FUTURE SNOW SURVEY OPERATIONS WITH SNOTEL

By

Phillip E. Farnes 1/

The Soil Conservation Service (SCS) SNOTEL (SNow survey TELemetry) system is going to broaden and change the operations of the Snow Survey Program. The SCS is now installing more than 500 automated snow survey sites in the western United States. SNOTEL uses meteor burst communication techniques for data transmission, Data will be available on a near-real-time basis to SCS snow survey offices and to cooperators who have agreements with SCS to obtain these data. Snow water equivalent, total precipitation, air temperature, and battery voltage will be measured at all sites. In addition, the system is capable of handling as many as 12 more sensors. Nominal polling will be twice daily, once before daylight and again soon after midday, to approximate maximum and minimum daily temperatures.

About one-fourth of the snow course sites in the western United States will be automated. The snow courses have historically been read on monthly intervals about four times annually. SNOTEL will generate about 150 times more data than are now being obtained by the SCS snow survey offices (Figure 1). Many other changes will occur as SNOTEL is implemented.

Montana has been allocated 63 of the more than 500 SNOTEL sites. About 9 additional sites will be installed by cooperators. Six sites have been installed by other agencies using their own telemetry network. This makes a total of 78 automated stations in Montana.

This network of stations will forecast streamflow at approximately 90 streamgaging stations in Montana. These stations have a drainage area of over 70,000 mi^2 (181,300 km^2) and have an average April through September runoff of about 27,500,000 acre-ft (33,900 hm^3).

In gross figures there will be one automated station in Montana for every 1.2 streamflow forecast points and 27,700 acres of irrigated land. Each station will represent a drainage area of about 900 mi^2 (2,330 km^2) with an average April through September runoff of 350,000 acre-ft (430 hm^3).

SNOTEL will bring significant changes to the Snow Survey Program. Field snow surveys will gradually become fewer. Snow courses will be measured on flexible schedules and probably once or twice in conjunction with winter maintenance trips to SNOTEL sites. Although there will be fewer snow surveyors they will be much more mobile and better trained. Surveys will be scheduled for general time periods to take advantage of good weather and good travel conditions rather than for the first of the month.

Data from manual snow surveys will become less important for water supply forecasts, and it is conceivable that monthly manual snow surveys could be phased out in many areas within 10 to 15 years.

At most of the nonautomated snow courses, water equivalents can be estimated monthly from telemetered data. It will be possible to compute and publish water equivalents for all snow courses on the first of each month whether the snow course was actually measured or not. Also a snow course measured before or after the first of the month could be adjusted to reflect the first-of-the month value by comparison with SNOTEL data (Fig. 2).

Office procedures will change as dramatically as the field snow survey program. The increase in volume of data being received is almost overwhelming. Computers will be used extensively, but all data must continue to be evaluated by trained staff because some data may pass computer validation but not accurately represent field conditions. The current line of sensors being installed at SNOTEL sites may not produce perfect data. At

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1/ Snow Survey Supervisor, Soil Conservation Service, Bozeman, Montana. Presented at the Western Snow Conference, Otter Rock, Oregon, April 18-20, 1978.

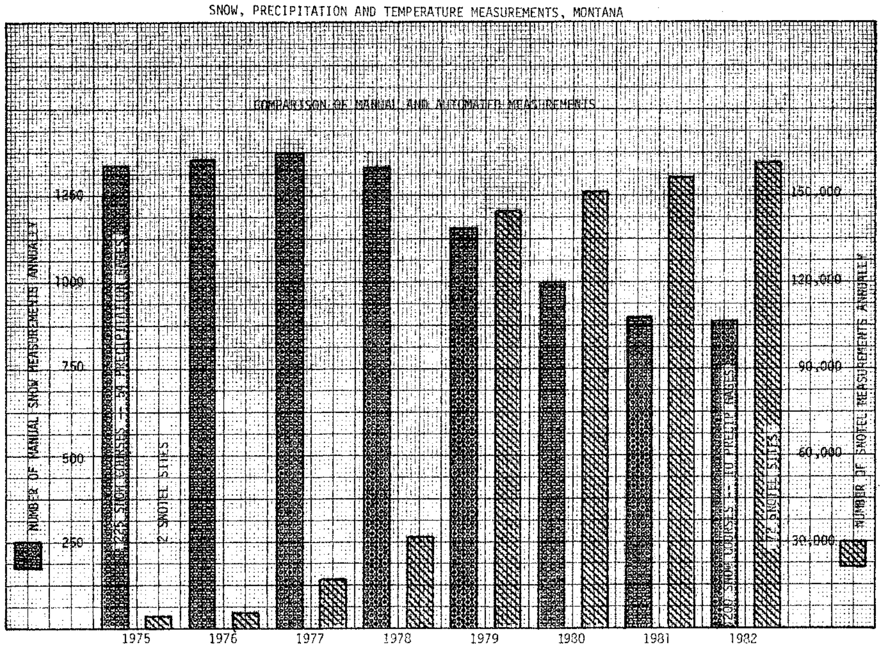

Figure 1

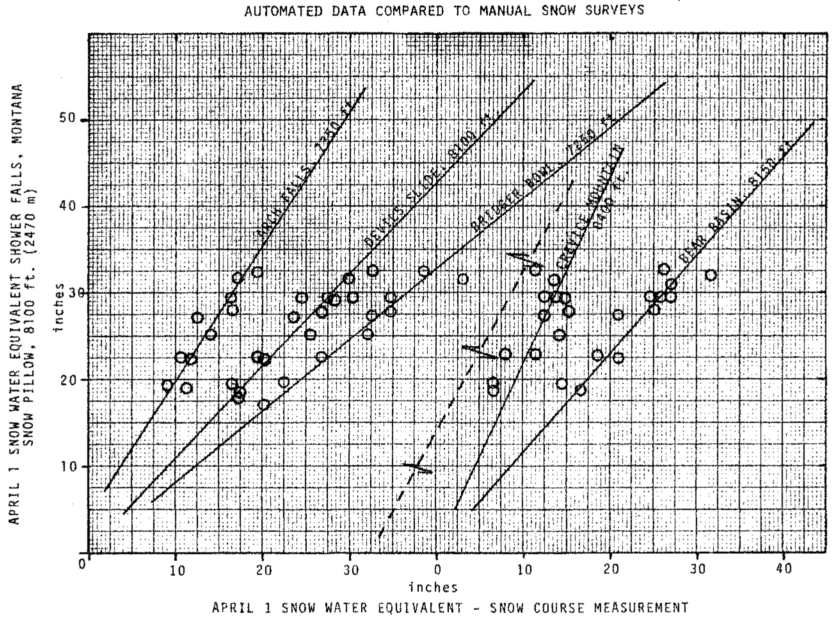

Figure 2

certain temperatures snow adheres to the orifice of precipitation gages and forms snow caps. Snow can also adhere to the inside walls of the precipitation gages during storms and drop into the precipitation solution after weather warms. This may happen during a period of no precipitation, but the sensors will indicate precipitation all the same.

Ice layers in the snowpack can cause snow pressure sensing devices to yield inaccurate data. Equipment such as transducers, which are used to convert pressure on snow pillows and precipitation gages to electrical output for data transmission, can develop malfunctions and may be subject to temperature variations. Air temperature sensors can become encased in snow and ice and inaccurately record temperature. Telemetry systems are also subject to transmission problems and interference. Computers can develop "bugs" or break down.

For these reasons, staff trained in hydrology and climate will analyze the data shortly after they are received. Comparisons must be made between sensors at a site and between adjacent sites to verify the data before they are used for forecasting or are released to cooperators. Tabulation and reporting of data, now done monthly, will be done almost daily. Procedures will have to be worked out on how frequently reports will be printed and issued and on whether special reports will be issued when there are major changes in hydrologic or climatic conditions.

Close contact will be maintained with local SCS field offices. Weekly or more frequent reports will be provided to these offices either by hard copy or by remote terminals. Local ranchers, farmers, and others interested in the snowpack or water supply can telephone these local offices for current snow data or water supply conditions.

Farmers and ranchers who irrigate by direct stream diversions will probably be most interested in general snowpack conditions, early-season streamflow predictions, and short-term streamflow forecasts during the irrigating season.

On streams where the irrigation water supply comes from direct diversion, it will help irrigators to know in advance when various water rights are to be restricted. The amount of direct diversion is affected by legal water rights, upstream water withdrawal, temperature, soil moisture, snow cover, and precipitation. On most western streams without significant storage, there is an excess of water during the main snowmelt period when irrigation demand is low. But as the streamflow decreases, irrigation demands increase; and there is usually a shortage of water during late spring and summer. In some years the water supply is adequate for irrigation, but in others it is extremely low. To assist individuals faced with these uncertain conditions we are investigating appropriate models that use SNOTEL data to yield accurate forecasts of streamflow 10 to 15 days in advance.

Reservoir operators will be most interested in seasonal volume forecasts of inflow and in short term forecasts during peak flow periods. Using early-season forecasts, operators can balance storage levels with inflow-outflow requirements. During peak flow events, short-term forecasts will provide data for fine-tuning operations.

Many other water users will also benefit from accurate short-term forecasts and more accurate volume forecasts, including those who work with hydroelectric power generation, flood control, water quality, and municipal and industrial supplies.

Near-real-time data and realistic hydrologic models have the potential for yielding good forecasts of streamflow. A number of models have already been developed, but their usefulness has been limited by the lack of good real-time data from the main water-producing zones. Using today's data from remote SNOTEL sites in good hydrologic models and using future projections of precipitation and temperature can provide realistic estimates of future streamflows.

By using data from extreme high and low years to show possible future conditions, models can yield data that will provide considerable insight into probabilities of flows that could be expected under different combinations of precipitation and temperature. These data can be updated as the season progresses. Theoretically, the accuracy of the forecasts will improve during the season as more actual data become available and fewer data are projected.

Daily data can be used to predict conditions for almost any part of a watershed. By using daily SNOTEL and valley climatological station data to develop elevation versus temperature (Figure 3) and elevation versus precipitation curves (Figure 4), the snowfall, precipitation, temperature, and melt can be estimated for any point in a watershed. This technique of developing data for various elevation zones within a watershed will probably be the most common method used to input data into hydrologic models.

To use hydrologic models for forecasting, the vertical (elevation) distribution of potential SNOTEL sites is more important than the correlation of snow courses with runoff. Elevation versus runoff curves (Figure 5) help to determine a desirable distribution. If only one site can be located in a drainage, the best location is near the mean water-producing elevation. If two SNOTEL sites are to be located in a drainage, a 30 and 70 percent yield elevation is most desirable. If a valley climate station near the lowest part of the drainage can be brought into the data base, a 40 and 80 percent yield elevation may provide the best coverage. Data from one site can usually represent a vertical elevation zone of 1,500 (450 m) to 2,000 (600 m) feet.

Data from different elevations are also needed to get an accurate index of snowfall, melt, precipitation, and temperature over a basin and to monitor the hydrologic effects of various storm events, orographic influence, and temperature inversions.

Accurate estimates of potential runoff can be used to optimize hydroelectric power generation and reduce the consumption of fossil fuels needed for power generation.

By using models we could develop extensive hydrologic data for many other uses. For example, it is conceivable that a watershed could be calibrated with as few as three years of actual data. By using various combinations of data for precipitation, temperature, and snowpack, we could develop a series of realistic hydrographs to provide information needed by hydrologists and planners. These hydrographs could be used in designing spillways, culverts, and bridges; in allocating reservoir storage capacities; in delineating flood plains; in measuring the frequency of various hydrologic events; and in estimating many other characteristics that affect streamflow.

We could also use models for realistic measurements of the effects of logging, fires, and other vegetative manipulation on the amount and timing of peak flow, total volume runoff, sediment yield, and other water quality factors.

The basic data received by SNOTEL can be used by other specialists. For example, sensors to measure humidity, soil moisture, and wind speed and direction can help foresters predict forest fires and their spread. Solar heat units can be estimated from temperatures so that range specialists can estimate plant development and forage production of rangeland. Many other natural events are related to solar heat units. A few of these are hatching of insects, the melting of ice in mountain lakes and melting of snow on high elevation roads and trails. Stream temperatures can be related to the amount of snowmelt water entering a stream system and to recent air temperatures.

Daily SNOTEL data on snowfall and temperatures can be combined with wind data to help expand the data base for predicting avalanche potential. Fall, winter, and spring snowfall and temperature data can help wildlife managers determine the effects on wildlife populations and survival, success of spring spawners, and success of waterfowl reproduction. Better documentation of precipitation intensities, mountain climate, and seasonal variation in relation to valley climate will be possible.

Our limited experience with near-real-time data suggests that we have only scratched the surface of the potential for automated data acquisition systems such as SNOTEL.

PRECIPITATION COMPARISON WITH ELEVATION
Hyalite Creek Drainage, Montana

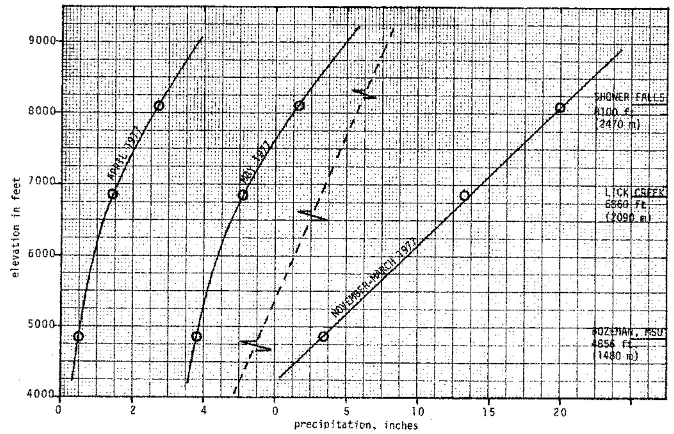

Figure 4.

TEMPERATURE COMPARISON WITH ELEVATION
Hyalite Creek Drainage, Montana

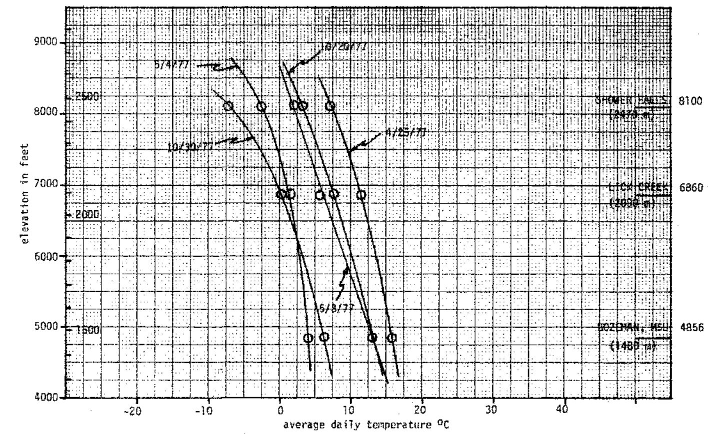

Figure 3.

RUNOFF COMPARISON WITH ELEVATION
Lower Willow Creek near Hall, Montana

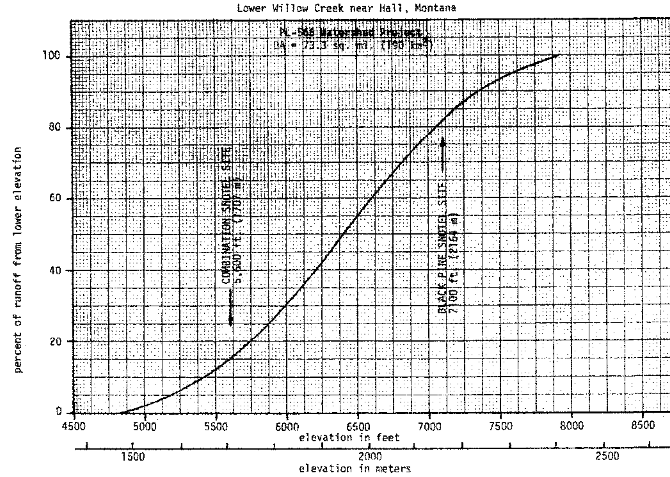

Figure 5.

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