EVALUATION OF SAMSON FOR USE IN A SOUTH PLATTE DECISION SUPPORT SYSTEM

by

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In a South Platte Decision Support System

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Abstract

The South Platte River basin is a tributary of the Missouri River. Three States share the basin (Colorado, Nebraska and Wyoming), with most of the basin in Colorado (79 percent). Colorado's population has been growing rapidly, especially in Front-Range cities, increasing the demand on water resources in the basin. Highly productive plains agriculture is also a substantial user of water resources and new uses also can be expected for wildlife and recreation. A decision support system (DSS) is being planned by the State of Colorado for water management in South Platte River Basin. Anticipated needs of the system include data development and some model development specific to the South Platte. Due to the unique characteristics of the South Platte River Basin, the implementation of this framework is expected to be slightly different from other basins in Colorado. The SAMSON (Stream-Aquifer Model for Management by SimulatiON) Model, developed in the 1980s specifically for the South Platte River Basin, has been recommended by past studies for use in a South Platte DSS. This report provides an analysis of the current SAMSON model. The conclusions of this report recommend that SAMSON in its present form not be used as part of a DSS, largely due to recent developments in modeling philosophy, application, and use. SAMSON proved the entire South Platte River Basin system could be effectively modeled, and pointed to the priorities for data collection and development. Components of SAMSON could be part of future DSS systems, but they should be separated into individual modules and evaluated individually against existing models. In summary, the analysis of SAMSON clearly shows the need for a modular and data-centered approach for a South Platte DSS.

Preface

As Colorado increases the sophistication of its water management system via Decision Support Systems (DSS), past water models must be evaluated to determine their potential contributions to future DSS development efforts. Evaluating water management models evokes many opinions. The SAMSON Model, developed in the early 1980s, is no exception. To ensure a thorough and balanced evaluation, CWRRI asked a group of faculty and South Platte water managers to prepare an assessment of SAMSON, given today's technology and needs. The following letter summarizes the group's findings while the full report contains details of the evaluation.

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Section 1: Introduction

The South Platte River basin, with a drainage area of about 62,400 km^2 (24,300 mi^2) is one of the main tributaries of the Missouri River, Figure 1[1]. The South Platte basin is divided into two regions: the Rocky Mountains and the Great Plains. The western portion of the basin comprises the eastern slope of the Rockies. The eastern portion, on the plains, consists of rolling hills and valleys. Three States share the Basin: Colorado (79 percent), Nebraska (15 percent), and Wyoming (6 percent).

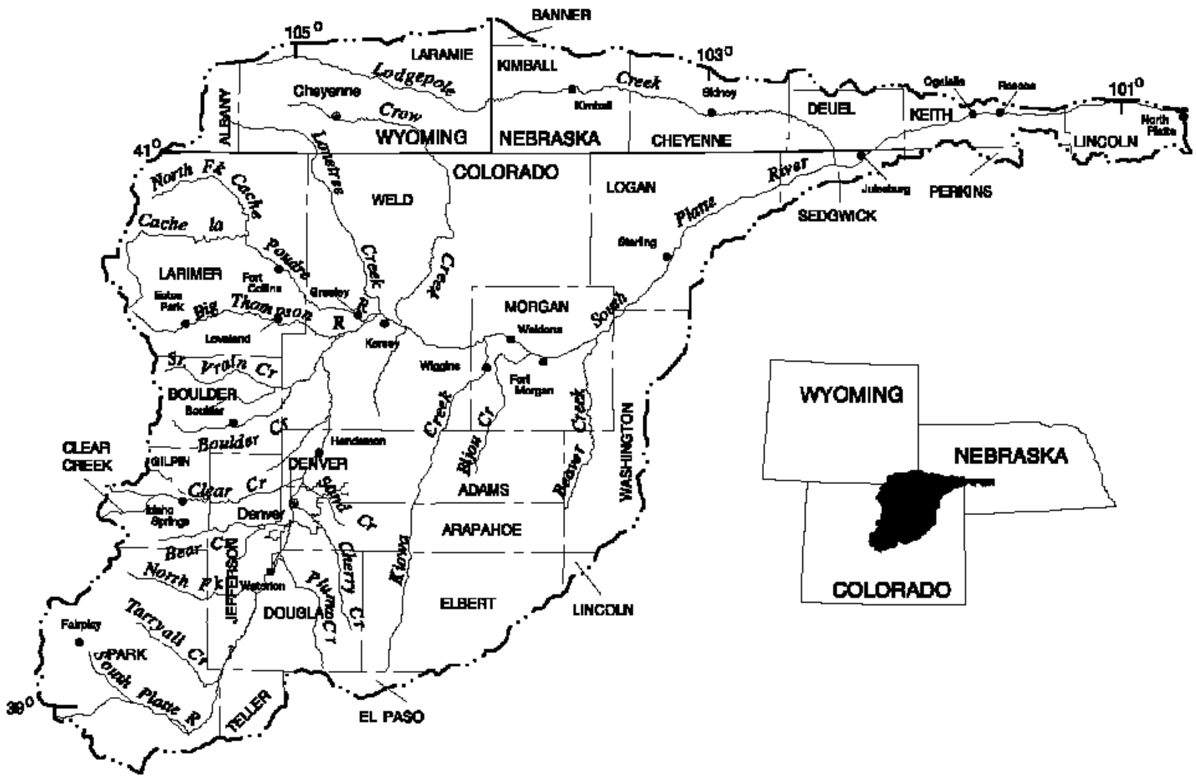

Figure 1. Location of the study unit and selected cities and streams in the South Platte River Basin.

Most of the South Platte River Basin is in the State of Colorado. Since the 1990 census, Colorado has grown at an average of almost 2.5 percent annually. The 1992-1993 growth rate of 2.9 percent was the third highest in the nation (Colorado, 1996). Agriculture accounts for about 37 percent of the land use in the South Platte River Basin, with about 1.4 million acres of land irrigated by the South Platte in Colorado.

According to the USGS, the estimated total off-stream water diverted from the South Platte River Basin in 1990 was 3,900 Mgal/d (12,000 acre-feet per day or 4.4 million acre-feet per year). Of this amount, 71 percent is surface water and 29 percent is groundwater. The principal uses were irrigation (70.8 percent), power generation (14.6 percent), and domestic use (8.4 percent). Large

[1] source URL = http://srv2dcolka.cr.usgs.gov/nawqa/splt/factsheets/FSLITKE.htm

instream uses of water include hydroelectric use and reservoir evaporation. About 40 percent of the domestic use is for lawn watering. The remaining water-use categories (commercial, industrial, livestock, mining and other) account for only 6.2 percent of total off-stream water use (USGS, 1993).

The major users of the river system are Front Range cities and the highly productive plains agriculture, and both groups are very diligent in obtaining water from the Platte River System. A framework for modeling and decision support for the overall water use in South Platter River Basin could help to identify existing and potential problems and solutions for coordinating and managing the water use in the basin both for municipal and agricultural uses.

