FORECAST STUDY FOR PRAIRIE PROVINCES WATER BOARD 1/

By

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Introduction

All natural resources, including water, were controlled by the Federal Government until 1931. In that year control was transferred to each province.

While the provinces have the proprietary right to water, the Federal Government has always had specific jurisdiction over some aspects of water use such as stream gauging, navigation, fisheries, etc. It has participated in a large number of flood control and conservation projects. The very nature of water resources in the three Prairie Provinces (and elsewhere in Canada) requires some federal involvement because most streams are interprovincial or international.

Joint federal - provincial co-ordination of Alberta, Saskatchewan and Manitoba interprovincial water resources development has been achieved through the Prairie Provinces Water Board (PPWB). Originally established in 1948, the Board granted specific allocations of water from interprovincial streams for definite projects.

The most important advancement for the long-term management and development of prairie water resources occurred with the signing of the Apportionment Agreement on Oct. 30, 1969. After several years of negotiation, a formula was developed for equitable apportionment of all waters flowing from west to east across the three Prairie Provinces.

No longer will water in these streams be allocated on a project-by-project basis. No longer does a province have to accelerate development to ensure its fair share. Each province knows that a fixed proportion of the flow is available in perpetuity. The agreement makes provision for the day when all the water available under natural conditions will be allocated and diversions become necessary to meet growing demands. No matter where these occur, all parties will share in development costs on the basis of benefits derived.

As part of the Apportionment Agreement, the three Prairie Provinces and the Federal Government reconstituted the PPWB. It is now responsible for administration of the terms of the Apportionment Agreement. Governments can utilize the new Board as a means of joint action on water problems that overlap provincial boundaries. Typical of these is the current study on hydrometeorological network deficiencies, natural flow determination and forecasting within the Prairie Provinces conducted jointly by Atmospheric Environment Service and Water Survey of Canada. Subsequent sections highlight only certain hydrometeorological aspects of the South Saskatchewan River basin forecasting study which may be of interest to professionals in this field. A major portion of the original study was devoted to identifying forecasting requirements, consolidating existing forecasts and formulating a long-range master plan for a forecasting system.

South Saskatchewan River Basin Physiography

Several topographic and climatic features complicate South Saskatchewan River runoff forecasting. Of the total 56,500 square miles gross drainage area, about 25 percent encompass the eastern slopes of the Rocky Mountains and contiguous foothills (See Figure 1). Yet this relatively small area contributes about 75 percent of the total runoff in a median year. Plains runoff is usually very low simply because precipitation is much less and losses are greater than in the mountains and foothills. Provisional estimates of mean annual precipitation and runoff, for each geographical subdivision, are contrasted below:

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Table 1

South Saskatchewan River Basin

Estimated Mean Annual Precipitation and Runoff

Geographic Subdivision	Mean Annual Precipitation (inches)	Mean Annual Runoff (inches)	Runoff as Per Cent of Precipitation
<u>Mountains</u> -			
Southern	37	20	54
Central	27	14	52
<u>Foothills</u> -	21	6 to 8	28 to 38
<u>Plains</u> -	15	0.2 to 1.0	1 to 7

The vast South Saskatchewan River basin plains are somewhat of a "bogey man" in runoff forecasting. Although their long-term contribution may be low, in certain years when certain hydrometeorologic factors reinforce each other, the plains are capable of producing a large volume of runoff. Two hydrographs are plotted in Figure 2A to demonstrate the large variation in annual runoff for a typical plains stream. Peak discharges can be as low as 10 cfs in one year, yet approach 1,000 cfs in others. Annual spring snowmelt runoff volume for three plains streams are given in Table 2.

