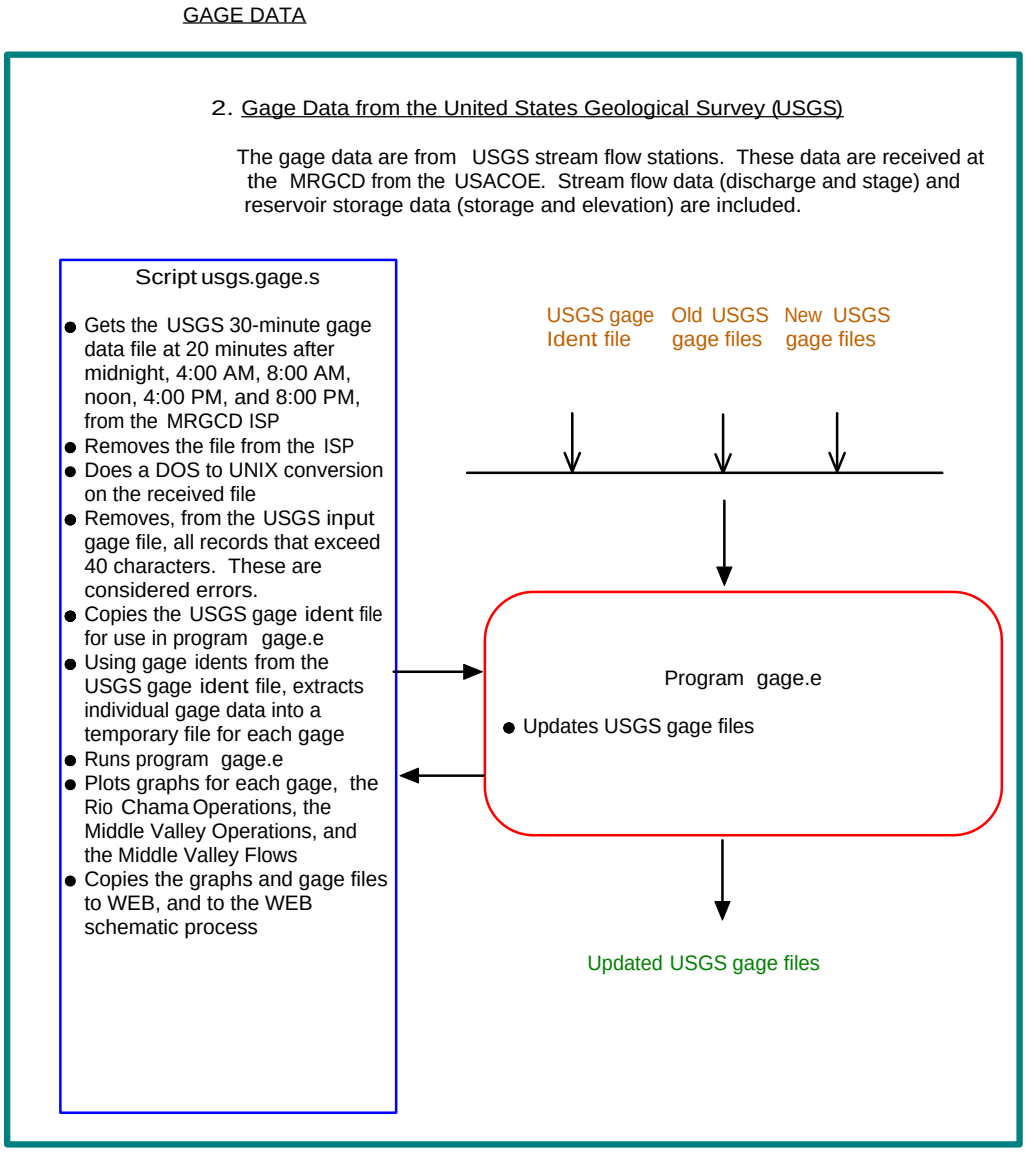

Figure 71: Flow Diagram of Gage Data, Page 2 - Gage Data from the United States Geological Survey (USGS)

