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PRAIRIE PROVINCES WATER BOARD

MEMORANDUM #5

# THE USE OF HYDROMETEOROLOGICAL INFORMATION

# FOR

# FLOOD FORECASTS ON THE PRAIRIES

Prepared by

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Engineering Secretary
Prairie Provinces Water Board
Regina, Saskatchewan

December, 1961

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## GENERAL

This summary of flood forecasting activities and data requirements on the prairies has been compiled primarily from information obtained from members of the Prairie Provinces Water Board. Some data was obtained from agencies interested in stream regulation.

Although the Board has noted several needs for hydrometeorological services relating to agricultural problems, the subject matter here is confined to flood forecasting, flood warnings, and quantitative run-off forecasting. There is a National Committee on Agro-Meteorology which, among other things, has undertaken "to consider and define the needs of agriculture for meteorological services". No attempt has been made to duplicate their efforts.

This report is presented in five parts. This section is followed by a discussion of the "Causes of Floods on the Prairies". A brief description of the nature and distribution of prairie "flood damages" is then presented. Following this is an account of existing "flood forecasting" services supplemented by an assessment of services which may be needed in the near future. Finally, under the heading "Hydrometeorological Requirements" the role of meteorology in improving flood forecasts is summarized.

CAUSES OF FLOODS ON THE PRAIRIES

Floods on the prairies are caused by rapid snowmelt, excessive rains, ice jams, or some combination of these factors. Small streams across the prairies are subject to annual snowmelt floods. Rain floods, though possibly more severe, tend to be rare on small streams. Large streams also have pure snowmelt and pure rain floods but a combination of the two becomes more probable as the size of the basin increases. One of the most frequent causes of flooding on both large and small streams is the ice jam.

Most of the larger prairie rivers are located so that spring break-up in the headwaters occurs with the lower reaches of the river still in the grip of winter. This accentuates a normal ice-jamming problem during the spring break-up period. Ice-jam floods are almost unpredictable although many of the highest river stages occur at this time. At Outlook, for example, on the South Saskatchewan river, the highest spring break-up level on record occurred on March 31, 1960. The amount of water in the spring run-off hydrograph was one of the smallest on record. On the Assiniboine river below Portage la Prairie the dyked river channel has an open-water capacity of 18,000 to 20,000 c.f.s., but overbank flow has occurred with much smaller flows due to ice jams. At Calgary, on the Bow river, winter flooding is more frequent than summer flooding due to the formation and subsequent jamming of frazil ice.

The predictability of ice jams is a question often debated in the West, but generally speaking no one has produced a scientific method for evaluating this hazard. For this reason ice-jam floods are excluded from this discussion even though they may equal or exceed the flood stages recorded during open-water seasons.

## FLOOD DAMAGES

Large rivers are usually associated with large urban centres. Fortunately, in most parts of the prairies the flood plains in these centres are not developed, or are being developed as park areas. This is true of Lethbridge, Edmonton, Saskatoon, Regina, Swift Current, and partially true of Calgary. The flood of 1953, for example, in the South Saskatchewan River Basin, although one of the largest on record, caused a readily assessable damage of only $365,000.00[1]. The bulk of the damage accrued to works in or crossing the rivers. At Regina the Wascana creek channel has been improved to pass floods with a recurrence interval of 50 years or more and the entire adjoining areas are zoned for parks. The Town of Lumsden on the Qu'Appelle river has had dykes constructed to contain a flood 50% greater than the largest recorded during a 50-year period.

The Winnipeg area is an exception. Here the Red and Assiniboine rivers travel large distances through heavily populated rural and urban areas situated on a very level plain which the river inundates during severe floods. Flood damages in the area can be very substantial as indicated by the following table.