Table 2

Early Spring Snowmelt Runoff for Three Small Prairie Streams

Year	Alkali Creek (05CK005)		Bullpound Creek (05CG002)		Peigan Creek (05AH041)		Three Creek Weighted* Percentage
	Runoff (cfs-months)	% of 1965	Runoff (cfs-months)	% of 1965	Runoff (cfs-months)	% of 1965	
1961					2.9	1.0	1
1962			2.8	7	33.4	10.8	8
1963	1.0	0.5	8.7	23	30.3	9.9	9
1964	0.7	0.5	nil	0	64	32	9
1965	195	100	39	100	310	100	100
1966	23.7	12	12.3	32	170	58	23
1967	23.0	12	34	88	178	14.2	47
1968	0.16	0.1	0.6	1.5	44	55	5
1969	177	91	10.5	27	170	32	64
1970	8.5	4.5	24	62	100		30

* - Station weights are: 0.4 x Alkali Creek
0.3 x Bullpound Creek
0.3 x Peigan Creek

Development of mathematical forecasting relationships is greatly complicated because of this extreme variability in plains runoff. This is partly attributable to excessive winter snowpack EVSUB occasioned by Chinooks. Figure 28 provides a general idea of the high incidence of winter Chinooks in Southern Alberta. A further complication is the lack of certain basic data (such as soil moisture) essential to establishing the proper relationships between runoff and the various hydrometeorological parameters.

<u>Basic Data Networks in the South Saskatchewan River Basin</u>

Very few of the basic data networks were originally designed with streamflow forecasting in mind. This imposes unusual demands on hydrologists to develop and implement forecasts. The 1971 status of these networks as they pertain to current forecasting needs (in a 56,500 square mile river basin) is summarized below:

1) <u>Soil Moisture Network</u> - Non-existent other than for a few miscellaneous observations at several experimental farms.

2) <u>Snowpillow Network</u> - One mountain snowpillow with two years' record. No plains or foothills sites.

3) <u>Snow Courses</u> - Good long-term data available from the nine courses in the mountain headwaters of the Bow and St. Mary Rivers. Records are inadequate to assess other sites.

4) <u>Climatological Stations</u> - Long-term records available for three higher elevation mountain sites, five valley stations and thirty-six plains-foothill stations.

5) <u>Mountain Storage Precipitation Gauges</u> - Exceptionally good network consisting originally of about 75 gauges. After 1971 forecasting evaluation, the network was pruned down to about 45 good sites. Although established in 1953, records in most cases are continuous only from 1956 due to an inadvertent oversight in 1955 to read most gauges.

<u>Development of a South Saskatchewan River Basin Forecasting System</u>

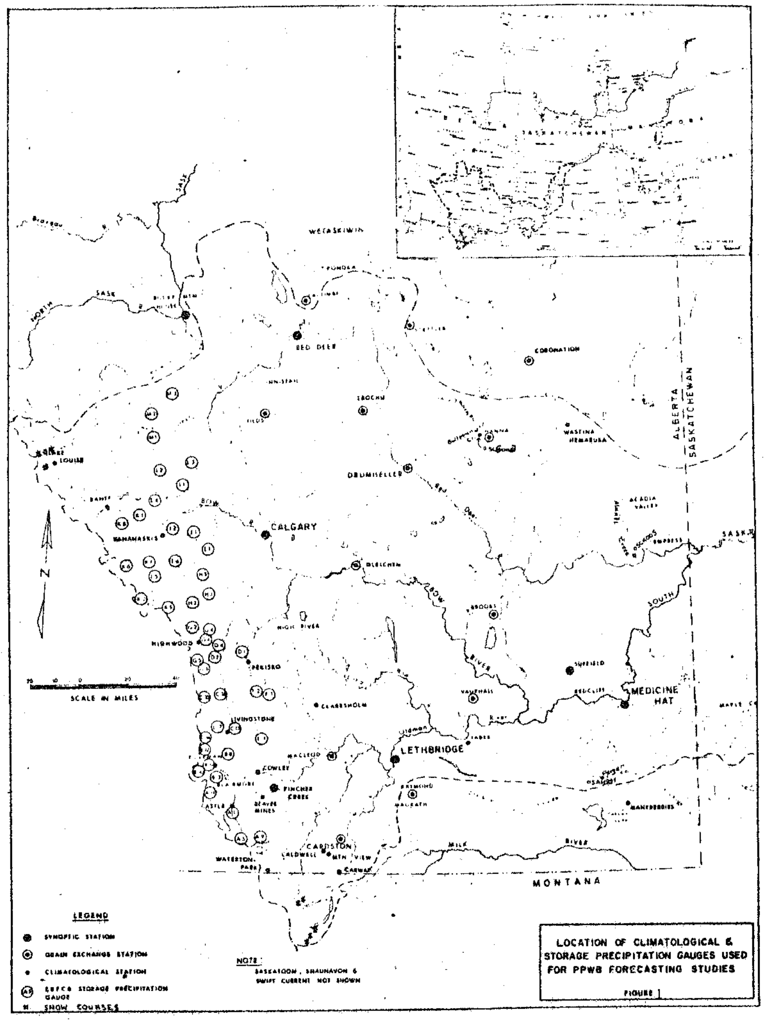
Water is a precious commodity within the South Saskatchewan River, with approximately 0.5 million acres under irrigation. Power considerations are also paramount. Eight hydro stations have been built with a 500,000 KW generating capacity. Further downstream on the Saskatchewan River proper, much greater power plants now operate. Recreation interests, municipal water supplies and other interests all rely on South Saskatchewan River flows. Consequently, accurate and timely forecasts are of utmost importance.