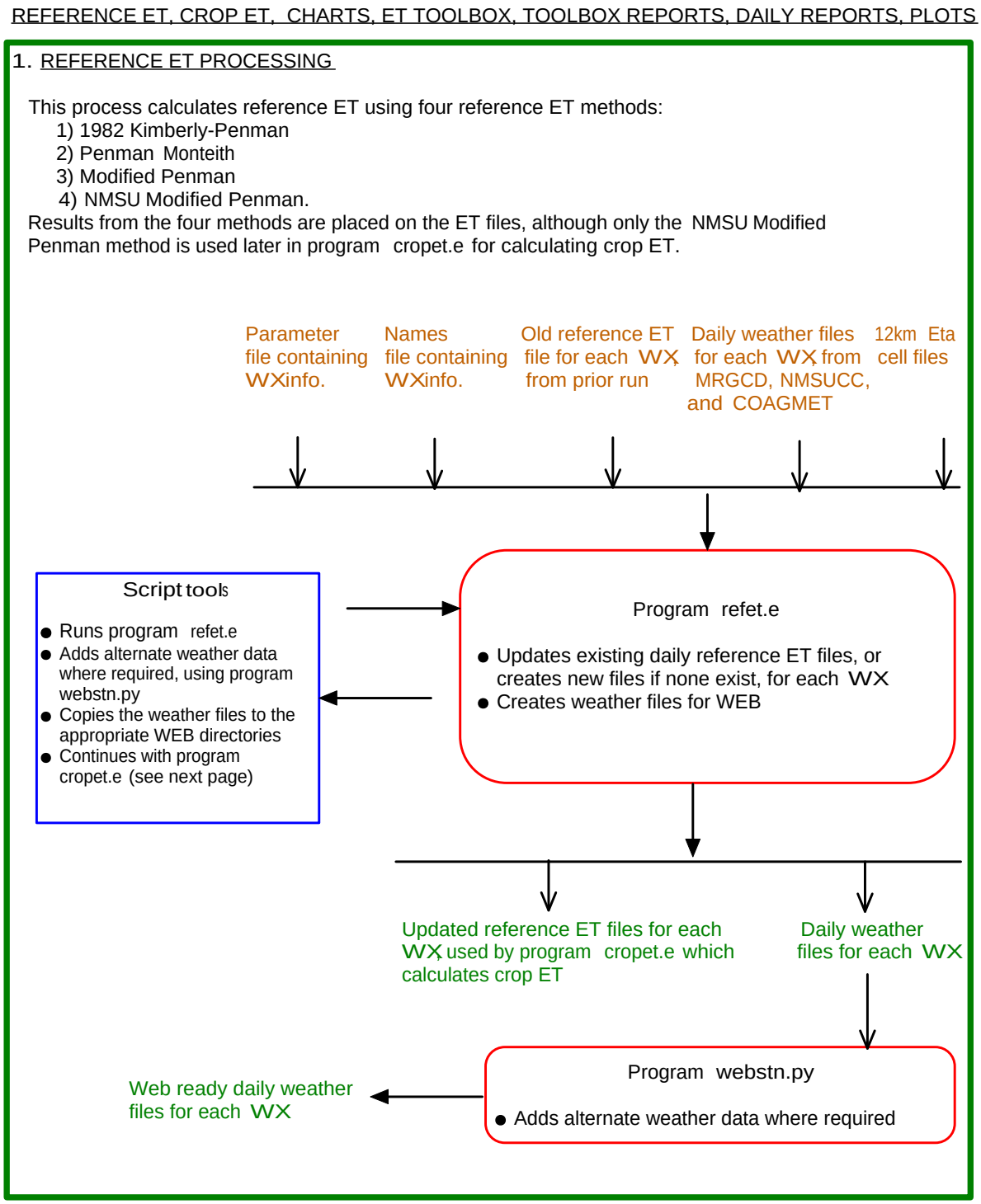

Figure 72: Flow Diagram of Reference ET Etc., Page 1 - Reference ET Processing

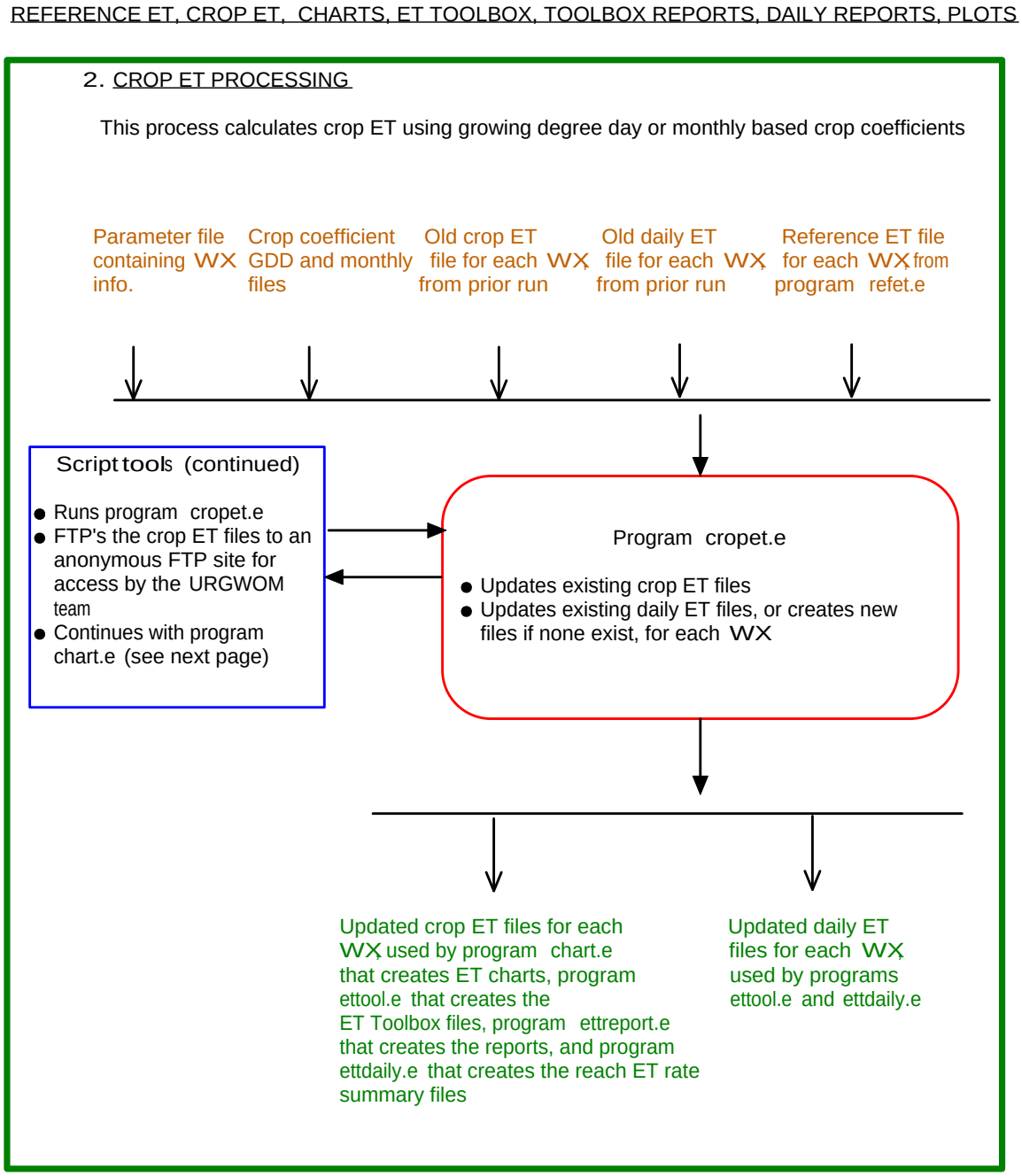

Figure 73: Flow Diagram of Reference ET Etc., Page 2 - Crop ET Processing

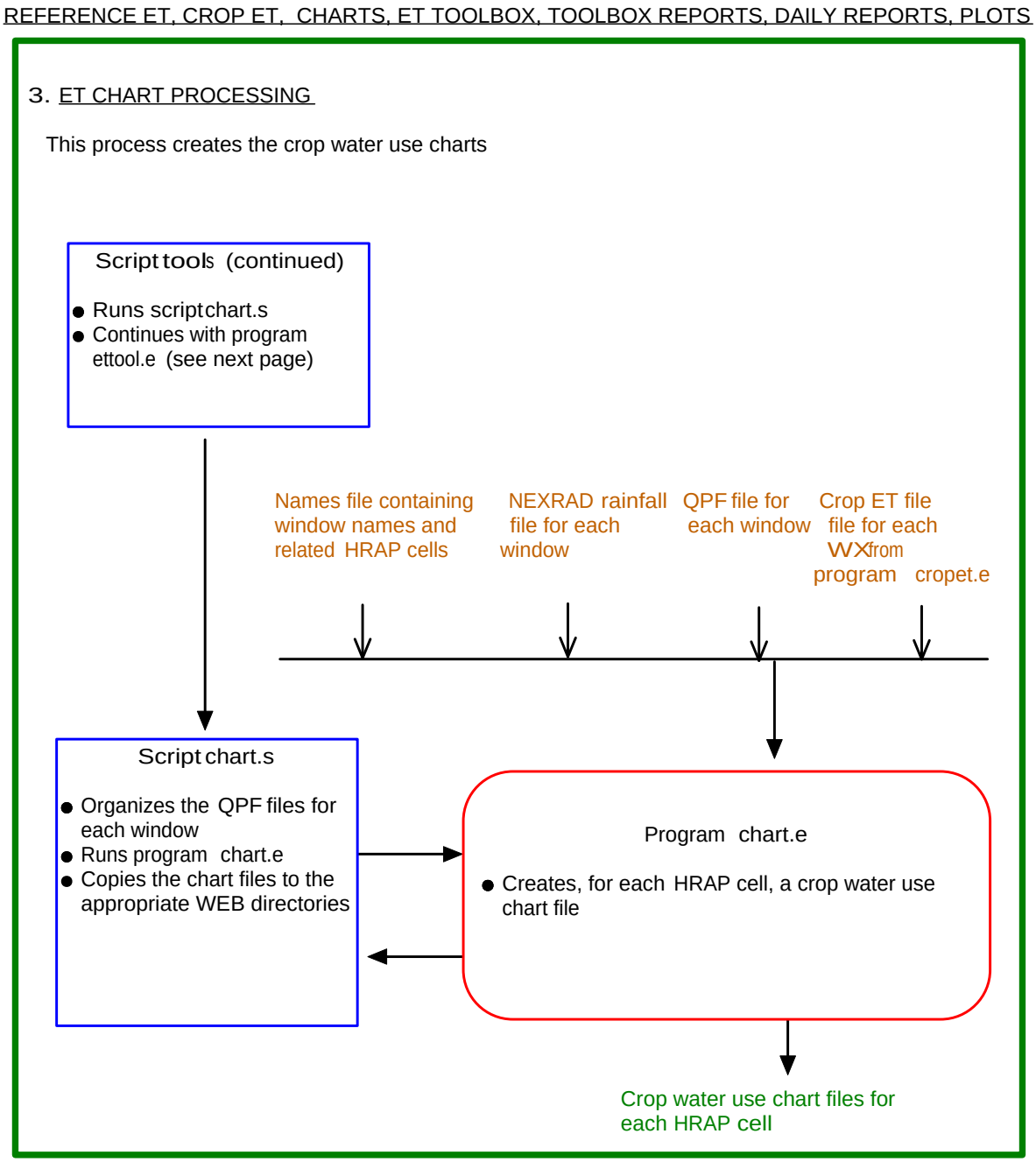

Figure 74: Flow Diagram of Reference ET Etc., Page 3 - ET Chart Processing