DAMAGE IN DOLLARS WHICH WOULD HAVE OCCURRED IN 1957 IF FLOODS HAD BEEN EXPERIENCED EQUAL TO THOSE IN THE YEARS NOTED:[2]
(Assuming no flood diversions or storage)

| Year of Flood | Frequency of Flood | Damage in Greater Winnipeg | Frequency of Flood | Other damage in Red & Assiniboine* Valleys | Total |
|---|---|---|---|---|---|
| 1948 | 1:12 | 650,000 | 1:11 | 2,870,000 | 3,520,000 |
| 1950 | 1:36 | 114,000,000 | 1:46 | 15,260,000 | 129,260,000 |
| 1852 | 1:150 | 593,000,000 | 1:150 | 29,316,000 | 622,000,000 |
| 1826 | 1:460 | 852,000,000 | ? | 40,000,000 | 892,000,000 |

* Lower quality estimate than other figures

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1 "Floods in the South Saskatchewan River Basin"
E.P. Collier, Calgary Office, Water Resources Branch, 1957.

2 For further details the reader should refer to report of Manitoba Royal Commission on "Flood Cost Benefit" - 1958.

Flood Damages (Cont'd)

Most of the small streams on the prairies (with basin lags of less than 2 days) traverse rural areas. Due to low population densities, damages tend to be confined to railroads, highways, and temporary agricultural flooding. Railroad and highway damage is directly related to the adequacy of culvert and bridge design. Temporary agricultural flooding, particularly in the spring, may be more beneficial than damaging. Sustained agricultural flooding is usually related to larger rivers or drainage districts where adequacy of design (drainage ditches, levees, etc.) determines the amount of damage regardless of forecasts.

## FLOOD FORECASTING

For the Red and Assiniboine basins a permanent Flood Forecasting Committee has been established. The Meteorological Branch is represented on that committee. The forecasting procedures used by that committee are described in two reports "Report on Investigations into Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area - 1953", and "Report on Conservation and Flood Control on the Assiniboine River - 1952". The following table describes the parameters used in making flood forecasts for these rivers.

PARAMETERS USED IN FORECASTING FLOODS ON THE ASSINIBOINE AND RED RIVERS

| ASSINIBOINE RIVER | RED RIVER |
|---|---|
| 1) Accumulated Snowfall Index<br>1/10th of total snowfall from freeze-up to beginning of melting period. 2/10ths of snowfall during melting period plus rainfall during melt period. | 1) Accumulated Snowfall Index<br>1/10th of total snowfall from freeze-up to Feb.28th. |
| 2) Melting Index<br>Average daily excess Temperature above 32°F. during period from beginning of melt to peak flow,<br>plus<br>double the precipitation during the melt period,<br>plus<br>insolation correction for early or late melt. | 2) Melting Index<br>Average daily excess temperature above 32°F. during the melt period. |
| | 3) Precipitation<br>Precipitation plus 1/10th of snowfall from March 1st to end of break-up period. |
| 3) Antecedent Index<br>A sum of weighted monthly precipitation through the basin from June 1st to Nov. 5th. | 4) Soil Priming Index<br>Average flow of river from October to January the previous year. |

In preparing an Assiniboine river forecast the sequence is as follows. A co-axial graph is entered using the computed accumulated snowfall index. The next variable considered is the computed antecedent index. Finally, the volume of run-off is estimated by assuming a value for the melting index. The actual peak stage is estimated from unit hydrographs which have been prepared for many floods. If, for example, mean values were selected for the first two parameters, the assumption of a minimum recorded melting index would lead to a forecast of a low-water year at Brandon. The assumption of a mean-melting index would lead to a forecast of average run-off. The assumption of the maximum recorded melting index (by actual trial) would lead to a forecast of run-off double the average with flooding conditions probable.

A similar test was made of the Red River forecasting procedures. In this case accumulated snowfall was taken as the fifth heaviest on record, and the antecedent index was assumed to be the fifth wettest on record. The snowmelt and spring rain indices were taken as the greatest in 20 years and the smallest in 20 years in order to prepare two flood estimates. In the first instance a super flood volume 50% greater than 1950 was predicted, and in the second trial a much smaller flood equal to that in 1948 was predicted.

From these examples it is quite obvious that the warm-up pattern and the rain during the melting period are extremely critical in forecasting the magnitude of the flood.

It should be pointed out that information from upstream river gauges provide up to 7 days warning of a fairly accurate nature. Forecasts embodying meteorological parameters are used to extend this warning period.

