New Mexico Interstate Stream Commission
FY 2006 Project Report

EFFICIENT IRRIGATION WATER MANAGEMENT AND USE IN THE MIDDLE RIO GRANDE

Dr. Ramchand Oad
Assisted by Dr. Luis Garcia, Kristoph Kinzli and Dave Patterson at Colorado State University; and Dr. Nabil Shafike of New Mexico Interstate Stream Commission.

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Colorado State University
Knowledge to Go Places

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EFFICIENT IRRIGATION WATER MANAGEMENT AND USE IN THE MIDDLE RIO GRANDE

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1.0 INTRODUCTION

This project was conducted in the Middle Rio Grande Conservancy District (MRGCD) with Fiscal Year 2006 funding from the New Mexico Interstate Stream Commission (NMISC). The primary purpose was to make improvements to the Decision-Support System (DSS) water management model that was formulated in the years 2004-05, and to complete the related datasets for the Belen and Socorro divisions. The overall goal of the DSS project is to develop information and tools that will support improvements in MRGCD irrigation system operations, including efficient water delivery to irrigators. Key elements of the work conducted under FY-2006 ISC funding include:

(i) Update and complete data sets for the years 2004 and 2005 and prepare draft for 2006, which will include information on weather, cropping patterns, river water diversions and ditch-rider field logs.

(ii) Implement and test the DSS model in areas where the model and data sets have been completed (Belen and Socorro Divisions). Testing will consist of implementing the model in the field and observing how well the model functions as compared to the actual water delivery practice of the ditch-riders in the field.

(iii) Conduct on-going improvements to the model, including:
- Add the capabilities of using ET-Toolbox in addition to the IDSCU model for computing crop water requirements.
- Refine the methodology of accounting for return flow in the DSS model
- Investigate whether the DSS model can be operated using forecasted weather.

This work was undertaken by Colorado State University under the direction of Dr. Ramchand Oad, with assistance from Dr. Luis Garcia, Director of the Integrated Decision Support Center. The NMISC and MRGCD provided additional technical and field support.

1.1 Project Overview and Justification

The MRGCD manages an irrigation system along approximately 150 river miles of the Middle Rio Grande Valley in New Mexico, between Cochiti Dam and the northern boundary of the Bosque del Apache National Wildlife Refuge. The MRGCD irrigation system is the primary user of water in the Middle Rio Grande Valley, and the DSS project was developed to address the identified need for more efficient water use and management in the MRGCD service area. The project objective is being accomplished through the development of a decision-support system (DSS) to support improvements in system management and water delivery procedures. The DSS consists of informational databases and integrated model components, or modules, simulating water demand, water supply and scheduling. The DSS is used to explore options for supporting scheduled water delivery procedures. The project was started in year 2004 (ESA Program FY 2003), with data collection and DSS model development efforts focused on the Belen Division. The work included formulation of the basic structure of the model and its programming, and development of data sets for the three main canal service areas of the Belen Division. During the years 2005-06, the DSS was expanded to include the Socorro Division and field validation and testing of the model has been performed in the Belen Division.

1.2 Report Organization

Chapter 2 of this report briefly provides background information on the study area, the structure and management of the MRGCD, and the use of decision-support models to support efficient water delivery in irrigation systems. For more detailed information including DSS model conceptualization, formulation and programming, the reader is referred to previous years' project completion reports (Oad et al. 2005; Oad et al. 2006).

Chapter 3 describes completion of datasets for years 2004-06 for the Belen and Socorro Divisions. All data sets for the two divisions were successfully updated and completed, and include information on weather, irrigated service areas and cropping patterns, and the MRGCD water diversions into the main canals. Chapter 4 describes the results of field implementation and testing conducted in the limited time period of Sept.15-Oct.30, 2006, and chapter 5 reports the major improvements made to the DSS model. Detailed technical material and supporting data are organized within several appendices at the end of the main report. In addition, a compact disk (CD) is attached, containing data on irrigated service areas and cropping patterns for the years 2004-06.

2.0 BACKGROUND INFORMATION

2.1 Middle Rio Grande Valley

The Middle Rio Grande (MRG) Valley runs north to south through central New Mexico from Cochiti Reservoir to the headwaters of Elephant Butte Reservoir, a distance of approximately 175 miles (Figure 1). The valley is narrow, with the majority of water use occurring within five miles on either side of the river. The *bosque*, or the riverside forest of cottonwood and salt cedar, is supported by waters of the Rio Grande. Surrounding the river forest, there is widespread irrigated farming. The City of Albuquerque and several smaller communities are located in and adjacent to the MRG Valley. Although the valley receives less than 10 inches of rainfall annually, it supports a rich and diverse ecosystem of fish and wildlife and is a common resource for communities in the region

Water supply available for use in the MRG Valley includes native flow of the Rio Grande and its tributaries, allocated according to the Rio Grande Compact of 1939; San Juan-Chama (SJC) project water, obtained via a trans-mountain diversion from the Colorado River system; and, groundwater. Water is fully appropriated in the MRG Valley and its utilization is limited by the Rio Grande Compact and state laws. The Compact sets forth a schedule of deliveries of native Rio Grande water from Colorado to New Mexico and from New Mexico to Texas.

Water demand in the MRG Valley includes irrigated agriculture in the MRGCD (which includes 6 Indian Pueblos), municipal and industrial consumption. In addition to these demands, there are significant consumptive uses associated with riparian vegetation and wetlands, river and reservoir evaporation. Superimposed on these demands are river flow targets associated with federally-listed endangered species.

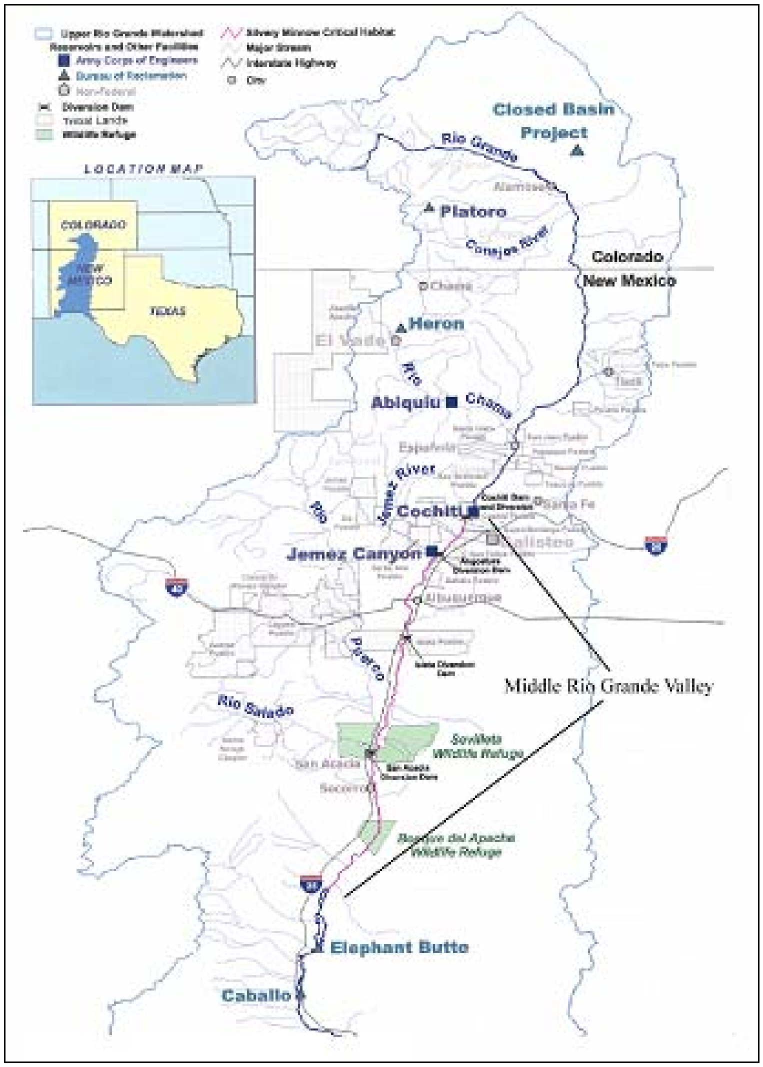


Figure 1. The Middle Rio Grande Valley

2.2 Middle Rio Grande Water Conservancy District (MRGCD)

The MRGCD was formed in 1925 in response to the flooding and the deterioration of the complex, and very old, irrigation network in the Middle Rio Grande valley. It services irrigators from Cochiti Reservoir to the northern boundary of the Bosque del Apache National Wildlife Refuge. Figure 2 displays a map of the MRGCD service area.

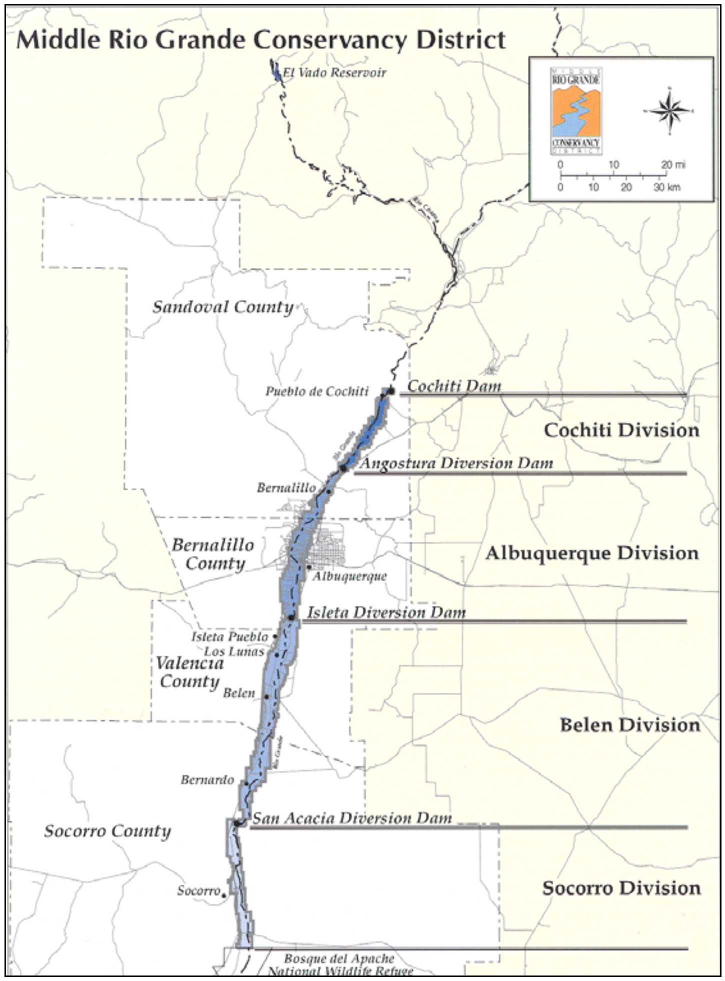


Figure 2. The MRGCD Service Area

Irrigation facilities managed by the MRGCD divert water from the river to service agricultural lands, which include small urban parcels and large tracts that produce alfalfa, pasture, corn, orchards, and vegetable crops. The diversity of users includes six Indian Pueblos, large farm parcels, community ditch associations and urban landscape irrigators. The MRGCD supplies water to its four divisions – Cochiti, Albuquerque, Belen and Socorro – through the Cochiti Dam and Angostura, Isleta and San Acacia diversion weirs.

Each division office includes administrative, field maintenance and water operation services. A division manager and several ditch-riders manage water delivery operations in each of the four divisions. Ditch-riders are responsible for the distribution of water to users in a particular service area, and for coordination of water delivery with the ditch-riders serving adjacent areas. During the recent drought years, the MRGCD has taken a proactive approach to improving its water delivery operations and management of available water. Division managers and ditch-riders are increasingly practicing scheduled water delivery, which is an effective way to fulfill demand with reduced supply.

2.3 Study Area Description

At a broad level, the study area for the DSS project includes the entire area served by the MRGCD. For field testing in year 2006, the project focused on the Belen and Socorro Divisions. Belen Division is the largest division, in terms of service area, in the MRGCD, and delivers water to about 20,000 acres. The Belen Division extends from the Isleta Dam south to the San Acacia Dam. The work conducted in this study relates to the non-Pueblo irrigated lands within the Belen Division served by the Peralta Main Canal, the Belen Highline Canal and the San Juan Main Canal. It consists of a complex network of water delivery canals that service large farm parcels, community ditches and recently urbanized areas. A map of the Belen Division is displayed in Figure 3.

For water delivery administration, the Belen division is organized into ten ditch-rider service areas. Water is diverted from the Isleta diversion structure on both the east and west sides of the river. Water on the west side of the river is diverted through the Belen Highline Canal, and water on the east side is diverted through the Peralta Main Canal and Chical Lateral, as well as two small Indian ditches. The drainage and return flow from the Belen Division service area is captured and utilized for irrigation in the downstream Socorro Division. Therefore, water management in the Belen Division impacts water availability in the Socorro Division.

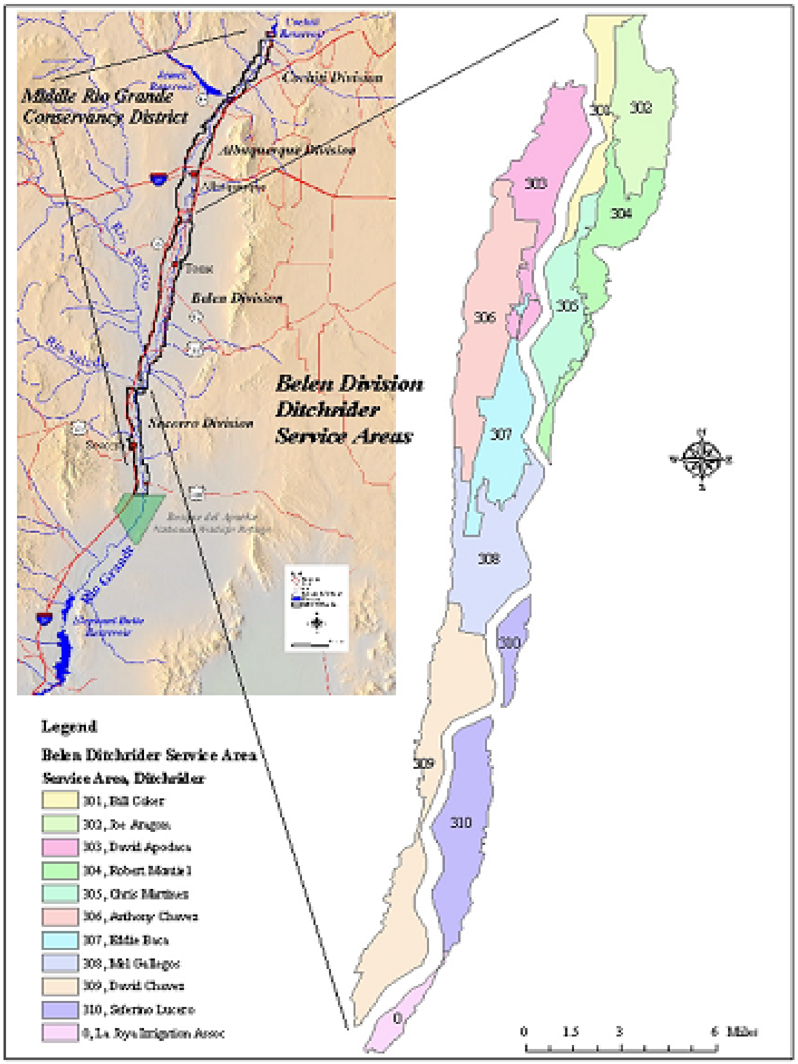


Figure 3. MRGCD Belen Division Displaying the Ditch-rider Service Areas

The Socorro Division (Fig. 4) irrigates approximately 12,000 acres (about 20% of total irrigated area of MRGCD) of primarily alfalfa, corn, chile, and vegetables. The division includes mainly large-scale irrigators and is characterized as rural in comparison to the other MRGCD divisions. It receives river water at the San Acacia Diversion Structure as well as a substantial amount of drain flow and return flow from the upstream Belen Division through the Unit 7 Drain. The water entering the division through both of these sources is conveyed in one main canal, the Socorro Main Canal. Water delivery in the Socorro Division is facilitated by four ditch-riders.