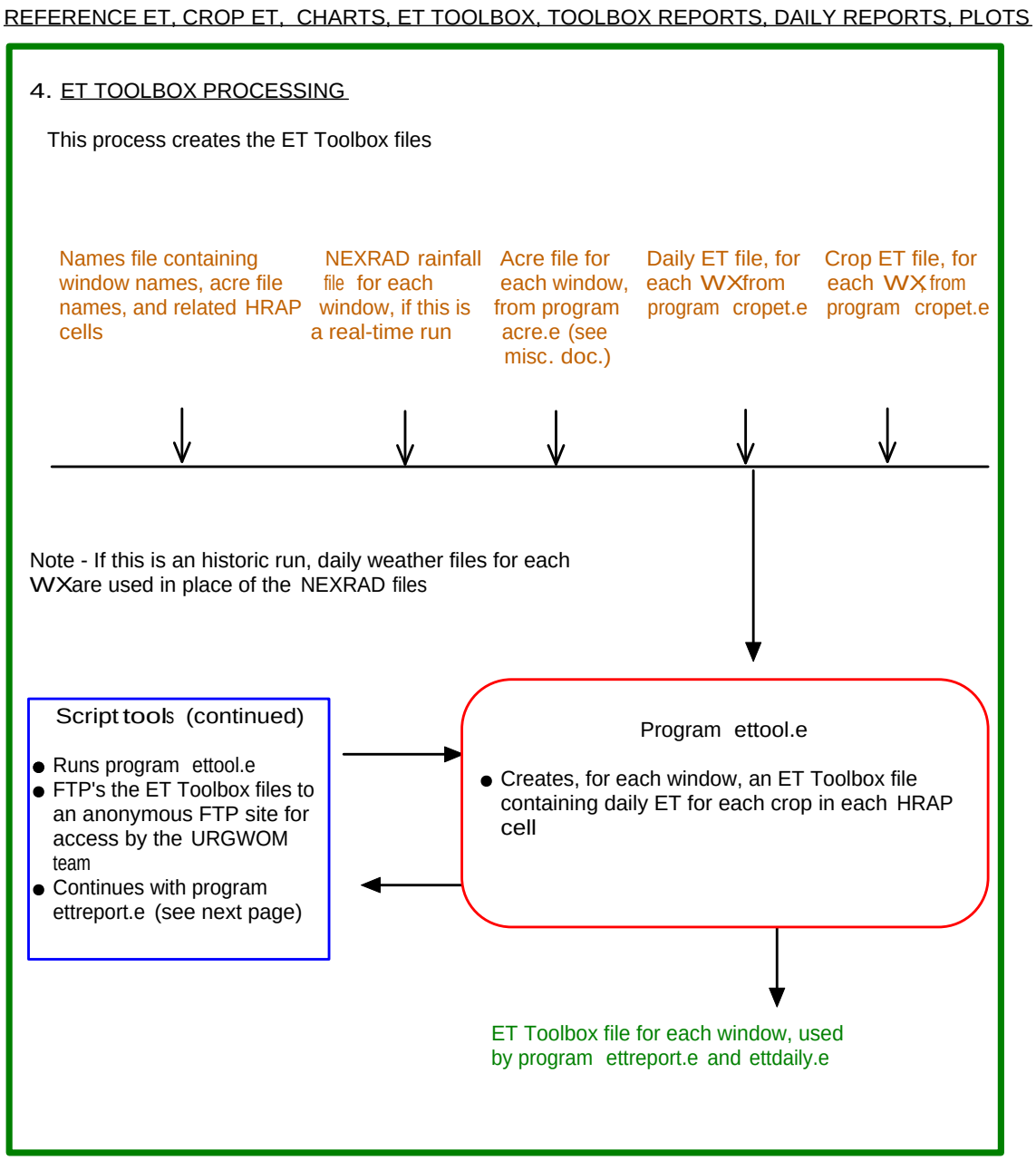

Figure 75: Flow Diagram of Reference ET Etc., Page 4 - ET Toolbox Processing

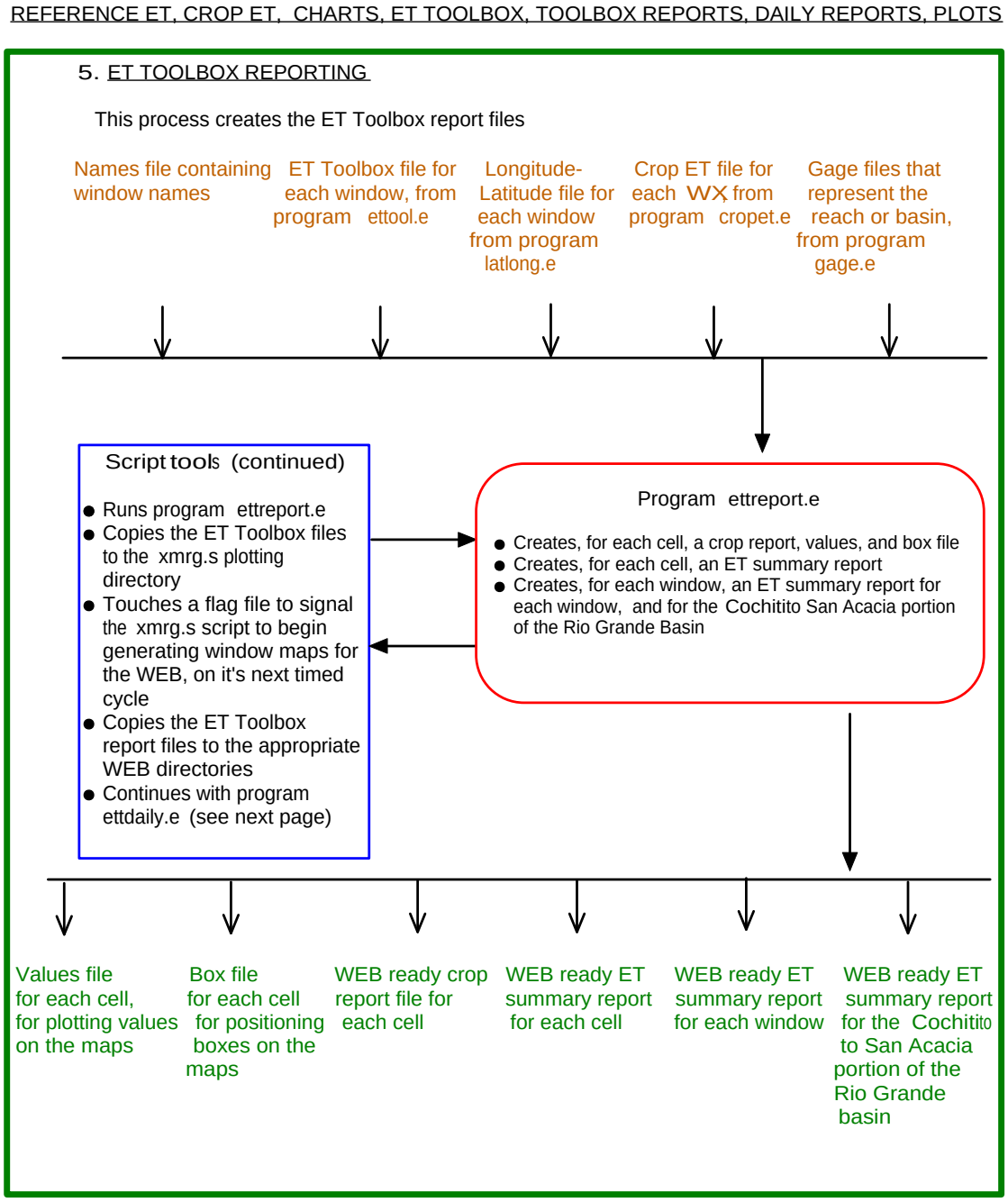

Figure 76: Flow Diagram of Reference ET Etc., Page 5 - ET Toolbox Reporting

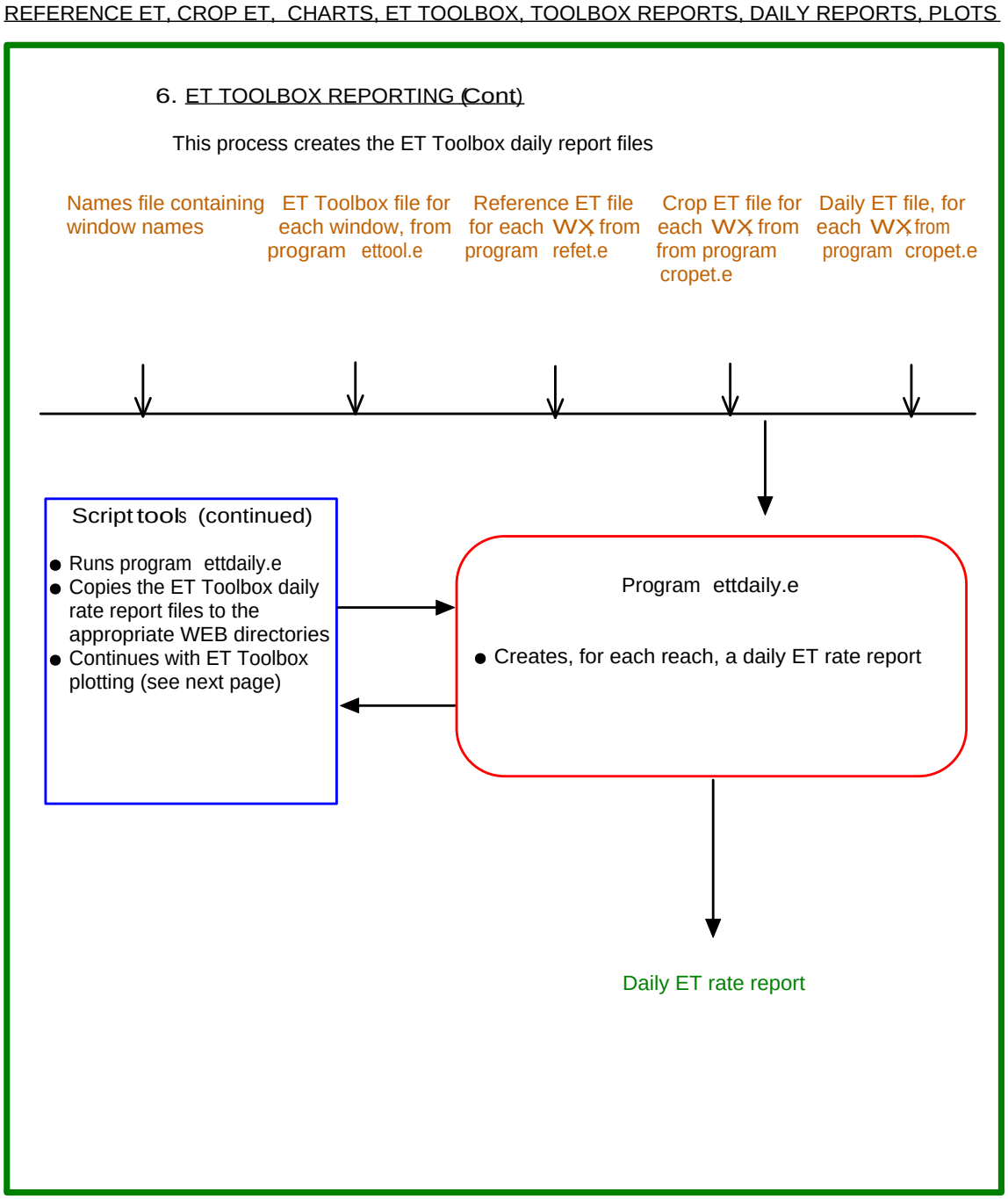

Figure 77: Flow Diagram of Reference ET Etc., Page 6 - ET Toolbox Reporting (Cont.)

