FUTURE DIRECTION OF SNOW SURVEYS AND WATER SUPPLY FORECASTING IN THE SOIL CONSERVATION SERVICE

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INTRODUCTION

Those of you who keep track of such things will have noted that almost every session of the Western Snow Conference has one or more papers on the history of our science and profession and on future directions. Our pride and fascination with the history is certainly understandable. From humble and tentative beginnings in the first decades of this century, a science was established that supported the development of the water resources in the West. The Soil Conservation Service (SCS) was created in 1935 and soon was involved in water conservation and designated by Congress as the lead agency for cooperative, snow surveys, and water supply forecasting (except for California where the existing state government retained those responsibilities). The 1988 conference included an excellent paper by Pete Palmer that covered our history and looked into the future (Palmer, 1988). I will not review that history.

Why do we need another paper on future directions and, specifically, on future directions for the SCS program? An obvious answer is that estimates of future conditions--technologic, economic, political--are always changing, and the future, when it arrives, is rarely exactly what had been estimated. Consequently most human enterprises regularly reevaluate their anticipated future direction. It is a critical part of effective management in SCS.

An equally important answer is that, as water resource professionals, we share an appreciation for the earth's resources, especially its water. We are committed to doing a better job in managing and conserving water; most of us are devoting our careers to that goal. We have a professional interest in the future.

In this paper I will cover five aspects of the future direction for Snow Surveys and Water Supply Forecasting in the SCS:

1. Increasing demands on water resources and needs for data,
2. Data collection technologies,
3. Water supply forecasting,
4. Interagency cooperation, and
5. Decision making for water resources.

INCREASING DEMANDS ON WATER RESOURCES AND NEEDS FOR DATA

First, the setting for the future must recognize the increasing demands on water resources, both quantity and quality, in the Western U.S. This is evident to professionals, and these increasing demands will dictate some of our actions in the 1990's. Fortunately, an increasingly large segment of the public is becoming knowledgeable on water resources. Huge water storage and conveyance projects have been built based on our best estimates of the future water supply and assessments of future demands. These water management facilities level the extremes in water supply; they allow us to partially control nature's delivery schedule, and they provide a form of limited supply insurance. But, with only a few exceptions, there are no more large dams coming on-line to support increased development or to guarantee adequate supplies for all users.

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The curtailment in new project development has generally not been accompanied by a reduction in projected water use. Increased irrigation efficiencies and conservation in the agricultural, metropolitan, and industrial sectors are all moves in the right direction. Because agriculture is the largest consumptive user of water--about 80 percent of the total--any reduction in this water requirement is extremely important. There are many different studies of potential irrigation efficiencies; the SCS estimate made in the late 70's, is proving to be generally reliable for average values (USDA, Soil Conservation Service, 1978):

AVERAGE IRRIGATION EFFICIENCIES - PERCENT

	1980	2000 TREND	2000 HIGH
OFF-FARM	80	85	90
ON-FARM	55	60	65
SYSTEM	45	50	60

Figure 1: Projected Irrigation Efficiencies for the U.S., 1980-2000.

Off-farm conveyance efficiencies are improved by practices such as lining ditches; on-farm application efficiencies are improved by practices such as laser plane land leveling, gated pipe and conversion to sprinklers or drip. The technologies exist to attain the "HIGH" potential efficiencies, but some of these improvements are expensive for the crops being grown. They often cannot be justified by increased production profits unless the price of water is a significant factor.

Conservation can reduce the water used by an urban household, but the maximum reduction is about 20 percent. The Metropolitan Water District (Los Angeles) had only achieved about five percent reduction in use through conservation by 1989. They estimate a total of 10 percent by 2000. A somewhat higher maximum reduction can be obtained for certain industries through conservation and reuse. But, once the conservation reductions have been made, little opportunity remains for additional savings without massive economic consequences.

Instream requirements have been studied and quantified. Their legal and administrative standing is increasing. Land management agencies are giving closer consideration to the water requirements on the lands they administer, particularly wilderness areas. Lakes, riparian ecosystems and wetlands are now receiving recognition as legitimate demands on the water supply. Pyramid Lake in Nevada and Mono Lake in California are recent examples where reductions in stream diversion were mandated to reestablish and sustain historic lake levels, and the battles are continuing.