1.0 South Platte Model Evaluation Project

Determining the current uses of water resources and anticipating future management alternatives requires data collection (physical, temporal, and spatial) and modeling systems that are data driven and fully interactive. With so many stakeholder groups working with water resources in the basin, general tools should be developed with common databases so that individual groups can analyzed management alternatives.

To bring together data collection efforts and explore common modeling approaches, the Integrated Decision Support (IDS) Group has been working with the Colorado Water Resources Research Institute on a project called "South Platte Model Evaluation Project." An advisory committee was formed with the following representatives:

Jon Altenhofen - Northern Colorado Water Conservancy District
Ray Bennett - State Engineers Office (Denver)
James Hall - State Engineers Office (Greeley)
Forrest Leaf - Central Colorado Water Conservancy District
Jack Odor - Groundwater Appropriators of the South Platte

This committee met regularly (about every 6 weeks beginning in early 1996) and evaluated the available data, data needs of the users, and modeling strategies. The group has used the work done by Darrell Fontane, Henry Kunhardt, and Robert Leaf (Kunhardt and Fontane, 1995 and Fontane et al., 1994). Based on the information provided by the advisory group members, a small groundwater data development effort was started. This effort involved the development of GIS databases for well location and streamflow depletion factors (SDFs). The committee emphasized that understanding the groundwater resources through better data and models was a priority for maximizing future conjunctive use opportunities.

As part of this effort, IDS has evaluated SAMSON (Stream-Aquifer Model for Management by SimulatiON) model. The committee wanted to determine the needs of state, local, and private agencies who would be using water management models, and evaluate what role the SAMSON model could play in meeting those needs.

2.0 Relation to Current And Earlier Work in the South Platte

Kunhardt and Fontane (1995), in a Colorado Water Resources Research Institute publication titled "Initiating a water management DSS for the South Platte Basin" (Water in the Balance No. 2), noted that as the South Platte River system operates closer and closer to its absolute capacity (exploding urban population, new mandates for instream flows), 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 authors pointed out some technical and institutional issues for the development of a Decision Support System for the South Platte River Basin. The technical issues are: final development and calibration of a basin-wide, surface/groundwater model, development and calibration of an appropriate water quality model, and most importantly, development and verification of the database to support the models. The institutional issues are: the South Platte Basin, although smaller in area than the Colorado River Basin, will be more complex to model because of groundwater use and the fact that demands typically exceed supplies; the development of a DSS should occur incrementally with close communication among model developers, water users and government administrators.

The South Platte Water Rights Management System (SPWRMS) developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES), under contract with the Colorado Office of the State Engineer (SEO), is a real-time water rights management system for the South Platte that can be remotely accessed from PCs. This system uses the Informix database located in Denver and allows users to query and update information. This database is updated from satellite information gathered from stream gages and existing water rights (CADSWES, 1994). The South Platte Water Rights Management System receives input from PCs in the field, workstation users, and a satellite network. The users have immediate access through computers via modems, which allows them to connect to the SPWRMS server by telephone from anywhere within the South Platte River basin. Data indicating the physical state of the river resides in a central database with legal and administrative information. SPWRMS provides tools for viewing this data and testing hypothetical scenarios. The SPWRMS focuses on improving daily river management by enhancing information exchange. The SPWRMS assist water commissioners and other water administrators by making information more readily available. The database contains administrative information, such as the State water rights tabulation for Division 1, as well as real-time river flows for numerous gaging stations on the South Platte and its tributaries. SPWRMS users have access to current diversions, flows, and river calls, as well as historical information. SPWRMS keeps track of river calls. Use of hydrographs allows water administrators and decision-makers to see when more water becomes available to users.

The Northern PTFLOW (PoinT FLOW) analysis is an accounting software that is used to determine reach gains and losses between gaging points on a daily basis. Although not a predictive physically based model, this software can be used in the evaluation of well depletions to the river and aquifer recharge operations, and assists water administrators and water resource planners in locating points of minimum flow which will in turn help identify potential exchanges and potential new diversions. The PTFLOW uses data from the South Platte Water Rights Management System (SPWRMS) providing real time and historic point flow computations.

Maurice Hall has completed his dissertation in the Department of Earth Resources at Colorado State University, titled "Simulation of Nitrates in a Regional Subsurface System: Linking Surface Management with Groundwater Quality." He used a study area near Greeley in the South Platte. His work, based on a set of pre-existing models, will provide some important ideas related to the problems with nitrate contamination in the groundwater.

The State of Colorado (CWCB, 1995), has a plan and schedule to develop a statewide "Colorado Water Decision Support System." The development of this system is estimated to cost 5 million dollars and will take approximately 8 years to complete. This project would be an extension to the Colorado River Decision Support System (CRDSS) project. Because of the geology of the western slope, data and models for groundwater were not required for the Colorado River Basin. Therefore, to extend CRDSS to Divisions 1, 2, and 3 data and models for groundwater may be needed to realize a "Colorado Water Decision support system" or CWDSS. Both Luis Garcia and Darrell Fontane participated in the CRDSS project for the Western Slope.

John Eckardt's dissertation published at Colorado State University in 1991, titled "Real Time Reservoir Operation Decision Support under the Appropriation Doctrine," focused on identifying and resolving the problems of operating a reservoir system in real-time under the prior appropriation doctrine of water rights. Eckhardt noted that operators suffer more from information overload than lack of information, and showed how a systems approach can help them sort out their options. Based on the latest DSS technology, a framework for real-time reservoir operations decision support was then developed to implement the procedure.

Jeffrey Fredericks (1993), in his dissertation presented at Colorado State University titled "Decision Support System for Conjunctive Stream-Aquifer Management under prior appropriation," prepared a micro-computer based DSS for conjunctive stream-aquifer management under prior appropriation. Almost like Eckhardt, Fredericks accomplished his work through a synthesis of existing technology rather than development of new models. The computer-aided design and drafting package, AUTOCAD, and a raster GIS package for PC's called IDRISI, were used for preparing and processing grid-based spatial data. To demonstrate the capabilities of the conjunctive stream aquifer management Decision Support System (DSS), a case study was carried out on a portion of the lower South Platte River Basin in Colorado. Fredericks's framework could conceivably be expanded to include the entire basin, but it is clear that the entire basin is considerably more complex than the test case.

3.0 Scope of this Project

The Colorado Water Resources Research Institute (CWRRI) funded for FY96 a small project to evaluate the status of SAMSON and determine if it could be used as part of a Decision Support System for the South Platte River Basin. The focus was on evaluating the SAMSON model (**S**tream-**A**quifer **M**odel for Management by **S**imulati**ON**) in the context of a Decision Support System. The specific objectives of the Project were to:

1. Understand the SAMSON model as it actually operates.
2. Identify the physical constraints that limit the use and calibration of the model.
3. Evaluate data requirements and data availability for the model.
4. Identify the issues related to the use of the model by water management groups.
5. Evaluate the role if any that the model could play in a DSS.