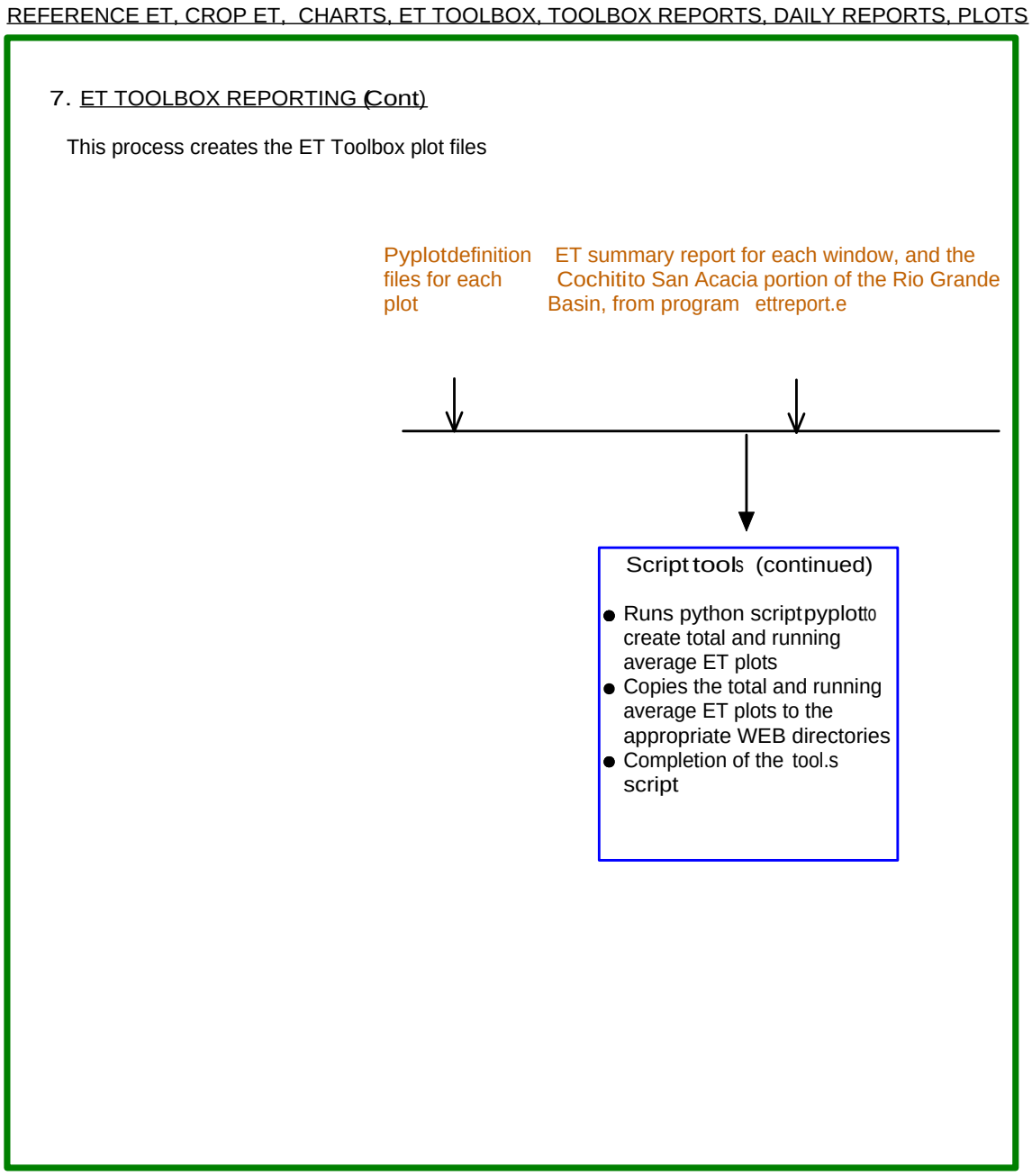

Figure 78: Flow Diagram of Reference ET Etc., Page 7 - ET Toolbox Reporting (Cont.)

