

SNOW MEASUREMENT PRACTICES

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INTRODUCTION

Snow is one of our most valuable resources. It is the major source of fresh water in northern countries. It also provides recreation and protects vegetation. Snow may also cause serious damage and inconvenience. Heavy snowfall may damage structures and obstruct transportation; its melt waters may produce or contribute to devastating floods. The efficient and economic use of this valuable, but sometimes treacherous resource, and the control of runoff depend on our understanding its characteristics through measurement.

The time is now opportune to critically review measurement practices. Resource management and development is resulting in an accelerating demand for more and more precise measurements. Our limited manpower and economic resources necessitate that we have a very meaningful measurement program if we are to meet the demand. Measurements must be made with a purpose, intelligently and efficiently making full allowance for our changing requirements and technology.

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PLANNING

Objectives must be kept clearly in mind when developing a measurement program. The network density type, frequency and accuracy of measurement must be specified to meet the stated objectives. Regional and national interests must also be kept in mind. To satisfy the increasing demand for measurements and to have measurements which are comparable from one location to another it is desirable to integrate programs and standardize on equipment and procedures whenever possible.

Most snow courses have been developed to aid in predicting streamflow volumes and peaks. Such measurements are used as indices of runoff and consequently the values need not be representative of a broad area, or absolute values. What is necessary is that the procedures, instruments and site exposures remain constant and that the observations indicate the variability from year to year.

Watershed research problems, on the other hand, frequently require that the total mass of snow on a watershed be known. The heterogeneity of snow cover is generally such that only an estimate, sometimes called an "absolute estimate" of this amount can be obtained. Measurements for these problems must generally be precise, and representative.

Still other measurements of water-equivalent and depth are used to solve problems in agriculture, recreational activity, etc. The use and application of these data are highly varied and are not discussed further here.

The following steps should be considered in developing a measurement program:

- (1) define the problem,
- (2) determine what information (quantity and quality) is needed to provide the answers within the desired levels of accuracy,
- (3) ascertain the usefulness of information available from other sources and therefore what additional information must be obtained,
- (4) program to obtain the necessary additional information,
- (5) plan to continually evaluate the measurement program and modify it as required.

It is only after observations have been taken that it is possible to evaluate the usefulness of a measurement network. If it is found that the data do not satisfy the objectives, then the program and/or objectives must be changed.

Economics, access, and manpower may also make it necessary to change objectives.

Indices

The best index to water yield or peak flow is likely to be given by measurements of those areas of major snow accumulation which are immediately adjacent to the river channel, and which have the highest runoff coefficient. Areas of major accumulation may be identified by aerial photography taken following early spring melting. The areas contributing most to streamflow may be identified from morphological considerations.

Courses should be established in each, relatively homogeneous area which contributes substantially to streamflow in a distinctive manner. Forested and non-forested areas, northeastern and southwestern slopes may each require courses because of the differences in runoff timing and rate likely to be found in each case. Sampling points need not, therefore be placed at representative sites, or apportioned according to vegetative cover. There are significant hazards in sampling too close to trees, e.g. secular change, the effects of fire, disease, and radiant exchange between trees and snow cover. Instead of "hybrid" courses it may be preferable to have one good index for each hydrologically-distinct, contributing area.

A large number of sampling points are used on many courses, (up to 50 on Canadian courses). The need for this number is open to question. For example, Wilson (1966) found that out of 40 courses with 15 to 40 sampling points each only in one case did the snow course average provide a better index of streamflow than an individual sample within the course; and in three cases the results were identical. There is merit in sampling at many representative points; but it is apparent that bad points are also being sampled, and that the data from these are detracting from the good measurements. Continuing evaluation would eliminate the continued collection of poor data, and probably greatly reduce the time and effort placed in snow surveys.

Wilson's (1966) findings are very encouraging since they indicate the potential of good single-point observations. Aerial snow markers, placed at sample points which correlate highly with streamflow, may provide an index which is equally useful as the snow course average. The same is true of pressure pillows and radioactive isotope snow gauges. The automation or simplification of snow surveying is, therefore within our grasp. We must be alert to the possibilities arising from new developments and not tied inextricably to traditional data collecting procedures.

Survey data used as indices, need not be exact. What is important is that any bias, due to the instrument, procedure or other cause, be in the same direction and proportion from year to year. The accuracy of the instrument is not important if the bias is constant; however it is highly desirable that a standard instrument be adopted, thereby obviating the need for conversion of data. Both survey and climatological measurements are subject to instrument, observational and systematic error. This does not impair the usefulness of these records as indices provided standards of measurement, observation and exposure of sampling sites are maintained.

The possibility of using climatological measurements of snowfall and snow depth should be considered in planning or evaluating a snow measurement network. Climatological data may be manipulated either by accounting, or by depth-density relationships, to useful estimates of water equivalent. These records may also provide history which is unavailable from other sources. There is a good possibility that these records alone may satisfy some needs. In other cases they may provide a useful supplement and reduce survey requirements. Considering the cost and effort required to adequately measure our snow resources, the possibility of using climatological data should be given serious consideration.

Absolute Estimates

Absolute areal values of snow cover water equivalent over a watershed are not obtainable by present methods; however they may be estimated with some skill.

Random sampling procedures may be used for small areas. The traditional snow course is then replaced by a random pattern of point samples, the number of which is dependent on the area and the snow cover variability.

This procedure may be simplified in areas which have uniform topography and vegetative cover. The areal variation in snow cover density is frequently small in such areas. A large number of snow stakes and a few density samples may then be used in place of large numbers of depth-density or water equivalent measurements.

If the watershed is large, stratified random sampling may be used to estimate the basin water equivalent. Sampling is carried out in source areas which are characteristic of large sections of the watershed. Watershed inventories and general networks are required to establish what areas respond in a manner similar to the source area. The number of source areas to be sampled may be substantial if stratification is made according to all physiographic and vegetative features.

Photogrammetry combined with density sampling provides another means of obtaining absolute estimates of the snow cover water equivalent.

Absolute estimates require measurements which are free from instrumental, observational and exposure errors. Great care must be taken in the selection, operation and replacement of instruments, and in the interpretation of the data. Instrument performance must be evaluated, and sources of bias minimized.

The performance of both the network and instruments is not known until after a period of adequate observation. The measurements must be subject to a continuing review to ascertain the adequate performance of both, and to ensure that the necessary information is obtained in the best form and in the most efficient manner consistent with limitations imposed by manpower and economy.

CONCLUSIONS

The measurement of snow cover in quantity and quality sufficient to meet the needs for resource use and development is a challenging problem which requires efficient use of manpower, funds and technology. Measurement procedures should be continually reviewed to ensure:

- (1) that the needed information is obtained in the most appropriate form and with required precision,
- (2) that time, funds and energy are not wasted in the collection of data which is redundant, impaired, or possibly insufficient in quantity,
- (3) full use of alternative procedures and data sources.

REFERENCES

Wilson 1966 Determination and Uses of Best Individual Sampling
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