Four project phases were identified to produce an evaluation:

Phase 1: Understanding the issues and a review of relevant literature

During Phase 1 an understanding of the water management issues (water rights, institutional, compact, water quality, endangered species etc.), as well as a review of relevant literature have been completed.

Phase 2: Understanding the SAMSON model

The understanding of the SAMSON model was completed in Phase 2 of the project by running the model and identifying: (i) the physical constraints and strengths, (ii) the data requirements, (iii) the data availability for the model, and (iv) the limitations of the model.

Phase 3: Understanding the specific needs for the South Platte River

To understand the specific needs for the South Platte River, an "Advisory Committee" was appointed during the project.

Phase 4: Evaluation

Due to some major constraints in terms of data availability (as identified in Phase 2 of the Project), testing of the data present in the sample database was performed. The present evaluation determines if the SAMSON model could be used in a future Decision Support System.

4.0 Acknowledgments

This work was funded through a grant from the Colorado Water Resources Research Institute (CWRRI). Acknowledgment goes to the "Advisory Committee" composed of five members including Jon Altenhofen, Ray Bennett, James Hall, Forrest Leaf, and Jack Odor for their valuable insight and contributions to this project.

Section 2: History of SAMSON

The SAMSON (Stream Aquifer Model for Management by SimulatiON) model was developed in the 1980s, over a 15-year period, primarily by Jorge Restrepo and Hubert Morel- Seytoux. Originally developed on a Cyber 205 (CDC-205) in Fortran (Morel Seytoux, 1987), the model was ported to a PC in 1991 (Quick Basic).

SAMSON was evaluated in the late 1980s by a "Technical Support Subcommittee" (TSS), part of the South Platte Basin Water Management Committee (SPBWMC) involved in the South Platte Basin Study. The study was sponsored by the following entities: Central Colorado Water Conservancy District (CCWCD), Lower South Platte Water Conservancy District (LSPWCD), St. Vrain and Left Hand Water Conservancy District (SV&LHWCD), and Northern Colorado Water Conservancy District (NCWCD). Other entities also contributed to the TSS: Groundwater Appropriators of the South Platte (GASP), the South Platte Basin Coalition, Denver Water Board, Colorado Division of Water Resources, Colorado Water Resources and Power Development Authority, U.S. Geological Survey, and the Bureau of Reclamation.

Some of the activities performed during the September 1988-November 1989 period of the study included: (i) interviews with individuals associated with irrigation entities, and (ii) identification and evaluation of computer models that could be applied to the South Platte River, downstream of Denver.

In December, 1987, members of the Technical Support Subcommittee (TSS) [including appointments from each of the following: USGS(1), LWPWCD(1), CCWCD(1), NCWCD(2), USBR(1), GASP(1)] began a review of available computer models that could be adapted to meet the needs of the South Platte Basin Study. The seven models considered for use in the South Platte Basin Study were: (i) South Platte Water Management Model developed by the USGS, (ii) SAMSON Model developed by the CWRRI, (iii) DRAM or Dynamic Resource Allocation Model developed by Cheryl Signs Engineering, (iv) RIBSIM or River Basin Simulation Model developed by Leonard Rice Consulting Water Engineers, Inc., (v) CRAM or Central Resource Allocation Model developed by WBLA, Inc., (vi) BESTSM or Boyle Engineering's Streamflow Simulation Model developed by Boyle Engineering Corporation, and (vii) WRAM or Water Rights Allocation Model and DYNFLOW developed by Camp Dresser & Mckee, Inc. Nine months later (August 9, 1988), the TSS recommended that the SAMSON Model be selected for use in the study.

On September 13, 1988, the Executive Committee approved the recommendation of the TSS regarding the selection of the SAMSON model and concluded: (i) that extensive work was needed before the SAMSON model can be used in the South Platte Basin Study, (ii) that verification of the data currently contained in the model's database is required, and (iii) that some efforts relating to the calibration and the validation of the model must be completed. The last two efforts regarding data checking and model calibration were never done or completed as stated on February 1, 1995 in a memo from the Northern Colorado Water Conservancy District.

On June 7, 1989, a contract was signed with Mr. Robert Main (a retiree from the USBR) for accomplishing the computer programming and related work necessary to adapt SAMSON to the needs of the study. The work included the following tasks: (i) review the model’s program and document the program’s structure; (ii) modify the model’s code to allow faster and more efficient execution; (iii) incorporate modifications to allow input and output data to be entered and displayed in english rather than metric units; and (iv) develop a user-friendly, menu-driven IBM-PC compatible graphics package that will allow the display of input and output data. Mr. Main's work was completed and transmitted to the NCWCD in October 1991. The documents included some changes to the SAMSON model, the state of the SAMSON modeling system, description of the SAMSON model test problem, and user’s manuals for an EXTRACT program written in FORTRAN (which allows the user to extract from the large binary file produced during a SAMSON model run some data of interest) and a GPPP program written in Quick Basic v.4.5 (which allows to plotting output from the SAMSON model via the EXTRACT program). The new version of the SAMSON model, as revised by Mr. Main, was the one used for evaluation in this project.

Section 3: Evaluation of SAMSON

The SAMSON model was developed as a tool to respond to the complexity of the interactions between different components of the South Platte system (e.g., water rights, irrigation, pumping, diversions, water reuse). It was supposed to provide daily management information as well as guidance for long-term strategic planning on how to develop conjunctive use to the fullest extent and how to recharge the aquifer.

The objective of the model, as stated by Morel-Seytoux and Restrepo (1988), was the evaluation of basic state variables (e.g., groundwater table, reservoir water content) from which a variety of other quantities may be derived. The program determines among other things: point flows in the river at diversion points; flows at the Colorado-Nebraska state line; the amount of surface water and groundwater available to "supply areas" (farm, city or industrial area; only farm is implemented in the SAMSON model) and reservoirs; the evolution in time of the water table during the simulation horizon; the amount of water recharged to the aquifer, the amount of groundwater return flow to the river, and the amount of losses to the atmosphere through evaporation and evapotranspiration.

SAMSON simulates a large-scale stream-aquifer system, the South Platte, and is used to evaluate different management strategies for the South Platte River. The model has two components: physical and allocation. It predicts the response of the system for each modification or different water resource management strategies that are introduced into the simulated area. It can be used to simulate the entire river basin system on a daily basis.

The primary limitations of the application of SAMSON are mainly due to the inadequacy of available data, including the collection, data base storage, and retrieval of information necessary for the model. It is difficult for the uninitiated user to understand and use it properly. The extensive amount of information needed to run the program for a large-scale area such as the South Platte makes the model configuration almost too big to be used.