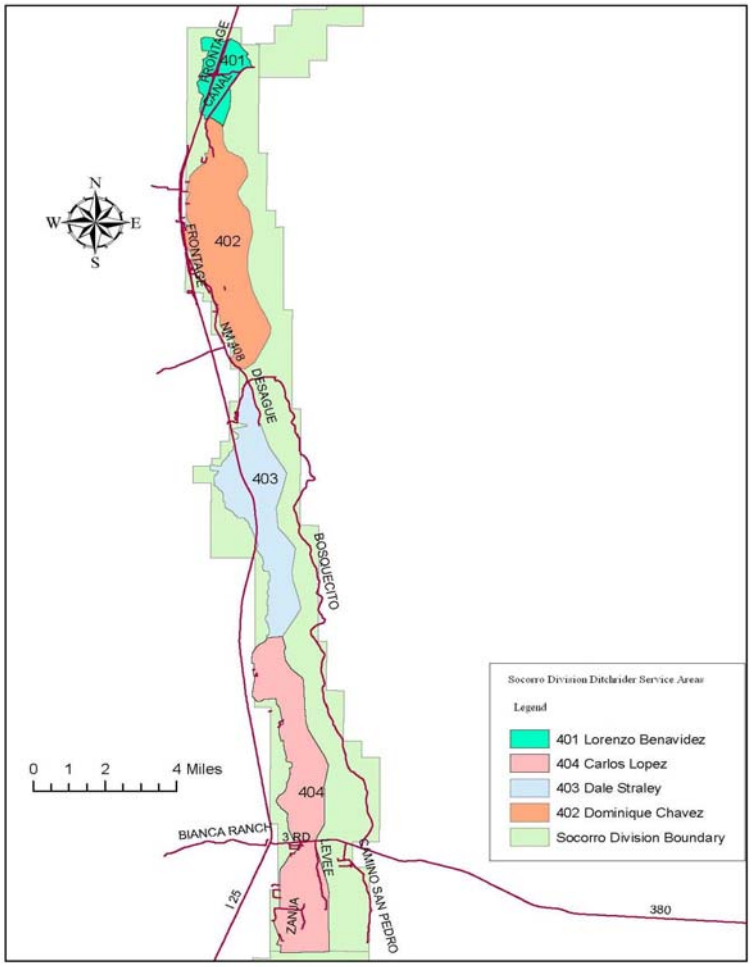


Figure 4. Socorro Division Displaying the Ditch-rider Service Areas

The structure of the Socorro Division is inherently more efficient than that of the Belen Division, due to simpler physical configuration – one main canal feeding a smaller number of laterals – and larger farm size with limited urbanization. The Socorro Division is the tail end of the MRGCD irrigation system. Tail-water from the Socorro division is utilized by the Bosque del Apache National Wildlife Refuge for agricultural lands and for ponds and wetlands. There are no Pueblo irrigators in the Socorro Division.

2.4 Decision Support Modeling

In the current project, a Decision-Support System (DSS) has been formulated to model and assist with implementation of scheduled water delivery in the MRGCD's Belen and Socorro Divisions. A DSS combines the intellectual resources of the user with the capabilities of computers to improve the quality of decision-making. It is a logical arrangement of information, including engineering models, field data, GIS and graphical user interfaces, and is used by managers to make informed decisions. In irrigation systems, a DSS can organize information about water demand in the service area and then schedule available water supplies to efficiently fulfill the demand.

The conceptual problem addressed by a DSS for an irrigation system is how best to route water supply in a main canal to its laterals so that the required water diversion is minimized. The desirable solution to this problem is "demand-driven", in the sense that it should be based on a realistic estimation of water demand. The water demand in a lateral canal service area, or at an irrigated parcel, can be predicted throughout the season through analysis of information on the irrigated area, crop type and soil characteristics. The important demand concepts are:

- Irrigation timing: When is water supply needed to meet crop demand?
- Irrigation duration: How long is the water supply needed during an irrigation event?
- Time between irrigation: How often must irrigation events occur for given service area?

The DSS consists of three elements, or modules:

- A water demand module that calculates crop consumptive use and soil moisture storage, aggregated by lateral service area;
- A water supply network module that represents the layout of the conveyance system, main canal inflow, conveyance system physical properties, and the relative location of diversions for lateral service area; and,
- A scheduling module that routes water through the supply network to meet irrigation demand, using a mass-balance approach and based on a ranking system that depends on the existing water deficit in the root-zone.

A Graphical User Interface (GUI) links the three modules of the DSS, and allows users to access data and output for the system. Figure 5 displays a schematic of the DSS structure including the three modules. The project GIS and databases are used to develop input for both the *water demand* and the *supply network* modules. Some of the input is directly linked through the GUI and some is handled externally. Detailed descriptions of the DSS model formulation, compilation of the DSS structure and related data sets for the main canals in the Belen and Socorro Divisions are provided in previous project reports (Oad et al. 2005; Oad et al. 2006).

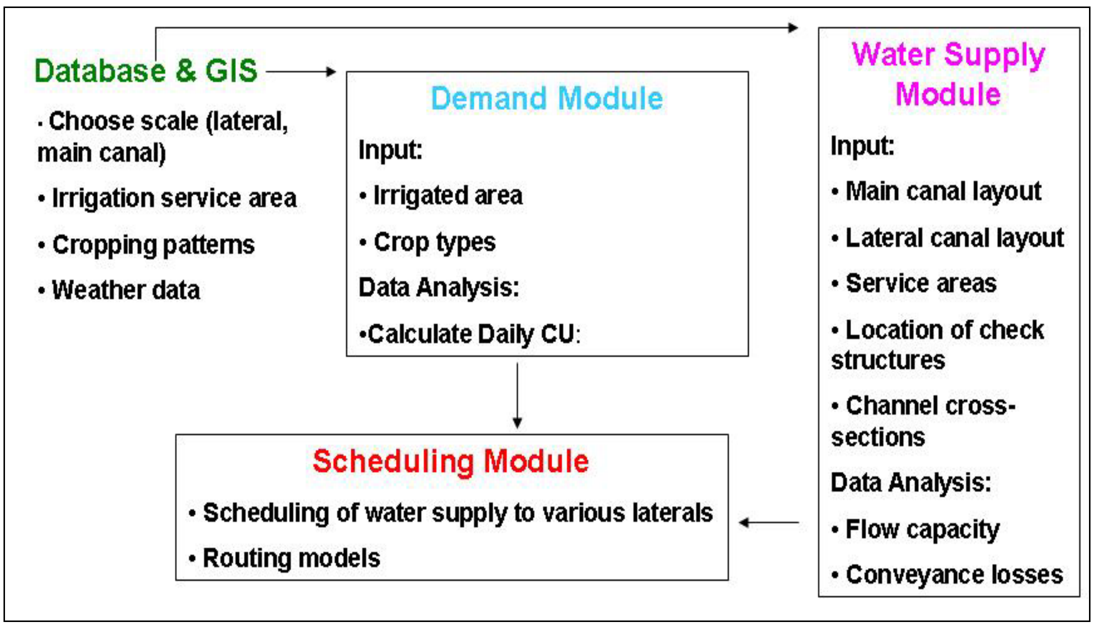


Figure 5. Schematic of the DSS Model Structure

3.0 DSS DATA FILES

One of the project goals for the year 2006 was to update and complete data sets for the 2004, 2005, and 2006 irrigation seasons for the Belen and Socorro Divisions. This task was accomplished during the 2006 field work in New Mexico. The completed data sets consist of weather data, ditch-rider field logs, ditch-rider interviews, cropping patterns, and river water diversions for the Belen and Socorro Divisions of the MRGCD.

3.1 Belen Division Data Files

3.1.1 Weather data

Weather data for the Belen Division were obtained from the Bureau of Reclamation ET Toolbox, which provides daily weather data along the Rio Grande. The weather data obtained through the ET Toolbox consist of climatic variables necessary to calculate crop evapo-transpiration using the modified Penman-Montieth equation. The Penman-Montieth equation and the required climatic variables are described below:

$$ET = \frac{\left[\frac{\Delta}{\Delta + \gamma^*}(R_n - G) + \frac{\gamma}{\Delta + \gamma^*} K_1 \frac{0.622 \lambda \rho}{P} \frac{1}{r_a}(e_s - e_a) \right]}{\lambda}$$

$$\gamma^* = \gamma(1 + \frac{r_c}{r_a})$$

Where:

R_n calculated net radiation at the crop surface (MJ/m$^{2}\cdot$day)
G soil heat flux density at the soil surface (MJ/m$^{2}\cdot$day)
e_s saturation vapor pressure at 1.5 to 2 m height (KPa), calculated daily as the average of saturation vapor pressure at maximum and minimum air temperature
e_a mean actual vapor pressure at 1.5 to 2.5 m heights (Kpa)
Δ slope of saturation vapor pressure-temperature curve (Kpa/^{o}C)
γ psychrometric constant (Kpa/^{o}C)

r_a aerodynamic resistance to sensible heat and vapor transfer (air resistance) (s/m)
r_c surface resistance to vapor transfer (canopy resistance) (s/m)
ρ air density (Kg/m^3)
P mean atmospheric pressure at site elevation (Kpa)
K_1 dimension coefficient ($8.64X10^4$ s/day).
λ latent heat of vaporization (MJ/Kg)

Rainfall data were obtained separately from the National Weather Service's Hydrologic Rainfall Analysis Project (HRAP). The HRAP divides land area into four kilometer (resolution increased to 1 km in 2007) grid cells that are used to calculate rainfall. Each lateral service area in the Belen Division was overlaid with the spatially appropriate HRAP grid allowing for the calculation of rainfall on a lateral service area level. The data from the ET Toolbox website and the HRAP site were downloaded into the DSS to complete the weather data sets for years 2004, 2005, and 2006.

3.1.2 Ditch-rider field logs

The processing of ditch-rider logbooks consisted of manually incorporating data from the logbooks into a Microsoft Access file. The data inputted into the Access File using the logbooks were for the years 2005 and 2006. The data for 2004 had already been collected during previous project work and been incorporated into the DSS. The data updated using the logbooks consisted of acreage and crop type for each parcel in the MRGCD. Each parcel in the MRGCD (over 15,000), which includes the Albuquerque and Cochiti divisions was updated in order to allow for simplified expansion of the DSS in the future. The process of manually entering data for each individual parcel was tedious and time consuming but justified as the final dataset contains data for all four MRGCD divisions for the years of 2005 and 2006. These data can be aggregated on a lateral service area level and easily incorporated into the DSS. Using the database, the acreage and crop type for each lateral service area in Belen was determined for the 2005 and 2006 irrigation seasons. These data were analyzed by the DSS model, and comparisons were made between the DSS recommendations and the actual ditch-rider practice.

3.1.3 Ditch-rider interviews

Ditch-rider interviews were conducted with all ditch-riders in the Belen Division, to determine the water delivery practice used during the 2006 irrigation season. Operational data obtained from these interviews included the irrigation duration, the average flow required for irrigation and the time between irrigation events for each lateral service area; and other standard operational practices including the degree to which scheduled water delivery was practiced. Information on ditches where scheduled water delivery was practiced were tabulated and used to compare ditch-rider scheduling practice to the recommended scheduling practice by the DSS (Table 1). All ditches have been required to practice scheduling since year 2002, as a matter policy. The degree to which the ditch-riders have been able to actually follow this practice varies through the division. Initially there was some apprehension, both from irrigators and ditch-riders, but every year has seen an increase in the acceptance and cooperation for scheduled water delivery.

Table 1: Ditch-Rider Water Delivery Practice in Belen Division during 2006

Lateral Name	No. of Days Ditch was Running (days)	No. of Days Ditch was Off (days)	Mean Flow-rates (cfs)
BELEN GRANT LATERAL #1	16.00	21.00	16
BELEN GRANT LATERAL #2	16.00	14.00	16
BOSQUE SMITH LATERAL	2.00	17.00	2
BRAUGHT LATERAL	3.00	21.00	3
CALDWELL LATERAL	3.00	21.00	3
GABALDON LATERAL	10.00	6.00	10
JACKSON ACEQUIA	4.00	21.00	4
JARAL LATERAL #1	8.00	13.00	8
JARAL LATERAL #2	6.00	13.00	6
NEW JARALES	2.00	20.00	2
JARAL EXTENSION	2.00	19.00	2
LAS NUTRIAS LATERAL	18.00	10.00	18
RINCON ACEQUIA	7.00	15.00	7
SABINAL LATERAL #1	7.00	13.00	7
SABINAL LATERAL #2	5.00	13.00	5
SAN FERNANDEZ 1	3.00	21.00	3
SAN FERNANDEZ 3 (Moya)	2.00	21.00	2
SAN FERNANDEZ 4	4.00	21.00	4
SANCHEZ DITCH	2.00	20.00	2
TIBO DITCH	2.00	20.00	2
VALENCIA ACEQUIA	4.00	19.00	4

3.1.4 Irrigated Acreage and Cropping patterns

Irrigated service areas and cropping patterns were determined from the Microsoft Access database developed from the ditch-rider logbooks. The database includes crop type and acreage data for each irrigated parcel and identifies the lateral used to irrigate that parcel. Table 2 shows the irrigated acreage by lateral for the Belen Division. The La Joya lateral is displayed in red because it is treated as a separate acequia community and is not under MRGCD jurisdiction.

Table 2: Irrigated Acreage by Lateral in the Belen Division

Div Name	Lateral or Acequia	Service Area Acreage	Irrigated Acreage 2006	Irrigated Acreage 2005	Irrigated Acreage 2004	Irrigated Acreage 2003
Belen	Arroyos Lower Acequia	1305	488.7	466.2	466.2	466.23
Belen	Arroyos Upper Acequia	424	107.6	106.2	129.76	152.4476
Belen	Belen Grant # 1	396	228.3	221.4	226.2	226.23
Belen	Belen Grant # 2	815	620.5	771.5	771.5	771.5
Belen	Belen Highline Canal	5557	926	939.4	951.6	865.5
Belen	Belen New Acequia	3581	1766	1763	1875	1802.74
Belen	Belen New Wasteway	350	38.75	38.75	38.75	50.9855
Belen	Belen Old Acequia	520	147.4	146.4	151.3	150.95
Belen	Belen Riverside Lateral	34	8.28	8.28	8.28	8.28
Belen	Bosque - Smith Lateral	258	55.17	55.91	66.86	66.86
Belen	Braught Lateral	165	107.7	101.6	105.5	105.635
Belen	Caldwell Lateral	389	69.29	50.33	84.4	84.4
Belen	Casa Colorada / Sais Lateral	1169	895	879.3	885.1	1025.17
Belen	Chical Lateral	797	222.6	220.6	294.4	294.36
Belen	Chical Lateral Extension	508	270.8	262.4	263.1	288.85
Belen	Enrique Lateral	251	110.5	111.1	104.6	104.62
Belen	Gabaldon Lateral	620	284.6	249.9	249.9	240.85
Belen	Garcia #1 Lateral	1188	194.8	187.8	187.8	187.8
Belen	Garcia Extension Acequia	6069	1779.2	1803.6	1807.6	1807.6
Belen	Garcia Upper Acequia	878	54.57	54.05	54.05	54.05
Belen	Harlan Henderson Lateral	2213	1225	753.4	753.4	599.1567
Belen	Hells Canyon Lateral	2021	554.2	541.4	554.1	567.07
Belen	Huning Lateral	1408	261.5	273.1	320.3	320
Belen	Jackson Acequia	478	121.6	110.3	111.5	112.564
Belen	Jaral #1 Lateral	874	449.8	435.2	432.2	372.08
Belen	Jaral #2 Lateral	310	199.1	171.3	171.3	171.26
Belen	Jarales New Acequia	113	36.4	34.78	34.78	34.78
Belen	Jarales Old Acequia	2465	818.8	801.3	798.8	776.65
Belen	La Costancia Lateral	1858	861.6	822.8	735.3	773.05
Belen	La Joya Acequia	1175	800	800	800	800
Belen	Las Cercas Acequia	1148	336.1	331.2	325.4	326.2
Belen	Las Nutrias Lateral	1012	756.8	680.7	708.1	761.27
Belen	Los Chavez Acequia	1275	517.9	515.6	629.6	629.6
Belen	Los Chavez Lateral	154	36.61	39.37	39.37	39.37
Belen	Los Lunas Acequia	1501	1146	529	529	533.9
Belen	Middle Upper Acequia	664	247.7	252.6	274.3	270.5
Belen	Otero Lateral	2184	1086	1062	1049	1883.94
Belen	Peralta Acequia	930	197.2	196.6	202.6	203.6
Belen	Peralta Main Canal	6272	1080	1104	979.6	956.9
Belen	Rincon Acequia	159	71.19	65.6	65.6	65.6
Belen	Sabinal #1 Lateral	1116	503.8	500.8	500.8	763.79
Belen	Sabinal #2 Lateral	530	203.2	200.8	198.5	181.72
Belen	San Fernandez # 1 Acequia		65.93	63.71	63.92	63.92

Div Name	Lateral or Acequia	Service Area Acreage	Irrigated Acreage 2006	Irrigated Acreage 2005	Irrigated Acreage 2004	Irrigated Acreage 2003
Belen	San Fernandez # 3 Acequia		37.19	46.2	47.05	47.05
Belen	San Fernandez # 4 Acequia	115	60.41	60.41	60	60
Belen	San Juan Acequia	453	265.4	263.6	287.2	286.65
Belen	San Juan Main Canal	2999	2194.1	2011	2019	2033.88
Belen	San Juan Feeder		2.68	1.94	1.94	1.94
Belen	Sanchez Acequia	129	20.7	19.79	19.79	19.79
Belen	Sausal Lateral	1071	660.6	648.2	635.6	635.5
Belen	Tibo Feeder	136	17.5	17.13	17.13	17.63
Belen	Tome Acequia	1322	810.4	813	729.1	711.04
Belen	Valencia Acequia	919	261.7	263.3	276.5	324.62
Belen	Vallejos Lateral	286	183.7	182.9	167.9	167.9
Belen	Total Acreage	62564	24466.57	23050.75	23260.58	24267.9788

The cropping pattern for each lateral was then determined by year and crop type using the query function in Microsoft Access to delineate acreages and crop type by lateral service area. The cropping patterns for each lateral were completed for the 2004, 2005 and 2006 irrigation seasons. These data were inputted into the DSS to determine the crop irrigation requirement for each lateral service area. The detailed data about irrigated service area and crop types are included in Appendix A.

