USING ALL AVAILABLE HYDROLOGIC DATA

By

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Introduction

In hydrology most of the underlying physical processes are extremely complex, and continually varying with time and from one place to another. Thus, although an understanding of the physical processes is necessary, applied or engineering hydrology is largely empirical in nature and is probably best considered as the management of information. The design of hydrologic data collection networks should therefore be approached with the questions: What information do we need? and What is the most efficient method of obtaining it?

One of the basic difficulties in managing hydrologic information is that there are different types of hydrologic data which are not directly comparable. For instance, at snow courses measurements are made of the accumulated snow at specific points, at specific times, whereas streamflow data is usually recorded continuously and it integrates the information on runoff from whole drainage basins. In theory one type of data should complement another but in practice it has been difficult to make full use of different kinds of data, for quantitative purposes.

A new method for simultaneously using meteorological and streamflow data to estimate the distribution of mean annual runoff over large areas has recently been developed by Soloman et. al. (1) and applied in Eastern Canada. The technique, referred to as the grid square method, represents one very promising tool for the management of hydrologic information. This paper presents the results of a study (2) made to check on the applicability of the technique to an area in British Columbia, and extend it to make use of snow course data in addition to meteorological and streamflow data.

The grid square method

The grid square method is somewhat analogous to finite element methods in structural engineering. The drainage area is broken up into a number of squares and physiographic parameters such as mean elevation, distance from the sea, etc. are determined for each square and for each meteorological station. Mean annual precipitation and temperature are correlated with the physiographic parameters using stepwise multiple regression and from the resulting regression equations values are computed for each square. Mean annual evaporation from each square is next computed by Turc's formula: (3)

$$E = \frac{P}{\sqrt{0.9 + \frac{P^2}{L(t)^2}}}$$

Where $L(t) = 300 + 25t + 0.05t^3$

E = Actual annual evaporation (mm.)

P = Annual precipitation (mm.)

t = Mean annual temperature ($^\circ$C)

Runoff from each square is obtained by subtracting the computed evaporation from the precipitation and total basin runoff is then obtained by summing the runoff from all the constituent squares (and partial squares). If the computed runoff disagrees with the recorded runoff the precipitation in all squares is adjusted by a factor to give the correct total runoff (assuming the evaporation remains unchanged). A new set of regression equations is derived using both the original meteorological data and the adjusted precipitation for each square. From these equations new estimates of precipitation are made for each square and the whole process is repeated until the computed and recorded runoff values

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agree to within some specified tolerance. The process usually converges within a few iterations and the final results provide estimates of average annual precipitation, temperature, evaporation and runoff for each square in the basin thus providing data on the areal variation of these parameters.

The usefulness of the method obviously hinges on the accuracy of Turc's formula and on how well the stations define the pattern of precipitation over the basin. In the iteration process the statistical independence of the data is lost and standard statistical tests cannot be applied. The results can therefore only be rigorously checked by comparison with independent data from sub basins i.e. data which has not been used in the computations. However, indications of the accuracy of the assumptions about evaporation and precipitation can be obtained from the first estimate of runoff and this was the method used since independent data was scarce.

The study area

The South Thompson River Basin shown in Fig. 1 was used as the study area since the grid square method had already been applied to this basin (4) and the data were available. It is also one of the few areas in British Columbia where there are sufficient meteorologic and hydrologic data for a meaningful study. The basin has an area of 6,350 square miles and it is divided into squares by a 10 kilometer grid. There are 212 squares completely or partially within the drainage basin and a total of 37 precipitation stations, 15 within the basin and 22 around the periphery; of these 28 also have adequate temperature records. There are 4 stream gauges which were operable during 1956-66, the 10 year base period selected for the study.

Physiographic parameters used were: mean elevation, determined by averaging the elevations at the corners, the intermediate 5 kilometer points and the centre; land slope, determined by Horton's method of counting the contour lines crossing the North South and East West centre lines of each square; distance to main moisture barrier, determined as the distance in a South West direction (the direction of predominant moisture inflow) to a line drawn through the centre of the Coast and Mountains; latitude, taken as the distance from the U. S. border; and shield effect, determined by summing the average barrier heights for 28 miles, again in a South West direction.

Stepwise regression was used and only those parameters significant at the 1% level were retained in any equation, except that in a few runs elevation was considered to be important and was retained in all equations regardless of its statistical significance.

Evaporation

Turc's formula is empirical, but widely used and more convenient for estimating average annual actual evaporation than any other method. An attempt was made to check directly on its applicability to the interior of British Columbia but due to the rugged topography and scarcity of data it was not possible to estimate actual evaporation over any representative drainage area or even at any one point with sufficient accuracy. Since the only other suitable method appeared to be Thornthwaite's (5) the two were compared by trying both in the grid square method and comparing the results. The comparison was based on the first estimate of runoff since otherwise the iteration process would have destroyed the basis of comparison.