The model is a "discrete kernel" model in that all hydrologic information is stored within a grid area. Each grid cell is one square mile. The discrete kernel technique is used for modeling the saturated groundwater zone. A program GENERAT generates all the discrete kernel coefficients necessary to model an unconfined aquifer system. GENSAM, an acronym for the GENERAT application, was created to be used with SAMSON. Using the coefficients obtained in program GENSAM, SAMSON simulates the response of the aquifer system to any pattern of excitations. In order to use the GENSAM program, the user is required to delineate the aquifer system, superimpose and number a grid system, and gather and input all required data (Morel-Seytoux and Restrepo, 1987).

SAMSON consists of two major components:

1. The <u>decision or allocation model</u> which distributes the surface and groundwaters in the river basin for daily operations among the water users according to some specified rules of operation. It deals with the decision processes of the agencies or individuals in charge of operating the system. The water allocation model generates control variables that determine

the system excitations. The control variables are the diversions from the streams or reservoirs and pumping from farm and city wells. These excitations are needed as inputs by the physical model. The amount of surface water to be diverted from the streams depends upon the water right priority, the amount of water physically available in the stream, the irrigation water requirement at the farms and/or other controls imposed by the management strategy.

2. The physical model, using the results of the allocation model, predicts the new state of the basin based on physical laws that govern the movement of the water both above and below the ground surface. The physical system may be divided conceptually into four basic components: (1) the surface water system (rivers, reservoirs, diversion canals, surface reservoir spill canals to the river, and artificial recharge of the aquifer), (2) the root zone, (3) the unsaturated zone from the root zone lower boundary to the groundwater level, and (4) the saturated zone of the aquifer (Morel-Seytoux and Restrepo, 1987). Most of these processes are modeled on a daily basis. The aquifer system however, is modeled on a weekly time scale because groundwater flow is much slower than that of surface water.

5.0 Simulation and calibration

The model was formulated, and a calibration was attempted for the South Platte River basin from Denver to the Nebraska state line. Two options are available when running SAMSON (Morel-Seytoux and Restrepo, 1987):

1. Calibration which uses historical and operational data. The user can adjust different parameters in order to obtain a good match between observed and historical values. The calibration period should include both extreme high and extreme low events. The calibration was completed by a trial-and-error procedure on a five-year period, starting on January 1, 1968.

2. Simulation which needs only inflows to the study area and climatological data for the current calculation day. The user can try different allocation strategies, climatological conditions, and physical parameters. Thus, it is possible to compare different output results for water management studies.

6.0 Data requirements

The initial tasks required of a potential user of the SAMSON model are to clearly define (Morel-Seytoux and Restrepo, 1987):

- the region which is to be simulated, defining the edges of the aquifer system using information about the hydrogeologic characteristics
- the river system, including the location of the river gaging stations
- the layout of the main distribution canals of the supply areas

- the cells receiving canal seepage water in order to route the flows diverted from the rivers or reservoirs to the supply areas through the canals.

In addition, a map showing the boundaries of the supply areas, non-supply areas (all area which is not supplied with water), surface reservoirs, ponds, etc. is required.

The input requirement of SAMSON is divided in six sections (Morel-Seytoux and Restrepo, 1987):

- General control parameters (control variables and options for a particular execution of the model)

- Physical system information (information that provides the discrete representation of the physical system: information on the saturated aquifer system, parameters for the entire study area and for individual river systems, parameters for each river system configuration, information on the configuration of the river, reservoirs and aquifer supply areas, physical information of pond areas, phreatophyte growth areas for each river configuration, agronomic information for all crops, climatological stations and gaging stations, and boundary conditions for the entire river-aquifer system)

- Allocation information (information on water rights and augmentation plans in the study area)

- Values of the initial state of the system (information for the river reaches, the river diversion and inflow points, the reservoirs, and the climatological stations)

- Daily climatological information during the calculation horizon (temperature, wind velocity, relative humidity, precipitation depth, and precipitation duration)

- Daily historical information during the calculation horizon (daily flow at each river gaging station, at each diversion point in the South Platte, and at each river inflow point; daily surface reservoir information, daily climatological information, daily pumping historical values and daily values for augmentation plans).

The input requirement of GENSAM is the transmissivity and effective porosity of the system. The program GENSAM allows the user to input a specific value of transmissivity and effective porosity for each cell, or to input constant values that will be used for each cell. If the system has constant transmissivity, only one value is required (Morel-Seytoux and Restrepo, 1987).

The data requirements for SAMSON are summarized as follows:

- Number of cells: 1678 (size 1mile x 1mile; 1609 meters x 1609 meters)
- Number of diversion points along the South Platte River system: 80
- Number of reaches in the South Platte River: 336

- Number of inflow points into the South Platte River: 55 (includes rivers, creeks, main distribution and bifurcation canals, reservoir spill canals, city return flows)
- Number of water rights: 167
- Number of augmentation plans (well, group of wells, surface reservoir): 12
- Topography
- Aquifer parameters
- Hydraulic properties of the stream
- Seepage characteristics of the canals and reservoirs
- Canal configuration
- Configuration of the stream-aquifer system
- Supply irrigated area configuration
- List of Crops: Small grains, Winter wheat, Sorghum, Alfalfa (P-1st Cut), Alfalfa (NP-1st Cut), Alfalfa (2nd Cut), Alfalfa (3rd Cut), Corn, Sugar beets, Beans, Potatoes, Onions
- Soil characteristics of the root zone
- Reservoir system configuration
- Reservoir storages (11): Barr Lake, Pond, Milton, Lower Latham, Empire, Riverside, Bijou #2, Jackson Lake, Prewitt, Sterling, and Julesburg.
- Ponds (7): Bijou, Fort Morgan, Pioneer Terminate Ditch, Lower Platte-Beaver, Hassle-Davis Bros., Home ranch of WYM BRAVO, Condon Harmony ditch.
- Non-supply area configuration
- Recharge information
- Daily precipitation
- Climatological stations (14): Denver(52220), Longmont (55116), Fort Lupton (53027), Greeley (53553), Briggsdale (50945), Wiggins (59025), New Raymer (55922), Fort Morgan (53038), Sterling (57950), Leroy (54945), Fleming (52944), Sedgwick (57515), Julesburg (54413).
  - daily temperature
  - wind velocity
  - humidity
  - daily discharge river flow
- River gaging stations (6): Denver (06714000), Henderson (06720500), Kersey (06754000), Weldona (06758500), Balzac (0676000), Julesburg (0676400).
- Water rights (167 identified in study area) information
- Location of wells and pumping rates

7.0 Sources of data

The sources of data, as used in the SAMSON model, are the following:

- Aquifer boundaries - USGS maps, compiled by Hurr et al. (1972)
- Ground surface elevation (river system) - USGS topographic maps
- Water table elevation values (river system) - Water table elevation contour maps, compiled by Hurr et al. (1972)
- Specific yield of aquifer (average) - Hurr et al. (1972)
- Average transmissivity for each cell - Transmissivity contour maps, compiled by Hurr et al. (1972)
- Saturated thickness values - Saturated thickness contour maps, compiled by Hurr et al. (1972)
- Waterlogged cells - USGS topographic maps and Division of water Resources (State of Colorado), aerial photographic maps
- River reach length, width, bed elevation - USGS topographic maps and Division of Water Resources (State of Colorado), aerial photographic maps
- River diversion points - State Engineer's Office
- Diversion capacities - Colorado water data bank
- Rating curves for gaging station - State Engineer's Office
- Canal reach length, bed slope/elevation - USGS topographic maps
- Canal capacities - Colorado water data bank
- Seepage characteristics (canals) - Woodward-Clyde Consultants (1982)
- Boundaries of supply areas - USGS topographic maps and USDA land use maps
- On-farm efficiencies for supply areas - Woodward-Clyde Consultants (1982) and ditch companies
- Location and capacity of irrigation wells - Colorado Water Data bank
- Total irrigated area under ditch company - Ditch companies in study area
- Crop distribution for entire region - Colorado Agricultural Statistics and ditch companies
- Soil characteristics of root zone - Soil Conservation Service curve numbers based on soil type in each area
- Location and area of each reservoir - USGS topographic maps
- Bare soil distribution information - Division of Water Resources (State of Colorado), aerial photographic maps
- Phreatophyte growth area information - Ditch companies in study areas

- Recharge areas (identification, location) - Central Colorado Water Conservancy District Groundwater Management Subdistrict, Groundwater Appropriators of the South Platte River Basin, Inc. and ditch companies in study area
- Daily precipitation - Colorado Climate Center
- Precipitation duration - Colorado Climate Center (3 climatological stations)
- Daily temperature - Colorado Climate Center
- Wind velocity - Colorado Climate Center
- Humidity values - Colorado Climate Center
- Daily discharge and river flows - USGS data bank (WATSTORE)
- Water rights information - Colorado Water Data Bank
- Daily releases from reservoirs - Not available
- Pumping rates (weekly, monthly, season) - Not available

A dataset used for the calibration effort for SAMSON was run again to verify the status of that dataset and quantify how well it had been calibrated. The output at six gaging stations from Denver to Galesburg is presented in Figures 2-7. The model tracks the peak and low flows for HENDERSON and KERSEY remarkably well. It does not do as well in the quantity of the estimates. It over-estimates the flow at HENDERSON and under-estimates the flow at KERSEY. The discrepancy in quantity continues to grow from WELDONA to BALZAC, being the largest at JULESBURG. The timing of the flows is still fairly good at BALZAC but the quantity of the estimates is poor, especially at the JULESBURG station. From the results it can be seen that the model does a good job in tracking trends and timing, but the difference between measured and computed flows increases while moving downstream, being the worst at the JULESBURG gage.

