METEOROLOGY IN WATERSHED RESEARCH IN ALBERTA

By

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NEED FOR WATERSHED RESEARCH

Canada has a worldwide reputation for being rich in fresh water. School children are taught that we have one quarter of the world's total. However, in some parts of our country, agricultural and industrial development is limited by inadequate or unreliable supplies. As an example, in the dry year of 1962, every acre-foot which came down the Bow River at Calgary was "spoken for" for irrigation and industry; there was none left for expansion. Obviously, then, an increased or more stable water supply is necessary. Dams and other "plumbing fixtures" are expensive, have limited capacity, and in high sediment areas, have a relatively short life. Studies in other parts of the world have shown that intelligent management of the headwaters of a river can increase the annual flow.

The East Slopes (Alta.) Watershed Research Program was therefore established in 1960 to study the hydrology of the area with the aim of evaluating and improving land management practices for water production (Jeffrey, 1965). Increased total run-off is not the only goal. Because peak water demand is in July and August, it would be an important achievement if the peak on the hydrograph could be smoothed out or delayed from its usual June occurrence.

Three experimental basins were established in the South Saskatchewan headwaters in representative vegetative types; Marmot Creek in spruce, Streeter in aspen-rangeland, and Deer Creek in lodgepole pine. In 1967, the terms of reference of the program were enlarged to include all Alberta, and there are now ten projects of various sizes studying various problems in the hydrologic cycle in the province. Thirteen federal and provincial agencies are involved in the program on a co-operative basis, so administration frequently involves more tact and diplomacy than in a single agency project! However, administration is not the theme of this article.

THE WATER BALANCE APPROACH

The familiar water balance equation:

Precipitation = Run-off + Evapotranspiration ± Increase in groundwater and soil moisture storage,

provides a convenient means of illustrating the division of responsibility among the research agencies studying a basin's water balance. Input by the various agencies varies from basin to basin depending on the purpose of the study, but let us examine Marmot Creek as a good example.

Precipitation is naturally the responsibility of the Meteorological Branch and I will deal with this more fully later. Run-off is measured by Water Survey of Canada as the competent authority and five weirs have been installed in the basin. Department of Energy, Mines and Resources also measures sediment load and water quality. Measurement or estimation of evapotranspiration is a joint responsibility of the Meteorological Branch and Canada Department of Forestry since it is a function of both weather conditions and plant physiology. Changes in groundwater storage are the responsibility of Groundwater Division of Alberta Research Council, and a network of wells and piezometers is being established for this purpose. Department of Forestry studies changes in soil moisture using neutron probes and electrical resistance units.

There is one other field of investigation not covered by the water budget equation, that of snow hydrology. The study of snow accumulation patterns and melt rates with respect to elevation, slope, aspect, vegetation types and density, and forest removal practices as influenced by variations in radiation and sensible and latent heat fluxes is a joint responsibility of Meteorological Branch and Department of Forestry. I think this field holds the key to success of the entire program. It may be possible to partially control snow accumulation by forest harvesting practices. Pre-selected accumulation zones, relatively sheltered from sun and wind would have reduced evaporation and melt rates. While the total basin run-off might be increased slightly, the snowmelt flood peak could be reduced, thus decreasing erosion and increasing usable run-off.

The water balance approach also provides both a goal for which to aim and a check on the accuracy of each term. For instance, it would be very embarrassing if the precipitation measured was less than the run-off from the basin! Run-off is the only term which can be measured precisely. The others have varying degrees of difficulty of measurement and correspondingly large errors are possible.

DESCRIPTION OF MARMOT CREEK WATERSHED

Before delving more deeply into the meteorological input into the Marmot Creek study, a description of the basin is necessary. It is located about 50 miles west of Calgary on the west side of the Kananaskis Valley between the Fisher Range and the Continental Divide. Figure 1 is an aerial view looking westward to the divide in the background. Elevation ranges from 5200 to 9200 feet MSL, giving an average slope of 39% over its 3.6 square miles and creating severe access problems to the higher elevations. The lower reaches are covered with a dense stand of lodgepole pine, then mature spruce up to 100 feet tall extends to treeline at about 7500 feet. In the alpine area, shrubs and grasses give way to bare rock and talus.

