# SNOTEL: A MANAGEMENT TOOL FOR THE FUTURE

689-81

by

George D. McMillan 1/

## INTRODUCTION

In March 1977, the Soil Conservation magazine carried an article entitled "SNOTEL: Wave of the Present." In this article, Manes Barton, head of SCS's Water Supply Forecasting staff at Portland, Oregon, presented many of the details of the SNOTEL system being installed (Barton, 1977).

Since that time, the SNOTEL system has been put in place and we are getting operational experience in 10 States. SNOTEL has already changed our operation. We have had to make major adjustment in our staffs as data came "on line" and as the Soil Conservation Service (SCS) took over maintenance of the SNOTEL system last summer. In his article, Barton concluded:

> "Regardless of the level of automation in different States, snow surveyors will continue to go through essentially the same historical process--gathering data from January to June, processing the information through special formulas to obtain water forecasts, and issuing frequent outlook reports for every important watershed at key points along rivers and at reservoirs.
>
> "But future forecasts will be more accurate and up-to-date, thanks to quarter-inch silicon chips and to tiny bits of space debris meeting a fiery end."

## SNOTEL IS PART OF A BIGGER SYSTEM

SNOTEL (for "Snow Telemetry") is the automated portion of the Soil Conservation Service's snow survey and water supply forecasting activity. It involves the largest known application of "meteor burst" technology (Barton and Crook, 1980). Besides data collected by SNOTEL's 480 automated sites, SCS and the many individuals, organizations, and agencies cooperating in the Western snow survey collect data from a network of nearly 1,700 snow courses and other data sites. Some of these data sites are visited regularly by trained snow surveyors in aircraft, "snocats," and snowmobiles. Others are reached by the "traditional method"--on snowshoes or skis.

This program is a cooperative effort between SCS and others interested in managing the limited water available to this area. SCS has 22 professional full-time snow hydrologists and computer specialists assisted by 26 full-time statistical assistants, secretaries, and technicians. The latter now includes electronic technicians to assist with SNOTEL maintenance. In addition to this core staff, more than 200 SCS employees and scores from other organizations do the lion's share of the snow course data collection effort (Crook, 1981).

How much does one or more SNOTEL sites affect the accuracy of forecasts for a watershed? First reaction might be to say, "At least as much as one snow course." The second reaction might be: "We get five or six measurements per year from a snow course and twice-a-day measurements from the SNOTEL site, so the SNOTEL data is worth many times the value of the snow course data." Both answers are based on faulty assumptions. A SNOTEL site is not just a snow course with a radio transmitter.

Consider the difference between snow water measurement on the typical manual snow course and a SNOTEL site. The snow course has several predetermined points where depth of snow and the water equivalent are measured. In some cases, 20 or more points are measured on a single course. These multiple measurements can be compared, averaged, and analyzed

---

Presented at the Western Snow Conference, April 14-16, 1981, St. George, Utah.

1/ State Conservationist, USDA, Soil Conservation Service, Salt Lake City, Utah.

to determine accuracy of measurement and unusual snowpack conditions. On the other hand, the SNOTEL site sends a value for the weight of the snow on the pillow. This value may, or may not, be closely related to the amount of water over the pillow. Also, the amount of water over the pillow may, or may not, be closely related to the "average" condition for a portion of the watershed.

Add to this difference in number of measurements the likelihood of imperfect data from SNOTEL site sensors. At certain temperatures snow adheres to the orifice of precipitation gages and forms snow caps. Snow also can stick to the inside walls of the precipitation gages and drop into the solution when the weather warms. Ice layers can bridge over pillows causing inaccurate pressure measurements. Each of these conditions will indicate a change in precipitation data when the temperature changes. Temperature sensors can become encased in snow and ice and improperly record temperature. Transducers, which convert pressure on snow pillows and precipitation gages to electrical data, and electronic equipment can malfunction. Telemetry systems and computers can develop "bugs" or can break down (Farnes, 1978).

Two SCS State snow survey supervisors recently were asked about the impact if SNOTEL were the sole source of data for making water supply forecasts. One answered:

> "I would not recommend discontinuing manual measurements until such a time as we are confident that the data can be measured by SNOTEL."

He pointed out some of the system's shortcomings: problems with data, correlation of pillow data with snow courses, and areas not covered by SNOTEL. He continued by saying:

> "I would guess that 90 to 100 SNOTEL sites would be needed (in this State) to completely eliminate the need for manual readings. We have many areas where cooperators measure snow courses now, and I am sure they would continue. Presently, if SCS pulled out of the manual measurements, there would still be between 40 and 50 percent of the snow courses measured manually. This number would drop as the cooperators developed confidence in the system.
>
> "I hope that any phase-out can be gradual, organized, and well planned."

The second snow survey supervisor responded by showing a map of snow courses and SNOTEL locations, including those SNOTEL sites which were not colocated with previously established snow courses with long records. He said:

> "With as sparse a network density of SNOTEL sites as we currently have, it would be highly questionable to attempt to extrapolate telemetered snowpack and precipitation data to the full 175 snow courses. The snow course network density is about the minimum that one can use to accurately inventory the mountain snowpack. In fact, we constantly have requests to add more snow courses because of the accelerating pressures to better manage available supplies of water."

## SNOW SURVEY MANAGEMENT IN THE 1980's

SCS is focusing snow survey planning on: (1) Further refining performance characteristics of the SNOTEL operating system; (2) analyzing water user needs for real time hydrometeorological data, aided by full public participation; (3) strengthening cooperative relationships with State, Federal, and private groups involved in the surveys or in managing water resources in the West; and (4) integrating the snow survey and water supply forecasting program into overall inventory and monitoring efforts.