Since Thornthwaite's method involves water balance computations on a monthly basis, regression equations relating temperature and precipitation to the physiographic parameters had to be computed for each month.

A typical equation is

$$PJ = 5.4 - 0.047DB + .00018DB^2 - 0.000038L^2$$

where PJ = Precipitation in January
DB = Distance to Barrier)
L = Distance to U. S. Border) In Kilometers

The formulae and procedure for the computation of evaporation for each square were those given by Cavadias (6). Several values for the soil moisture storage capacity were tried

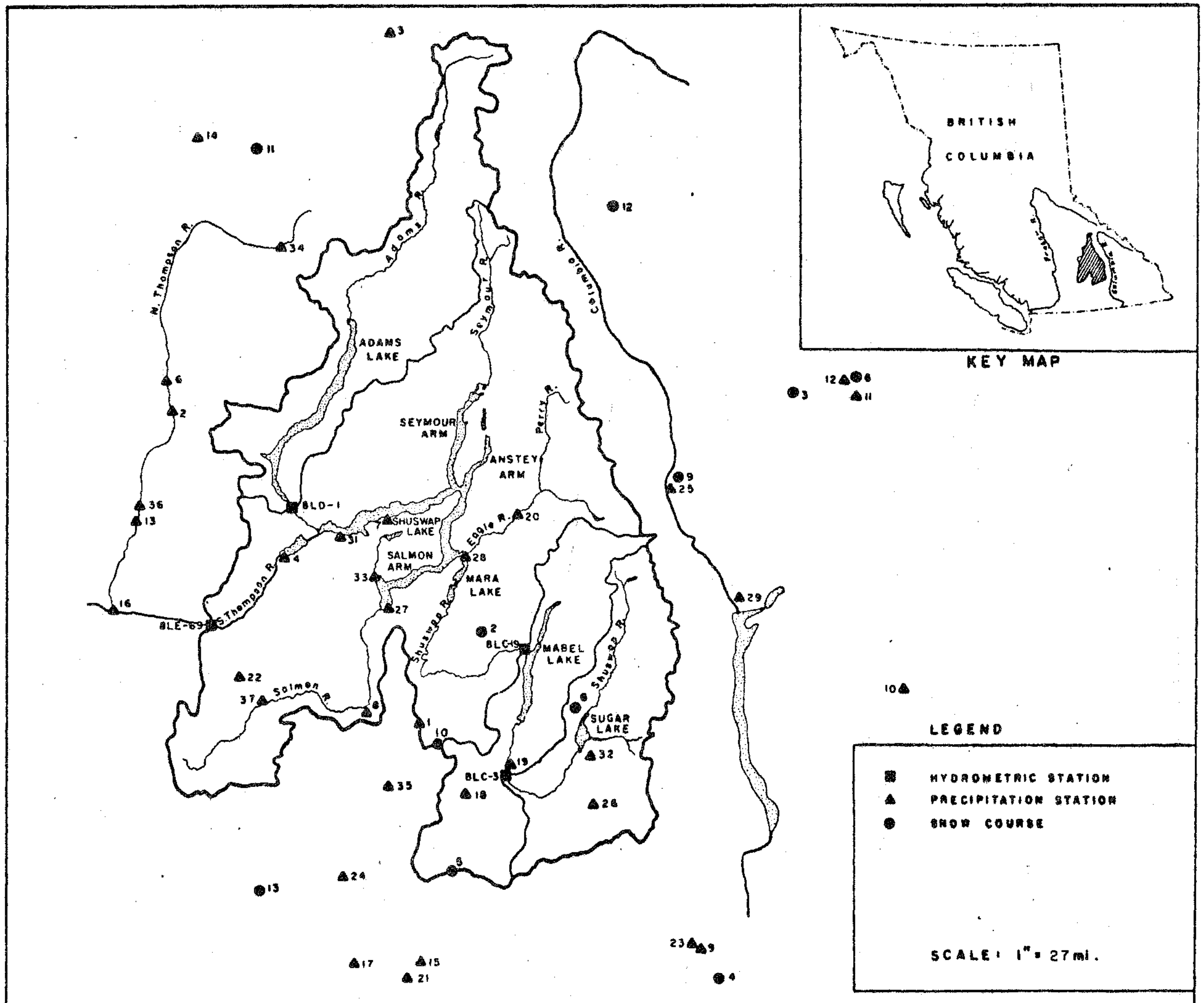

FIGURE I SOUTH THOMPSON RIVER BASIN HYDROMETEOROLOGICAL STATIONS.

but since it was found that results were insensitive to the actual value a standard value of 14" was used. The results of the comparison are given in Table 1.

