A MODERN FORECAST FOR COLUMBIA RIVER AT BIRCHBANK, B. C.

by
M. W. Nelson and W. D. Simons1/

The recent history of the Pacific Northwest in the United States and Canada has been tied to the use of the water resources of this region. In early days there were ample supplies readily available to meet all needs. The lakes and rivers were used for transportation and as a source of food. Dams and ditches were constructed so that crops could be irrigated. The energy of falling water was captured by means of dams and powerhouses so that the needs of industry might be served. Systems of dikes and levees supplemented by reservoirs provided some protection against the destruction of floods. Utilization in the early days was very simple but the continued economic expansion has led to larger and more complex projects to utilize the vast water resources of the region.

The future envisions even more complex developments and a more nearly complete utilization of these resources. Some of the schemes which are currently under investigation in the Columbia River basin stagger the imagination of even the most progressive engineers and scientists.

The days are past when there is sufficient readily and cheaply available water to meet any and all desires of the region. Modern-day projects are designed with facilities to minimize periods of critical water supply and to more effectively utilize the available supplies. The successful operation of water-use projects is dependent, to a large measure, upon the ability of the operator to anticipate and evaluate future water conditions. In this manner he may make the best use of facilities provided by the designer. Thus an accurate forcast of future runoff is a valuable tool for the operation of these projects.

This paper presents an example of a forecasting procedure that is deemed accurate enough to meet the needs of the project operators. This procedure is not a radical departure from those used in the past. It is an integration of the composite progress and imagination of many individuals and agencies collecting and analyzing the various factors which affect the runoff of our rivers Hydrologists, snow surveyors, meteorologists, and statisticians all have contributed directly to the development of the modern forecasting procedures.

For many years the Water Resources Division of the U. S. Geological Survey and the Water Resources Branch of the Canadian Department of Northern Affairs and National Resources have been collecting data on the runoff of boundary and transboundary rivers. These records have served to indicate the magnitude of the water resources and the wide fluctuations which occur from season to season, year to year and place to place. The rugged snow surveyors of the U. S. Soil Conservation Service and the British Columbia Department of Lands and Forests have worked side by side for more than 20 years sampling the snow pack. Undoubtedly during the earlier years questions arose as to the usefulness of these data, which now provide the primary factor for accurate seasonal forecasts of the streamflow indicated in this paper. Similarly, the meteorologists of the U. S. Weather Bureau and the Canadian Department of Transport, Meteorological Division, have collaborated in collecting the weather data utilized in the procedure described herein. It is gratifying to note that these programs carried on by various governmental agencies, supplemented by contributions by local interests, have progressed steadily and harmoniously through the years. It is only because of the vast background of data, collected through this teamwork effort, that hydrologic tools can be developed to make efficient use of available water supplies.

The forecasting procedure presented is relatively simple in its overall aspects. However, refinements of earlier procedures have been incorporated which makes this particular procedure an example of what can be accomplished through cooperative effort. Basically the procedure indicates that the April through September runoff of the Columbia River at Birchbank, B. C., is dependent upon the following factors: snow conditions, base flow, and precipitation during April and May. Forecasts have been developed for the first of the months of April, May and June. The same indices for snow-water content and base flow are utilized in all three procedures. For April 1 the forecast is based upon the snow-water content and base flow. The precipitation during April is utilized in the May forecast and the April plus May precipitation in the development of the June forecast. The following table presents the basic data from which these forecasting procedures were developed: (next page)

The snow-water index is based upon the average of the March and April snow surveys for the following courses: Canoe River, Field, Glacier, Sinclair Pass, Kimberly, and Fernie in Canada, and Red Mountain and Bluebird Basin in the United States. This index is the major factor in forecasting the runoff during the April through September period.

The base-flow index is the average of the base flow existing on November 1 for the Columbia River near Castlegar and of the inflow to Kootenay Lake. This has been expressed as the percentage of the 1937-51 average. It is used as an index of the antecedent conditions of the watershed. The philosophy of developing and utilizing this index was presented to the Western Snow Conference in 1953 at Boise, Idaho.2/

1/ Respectively, Snow Survey Supervisor, U.S. Soil Conservation Service, and Staff Engineer, Water Resources Division, U.S. Geological Survey.

2/ "Concept and characteristics of base flow in the Columbia River Basin," by W. D. Simons.
"Effect of antecedent base flow in forecasting runoff of the Columbia River from snow survey data," by C. C. McDonald and M. W. Nelson.
"Base flow as a parameter in forecasting the April-June runoff" by M. W. Nelson, C. C. McDonald, and M. Barton.

BASIC DATA FOR
COLUMBIA RIVER AT BIRCHBANK, B. C.