Water quality standards for both surface and groundwater supplies increasingly result in water quantity requirements such as the international compact on the Colorado River. The Wellton-Mohawk Project in Arizona is an example of the very significant improvements that modern irrigation facilities and intensive management can make in water quality. Irrigation return flows that carried high salt loads to the Colorado River were reduced from about 220,000 acre feet annually to 110,000 acre feet.(Hedlund, 1988)

The pressures on us as water supply forecasters and snow surveyors are increasing along with the increasing demands for a limited and variable supply of water. Our clients need better forecasts that are more informative and more timely so that they can respond to quantity and quality requirements. They also require probability and risk information for some situations.

There is another aspect to future demands - the increasing needs for data. Global climate change, the greenhouse effect, acid rain: these now commonly-heard terms are examples of the recent worldwide concern with atmospheric sciences. Various government agencies and academic units are pursuing a variety of research in this general area. The data we have been collecting, editing, and archiving for the last 50-plus years has been identified as a unique resource of considerable value. Snow covered areas are recognized as "Extremely sensitive barometers of climate variability and change." (USGS, 1989)

In addition to the hydrometeorologic data we now collect, the network of SNOTEL automated data collection sites in pristine, remote, high altitude areas of the West presents excellent opportunities. These sites can be easily equipped to support both research such as the Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program, and operational monitoring such as the Forest Service and Bureau of Land Management cooperative Remote Automated Weather System (RAWS).

SCS has been preparing to meet these expanding challenges; they are very much a part of our plans for the future.

DATA COLLECTION TECHNOLOGIES

The second look into the future concerns new and improving data collection technologies. This conference and related professional meetings regularly present discussions of new methods and procedures in data collection. Data sources now include airborne gamma radiation and satellite snow cover technologies provided by the NWS National Remote Sensing Hydrology Program. Data collection sites have progressed from a monthly look at snow depth, water content, and density, to continuously reporting, automated remote sites such as the Data Collection Platforms (DCP), operating through the Geostationary Operational Environmental Satellites (GOES) and the SCS SNOwpack TELemetry system, SNOTEL (Schaefer, 1988). Operating with a daily system-wide response averaging over 97 percent, SNOTEL reports total precipitation, temperature, and other hydrometeorologic data in addition to snow water equivalent at about 560 sites. The third generation transceiver using meteor burst communications technology being installed by SCS in its system-wide modernization program, supports 32 sensors with variable reporting intervals, plus 32 calculated values, for a total of 64 channels per site. It is a proven technology, employed internationally and relied on by the U.S. Defense Department as one of the most dependable communications technologies available. SCS will continue to use meteor burst until a superior and more efficient technology becomes available.

The Centralized Forecasting System (CFS) was established in 1984 on a Data General super minicomputer as the focal point for data management, analysis, and access (Shafer and Huddleston, 1986). CFS incorporates a database architecture that is easily expanded to accommodate needs for additional data. Plans call for a major enhancement of CFS in 1993.

Consideration is being given to expanding SNOTEL technology nationwide in support of a network of soil moisture monitoring sites. Two new SNOTEL master stations in addition to the Boise, Idaho and Ogden, Utah masters would be required for this expansion. SNOTEL sites equipped with multiple soil moisture sensors are already in operation. In addition to soil moisture, SCS is cooperating with the Agricultural Research Service (ARS) in using portable SNOTEL sites to collect wind speed, direction, and particle count data in support of wind erosion studies. The 1990's will likely see a major expansion in the utilization of SNOTEL, linked to CFS, as a data collection and management network tied to a geographic information system (GIS).

In 1988 SCS launched a research and development (R&D) program in support of snow surveying and water supply forecasting. Under one part of this R&D program, we are actively pursuing with the ARS, the Corps of Engineers Cold Regions Research and Engineering Laboratory and others, the development of improved sensors. For example, laser and acoustic technologies will be investigated as replacements for the snow pillows. We are also investigating to find environmentally acceptable fluids for use in the SNOTEL sensors. Most of this R&D work is aimed at improving operational characteristics and reliability, and reducing maintenance requirements. Increased sensor accuracy is usually not a very important factor. For the most part, the ability to make accurate water supply forecasts is not being impeded by the sensors we have.