Elsewhere on the prairies there are no formal flood forecasting committees. The Alberta Water Resources Branch arranges for the reporting of upstream river stages for the North Saskatchewan and Pembina rivers when flood conditions threaten. Warnings are issued if severe floods are indicated. The Branch also provides a man at Calgary for short-term water level forecasts when frazil ice starts piling up in December or January. This is primarily a river routing problem at the present time due to an inadequate understanding of the quantitative relationship between weather and ice formation. Manitoba forecasts floods on the Saskatchewan river for The Pas area but this is based on river routing also.

For many large and small streams on the prairies various power, water development, and water administration agencies keep a fatherly eye on the flood potential and make qualitative flood forecasts for their own use. In most cases these requirements are satisfied by considering the relationships between upstream and downstream gauges, with very little use of meteorological parameters.

The development of additional flood forecasting services in the future will depend upon the need. The problems of developing flood forecasting techniques for small streams with basin lags less than 2 days are many and, as mentioned previously, the potential damages are not large.

However, a flood "alert" may become a regular service in the foreseeable future if quantitative forecasts of precipitation can be made with confidence. Wilson Creek Watershed in the Riding Mountains is an example of the application of an "alert" to small watersheds. Here the Weather Office notifies the Wilson Creek Watershed Committee as soon as one-half inch or more of rain has fallen within 6 hours and, if rainfall is expected to continue moderate or heavy. The committee then notifies its observers in the Experimental Watershed to prepare for intensive observations. Wherever such intensive service can be economically justified, this type of forecasting for small watersheds shows promise.

On large rivers, controlled development of flood plain areas combined with adequate hydrologic design for bridges, dams, and other works in rivers, will probably keep potential flood damages low near prairie urban centres. However, the near future will see the construction of numerous power plants, reservoirs, diversions, and other water control works on all major prairie rivers.

Eventually (perhaps I am optimistic), efforts will be made to operate these works in harmony with one another to make best use of the available water. The key to planning and implementing unified operation for these projects will be quantitative run-off forecasting. With a few exceptions[1], satisfactory relationships between seasonal run-off on these rivers and various meteorological parameters have not yet been developed. Hence it is difficult to suggest the specific meteorological parameters which must be forecast and how accurately.

For the Winnipeg area, the Red River Valley and the Assiniboine Valley, there has been a need for <u>flood</u> forecasting in the past and procedures have been developed. In the future there will be continued efforts to improve long-range flood forecasting (more than one week) primarily to prevent loss of life through hurried evacuation. The usefulness of these extended forecasts will depend primarily on the accuracy of the forecasts made for warm-up and precipitation during the melting period.

For the Assiniboine basin, there is some possibility that attempts will be made to control floods with flood-control reservoirs. Should these be built, the effectiveness of their operation would be greatly enhanced by good quantitative run-off forecasts.

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1 For the Upper Bow and St. Mary rivers the Water Resources Branch has developed a simple correlation between snow surveys and seasonal run-off. Seasonal run-off can be predicted for St. Mary river from this relationship with a standard error of 80,000 acre-feet - about 16% of the average flow. For the Bow river the forecast errors are similar.

## HYDROMETEOROLOGICAL REQUIREMENTS

In my opinion there are four ways in which the Meteorological Branch might contribute to improved flood forecasting on the prairies. These are:

1. Daily reports of 24-hour precipitation.
2. A better measure of snowpack water equivalent.
3. Five-day warm-up forecasts with an error of ±5°F. in mean daily temperatures.
4. Up to a five-day forecast of 24-hour precipitation in excess of 1 inch, with a suggested probability of occurrence. This would be for large storms - not thundercells.

Of these four items, numbers 1 and 2 would probably yield the greatest immediate benefits for the least investment. A more detailed explanation of these four points follows.

1. DAILY REPORTS OF 24-HOUR PRECIPITATION

One of the most useful tools in revising formal run-off forecasts, and in alerting gauge readers, is an early morning report on precipitation which has fallen the previous day. For the past two summers the Edmonton Forecast Office has operated a "weather watch" in the mountain and foothill area for the P.F.R.A. When advised of heavy precipitation, P.F.R.A. arranged for daily reporting of river stages at selected points. It was possible to prepare a 7-day forecast of river levels at the South Saskatchewan damsite from this information. However, for persons with province-wide or prairie-wide interest and responsibilities, a prairie-wide "weather watch" may be required.

At the present time three types of precipitation information are available as shown on the attached map:

(a) Reporting every 6 hours (synoptic network).

(b) Reporting daily by telegraph in summer (For daily "Grain Exchange" map).

(c) Reporting monthly (climatological network).

The members of the Board could indicate on the attached map, the "daily reporting" network needed to meet the requirements of flood forecasters and those responsible for a flood alert. The information could probably be made available at each of the Public Weather Offices in Winnipeg, Regina, and Edmonton.

2. WATER EQUIVALENT OF SNOWPACK

Anyone who has attempted to develop a co-axial graph for forecasting spring run-off will be familiar with the difficulties of developing a useful parameter by accumulating recorded winter snowfall. The density of newly fallen snow is variable. Snowpacks, particularly shallow ones, are subject to evaporation and melting losses. Finally, the snowmelt sequence of shallow snowpacks is poorly understood and an error arises when assumptions are made as to the effectiveness of the snow in producing run-off.

At Regina, McKay and Blackwell[1] are operating two snow courses to study the relationship between the water equivalent of the snowpack, the recorded snowfall, and the losses caused by melting and evaporation. Eventually it may be possible to compute the water equivalent in the snowpack over large areas with confidence prior to the snowmelt period using climatological records. This possibility would be enhanced if more measurements of snowpack water equivalent were available. The Meteorological Branch is now preparing to supply a number of stations with snow samplers to measure water equivalent at fortnightly intervals. If this information could be made available to flood forecasters immediately after it is observed it would greatly improve the usefulness of an "accumulated snowfall" parameter.

3. WARM-UP FORECASTS

Present warm-up forecast services include:

(a) Public Weather forecasts for at least 36 hours occasionally supplemented by an "outlook" for the following day. These are revised every 6 hours.

(b) a 5-day U.S. Weather Bureau forecast transmitted by facsimile to Public Weather Offices in Canada.

(c) A monthly weather outlook prepared by the U.S. Weather Bureau. This is revised twice monthly.

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1 "Plains Snowpack Water Equivalent from Climatological Records" McKay & Blackwell, presented at Western Snow Conference in Spokane April 1961.

Forecasts of snowmelt floods are extremely sensitive to the rate of warm-up as previously shown for the Red and Assiniboine rivers. Currently, for these rivers, river routing provides a 7-day warning. A one-week prognosis of maximum and minimum daily temperatures ±5°F. would extend this forecast by an additional week. Even if this very high standard could be achieved, Winnipeg should have three weeks warning in order to make adequate preparations.