Year	Snow Water (X_2)	Nov. 1 base flow (X_3)	April precip. (X_4)	April + May precip. (X'_4)	Runoff (X_1)
1937	10.4	62.3	2.40	3.72	32.7
1938	14.6	122.6	1.79	2.88	42.4
1939	12.2	80.6	.85	2.86	38.5
1940	9.5	131.2	1.84	3.58	37.7
1941	9.1	109.2	.48	3.73	33.1
1942	8.9	144.5	1.12	5.72	38.9
1943	14.6	80.1	2.18	3.66	39.5
1944	7.6	77.0	1.29	3.16	28.2
1945	9.0	92.4	2.08	3.61	32.8
1946	16.6	77.8	2.39	3.77	47.6
1947	16.1	71.0	1.71	2.77	43.8
1948	13.8	168.2	2.86	5.34	48.2
1949	13.5	84.8	1.33	2.95	35.9
1950	17.2	69.6	2.15	3.14	46.8
1951	17.9	133.4	1.04	3.39	45.9
1952	14.0	110.0	1.42	2.87	41.6

X_1 - April through September runoff in millions of acre-feet adjusted for change in contents of Kootenay Lake.
X_2 - snow-water index, in inches.
X_3 - November 1 base-blow index.
X_4 - average precipitation, in inches, for April.
X'_4 - average precipitation, in inches, for April plus May

The spring precipitation index is based upon the average of the precipitation at the following locations: Nelson, Golden, Fernie, Newgate, Glacier and Revelstoke, B. C., and Porthill, Idaho. These are utilized only in the May and June forecasts. Precipitation during the April through September period has only a limited effect upon observed runoff for most of the years studied. The later in the season the rainfall occurs the less effect it will have upon streamflow. Two major reasons for this are (1) the rapidly drying soil absorbs much of this precipitation and prevents it from reaching the stream channels and (2) losses through consumptive use increase as the summer season progresses until it may equal or exceed the rainfall occurring during that period.

Forecasting equations were developed by statistical procedures and all of the factors are considered significant. The equations are as follows:

April 1 $X_1 = 1.59X_2 + .07X_3 + 12.1$

May 1 $X_1 = 1.50X_2 + .07X_3 + 1.58X_4 + 10.36$

June 1 $X_1 = 1.72X_2 + .04X_3 + 2.10X'_4 + 6.26$

In order to test the ability of this procedure to reproduce the original data, forecasts were developed for the 1937-52 period and are summarized below:

Comparison of forecast values

	April		May		June		April thru Sept.
Year	Fore cast	% error	Fore- cast	% error	Fore- cast	% error	runoff observed
1937	33.0	+ 0.9	34.1	+ 4.3	34.4	+ 5.2	32.7
1938	43.9	+ 3.5	43.7	+ 3.1	42.3	- .2	42.4
1939	37.1	- 3.6	35.6	- 7.5	36.5	- 5.2	38.5
1940	36.4	- 3.4	36.7	- 2.6	35.4	- 6.1	37.7
1941	34.2	+ 3.3	32.4	- 2.1	34.1	+ 3.0	33.1
1942	36.4	- 6.4	35.6	- 8.5	39.4	+ 1.3	38.9
1943	40.9	+ 3.5	41.3	+ 4.6	42.3	+ 7.1	39.5
1944	29.6	+ 5.0	29.2	+ 3.5	29.0	+ 2.8	28.2
1945	32.9	+ .3	33.6	+ 2.4	33.0	+ .6	32.8
1946	43.9	- 7.8	44.5	- 6.5	45.8	- 3.8	47.6
1947	42.7	- 2.5	42.2	- 3.6	42.6	- 2.7	43.8
1948	45.8	- 5.0	47.4	- 1.7	47.9	- .6	48.2
1949	39.5	+10.0	38.6	+ 7.5	39.1	+ 8.9	35.9
1950	44.3	- 5.3	44.4	- 5.1	45.2	- 3.4	46.8
1951	49.9	+ 8.7	48.2	+ 5.0	49.5	+ 7.8	45.9
1952	42.1	+ 1.2	41.3	- .7	40.8	- 1.9	41.6

In the period used for development of the forecasting equation, the average error for the April forecast amounted to 4.4 percent with a maximum error of 10 percent. For the May forecast the average error was 4.3 percent with a maximum of 8.5 percent. The average error for the June forecasts decreased to 3.8 percent with a maximum of 8.9 percent. This is one means of evaluating results which might be expected in the future. In addition, forecasts for the 1953, 1954, and 1955 seasons were prepared using data for these years and the equations previously developed. The comparisons for these added years are summarized as follows:

Comparison of forecast values

	April		May		June		April thru Sept.
Year	Fore- cast	% error	Fore- cast	% error	Fore- cast	% error	runoff observed
1953	39.1	- 2.7	39.0	- 3.1	39.5	- 3.2	40.8
1954	53.0	- 2.8	53.5	- 1.8	55.9	+ 2.6	54.5*
1955	38.9	-10.6	40.2	- 7.6	41.7	- 4.1	43.5*

*Provisional unpublished data.