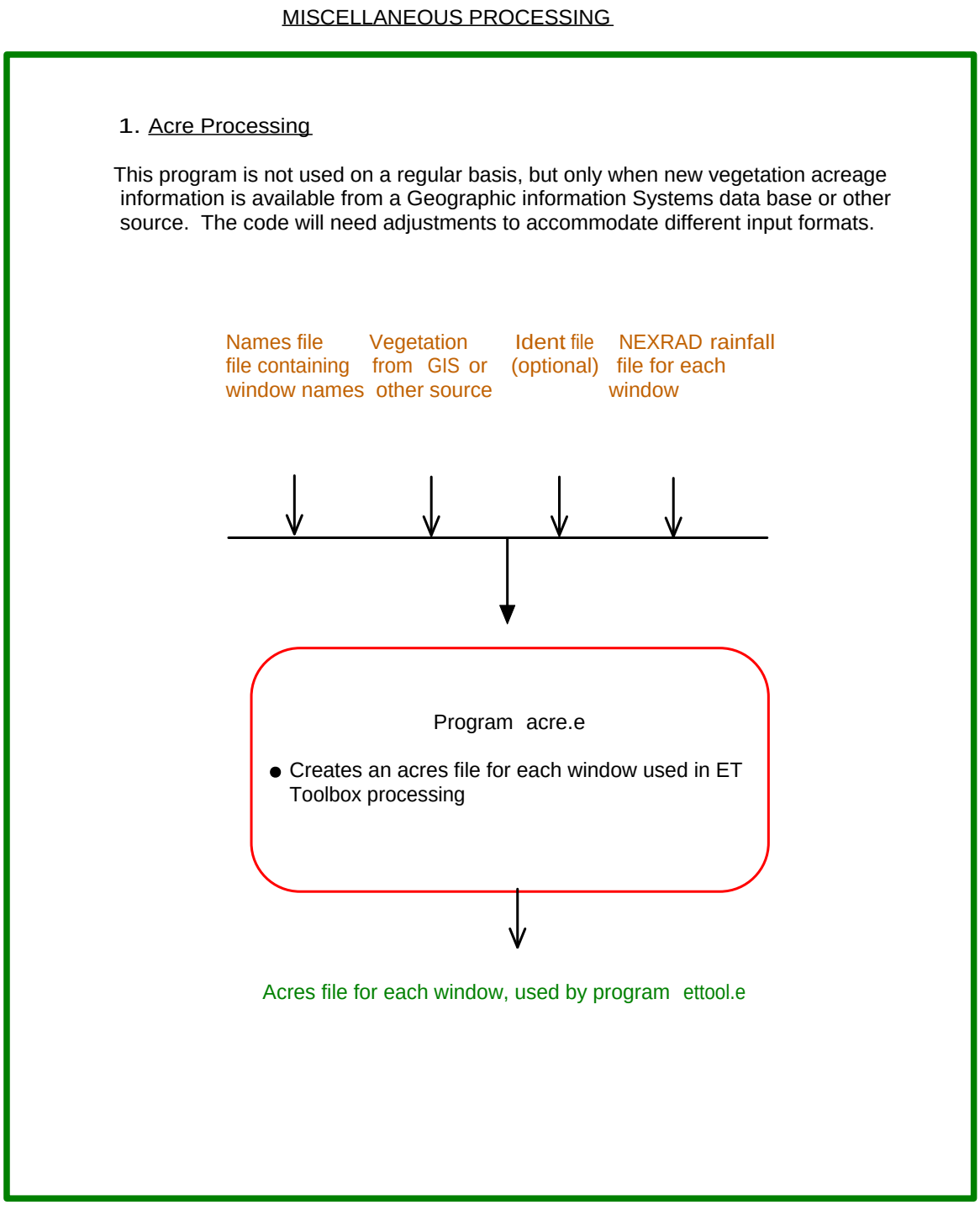

Figure 79: Flow Diagram of Miscellaneous Processing, Page 1 - Acre Processing

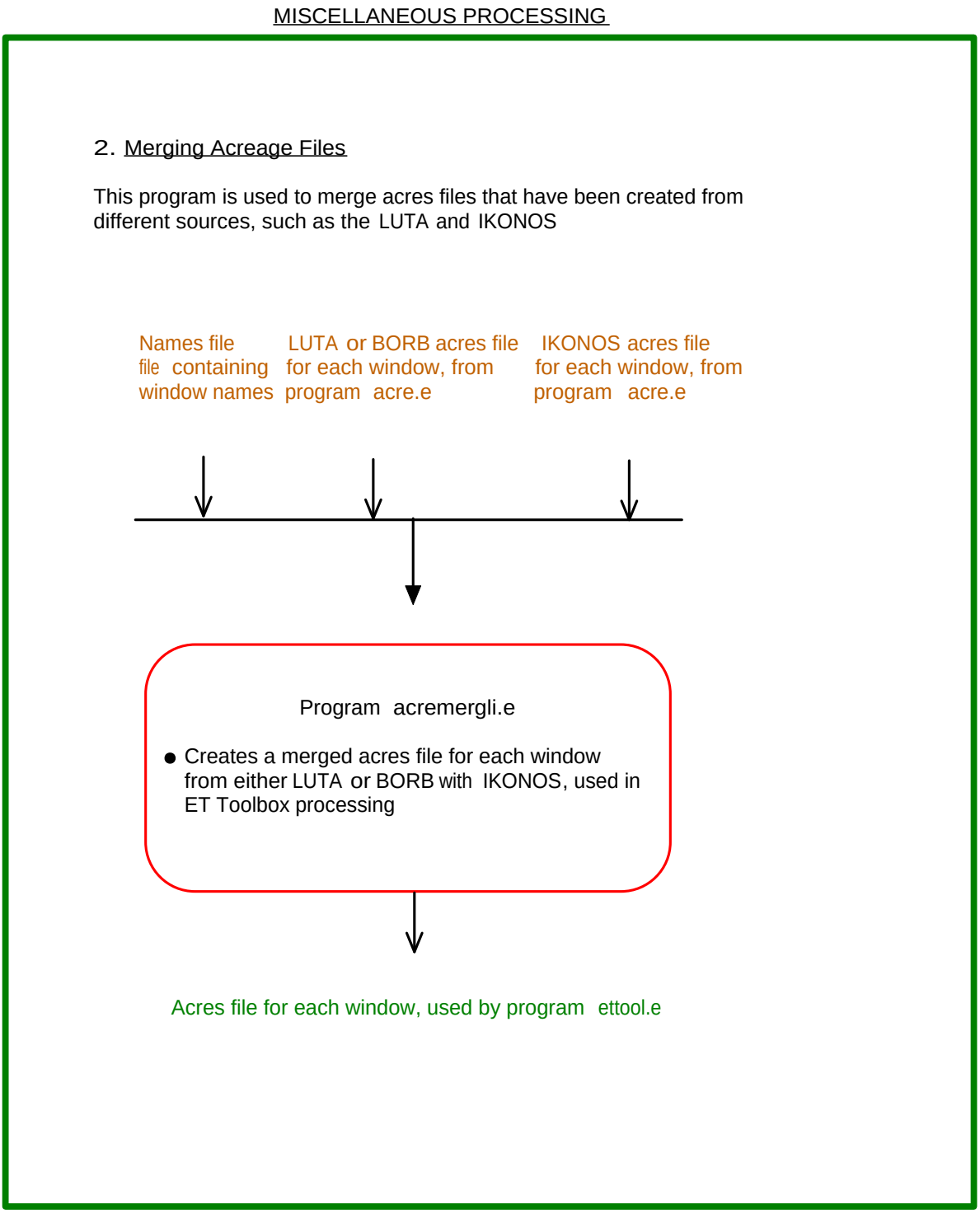

Figure 80: Flow Diagram of Miscellaneous Processing, Page 2 - Merging Acreage Files