3.1.5 River water diversion and return flow data

Flow data for diversions and return flows, as well as key mid-division locations, are collected by the MRGCD's real-time telemetry network. These data are made available during the season on a provisional basis via the USBR's ET-Toolbox website. At the end of the season, these data are reviewed for errors, outliers, gaps, and changing gauging station conditions. After the dataset was reviewed, it was provided by the MRGCD in final form for use in the DSS. Detailed data for all four MRGCD diversions and return flows are provided on the attached CD for the 2004- 2006 irrigation seasons.

3.2 Socorro Division Data Files

3.2.1 Weather data

Weather data for the Socorro Division were obtained from the Bureau of Reclamation ET Toolbox. The ET Toolbox provides daily weather data along the Rio Grande. The weather data obtained through the ET Toolbox consist of variables necessary to calculate the crop evapo-transpiration using the modified Penman-Montieth equation. Rainfall data were obtained separately from the National Weather Service's Hydrologic Rainfall Analysis Project (HRAP). The HRAP divides land area into four kilometer grid cells that are used to calculate rainfall. Each lateral service area in the Socorro Division was overlaid with the spatially appropriate HRAP grid allowing for the calculation of rainfall on a lateral service area level. The data from the ET Toolbox website were downloaded into the DSS to complete the weather data sets for the years 2004-2006.

3.2.2 Ditch-rider field logs

The processing of ditch-rider logbooks consisted of manually incorporating data from the logbooks into a Microsoft Access file. The data inputted into the Access File using the logbooks were for the years 2005 and 2006. The data for 2004 had already been collected during previous project work and been incorporated into the DSS. The data updated using the logbooks consisted of acreage and crop type for each parcel in the MRGCD. Each parcel in the MRGCD (over 15,000 in total), including the Albuquerque and Cochiti divisions, was updated in order to allow for simplified expansion of the DSS in the future. The final dataset contains data for all four MRGCD divisions for the years 2005 and 2006, and can be aggregated on a lateral service area level and easily incorporated into the DSS. Using the database, irrigated acreage and crop type for each lateral service area in Socorro were determined for the 2005 and 2006 irrigation seasons. These data were inserted into the DSS model so that comparisons between the DSS recommendations and ditch-rider practice could be made.

3.2.3 Ditch-rider interviews

Ditch-rider interviews were conducted with every ditch-rider in the Socorro Division. The operational data obtained from these interviews included the irrigation duration, the flow required for irrigation, and the time between irrigation events for each lateral service area (Table 3). All ditches have been officially required to practice scheduling since year 2002. The degree to which the ditch-riders have been able to actually follow this practice varies throughout the Socorro Division. Initially there was some apprehension, both from irrigators and ditch-riders, but every year has seen an increase in acceptance and cooperation in scheduled water delivery.

Table 3: Ditch-Rider Water Delivery Practice in Socorro Division during 2006

Lateral Name	Days Ditch was Running (days)	Days Ditch was Off (days)	Mean Flow-rates (cfs)
APODACA LATERAL	3.000	12.000	3
ISLA DITCH	6.000	10.000	6
JARAL DITCH	7.000	3.000	7
MORTON LATERAL	5.000	10.000	5
MOSLEY LATERAL	10.000	3.000	10
RINCONADO LATERAL	3.000	11.000	3
SAN ANTONIO LATERAL	4.000	11.000	4
SARRACINO LATERAL	4.000	10.000	4

3.2.4 Irrigated Acreage and Cropping patterns

Irrigated Acreage and cropping patterns were determined from the Microsoft Access database developed from the ditch-rider logbooks. Table 4 shows the total irrigated acreage by lateral for the Socorro Division. The cropping patterns for each lateral were completed for the 2004, 2005 and 2006 irrigation seasons. These data were inserted in the DSS to determine the crop irrigation requirement for each lateral service area. The detailed data about irrigated service area and crop types are included in Appendix A.

Table 4: Irrigated Acreage by Lateral in the Socorro Division

Div Name	Lateral or Acequia	Service Area Acreage	Irrigated Acreage 2006	Irrigated Acreage 2005	Irrigated Acreage 2004	Irrigated Acreage 2003
Socorro	Alamillo Acequia	442.39	227.1	220.7	345.87	316.697
Socorro	Apodaca Lateral	254.62	208.2	206.4	206.38	206.38
Socorro	Chambon Lateral	403.77	342	344.5	366.63	353.98
Socorro	Florida Lateral	443.2	99.85	97.61	108.32	116.3
Socorro	Isla Lateral	308.31	162.3	160.8	173.73	171.82
Socorro	Jaral Acequia	444.75	258.7	255.4	317.03	292.7
Socorro	Lemitar Acequia	321.01	189.4	189.5	203.41	204.89
Socorro	Lemitar Lateral	958.92	671.3	657.8	716.05	709.17
Socorro	Lemitar Wasteway	986.98	904.4	907.4	920.59	917.99
Socorro	Luis Lopez # 1 Acequia	221.21	177.8	178.8	203.69	210.7
Socorro	Luis Lopez # 2 Acequia	595.45	164.3	165.3	233.69	235.69
Socorro	Morton Lateral	150.73	154.3	154.3	151.94	151.94
Socorro	Mosley Lateral	483.22	479	473.5	473.51	473.51
Socorro	Polvadera Acequia	667.58	438.6	428.7	442.83	441.71
Socorro	Rinconada Acequia	215.68	11.91	11.91	86.74	86.74
Socorro	San Acacia Feeder	42.43	10.44	9.88	13.53	14.42
Socorro	San Acacia Lower Drain	91.96	58.67	50.3	50.8	59.11
Socorro	San Antonio Old Acequia	1508.06	936.5	914.4	984.32	995.36
Socorro	San Antonio Lateral	577.57	218.6	217.4	214.4	214.4
Socorro	San Antonito		269.7	269	269	268.97
Socorro	Sarracino Lateral		65.16	65.16	67.5	67.5
Socorro	Socorro Acequia	1522.33	472.2	462.1	508.35	493.65
Socorro	Socorro Center Main	1771.86	1409	1411	1443.02	1429.87
Socorro	Socorro North Main	2122.23	1728	1570	1468	1484.26
Socorro	Socorro South Main	2406.41	2094	2073	2096.8	2096.8
Socorro	Vasquez Lateral	417.02	356.2	353.5	386.66	386.66
Socorro	Total Acreage	17357.69	12107.63	11848.36	12452.79	12401.217

3.2.5 River water diversion and return flow data

Flow data for diversions and return flows, as well as key mid-division locations, are collected by the MRGCD's telemetry network. These data are made available during the season on a provisional basis via the USBR's ET-Toolbox website. At the end of the season, this data is reviewed for errors, outliers, gaps, and changing gauging station conditions. After the data was reviewed it was provided by the MRGCD in final form for use in the DSS. As mentioned, detailed data for all MRGCD diversions and return flows are provided on the attached CD for the 2004, 2005, and 2006 irrigation seasons.

4.0 FIELD TESTING AND IMPLEMENTATION

Field testing of the DSS model primarily consisted of comparing the actual water delivery practice in year 2006 to the water delivery schedules recommended by the DSS model for year 2006. The model implementation consisted of running the model and providing MRGCD a number of water delivery schedules to follow for the year 2007 irrigation season in the Belen and Socorro Divisions. The water delivery schedules were developed by considering three possible weather scenarios – a wet, a dry and an average year. Also, efforts were made to understand how the DSS model results and recommendations can be imported directly into the SCADA water control screens currently used by the MRGCD water delivery supervisor (David Gensler). This would allow the supervisor to simultaneously view the DSS recommended diversions and the actual flows in the main canals.

4.1 Trends in Irrigated Area

In order to investigate changes in irrigated area, the irrigated acreage for each division was calculated for the period 2003-2006. The numbers were calculated using the data provided in the ditch-rider logs and do not include irrigated Pueblo lands. It was found that on an annual basis the total irrigated acreage throughout the Belen and Socorro Divisions did not change significantly. In the Belen Division, the four year average for irrigated acreage was found to be 23,742 acres, with the largest change in irrigated acreage occurring between 2005 and 2006 with an increase of 1,416 irrigated acres. In the Socorro Division, the four years average for irrigated acreage was found to be 12,202 acres, with the largest change in irrigated acreage occurring between 2004 and 2005 with a decrease of 604 irrigated acres. In 2006 a total of 259 acres were added in Socorro indicating that the decrease in 2005 may have been due to farmers fallowing their fields. MRGCD believes that irrigated acreage has been slightly increasing in recent years, or at least remaining stable in the face of increasing urbanization, due to increased awareness of water and water rights. Landowners have become aware of the State of New Mexico's "use it or lose it" approach to water rights, and may be farming once fallowed lands. MRGCD has also been more aggressive in getting good accounting from its ditch-riders and it is possible that some lands now reported as being irrigated were being overlooked on previous years' logbooks. Figure 6 displays the trends in irrigated acreage for the Belen and Socorro Divisions over the period 2003-2006

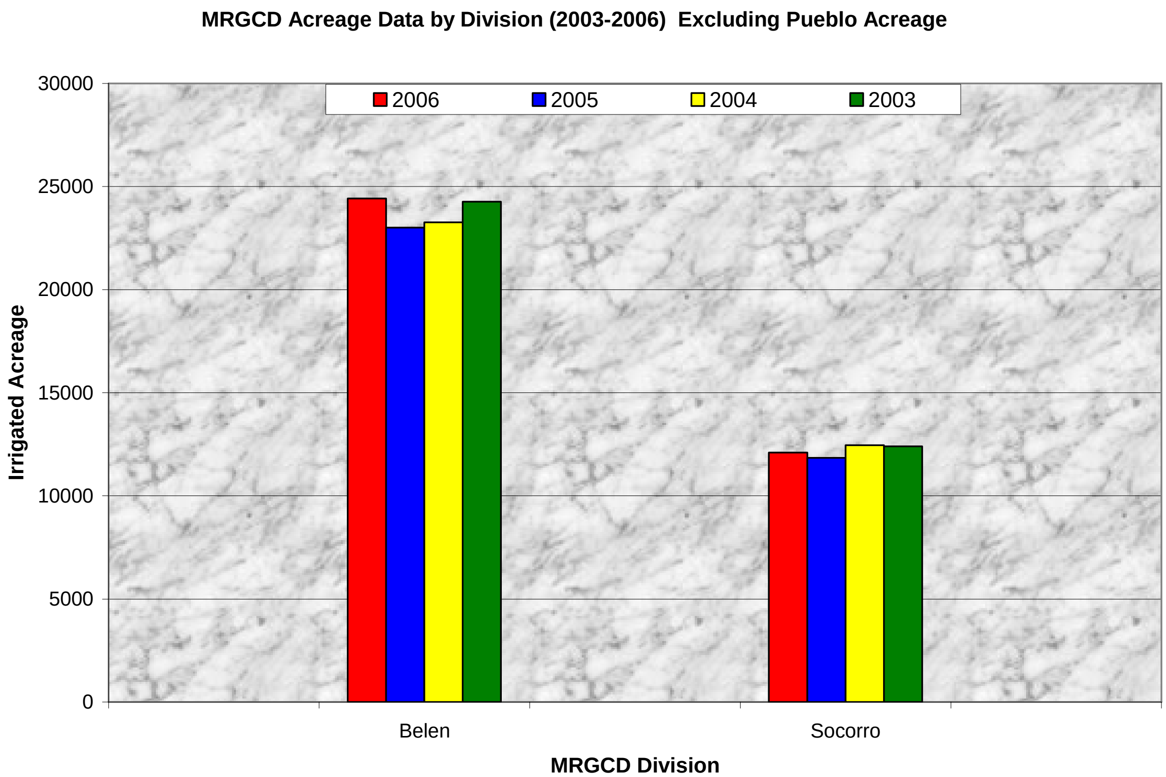


Figure 6. Trends in Irrigated Acreage for the Belen and Socorro Divisions.

The overall results of the acreage analysis indicate that the irrigated acreage in the Belen and Socorro Divisions has remained constant over the last four years.

4.2 Field Testing of DSS Model

To test the model prediction capability, the model was run in operational mode using 2006 water supply, weather, and crop area data. The readily available moisture (RAM) at the beginning of the season was set at zero. The RAM at the start of a delivery schedule was also set to zero in order to utilize the entire available soil moisture. The irrigation efficiency and the return flow percentage were both set at 50%, based on the results of previous sensitivity analysis and our review of the literature. The irrigation schedule recommended by the DSS model for 2006 was compared to the actual water delivery practice of ditch-riders in 2006. The key variables used for the comparison are: the irrigation duration, time between irrigations, and the irrigation flow-rate. Figures 7-9 show the comparison of irrigation duration, time between irrigations and irrigation flow rate for the 2006 irrigation season. Table 5 displays a legend for Figures 7-9. Table 6 displays the comparison between the DSS and actual practice for mean irrigation duration, mean time between irrigations and mean irrigation flow rate.