Before moving on to discuss the third area of the future, I want to state the SCS position on optimizing the cooperative data collection network. Our policy is based on maximum, but not total, reliance on the automated SNOTEL system. It includes an analysis of the SNOTEL network and expansion to fill critical data voids. Redundant and non-essential manual snow courses are being discontinued, but only after intensive evaluation of their value for water supply forecasting or other purposes. Consultation with interested agencies and cooperators is mandatory. The SCS State Conservationist has the final word. The number of manual courses has been reduced from 1610 in 1984 to 1223 in 1990. By water year 1991, we will probably have about 800. There will always be a place for manual snow courses, and we estimate a level population around 700. New courses continue to be added where a manual reading is all that is required, or as a precursor for an eventual SNOTEL site. Also, a provision is included in the Snow Course Reduction Plan for continuing to make one annual reading at certain discontinued sites; these are referred to as Basin Index Points.

WATER SUPPLY FORECASTING

The third look into the future, deals with water supply forecasting; what can we expect? Compared to the 1970's we now have tremendously increased capabilities for data storage, retrieval, computing, and analysis, but can we do a better job forecasting? In some instances we can, but not in all cases. Some early regression forecasts are producing acceptable forecasts that have not been improved by process simulation models. Let's examine briefly what goes into an idealized forecast model:

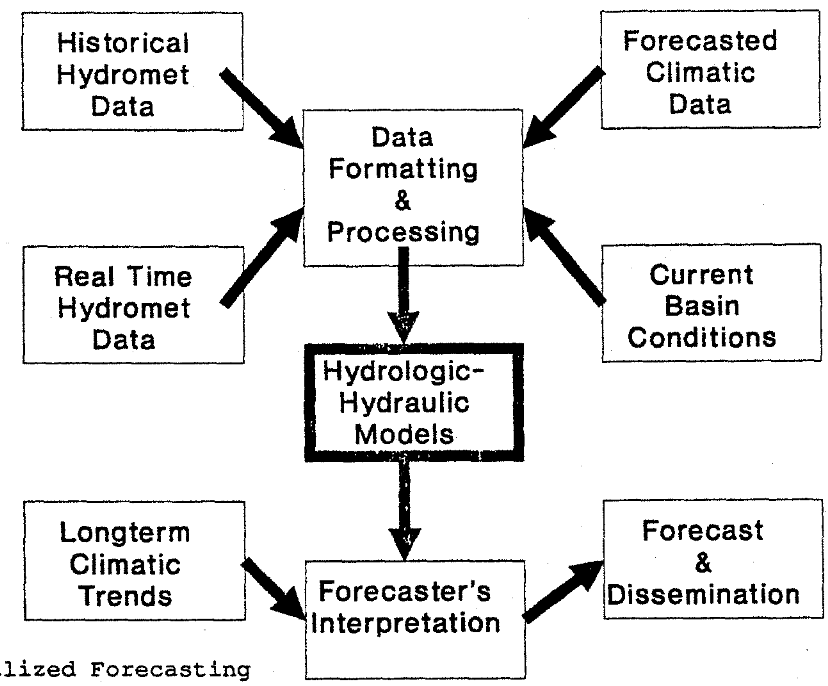

Figure 2: Idealized Forecasting

There are three elements that are always considered and a fourth that may be. The three elements are: historical hydrometeorological data, near real time hydrometeorological data, and current basin conditions. These elements often have problems such as incomplete or erroneous data sets, unavailable reports of current conditions, and problems with data availability and transfer between agencies. The fourth element, forecasted climatic conditions, presents a major problem--forecast accuracy. In many cases precipitation forecasts are not very reliable beyond one week; temperature predictions are usually not reliable beyond two weeks. SCS had been forecasting based on assumed average precipitation for the remainder of the forecast period. In 1989, we adopted a new rigorous procedure for developing regression forecasts that is based only on known conditions (Garen, 1989).

Data processing and formatting as well as model operation (both regression and process simulation) are facilitated by modern computers. But, the forecaster's interpretation still plays an important role. The water resource community is particularly well served by the cooperative nature of forecasting in the West. All water supply forecasts released by SCS are coordinated with the National Weather Service (NWS) and other agencies. Differences are investigated and resolved. Forecast equations or model inadequacies are identified and remedial actions are planned.