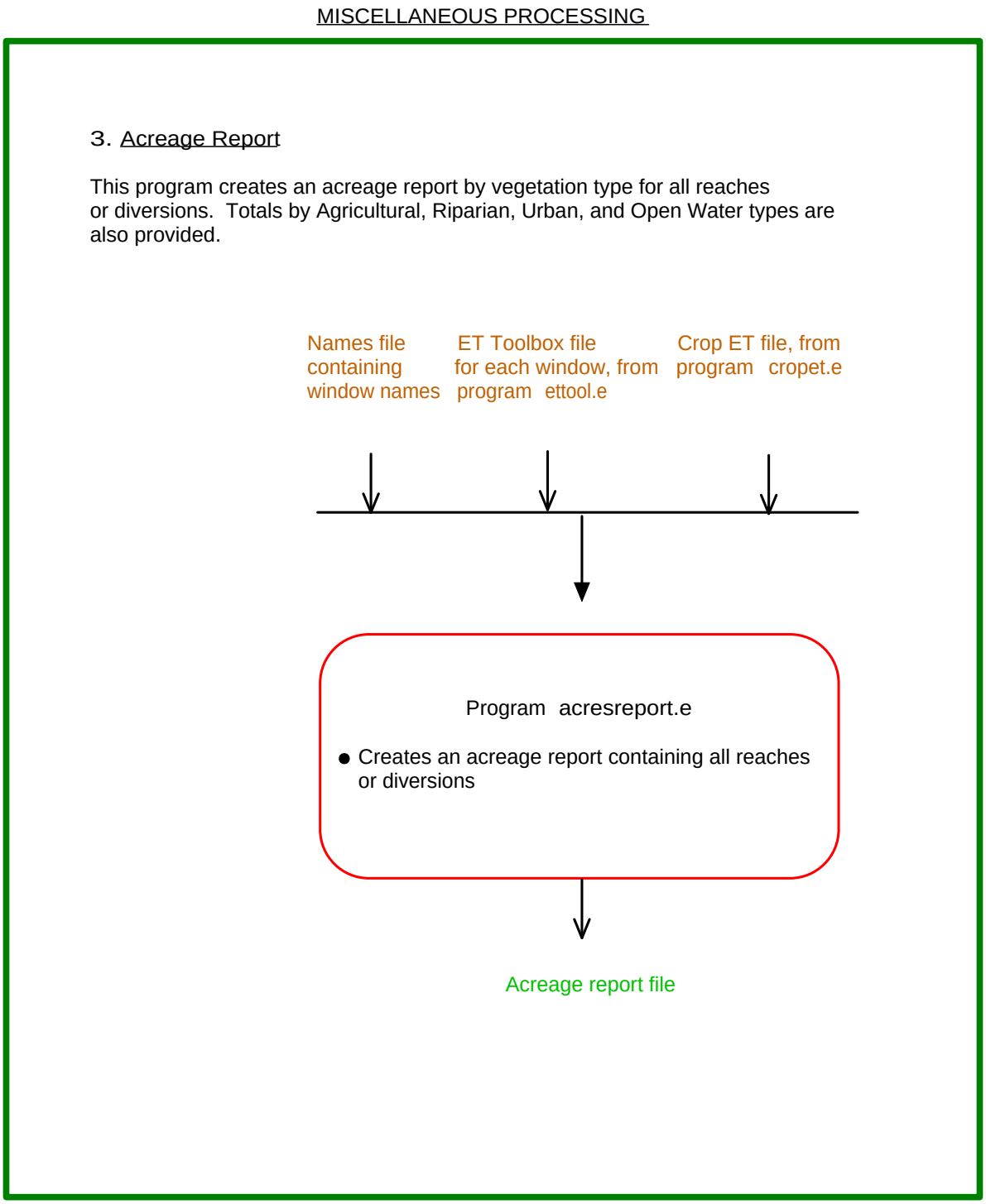

Figure 81: Flow Diagram of Miscellaneous Processing, Page 3 - Acreage Report

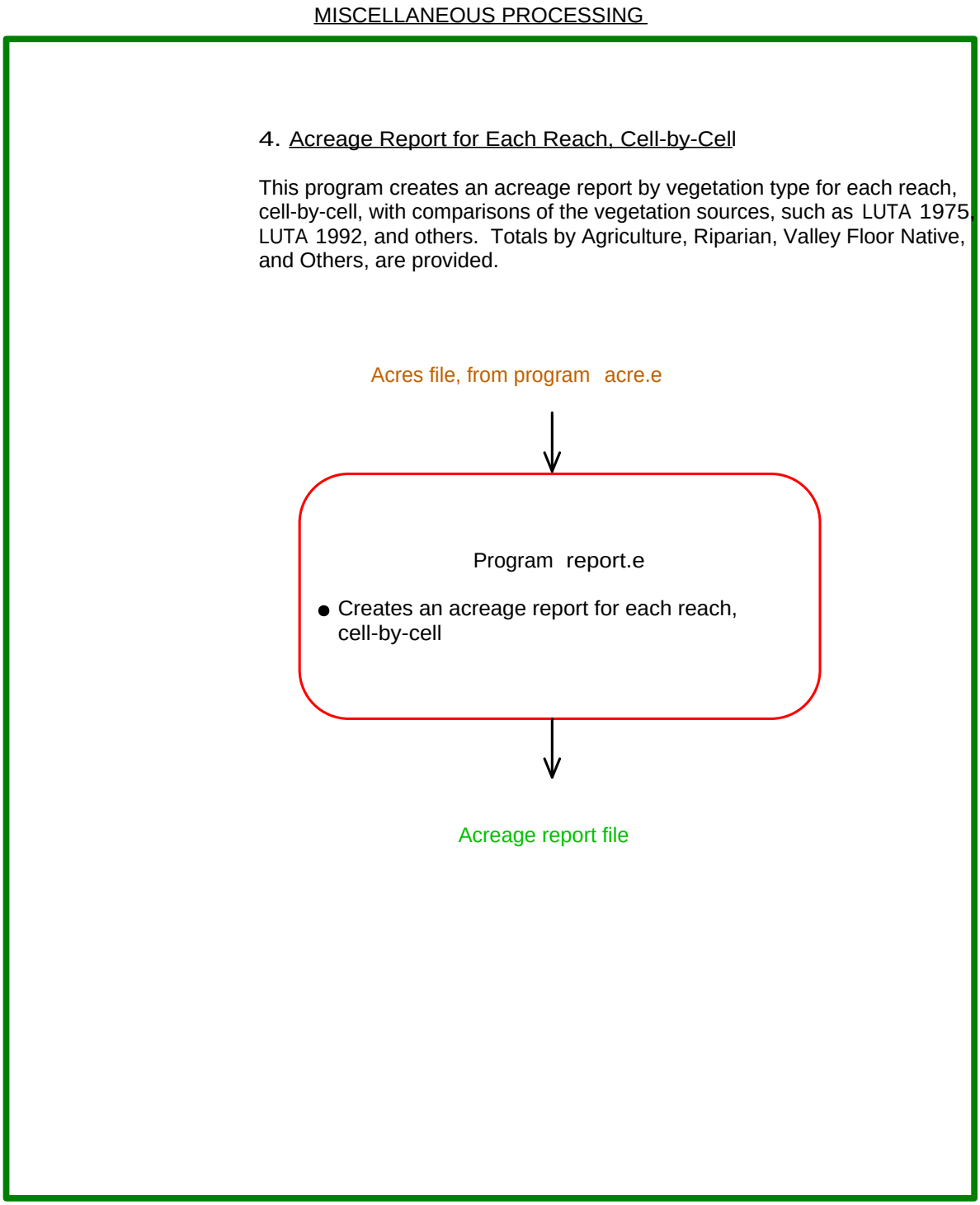

Figure 82: Flow Diagram of Miscellaneous Processing, Page 4 - Acreage Report for Each Reach Cell-by-cell

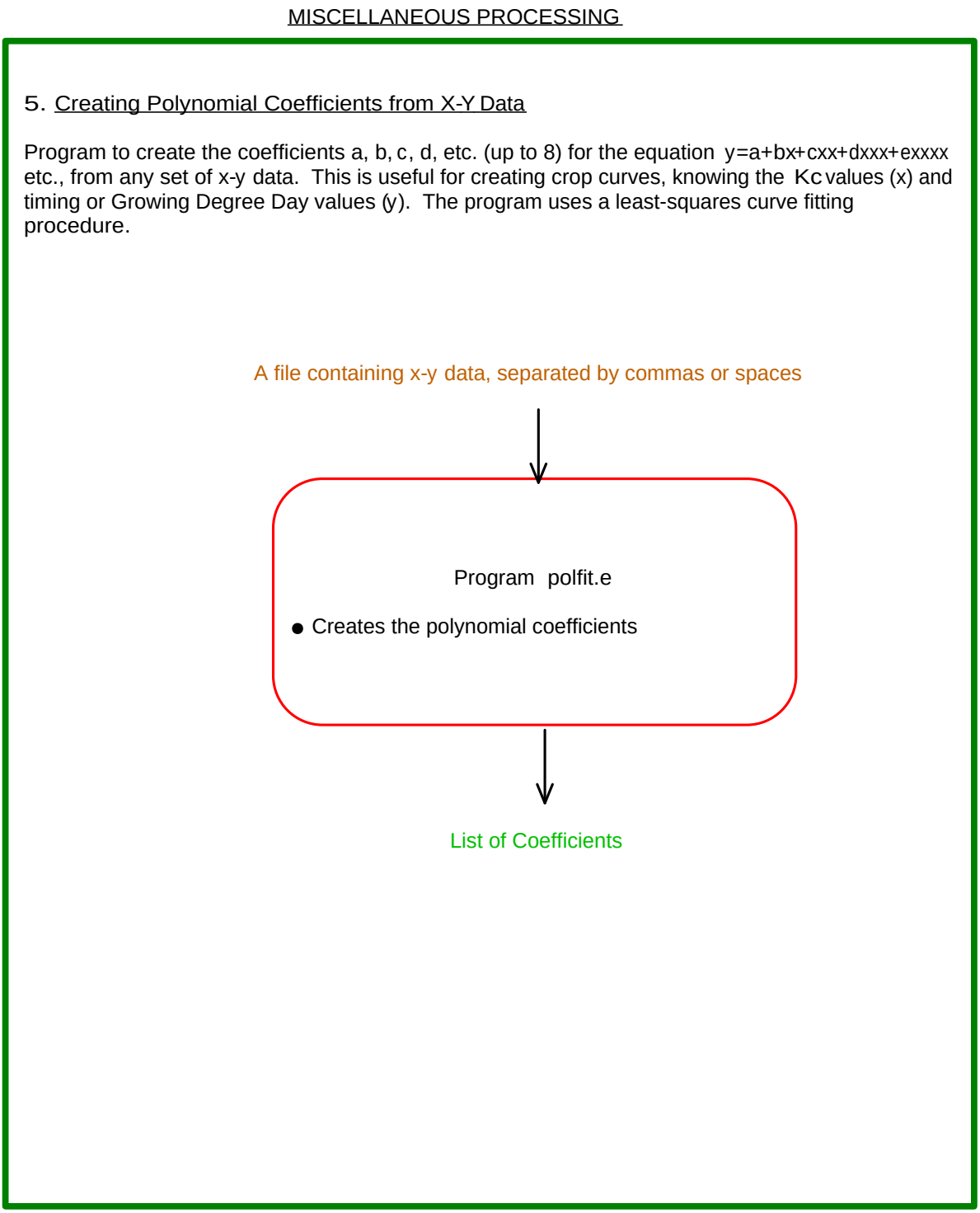

Figure 83: Flow Diagram of Miscellaneous Processing, Page 5 - Creating Polynominal Coefficients from X-Y Data