METEOROLOGICAL RESPONSIBILITIES AND PROBLEMS

The meteorological responsibilities in the program may be summarized in the following table:

Hydrological Component		Meteorological Parameters Required
Precipitation	....	Rainfall, snowfall, rainfall intensity.
Evapotranspiration	....	Solar radiation, air temperature and relative humidity, wind, pan evaporation.
Snow Accumulation and Melt	....	Snow depth, density and temperature, wind, radiation, air temperature and humidity.

To measure each of these parameters for each of the sub-basins at Marmot, two questions must be answered. First, how accurately can it be measured at a point? Secondly, is there a consistent pattern for it over the area, and at how many points must it be measured to determine that pattern? For practical reasons, a third question dominates the other two - where is an instrument which, operating without electric power, will measure and record the parameter accurately without attention for at least a month at a time?

For some of the questions I have partial answers. The rainfall pattern has been reasonably well defined as seen in Figure 2, the summer rainfall in 1965 (Storr, 1967). This is measured with a network of 33 raingauges. It is quite consistent from year to year and we are now trying to improve the accuracy of point measurements. The variation in

FIGURE 1: Aerial Photograph of Marmot Creek Watershed

MARMOT CREEK BASIN

1965 SUMMER RAIN

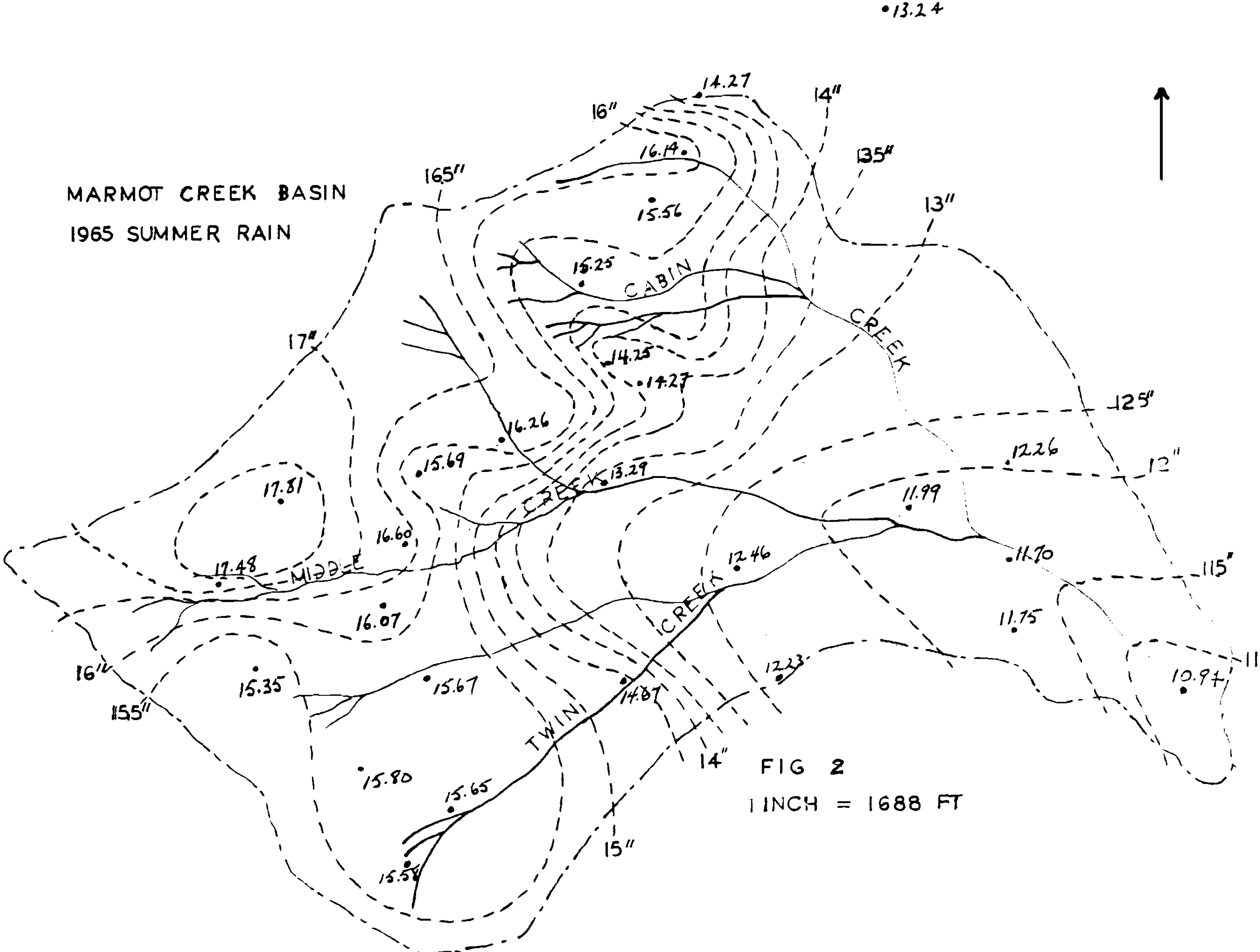

FIG 2

1 INCH = 1688 FT

total summer rainfall of almost seven inches in about $2\frac{1}{2}$ miles makes the rainfall maps in some climatic atlases seem very inadequate.

Snowfall measurements are a problem, and no final answer is in sight. Storage gauges undercatch by an unknown percentage because of exposure problems, and snow courses can't measure accumulated melt or evaporation. The best solution available is an approach that combines gauges and surveys.

The temperature pattern in summer is becoming established from thirteen hygrothermographs in Stevenson screens. Because of the access problem, we know practically nothing about winter temperatures or humidities.