For the most part, Global Climate Trends as addressed by global circulation models are not very helpful for regional and basin forecasting. SCS takes into account the El Nino--Southern Oscillation phenomenon which has an apparent correlation with climate patterns in the Western U.S. Future studies and model development may make both short term climate forecasts and long term climate trends more reliable and useful for water supply forecasting.

To sum up forecasting, the future for this decade includes steady and important improvements in various elements of water supply forecasting, particularly the ability to generate frequent predictions of various risk and probability scenarios. The CFS enhancement will support forecasting through the 1990's, including the increased data needs for process simulation modeling in a GIS workstation environment, for about 30 percent of SCS's forecast points. There are not likely to be dramatic system-wide improvements in accuracy.

INTERAGENCY COOPERATION

The fourth area I will cover highlights a very positive aspect of our profession--interagency cooperation. It is why sharing our views of the future is important. We are all closely related in our data collection and forecasting activities. Forecasts are based on data from a variety of agencies. For example, the SCS forecast for the Colorado River at Cameo uses SNOTEL data as well as USGS streamflow data and NWS climatological data. It also uses reservoir and transmountain diversion data from USBR, the Denver Water Board, and the Northern Colorado Water Conservancy District.

Interagency and International groups such as the Columbia River Water Management Group, the Colorado River Forecast Service, and the NWS/SCS Technical Committee explore and implement procedures and standards for automated data transfer and coordinated forecasts. This is an area where excellent progress has been made, but current and developing computer and data communications technologies will support enhanced cooperation. CROHMS, the Columbia River Operational Hydrometeorologic Management System, is an early example of several data collection agencies pooling their data. Full implementation of procedures such as SHEF (Standard Hydrometeorological Exchange Format) remain to be realized.

The 1990's will offer new opportunities for expanded interagency cooperation. SCS, ARS, EPA, USGS, and other agencies are working together to solve the nation's water quality problems. The NWS has exciting plans to improve their technological capabilities and to revise their operational structure (DOC, NOAA, National Weather Service, 1989). While the major NWS benefits will be for weather prediction, the River Forecast Centers will be able to take advantage of these improvements in carrying out their water supply forecasting role. Intensified interagency cooperation will pass these benefits on to water supply forecasters in SCS and the operating agencies. The nation's water users will be the ultimate beneficiaries of our continuing efforts for interagency cooperation. SCS is committed to being an active participant.

DECISION MAKING FOR WATER RESOURCES

The fifth and final area of this look into the future is the most important because it offers the greatest opportunity for improvement in water resource management through this decade. Several items are lumped into this fifth area under the term, decision making.

How effective are the nation's water resource decisions given all the improvements we have made in data collection and forecasting? Has there been a commensurate and concurrent improvement in water resource management? For the major operating and management agencies such as the Bureau of Reclamation, the Corps of Engineers, Salt River Project, and Bonneville Power, the answer is generally positive. But, if the view is broadened to include the hundreds of irrigation districts and thousands of agricultural operations as well as numerous municipalities, the answer is not so positive. In fact, in some cases decision making is about where it was 40 years ago. This has been an area of major concern to SCS, and we are intensifying our efforts to facilitate wise water management decisions at all levels. To better position the snow survey and water supply forecasting program for providing assistance on water management, SCS reorganized the program in 1983, and centralized the forecasting capability in Portland, Oregon (Barton, 1983). In addition to concentrating the agency's forecasting expertise, the reorganization allowed the field staff more time to work with the water users and other resource managers to improve their management capabilities. This effort is referred to in SCS as program integration.

The CFS in addition to being the focal point for analysis and forecasting, also supports forecast dissemination. CFS was designed for ease of access by cooperators and other agencies. A broad effort was launched in 1989 to make CFS the primary source for obtaining forecasts. This effort will intensify over the next three years as local training sessions are provided for the forecast users with computers and modems. Training materials cover not only access to the forecasts, but also forecast interpretation and decision making.

The printed monthly Water Supply Outlook for the Western United States will continue to be produced cooperatively by NWS and SCS; it is generally not used for operational decisions. SCS state outlook reports have been replaced by basin reports. They are a briefer more timely flyer, covering a particular basin (or several basins). The basin report is intended as a decision tool for those forecast users that do not have computer facilities or that prefer to receive the forecast printed.