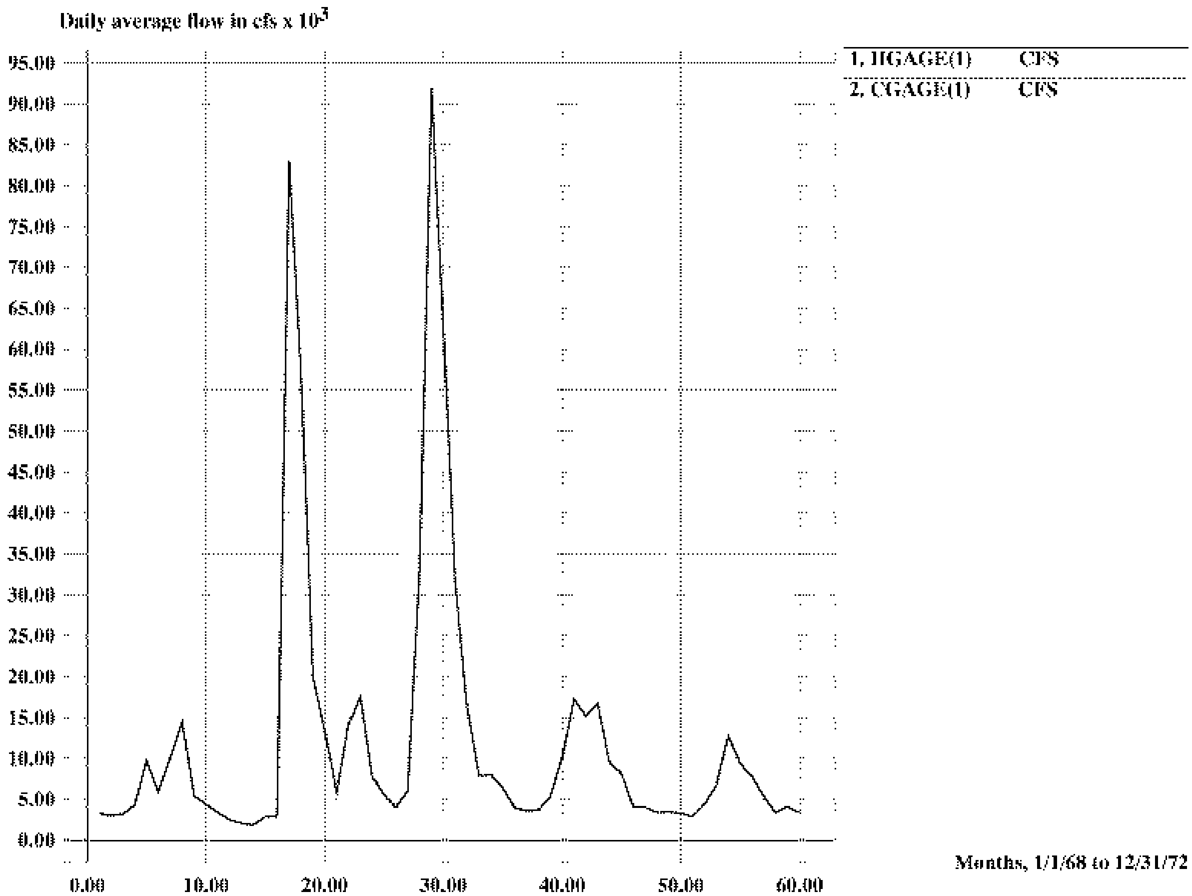

Figure 2: Computed and measured flows at gaging station 1, DENVER

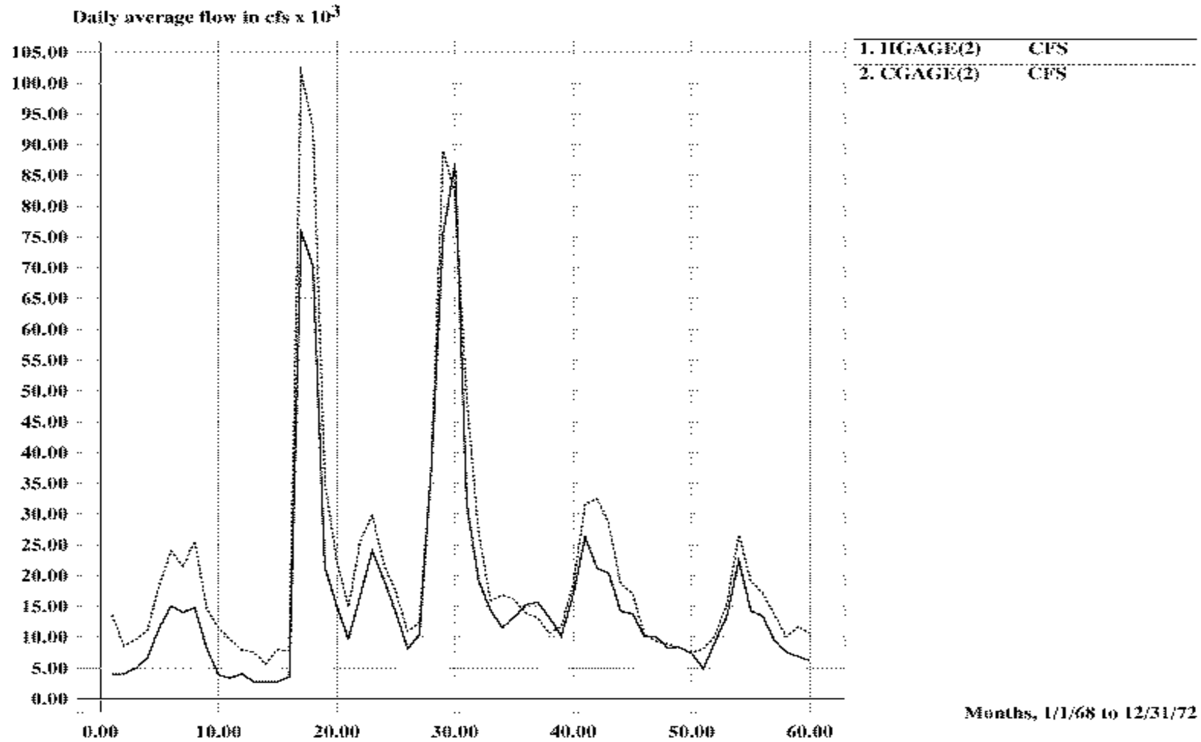

Figure 3: Computed and measured flows at gaging station 2, HENDERSON.

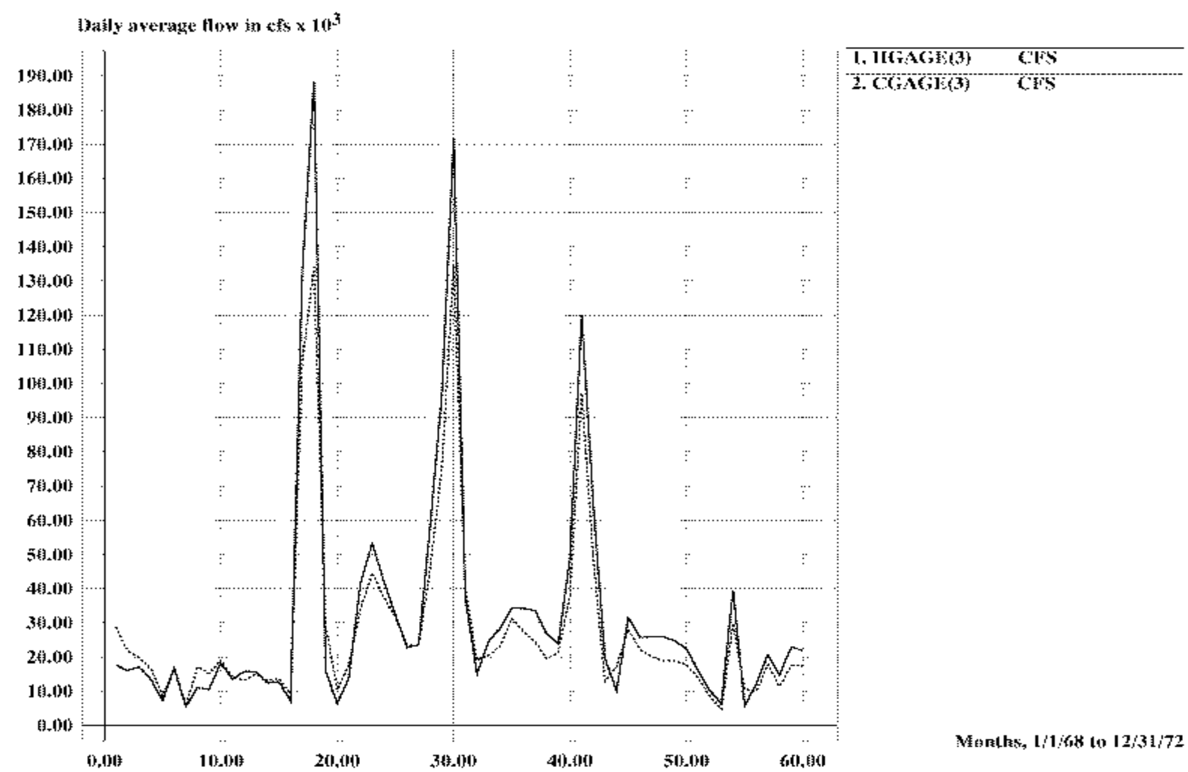

Figure 4: Computed and measured flows at gaging station 3, KERSEY.

