South Platte Mapping and Analysis Program (SPMAP)
Decision Support Tools for the Lower South Platte

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Completion Report No. 193

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Dear Reader:

Water managers in the South Platte are facing competing water demands. These demands include sustaining irrigated food production, providing high quality water to growing populations, and establishing flow conditions in the South Platte River to protect habitats for threatened and endangered species. To address these demands, managers require the use of computer-based technology to support decision making in the hope that water demands can be met in the best possible manner. This is especially true in the lower portion of the basin (from Denver to the state border) where the South Platte is underlaid by a shallow alluvial aquifer and the highest water demand is from irrigated agriculture.

In conjunction with an advisory committee comprised of representatives of water user organizations in the Lower South Platte Basin, modeling and analysis tools have been developed by the Integrated Decision Support (IDS) Group to address the informational needs of water user groups. These tools are expressly designed for the combination of ground and surface water supplies found in the Lower South Platte Basin. Water user organizations are applying these tools in water resources planning and using them to determine augmentation requirements and recharge benefits to flows in the South Platte River. Tools include the development of a spatial database with analysis tools, a consumptive use model for the South Platte, and a stream depletion factor interface to determine the impacts of groundwater withdrawals and recharges on river flows. This report will detail the software developed and provide a description of how these tools are being used to meet the needs of water providers in the Lower South Platte Basin.

This collaborative effort of water user groups and IDS Group is an excellent example of decision support system development and utilization. IDS with continual direction and feedback from water users has developed the tools, and the water users are applying these tools for water management decision making. This decision support system is not a static snap shot or the result of "one modeling scenario" but a dynamic tool where water users can test various parameters to determine the best decisions now and in the future.

Luis A. Garcia, IDS Group

Jon Altenhofen, NCWCD

Forrest Leaf, CCWCD

Jack Odor, GASP

Jim Hall, SEO Colorado, Division 1

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II. Project Summary

This project was created to address the data and tool development needs of water user groups in the Lower South Platte River Basin from below Denver to the state border. One of the primary functions of this software is to provide the tools needed by water user organizations to estimate agricultural demands on groundwater wells that require augmentation and to assist other water management objectives. To develop a consensus on the tasks needed for this project an advisory committee was formed. The committee is comprised of representatives from the Northern Colorado Water Conservancy District (NCWCD), the South Platte Lower River Group, Inc. (SPLRG), the Colorado State Engineers Office (SEO), Groundwater Appropriators of the South Platte (GASP), the Central Colorado Water Conservancy District (CCWCD), Lower South Platte Water Conservancy District (LSPWCD), City of Greeley (Greeley), and City of Fort Collins (Fort Collins). This committee met regularly throughout the project to determine approaches and tasks needed and to evaluate the software being developed.

Funding for this project was provided by the water organizations participating in the advisory committee listed above, the Colorado Water Resources Research Institute, Colorado State University Cooperative Extension, and US Bureau of Reclamation.

As part of this project, three main components have been identified for tool and/or data development. These components are collectively called the South Platte Mapping and Analysis Program (SPMAP). The ArcView Geographic Information System component (SPGIS) contains spatial data assembled for this project and can be used to develop input files for the South Platte Consumptive Use (SPCU) Model, which in turn can be used to develop input for a Stream Depletion Factor interface (SDF View).

Data and tools developed as part of this project are in direct response to the needs expressed by water providers in the basin and are currently being used to meet the modeling and data needs of the eight water user groups. All the documentation and software is available at the Integrated Decision Support Group website, subject to the approval of the advisory board:

http://www.ids.colostate.edu/projects/spmap

III. Introduction

Although not unique in Colorado, the sophistication of the Lower South Platte water delivery system is unparalleled. Water managers in the South Platte are facing competing demands for water including sustaining irrigated food production, providing high quality water to growing populations, and establishing flow conditions in the South Platte River to benefit habitats for threatened and endangered species.

In 1973 the Colorado Supreme Court ruled, "Underground waters supplying a stream are open to appropriation like surface waters, because they belong to the river." This put into law the idea that ground and surface waters are intrinsically connected and therefore there is a need to consider them jointly in water resource management decisions.

Specifically, there is a need to upgrade current technology used to manage the conjunctive use of ground and surface water resources. Such as using surface water to recharge groundwater aquifers, and alternatively recognizing that surface water resources can be impacted by groundwater withdrawals. Conjunctive use systems are complex and require data and tools that can work with both large and small areas and over different time scales.

Decision support systems have been employed in other Colorado river basins to model water supply, and the Lower South Platte River basin has been a testing ground for decision support systems since the early eighties. Due to the complex nature of the South Platte, computer tools promise significant benefits for improving water management.

Tools such as SPWRMS (South Platte Water Rights Management System), SAMPSON (Stream Aquifer Model for Management by Simulation and Optimization), and others have been evaluated and presented in a number of CWRRI publications (Raymond et al., 1996; McCarthy and Light, 1995; Kuhnhardt and Fontane 1995; Warner et al., 1994; and Klein, 1994). In addition to these efforts, the State of Colorado has begun a feasibility study to evaluate the implementation of a decision support system for the entire South Platte River Basin (CWCB, 2000b). In anticipation of this system, water management organizations are developing tools tailored to their specific needs.

The evolution of decision support systems has resulted in data-centered approaches that utilize independent and flexible modeling components. These components should be able to interact within the framework of the decision support system or operate independently for specific modeling tasks. Data gathered for the system should be accessible to all the models and tasks. The models should utilize output from other models as needed, but not require it. This approach calls for the development of tools and databases that are tailored to the water management needs for a particular river basin.

The goal of this project was to identify gaps in water management tools currently available in the Lower South Platte River Basin and implement computer systems that could be incorporated into a future decision support framework. This effort required the ability to match data acquisition, modeling, and user interfaces to meet manager's needs. New approaches to water research are being employed and university researchers are working hand-in-hand with water managers so that the computer tools developed aid in the managers' decision processes.

1.0 Water Issues in the Lower South Platte Basin

The South Platte Basin accounts for nearly 70% of Colorado's total population containing 2.7 million people. Colorado is one of the fastest growing states in the country, 23% growth from 1990 to 1998. Some 9 ditches and tunnels transport over 400,000 acre-ft of water from the North Platte, the Colorado, and the Arkansas River Basins to the South Platte River Basin (CWCB, 2001a).

The South Platte basin in Colorado has an unconsolidated alluvial aquifer that contains about 8 million acre-ft of storage. The lower portion of the basin in Colorado uses wells to obtain irrigation water from the aquifer. Annual groundwater pumping averages 418,000 acre-ft (Hurr et al., 1975).

The primary direct surface water delivery in the South Platte and Republican River Basins is agriculture, delivering over 2.2 million acre-ft annually. An additional 630,000 acre-ft per year are delivered to meet municipal and other uses, and 1.25 million acre-ft are delivered for storage, augmentation and recharge activities. Total surface water delivery in 1998 was over 4 million acre-ft (CWCB, 2001a).

Flows in the Platte River have been fully appropriated at certain times of the year since the late 1800s. The historical use of water has been primarily for agricultural development. According to the United States census of 1910, Colorado had more land under irrigation than any other State of the Union. Currently, the irrigated acreage in the South Platte River basin totals between 1.1 and 1.4 million acres. Corn (57%), hay (26%), dry beans (7%), winter wheat (6%) and barley (3%) represent the major irrigated crops in the basin.

At least four federally listed endangered bird species may be found on the Platte at different times of the year: whooping crane, interior least tern, piping plover, and peregrine falcon. There are also several native fish species that are listed as threaten or endangered species by Colorado and one fish (pallid sturgeon) is federally listed in Nebraska. Water management on the South Platte River may affect both groups of animals.

In Kuhnhardt and Fontane, (1995) the authors point out that the South Platte River system is operating closer and closer to its absolute capacity (because of growing urban population and new mandates for instream flows). The authors believe that partial solutions may lie in better coordination of reservoir operations, further development of conjunctive use potential, and more innovative trading and cooperation between decreed water users. The focus of this project is to develop tools for conjunctive management of ground and surface water to improve tools for water resources management.

The SPMAP project provides valuable tools for water managers in the South Platte basin who protect and provide water to agricultural and municipal users. It is especially important to accurately determine the timing and amounts of groundwater withdrawals and the subsequent river depletion effects and augmentation requirements on the South Platte River. Also, the consumptive use of water rights needs to be accurately calculated for water transfers. Good data and tools also help manage recharge efforts to benefit streamflow critical for threatened and endangered species and to ensure a stable water supply for the diverse uses along the South Platte River.

2.0 Project Development

The Integrated Decision Support (IDS) Group at Colorado State University has been working with eight Lower South Platte River local and regional water management organizations on this project since 1995. This work has been financially supported by the participating organizations, the Colorado Water Resources Research Institute (CWRRI), the CSU Cooperative Extension and the US Bureau of Reclamation.

Each participating organization, in addition to providing financial support for the project, has provided regular feedback through meetings held approximately every six weeks. The result of this close partnership is the development of a set of computer tools that are collectively called the South Platte Mapping and Analysis Program (SPMAP) for the shallow riverine aquifer along the South Platte denoted by the Stream Depletion Factor (SDF) Boundary (*Figure 1*).