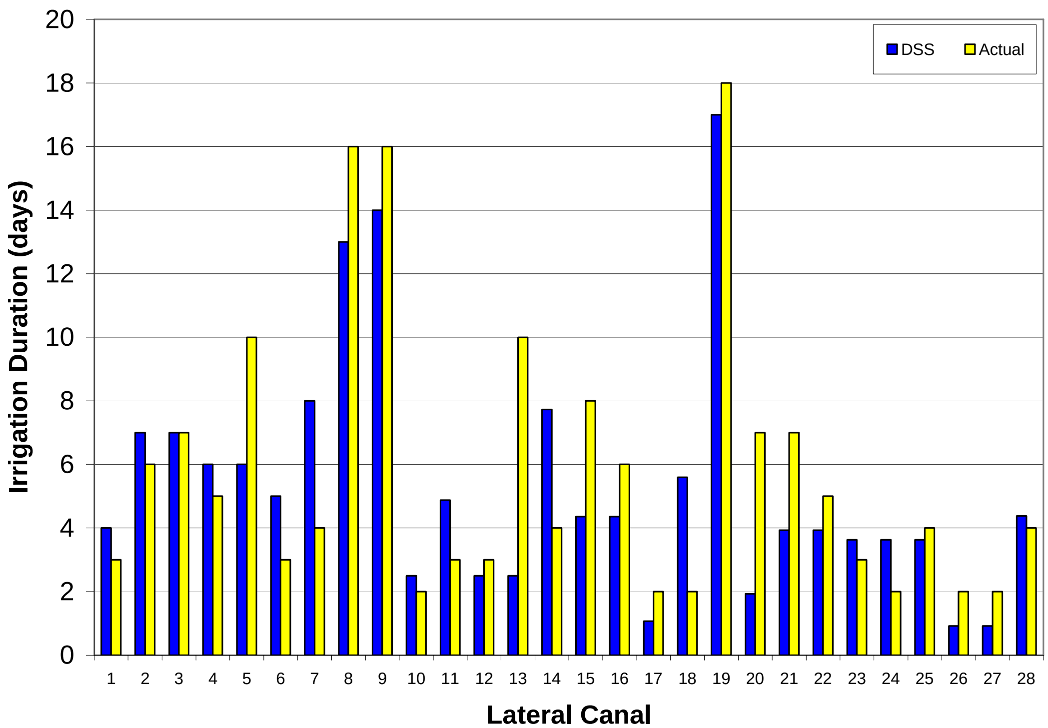


Figure 7. DSS Irrigation Duration compared to Actual Irrigation Duration

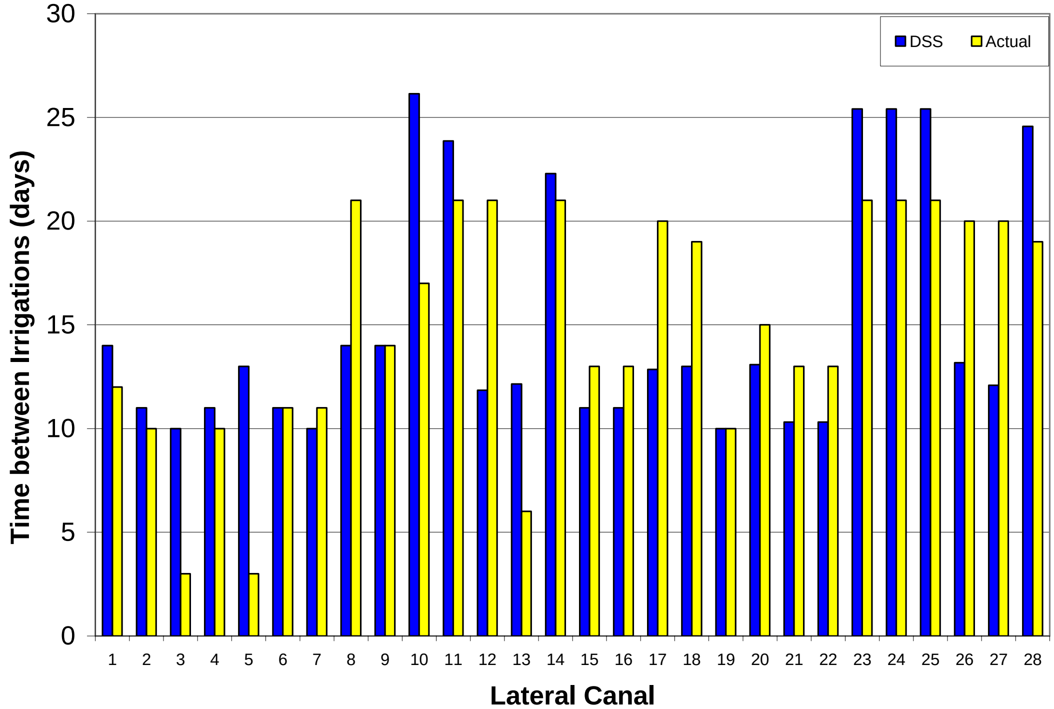


Figure 8. DSS Time between irrigations compared to Actual practice

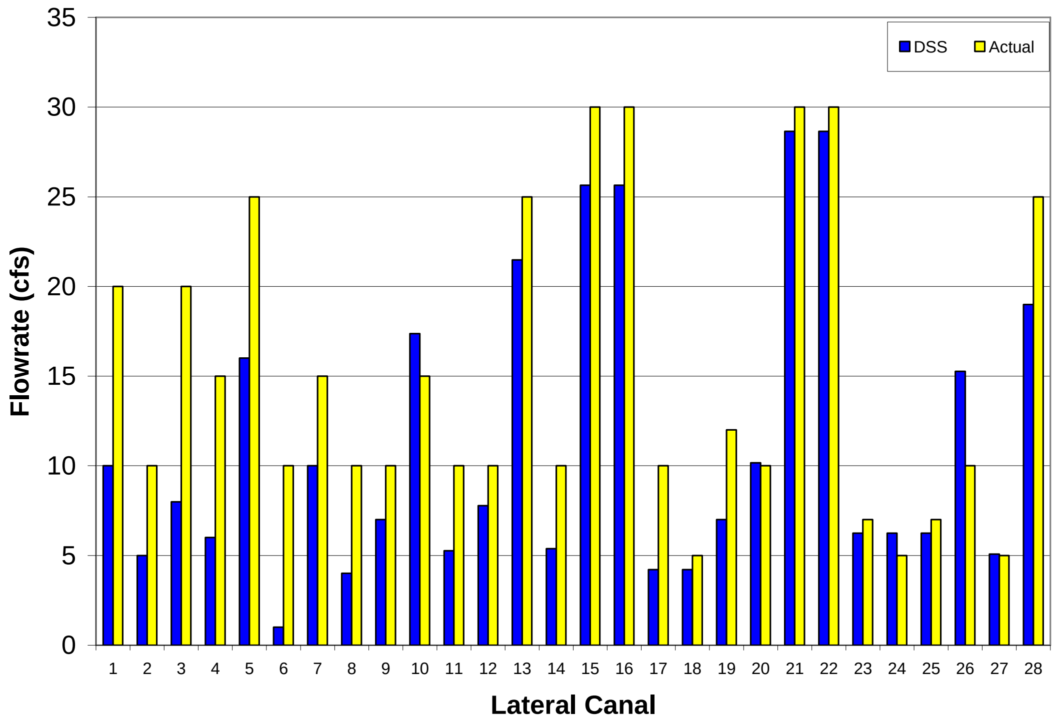


Figure 9. DSS Flow rate compared to Actual Flow rate for 28 Laterals in 2006

Table 5. Legend Relating Lateral Name to the Number used in Figures 7, 8, and 9

Lateral or Acequia Name	Number
APODACA LATERAL	1
ISLA DITCH	2
JARAL DITCH	3
MORTON LATERAL	4
MOSLEY LATERAL	5
RINCONADO LATERAL	6
SAN ANTONIO LATERAL	7
BELEN GRANT LATERAL #1	8
BELEN GRANT LATERAL #2	9
BOSQUE SMITH LATERAL	10
BRAUGHT LATERAL	11
CALDWELL LATERAL	12
GABALDON LATERAL	13
JACKSON ACEQUIA	14
JARAL LATERAL #1	15
JARAL LATERAL #2	16
NEW JARALES	17
JARAL EXTENSION	18
LAS NUTRIAS	19
RINCON ACEQUIA	20
SABINAL LATERAL #1	21
SABINAL LATERAL #2	22
SAN FERNANDEZ 1	23
SAN FERNANDEZ 3	24
SAN FERNANDEZ 4	25
SANCHEZ DITCH	26
TIBO DITCH	27
VALENCIA ACEQUIA	28

Table 6. Comparison of the DSS Recommendations to Actual Practice.

Irrigation Duration (days)

Year	Mean DSS Recommendation	Mean Ditch-rider Practice	Difference
2004 (2 Laterals)	4.41	3.50	-0.91
2005 (2 Laterals)	2.85	3.10	0.26
2006 (28 Laterals)	5.34	5.86	0.52

Time between Irrigations (days)

Year	Mean DSS Recommendation	Mean Ditch-rider Practice	Difference
2004 (2 Laterals)	13.85	16.00	2.15
2005 (2 Laterals)	15.13	16.00	0.88
2006 (28 Laterals)	15.07	14.96	-0.10

Irrigation Flow rate (cfs)

Year	Mean DSS Recommendation	Mean Ditch-rider Practice	Difference
2004 (2 Laterals)	6.49	9.00	2.52
2005 (2 Laterals)	5.89	9.50	3.62
2006 (28 Laterals)	11.30	15.04	3.73

Irrigation duration comparison results are acceptable for most laterals but large discrepancies exist between the model and the actual practice on a significant number of laterals. This could be due to several reasons. First, the information obtained through the ditch-rider interviews is quite subjective and might not reflect the actual irrigation practice. Second, the irrigation practice used by ditch-riders could be inappropriate which is indicated by the irrigation durations being either too short or too long. The fact that the 2006 irrigation season was the first time several ditch-riders practiced scheduled water delivery could explain the difference between the optimal duration represented by the DSS and the actual duration used in practice. Ditch-riders and most irrigators currently do not have soil moisture probes that can be used to indicate the need for irrigation. Scheduling is based on past practice, requests from irrigators, and physical limits to the water supply and system. The laterals with significant discrepancies warrant further investigation to determine if the model recommendations are reasonable or if the ditch-riders' practices need change.

DSS Model values for time between irrigations were slightly longer than the values obtained from the ditch rider practice, and large discrepancies exist between the model and the actual practice on a significant number of laterals. The reason for this could be that in actual practice, irrigation events occur before the soil moisture (RAM) is significantly depleted. Field observations during the 2005-06 irrigation seasons show that alfalfa fields were irrigated every ten days, which is excessive and would account for the shorter time between irrigation recorded from the field data. Irrigation intervals that are longer than the DSS recommendation indicate that the crops are possibly being stressed.

The actual flow rate proved to be significantly larger than the model recommendations. This is due to the fact that gauges do not exist on most canals and the flow rate given by the ditch-riders is at best an estimate. In the future, staff gages need to be installed on canals in order to develop stage-discharge relationships, or automated gates with flow meters need to replace aging lateral turnout structures.

In order to analyze the scheduled water delivery practice in depth, an analysis was performed on a selected ditch-rider service area. The ditch-rider service area was selected based on the fact that the ditch-rider in this area has been practicing scheduled water delivery for a period of three years and keeps rigorous records of his irrigation practices. These records were used to determine the irrigation schedules used on two lateral service areas, the Jackson and Braught Laterals, for years 2004-06. These field schedules were then compared to the DSS recommended schedules using the variables of irrigation duration, time between irrigations and the flow rate. Figures 10.a-b display the comparison of irrigation duration for the Jackson and Braught Lateral for the years of 2004-06. Figures 11.a-b display the comparison of time between irrigations for the Jackson and Braught Lateral for the years of 2004-06, and Figures 12.a-b display the comparison of irrigation flow rate for the Jackson and Braught Lateral for the years of 2004-06.