The format of the forecasts accessed on CFS as well as the forecasts in the basin reports has been modified to present four forecasts in addition to the most probable. They include forecasts for 90, 70, 30, and 10 percent exceedance probabilities. The 90 and 70 percent values are referred to as drier future conditions, while 10 and 30 are the wetter. This additional information is being provided to better support decision making.

While computer access to forecasts and more timely distribution of printed forecasts are important steps that support better decision making, our major improvement will take advantage of the unique network of SCS field offices throughout the West. The District Conservationists in these computer-equipped offices are being trained to access CFS and retrieve specific forecasts and related information needed by their clients. Training is also addressing decision making based on the forecasts. The enhancement of CFS will consider the development and implementation of expert system procedures at the Field Office level. An expert system will expand the capabilities of the District Conservationists to support their client's water resource decision making.

Earlier professional papers have reported on forecasts and related products being designed to serve very specific needs. Such as irrigation planning (Bell, 1987), reservoir operation (Marron, 1989), fish and game management, recreation, and avalanche hazard forecasting. Decision making in these specialized areas has seen very significant progress since 1985 by utilizing the specific and timely analyses based on forecasts and the hydrometeorological data available through CFS. This type of specific assistance will continue to be an important part of SCS water supply activity in the 1990's.

One final aspect of decision making that holds promise for affecting water resource decision making on a regional scale is the development and implementation of a water supply index. Most of us have witnessed the avoidance of the dreaded D-word in the halls of government, and its abuse and misuse by the press.

What is a drought, and how do we know if we are in one? A dry-land farmer may be facing disaster with inadequate soil moisture to even start crop growth, while a neighbor may see only a minor reduction in irrigation water being transported from an almost normal irrigation reservoir. The next operator who is pumping ground water has an adequate supply with just a slightly higher power bill. The municipal reservoir that supplies the local community may be almost dry with severe water rationing, brown lawns and dirty cars. Another corner of the state may have exactly opposite conditions. Does the state have a drought?

Obviously, this not-so-hypothetical situation calls for some timely and effective decision making. In these situations water resource management can be pivotal, but it is by no means a discrete consideration. The consequences of "drought decisions" reach into many aspects of a region's economy and quality of life, both in the present and for future years.

There is usually an abundance of data available, but how do the decision makers assimilate it and move toward some effective action? SCS believes that a drought index is helpful to facilitate decision making. The Palmer Drought Index may play a role, but it alone is not adequate in most cases. An index lumps together and simplifies, and most water supply forecasters would prefer decisions based on their forecasts. Developing an index that is accepted by the scientific community and the responsible officials can be complex.

In 1982, SCS and the Colorado State Engineer's Office developed a Surface Water Supply Index (SWSI) for seven basins in Colorado (Shafer, 1982). The SWSI considers non-exceedance probabilities for, reservoir storage, streamflow (June through November), snowpack (December through May), and precipitation. It uses a scale ranging from +4, abundant supply, to -4, severe drought. The experience in Colorado has been successful; SWSI as used by the governor's Water Availability Task Force does trigger the Colorado Drought Response Plan which initiates remedial actions in a timely manner with a reduced level of controversy. In Oregon, SCS participated in the Water Availability Committee of the Drought Council to implement a SWSI in 1989.

Based on that experience, SCS has entered into a cooperative agreement with the Climate Center at Colorado State University to study SWSI performance and to develop portable procedures for generating a SWSI for any state (or basin) in the West. Participation by state and regional climatologists as well as other federal and state agencies is being encouraged. We are hoping to see a network of SWSI's in place within the next couple years.

SUMMARY

This look into the future has touched on five areas: 1) Increasing demands on water resources and data needs, 2) Data collection technologies, 3) Water supply forecasting, 4) Interagency cooperation, and 5) Decision making for water resources.

Each of the five areas is important, and each will receive significant attention in the 1990's. SCS places a great deal of importance on more effective utilization of the data, forecasts, and related products that are currently produced by the snow surveying and water supply forecasting community. Effective decision making will continue to be an area with major emphasis.

As always, the future is exciting. Enormous demands will be made on our creativity, effectiveness, and reliability. To meet the challenges, we in this relatively small community must work together closely and share our technologies, data, and procedures. We must also frequently share our visions of the future, so that through professional interaction we can better chart the courses we are laying out to take us through the 1990's and into the next century.

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