A well defined valley wind has been noted at several places in the basin and documented on a few occasions (MacHattie, 1968; Munn and Storr, 1967; Storr, Tomlain, Cork, and Munn (under review)). It is of importance as a transport mechanism for heat and water vapor, but nothing is known about its frequency, areal variability or vertical extent. Also required is a wind analysis by direction and speed for periods of snowfall to aid in the design of forest cuts to trap the snow.

Net radiation has been observed above the forest canopy for four years, but the problems and frustrations that accompany radiation measurements of any kind have been experienced. Detailed maps showing theoretical spatial and temporal variations of clear-sky insolation have been prepared by Ferguson, Cork, Anderson, Mastoris and Weisman (in review), but have not yet been verified by actual observation. In the field, attempts will be made to measure all components of the radiation balance, but it seems clear that it will be necessary to resort to theory for some matters in order to produce detailed maps of net radiation. In 1967, an energy budget study produced some very interesting data on Bowen's ratio (for the apportionment of net radiation between latent and sensible heat) and its dependence on wind and weather conditions. If a replica of this study can determine the areal variations, if any, in the ratio we can use the net radiation map to produce a detailed daily map of evapotranspiration for the basin.

In the field of snow hydrology, we have derived a considerable amount of knowledge from 20 snow courses, but they do not give an adequate areal coverage of the basin, so supplementary measurements will be taken at a series of grid points. To help evaluate the sublimation of snow (especially under Alberta's famed chinooks) a project making periodic weighings of snow-filled pans will be started this winter.

CONCLUSION

I have tried to show the role of meteorology in watershed research in Alberta, using Marmot Creek as an example only. Some of the problems are sublime (sublimation of snow), others ridiculous (how to prevent porcupines from eating Stevenson screens). Of one thing I am sure--I don't have to look far for an unsolved one.

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