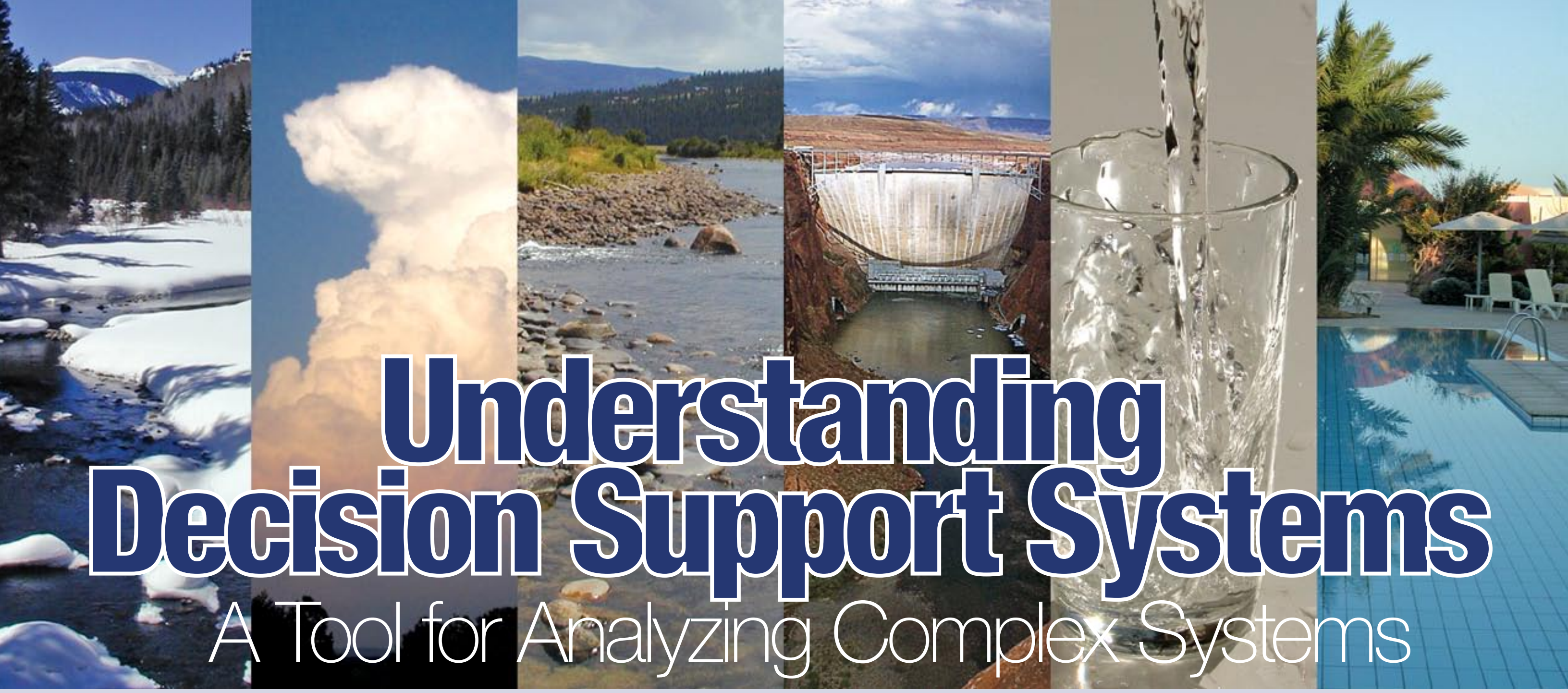

Understanding Decision Support Systems

A Tool for Analyzing Complex Systems

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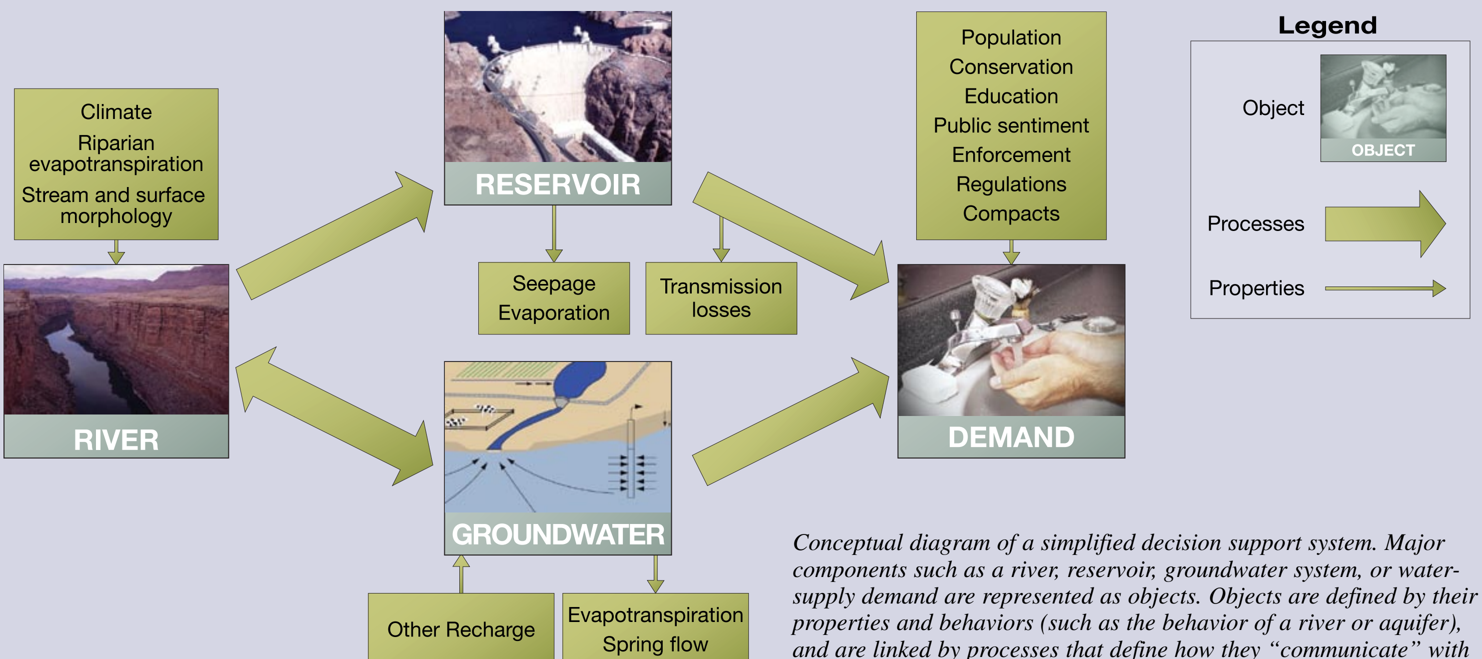
Decision support systems (DSS) are increasingly being used to help water resources managers balance stakeholders' competing demands against limited water supplies. Stakeholders may range from developers seeking additional water to endangered species requiring minimum river flows for survival. Supply issues can vary from basic groundwater availability to the cost of infrastructure to bring water from a distant source to a growing population. These considerations and many more must be weighed against one another to develop water supply portfolios that maximize supply while minimizing adverse impacts to stakeholders and the environment. A DSS provides a tool to evaluate these complex systems, perform "what-if" scenario analyses, and aid in choosing an appropriate supply portfolio. The DSS can also help resolve competing objectives and apply weighting schemes to decision attributes so that stakeholders can select which attributes are most important to them.

What is a DSS?

Many DSSs are based on the theory of complex systems, defined as systems consisting of many parts coupled together in nonlinear fashion. Thus they are more than simply the sum of their parts. Although two components may be related, changing one may not produce a proportional change in another. Multiple components may also react together in unexpected ways. A complex system model (sometimes called a dynamic support model) seeks to simulate these connections, and a DSS allows users to evaluate the effects and outcomes of changing various components within the complex system model.



Conceptual diagram of a simplified decision support system. Major components such as a river, reservoir, groundwater system, or water-supply demand are represented as objects. Objects are defined by their properties and behaviors (such as the behavior of a river or aquifer), and are linked by processes that define how they "communicate" with other objects (such as groundwater/surface water interaction).

Photo credit (from left): N. Molotch, G. Liolo, J. Hogan, K. Smith, C. Eduardo, M. Stowasser

Object-Based Models

DSS codes work by building object-based models that are connected by various processes and feedback loops. An object is a specific component in a system with behavior that can be quantitatively described. As a simple example, in a water-supply system based on surface water, a reservoir would be represented as an object in the DSS. The reservoir is related to other objects by inputs and outputs. Streamflow into the reservoir (either simulated or from historical records) is an input into the reservoir object, while water leaving the reservoir to meet demand is an output. The volume of water in the reservoir is described as a function of the initial volume in the reservoir at the beginning of the simulation and the amount of streamflow entering the reservoir at each time step in the simulation. Note that in this example, demand is not a function of streamflow (supply); therein lies one of the most basic problems of water supply that we face today.