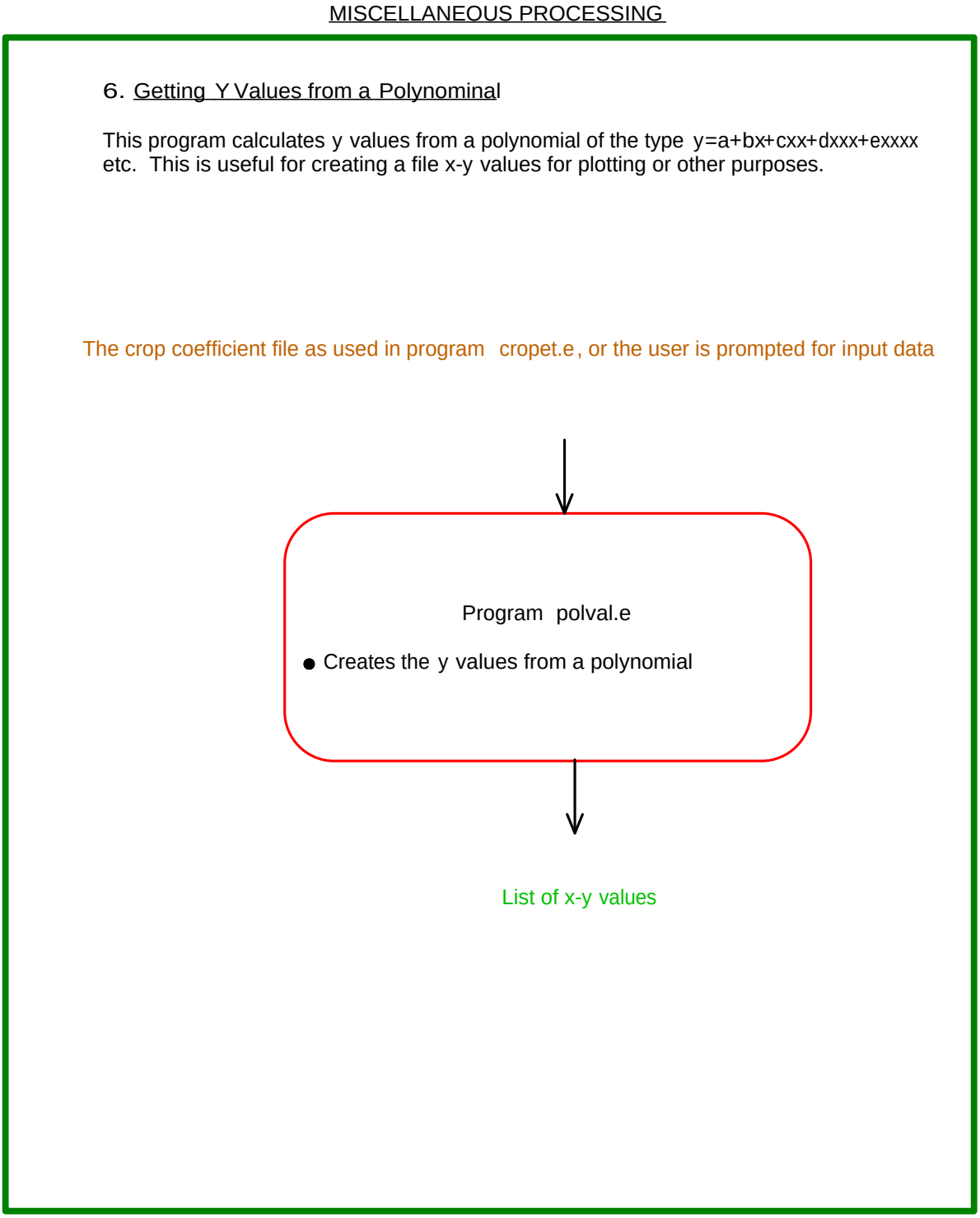

Figure 84: Flow Diagram of Miscellaneous Processing, Page 6 - Getting Y Values from a Polynominal

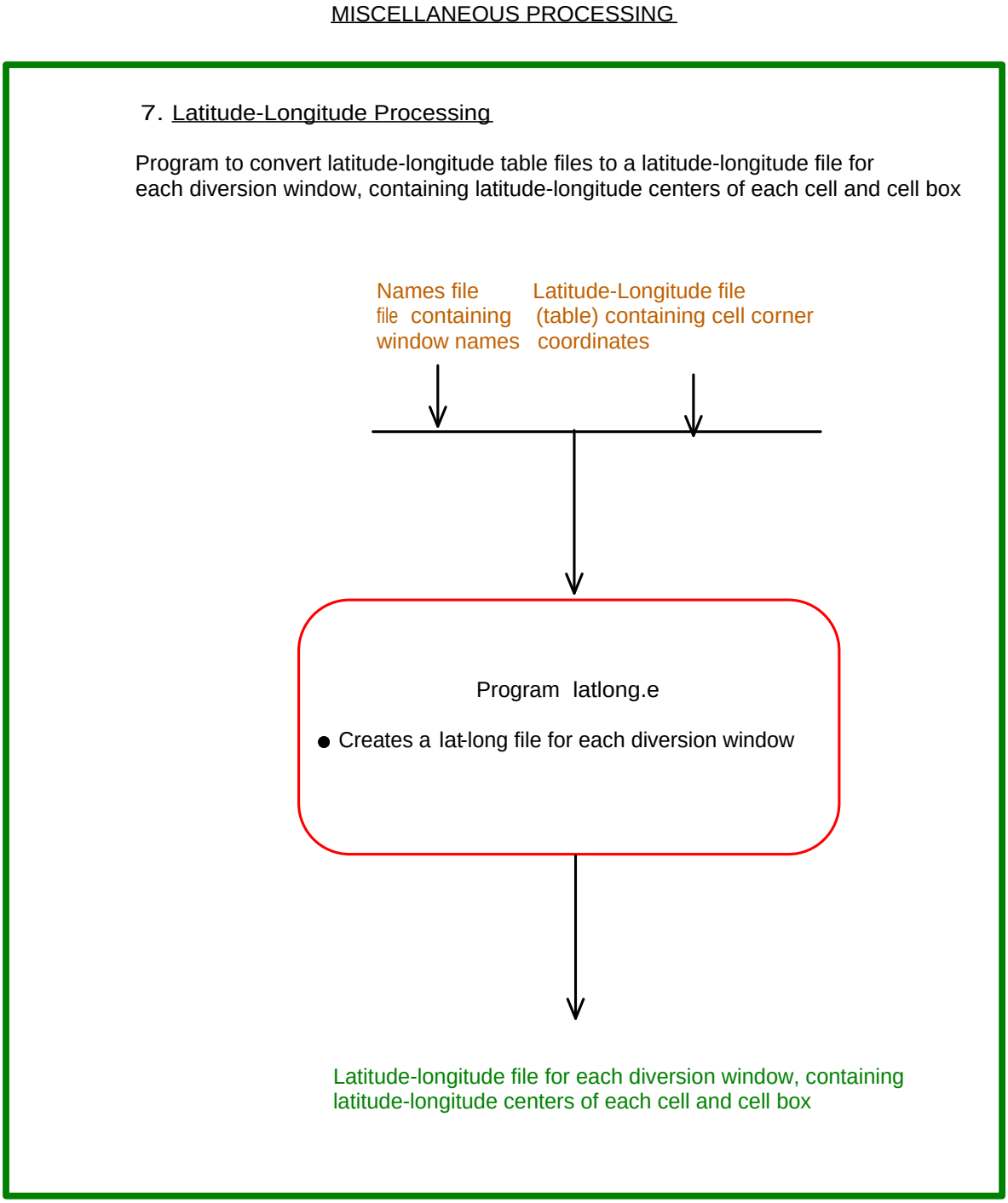

Figure 85: Flow Diagram of Miscellaneous Processing, Page 7 - Latitude-Longitude Processing

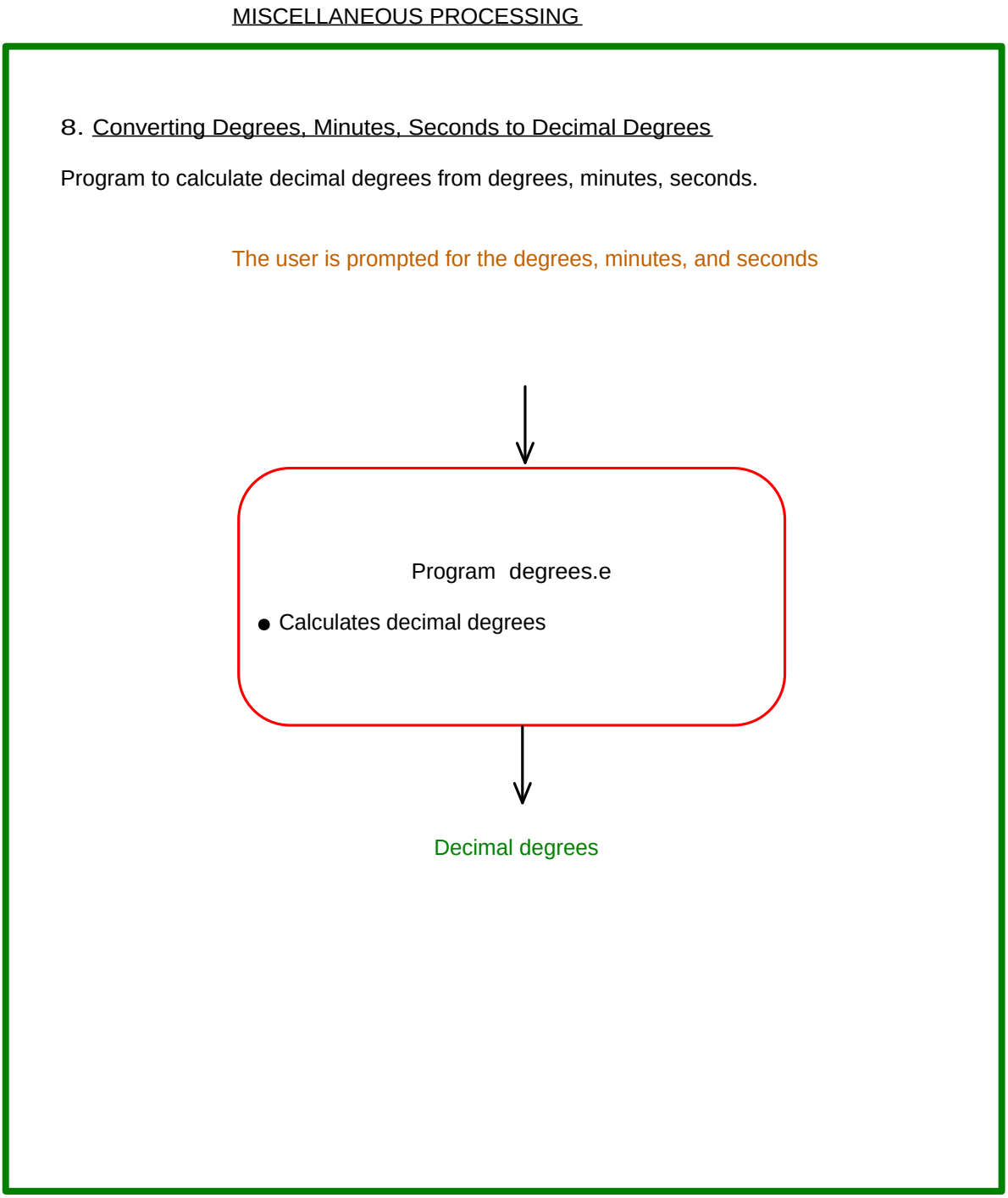

Figure 86: Flow Diagram of Miscellaneous Processing, Page 8 - Converting Degrees, Minutes, Seconds to Decimal Degrees