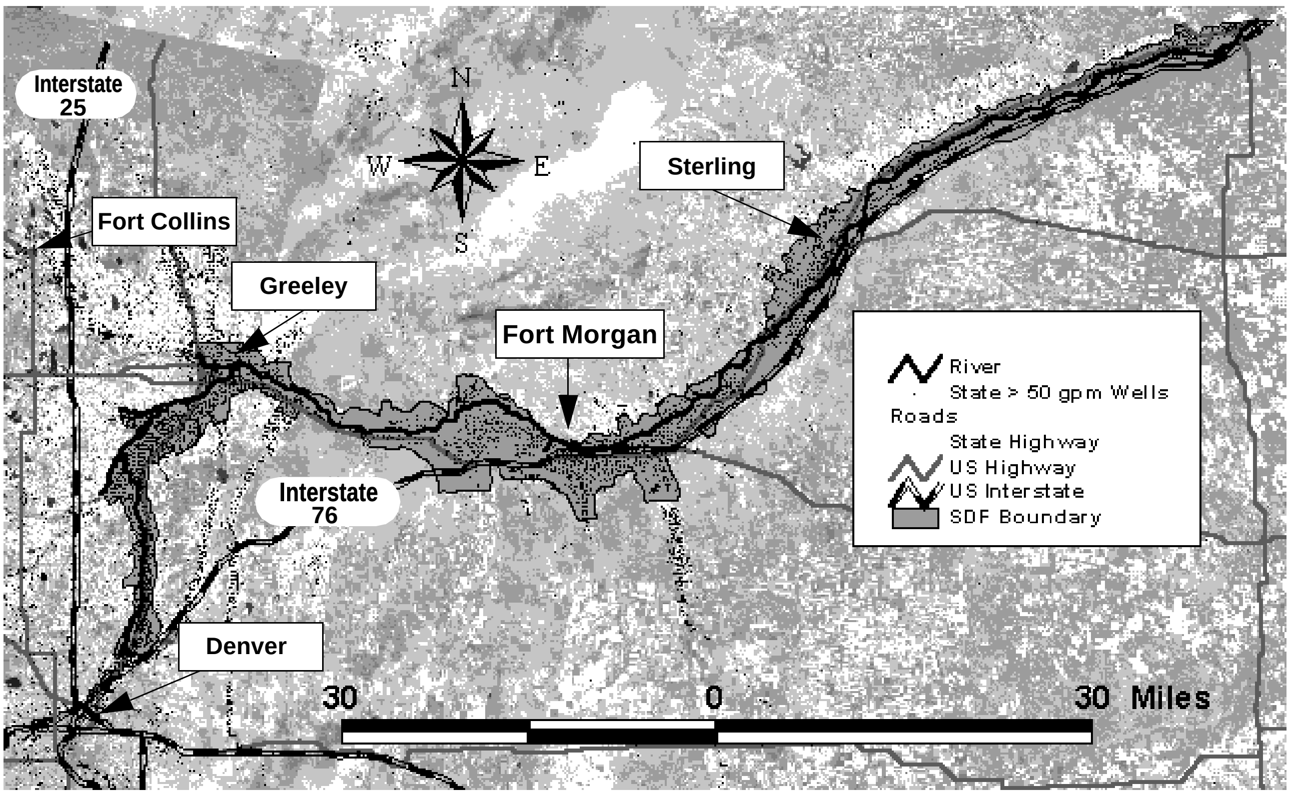

Figure 1: *Map of Lower South Platte Study Area*

The Geographic Information System South Platte GIS (SPGIS) Component is an ArcView based tool that allows the user to identify parcels of land, select wells that serve the parcels, identify the closest weather stations, and assign crop types to parcels. These data can be used to create input files for the SPCU Model (South Platte Consumptive Use Model). GIS themes for well locations, streamflow depletion factors, satellite images, USGS quad images, and basic data such as county boundaries, roads, and hydrography to assist in the mapping and analysis.

ArcView version 3.0+ was selected for the GIS platform, and an extension to ArcView using the Avenue scripting language was constructed. This system provides the analysis power of ArcView along with specially designed scripts and customized menus that allow users to view, select and analyze data.

Based on crop and weather data, managers can estimate the CU of ground and surface water in agricultural areas. Input for the SPCU Model can be developed through the GIS themes and spatial analysis features of SPGIS or can be entered directly into the SPCU Model interface. The SPCU model can compute monthly CU with the Blaney-Criddle and/or Kimberly-Penman methods or daily using the Penman-Monteith method. The output from different methods can be compared, and the Stream Depletion Factor Model (SDF View) can be run to estimate impacts on the South Platte River.

Water managers use Stream Depletion Factors (SDF) to determine the lag time between when irrigation well water is pumped from, or water is recharged to, the alluvial unconfined aquifer and when a depletion or accretion happens in the river. Based on CU of groundwater the augmentation requirements to replace water depleted from the South Platte River due to consumptive use from well pumping can be estimated. The model can also be used to estimate recharge rates for a given groundwater recharge system.

3.0 South Platte Advisory Committee

Since the focus of any tool or data development project should be to meet the needs of software users, close coordination with water providers in the basin at all stages was essential to this project's success. This close coordination was achieved by having regular meetings with the Advisory Committee (every 6 weeks) to review the development of the software and identify enhancements. The committee was comprised of representatives from:

- Northern Colorado Water Conservancy District (NCWCD)
- South Platte Lower River Group, Inc. (SPLRG)
- Central Colorado Water Conservancy District (CCWCD)
- Groundwater Appropriators of the South Platte (GASP)
- Colorado State Engineers Office (SEO), Division 1
- Lower South Platte Water Conservancy District (LSPWCD)
- City of Greeley (Greeley)
- City of Fort Collins (Fort Collins)
- Colorado Water Resources Research Institute (CWRRI)

The Advisory Committee identified the data needs and development of a spatial database and analytical tools (SPGIS), a model to calculated consumptive use (SPCU), and an interface to estimate stream depletion (SDF View) from consumptive use of groundwater as their most pressing needs for the Lower South Platte River Basin. This is partly because the out-of-priority impact of groundwater well pumping on the South Platte River flows must be augmented.

The SPMAP software is currently being used to meet the needs of organizations represented in the advisory committee and others to develop and operate augmentation plans, evaluate groundwater recharge systems.

4.0 Tool Development Philosophy - Use and Documentation

At each major stage of development the software was provided to the participating organizations via the World Wide Web along with on-line documentation available in the software and also hardcopy documentation that can be downloaded and printed from the internet.

Since water providers helped develop these tools, the tools have been put to use almost immediately. This situation has made for quick identification of bugs and needed enhancements and hence the quality and practicality of the software has been significantly improved. As part of this completion report an evaluation of the use of the software is provided in Section IV.

In addition to meeting the needs of users, the software development, data collection and tool development projects used existing models when possible. For example, the SPCU Model and SDF View make use of computational programs that were developed for other projects. IDS developed the SPCU Model as part of the Colorado River Decision Support System (CRDSS). Its capabilities were enhanced for SPMAP including the ability to handle groundwater demands. The SDF View computational program was developed by the USGS and only minor revisions to the underlying computational model were made.

To make the programs easier to use and provide new options for building input files and viewing output, Graphical User Interfaces (GUIs) were constructed in Visual C++. SPGIS was also constructed using Avenue scripts that customize analysis options and menu items in ArcView, a standard GIS package. The development and user platform is a PC running Windows 95/98/NT/2000.

Development has proceeded by using a "modular" approach, meaning tools can be used as stand-alone components or used in conjunction. New components and tools can be substituted or added to the system with minimal changes to the other components or the data storage.

User documentation for the software is available on the internet and can be accessed from Help menus in the interfaces. The combination of using developed models, building graphical interfaces, using Avenue scripts, following a modular approach and developing good documentation makes this software flexible, generalized, and easy to use.

5.0 Project History and Progress

In the 1970s and 1980s, CWRRI funded basic research to develop mathematical relationships (models) describing interactions between surface and groundwater in alluvium aquifers along the South Platte River. The result of this work was the model SAMPSON, described in Raymond et al. (1996). Data acquisition and computer technology at the time did not permit integrating the models into data acquisition systems or the convenient construction of user friendly interfaces. The ability to acquire basic resource management data via satellite combined with the exploding power of the microcomputer (both hardware and software) has provided water managers the ability to further develop decision support technology.

Since 1995, the IDS Group at CSU under the direction of Dr. Luis Garcia, a Professor in the College of Engineering, has been working with eight local and regional water management organizations along the South Platte River below Denver. The water managers and university researchers form a team that works extremely closely on all aspects of the research. Tools are being developed that can be part of a larger decision support framework or used independently. Data gathered for the project is stored in a spatial database system (SPGIS) and distributed to users via the internet and Compact Disks (CDs).

During 1995-96, project efforts focused on spatial data collection and evaluation. A GIS tool was developed as an extension to ArcView 3.0+ to provide users the capability to view and use spatial data, such as themes for irrigated lands, well locations, stream depletion factors, hydrography, weather stations, county boundaries, roads, and cities.

During 1997-98, project efforts focused on developing a Consumptive Use (SPCU) model and an interface for a Stream Depletion Factor (SDF) model. Satellite images were purchased to determine irrigated land area, field delineation, and crop type classifications. A Graphical User Interface (GUI) for the CU model was begun.

During 1998-99, efforts focused on the release of the Stream Depletion Factor (SDF) interface called SDF View and developing documentation. SDF View can be used to estimate the lag time between when irrigation well water is pumped from, or water is recharged to, an alluvial unconfined river aquifer and when a depletion or accretion happens in the river. SDF View has been used in developing managed groundwater recharge as a water supply in Colorado, Nebraska and Wyoming for a future Platte Basin Endangered Species Recovery Program.

The focus during the last year of the project (2000) was to finish the SPGIS, SDF View and SPCU Model Interfaces and provide documentation to the satisfaction of the participants. This conclusion provides a well-defined set of deliverables and brings to a closure the initial goals of the project.

One of the major tasks completed this last year was the development of the SPCU Model as a stand-alone interface. Additional methods and options have been added to the model. For example the SPCU Model can retrieve data from the statewide database being developed by the state engineer's office called HYDROBASE.

IV. Software Application and Use

This section will describe the way the participants in this project are using the data and software and the participant's contributions to its development. Participants were asked to fill out a questionnaire to determine the progression of software use and the value of this project.

1.0 Northern Colorado Water Conservancy District (NCWCD)

Northern Colorado Water Conservancy District (NCWCD) will be using the SPCU model to estimate consumptive use from groundwater sources in combination with SDF View to determine the timing and amounts of water needed to augment out-of-priority groundwater depletions.

"NCWCD will be incorporating the modules and data developed for SPMAP in its accounting for more than 20 decreed augmentation plans in the lower South Platte River."