Other water supply components such as climate, streamflow, groundwater availability, the interaction of groundwater a vnd surface water, and population (as it relates to demand) can be added to the DSS to link multiple objects (see diagram below left).

Streamflow, or the water in a river, can be represented as an object that is a function of climate (precipitation) and runoff characteristics. If modeled separately, streamflow is typically simulated using a surface-water model. But for a DSS, a more simplistic analytic equation or lookup table would likely be used. For example, a surface-water flow model could be used to develop an equation or lookup table that relates rainfall to streamflow at an index gauge just above the reservoir, thus providing the required input to the reservoir for the DSS simulation.

Groundwater availability is typically evaluated using a groundwater model, but in the context of a DSS, the groundwater model is represented more simplistically, such as by a lookup table that shows unit responses of drawdown per specified unit of pumping. In this manner the potential effects of pumping wells can be evaluated within the DSS. Note the feedback loop between streamflow and groundwater availability when there is hydraulic connection between the stream and the aquifer. During periods of high streamflow, the aquifer is recharged and more groundwater is available, but as groundwater pumping increases, more water is drawn out of streamflow and less is available to fill the reservoir. Administrative limits such as water rights and available infrastructure may also be factors for both surface water and groundwater supplies.

An object is a specific component in a system with behavior that can be quantitatively described.

All of these issues and limitations can be quantified within the DSS. The demand object also can be simplistically represented as a function of population: more people generally consume more water. In some western cities, however, demand has remained relatively constant in the face of growing population due to conservation measures, which can be quantified and used as input to the DSS.

A DSS can also be expanded to include political and public-acceptance issues to the extent that these can be quantified. For example, a DSS recently was used in a western city to evaluate whether the public was willing to give up a certain portion of its supply to allow relatively continuous flow in a river that passed through the city. The DSS also was used to evaluate the potential impacts and costs of using a portion of the supply for that purpose.

DSS in a Can

A variety of off-the-shelf DSS software packages are available. Programs like STELLA and Powersim provide an easy-to-use graphical user interface that allows users to model dynamic systems by creating objects and defining relationships between them. MATLAB, described as a "high-level technical computing language and interactive environment," provides much more flexibility in terms of defining and linking processes. Crystal Ball and similar programs allow decision-support simulations to be run in a spreadsheet environment. A geographic information system can be used as a decision-support tool by using different layers to represent the factors important to site selection for a particular use, for example, land ownership, depth to water, and geology when siting a well. Each layer is then weighted according to its importance, and when the layers are superimposed, the combined factors produce a map of aggregate suitability scores.

Although objects and processes are graphically represented in a DSS, they must still be developed by the user. To represent surface-groundwater interaction, one needs to develop an analytical solution or lookup table to describe the

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relationship that can be coded into the software. Software packages provide a convenient method of accounting to keep track of objects and processes in a graphical format. Conversely, more mathematically complex and potentially more powerful approaches such as MATLAB require more knowledge and training by the user both to develop the DSS and interpret the results.

Data Needs

For the most part, DSS models use data that many organizations may already have but are not using to full advantage. These include the basic building blocks needed to create a DSS such as a groundwater model, a surface-water model, climate and streamflow data, and population projections. One component of the DSS process is the technique of "data mining" by which various processes are used to extract valuable insights from existing data.

The level of difficulty in making all of the different kinds of data interface with each other depends on a variety of factors, including the desired complexity of the DSS, the number of input parameters, the range of conditions chosen to represent different scenarios, and the software used.

Challenges and Potentials

As in any modeling exercise, judging when enough detail has been included in a DSS to reliably simulate the behavior of a system can be difficult. The user must determine the point at which the dynamics of the system have been reasonably represented so that the model adequately serves decision-making purposes.

The credibility and popularity of DSSs for evaluating complex system behavior and analyzing management decisions are growing. The great advantage of these systems is their ability to evaluate multiple (and sometimes conflicting) objectives in reproducible fashion, using stakeholder input to weight the decision-making process and arrive at an optimal solution.

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