

# **A USER-CENTERED APPROACH TO DEVELOPING DECISION SUPPORT SYSTEMS FOR ESTIMATING PUMPING AND AUGMENTATION NEEDS IN COLORADO'S SOUTH PLATTE BASIN**

Luis A. Garcia<sup>1</sup>

## **ABSTRACT**

Throughout the United States, new models for computing augmentation requirements are being developed and applied. For the past eight years, I, along with my research team, the Integrated Decision Support Group (IDS), have had the opportunity to study the data and modeling needs of water users in the Lower South Platte River region in Colorado. With the active participation of the water users, IDS has prioritized the needs and then collected or generated the data and modeling tools necessary to meet these needs. This approach to Decision Support System (DSS) development is based on the premise that the user has a good understanding of what their current and future needs are, and with this in mind, we have developed an interactive and dynamic development process in which the users play an integral part. I refer to this approach as a "user-centered approach". With this approach, we have developed several data driven tools that are widely used in the South Platte Basin and other parts of Colorado. These tools are collectively called the "South Platte Mapping and Analysis Program" (SPMAP) ([www.ids.colostate.edu/projects/splatte](http://www.ids.colostate.edu/projects/splatte)). The project has been funded by water users, the Colorado Water Resources Research Institute, Colorado Cooperative Extension, Colorado Agricultural Experiment Station, the Division 1 Office of the Colorado State Engineer, and the United States Bureau of Reclamation.

## **INTRODUCTION**

In Colorado there is increased scrutiny of the amount of groundwater depletions caused by well pumping in alluvial aquifers. The impact of these depletions on river flows has prompted renewed interest in the methods used to calculate them.

Prolonged, severe drought and rapidly growing urban populations have exacerbated conflicts between ground and surface water users. Water managers are attempting to reconcile the desire to make use of the large amount of storage in the alluvial aquifer with the need to protect Colorado's Doctrine of Prior Appropriation and more senior surface water rights. In order to manage conjunctive use of surface and groundwater there are four components that need to be evaluated: 1) water demands, 2) water supplies, 3) depletions of groundwater, and 4) impacts to rivers due to depletions of groundwater and

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<sup>1</sup> Associate Professor of Civil Engineering at Colorado State University and Director of the Integrated Decision Support (IDS) Group. IDS Group—Civil Engineering, Colorado State University, Fort Collins, CO, 80523; Tel: 970-491-7620; E-mail: [garcia@engr.colostate.edu](mailto:garcia@engr.colostate.edu)

resulting augmentation requirements. SPMAP tools have been developed to deal with each one of these components.

### QUANTIFYING WATER DEMANDS

In many instances, groundwater in the South Platte Basin in Colorado is used as a supplemental water supply: groundwater is pumped when surface water supplies are unable to meet demand. Therefore, the first step in modeling a groundwater/surface water system is calculating the water demand for the system. In agricultural systems, the demand is normally determined using either crop evapotranspiration (ET) or an estimate derived from multiplying well pumping by a factor (normally referred to as a Presumptive Depletion Factor - PDF). In order to quantify consumptive use, the IDS Group developed a consumptive use model called IDSCU for the SPMAP project. The IDSCU Model allows users to determine crop consumptive use, irrigation water requirements, and depletions of groundwater using both ET and PDF methods. The model also allows users to compare the estimates of groundwater depletions calculated by both methods.

In the past when crop evapotranspiration was used as the method to estimate groundwater depletions these demands were computed using monthly evapotranspiration (ET) equations with the most commonly used method in Colorado being the SCS Blaney Criddle method. However, since more complete weather stations were installed around the state in the 1990's, data has become available for using daily reference crop ET methods such as the Penman-Monteith or the new ASCE standardized reference evapotranspiration equation, and these daily methods are gaining in popularity. The IDSCU model allows users to compute ET using both monthly and/or daily methods as well as compare the results obtained by using different ET methods.

The model enables water managers to estimate the consumptive use (CU) of groundwater based on surface water supplies and crop consumptive use estimates. Surface water supply information and information collected by local weather stations can be imported from the Colorado State Engineer's Office database, HydroBase, or manually entered by the user. Weather station information can also be imported from the Northern Colorado Water Conservancy District weather stations, the Colorado Agricultural Meteorological Network (Coagmet), or manually entered by the user. The IDSCU Model can compute monthly CU using the SCS Blaney Criddle, Calibrated Blaney-Criddle, Hargreaves, and Pochop methods. Daily CU estimates can be computed by the model using the Penman-Monteith, Kimberly-Penman, and the new ASCE standardized reference evapotranspiration equation. The IDSCU Model Graphical User Interface (GUI) main window is shown in Figure 1. On the lower right hand side of the main screen a number of buttons are displayed which allow the user to access pop-up screens for entering or modifying data pertaining to: crop characteristics, crop coefficients, weather data, surface water supplies, modeling area information, well information, and weather station weights.