-- Jon Altenhofen, NCWCD Supervisory Water Resource Engineer

NCWCD was instrumental in providing satellite imagery used in SPGIS and did most of the work building field boundaries theme based on satellite imagery. A single year of imagery was selected for this effort with the anticipation that subsequent years will involve updating field boundaries and crop types.

NCWCD has tested and evaluated the technical accuracy of both the SDF View and the SPCU Model, and provided weather data for the Kimberly-Penman evapotranspiration method. Weather stations maintained by NCWCD were included in the SPMAP interface. They can be selected and used to build weather data input files for the SPCU Model.

We want to acknowledge the efforts of Jon Altenhofen, who has taken the role of the unofficial chairman of the advisory committee for this project. His efforts in the support of this project have been invaluable.

2.0 Lower South Platte Water Conservancy District (LSPWCD)

As a water supplier to agricultural and municipal demands in the lower portion of the South Platte River, LSPWCD has similar interests as NCWCD and CCWCD in accurately estimating agricultural groundwater withdrawals that require augmentation. One goal of LSPWCD is to develop a comprehensive picture of Stream Depletion by combining individual farm SDF Model runs for an entire ditch system.

"Such an upgrade would involve the incorporation into one large input file for SDF View the results of individual farm analysis by the SPCU Model of groundwater CU by wells"

-- Jon Altenhofen, Coordinator for SPLRG

The combined influence of multiple point demands on the groundwater system can be evaluated using the SPMAP software.

3.0 Groundwater Appropriators of the South Platte (GASP)

GASP is a private company that augments groundwater withdrawals for agricultural and municipal water users.

"The work that you have accomplished... has been a very commendable demonstration of what research in conjunction with private and public sectors can accomplish."

-- Jack Odor, GASP Manager

In order to accurately estimate the amounts of consumptive use that need augmentation, GASP has been instrumental in locating wells in the Lower South Platte. A number of tools were incorporated into SPMAP to facilitate interviews with farmers to determine the actual location and use of groundwater wells (*Figure 2*).

The SPMAP software was used to identify and prioritize wells requiring accurate location using satellite GPS (Global Positioning Systems) equipment. Once these more accurate well locations are incorporated into SPGIS, they can be used in the SPCU model and SDF View to better estimate the amounts of groundwater depletions needing augmentation.

"... thanks for all the work you have done on the South Platte Map project. We currently have all of it installed and use all or some of it on a daily basis..."

-- Jack Odor, GASP Manager

Figure 2: *Dave King - GASP Meets with Phil Mortensen a Farmer between Fort Morgan and Brush to Determine the Location of Irrigation Wells on his Farm*

4.0 Central Colorado Water Conservancy District (CCWCD)

The CCWCD was organized in 1965 to serve the citizens of the South Platte Valley through the storage and distribution of the local water supply. CCWCD develops water, investigates water quality and augments over 1000 large capacity irrigation wells from Commerce City to Fort Morgan on the South Platte River.

"... this effort has been more productive and has provided far more benefits to water users then any previous CSU effort that Central has been involved in."

-- Forrest Leaf, CCWCD District Engineer

5.0 South Platte Lower River Group, Inc. (SPLRG)

SPLRG is a coalition of water organizations (NCWCD, LSPWCD, GASP, and the Platte River Project) and State of Colorado agencies (CDOW, CWCB, and CDWR). SPLRG's focus in the Lower South Platte River Basin in Colorado is coordinating activities to maintain adequate well augmentation, to develop Colorado's Tamarack Plan as part of a Platte Basin ESA Program, and to address Colorado species of concern issues.

The SDF View program is used to estimate accretion amounts and timing to the South Platte River resulting from managed groundwater recharge activities. Accurately knowing these amounts and the timing of when the flow increases in the South Platte River due to recharge is critical for effectively meeting Colorado's obligations with the Tamarack Plan. One of the purposes of the Tamarack Plan is to increase stream flows in the Great Bend area of Nebraska during critical periods for bird migrations. Another goal is to provide rearing habitat for threatened fish species in Colorado; again groundwater recharge plays a crucial role for maintaining habitat in these areas.

> *"The three modules developed with the IDS Group are being used by organizations involved in SPLRG and feedback is being received on potential enhancements."*
>
> ***-- Jon Altenhofen, Coordinator for SPLRG***

Since SPLRG is involved in the Three-State agreement between Colorado, Wyoming, and Nebraska, the SDF View software was made available for efforts to assist in the development of managed groundwater recharge in all three states to improve river flows for endangered species.

6.0 City of Fort Collins (Fort Collins)

Fort Collins is using the SPMAP tools to prepare for future water demands and supplies.

> *"I have had the opportunity to test the SPMAP and Consumptive Use Models being developed by the IDS group. Both models contain data and functionality that can be utilized by the Fort Collins Utilities and the Water Resources Planning Department"*
>
> ***-- Paul Weiss, Water Resources Engineer, Fort Collins Utilities***

As municipal water supply organizations in Northern Colorado prepare for future water supply demands, one of the potential sources is from irrigated agriculture. Only the consumptive use (CU) of agricultural water can be purchased for use in the cities' system. This requires the estimation of CU on a small scale for the land where the water purchase is being considered. Paul Weiss has been invaluable in testing the SPCU Model for this application.

> *"I have found the experience of working with the IDS group to be quite favorable. They have demonstrated a sincere effort in addressing and incorporating the various suggestions and recommendations I have offered. On several occasions they have taken time to demonstrate the full functionality of these tools and instruct me in their application."*
>
> ***-- Paul Weiss, Water Resources Engineer, Fort Collins Utilities***

Improving the planning and use of water resources in Northern Colorado is of interest to Fort Collins due to the interrelated use of the water supply.

> *"The extensive database and the model's inherent flexibility make it ideal for the type of decision making we are faced with."*
>
> ***-- Paul Weiss, Water Resources Engineer, Fort Collins Utilities***

7.0 City of Greeley (Greeley)

"The development of GIS data and the integration of GIS with the Stream Flow Depletion Factor Tool and the Consumptive Use Model will benefit everyone in the water resources field."

-- Tom Donkle, Water Resource Administrator, City of Greeley

Accurate GIS databases are difficult to build and can be expensive. Therefore many of the participants faced with developing their own GIS systems needed for water planning and management are participating in the SPMAP project in part to combine efforts and reduce the individual cost. This is equally true for software such as SPCU Model and SDF View.

Since Greeley shares in the same needs as Fort Collins and the other participants in the project, they have been a valuable member of this project and have been essential in testing and utilizing the spatial data and tools.

"SPMAP will serve as a model for all water resource management tools developed in the future.

-- Tom Donkle, Water Resource Administrator, City of Greeley

V. Description of Data and Software

This section of the report will describe in detail the functionality of each of the three SPMAP components and provide some guidelines on using them together. For more information the readers should refer to the user manuals for each of the components available on the internet at http://www.ids.colostate.edu/spmap.

1.0 South Platte Geographic Information System (SPGIS)

The goals of the GIS component of the South Platte project are to improve the quantity and quality of spatial data available to water managers in the Lower South Platte River Basin.

Spatial data and analysis tools have been developed to support these goals. This data is needed for accurate SPCU Model calculations and can be transferred to the SPCU model from within the ArcView interface (*Figure 3*).

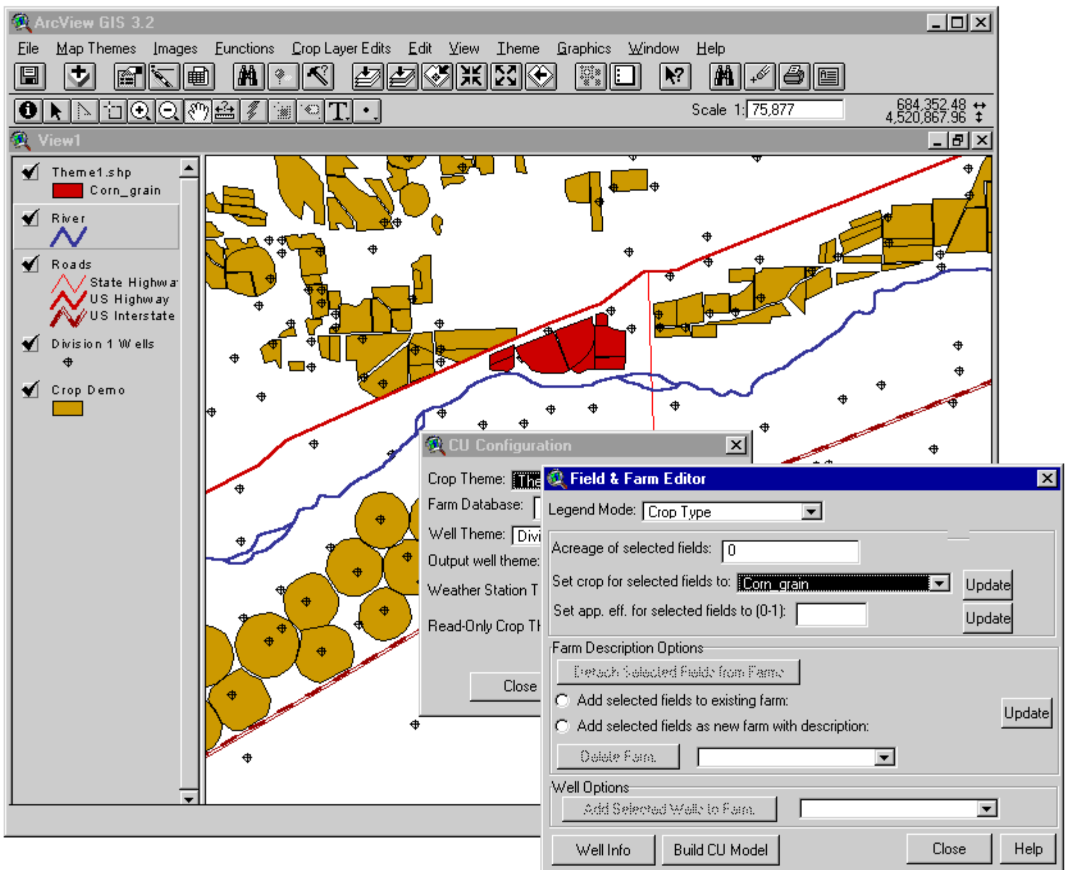

Figure 3: *SPGIS Interface with Dialog Window for the SPCU Model*

The development of GIS themes for well locations and streamflow depletion factors (SDFs) has been combined with other useful map themes to provide a comprehensive tool for mapping and analysis. ArcView version 3.0+ was selected for the platform and an extension to ArcView using the Avenue scripting language was constructed. This software is designed to run in a Windows 95/98/NT/2000 environment.

This section of the completion report will describe the SPMAP extension to ArcView (SPGIS), including creating and editing map layers, preparing a file for input into the SPCU Model, and printing maps from the system. The interface also contains on-line help that can be viewed from the interface.

1.1 Spatial Data Collected and Developed

The *ArcView GIS Users Manual* defines a map theme as a layer of geographic information for a particular attribute and location developed from various data types as described in *Table 1*. Many of the maps and/or images originally covered the entire state of Colorado, or were assembled for areas of Colorado greater than the South Platte Basin. These maps were “clipped” for Division 1 or Water District 64, using the 1:250,000 division and districts map. This table describes edits made to the maps during this project. Technical questions should be addressed to the IDS Group at Colorado State University.

Table 1: South Platte Mapping and Analysis Program Map Themes and Images

Theme Name	Description
Cities	City locations and populations for 1980, 1990, and estimated for 1991 by city. Obtained from the US Census Bureau.
Counties	United States Department of the Interior Geological Survey (USGS) digital line graphs (DLGs) data, updated and clipped for the Water Division 1.
Crop Demo	Populated using TM (thematic mapper) 25 meter multispectral satellite images combined with an Indian Remote Sensing (IRS-1C) 5 meter panchromatic (grey scale). These images were used to delineate field boundaries and crop types.
Ditches WD64 24K	Digitized from USGS quads by the Colorado Division of Wildlife, Aquatics, provided to IDS by the Northern Colorado Water Conservancy District.
Division 1 Wells	This theme contains wells identified in Division 1 by the State of Colorado. This theme was developed with help from the State Engineers Office (SEO) and is populated with legal and physical identifiers when possible.
Division 1 GPS Wells	As part of this effort, locations of wells have been updated using Global Positioning System (GPS) equipment. In some cases the locations have been changed from those in the Division 1 Wells theme.
Gages	USGS stream flow gages - from the USEPA Basins program
GASP River Reaches	Digitized and edited by the IDS group from originals, Schneider (1972).
Hydrography 100K	United States Department of the Interior Geological Survey (USGS) digital line graphs (DLGs) hydrography network data were used to populate this theme. This theme contains water features as vectors at 1:100,000 resolution. These data are grouped by their main attribute function as: rivers; streams; ditches and canals; aqueducts; wash and ephemeral drains; flumes, siphons, and penstocks; dams and weirs; tunnels; and undefined water features. The DLG characterization is obtained from the MAJOR and MINOR attribute definitions assigned by the USGS (USGS, 1983).
Irrigated Fields 1998	Created by Northern Colorado Water Conservancy District using the 5m black and white and the 164ft color images.

Table 1: South Platte Mapping and Analysis Program Map Themes and Images

Theme Name	Description
Lakes 24K	Digitized from USGS quads by the Colorado Division of Wildlife, Aquatics, provided to IDS by the Northern Colorado Water Conservancy District.
NCWCD Weather Stations	Locations of weather stations maintained by Northern Water Conservancy District, data is populated in files for use in the SPCU Model.
NWS Weather Stations	Locations of weather stations maintained by the National Weather Service, data is populated in files for use in the SPCU Model.
PLSS 24K	This theme describes the Public Land Survey System for eastern Colorado including section, township and range data obtained from USGS internet site at 30 minute resolution (1:62,000). Data was obtained in DLG format for over 200 separate tiles covering the northeastern portion of Colorado, the associated numeric codes were determined and the resulting coverages joined into seamless coverages
PLSS 100K	
PLSS 100K (no sections)	
Roads	Tiger Files - Vector information for highways and major roads.
Roads Minor	Tiger Files - Vector information for minor roads, information includes road type.
South Platte River	Digitized and edited by the IDS group from originals Hurr and Schneider (1972) provided by GASP.
State > 50 gpm Wells	Subset of the Division 1 Wells, with a capacity of greater than 50 gallons per minute.
Stream Depletion Factor (SDF)	Digitized from (Hurr and Schneider, 1972) for each reach in the South Platte River Basin. Once this coverage was digitized and edited for errors, the South Platte River was added with a SDF value of 0. ARC/INFO was used to generate a Triangular Irregular Network (TIN) line coverage using ARC/TIN. The TIN coverage was used to generate SDF isolines for every ten days. The resulting coverage was then split into small segments and converted to the GIS GRASS (Geographical Resources Analysis Support System) to generate 40 meter (0.59 acres) grid resolution raster maps. These raster maps were then joined for each Water District and exported back to ARC/INFO for display. The resulting coverages for each Water District in Water Division 1 show an SDF value for each acre in the South Platte River Basin.
SDF Boundary	
SDF 10m	
Streams 24K	Digitized from USGS quads by the Colorado Division of Wildlife, Aquatics, provided to IDS by the Northern Colorado Water Conservancy District.
Water Districts	The South Platte area is the same as the Water Division 1 area, therefore only the Water District boundaries within Division 1 are populated. United States Department of the Interior Geological Survey (USGS) digital line graphs (DLGs) data were used to populate this theme by the IDS Group at Colorado State University.
TM 30m Satellite Images	The 30 meter color imagery was obtained from a satellite placed in orbit by the United States Government. This satellite is commonly referred to as Landsat 5. The Landsat imagery is multispectral (records reflected energy in the green, blue, red, near infrared, middle infrared, far infrared and thermal bands) and has a spatial resolution of 30 meters. The imagery was processed by the Northern Colorado Water Conservancy District in 1996.
Select IRS 5m Satellite B & W Images	The 5 meter grayscale imagery was obtained from a satellite placed in orbit by the government of India. This satellite is commonly referred to a the IRS-1C. The IRS-1C imagery is panchromatic at a 5 meter pixel resolution. The IRS-1C imagery that is used for SPMAP is a mosaic of three different images. The shape of the merged imagery is an upside down “L” in which the lower leg was obtained May 5, 1996; the center was obtained on November 11, 1996; and the upper right leg was obtained on November 25, 1996. The imagery was processed by the Northern Colorado Water Conservancy District in 1996.

Table 1: South Platte Mapping and Analysis Program Map Themes and Images

Theme Name	Description
WD64 50m Color	The 50 meter color imagery was created by utilizing a cubic convolution algorithm (utilizing the 16 nearest neighbors) on the original 82 feet Landsat imagery. The Landsat imagery that is used for SPMAP is one image that was obtained September 4, 1996. Bands 4, 3, and 2 are displayed using the red, blue and green video guns resulting in a pseudo infrared color scheme. The imagery was processed by the Northern Colorado Water Conservancy District in 1996.
WD64 50m B & W	The 50 meter grayscale was created by utilizing a cubic convolution algorithm (utilizing the 16 nearest neighbors) on the original 5 meter IRS-1C imagery. The IRS-1C imagery that is used for SPMAP is a mosaic of three different images. The shape of the merged imagery is an upside down "L" in which the lower leg was obtained May 5, 1996; the center was obtained on Nov. 11, 1996; and the upper right leg was obtained on Nov. 25, 1996. The imagery was processed by the Northern Colorado Water Conservancy District in 1996.

1.2 Data Analysis Tools

Most of the data analysis tools developed to support the creation of input files for the SPCU Model are contained in the Crop Layer Edits pull-down menu. For more information on the use of these tools see the SPGIS User Manual or the online help available in the interface. Below is a short explanation of each of the tools.

1.2.1 Tools for Creating Crop Maps

These tools allow the user to convert an existing crop type map to a format compatible with the SPCU Model as well as tools for creating or modifying crop type maps. These tools include the ability to split and merge polygons that represent field boundaries and to assign crop types to the field polygons (*Figure 4*).

Crop maps can be grouped into modeling units containing individual fields with specific crop types. The consumptive use of modeling units can be computed as a farm in the SPCU Model. Modeling units are scaleable so the model can calculate the consumptive use of an entire basin or for an individual farm or field.

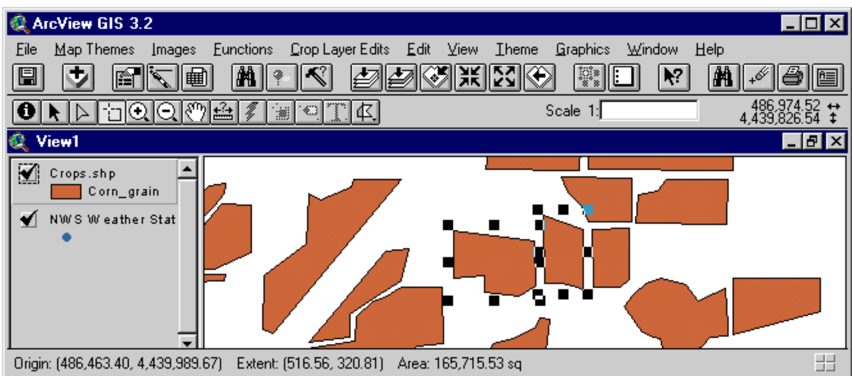

Figure 4: *Selecting Polygons to Merge*

1.2.2 Well Information

SPMAP can be used to assign wells to farms, The following data can be entered:

1. Associated Wells - These are wells that are currently associated with a farm.
2. SDF Options - There are four values that can be used for Stream Depletion Factors (SDF) for the well selected:
   - User Defined - This is an arbitrary user defined value.

