SNOW SURVEYING COMES OF AGE IN THE WEST

by

J. Douglas Helms[1]

Snow surveying and water supply forecasting entered a new era when the U. S. Department of Agriculture abolished the Bureau of Agricultural Engineering and transferred the Division of Irrigation to the Soil Conservation Service (SCS) on July 1, 1939. The Division of Irrigation was headquartered at Berkeley, California, with Walter W. McLaughlin as chief. The irrigation engineers in field offices in the western states had been in charge of the federal coordination of snow surveys since the U.S. Congress appropriated money for the work in 1935. Previously existing networks, such as those in Nevada, Utah, and California, continued under the agricultural experiment station or a state agency as was the case in California (Helms, 1991). The individuals who eventually came to be called snow survey supervisors were James C. Marr in Boise, Idaho, R. A. "Arch" Work at Medford, Oregon, Ralph Parshall in Fort Collins, Colorado, and Lou T. Jessup at Yakima, Washington. They generally operated independently, though Marr was the acknowledged leader. Since the beginning of snow surveys, Marr had devoted all of his working hours to building up the snow surveying activities and had dropped his irrigation work (Marr correspondence).

The early years had been a time of rapid expansion--laying out snow courses, working out agreements with cooperators and users, compiling data, making forecasts, and reproducing the forecasts for distribution. Arch Work recalled that the group had decided working independently was the most efficient operation.

> We were pretty decentralized. I understand perfectly the need to centralize snow survey work under SNOTEL.... But in those early days, we believed it was more practical and more profitable, in terms of public relations, to decentralize. I think it was a profitable position to take because they weren't restricted by regulations superimposed upon them by someone who didn't know very much about the business (Work interview, 1989).

The group created enough interest that the requests for additional snow courses eventually exceeded the meager appropriation and manpower available (Work interview, 1989; Marr correspondence).

The move to the Soil Conservation Service increased the area covered by snow courses as well as the application of forecasts (Work, 1989). The Soil Conservation Service had begun in 1937 to encourage the creation of conservation districts under state law. The districts had locally elected supervisors and directors. After a district signed a cooperative agreement with USDA, the Soil Conservation Service would assign staff to work with the district. The move added a large number of SCS employees as potential snow surveyors. Also, snow survey offices were opened at Reno, Nevada and Logan, Utah (Work, 1948).

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National Historian, Soil Conservation Service, U.S. Department of Agriculture, P.O. Box 2890, Washington, D.C. 20013.

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In terms of applications the Soil Conservation Service had become the primary agency of USDA advising farmers on technical matters concerning the storage, movement, and use of water on the farm. SCS assumed responsibility for advising farmers on irrigation and drainage along with water supply forecasting. Working through the field staffs and the conservation districts, there was great potential for using snow surveys in irrigation.

Arch Work believed that the snow surveying generally received strong support from the leadership of SCS, especially Chiefs Hugh Hammond Bennett and Don Williams, as well as the important staffs in administration, engineering, and public information (Work, 1989). The public information group especially appreciated the romance of "snow surveys" as a means of publicizing the agency. When most research functions of the Soil Conservation Service were transferred to the Agricultural Research Administration effective November 15, 1952, the water supply forecasting remained in SCS.

SNOW SURVEYING PUBLICATION

The Division of Irrigation group realized that future expansion of the snow courses and water supply forecasting would be greatly enhanced by a snow survey manual. When the Division of Irrigation got involved in the work, the division's field people learned from experienced snow surveyors George D. Clyde and James E. Church (Helms, 1991). Also, literature on the subject was accumulating since the Western Interstate Snow-Survey Conference, begun in 1933, published articles on methods and procedures in its proceedings. But new snow surveyors and forecasters needed a manual, a compendium of the existing knowledge on snow surveys. James C. Marr, who had general supervision of the snow surveying work from his Boise, Idaho office, called upon the experts in the field for help in writing a manual on principles, purposes, and procedures of snow surveying. Snow Surveying (USDA Miscellaneous Publication No. 380) appeared in 1940. In addition to his own experiences Marr solicited information from the other snow survey supervisors (Parshall, Jessup and Work) as well as George D. Clyde, J. E. Church, O. W. Munson, and Harold Conkling, the deputy state engineer of California. The manual described the care and use of equipment, snow sampling procedures, field office work, uses of water supply forecasts, maintenance of snow courses, stocking shelters, winter travel and other topics (Marr, 1939; Marr, 1940). Prior to the use of aircraft, expansion of snow surveys depended in part on making cabins available. Snow surveyors needed cabins in order to make a trip of several days to remote snow courses. In the 1939 Transactions, American Geophysical Union Arch Work and Ralph Parshall published a guide for the construction of snow survey cabins (Work and Parshall, 1939).

SNOW SURVEY NETWORK

The snow survey work expanded throughout the late 1930s. By the spring of 1940 approximately 753 snow surveyors made readings at 14,295 sampling points on 1,000 snow courses. The brunt of the snow surveying work fell on the rangers of the U. S. Forest Service and the National Park Service. Snow surveyors had available some 339 shelters. Only a portion of those had been built specifically for snow survey work. Others belonged to mining companies, power companies, and lumber interests. As the groups worked to add new cabins they tried to locate them about 16 miles apart, the average day's journey. Altogether the Division of Irrigation had about 50 cooperating federal, state, and local agencies and companies (McLaughlin, 1940; Work, 1989).

The network of snow courses developed rapidly. By 1943 there were 829 snow courses being surveyed. There had been about 1,000 courses, but the group eliminated some of these as unnecessary. There were 177 active cooperators. The surveyors had about 266 shelter cabins available to them, 77 of which were owned by the federal government. The network stocked 115 of these with food. In addition to the mimeographed releases there were some 153 radio broadcasts made during 1943 (McLaughlin, 1943).

PUBLICITY

Winter sports enthusiasts recognized the value of the snow surveys for skiing and other activities. In the summer of 1937, the Division of Irrigation was asked to provide information on conditions for winter sports. The snow supervisors took to the airwaves on the National Broadcasting Company. The offices at Berkeley, Medford, Boise, Fort Collins, and Logan collected information on 64 winter sports areas and had the information ready for a Friday broadcast at 9:00 p.m. The National Broadcasting Company carried "Snowcasts" on the San Francisco station as well as two stations in Idaho, two in Washington, four or five in Utah, and one in Colorado (Work, 1989; Work, n.d.; McLaughlin, 1940).

Actually some of the broadcasts contained more than just the information on snow. For instance James Marr in Boise received information from the U. S. Forest Service and the Sun Valley Lodge. Listeners to Winter Sports Broadcast on December 31, 1937 over KIDO in Boise would have heard that a new ski lift and two new ski hills would open at the Payette Lakes winter sports area. At Sun Valley the University of Washington and Dartmouth College competed in a ski meet. Marr encouraged McLaughlin to include the Sun Valley forecast in the broadcast from San Francisco since the lodge drew many of its patrons from the West Coast, and in fact preferred them to local clientele. He wrote to McLaughlin, "In fact, the presence there of local people is looked upon as an obligation rather than an asset. That is, they are taken care of but their coming is not overly encouraged" (Marr correspondence).

The snow survey scored a major publicity triumph in 1942 with the appearance of "Engineers Survey Snow" in the April 1942 issue of Life magazine. Readers saw photographs of Arch Work and Jack Frost surveying near Oregon's Crater Lake. National Geographic featured snow surveys in their November 1949 issue. Arch Work assisted one of the magazine's writers, Leo Borah, in 1946 when he transported Borah to Crater Lake in a "Sno-Cat." Work suggested to Borah that a trip from the California-Oregon border along the crest of the Cascade range to the Columbia River would provide National Geographic with a splendid article. The Tucker Sno-Cat Company furnished the transportation and a mechanic-driver (the son of the owner) for the 23-day trip. The party of seven included Work, writer Andrew H. Brown, National Geographic photographer Jack Fletcher, SCS photographer Robert F. Branstead, Jasper Tucker, Harvey Woods, and Gaeton Sturdevant. The trip commenced in mid-March presumably after the heaviest snows. But snow fell all but two days during the trip. It snowed about ten feet along the journey. While publicity was an unannounced motivation, there was an operational objective. During the snow surveying season, surveyors ascended to various points near the crest of the Cascade range from the valley floor. The snow survey group had conjectured that one trip along the spine of the range in "Sno-Cats" might be a more efficient method of surveying. The trip convinced the group to stick with the earlier method (Work, n. d.; Brown, 1949).

ACCURACY OF FORECASTS AND IMPROVEMENT OF METHODS

Some of the long-time users of snow surveys in the West were dedicated believers in their value. After the beginning of federal coordination in 1935, the snow survey supervisors added new cooperators and users rapidly. Credibility with these new users rested on the reliability of forecasts. The group chose to use the percentage method developed by James E. Church, which assumed that normal snow cover produced normal runoff. Snow course measurements were correlated with streamflow data collected by the U.S. Geological Survey and used in succeeding years to predict streamflow from the snow course measurements. The method assumed that the most important factor was precipitation and that losses could be grouped together and given a fixed value depending upon the particular watershed. The accumulation of several years or decades of records would supply values pertinent to the watershed. (Clyde, 1939). Snow surveyors believed they needed at least 10 years of data for reasonably reliable forecasts (Work, 1898).

However, where there was no historical record, and there was none for many of the courses, the methods sometimes did not work well in the seasons of subnormal or above-normal rainfall. In these cases when the forecast was off it could be off 30 to 60 percent; in a few cases it was off by 100 percent (McLaughlin, 1943). Also the reliability of forecasts varied from one region to another, as the forecasters quickly realized when they moved into the southwest. The variability of spring and summer rainfall meant that forecasts for New Mexico generally had a 55.7 error rate (Beaumont, 1957).

Early snow survey supervisors realized there were many factors which could influence total runoff as well as distribution, but which were not taken into account in the percentage method. The proceedings of the Western Interstate Snow-Survey Conference, later the Western Snow Conference, included numerous articles on attempts to accommodate these various factors in forecasting.

First of all, not everyone agreed that snow surveys were the best indicators of streamflow. The Weather Bureau maintained that precipitation, even if it came from the valleys rather than the mountain, was just as good an indication. In commenting on a paper by George D. Clyde and Arch Work at a Western Interstate Snow Conference in 1943, Merrill Bernard of the Weather Bureau's Washington office made the case for relying on precipitation:

> It is not in accord with known facts to discredit the "Valley Station" as a significant index to precipitation at higher levels. Precipitation-events (storm periods) have within themselves a unity which expresses itself in a high degree of dependency of precipitation measured at points of different elevation (including those below and within significant distance of the average snow-line), even though the character of the precipitation (rain or snow) is different at the points compared (Clyde and Work, 1943, Discussion by Bernard).

While the snow survey supervisors disagreed with this attitude, they did come to acknowledge the value of snow course below the permanent snow pack.

Low flows, peak flows, distribution of flows concerned users for a variety of reasons and involved many interrelated and complicated factors. On rivers without large storage reservoirs, the concern of irrigation farmers was not merely the total supply but the daily distribution of flow. Using historical records for the Logan, Ogden, Weber, and Provo Rivers in Utah, George D. Clyde developed a daily hydrograph and was then able to relate it to forecast curves (Clyde, 1939). One result of this concern was that the groups began forecasting for the date of the low flow in addition to the streamflow forecasts for April through September (Work, 1989).

Operators of multiple-purpose reservoirs particularly needed information about total flow and peak flow so as to make the maximum use of reservoirs for flood control, irrigation water storage, and hydroelectric power production. Fred Paget of California's Division of Water Resources believed temperatures at low elevation stations could be indexed to mountain temperatures and be used to assist in operation of reservoirs for flood control on the Kings River (Paget, 1943). Quite a number of the Soil Conservation Service group, such as Arch Work, Moreley Nelson, and others in university and state agencies, published various articles pointing out the influence of soil moisture, groundwater levels, rainfall and temperature on streamflow. Work summarized many of the considerations in his Stream-Flow Forecasting From Snow Surveys (Work, 1953). Collectively the early group of snow surveyors knew many of the factors that influenced runoff. Essentially, they knew the right questions to ask. Relying on monthly snow surveys, however, did not give them timely information on soil moisture, temperature and precipitation. The current SNOTEL system can provide not only the information on snow pack but also information on precipitation, temperature, soil moisture, and other factors on a timely basis to be use in forecasting. More powerful computers allow forecasters today to assess the relative importance of various factors in streamflow.

USES OF SNOW SURVEYS

Although water supply forecasters perceived a need to refine and improve forecasting methods, the percentage method was sufficient to make dramatic demonstrations of the value of snow surveys. The forecasters gradually accumulated examples of the value of snow surveys. George D. Clyde of the Utah Agricultural Experiment Station had made the most dramatic demonstration of the value of snow surveys. Clyde's April 1934 forecast predicted most watersheds in Utah would receive only 25 to 50 percent of their normal streamflows. The governor immediately made Clyde his special representative to contact all the water users to assist them in developing plans to use the limited amount of water that would be available (Clyde, 1934). Evidently Clyde performed admirably in getting farmers to adjust their planting schedules and acreage planted. This demonstration was one of the reasons Congress provided for federal coordination of snow surveys. In the late 1940s Clyde, a longtime professor of engineering at Utah State University, became the head of the Division of Irrigation and Water Conservation in the Soil Conservation Service. He moved the office from Berkeley to Logan, Utah.

The snow survey supervisors gradually added to these examples and used these in their publicity. Agencies doing construction and rehabilitation work on rivers needed streamflow information in order to determine the type measures needed to protect the construction. When the area below Elephant Butte Reservoir was going to be worked on in 1942, New Mexico wanted to know the total runoff from the Upper Rio Grande into the Elephant Butte Reservoir. The prediction was 1,941,000 acre-feet and the actual total was 1,938,000 acre-feet. Another forecast of the flow of the Columbia River allowed the Corps of Engineers to avoid unnecessary protection work for their construction near The Dalles (McLaughlin, 1943).

Even the most ardent believers in snow surveys could not predict all the uses. They received inquiries, especially in times of water shortage, from financial institutions, mercantile companies, eastern wholesale houses, power-companies, mines, municipalities, navigational interests, and agriculture (McLaughlin, 1943). In agriculture of course the main interest was in being able to adjust the timing as well as the amount of acreage planted. The sugar-beet companies soon learned to await the water-supply forecasts before signing contacts and adjusting the acreage contracts to the forecasts (McLaughlin, 1943.) In 1946 snow surveys in early spring indicated that the water supply for Deschutes and Cook Counties, Oregon greatly exceeded normal. Farmers were able to plant an additional 6,500 acres of land. The value of the produce was about $500,000 (Work, 1953). The information was particularly valuable in operating multiple-purpose reservoirs which stored irrigation water as well as producing some hydro-electric power. With good information the reservoir manager could maintain the maximum irrigation water and use the surplus to produce power for sale.

FLOODING

Although the water supply forecasting group was not to be involved in flood forecasting, the value of the forecasts for determining volume as well as peak flows was recognized. In fact the early reports mentioned specifically the flood hazard. The value of snow surveys for assisting in flood prediction was made dramatically evident in the Columbia River flood of 1948. The May 1 1948 forecast by James C. Marr from Boise, Idaho read:

> Retarded snow melt and above normal precipitation during April will increase the amount and rate of runoff throughout the northern and western parts of Columbia River Basin. The outlook a month ago in these areas for greater than normal runoff with possible flood hazard has changed to certainty of runoff of flood proportions with attendant damage in vulnerable areas.... Also extra high water may be expected on all of these streams during the latter part of May and June. This same situation may also extend to lower Columbia River.

The 1948 Columbia flood resulted in more than 50 deaths and property damage of 100 million dollars. (Clyde and Houston, 1951).

The weather in 1948 provided the exact combination for flooding. The snow cover was above normal in water equivalent. There was cold weather during the early part of the melting period, followed by above-normal temperatures in the latter part of the melting period followed by above-normal precipitation during the melting period. The Columbia River flood of 1948 had all of the above conditions. Arch Work used this and other conditions in writing Stream-Flow Forecasting From Snow Surveys (Work, 1953).

The snow courses provided information from the higher elevations, above the line where melting usually occurred in the winter, while most of the Weather Bureau's precipitation data stations were located in the lower elevations. Regardless of the agreement on flood forecasting, the important fact was that the operators of reservoirs, namely the Corps of Engineers and the Bureau of Reclamation, used the information in storing and releasing water. According to the Corps of Engineers and the Bureau of Reclamation, warnings in 1950 allowed the operation of reservoirs so that $5,600,000 in flood damages could be avoided (Clyde and Houston, 1951). The 1950 estimates had been for heavy snow pack. During 1956 the Corps of Engineers believed they had saved 37 million in flood damages by taking protective measures due to the water supply forecast (Beaumont, 1967). SCS believed that water supply forecasts had been used to avert $70 million in flood damages along the Columbia during the period 1956-1962 by use of reservoir control (Work and Shannon, 1964).

Another case of using snow surveys to lessen flood damages occurred in 1954 on the Kootenai River in Idaho. The April 9 forecast mentioned a potential flood and the May 10 survey predicted a 35.5 foot river crest. The town was evacuated and the dikes reinforced with the assistance of federal troops. The river crested at 35.55 feet (Work, 1955).

The Bonneville Power Administration, in the early 1970s, estimated an annual value of $385,000 for power generation in three reservoirs studied. The U. S. Bureau of Reclamation in 1968 estimated they had avoided $495,000 in flood damages from Bull Lake, Pilot Butte, and Boysen Reservoirs in Wyoming. Similarly the Salt River Project believed it had prevented $600,000 in flood damages in 1960. The snow survey was used to operate the reservoirs in the Columbia River Basin. The average annual savings between 1956-1962 was 9.8 million (Soil Conservation Service, 1973).

MATURATION OF PROGRAM

By the late 1940s the program had reached a high degree of maturation. In 1948 the Division of Irrigation and the cooperating agencies made forecasts at approximately 176 gaging stations. About 1,000 snow surveyors made 2,400 different surveys at 950 courses. There was equipment to be repaired and cabins to be built, maintained and stocked with food. As soon as surveys were made the information had to be tabulated, forecasts made, and meetings held with forecast committees and local groups of water users.

Snow survey supervisors made forecasts for the Columbia River Basin (5), Rio Grande River basin (4), Oregon (4), Utah (1), Nevada (2), California (4) by the California Division of Water Rights, Colorado River Basin (4), Missouri & Arkansas River Basin (4), Montana (3), Arizona (3), and British Columbia (4) by the British Columbia Government.

Snow survey supervisors sent out 5,000 mimeographed copies of forecasts. Just as one example of publicity within a state, 56 Oregon newspapers and 13 radio stations publicized the results. At least three magazines published reports covering the entire West, Reclamation Era, Western Construction News, and Electrical West (Work, 1948).

At the end of the first two decades, the snow survey supervisors were generally pleased with the operations. They wanted to expand the system of forecast committees but believed that additional information snow survey personnel would be needed. One goal of the group in Arch Work's words was to "provide dependable streamflow forecasts for the benefit of farm operators on the smallest tributaries and on downstream industrial developments on major streams" (Work, 1948). The accumulation of data for over ten years made some of this possible, but the group was beset by the time-consuming calculations necessary to deal with the mass of data.

The snow survey supervisors continued to test and promote different modes of mechanizing the snow surveys. They tested over-snow machines produced by private as well as government agencies. They made more use of airplanes to reach high-altitude snow markers. In time the water supply forecast group helped develop some of the technology to gather information more rapidly and easily.

Current technology, rather than diminishing our appreciation of snow survey achievements in the decades from 1930 to 1950, helps enhance it. Working with a meager budget, but much cooperation, the snow survey group along with California's Division of Water Resources proved the feasibility of regionwide snow surveys and set the stage for public support of mechanization of the operations.

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