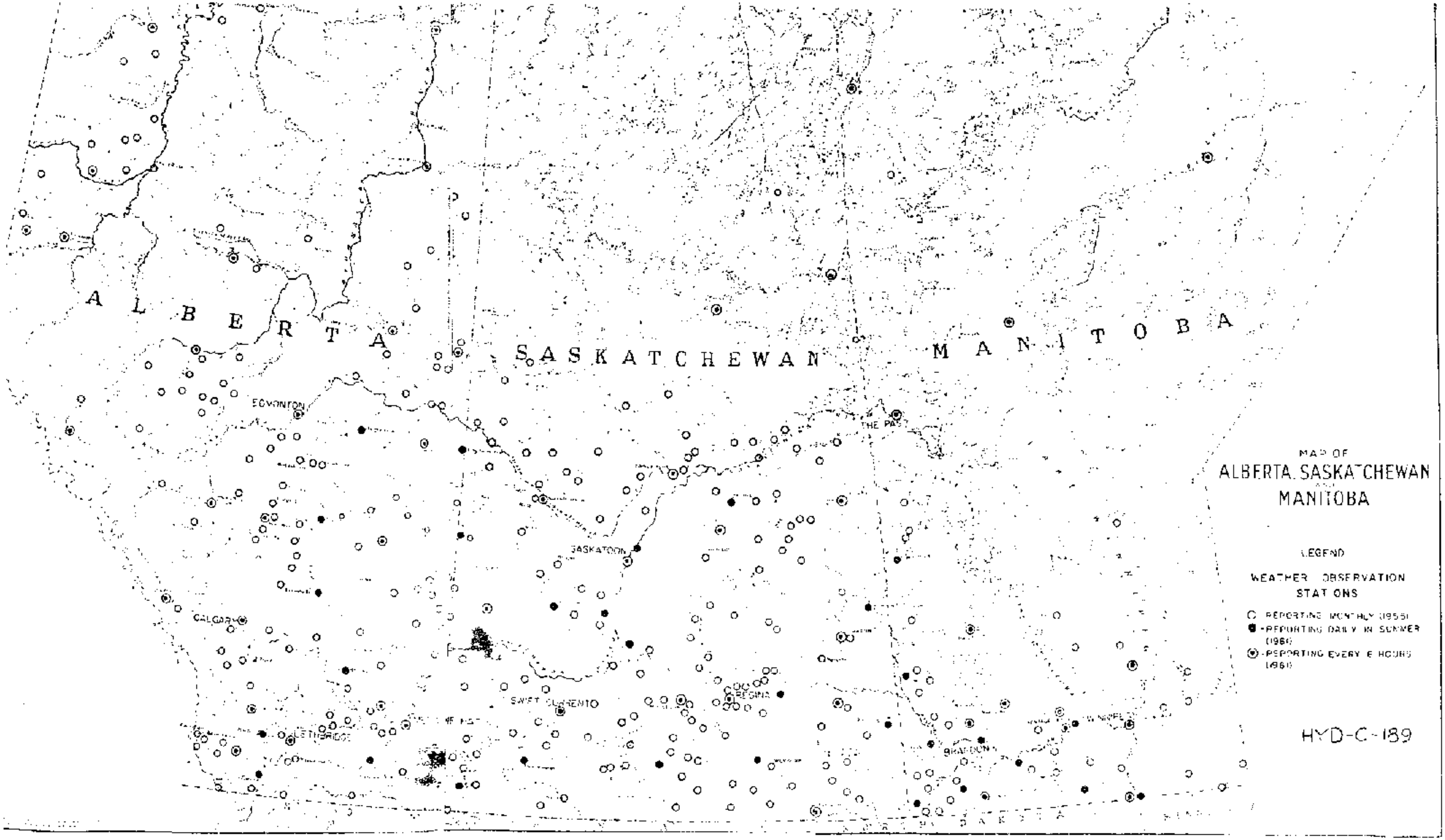
Elsewhere on the prairies there is no urgent need for extended warm-up forecasts.

4. FORECASTS OF 24-HOUR PRECIPITATION IN EXCESS OF 1 INCH

The existing forecast services as listed in the previous paragraph suggest whether or not rainfall will occur but there is no formal service for quantitative precipitation forecasts. However, the U.S. Weather Bureau issues a quantitative forecast of 24-hour precipitation which might be extrapolated into southern Canada. Perhaps this could be made available at Canadian Public Weather Offices.

If the services mentioned in item 1 above were instituted, then forecasted rainfall amounts would provide only a one or two day increase in the flood forecasting period. The value of this extra day appears small at the present time. Perhaps future flood forecasting needs will place more emphasis on this item.

In any case, the issuance of flood warnings on the basis of such precipitation forecasts would require a very clear understanding on the part of the flood forecaster of the possible errors.


MAP OF
ALBERTA, SASKATCHEWAN
MANITOBA
LEGEND
WEATHER OBSERVATION STATIONS
REPORTING MONTHLY (1955)
REPORTING DAILY IN SUMMER (1961)
REPORTING EVERY 6 HOURS (1961)
HYD-C-189
ALBERTA
SASKATCHEWAN
MANITOBA
EDMONTON
CALGARY
LETHBRIDGE
SASKATOON
SWIFT CURRENT
REGINA
THE PAS
BRANDON
WINNIPEG