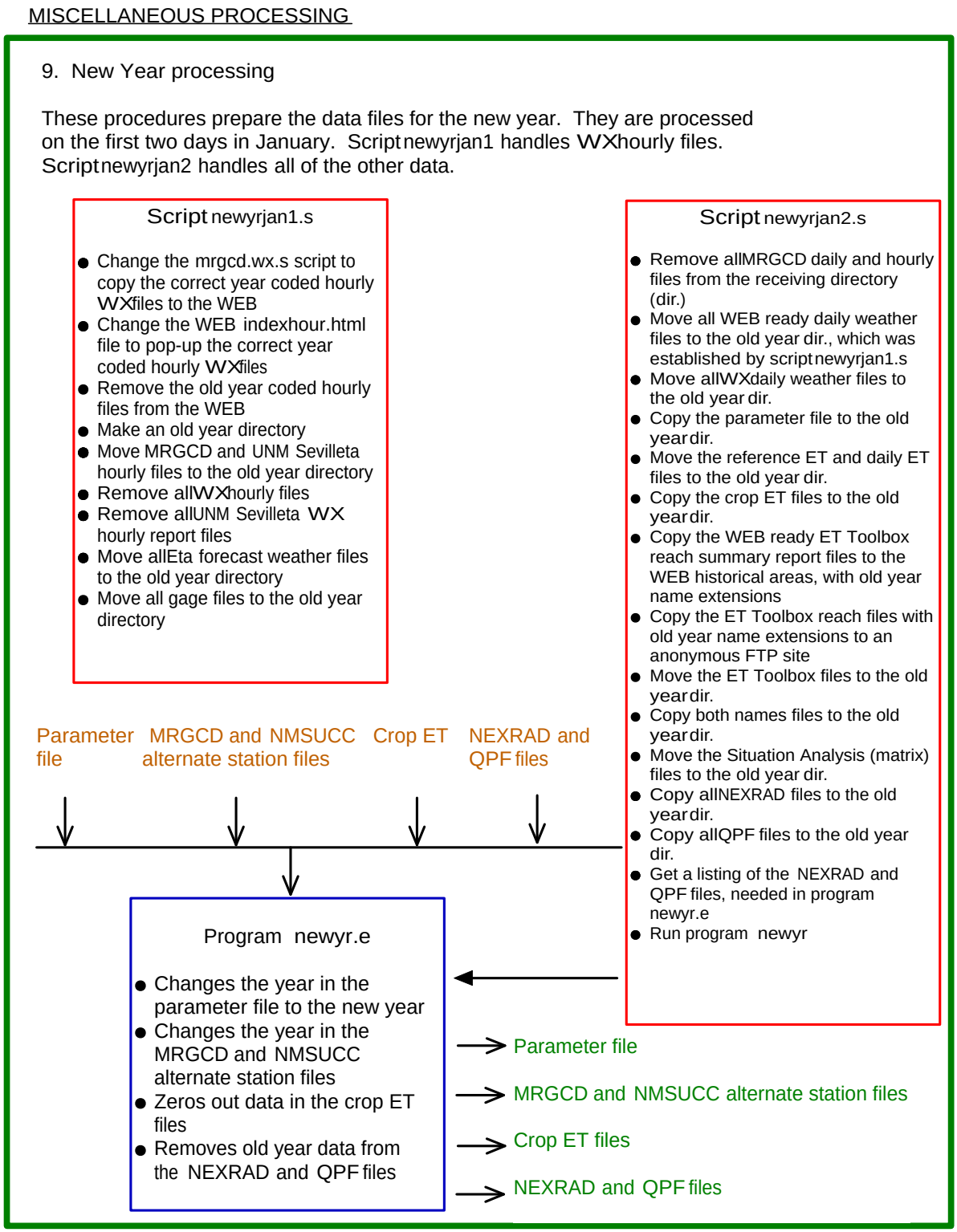

Figure 87: Flow Diagram of Miscellaneous Processing, Page 9 - New Year Processing

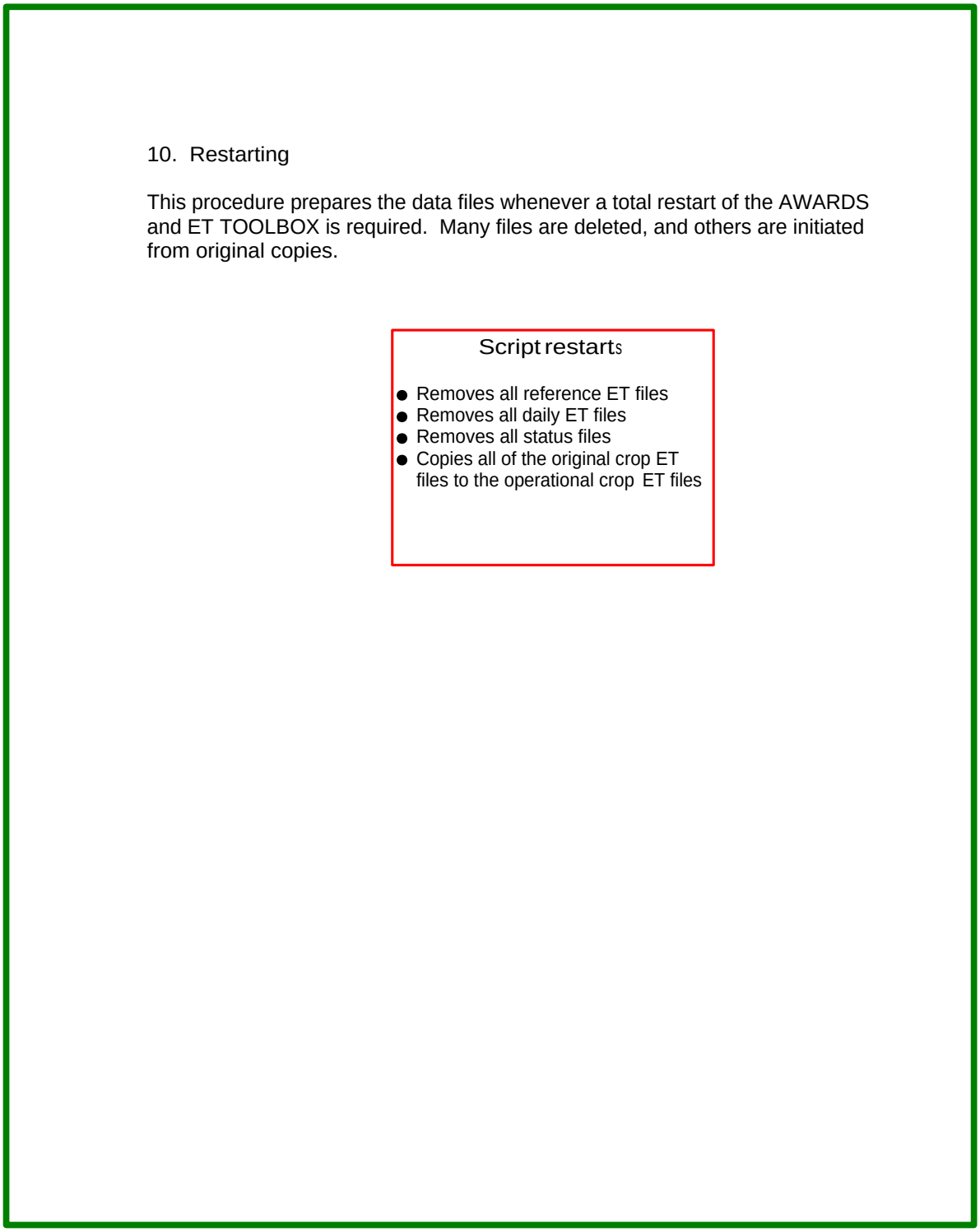

Figure 88: Flow Diagram of Miscellaneous Processing, Page 10 - Restarting

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Figure 89: