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Snow Survey Provides Basis for Close Forecast of Watershed's Yield

Rapid and Economical Methods of Measuring Large Areas of Snow at High Altitudes Prove Useful at Lake Tahoe, Nevada

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IN THE SPRING of 1909, the staff of Mount Rose Observatory of the University of Nevada inaugurated a system of snow surveys over limited areas by following contour lines and making measurements of water content at regular and frequent intervals. Since that time, however, such surveys have been confined to typical slopes, for the purpose of investigating the larger problems of the influence of mountains and forests on the conservation of snow. This work has been carried on mainly in the basin of Lake Tahoe, in the heart of the Sierra Nevada Mountains.

The basis measures approximately 20 x 30 miles, the watershed extending 5 miles from the lake on every side except the south, where it extends 10 miles or more. The watershed rises at one point 4675 ft. above the level of the lake and has a mean elevation above it of 1275 ft. The slopes of the watershed are complex and the forest cover varies from dense fir to low manzanita and sparse sagebrush. The snowfall, which naturally varies with elevation, also varies greatly at similar levels.

Lake's Level Closely Predicted

In the spring of 1912, in a definite effort to determine the water content of the entire basin, one observer and assistant, by means of motor boat and explorers' camp, succeeded in a total of three week's work in obtaining sufficient data to enable L. O. Murphy, hydrographer of the Truckee River General Electric Company, which controls the outlet of the lake, to estimate within 0.1 ft. the actual maximum level of the lake for the following summer.

The result was made possible more by the instruments employed than by refinement of method. The lightness and efficiency of the Mount Rose sampler and weigher, shown in the drawing, made ascents of 3000 ft. possible in a single day, with sufficient time en route to obtain from 50 to 60 measurements of depth and water content of the snow. The water content of a sample is determined by weighing the tube and its core upon a spring scale, the dial of which is ruled to indicate the depth of water instead of its weight. Rapid and complete measurements were possible under all conditions of depth and density, and so precise were the sampler and spring balance that both depth and water content could be determined to tenths of an inch. By thus combining precision with multiplicity of measurements the average snow on the ground in the immediate region could be accurately determined, irrespective of local peculiarities such as trees, brush, ravines, etc., or irregularities in water content due to drifts, hollows, and the uneven settling of the snow.

THE TWENTY-FOOT SNOW SAMPLER

General Method Pursued

The general method pursued was to determine the water content of the snow on typical slopes and under characteristic forest covers, making each topographic unit as large as possible. Measurements were made in sufficient sections of the basin to determine the local difference in snowfall, and enough courses at high levels were measured to determine the relation of the snowfall on the higher slopes of the watershed to that on the floor of the basin. The courses did not always follow contour lines but were frequently diagonal, and sometimes vertical to them, being so laid as to determine the water content of the slope in question. On occasions, courses have been laid for 2000 ft. or more directly up the face of a mountain, particularly when the rate of increase in snowfall with elevation was being determined. If avoidable, no course had less than 25 measurements and one had as many as 59. The distance between measurements was kept uniform. Thus the average of the measurements of any course could be taken as a fair representative of the average depth of the snow over the entire slope.

In the survey of the Tahoe watershed 33 courses were measured. Most of these were on the western side of the lake, where the snowfall is heaviest, and were distributed equally along the entire watershed from north to south, for the local differences in precipitation vary from 37 to 66 per cent between the center and the north and south ends. The snowfall on the eastern side of the basin is much lighter and required proportionately fewer courses. The highest course in the basin was at the elevation of 2775 ft. above the lake.

The courses were afterwards plotted on a topographic map and the average snow cover of the entire basin was computed from the known area of the region. The losses by evaporation were computed on the basis of losses as in previous years.

Measurements usually were made later at the higher levels instead of on the floor of the basin, for melting begins there somewhat later than below, and the snow also continues to fall there somewhat longer.

The snow on the ground at the time of this survey was only 70 per cent of that found in 1910, a year nine-tenths normal. The maximum depth of snow found in the regular courses was 98 in. in 1912 and 129 in. in 1910. Depths of 210 and 250 in., however, have been found at a few points in the basin.

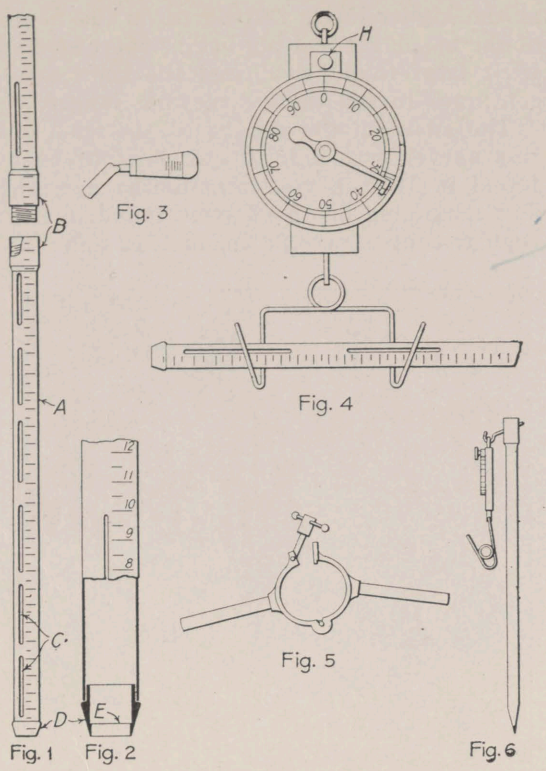
PAN IN PERFECT CONDITION AFTER SNOW STORM

Advantages Over Contour-Line Surveys

The advantages of the method of snow-surveying described are evident. It is a practical substitute for the method of contour-line surveying, which is too expensive to put into operation. It will greatly increase accuracy in estimating the water content of the snow over large areas and probably at no greater expense than required for the maintenance of isolated snow observers. The work also can be centralized in the hands of fewer and probably more capable observers. Although the presence of a lake in the basin measured made access to its various portions easier, most basins are accessible from some adjacent settlement that can be reached by the usual methods of winter travel. Considerable climbing on snow-shoes is necessarily involved, but with a sampler and weigher of sufficient range and lightness an ascent of 3000 to 5000 ft. can be made in a long day and time be left to make 50 or more deep measurements en route.

As the quantitative relationship between the snowfall at the higher levels and at the lower becomes better known, it may be possible to compute the actual snowfall at the higher levels from what might be called the symptomatic snowfall at the lower. The rate of melting and evaporation at the higher levels can also possibly be determined in like manner in terms of the weather. The data on these points, however, are thus far both meager and conflicting.

The survey of 1913 has domonstrated the general accuracy of snow surveying and the superiority of field work over routine measurements at a single station in the basin. Owing to delay in arranging cooperation with the interests using the waters of Lake Tahoe, the survey was not begun until April 11, when the snow at the lower levels was already partially melted. However, the survey at the higher levels was extended considerably beyond the lim-



DETAILS OF SNOW SAMPLER USED IN LAKE TAHOE BASIN

its of the survey of 1912. Thirty-one courses in all were measured and 725 separate measurements made, yet only two and one-half weeks were spent in the work.

The excess of snow (in water equivalent) over that of 1912 was approximately 30 per cent, the averages at four points in the basin being: Spooner's Ranch, 27 per cent (based upon depth only); Ward Creek, 33.6 per cent; Rubicon Park, 34.2 per cent; Mount Tallac, 32.6 per cent.

The rise in the level of Lake Tahoe over that of 1912 was only 0.35 ft. or 30.4 per cent, the accuracy of the forecast based on the snow measurements being thus well within that attained in 1912. According to the measurements made at eight stations of the U. S. Weather Bureau, the average precipitation of the entire basin at the level of the lake was 22.6 per cent greater than in 1912.

Value of Field Measurements

The value of field measurements over measurements at a single station is demonstrated by the fact that at Tahoe City, where is the principal snowfall station on Lake Tahoe, the local precipitation indicated an excess of 86.6 per cent over 1912, whereas the snow survey indicated an excess of only 33.5 per cent (including Spooner's, 31.9 per cent), or within 10.9 per cent of the excess indicated by the average of the measurements of precipitation at the eight stations of the Weather Bureau on the lake, and within 3.1 per cent of the level actually attained by the lake itself. Furthermore, the expense of the survey was considerably less than one-half of the amount necessary to maintain the eight stations. It is, of course, true that these stations furnish climatic statistics of precipitation, measured storm by storm, and of snow on the ground, measured month by month, which the snow survey, if restricted to the time of melting, cannot do.

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Owing to the unusually heavy precipitation at Lake Tahoe in 1914, the snow survey of the Tahoe Basin was made as early as February to forecast the level of the lake in abundant time to release the surplus water without flooding the ranch lands below. The level of the lake had already risen 2.2 ft. above the minimum in the autumn.

The relation of the water equivalent of the snow on the west side of the basin, where the heaviest precipitation falls, to that of 1913 was found to be as follows:

Relation of Water Equivalent of Snow

	1913, inches	1914 inches	1914 per cent of 1913
North End	29.03	57.93	199.6
North Central	19.09	37.76	197.8
South Central	30.22	53.09	175.7
South End	22.27	44.85	201.4
Average percentage			193.6

The rise of the lake in 1913 (on the assumption that the gates were closed) was 1.5 ft. On this basis, the rise for 1914 should have been 2.85 ft., or 5.05 ft. above the autumn minimum, leaving a reserve of 0.95 ft. below the maximum level. Since February additional precipitation has fallen, amounting to 5 in., which with a subsequent rise of 0.2 ft. in the lake level, should make a total rise for the season of 5.5 ft., or slightly less, if allowance be made for increase in evaporation during the unusually clear weather of February and March.

1913-14 compared with 1889-90

A rough check upon the present estimate is furnished by the season of 1889-90, when, as in 1914, the precipitation was unusually heavy and the run-off influenced by two dry years preceding. The precipitation for 1889-90 and 1913-14 appears from markings of snow level on the trees to be approximately equal. In the former season, the lake rose "one or two inches less than 5 ft." above its minimum level of the preceding autumn, or within approximately 0.5 ft. of the estimate of the level for the present season.

The assurance to the property owners on the lake that their lands would not be flooded and to the power companies and ranchers that their source of supply would be abundant fully justified the survey.