Table 1. Comparison of first estimates of runoff

River	Drainage area	Recorded flow (cfs)	Turc's Est. flow	Turc's % Diff.	Thornthwaite Est. flow	Thornthwaite % Diff.
Shuswap	776	1800	1940	+ 7.8	1262	-29.2
Shuswap	784	1090	1548	+42.0	990	- 9.2
Adams	1156	2560	3281	+38.2	2612	+ 2.0
S. Thompson	3634	5250	7063	+34.6	4633	-11.8
TOTAL	6350	10700	13831	+29.2	9498	-11.2

The above table shows that Thornthwaite's method of estimating evaporation gives a better first estimate of runoff than Turc's formula although, a contributing factor could have been that, with the former, computations were made on a monthly rather than an annual basis. There is evidence from another study in the Stuart Basin in North Central British Columbia (7) that there are quite different patterns of precipitation in summer and winter. If this is also true in the S. Thompson basin then an annual basis may be inherently unsatisfactory.

In the calculations the variables retained in the regression equation were those which were significant at the 1% level all others being rejected. Since in many cases elevation was not retained a new set of equations was derived in which elevation was always included regardless of its statistical significance. The corresponding first estimate of runoff again using the Thornthwaite evaporation formulae, indicated discrepancies of the same order as before but this time the runoff, and hence the precipitation, values were overestimated. The influence of elevation on precipitation is therefore very significant.

Use of snow course data

In British Columbia most meteorological stations are located in the valleys and the South Thompson basin, with all stations below Elev. 4100, is no exception. Snow courses, on the other hand, are nearly all located at higher elevations and in the South Thompson basin all are at elevations above 6000 feet. Since the runoff per unit area is greater at the higher elevations, the snow courses obviously provide valuable information on the precipitation distribution.

Before attempting to incorporate snow course data, available snow pillow data were examined and an attempt was made to develop a relationship between snowmelt before April 1 and mean monthly temperatures for use with the snow course readings in computing total winter precipitation at the snow courses. The snow pillows are at Barkerville to the North and Blackwall to the South of the study area. It was found that the amount of winter melt was very small and that the April 1 water equivalent gave an estimate of the November to March precipitation good enough for all practical purposes.

Next several attempts were made to "scale up" the snow course data to obtain estimates of total annual precipitation at the snow course sites but these all proved unsuccessful.

Finally, the snow course data were taken to represent the November to March total precipitation at the snow course sites and used together with data from the meteorologic stations to establish a regression equation relating total winter precipitation to the physiographic parameters. Evaporation was assumed to be negligible during this period. For the remainder of the year monthly data from the meteorological stations were used and the runoff computed (using the Thornthwaite formulae to compute evaporation) as outlined in the previous section. The following results were obtained.

The following results give estimates similar to, although slightly inferior to, those in Table 1. Other results, almost but not quite, as good were obtained by treating the November to March period as a unit but not using the snow course data to supplement the precipitation data.

Table 2. First Estimate of Runoff

River	Drainage Area (square miles)	Recorded flow c.f.s.	Estimated flow c.f.s.	Difference %
Shuswap	776	1800	1748	- 2.9
Shuswap	784	1090	1361	+24.9
Adams	1156	2560	2852	+11.4
S. Thompson	3634	5250	6142	+17.0
TOTAL	6350	10700	12103	+13.1

All estimates could have been improved by iteration and this would normally have been the next step; but there would then have been no basis for comparison between alternatives. However, snow course data would provide good, high elevation "anchor" information which would be very valuable in the iteration process.

Conclusions

The study showed that better first estimates of runoff could be obtained with Thornthwaite's method of estimating evaporation than with Turc's formula thus indicating greater accuracy with Thornthwaite's method. However, part of the apparent disadvantage of Turc's formula may be due to the fact that it was used with estimates of annual precipitation which may have no single coherent pattern but two different patterns, one for summer and another in winter. It may be possible to modify the coefficients in Turc's formula to give good seasonal estimates of evaporation.

The study indicated that snow course data could be used together with meteorological data in deriving a regression equation for precipitation for the period November to March. On the basis of the first estimate of runoff inclusion of the snow course data did not significantly change the results but it is believed that in the iteration process use of this data would have a useful stabilizing influence.

In summary there are indications that the grid square method in its original form is not completely satisfactory for the interior of British Columbia but it can be improved by substituting the Thornthwaite method of computing evaporation for Turc's method (or possibly modifying the constants in Turc's formula) and by using snow course data to supplement precipitation data for the winter period November to May.

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