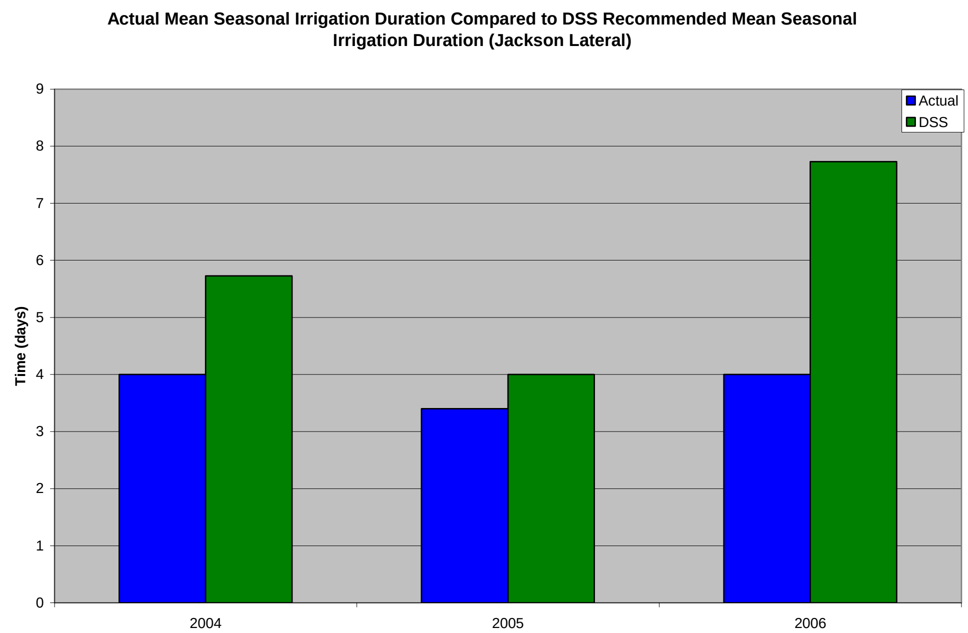


Figure 10.a. Comparison of Irrigation Duration for the Jackson Lateral

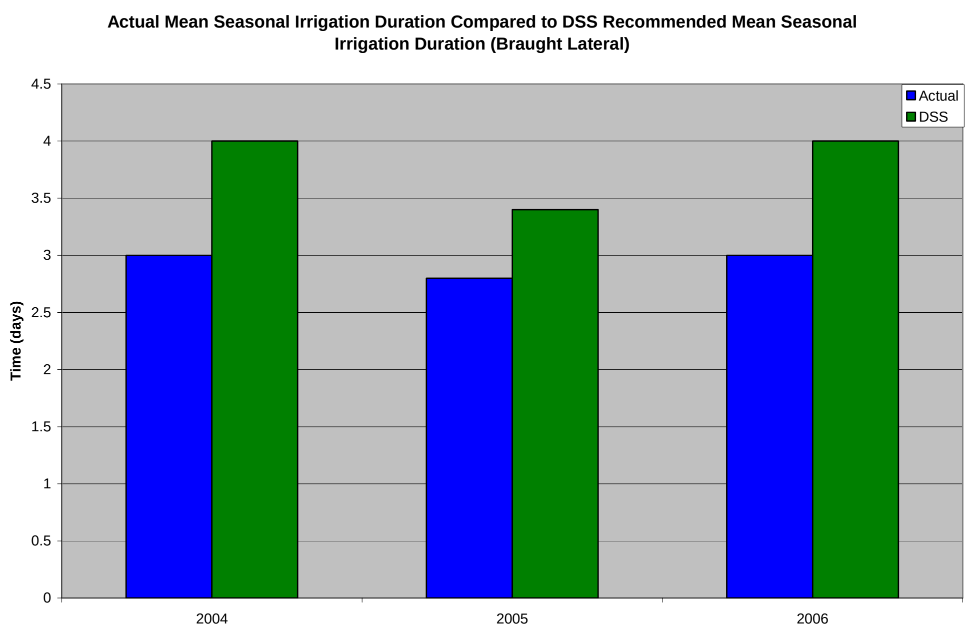


Figure 10.b. Comparison of Irrigation Duration for the Braught Lateral

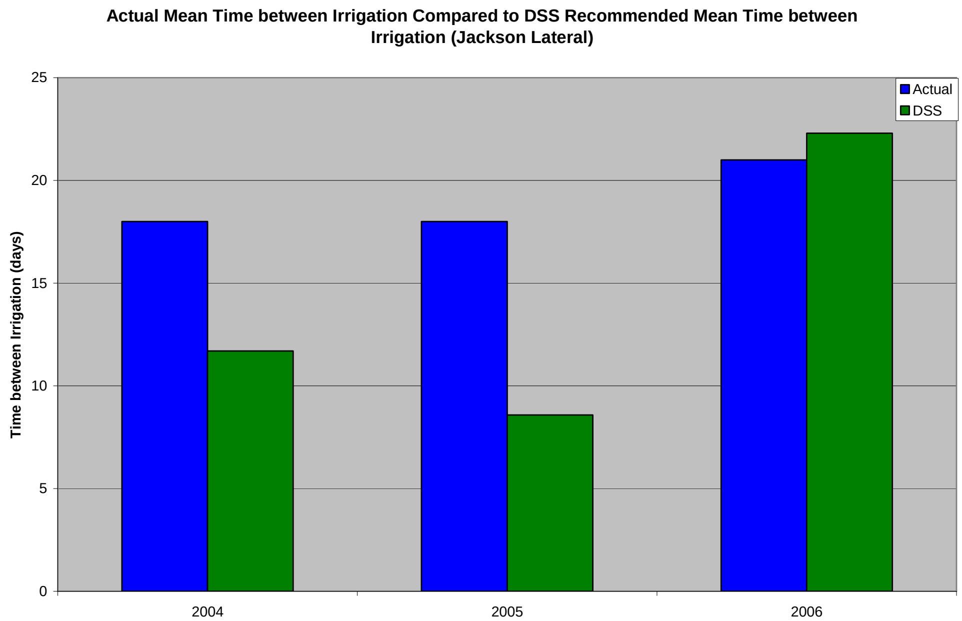


Figure 11.a. Comparison of Time between Irrigations for the Jackson Lateral

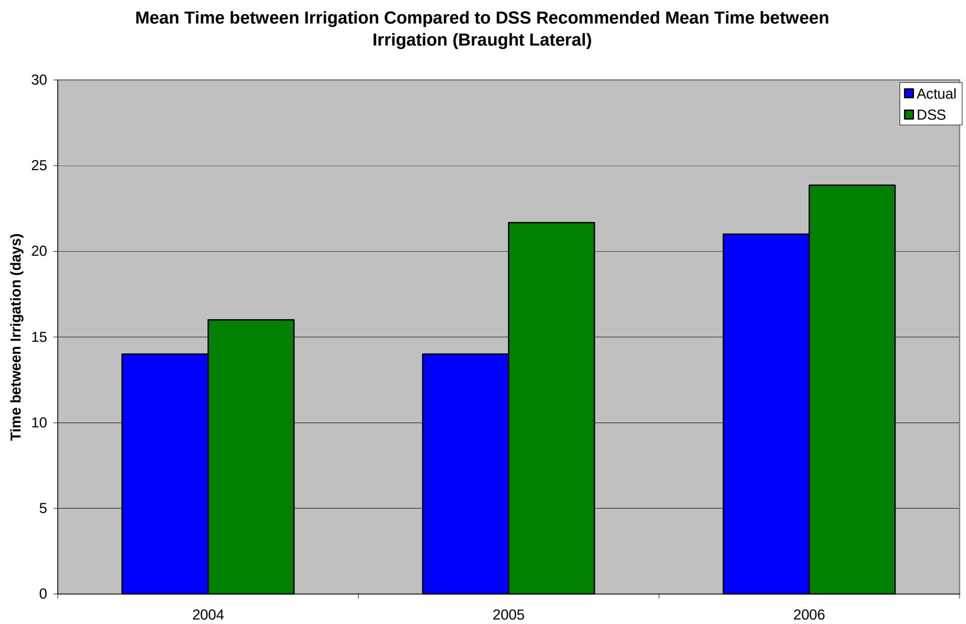


Figure 11.b. Comparison of Time between Irrigations for the Braught Lateral

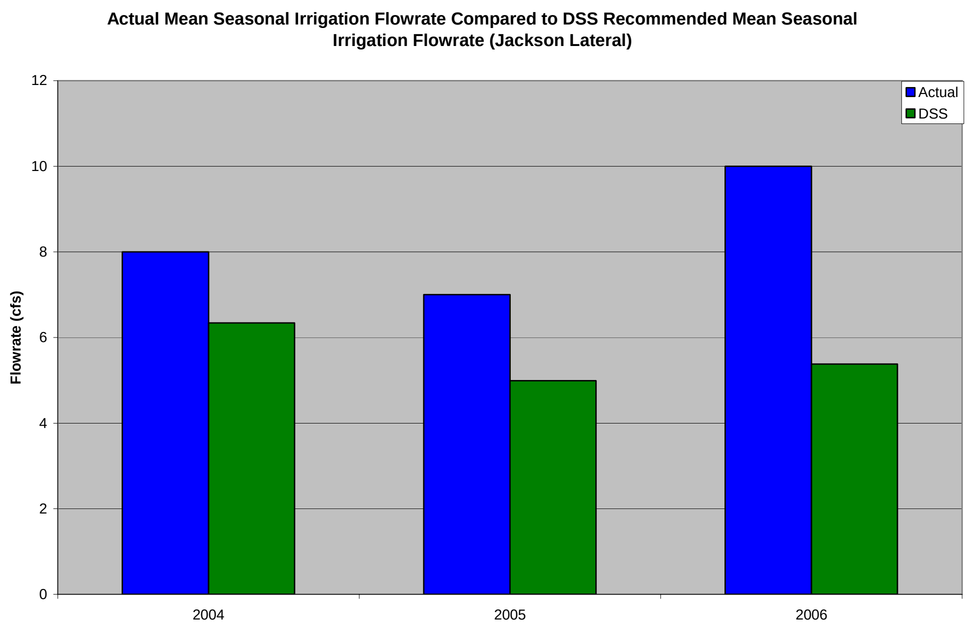


Figure 12.a. Comparison of Irrigation Flow rate for the Jackson Lateral

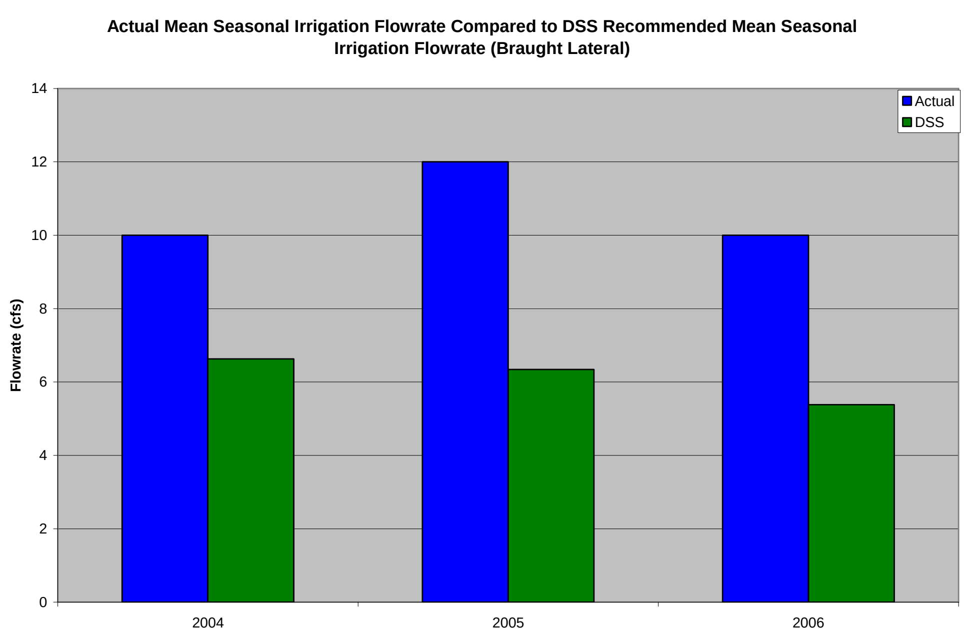


Figure 12.b. Comparison of Irrigation Flowrate for the Braught Lateral

For the variable of irrigation duration, the DSS recommendation is slightly longer with a large discrepancy occurring on the Jackson Lateral in 2006. This could possibly represent the fact that ditch-rider is deficit irrigating by not filling up the entire root zone or that the root zone still has sufficient moisture when an irrigation event commences. Time between irrigation on the Jackson Lateral was much longer in practice in 2004 and 2005 than the DSS recommendation. This could possibly indicate the stressing of crops due to depletion beyond the entire readily available moisture. In 2006, the time between irrigation on the Jackson Lateral for the DSS and actual practice coincided well.

For the Braught Lateral, the actual time between irrigations was shorter than the DSS recommendation indicating that the Braught was possibly irrigated before the soil moisture was significantly depleted. The actual flowrate proved to be significantly larger than the model recommendations on both the Jackson and Braught Laterals. This is due to the fact that gauges do not exist on most canals and the flow rate given by the ditch-riders is at best a simple estimate. The data on flow rate collected from the ditch-riders is subjective and therefore must be considered in that context when comparing the DSS recommendation and ditch-rider practice. When comparing the irrigation duration, time between irrigations, and the required irrigation flow rate the results from the model compare well with the field data. Overall, the water delivery schedule developed by the DSS is reasonable and within the limits set forth by the MRGCD. The desired water delivery schedule requirements for the MRGCD are based on a 14 to 21 day rotation and the model recommendations fall within these limits.

Using scheduled water delivery and physical system improvements, the MRGCD has been able to significantly reduce their river diversions. Historically the MRGCD diverted as much as 600,000 acre feet per year from the Rio Grande. Over the last three years, their diversions have averaged 330,000 acre feet per year. Figure 13 shows the decreasing trend in total MRGCD river diversions.

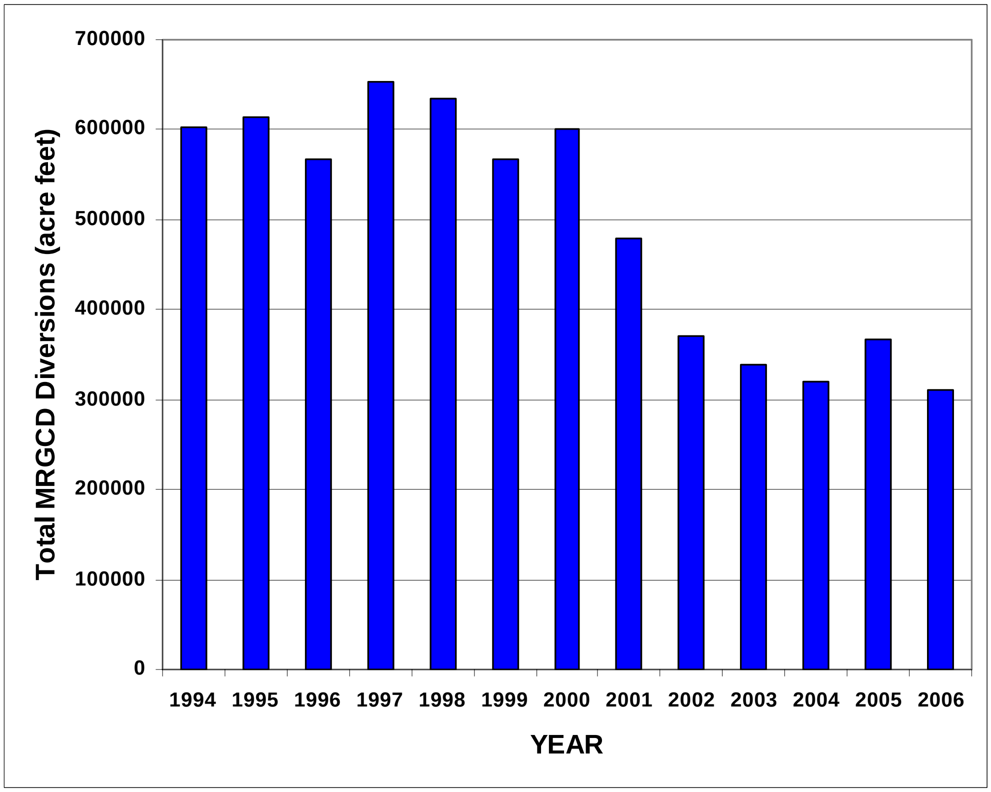


Figure 13. Annual MRGCD River Diversions.

4.3 <u>2007-Irrigation Season Planning</u>

At the beginning of 2007-irrigation season, MRGCD water supervisor wanted to use the DSS for planning water delivery schedules. Therefore, the DSS was run in planning mode to develop a seasonal water delivery schedule and diversion patterns for each main canal. The schedules for 2007 were developed using the same model settings as in the validation analysis – RAM set to zero at the beginning of the season and it will be entirely depleted before the start of each irrigation, and the irrigation efficiency and the return flow percentage set at 50%. Due to the addition of the ability to use forecasted weather scenarios, it was possible to develop a dry and a wet scenario using the planning mode for 2007. Based on the cropping analysis, it was deemed appropriate to use 2006 irrigated acreage for the forecasted 2007 season because total irrigated acreage in the MRGCD does not change significantly from year to year. Planning scenarios for the MRGCD to follow for the 2007 irrigation season were developed for five main canals and irrigation schedules were developed for all laterals in the Belen and Socorro Divisions.

Canal operational schedules for 2007 were developed using both a dry and a wet weather scenario for the five main canals in the two divisions, which are Peralta Main, Chical Lateral, San Juan Main Canal, Belen Highline Canal and the Socorro Main Canal. The canal operational schedules based on either a dry or wet scenario were sent to David Gensler to be incorporated in his daily operations of the five main canals in 2007. A request has been made to the water managers at the division level to attempt to implement the schedules, or to explain why they cannot be implemented. Figures 14-18 display the hydrographs for the five main canals using Planning Mode for 2007 with a dry weather scenario.

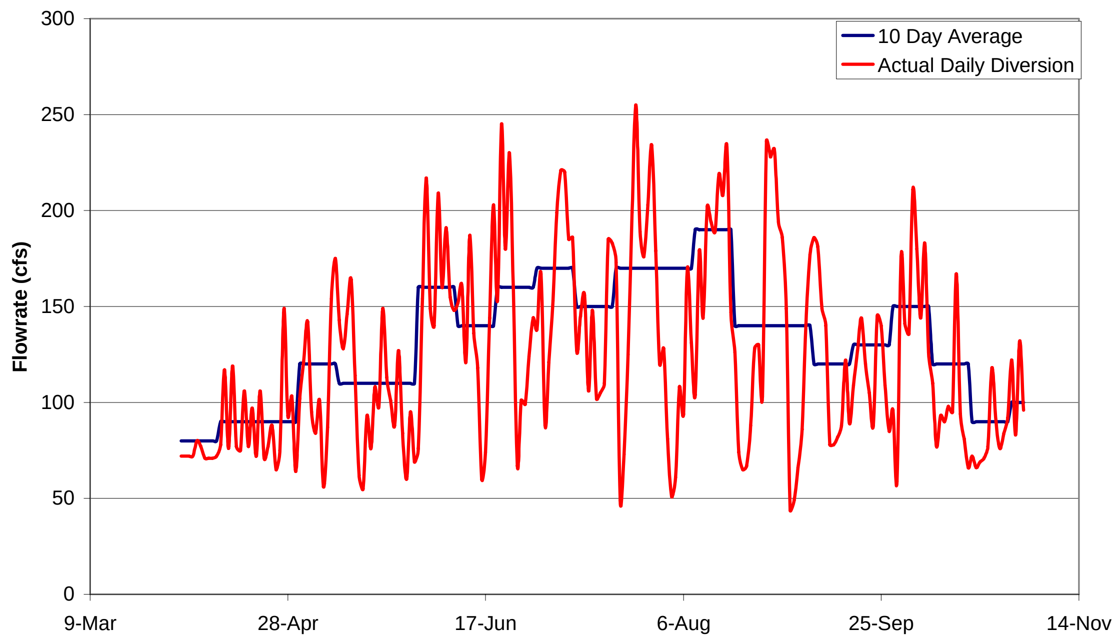


Figure 14. 2007 Forecasted Water Delivery Hydrograph for the Peralta Main Canal (Dry Weather Scenario)

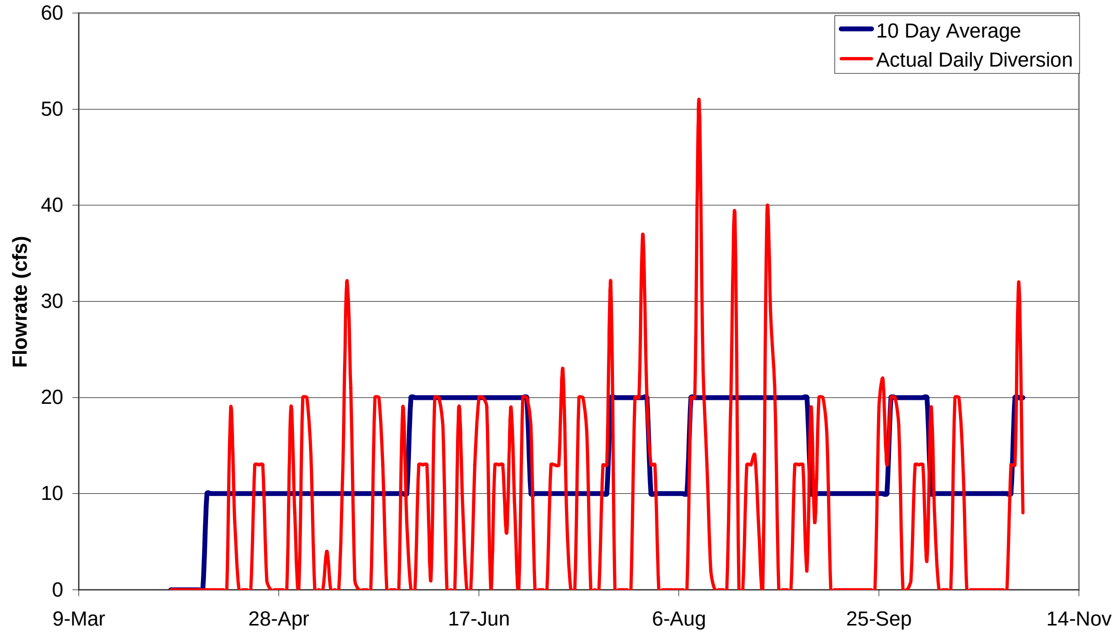


Figure 15. 2007 Forecasted Water Delivery Hydrograph for the Chical Canal (Dry Weather Scenario)

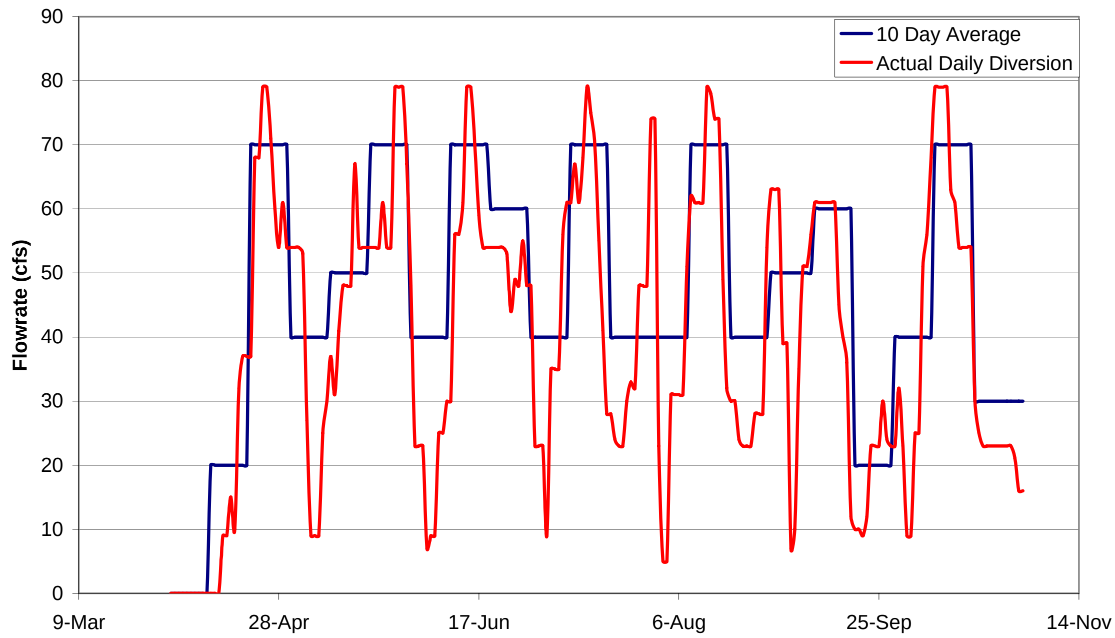


Figure 16. 2007 Forecasted Water Delivery Hydrograph for the San Juan Main Canal (Dry Weather Scenario)