- Decreed Location - This value was computed using the SDF coverage and the decreed location.
- Augmentation Plan - This is the official SDF designation from a well augmentation decree.
- GPS Location - This SDF value is computed using the well's GPS Location.

3. CU Analysis Type - The well can supply a percentage of the water requirements for a farm.

1.3 Specialized Tools

Specialized tools within ArcView are created using Avenue scripts and can be used to perform the functions that are particular to the needs of the South Platte. Most of these tools are available in the Functions pull-down menu and there is on-line and hard-copy documentation available for instructions on using the tools.

1.3.1 Well locations

The Compare Common Themes function computes the distance between wells (or any point theme) with common ID numbers. Central, GASP, and Lower South Platte wells located by GPS can be compared with the locations of the wells in the state well database using this common identification number.

Comparisons like these are used to prioritize which wells should be targeted for review of their assigned SDF values. The location of wells is important for assigning an accurate SDF value and determining problems in the well databases from different data sources. Once a well has been identified, the location can be determined accurately using a GPS unit (*Figure 5*).

Tools have also been developed to determine UTM locations given township, range, section, and footing call locations.

Figure 5: *Dave King of GASP Obtaining the GPS Location of an Irrigation Well*

1.3.2 Printing Pre-defined Layouts

The advisory committee wanted a way to print pre-defined layouts or locations selected from the interface. This includes printing views of background images and other land features for interviews with farmers to more accurately locate wells and determine crop types. Tools were developed to print a series of pre-selected areas located using the public land survey system coordinates. Once a more accurate description for a well has been established with a farmer, the location can be obtained using a GPS unit (*Figure 5*). This location can then be used to determine a more accurate SDF value.

2.0 South Platte Consumptive Use Model (SPCU)

Water managers in the South Platte River Basin need an efficient process for accurately computing field and farm Consumptive Use (CU) to determine augmentation requirements for groundwater wells or estimate the amount of water available for a different use. Based on surface water supplies and consumptive use estimates, managers can estimate the CU of ground or surface water supplies using the SPCU Model.

2.1 Background and Compatibility with Other Systems

Input for the SPCU Model can be developed through GIS themes and the spatial analysis features of SPGIS or entered directly into the interface. The SPCU Model computes CU monthly using the Blaney-Criddle or Kimberly-Penman methods for computing CU. The Kimberly-Penman method, as implemented in this model, uses monthly reference crop Evapotranspiration (ETr) estimates provided by NCWCD as part of their weather data. The Blaney-Criddle method is a monthly calculation based on temperature.

The SPCU Model can also calculate daily consumptive use using the Penman-Monteith method. The SPCU Model computes CU by applying crop coefficients that describe water use characteristics of crops during the growing season, water supplies, and weather data.

2.2 Overview of Consumptive Use Calculation

Consumptive use is primarily evapotranspiration (ET), which is water evaporated or transpired from plant foliage and adjacent soil during crop growth. The model assumes that water not consumptively used by crops returns to the river system via surface runoff or deep percolation.

Three techniques have been selected based on the data availability in the South Platte River Basin (i.e., Blaney-Criddle, Kimberly-Penman, and Penman-Monteith). The Blaney-Criddle and Kimberly-Penman methods allow monthly calculations and the Penman-Monteith method can be used on a daily time step. The computation of potential ET for the Blaney-Criddle and the Kimberly-Penman methods includes an option for calculating a soil moisture budget. The Kimberly-Penman uses monthly potential ET estimates from a file and applies crop and area information to determine CU. For both of the monthly models, surface water supplies can be specified to meet crop CU.

If there is additional CU beyond what surface water supplies can meet, wells tied to the farm are typically assumed to supply the additional CU, depending on the options selected. Weights can be assigned to weather stations, reflecting their relative influence.

CU Model input datasets can be created using the Geographical Information System (SPGIS) capabilities in SPMAP. This process includes specifying modeling area and model information using ArcView from the spatial data populated in SPGIS. SPCU Model input data includes crop types, areas occupied by individual crops, planting dates, irrigation amounts, precipitation, soil types, and temperatures. Additionally, weather and water supply data can be added from State of Colorado HYDROBASE data files that can be retrieved from the internet.

2.3 Development of Graphical User Interface for Windows 95/98/NT/2000

The original CU Model was developed for the Colorado River Decision Support System, and is the basis for the Colorado Decision Support Systems CU Model being implemented in river basins throughout the State of Colorado.

The SPCU Model contains a computational component written in FORTRAN and a Graphical User Interface (GUI), see (*Figure 6*).

The GUI was originally developed for a UNIX Platform, but for this project this GUI was reconstructed in a Windows 95/98/NT/2000 environment using C++.

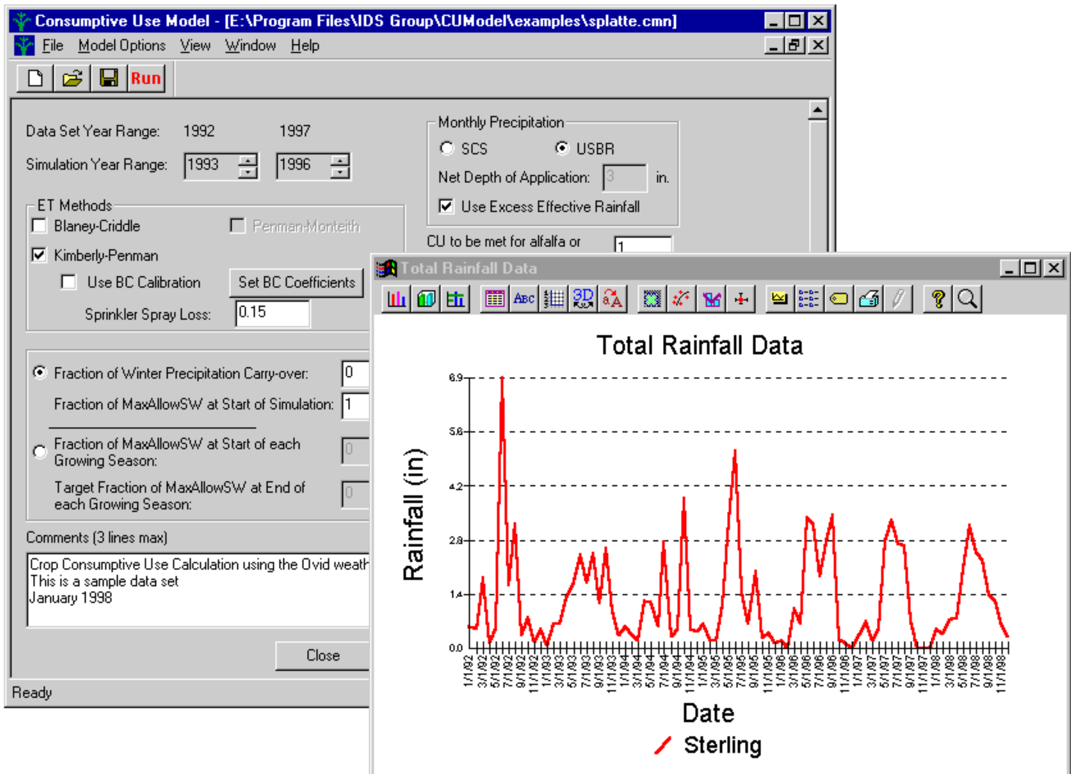

Figure 6: *SPCU Model Interface*

2.4 Functionality Developed for South Platte Modeling Needs

A number of improvements and enhancements were made to the CRDSS CU Model for the application to the lower South Platte River Basin. Along with improvements in the interface for developing input (including using the spatial abilities of SPGIS), a number of output features have been added specific to the needs of the Managers in the South Platte.

An additional method for computing Evapotranspiration (Kimberly-Penman) was added to take advantage of data available from the Northern Colorado Water Conservancy District. Improvements were made to the computational component to make it more efficient and accurate. Through user feedback, improvements at every step of the process of calculating CU have been made. For more information see the SPCU Model User Manual.

2.5 Description of SPCU Model Functionality

Several spatial and temporal scales for the SPCU Model are supported. Users are interested in calculating CU for single fields. Therefore the interface has been designed and tested with this in mind, and has yielded a very flexible tool that can meet anticipated needs of water managers in the South Platte. Below is a description of some of the features of the SPCU Model. For more detailed information see the SPCU User Manual available at the internet site.

2.5.1 Importing Input Files from SPGIS

SPGIS can be used to create input files for the SPCU Model. This is done by selecting areas for farms and fields, and assigning crop types and wells to each selected area. SDF values for each well have been assigned based on maps generated from SDF contour maps and the location of the wells. The information generated from SPGIS can then be imported into the CU Model.

2.5.2 Specifying the Modeling Area

The modeling area can be made up of multiple farms with water supply information specified. Each farm can contain multiple fields that have crop use specified. The model is scaleable, allowing the user to compute consumptive use for an entire river basin or for an individual field. Scenarios can be run to reflect expected land-use or water supply changes. The model has been used to determine consumptive use for potential climate changes on water resources in the Great Plains (Ojima et al., 1999) and projects to determine water use in one or two fields for one season.

2.5.3 Editing Weather Data

Weather data can be specified by selecting weather stations in the SPGIS interface or can be downloaded from the State's HYDROBASE. Data includes daily maximum and minimum temperatures, precipitation, and frost dates. With the link to the database, weather data can be updated with the latest information for a SPCU Model run. If more data is available for a local area or there is a need to do future projects, data can be entered manually or from spreadsheets.

2.5.4 Water Supply Options

There are three options that can be set to regulate the use of water for a CU model run.

- The CU of Alfalfa and Grass can be limited by a specified fraction.
- The amount of water specified for winter carry-over can be set to contribute to the consumptive use of crops during the growing season in the spring and therefore will offset some of the requirements of surface or groundwater supplies.
- If water supply data is specified, surface and groundwater will be used to determine how much water is available for comparison with potential ET to determine shortages and excesses. Water supply information can be specified by importing surface water diversion data from the State's HYDROBASE or ground and surface water supply data can be entered directly by the user.