The IDSCU Model allows users to generate data to run the model before (pre) or after (post) the historical data period. The user may select to generate pre- or post-historical data by averaging selected years, repeating a selected year, or repeating a sequence of years (Figure 2) and computing the CU for them. The model is also capable of generating input and output displays for all year types (calendar, irrigation, and water).

The model can calculate CU or Irrigation Water Requirements (IWR) with or without using soil moisture. The model does a water budget and determines the times when crops might be water short as well as the amount of CU met from both surface and groundwater. As mentioned previously, with the IDSCU Model, users are able to compute the CU for multiple ET methods (both monthly and daily – assuming the data is available for both). The GUI allows users to compare the CU computed with different methods and computes ratios between the different methods. This functionality allows users to evaluate the difference between different ET methods as well as provide some guidance for users if they are interested in calibrating a monthly method based on the differences between the monthly aggregated values of daily ET methods and computed monthly ET values.

When pumping records are available, users may enter either monthly or total annual pumping. If the user enters total annual pumping the model has the capability of distributing the pumping into monthly values for agricultural or non-agricultural wells. The model also allows the user to enter a Presumptive Depletion Factor (PDF) for each well. The PDF is a calculated factor that estimates the amount of pumping that is used to meet CU. If the user provides values for pumping and a PDF, the model can calculate the depletions of groundwater to meet crop CU as pumping multiplied by PDF. The model also calculates the amount of groundwater depletion based on ET method(s) and a water budget. The model allows users to compare the depletions of groundwater based on both methods (PDF and ET) and check if the two values of depletion of groundwater are similar.

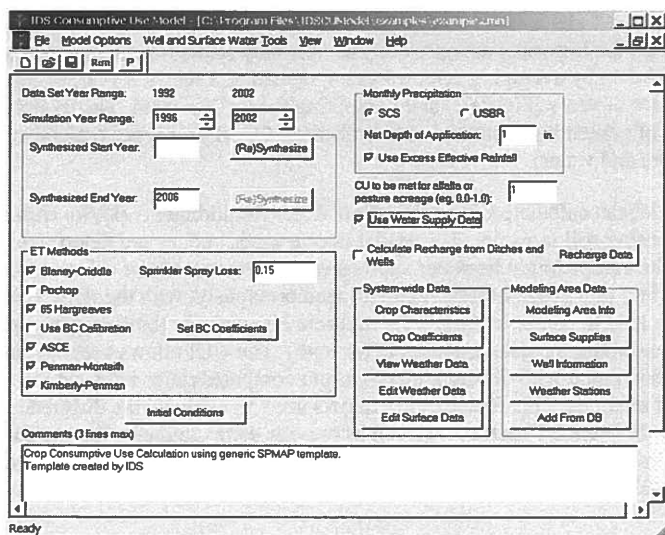


Figure 1: IDSCU Main Interface Window.

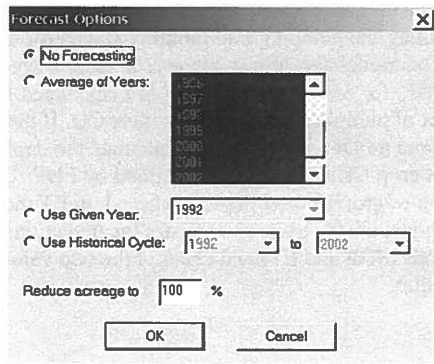


Figure 2: IDSCU Forecasting Options.

The computation of potential ET for all the methods includes an option for calculating a soil moisture budget. For 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 a modeling unit are typically assumed to supply the additional CU. Weights can be assigned to weather stations, reflecting their relative influence in computing the CU for a particular modeling area.

## QUANTIFICATION OF WATER SUPPLIES

Water supplies are normally from two sources 1) surface water supplies, and 2) groundwater pumping. The model allows users to query the State Engineers Office database (Hydrobase) in order to generate a set of diversion records for different ditches or diversion structures. Users may also build a set of diversion records for different ditches or diversion structures by entering the diversion records manually. The surface supply for each modeling area is then calculated by assigning one or more surface supply ditches or structures to it. The IDSCU Model requires users to enter the shares for each ditch or structure that are owned by each modeling area (Figure 3). The amount of shares for a particular ditch that are assigned to a modeling area can vary from year to year enabling users to evaluate the impact of leasing water in certain years. In the event that the user has headgate diversion records, these can be entered for each modeling area.