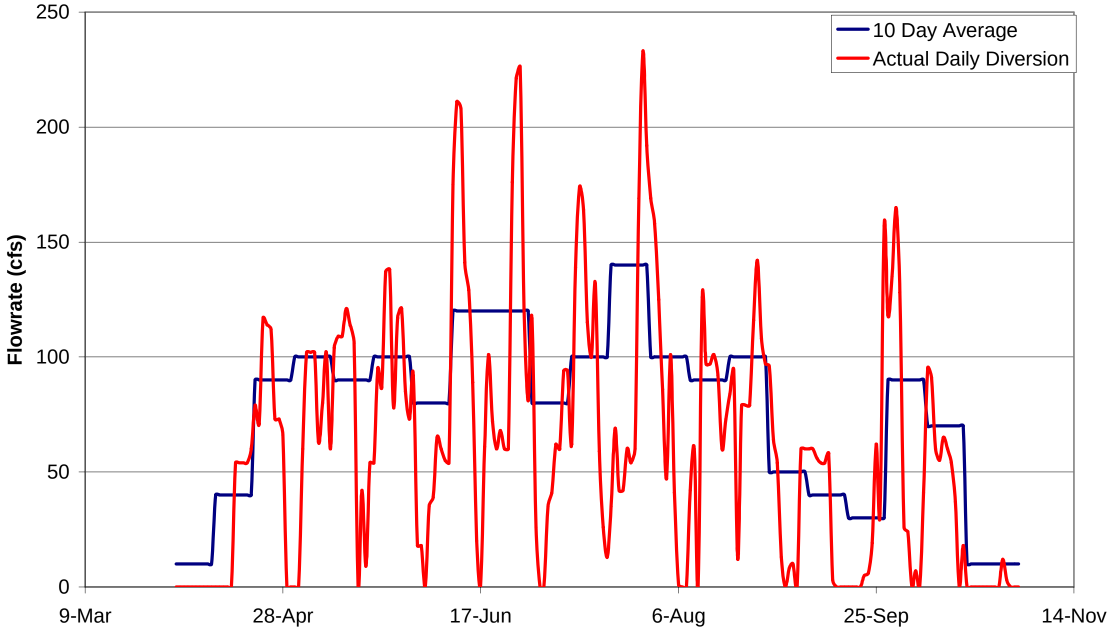


Figure 17. 2007 Forecasted Water Delivery Hydrograph for the Belen Highline Canal (Dry Weather Scenario)

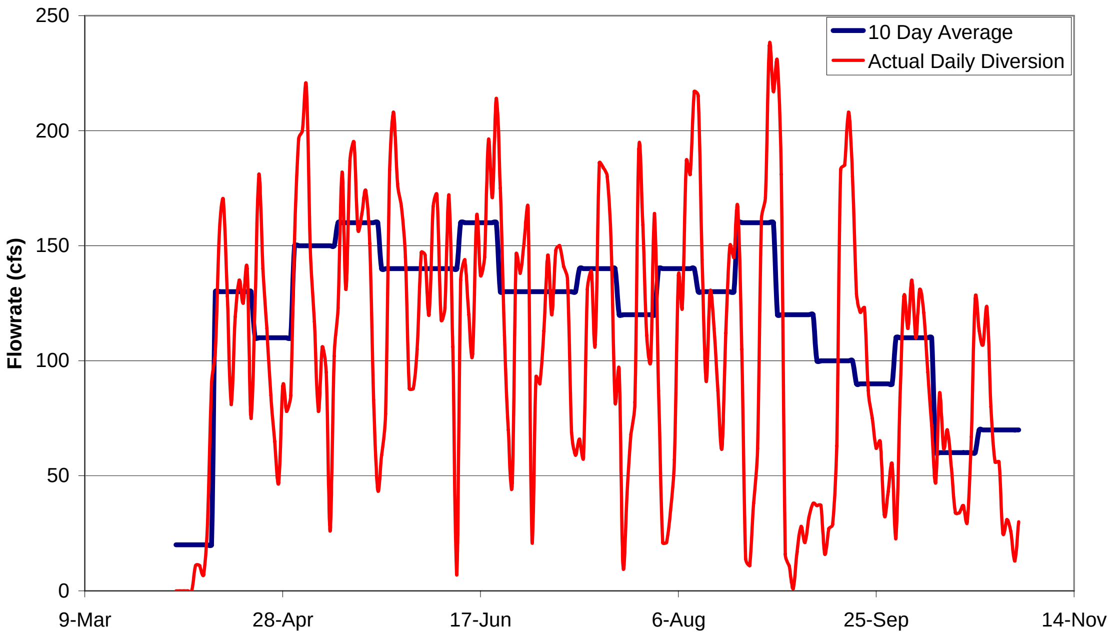


Figure 18. 2007 Forecasted Water Delivery Hydrograph for the Socorro Main Canal (Dry Weather Scenario)

The lateral canal operational schedules were also developed with required irrigation duration, time between irrigations, and lateral canal flow-rate. The total acreage irrigated as well as the consumptive irrigation requirement, and required diversions for each lateral service area are also included. Tables 7-11 display the water delivery schedules for the lateral canals for the five main canals, using a dry weather scenario. The schedules include information related to irrigation duration, time between irrigations, lateral canal flow-rate, total acreage irrigated, consumptive irrigation requirement, and required yearly diversion.

Table 7. Forecasted 2007 Water Delivery Schedule for Laterals on the Peralta Main Canal (Dry Weather Scenario).

Lateral	Acreage	Avg Irrig Duration (Days)	Avg Time Between Irrigations (Days)	Average Flow (CFS)	Days of Crop Stress	Crop Irrigation Requirement (Ac-Ft)	Diversion Required (Ac-Ft)
Chical 1	223	2	8	16	0	748	1284
Otero 1	147	1	9	22	0	515	911
PM 1	125	2	9	110	0	398	709
Hell Canyon 1	159	2	9	12	0	493	888
Otero 2	196	1	9	26	0	620	1127
Braught	108	2	8	5	3	409	691
Jackson	122	3	8	6	0	372	628
Chical 2	271	2	7	18	0	911	1586
Bosque	55	1	8	20	0	180	334
PM 2	6	1	6	98	0	23	42
Hell Canyon 2	326	2	6	21	0	1186	1998
Middle Peralta Acequia	248	1	10	20	0	627	1141
PM 3	227	2	4	92	0	675	1068
Hell Canyon 3	66	1	8	19	0	222	406
Otero 3	743	3	4	22	0	2169	3350
Peralta Acequia	197	2	9	17	0	630	1133
Valencia	262	1	9	16	0	849	1504
Las Cercas	336	3	6	11	0	1214	1953
Enrique1	110	2	6	10	0	414	734
La Constancia	860	3	5	26	0	3193	4947
PM 4	85	1	8	67	0	287	521
San Fernandez #4	60	2	9	5	0	230	405
PM 5	57	1	8	64	0	172	318
PM 6	646	3	5	51	0	2426	3734
Tome	810	2	4	35	0	3073	4846
Vallejos	184	2	5	16	0	709	1195

Table 8. Forecasted 2007 Water Delivery Schedule for Laterals on the Chical Canal (Dry Weather Scenario).

Structure	Average Irrigaton Duration (Days)	Avg Time Between Irrigations (Days)	Average Flow (CFS)	Days of Crop Stress	Crop Irrigation Requirement (Ac-Ft)	Diversion Required (Ac-Ft)
Chical 1	2	8	16	0	748	1284
Otero 1 (PM (ND1))	1	9	22	0	515	911
PM 1 (PM (ND1))	2	9	110	0	398	709
Hell Canyon 1 (Chical 1)	2	9	12	0	493	888
Otero 2 (Otero 1)	1	9	26	0	620	1127
Braught (Otero 1)	2	8	5	3	409	691
Jackson (PM 1)	3	8	6	0	372	628
Chical 2	2	7	18	0	911	1586
Bosque (PM (ND2))	1	8	20	0	180	334
PM 2 (PM (ND2))	1	6	98	0	23	42
Hell Canyon 2	2	6	21	0	1186	1998
Middle Peralta Acequia (PM 2)	1	10	20	0	627	1141
PM 3 (PM 2)	2	4	92	0	675	1068
Hell Canyon 3	1	8	19	0	222	406
Otero 3 (Otero (ND2))	3	4	22	0	2169	3350
Peralta Acequia (Middle Peralta	2	9	17	0	630	1133
Valencia	1	9	16	0	849	1504
Las Cercas (PM (ND3))	3	6	11	0	1214	1953
Enrique1 (Hell Canyon (ND3))	2	6	10	0	414	734
La Constancia (PM (ND4))	3	5	26	0	3193	4947
PM 4 (PM (ND4))	1	8	67	0	287	521
San Fernandez #4 (PM (ND5))	2	9	5	0	230	405
PM 5 (PM (ND5))	1	8	64	0	172	318
PM 6 (PM (ND7))	3	5	51	0	2426	3734
Tome (PM (ND6))	2	4	35	0	3073	4846
Vallejos (Tome)	2	5	16	0	709	1195

Table 9. Forecasted 2007 Water Delivery Schedule for Laterals on the San Juan Main Canal .

Structure	Irrigation Duration (Days)	Avg Time Between Irrigations (Days)	Average Flow (CFS)	Days of Crop Stress	Crop Irrigation Requirement (Ac-Ft)	Diversion Required (Ac-Ft)
San Juan Main Canal #1	3	27	42	0	118	214
Casa Colorada	18	11	11	0	3860	5174
San Juan Main Canal #2	14	13	35	0	5507	7983
Las Nutrias #1	19	11	7	0	2718	3596
San Juan Acequia 2	24	5	5	0	4697	5450
Belen Grant #2	15	13	7	0	2044	2854
Belen Grant #1	14	14	4	0	883	1308
San Juan Main Canal #3	12	16	13	0	2212	3351

Table 10 . Forecasted 2007 Water Delivery Schedule for Laterals on the Belen Highline Main Canal (Dry Weather Scenario).

Structure	Average Irrigaton Duration (Days)	Avg Time Between Irrigations (Days)	Average Flow (CFS)	Days of Crop Stress	Crop Irrigation Requirement (Ac-Ft)	Diversion Required (Ac-Ft)
New Belen 1	2	11	34	0	794	1393
Belen High Line 2	3	9	41	0	1354	2320
Huning Lateral	2	11	26	0	895	1630
Los Lunas Acequia	4	8	31	0	3104	4954
Belen High Line 3	1	11	38	0	400	731
Los Chavez Acequia	4	9	24	0	1974	3239
Los Chavez Lateral	1	14	27	0	139	257
Gabaldon	2	11	19	6	930	1636
Harlen Henderson	4	7	38	0	3990	6224
New Belen 2	6	8	30	0	5373	8160
Tibo Ditch	1	13	4	0	36	70
Sanchez ditch 1	1	11	11	0	44	82
Belen High Line 4	1	11	45	0	18	33
Old Belen	2	13	15	3	474	857
Garcia Acequia 2	2	12	15	0	417	758
Garcia Acequia 1	1	14	16	1	456	843
Caldwell	2	12	8	0	265	472
Upper Arroyos	1	12	23	0	406	744
Old Jarales	5	9	21	0	3011	4887
New Jarales	1	12	9	0	145	270
New Belen Wasteway	1	11	11	0	118	218
Garcia Acequia 3	2	13	17	0	775	1409
Garcia Lateral	4	8	48	0	4323	6874
Rincon	1	13	12	0	246	454
Sabinal Lateral #1	2	11	31	0	1421	2489
Lower Arroyos	3	10	23	0	1714	2899
Jaral Lateral #1	4	9	27	2	2483	4028

Table 11. Forecasted 2007 Water Delivery Schedule for Laterals on the Socorro Main Canal (Dry Weather Scenario).

Structure	Average Irrigaton Duration (Days)	Avg Time Between Irrigations (Days)	Average Flow (CFS)	Days of Crop Stress	Crop Irrigation Requirement (Ac-Ft)	Diversion Required (Ac-Ft)
Rinconada Lateral	5	12	1	0	59	97
SM 3	6	11	103	0	6407	10157
Alamillio Lateral	4	11	8	0	725	1155
Polvadera Ditch	6	12	13	0	1568	2480
Vasquez Lateral	7	12	9	0	1399	2143
Morton Ditch	5	12	6	0	697	1097
Lemitar Lateral 1	6	11	11	0	1626	2545
Sarracino Lateral	5	13	6	0	320	525
Isla Acequia	4	13	5	0	323	556
Chambon Lateral	4	11	8	0	609	1021
SM 9	7	9	62	0	2944	4595
Lemitar Acequia	3	15	7	0	355	612
Socorro Ditch 1	6	10	7	0	977	1509
Florida Lateral	3	15	4	0	199	352
Jaral Ditch	4	13	9	0	509	873
Luis Lopez Ditch 1	3	14	10	0	337	591
SM 12	10	6	42	0	8757	11472
Luis Lopez Ditch 2	4	14	8	0	636	1048
San Antonio Ditch 1	8	10	22	0	4522	6653
Apodaca Lateral	4	13	15	0	965	1602
Mosley Lateral 2 and Brass Lateral	6	11	16	0	2054	3165
San Antonio Lateral	8	10	10	0	2018	2961

5.0 IMPROVEMENTS TO THE DSS MODEL

During the project work in year 2006, multiple improvements to the DSS were completed. The model improvements made include the capability to use both IDSCU and ET Toolbox to calculate crop demand, the ability to use forecasted weather scenarios, improvements to the model output, and the validation of return flow assumptions

5.1 Major Model Improvements

During the 2006 DSS project, significant improvements were made to the model codes, including the SWAP and IDSCU codes. These improvements are described in this section.

1) The SWAP model has been revised and the ability to use the ET Toolbox or IDSCU has been incorporated. An Access database containing the daily crop irrigation requirement (CIR) for all cropped acreage in a given lateral service area has been added and can be populated using either IDSCU or the ET Toolbox.

2) The new interface contains tools to populate the CIR database using the IDSCU model and the ET Toolbox. IDSCU datasets can be selected and read into the database using the project name for the lateral service area. ET Toolbox data can be read into the database by river reach either from the web or from local ET Toolbox reach files. Both the National Weather Service Hydrologic Rainfall Analysis Project (HRAP) and the new Quantitative Precipitation Estimation (QPE) cell indexing can be used.

3) Tools for synthesizing net water requirement data have been added that allow the user to build a year's worth of data by averaging a selection of historical data or by repeating a cycle of historical data.

4) The readily available moisture is now computed directly by the model rather than IDSCU. Each crop is assigned a starting root depth, a maximum root depth, the number of days until full cover is reached, and the management allowed depletion. The root is

assumed to grow linearly each day once the crop's net water requirement is greater than zero until full cover is reached. The readily available moisture at each field in a demand is then calculated by multiplying the root depth by the field's soil moisture holding capacity and the management allowed depletion of the field's crop.

5) Yearly statistics for each service area have been added to the model output, including average irrigation duration, average time between irrigations, average flow, days of crop stress, total crop irrigation requirement, division demand, and total diversions. Additional improvements to the model output include the daily running total of flow for each service area and the yearly total or average of each output parameter.

6) The interface has been completely redesigned in order to improve software installation, speed, and usability.

5.2 Description of Model Restructuring

During the 2006 project, the major model improvement included the development of the capability to use both IDSCU and ET Toolbox to calculate crop demand. This change required significant restructuring of the model and the associated databases. This section describes the restructuring in detail.

The first step in the restructuring process was to develop an Access database with the ability to use both IDSCU and ET Toolbox. The Access database consists of a Location table and a Source table. The Location table stores the name of the service area or site and the Source table is used for documentation. The Location table is comprised of 6 components that include the crop type and the acreage. Figure 19 displays the Location and Source table link and the associated data stored in the Location table.

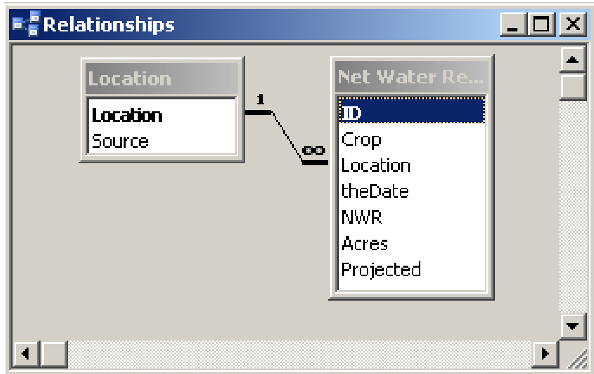


Figure 19. Location and Source Table Link

The net water requirement data stores the crop irrigation requirement (CIR) for an acre of a given crop for a given location on a given day. The Location database can be populated using the Crop and Soil Editor which is located in the pull down menu under data**.** The first step in populating the Location database is to select the ET database. As mentioned, the ET database can be calculated using either the IDSCU model or the ET data from the ET Toolbox. The Crop and Soil Editor screen is displayed in Figure 20 and displays the tabs for selecting either IDSCU or ET-toolbox

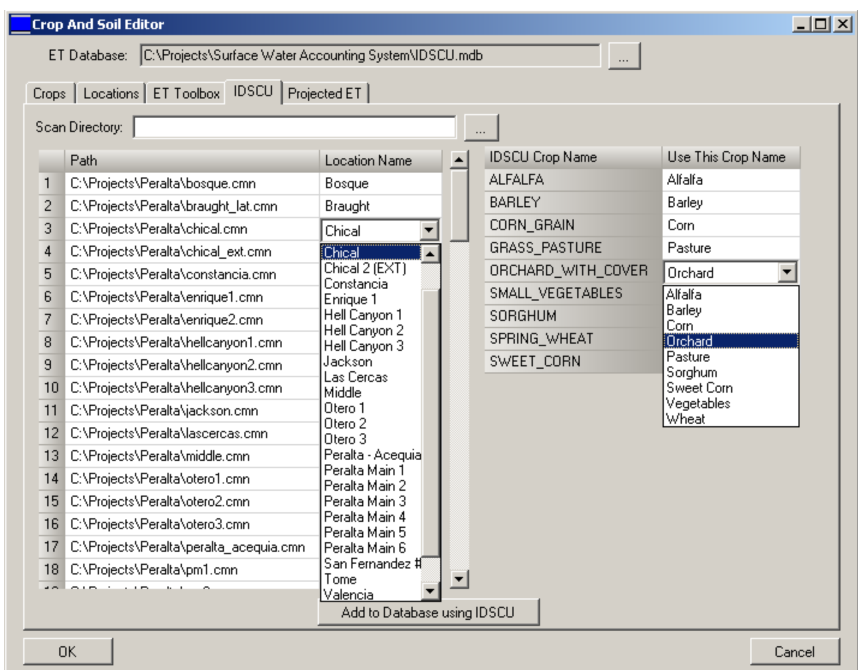


Figure 20. Crop and Soil Editor Screen

The crop parameters in the restructured DSS are selected using the crops tab under the Crop and Soil Editor. Figure 21 displays the crop parameter input tab.