The water distribution mode includes options to enter individual farm headgate flow or pro-rating a total ditch flow to a farm by applying a conveyance efficiency. Water supply options can be specialized for individual farms or fields. Efficiencies for conveyance of water to the farm can be specified and application efficiencies for fields can be specified. These options allow a sprinkler efficiency to be assigned for sprinkler irrigation systems.

2.5.5 Groundwater Supply and Well Information

There is extensive support for groundwater supply information, including tools for entering pumping records for individual groundwater wells (*Figure 7*).

Wells in the South Platte basin have a decreed SDF value that has been estimated based on the location of the well. SDF values have also been computed based on GPS locations. This information can be forwarded to SDF View to estimate the depletion impacts to the South Platte River of the well pumping. There are two calculation modes for groundwater in the SPCU Model. Not allowing shortages will assign consumptive use not met by rainfall and surface water sources to be met by wells. Allowing shortages will only use the well discharge measurement supplies and the well application efficiencies specified; unmet consumptive use is listed as a shortage.

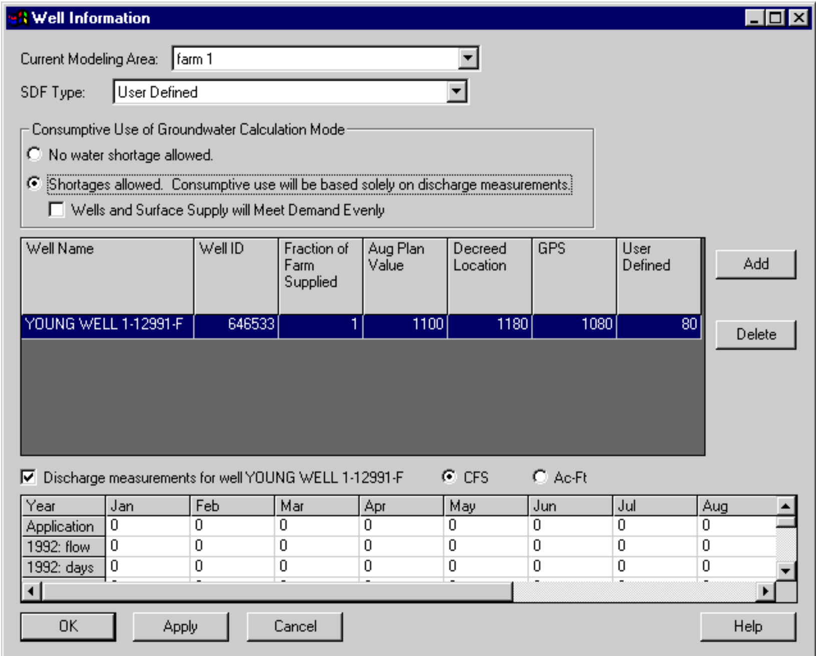

Figure 7: *SPCU Model Well Information Window*

A typical way to allocate water supply to meet demand in excess of precipitation is to assign the surface supplies first with the remaining demand being met by wells. Another option is available that applies the demand to both sources evenly, each supplying half of the demand not met by precipitation.

2.5.6 Evapotranspiration Estimation (ET) Methods

The SPCU Model allows users to select methods for estimating ET and to produce output that shows comparisons for the estimates calculated using different methods.

- **Blaney-Criddle** - This is a monthly method that was developed initially by the Natural Resources Conservation Service (formerly the Soil Conservation Service) and uses temperature, precipitation, and crop data. This method can be used with calibration factors (i.e. monthly multipliers) and a sprinkler spray loss can also be entered for sprinkler irrigation systems.
- **Kimberly-Penman** - This method calculates ET based on monthly values from reference crop ET from NCWCD weather stations. A sprinkler spray loss factor can also be used with the Kimberly-Penman method.
- **Penman-Monteith** - This method operates on a daily time step and requires detailed climate data for determining the reference crop ET. The Penman-Monteith method only computes crop ET and can not be used in the farm soil water balances with surface and groundwater supplies.

2.5.7 Monthly Precipitation Methods

Two precipitation methods can be used for effective rainfall. An option exists which can affect the soil moisture budget when rainfall is in excess of consumptive use for crops in a given month by allowing excess effective rainfall to be stored in the soil.

1. **SCS** (Soil Conservation Service) - Precipitation method, based on the SCS methodology, in which effective rainfall is dependent on the net depth of application and the average monthly consumptive use.

2. **USBR** (United States Bureau of Reclamation) - Precipitation estimation method, based on U.S. Bureau of Reclamation methodology, in which effective rainfall is linearly related to average monthly rainfall.

2.5.8 Soil and Crop Characteristics

Crop data determine the water-use characteristics of crops during plant development. These data include the earliest and latest moisture use related to frost temperature, water holding capacity, root depth, and management allowable depletion. In addition, planting and harvest dates can also be entered (*Figure 8*).

There are three options that can be used for determining the frost dates. A monthly mean temperature from the weather data to determine the frost dates. The second two methods use the published 28 or 32 degree frost dates from the weather station data selected for the area. Since alfalfa is typically harvested more than once a year, multiple dates can be specified for when these cuttings take place.

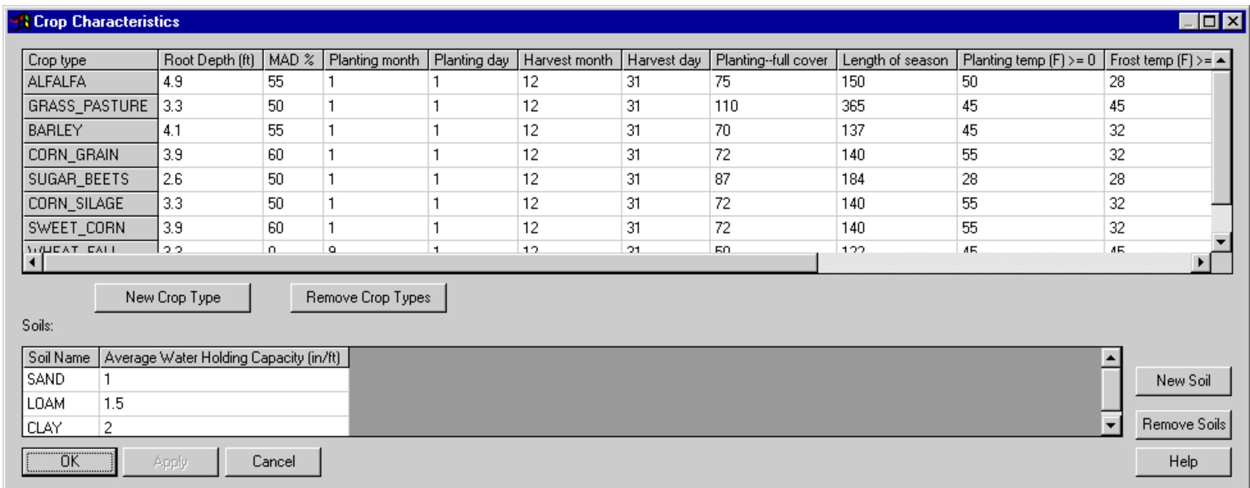

Figure 8: *Crop Characteristics Window*

There are four basic soil types (clay, silt, sand, and loam) and other soil types that are combinations of the four (such as sandy loam or sandy clay loam) can be added. The main parameter that changes with soil type is the Available Water Holding Capacity (AWC). A value for AWC can be entered for each soil type added.

Coefficients for crops determine the water-use characteristics of crops. Crop coefficients, typically referred to by the variable KC, multiplied by reference ET, define the consumptive use of a crop throughout a given number of days called the period (*Figure 9*). Different Kc values are used for the Blaney-Criddle, Kimberly-Penman, and Penman-Monteith. The planting and harvest dates for the crop define the beginning and end of the period. For the Penman-Monteith method crop coefficients can be based on Alfalfa or Grass (Pasture) reference crops.

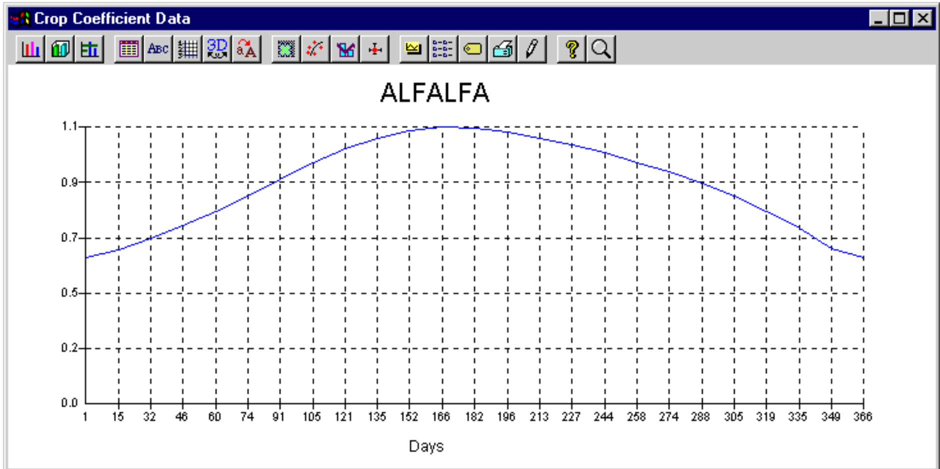

***Figure 9:** Plot of Crop Coefficients for Alfalfa for the Blaney Criddle Method*

2.5.9 CU Model Computation Options

Several properties of the SPCU Model can be specified, such as the time period for the model run, and the type of ET method(s) used.

Templates can be created to store information common for a geographical area such as crop characteristics and weather data. This allows the user to create scenarios without the need to enter common data for each set of input files.

2.5.10 Viewing SPCU Model Results

The **Results** window is displayed after the model is run (*Figure 10*).