For groundwater pumping, users may enter monthly groundwater pumping, or if the user only has total annual pumping, the model has the ability to distribute annual pumping into monthly values for agricultural and non-agricultural wells.

Surface Supplies

Current Modeling Area: Farm 1

Water Distribution Mode

☒ User Supplied Flow (Headgate) ☒ Farm Allotment Varies by Year

☐ Pro-rated Flow (Flow \* (Allotment / Total) \* Conv. Eff.) ☐ Pro-rate Surface Water by Acres Irrigated

Ditch/Res Name	Ditch ID	Total	Units	Avg. Farm Allotment	Conv. Eff. (0.0-1.0)	SDF
Supplemental	---	---	---	---	---	---
DEUEL SNYDER CANAL	1	---	---	---	0.7	0
TOTAL	---	---	---	---	---	---

New Ditch

Delete Ditches

Data for ditch/reservoir DEUEL SNYDER CANAL:

Monthly Surface Water Supply Distribution (ac-ft)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Farm Allotment
1992	0	0	0	11.6	38.38	24	16.31	9.42	16.36	14.73	4.96	0	5
1993	0	0	0	0	32.63	23.45	19.39	10.85	9.17	4.76	0	0	5
1994	0	0	0	9.82	29.9	41.31	10.12	8.98	16.96	4.36	0	0	5

OK Apply Cancel Help

Figure 3: IDSCU GUI for Surface Supply Options

## QUANTIFICATION OF DEPLETION OF GROUNDWATER

After obtaining an estimate of the water demand and supply, the IDSCU model can compute depletions of both surface and groundwater (Figure 4). Users may evaluate the impacts of the groundwater depletions by examining whether the groundwater is a primary or supplemental source of water and by examining well efficiency using a "Presumptive Depletion Factor" (PDF). The model also can compute groundwater depletions based on a water budget as shown in Figure 5.



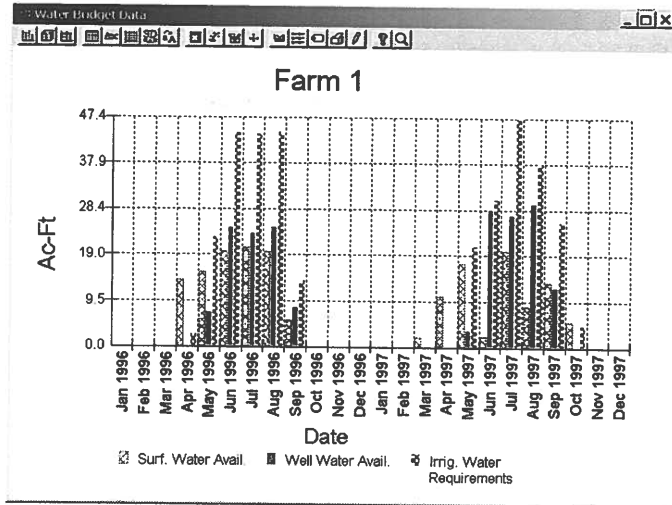


Figure 6: IDSCU GUI Water Budget Sample Plot.

### QUANTIFICATION OF AUGMENTATION REQUIREMENTS

Colorado water managers need to determine the lag time from when a well is pumped or water is recharged to a recharge site and when a depletion or accretion happens in the river. Historically the Stream Depletion Factor (SDF) (Jenkins, 1968) methodology has been used in Colorado to determine the impact of the depletions of groundwater on a particular stream, and the IDS Group has developed the SDF View model to calculate monthly depletions or accretions (in the case of recharge sites) using the SDF methodology. However, the SDF methodology is an analytical technique based on several boundary assumptions. Although analytical techniques are convenient and, if properly calibrated, very valuable tools, they are not able to handle the heterogeneity of an aquifer. Models were needed to support the use of other analytical techniques that have different boundary conditions (no flow boundaries, alluvial aquifers, etc.).

In order to meet additional needs expressed by water users, a new model based on the State Engineer's Office system was implemented by the IDS Group in the past year. This model is called the IDS Alluvial Water Accounting System (IDS AWAS). This new model has the capability of modeling different time steps (daily, monthly, and annually) and allows users to evaluate different types of boundary conditions. Figure 8 shows the IDS AWAS input screen. Figure 9 and 10 shows IDS AWAS output, in tabular and plot forms.

The IDS Group's work in the South Platte is one framework for the development and implementation of decision support tools to assist water managers. There continue to be opportunities for updating the current methodology used for calculating augmentation requirements. Fertile areas for ongoing research include developing, maintaining, updating, and deploying DSS.

AWAS - Alluvial Water Accounting System - [D:\Documents\presentations\USC1D\_splnatp\_04\exam...]