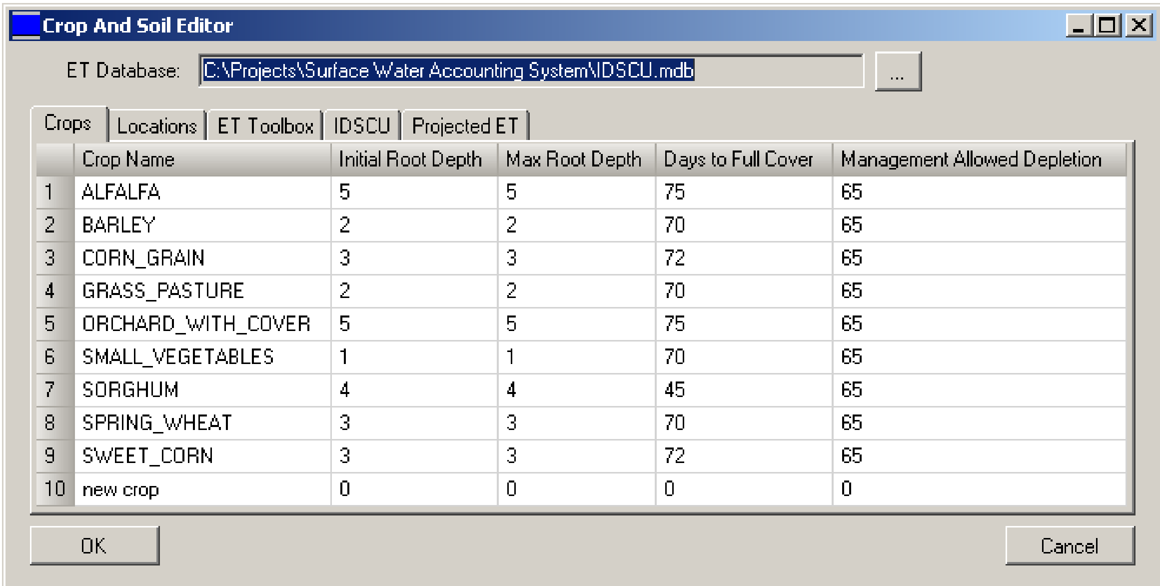
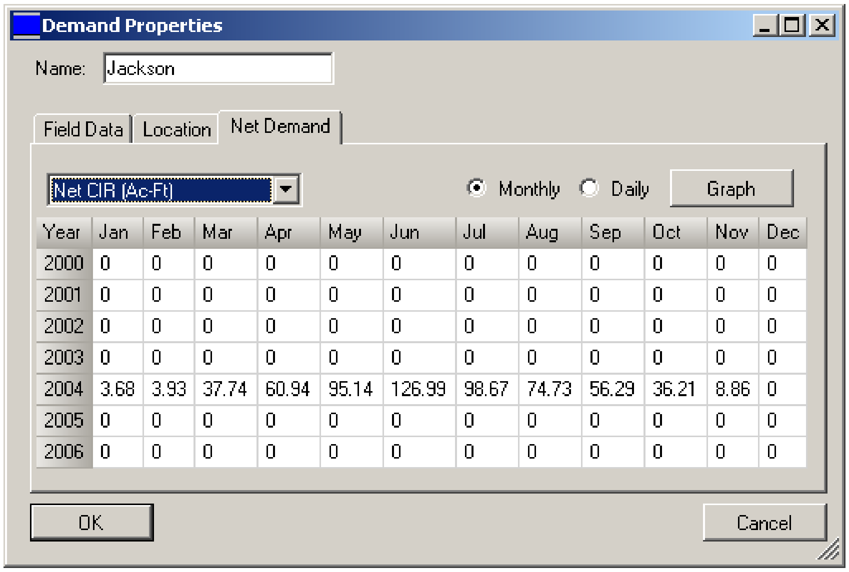


Figure 21. Crop Parameter Input Tab

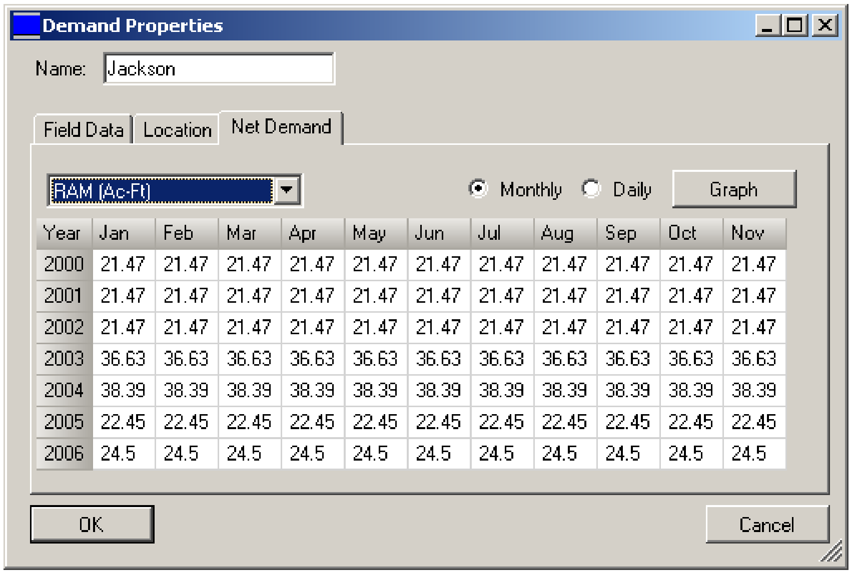
A connection between the demand and the database can be made by using the demand node editor. Under the location name, choose the name of the demand from the list and set the weight of the cell to 1. This can be done automatically for every demand by selecting the Add Demand Name to Location from the Data->Demands menu.

A GIS layer was created by combining a service area layer with the NWS Hydrologic Rainfall Analysis Project (HRAP) layer to make hrap_irr_acres2004. In 2007, the ET Toolbox switched over to the Quantitative Precipitation Estimation (QPE), so another layer called qpe_irr_acres2004_intersect was created in the same way. By selecting the appropriate fields and filters, the contribution of each location to the demand can be calculated. The Portion of Location that the Service Area covers is the service area acreage divided by the total irrigated acreage of that cell and is used only as information for the user. The weight of the cell is the contribution of that location to the entire service area and is the number of irrigated acres of the service that falls in that location divided by the total number of irrigated acres in the service area. The water requirement for the service area will be the weighted average of the water requirements of all the locations that comprise the service area. With the crop parameters defined and the location information entered, the crop irrigation requirement (CIR) and readily available moisture can be calculated. Figure 22 displays the demand properties screen in which the CIR is calculated and Figure 23 displays the demand properties screen with the readily available moisture calculated.



Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	3.68	3.93	37.74	60.94	95.14	126.99	98.67	74.73	56.29	36.21	8.86	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0

Figure 22. Demand Properties Screen showing CIR



Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
2000	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47
2001	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47
2002	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47
2003	36.63	36.63	36.63	36.63	36.63	36.63	36.63	36.63	36.63	36.63	36.63
2004	38.39	38.39	38.39	38.39	38.39	38.39	38.39	38.39	38.39	38.39	38.39
2005	22.45	22.45	22.45	22.45	22.45	22.45	22.45	22.45	22.45	22.45	22.45
2006	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5

Figure 23. Demand Properties Screen showing RAM

The changes and restructuring described allow the user to select either the ET Toolbox or the IDSCU for ET calculations. Using the ET Toolbox data allows for a more streamlined program and a much decreased run time of the model. Once the CIR and RAM are calculated, the DSS uses SWAP to calculate the most efficient water delivery schedule.

5.3 <u>Incorporation of Weather Scenarios</u>

The ability of the model to use projected weather scenarios was added during the year 2006. The model can currently use three weather scenarios based on the available weather data from the MRGCD weather stations. The model can run using a wet, dry, or average scenario in planning mode. The period of record for the MRGCD weather stations is rather short so the wet, dry, and average scenarios are representative of the weather patterns between 2001 and 2006 from the ET Toolbox. Testing of the model was conducted to insure that the weather scenarios produced reasonable results. The testing results show that the shortest rotations occur during the dry scenario, the longest rotations occur during the wet scenario, and that the average scenario produces an intermediate rotation length. The overall water usage increased from the wet scenario to the average scenario, and again from the average scenario to the dry scenario.

5.4 <u>Modeling of Ground and Surface Water Return Flow</u>

The DSS models return flow (both ground and surface water) by assuming that a portion of water applied to the land that is not consumptively used will flow into the drains. Currently the model assumption is that 25% of all applied irrigation water will become return flow, through a combination of surface and subsurface flow, and be available downstream for reuse. For example, if a lateral service area irrigates at 50% efficiency and 50% of the water that is not used consumptively is available as return flow, then if 100 acre-feet of water are applied, 25 acre-feet of water will eventually appear in drains as return flow. The pattern of return flow currently used by the DSS is based on the assumption that 40% of the return flow is available on the first day after irrigation, 30% is available the second day, 20% is available the third day, and 10% is available the fourth day after irrigation has occurred. Following our example, if 40% of the return flow is set to return on day 1 and 30% on day two, then 10 acre-feet of water will appear on the day after, and 7.5 acre-feet of water will appear two days after the water was applied. After three days 5 acre-feet will be available and after four days 2.5 acre-feet will be available.

Analysis of Return Flow Assumptions

The primary purpose of this analysis was to evaluate the assumption that the magnitude of return flow is close to 25% of water application. We can use a mass balance approach on a control volume, such as a lateral or main canal service area, and account for all inflows and outflows from this control volume. Given the extremely complicated drainage patterns from irrigated lands, we chose a large-scale control volume, that of a main canal, and compared flow diversion into a main canal and the resulting flow to drains from the main canal service area. However, the drain flow includes both the return flow from irrigated lands and the in-stream channel flow that is in some cases intentionally routed for use in the downstream areas. As such, the following analysis of drainage flow as a percentage of inflow in the main canals is not directly comparable to the assumption of return flow being 25% of applied water.

The diversion and drain flow data were analyzed for the Cochiti Main, Belen Highline and Peralta Main canals for the years 2004-06, since all drains in these areas are gauged now. First, the base flow of the drains was determined and subtracted from the drain flow hydrographs. Base-flow was determined as the three year average flow rate in drains during the period when main canals were shut off from October 31st to March 1st. The net drain flow with base-flow removed was then compared to the canal inflow to determine the percentage of canal diversions that returns to drains downstream. Figures 24.a and 24.b display the hydrograph for the East Side of the Belen Division with the drain flow hydrograph including base-flow and with base-flow removed. Tables 12-14 display the results of the analysis for the east side of the Belen Division, Cochiti Main Canal, and the Belen Highline Canal. The gages used to compute total inflow were the Belen Highline Canal, Peralta Main Canal, Chical Main Canal, Isleta Drain Return Flow, and the Corrales Main. The gages used to compute outflow were the Peralta wasteway, Storey wasteway, Lower Peralta Drain, San Juan Drain, Unit 7 Drain, and the Upper Corrales Drain.

Results for the Belen east side show that roughly 20- 40% of the main canal inflow is collected by drains downstream. These percentage numbers for drain flow indicate that the assumption of return flow being 25 % is reasonable. On the Belen west side, the drainage percentage is much higher – 40 to 75% -- which is as expected since a much larger percentage of in-stream flow is routed in the west side canals for use in the downstream Socorro main canal.

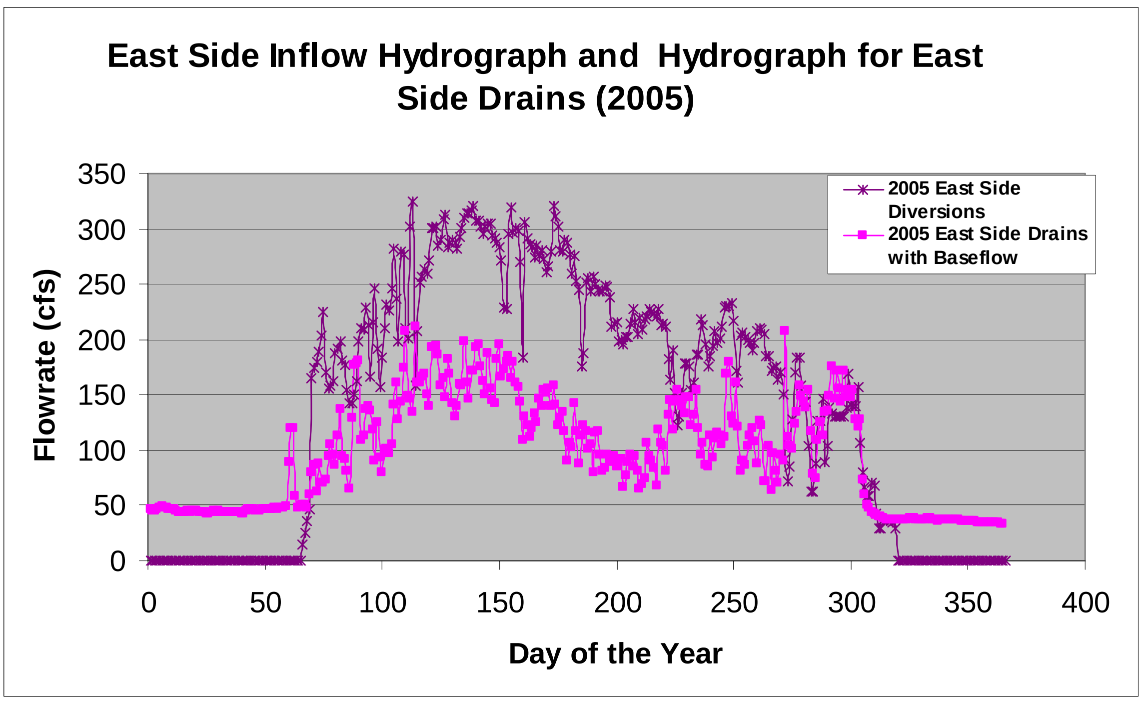


Figure 24.a. Inflow Hydrograph for the East Side of the Belen Division and Hydrograph for East side Drains with Base-flow for 2005.

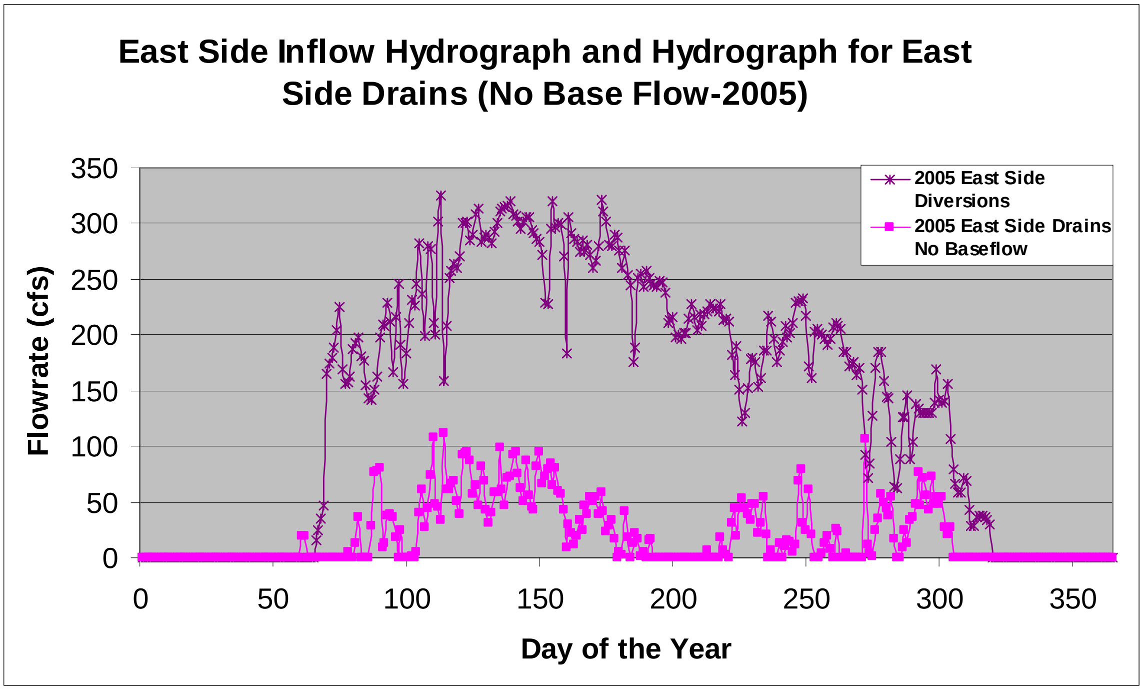


Figure 24.b. Inflow Hydrograph for the East Side of the Belen Division and Hydrograph for East side Drains with Base-flow removed for 2005.