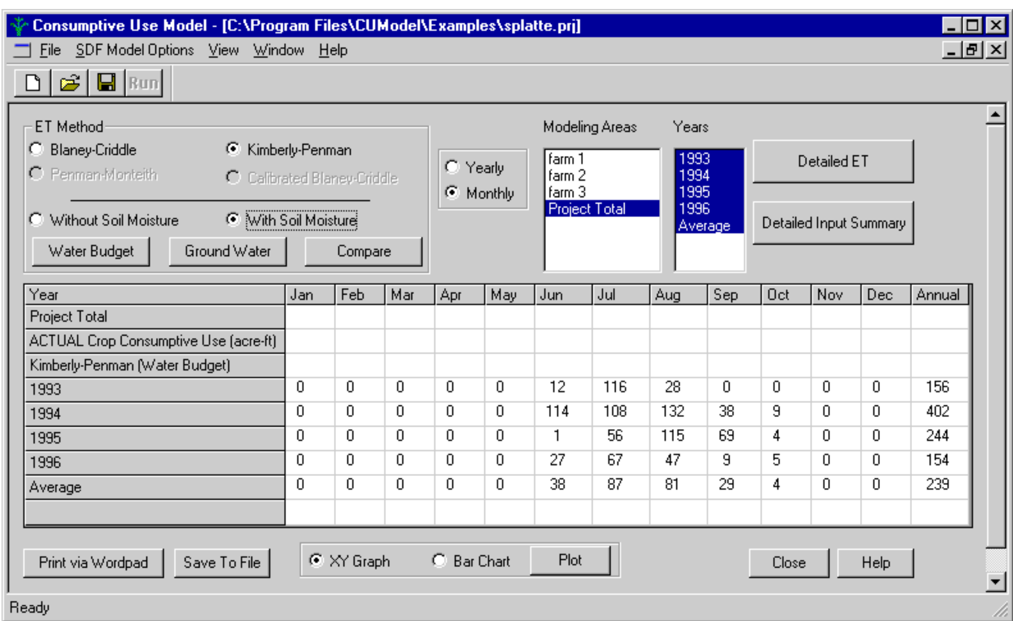

***Figure 10:** SPCU Model Results Window*

Data can be plotted and output from different evapotranspiration methods can be compared (*Figure 11*).

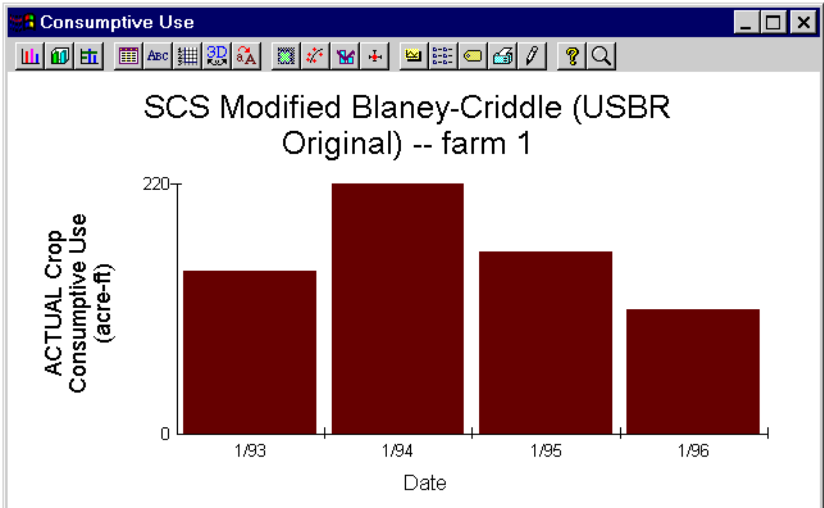

Figure 11: *Example of Output Plot*

One of the more complicated outputs is for the water budget option used with the monthly methods. The Advisory Committee desired detail results output so that a complete tally of water could be made as the output data is viewed from left to right (*Figure 12*).

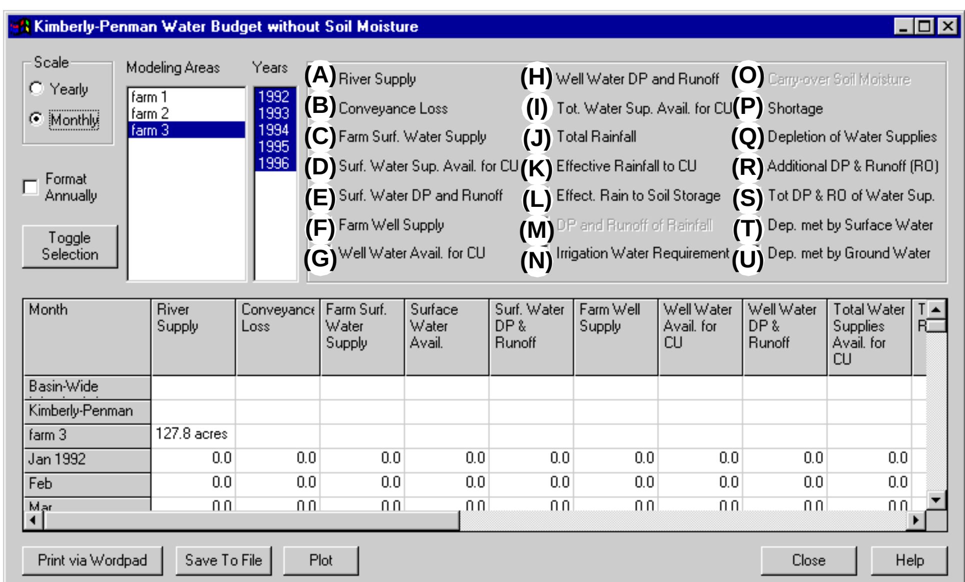

Figure 12: *Water Budget Window*

Below is a description of the water budget output from the SPCU Model by column with details about how each column is calculated as shown in *Table 2*.

Table 2: Water Budget Output from SPCU

Item	Name	Relationship	Description
A	River Supply		For a given farm (modeling area), sum of river headgate prorata diversions for the various surface water sources. River headgate prorata diversion is total river headgate diversions for a given water source multiplied by "farm share allotment divided by total shares".
B	Conveyance Loss	[(1-Con Eff.) x A]	The sum of one minus the *Conveyance Efficiency* multiplied by *River Supply (A)*.
C	Farm Surface Water Supply	[A - B]	*River Supply (A)* minus *Conveyance Loss (B)*.
D	Surface Water Supply Available for CU	[Appl Eff. x C]	*Application Efficiency* multiplied by *Farm Surface Water Supply (C)*.
E	Surface Water Deep Percolation and Runoff	[C - D]	*Farm Surface Water Supply (C)* minus *Surface Water Supply Available for CU (D)*.
F	Farm Well Supply (Sum Well Discharge)		Sum of discharge measurements in acre-ft for all wells on the selected farm (modeling area).
G	Well Water Available for CU	[App Eff x F]	*Application Efficiency* for well water multiplied by *Farm Well Supply (F)*.
H	Well Water Loss due to Deep Percolation and Runoff	[F - G]	*Farm Well Supply (F)* minus *Well Water Available for CU (G)*.
I	Total Water Supplies (Surface + Wells) Available for CU	[D + G]	If wells are used as part of the water supply, this term represents the *Surface Water Supply Available for CU (D)* plus *Well Water Available for CU (G)*. Otherwise this term is equal to *Surface Water Supply Available for CU (D)*.
J	Total Rainfall		Measured in acre-ft for total farm irrigated acres.
K	Effective Rainfall to CU		Effective rainfall is computed using the SCS or USBR method limited by CU. This value is computed by field and then summed for the farm (modeling area), depending on the selection of method made in the main window See "Monthly Precipitation Methods" on page 20..
L	Effective Rainfall to Soil Storage		Both effective rainfall methods meet the consumptive use first and put the remaining effective rainfall (i.e. *Effective Rainfall computed without CU limit* - K) into the soil profile up to the limit of the storage capacity. The available soil Storage is set by *Average Water Holding Capacity* and the *Maximum* Allowed Depletion (MAD), and then multiplied by the Root Depth for each crop and the area of the field. This option is available, only if the With Soil Moisture Budget option is selected.
M	Deep Percolation and Runoff of Rainfall	[J - (K + L)]	*Total Rainfall (J)* minus the sum of *Effective Rainfall (K)* plus the *Effective Rainfall to Soil Storage (L)*.
N	Irrigation Water Requirement (IWR)	[Gross CU - K]	Total consumptive use minus *Effective Rainfall to CU (K)* computed by field and then summed for the farm (modeling area).

Table 2: Water Budget Output from SPCU

Item	Name	Relationship	Description
O	Carry-over Soil Moisture (Calculated at the End of the Month)		The Carry-over Soil Moisture from the previous month plus the *Effective Rainfall to Soil Storage (L)* plus *Total Water Supplies for CU (I)* minus *Irrigation Water Requirement (N)*. This value is calculated based on the following conditions: • If Carry-over Soil Moisture (O) is less than zero, then the value is set to zero. • If Carry-over Soil Moisture (O) is greater than zero but less than the MAX value, then it is the normal calculation (i.e. Carry over from prev. month + L + I - N). • If Carry-over Soil Moisture (O) is greater than MAX, then the value is set to MAX.
P	Shortage	[N - I - O]	The shortage value is zero for scenarios where the groundwater is assumed to meet all remaining IWR past that met from surface supplies or soil moisture storage. If shortages are allowed, then the shortage is the *Irrigation Water Requirement (N)* minus *Total Water Supplies (I)* minus *Carry-over Soil Moisture (O).*
Q	Depletion of Water Supplies	[(O - (Carry-over from Previous Month + L)) + (N - P)]	The *Carry-over Soil Moisture (O)* minus the carry-over storage from the previous month plus the *Effective Rainfall to Soil Storage (L)* all added to *Irrigation Water Requirement (N)* minus the *Available Soil Moisture (i.e. Carry-over Soil Moisture (O) - Carry-over from Prev. Month + L)*.
R	Additional Deep Percolation and Runoff of Water Supplies	[I - Q]	This is the *Total Water Supplies Available for CU (I)* minus *Depletion of Water Supplies (Q)*.
S	Total Deep Percolation and Runoff of Water Supplies	[E + H + R]	*Surface Water Deep Percolation and Runoff (E)* plus *Well Water Deep Percolation and runoff (H)* plus *Additional Deep Percolation and Runoff of Water Supplies (R)*.
T	Depletion Met by Surface Water		Amount of surface water used to meet the IWR and to refill the soil moisture (if applicable).
U	Depletion met by Groundwater		Amount of well pumping used to meet the IWR and refill the soil moisture in the case when well pumping is specified. If well pumping is not specified then this represents the amount of water required to meet the IWR for a month after all the surface water available for CU that has been allocated and all the soil moisture used (if applicable).