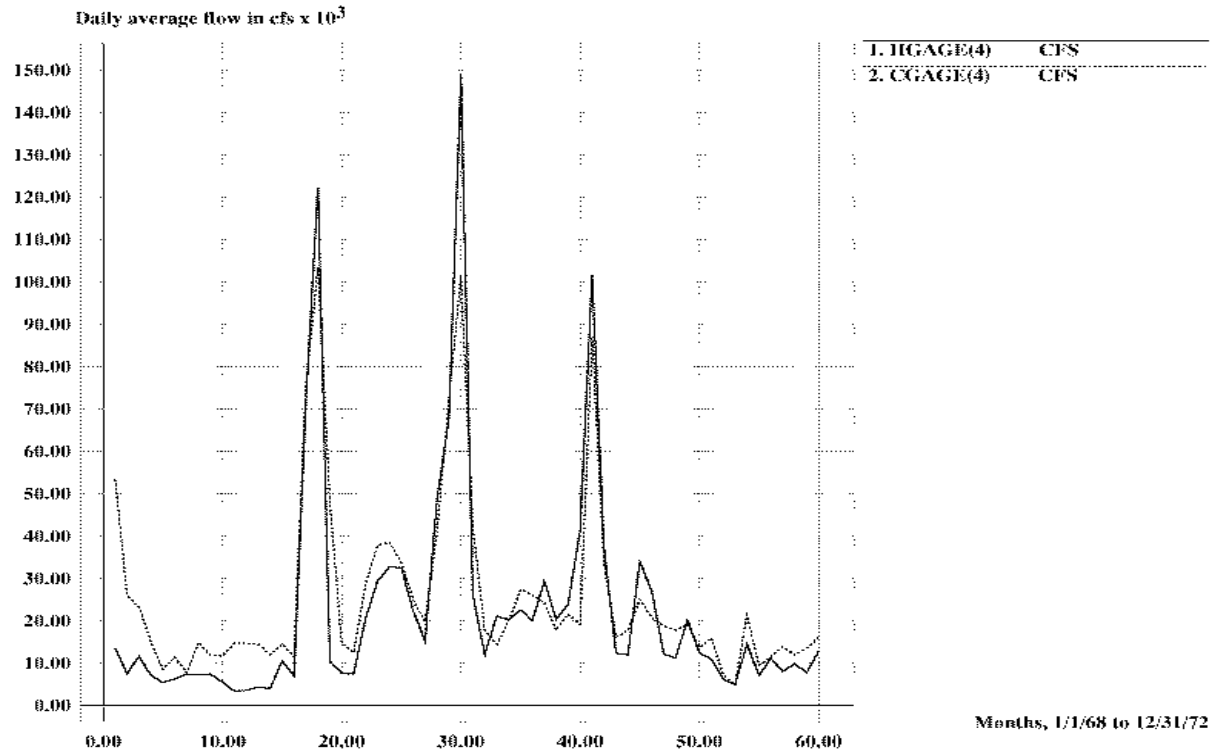

Figure 5: Computed and measured flows at gaging station 4, WELDONA.

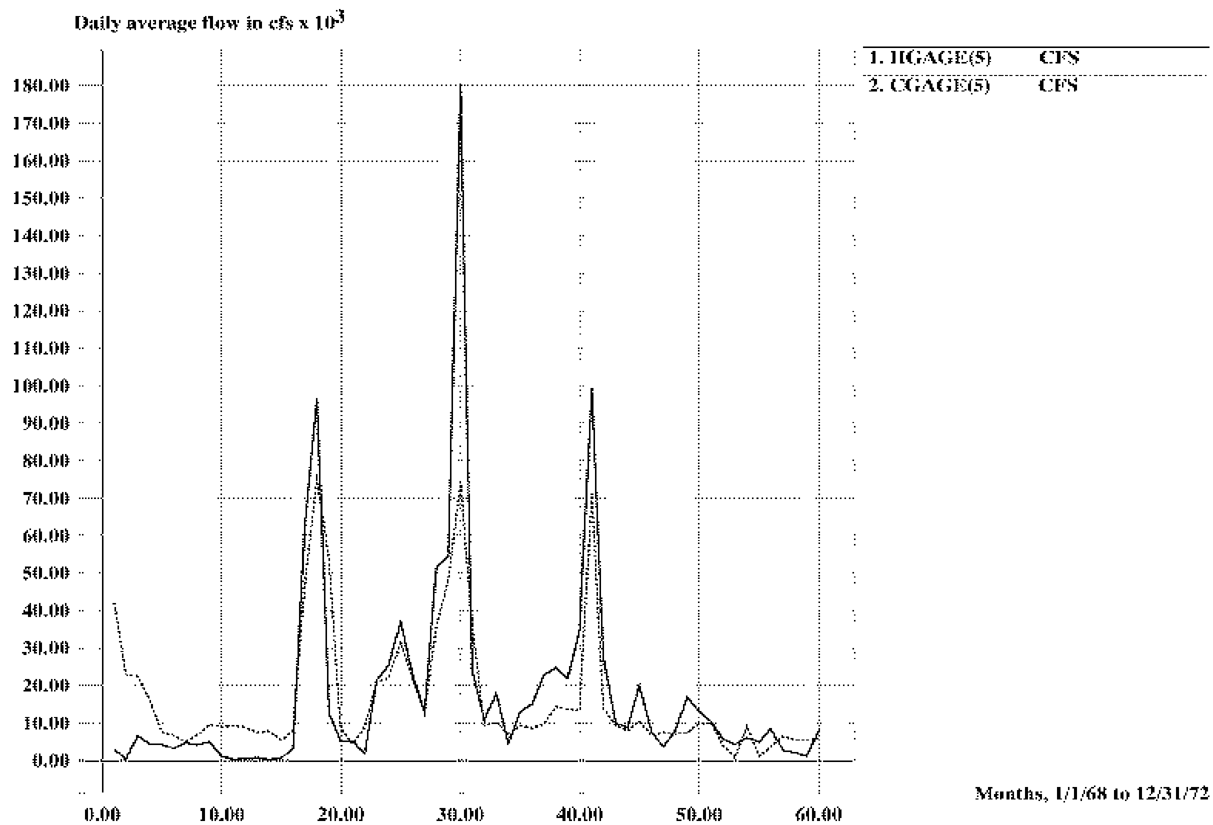

Figure 6: Computed and measured flows at gaging station 5, BALZAC.