Table 12. Annual Diversion and Return Flow for the East Side of the Belen Division

Isleta Diversion	Volumes (ac-ft)		
		Year	
Total East Side Diversion	2004	2005	2006
	82999	102392	94169
Total Return Flow East Side with Base Flow Removed	2004	2005	2006
	25629	14338	21042
Percentage Return Flow	30.88%	14.00%	22.35%
Three Year Average	22.41%		

Table 13. Annual Diversion and Return Flow for the Cochiti Main Canal

Cochiti Main Canal	Volumes (ac-ft)		
	Year		
Total Cochiti Main Diversion	2004	2005	2006
	16598	38834	35379
Total Return Flow in Algodones Drain with Base Flow Removed	2004	2005	2006
	7861	15217	9561
Percentage Return Flow	47.36%	39.19%	27.02%
Three Year Average	37.86%		

Table 14. Annual Diversion and Return Flow for the Belen Highline Canal and Unit 7 Drain in the Belen Division.

Belen Highline Main Canal	Volumes (ac-ft)		
	Year		
Total West Side Diversion at Isleta	2004	2005	2006
	94983	120576	109641
Total Return Flow in Unit 7 Drain with Base Flow Removed	2004	2005	2006
	70315	48391	57486
Percentage Return Flow	74.03%	40.13%	52.43%
Three Year Average	55.53%		

Overall, the analysis of groundwater return flow on a main canal service area level indicates that between 25 and 40% of the total diversion is available as return flow downstream. The completed analysis compares total diversion and return flow on a main canal level and therefore further research is needed to quantify the percentage of return flow originating solely from irrigation water application.

In addition to evaluating the percentage of flow returning in the drains, the return flow distribution was analyzed. The return flow distribution from the Corrales Main and Corrales Drain were compared to each other to determine any patterns in return flow. Figure 25 displays the hydrographs of the Corrales Main diversion and the Corrales Drain return flow. This was done in order to refine the return flow distribution that is used in the model. The Corrales Main and Corrales Drain were chosen for this analysis based on the advice of David Gensler and the fact that they represented an isolated system with gaged inflow and return flow. The return flow distribution currently used by the DSS is based on the principle that 40% of the return flow is available on the first day after irrigation, 30% is available the second day, 20% is available the third day, and 10% is available the fourth day after irrigation has occurred. The analyses was aimed at discerning if the DSS return flow distribution was representative of condition in the field.

The analysis completed on the Corrales Main and drain subsystem revealed that the canal and the drain are inter-connected. This indicates some surface water connection, and return flow distribution analysis is more complex than expected. Changes in flow in the main canal sometimes were observed in the drain on the same day. This is one of the few sub-systems in the MRGCD with minimal external influence, and where a reasonably good record exists of both inflow and return flow. Additional data will be collected from this system, as well as other systems with adequate records, to devise a method of determining return flow distribution.

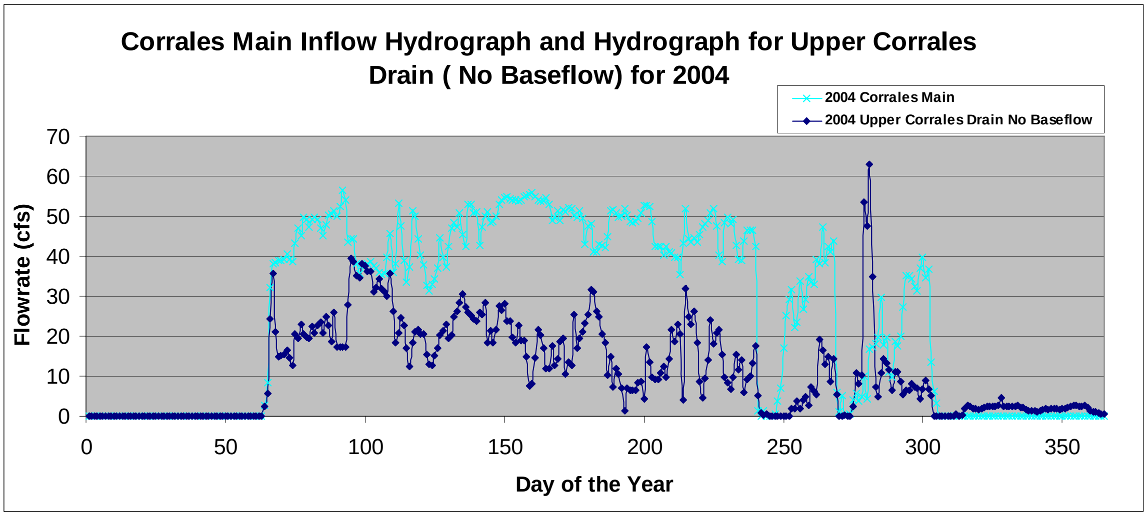


Figure 25. Corrales Main Diversion and the Corrales Drain Return Flow

6.0 CONCLUSIONS AND RECOMMENDATIONS

The project objectives for year 2006 were successfully achieved. We now have complete updated data sets for the Belen and Socorro Divisions for years 2004-06. The data include river water diversions, irrigated service areas, cropping patterns, soil types, and weather related parameters. The DSS model itself has been greatly improved in several important ways. The model has been revised and the ability to use either the ET Toolbox or IDSCU has been incorporated, for estimating crop ET and the crop irrigation requirement (CIR). An Access database containing the daily CIR for all cropped acreage in a given lateral service area has been added and can be populated using either IDSCU or the ET Toolbox. This improvement has allowed the DSS model to work more efficiently. Another important improvement is the ability of the model to use projected weather scenarios to recommend related water delivery schedules. The model can currently use three weather scenarios based on the available weather data from the MRGCD weather stations – a wet, a dry or an average scenario in planning mode.

The future plan for the DSS and efficient water delivery project is to work on two interrelated aspects: i). to facilitate its implementation in MRGCD water delivery operations where the model and related datasets have been completed (Belen and Socorro Divisions), and ii). to extend the model formulation and development of data sets for the remaining two divisions (Cochiti and Albuquerque). Towards this purpose, the project team has submitted a comprehensive project proposal for funding by the ESA Collaborative Program. Following are the three key focus areas for future project efforts.

DSS Implementation: During 2007, water delivery schedules developed using the DSS were provided to the MRGCD hydrologist (David Gensler) and are currently being used to schedule irrigation deliveries. For effective implementation of DSS in the future, it is highly desirable to import DSS recommendations directly into the SCADA water control screens currently used by the MRGCD central office. This will allow MRGCD water delivery supervisor (David Gensler) to simultaneously view the DSS recommended diversions and the actual flows in the main canals. Having both the recommended and actual diversions on his water control screen will allow him to determine over allocations and correct them in real time.

Public Outreach: The DSS project success can only be achieved if the MRGCD and its irrigators are active participant in the process, and are willing and able to implement the changes recommended by the project. Public outreach, therefore, will be critical in the future, for implementing scheduled water delivery and related tools such as the decision-support system. The MRGCD has recently established a Public Information Office at its headquarters, which is aggressively pursuing various strategies of conveying information to their water users and encouraging participation in efficiency improvement measures. Our project can use the facilities of this office to plan and carry out a public outreach program, which can effectively convey project information to the MRGCD water users and seek their cooperation. A preliminary strategy for future public outreach efforts can be outlined as following.

- Write a Newsletter with summarized information about the project and mail it to all MRGCD water users in a particular division,

- E-mail the newsletter (in pdf form) to all Neighborhood Associations and tribes in the North and the South Valleys,

- Attend meetings of the Neighborhood Associations and present the information to the water users. There are reportedly active neighborhood associations that regularly meet in nearby community centers. These meetings are generally well attended, where we can meet with smaller number of water users at a time and effectively exchange information about the project.

- Send information to water users through the MRGCD Newsletter, which is published and sent every quarter.

- Develop informational messages and place them on MRGCD website. These messages about the project can be linked to other information deemed useful for the operations of the water users such as the weather data and recommendations on irrigation.

Extension of DSS Model Formulation: The next logical steps in the future would be to extend the decision-support system to include the remaining Albuquerque and Cochiti

Divisions while continuously testing and validating the model to improve its performance. Future work that can be performed over the next 3-4 years can be outlined as follows:

a. Extension of the project work to include the Albuquerque Division and its main canal service areas (Albuquerque main canal) – FY07,
b. Extension of the project work to include the Cochiti Division and its main canal service areas (Cochiti East and Sili main canals) – FY08
c. Field implementation and testing of the model in areas where the model and data sets have been completed – FY 2007-08,
d. Improvement of the model structure, elements, and overall performance. Implementation in the MRGCD service area – FY 2007-09.

References

Oad, Ramchand: 2006 (Assisted by Luis Garcia, Dave Patterson and Kristoph Kinzli of Colorado State University; Deborah Hathaway, Dagmar Llewellyn and Rick Young of S. S. Papadopulos & Assoc.; and Dr. Nabil Shafike of NMISC). Water Management Decision-Support System for the Middle Rio Grande Conservancy District. New Mexico Interstate Stream Commission FY 2004 Project Report. March 2006.

Oad, Ramchand: 2005 (Assisted by Luis Garcia, Dave Patterson and Kristoph Kinzli of Colorado State University; Deborah Hathaway, Dagmar Llewellyn and Rick Young of S. S. Papadopulos & Assoc.; and Dr. Nabil Shafike of NMISC). Water Management Decision-Support System for the Middle Rio Grande Irrigation. New Mexico Interstate Stream Commission FY 2003 Project Report. June 13, 2005.

Appendix A – Service Area Acreage Reports for 2004 - 2006

Note: To minimize the report length, only one main canal acreage report is provided here. The remaining acreage reports are included in the CD.

Belen Division (Peralta Main Canal)

Valencia

Crop	2004	2005	2006
ALFALFA	116.4	92.7	48.7
GRASS_PASTURE	199.5	149.0	195.7
BARLEY	0.0	19.8	17.3
SORGHUM	0.0	0.0	0.0
SPRING_WHEAT	7.8	1.9	0.0
Total	322.0	260.0	260.0

Vallejos

Crop	2004	2005	2006
ALFALFA	185.5	146.3	145.8
GRASS_PASTURE	65.3	36.6	37.9
Total	250.0	182.0	182.0

Enrique 1

Crop	2004	2005	2006
ALFALFA	66.3	82.9	97.1
GRASS_PASTURE	43.9	26.1	6.2
BARLEY	3.9	2.1	7.2
Total	112.0	110.0	110.0

Constancia

Crop	2004	2005	2006
ALFALFA	724.6	516.1	574.0
GRASS_PASTURE	234.0	228.7	210.8
BARLEY	125.0	77.0	69.8
ORCHARD_WITH_COVER	1.8	1.0	5.3
Total	1082.0	821.0	858.0

Bosque

Crop	2004	2005	2006
ALFALFA	74.7	39.8	39.4
GRASS_PASTURE	25.0	13.1	12.8
ORCHARD_WITH_COVER	0.0	3.0	3.0
Total	99.0	55.0	54.0

Peralta Main 6

Crop	2004	2005	2006
ALFALFA	741.1	601.8	548.0
GRASS_PASTURE	112.1	84.8	88.8
BARLEY	9.4	9.4	9.4
Total	862.0	694.0	645.0

Las Cercas

Crop	2004	2005	2006
ALFALFA	310.3	239.0	235.8
GRASS_PASTURE	102.1	88.4	69.4
BARLEY	3.8	3.8	31.0
Total	415.0	329.0	334.0

Tome

Crop	2004	2005	2006
ALFALFA	723.6	672.8	706.9
GRASS_PASTURE	183.3	107.3	57.9
BARLEY	14.3	31.9	0.0
SMALL_VEGETABLES	1.0	1.0	0.0
SORGHUM	15.0	0.0	0.0
SWEET_CORN	5.1	0.0	45.6
Total	941.0	811.0	808.0

San Fernandez #4

Crop	2004	2005	2006
ALFALFA	2.0	0.0	0.0
GRASS_PASTURE	77.6	44.9	60.4
BARLEY	15.7	15.6	0.0
Total	94.0	59.0	60.0

Hell Canyon 3

Crop	2004	2005	2006
ALFALFA	78.6	37.5	37.5
GRASS_PASTURE	16.4	9.0	9.7
BARLEY	50.9	23.5	19.2
Total	144.0	68.0	65.0

Hell Canyon 2

Crop	2004	2005	2006
ALFALFA	410.0	196.4	196.4
SMALL_VEGETABLES	7.8	4.0	4.0
GRASS_PASTURE	205.6	112.0	121.0
BARLEY	8.3	4.5	4.5
Total	629.0	316.0	325.0

Hell Canyon 1

Crop	2004	2005	2006
ALFALFA	86.2	41.0	41.4
GRASS_PASTURE	180.0	100.8	109.0
SORGHUM	0.0	0.0	0.0
BARLEY	22.9	10.4	8.6
Total	288.0	150.0	158.0

Middle

Crop	2004	2005	2006
ALFALFA	129.1	109.5	0.0
GRASS_PASTURE	135.1	84.6	150.6
BARLEY	30.2	30.2	97.1
SMALL_VEGETABLES	0.0	13.2	0.0
Total	294.0	236.0	247.0

Peralta - Acequia

Crop	2004	2005	2006
ALFALFA	79.8	72.5	59.3
GRASS_PASTURE	161.1	108.6	137.9
BARLEY	11.6	15.6	0.0
ORCHARD_WITH_COVER	1.7	0.0	0.0
SORGHUM	0.0	0.0	0.0
Total	252.0	195.0	196.0

Jackson

Crop	2004	2005	2006
ALFALFA	39.3	12.3	7.0
GRASS_PASTURE	112.5	94.1	99.3
SPRING_WHEAT	4.0	0.0	12.3
ORCHARD_WITH_COVER	2.7	0.0	3.0
CORN_GRAIN	0.0	4.0	0.0
Total	157.0	110.0	121.0

Otero 1

Crop	2004	2005	2006
ALFALFA	164.9	67.9	88.3
GRASS_PASTURE	23.7	30.1	67.1
Total	187.0	97.0	155.0

Otero 2

Crop	2004	2005	2006
ALFALFA	194.3	79.5	103.0
ORCHARD_WITH_COVER	0.0	0.0	0.0
GRASS_PASTURE	28.5	36.4	81.0
CORN_GRAIN	10.0	10.0	10.0
SMALL_VEGETABLES	2.0	2.0	2.0
Total	234.0	127.0	196.0

Otero 3

Crop	2004	2005	2006
ALFALFA	27.3	11.1	14.4
ORCHARD_WITH_COVER	4.0	4.0	4.0
GRASS_PASTURE	28.9	36.7	82.4
BARLEY	52.0	0.0	0.0
SMALL_VEGETABLES	8.9	8.0	0.0
SORGHUM	0.0	0.0	0.0
CORN_GRAIN	441.9	787.5	642.0
Total	560.0	846.0	741.0

Braught

Crop	2004	2005	2006
ALFALFA	70.1	0.0	2.0
GRASS_PASTURE	56.7	101.5	105.7
Total	126.0	101.0	107.0

Chical 2 (EXT)

Crop	2004	2005	2006
ALFALFA	258.1	202.6	156.7
GRASS_PASTURE	88.1	52.7	39.3
BARLEY	7.1	7.1	74.9
Total	353.0	261.0	269.0

Peralta Main 1

Crop	2004	2005	2006
ALFALFA	30.6	24.3	22.2
SMALL_VEGETABLES	0.0	0.0	0.0
GRASS_PASTURE	87.9	59.0	95.9
ORCHARD_WITH_COVER	0.0	4.1	6.6
Total	117.0	87.0	123.0

Peralta Main 2

Crop	2004	2005	2006
ALFALFA	5.9	5.9	5.9
Total	5.0	5.0	5.0

Peralta Main 3

Crop	2004	2005	2006
CORN_GRAIN	125.8	150.0	227.0
BARLEY	138.1	76.4	0.0
SWEET_CORN	16.7	0.0	0.0
GRASS_PASTURE	1.0	0.0	0.0
Total	280.0	226.0	227.0

Peralta Main 4

Crop	2004	2005	2006
ALFALFA	16.4	13.3	11.7
SWEET_CORN	37.2	41.0	41.0
GRASS_PASTURE	29.0	31.0	32.8
Total	82.0	84.0	84.0

Peralta Main 5

Crop	2004	2005	2006
ALFALFA	8.3	8.3	8.3
SWEET_CORN	49.1	49.1	49.1
Total	57.0	57.0	57.0

Chical

Crop	2004	2005	2006
ALFALFA	158.1	125.9	102.0
SMALL_VEGETABLES	7.4	0.0	1.1
SORGHUM	5.2	5.2	0.0
GRASS_PASTURE	119.2	89.5	119.5
Total	289.0	219.0	221.0