The PPWB forecasting project first identified forecasting requirements of all user agencies in the three Prairie Provinces. Based on these and apportionment considerations, a long-range master plan has been formulated which carefully balances user requirements against forecast accuracy, timeliness, peripheral interpretation information and operating costs. A breakdown of major forecast categories and procedures is provided hereunder.

<u>Water Supply Forecasts</u>

Due to the extreme variability of plains runoff, separate forecasts are proposed based on modifications to a soil moisture computer program developed by Baier et al (1971). It evolved from an earlier version by Holmes and Robertson (1959). M. A. Kohler was the first to recognize its forecasting potential. Prairie snowmelt procedures developed and described by McKay and Blackwell (1961) plus recent advances in prairie snow hydrology have been incorporated into the accurate soil moisture program. It is now possible to handle brief periods of premature snowmelt (such as depicted by the 1970 hydrograph in Figure 2) which may or may not appreciably alter the subsequent soil infiltration rate depending on subsequent temperatures.

Spring and summer foothill and mountain runoff is predicted from climatological station data or mountain storage precipitation gauge data using multiple regression or the recently developed Parametric Model described by Solomon et al (1971). Appropriate



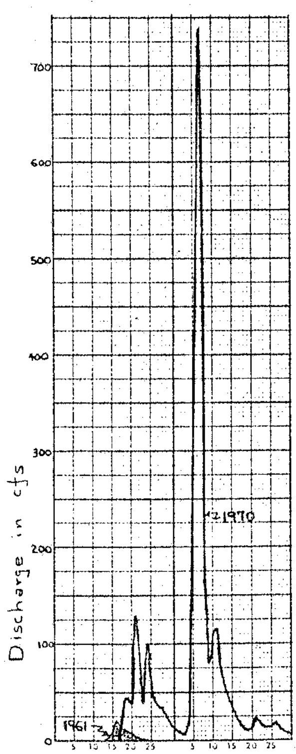


Fig. 2A. Spring Runoff Extremes (Plains Streams) Peigan Creek near Pakowski Road

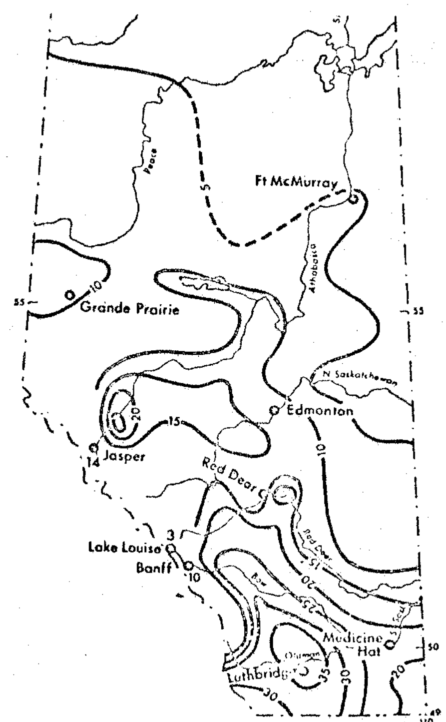


Fig. 2B Mean number of days with chinooks (Max 39°) during the winter (Dec., Jan., Feb.) 1931-65 corrections for winter snowpack EVSUB can be made by procedures outlined by Peak (1969). However, a very simple but accurate method was developed to provide correction factors to adjust the EVSUB and other losses. This method has been designated the "Integrating Loss Basin" method and will be described briefly later.