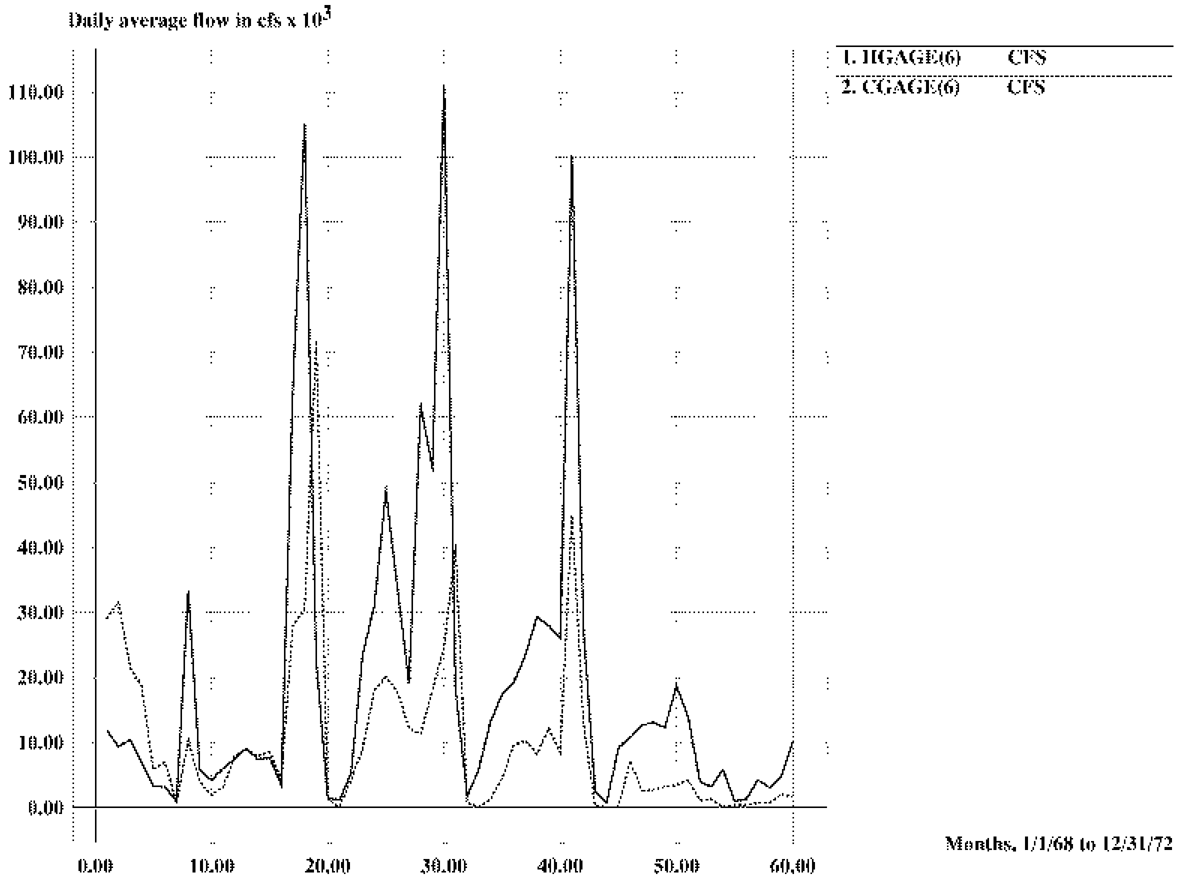

Figure 7: Computed and measured flows at gaging station 6, JULESBURG.

Section 5: Summary, Conclusions and Recommendations

The objective of this research was to evaluate the SAMSON model (Stream-Aquifer Model for Management by SimulatiON) in the context of a Decision Support System for the South Platte River Basin. SAMSON originally was developed on a Cyber 205 mainframe computer in FORTRAN (Morel Seytoux, 1987), the model was ported to a PC in 1991 (Quick Basic) through the efforts of the South Platte Basin Study Technical Support Subcommittee. The model, in its two versions, has not yet been used for decision making in the South Platte River Basin.

The specific objectives of this Project were to:

- Understand the SAMSON model
- Identify the physical constraints which limit the use and calibration of the model
- Evaluate data requirements and data availability for the model
- Identify the issues related to the use of the model by the state, local, and private agencies
- Evaluate the role if any that the model could play in a DSS (Decision Support System).

SAMSON was developed during the late 1970s and early 1980s, and was a very valuable tool that proved water resources modeling applications for the South Platte River Basin were both possible and feasible. The SAMSON model was developed in the early stages of computer applications to river basin water management. At the time of its development, the model only could be run as batch files on a main-frame computer. Multiple runs for different scenarios and user interaction was kept to a minimum, since the user would literally have to schedule a model run on a main-frame. Therefore, building the input dataset and reviewing the output were typically one-time events and not interactive. Given the technical limitations of the time, SAMSON provided a general understanding of the interaction of surface and groundwater in the South Platte River Basin. More importantly, it showed that this type of modeling could help in understanding the management of water resources in the South Platte.

In this project, we have focused on trying to determine the state of the current version of the model, determining the needs and issues related to state, local, and private agencies who would be using this model, and evaluate what role the model could play in meeting those needs as part of Decision Support System.

Methodology:

Luis Garcia and Herve Raymond worked closely with an advisory committee comprised of the following representatives:

Jon Altenhofen - Northern Colorado Water Conservancy District
Ray Bennett - State Engineers Office (Denver)
James Hall - State Engineers Office (Greeley)

Forest Leaf - Central Colorado Water Conservancy District
Jack Odor - Groundwater Appropriators of the South Platte

This group met regularly and evaluated the available data and models available for the South Platte. The group also identified specific data and modeling needs that could be achieved through joint efforts. The group used the work published and/or researched by The Colorado Water Conservation Board, John Eckhardt, Darrell Fontane, Henry Kunhardt, Robert Leaf etc. (CWCB, 1995; Kunhardt and Fontane, 1995; Fontane et al., 1994; Fredericks, 1993; Eckardt, 1991).

Four phases have been completed to produce an evaluation of the SAMSON model:

- Phase 1: Literature Review - During Phase 1 an understanding of the issues (water resources, water rights, water management and institutions, compact, water quality, endangered species and Memorandum of Agreement) as well as a review of relevant literature has been completed.
- Phase 2: Understanding the SAMSON model - The understanding of the SAMSON model was completed in Phase 2 of the project by running the model, and identifying: (i) the physical constraints and strengths, (ii) the data requirements, (iii) the data availability for the model, and (iv) the limitations of the model.
- Phase 3: Specific needs for the South Platte River - To understand the specific needs for the South Platte River, an "Advisory Committee" was appointed during the project as discussed earlier. Additional meetings are planned to continue work in data and development of some components.
- Phase 4: Evaluation - The original sample data for SAMSON was reformatted to run with the latest version of SAMSON. This data was developed to formulate and calibrate the South Platte River basin from Denver to the Nebraska state line (Morel-Seytoux and Restrepo, 1987). Some minor modifications were made to the code and SAMPSON was run using the sample data.

Principal Findings

Since the initial development of the SAMSON model, computer speed and availability has revolutionized the modeling process and users expect a much higher degree of interaction with models. Consequently, there have been significant advances in hardware technology as well as the philosophy of software development. Modeling philosophy has evolved towards building decision support frameworks composed of small modules rather than a single, very complex model. A modular design allows for the inclusion of models from different sources within a data-centered approach. These systems typically have a relational database with routines for pre and post processing and interchange of data that are generic enough to support multiple models.

When SAMSON was developed, the data-driven approach was not a common practice. Therefore, some of the conditions it uses for modeling are built into the source code and cannot be specified by the user. This makes it very difficult to update and modify the code. SAMSON attempts to model all processes that take place in the basin in a single program (e.g. water rights, consumptive use, groundwater, etc.). This makes the code extremely complex and very difficult to manage.

In summary, when the SAMSON model was originally developed, the modeling philosophy was geared toward a one time comprehensive model run, which was standard practice. However, current modeling approaches emphasize building smaller, independent and data-driven components that deal with one task such as consumptive use. Data interchange mechanisms can be used to assemble different components into a DSS framework.

SAMSON provided a valuable service by proving that surface and groundwater could be modeled as a combined system, even in such a complex system as the South Platte River Basin. The model was instrumental in the development of modeling for the South Platte, but as with many computer-based tools, newer advances have made the use of the complete system impractical. Components of SAMSON could be used as part of a future DSS, but these components would need to be separated from the main program and some of the computer code might need to be modified in the light of current modeling approaches.

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