It is significant to note that these additional comparisons line up consistently with those previously computed. This adds further faith in the accuracy of forecasts made in this manner.

The potential as exemplified by this procedure indicates that accurate forecasting techniques are being devised for parts of western Canada and United States. It is apparent that further advances can be made in improving the forecasting of seasonal runoff at other locations in the Pacific Northwest. These tools will assist in making the maximum use of the facilities which have been built into the water-use projects. It is highly desirable that the splendid teamwork of the past in collecting and analyzing data be expanded in the future. The friendly and cooperative efforts of all interested Canadian and United States agencies and individuals can be guided towards those objectives of common interest. This is not a task for a single individual or agency but it relies upon the collective efforts of all of us working together for the future.

FORECASTING POWELL LAKE RUNOFF

by
A. E. Chard[1]

Our snow course is perhaps somewhat unique to many of you in that it is so close to tidewater. To get up to the course, we start practically from scratch and in 2-1/2 miles (7 hours) of hiking we go from green grass on the edge of Powell Lake at 180 feet above sea level to as much as 12 feet of snow at the course, 3,000 feet in elevation.

All of the 580 square miles of Powell Lake watershed is within 20 miles of tidewater. In the upper reaches, which has peaks up to 7,000 feet elevation and a good deal of which is snowfields at 4,000 to 6,000 feet in elevation, the precipitation is annually around 100 inches and in some of the lower valleys at the head of Powell Lake it is considerably more. In these valleys the vegetation is very dense and the heavy hanging moss growths on the trees gives the weird effect which is also seen in the "rain" forests of the Olympic peninsula and the West Coast of Vancouver Island. Calculations show that the average annual precipitation over the whole watershed must be more than 80 inches to give the actual average runoff of 3,000 c.f.s. from Powell Lake, and this allows nothing for transpiration and evaporation losses. The fact which shows the importance of the snow pack to the runoff is that about one third of the total runoff comes directly from melting snow.

This Snow Course measurement is also used to estimate the runoff into Lois (Gordon Pasha Lakes). Its watershed areas of 184 square miles is adjacent to Powell and is comparatively close to tidewater also. It is generally lower in elevation, has less annual precipitation and less runoff per square mile, than Powell.

More than 100,000 horsepower is generated from the two hydro developments, and this power is used to operate the world's largest newsprint mill at Powell River, turning out now, more than 1,250 tons of newsprint daily. Three hundred tons of newsprint production will be added to this making a total production of 1,550 tons per twenty four hours after our new No. 9 Paper Machine gets started the latter part of this year.

How the Snow Survey Information is Used and its Value

Measurements are made twice during the winter, about January 15th and March 20th. As yet there are only three years or records for the January surveys but the measurement usually has given a very good idea of how much snow water content may be expected in March. For instance, this year we measured twenty-five point nine inches of water content in January which was high compared to the other years and the March measurement was consistent with this, in that there was 46.5 inches which is 50% above our seventeen year March average and close to the peak of fifty inches measured in March 1954.

With the indication from the January measurements we can determine how to operate our power plant until the March survey. If our Lake storage is low and the snow pack is poor we may have to use additional steam power. Also, if the lakes are very low even though the snow pack is good we may have to use additional steam power to make certain of enough water to last until the Spring runoff starts. In this latter case if the January snow pack was heavy we would only use enough additional steam power to get us by until the runoff started, but if the snow pack was low we would use all our available steam power to try to save water for the following summer and fall.

There are similar decisions to be made after the March surveys. This year even though the March snow pack was about 50% above average the Powell Lake level was so low that it was necessary to use extra steam generated power to prevent the Lake from dropping too low before the Spring runoff started. On the average the Spring runoff starts April 15th but last year, 1955, it was May 15th. This year the runoff actually started April 10th and as the snow pack was very good the additional steam generated power was shut down a few days later on April 16th, because with normal Spring, Summer and Fall precipitation, Lake elevations will not drop to dangerous levels.

Information obtained from the snow surveys is valuable in two ways:

1. In order that additional steam power generating equipment may be used in time to keep the Lake elevations from getting dangerously low and possibly causing the shut down of newsprint machines because of lack of power.

2. So that steam power generating equipment can be used as little as possible and keep costs down.

1/ Development Engineer, Powell River Company Limited, Powell River, B. C.