Winter water supply forecasts are based on simple correlation techniques.

Flood and Streamflow Forecasts

The U. S. Army Corps of Engineers SSARR Model and the UBC Fraser River Model described by Quick et al (1970) have been mobilized for both streamflow and flood forecasting.

Soil Moisture and Irrigation Demand Forecasts

Intelligent interpretation of forecasts by various users is usually contingent on peripheral information. Two important ones are soil moisture and irrigation diversion. Weekly forecasts of these would be provided by the same soil moisture program used to compute plains runoff.

Integrating Loss Basin Correction Factors

Lack of radiosonde and/or high mountain climatological data, needed for EVSUB computations, necessitated the use of data from suitable plains stations such as Lethbridge. As a result of these computations, and 1971-72 operation of an EVSUB station at Calgary (and related hydrologic investigations), it was discovered that the snowmelt runoff of small, truly plains streams could be used to compute appropriate correction factors to apply to April-to-October water supply forecasts. The basic hydrometeorological considerations in this technique are that plains and mountain EVSUB and other losses are functionally related, at least in the South Saskatchewan River basin. As shown by the Figure 2 hydrograph, the snowmelt runoff for these plains streams may be complete by April 1st. Even if runoff is delayed or above normal, appropriate recession curve techniques can be employed to reliably estimate the total snowmelt runoff for these streams by April 10th. Three small plains streams have provisionally been selected for computing "Integrating Loss Basin" correction factors. Snowmelt runoff volumes (as determined by U. S. Army Corps of Engineers procedures) for these streams are presented in Table 2. Historic, April-to-October water supply forecasts for the South Saskatchewan River and its large Oldman River tributary are given in Table 3. Initial forecasts are based on winter storage precipitation data, summer rainfall and winter base flows. The initial forecast residuals (as per cent) are plotted against the weighted snowmelt runoff (also expressed in per cent) for the three integrating loss basins. Graphs for the two forecast locations are plotted on Fig. 3. The actual curve values are subsequently used to provide the "per cent correction" applied to all forecasts. Accuracy is significantly improved. In the case of South Saskatchewan River forecasts, the original ±23% extreme residuals are reduced to about ±8%. Similar improvement is attained for Oldman River at Lethbridge.

Table 3

Observed and Forecasted Flows, Plus Integrating Loss Basin Corrections

Location	Year	Observed Runoff and Forecasted Runoff (April to October)		Initial Forecast Residual		Forecast Corrections Using Integrating Loss Basins	
		Observed	Initial Forecast	CFS-Months	% Deviation	Curve Value % Correction	Adjusted Forecast % Deviation
South Saskatchewan River at Alta.-Sask. Boundary	1961	91,971	112,901	20,930	22.76	-23.0	-0.3
	1962	86,419	98,996	12,577	14.55	-15.0	-0.4
	1963	98,872	103,935	5,063	5.12	-13.0	-8.1
	1964	116,989	138,455	21,466	18.35	-15.0	3.4
	1965	154,539	129,597	-24,941	-16.14	22.5	6.4
	1966	114,623	124,442	9,819	8.57	- 3.0	5.5
	1967	152,083	131,723	-20,359	-13.39	11.8	-1.6
	1968	88,451	109,797	21,346	24.13	-19.0	5.1
	1969	140,703	110,883	-29,819	-21.19	18.0	-3.2
	1970	95,806	94,610	- 1,195	- 1.25	2.5	1.2
Oldman River at Lethbridge	1961	36,488	42,916	6,428	17.62	-17.6	0.0
	1962	31,552	33,976	2,424	7.68	- 7.5	.1
	1963	37,091	38,389	1,298	3.50	- 7.5	-4.0
	1964	54,116	55,850	1,734	3.21	- 7.5	-4.3
	1965	53,049	45,658	-7,390	-13.93	16.5	2.6
	1966	43,307	41,477	-1,829	- 4.22	2.5	1.7
	1967	60,708	52,201	-8,506	-14.01	11.0	-3.0
	1968	38,470	44,250	5,780	15.02	-11.6	3.4
	1969	46,955	40,604	-6,350	-13.53	13.5	0.0
	1970	38,773	39,180	407	1.05	6.0	7.0

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