2.5.11 SDF Model Export Options

There is an option in the SPCU Model to bring up the SDF View interface with input from the SPCU Model results.

2.5.12 Detailed Output Reports

The detailed reports display information specific to the type of ET Method selected and details about the input file selections. Comparison of different ET methods can also be generated. These reports can be used to transfer data to spreadsheets by cutting and pasting in the window or detailed output reports can be printed or exported to a word processor (*Figure 13*).

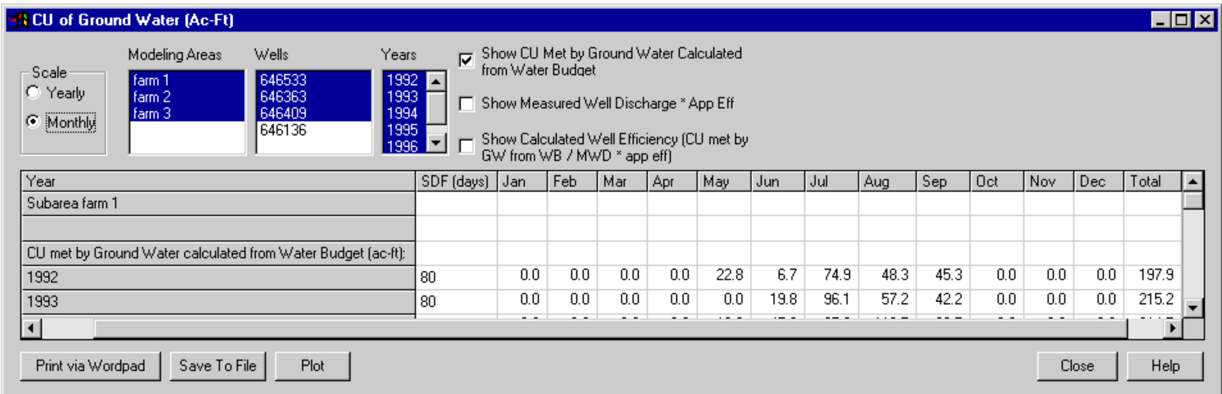

Figure 13: *CU of Groundwater Window*

3.0 Stream Depletion Factor Interface (SDF View)

Water managers use Stream Depletion Factors (SDF) to determine the lag time from when irrigation well water is pumped from, or water is recharged to, an alluvial unconfined river aquifer and when a depletion or accretion happens in the river. Required input information for SDF View is the consumptive use amount of the well water or net recharge amounts and SDF values with units of days for irrigation wells or recharge basins (*Figure 14*).

For the South Platte River Basin in Colorado SDF values are typically obtained from SDF contours maps developed by the USGS (Hurr et al., 1972). See Warner et al. 1994 for a description of the SDF methodology and its application in South Platte recharge and augmentation plans.

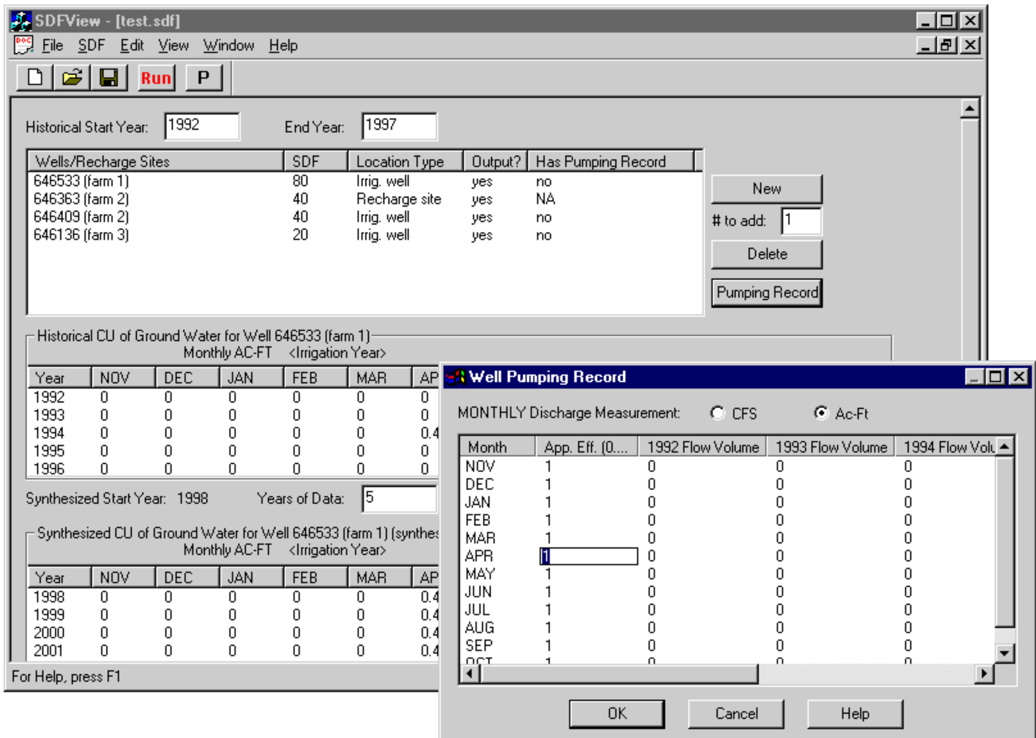

Figure 14: *SDF View Interface*

3.1 Background and Compatibility with Other Systems

The SDF View interface is based on the USGS FORTRAN program to calculate depletions to an aquifer based on groundwater withdraws. SDF View uses this computational program along with additional tools developed for managers on the South Platte River. For example a common task is to compute depletions or accretions to the river based on projected data. Projected data can be average values from historical records or repeated historical records.

Tools in SDF View allow the user to do this through menu items instead of requiring them to build an input file for the computational component. Input can also come from the SPCU Model, based on estimates of groundwater pumping withdrawn to meet crop watering needs. This interface can be used as a stand-alone model.

3.2 Development of SDF View Interface for Windows 95/98/NT/2000

The base FORTRAN model for SDF View is the USGS's SDF Model. After input file filters were built and tested for the USGS Model, a GUI was constructed using Visual C++ and tested by the advisory committee. A number of additional functions were identified to be implemented with SDF View, primarily tools to build the input files and view output.

3.3 Functionality Developed for Needs in the South Platte

As with the other tools developed as part of SPMAP, the functionality of SDF View was developed in close coordination with the South Platte Advisory Committee.

3.3.1 Building SDF Input Files

Data can be entered in irrigation, calendar, or USGS year types with monthly totals or average daily values. Most of the time data are available in monthly totals, therefore the conversion used to run the model in average daily values has two options. The default option is to use actual numbers of days in the month and taking into account leap years. You can also use a conversion rate that is the same for all months and years (30.417 days per month).

You can enter recharge or consumptive use amounts directly or you can use pumping records that will compute consumptive use amounts based on gross pumping and an application efficiency to obtain consumptive use of groundwater. Data for SDF View can be entered into a spreadsheet and then imported.

3.3.2 Projecting Data to Build an Input File

SDF View can be used to project future depletions or accretions to a river. This is done first by entering known historical data for recharge and consumptive use and then projecting into the future by repeating the record and/or averages over a selected range of historical years or a single year.

3.3.3 Running the SDF View Model

The USGS computational component is designed to run based on USGS water years (start in October and ends in September. Therefore functionality was built into the system for users to convert data sets from calendar or irrigation water years. The basic difference is the beginning and ending of month of the year system, for example the calendar year starts in January and ends in December, an irrigation water year starts in November and ends in October.

3.3.4 Output Display

Output from SDF View can be printed, exported to spreadsheets, or plotted with the interface. The type of water year can be selected for the output display of the depletion/accretion impacts at the river computed by SDF View.

4.0 Combined Use of Software

The combination of the three tools developed for SPMAP provide a comprehensive and flexible approach to meeting the modeling needs of water managers on the South Platte River. The GIS tools can be used to determine the location and size of irrigated lands, groundwater wells, weather stations and other data important for determining consumptive use for an area. This data can then be used to run the SPCU Model to estimate CU as well as groundwater withdrawals to meet crop water needs. The CU withdrawals by pumping can then be exported to SDF View which can estimate the impact groundwater pumping will have on the South Platte river. SDF View can also be used to determine the effects of groundwater recharge on the South Platte river.

VI. Conclusions

The success of this project would not have been possible without the direct feedback and support of the South Platte Advisory Committee. We extend our thanks to all members of the committee for their valuable input during this project.

This collaborative effort of water user groups and IDS is an excellent example of how a number of diverse users can contribute to the development and use of common computer tools which can benefit all. The Lower South Platte is a critical resource for agricultural production and for overall Colorado water policy. The alluvial South Platte aquifer conjunctive use systems (ground and surface water) have a history of use that is unique in the United States. This project because of its unique approach provides a set of tools that can be used for a myriad of applications required by water managers on the Lower South Platte. A new phase of the project will be started this year to further identify data and tool development needs, as well as improving the usefulness of existing tools. The tools developed as part of this project can easily be incorporated into a larger structure or additional modules/models can be incorporated into the existing structure developed for this project.

The SPMAP tools provide practical tools for water managers to meet future challenges in managing a complex system to meet increasingly complex goals. The software and documentation is provided on the internet at:

- http://www.ids.colostate.edu/projects/spmap

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http://www.ids.colostate.edu/projects/spmap

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