File View Help

Run

Daily & Monthly Input | Daily Output

Starting Year: 1996 Ending Year: 2002 Time: Months Year Type: Calendar

Well Name	Description	Type	Boundary Condition	W (Feet)	B (Feet)	Tra
Well 1	Imported from IDSCU	Irrigation	Effective SDF	0	0	0

New Well Delete Wells

Pumping Record Calculation Data

☒ Consumptive Use ☐ App Eff

Consumptive Use for Well 1 (acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	0	0	0	0	7.1	24.8	23.5	24.8	8.2	0	0	0
1997	0	0	0	0	3.6	28.5	27.4	29.8	12.4	0	0	0
1998	0	0	0	0.2	15	22.9	32.6	28.6	16.5	1.5	0	0
1999	0	0	0	0	9.2	24.3	35.7	35.3	6.8	0	0	0
2000	0	0	0	5.4	10.1	26	49.5	42.9	15	0	0	0
2001	n	n	n	5.2	9.8	17.2	41.5	30.2	27.6	n	n	n

For Help, press F1

Figure 8: IDS AWAS GUI Input Screen.

AWAS - Alluvial Water Accounting System - [D:\Documents\presentations\USC1D\_splnatp\_04\exam...]

File Functions View Window Help

Run

Daily & Monthly Input | Daily Output

Scale: Output For Well/Recharge Stats: Years

☒ Monthly ☐ Daily ☐ Year

Recharge Summary  
CU of Ground Water Summary  
Net Impact on Stream

☒ Calendar ☐ Irrigation ☐ USGS

1996 1997 1998 1999 2000 2001 2002

☒ Show CU of Ground Waters/Net Recharge Data  
☒ Show Depletion/Accretion Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
CU of Ground Water for Well 1 (ac-ft)									
1996	0	0	0	0	-7.1	-24.8	-23.5	-24.8	-8.2
1997	0	0	0	0	-3.6	-28.5	-27.4	-29.8	-12
1998	0	0	0	-0.2	-15	-22.9	-32.6	-28.6	-16
Depletion for Well 1 (ac-ft)									
1996	0	0	0	0	-0.487	-3.007	-7.555	-10.139	-10
1997	-3.015	-2.186	-2.003	-1.631	-1.691	-3.774	-9.235	-12.434	-13

For Help, press F1

Figure 9: IDS AWAS GUI Output Screen.



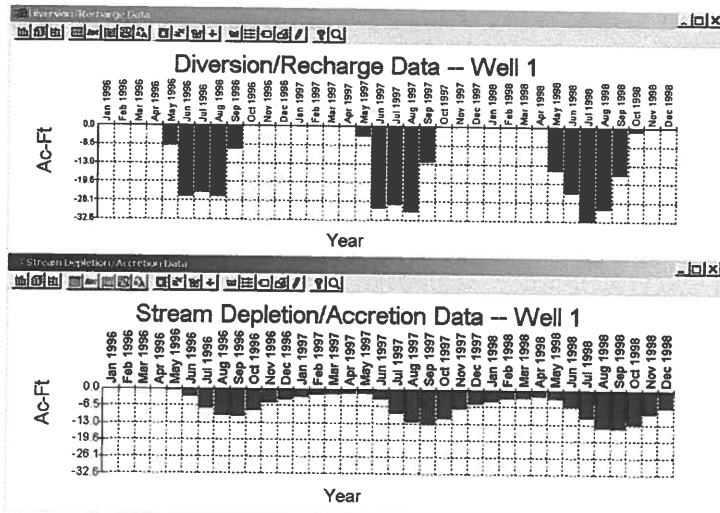


Figure 10: IDS AWAS Output Sample Plot.

### SOFTWARE DEVELOPMENT APPROACH

Building on good communication with water users, the IDS Group adopts a user-centered approach to Decision Support System (DSS) development. Using this approach, we have developed several data driven tools that are widely used in the South Platte and other parts of Colorado. These tools are collectively called the "South Platte Mapping and Analysis Program" (SPMAP) ([www.ids.colostate.edu/projects/splatte](http://www.ids.colostate.edu/projects/splatte)).

The SPMAP tools include a GIS tool, a tool for calculating CU, and a tool for calculating depletions to an aquifer. 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 IDSCU Model to estimate CU as well as groundwater withdrawals to meet crop water needs. The CU withdrawals by pumping can then be exported to IDS AWAS, which can estimate the impact groundwater pumping will have on the river. SDF View or IDS AWAS can also be used to determine the effects of groundwater recharge on the river. They provide a comprehensive and flexible approach to meeting the modeling needs of water managers on the South Platte River.

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

To make the programs easier to use and provide new options for building input files and viewing output, Graphical User Interfaces (GUIs) are constructed in Visual C. 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 tandem. 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 model 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.