### Refining the SNOTEL System

As we gain experience in the use of SNOTEL, we begin to see opportunities to expand, revise, and refine the system. We have two potentials for expansion. One is adding sites to the system, the other is adding sensors to each site.

When SNOTEL was authorized, just over 500 sites were approved. However, with further expansion in the future, the master stations and data handling facilities were to have the capacity to handle 1,000 sites (Rallison, 1981).

As each snow survey supervisor incorporates SNOTEL data from each site into the model used for forecasts for each watershed, the extent to which the SNOTEL site reflects the water supply will begin to emerge. As the SNOTEL data is correlated with the total watershed picture, the need for additional sites and the potential for dropping manual courses will become apparent. Fine tuning SNOTEL will be an ongoing task for several years. As each new site is added, the fine tuning process will continue.

I quoted earlier from the snow survey supervisor who estimated the need for "90 to 100 SNOTEL sites" in his State. That supervisor, however, would prefer a little time to use the data presently being collected before he selects where the other 30 to 40 sites should be located.

One way SNOTEL is being refined is by adding a microprocessor to the equipment at the site. This removes many of the data limitations that have been present in SNOTEL. The primary reason for polling the sites twice daily is to obtain an approximate high and low temperature for the site. The microprocessor can be programed to record the high, low, and mean daily temperature. These three values can then be telemetered at a single polling. Sites with a microprocesser also can be programed to report automatically when any of the measured parameters changes drastically.

As we consider adding sensors to existing sites, we encounter several questions: How many sensors do we add? What kind of sensors do we add? Which do we add first? Soil moisture, water quality, wind direction and velocity--the list of options goes on. The basic SNOTEL site measures four parameters: precipitation, temperature, weight of snow on the pillows, and battery voltage. The system design allows for the addition of up to 12 more measurements (Jones, 1980). The potential for expansion suggests several "open doors" for data collection for tomorrow's manager.

Meeting Water User Needs for Real Time Data

One of the results of providing SNOTEL sites to the Mount St. Helen area is the modification which currently is underway to provide event-reporting capability. As this event-reporting capability becomes a part of more locations in the system, we will have to adjust our forecast updating schedule to allow for taking advantage of this "real time" data. Our forecasting models will need to include the flexibility to use real time data, the stability to reflect nature's consistencies, and the basis to determine the relative weight of each.

As our data improves, new users with different information needs will surface. This should be a real challenge to our managers.

Strengthening Cooperation with Others in the West

During the past couple of years, SCS has been involved with a study involving public participation and whether the snow survey program should be turned over to the local people completely.

As we heard the call for continued leadership from the Soil Conservation Service, we also heard the requests for additional sharing of our data. We heard the complaints of duplication between agencies and the encouragements for us to talk to other agencies, to work with them, and to fully share our data with all potential data users.

We are committed to meeting the public needs to the best of our ability within the limitations of our staff and our budgets.

In some cases, these very limitations of staff and budget prevent us from cooperating to the extent we would like. Recently we got a request in one of our Northern States asking for some modifications to SNOTEL. We stated our plans for implementing the system within our current budget. As a result of our response, the organization that had suggested the modification started their own collection system that will partially duplicate our ongoing effort. I hope we can freely share our data so we can now at least get the most out of the duplication.

## Integrating Snow Survey into SCS's Overall Inventory and Monitoring Effort

In addition to SNOTEL and the other snow survey activities, SCS is involved in the Western States with many types of resource inventory and monitoring efforts. We also are involved with cooperative measurements of snowfall, acidity and heavy metal content of precipitation, and other inventories in other States.

The highly skilled snow survey and water supply forecasting capability that has been developed has a lot to offer the other inventory efforts of the Department of Agriculture. Our snow survey data are available to the National Weather Service and others. We have, however, in some cases, failed to integrate this expertise and data into the wider scope of SCS's responsibilities.

Interest is currently increasing for a nationwide soil moisture monitoring network. Is a soil moisture sensor at each SNOTEL site feasible? Would it be worth the cost? Should our meteorburst communication system be expanded with one or two more master stations to cover the rest of the United States? Should we use satellite communication instead of meteorburst for part of our data collection network? The questions go on and on. Some we answer, some we postpone. But one thing we know: SNOTEL is a management tool for today and for the future.

## REFERENCES


Barton, M. 1977: SNOTEL: Wave of the Present, Soil Conservation 42(8), Washington, D.C. pp. 12-14.

Barton, M., and A. G. Crook. 1980: Operational Experience with the SNOTEL Syste, Proceedings of the American Society of Civil Engineers 1980 Annual Convention, Hollywood-by-the-Sea, Florida, 10 pp.

Crook, A. G. 1981: History of Snow Surveys, paper presented at West-wide Snow Survey Training School, Park City, Utah, 4 pp.

Farnes, P. 1978: Future Snow Survey Operations with SNOTEL, Western Snow Conference, Otter Rock, Oregon.

Jones, K. 1980: The Use of SNOTEL, paper presented at West-wide Snow Survey Training School, Mt. Hood, Oregon, 8 pp.

Rallison, R. 1981: Automated System for Collecting Snow and Related Hydrological Data in Mountains of the Western United States, Hydrological Sciences Bulletin 26,1, pp. 83-89.