FILE COPY SWAN 1989

CANADIAN HYDROLOGY SYMPOSIUM (CHS:88)
ASSOCIATE COMMITTEE ON HYDROLOGY
NATIONAL RESEARCH COUNCIL OF CANADA
MAY 9-11, 1988
BANFF, ALBERTA

CHS 88 SCH

SYMPOSIUM CANADIEN D'HYDROLOGIE (SCH:88)
COMITÉ ASSOCIÉ D'HYDROLOGIE
CONSEIL NATIONAL DE RECHERCHES CANADA
LES 9-11 MAI 1988
BANFF, ALBERTA

The Marmot and Streeter Experimental Basin Programs

R.H. SWANSON
Project Leader, Forest Hydrology and Microclimate Research, Forestry Canada, Edmonton.
W.D. HUME
Chief, Scientific Services Division, Atmospheric Environment Service, Edmonton, Alberta
G.H. MORTON
Chief, Water Resources Branch, Conservation and Protection, Calgary, Alberta

ABSTRACT The Eastern Rockies Forest Conservation Board (ERFCB) was constituted in 1947 in recognition of the special status that the eastern slopes watershed had with respect to water supply in the Saskatchewan River. One of the ERFCB's principal functions was "...the conservation, development, maintenance and management of the forests in such area [the eastern slopes watershed] with a view to obtaining the greatest possible flow of water in the Saskatchewan River and its tributaries." Upon its request, the Alberta Watershed Research Program (AWRP) was initiated during the period 1960-1963 with the establishment of experimental watersheds at Marmot Creek and Streeter Creek to examine the effects of forest cutting on streamflow and groundwater. The results are now available, and models that can be used to predict the impact of forest cutting on water yield throughout the eastern slopes are available to forest and water management agencies.

In spite of this ostentatious beginning and wealth of technology transfer tools, the impact of the Marmot and Streeter projects on water management in Alberta and upon forest management within the eastern slopes watershed is essentially non-existent. The primary reason for this is the changing land use and management pattern within the eastern slopes watershed which, to date, has frustrated all efforts to establish even a pilot-scale watershed management project. Thus, even if water yields could have been quadrupled, it appears that the results will probably will never be applied in the eastern slopes.

This does not mean that the research program has been without benefit. For instance, the Marmot data sets proved valuable for the recreational development for the 1988 Winter Olympics, as the Marmot snow, wind, and temperature data were used in preparing climatologies for the Nakiska ski area. Both Marmot and Streeter have provided valuable hydrologic process and treatment effects data for developing, modifying and testing watershed simulation models. And both areas have been the subject of several MSc. and PhD. theses.

Should the need for another similar program be demonstrated, current technologies in instrumentation and simulation modelling would permit the accomplishment of more with less manpower and in a shorter time period. Experimental watersheds such as Marmot and Streeter should never have been expected to be representative of effects achievable elsewhere nor to yield results that could be directly applied. They should be regarded as places to test models and simulated results of proposed treatments against those

THIS FILE COPY MUST BE RETURNED

TO: INFORMATION SECTION
NORTHERN FORESTRY CENTRE
5320-122 STREET
EDMONTON, ALBERTA T6H 3S5

actually obtained in order to establish the credibility of those models for application elsewhere.

RÉSUMÉ Le "Eastern Rockies Forest Conservation Board" (ERFCB) a été créé en 1947 à cause du rôle prépondérant des bassins du versant est des Rocheuses dans la génération des débits de la rivière Saskatchewan. Une des principales fonctions du ERFCB était "...la conservation, le développement, le maintien et la gestion des forêts dans de telles zones [les bassins du versant est] en vue d'obtenir les débits les plus hauts possibles dans la rivière Saskatchewan et ses tributaires." A la demande du ERFCB, le "Alberta Water Research Program" (AWRP), fut initié de 1960 à 1963 avec la mise en place des bassins expérimentaux de Marmot Creek et de Streeter pour l'étude de l'effet des coupes forestières sur les eaux de surface et souterraines. Les résultats de ces études ainsi que des modèles servant à prédire l'impact de la coupe sur les débits dans les bassins du versant est des Rocheuses sont maintenant disponibles.

Malgré le haut profil des bassins de Marmot Creek et de Streeter, et l'abondance des mécanismes de transfert technologique, l'impact de ces projets sur la gestion de l'eau et l'aménagement forestier en Alberta est essentiellement non-existant. La raison première de cet état de chose est que les changements dans les patrons d'utilisation et de gestion des terres ont contrecarré les efforts de mise en place de projets d'aménagement de bassins, même à l'échelle de projet pilote. En fait, peu importe les accroissements de débits démontrés, il semble bien que ces résultats ne seront jamais appliqués dans les bassins du versant est des Rocheuses.

Le programme de recherche n'a toutefois pas été sans bénéfices. Les données de Marmot ont été très utiles aux Jeux Olympiques d'hiver 1988; en effet, les données de neige, vent et températures recueillies sur le bassins ont aidé à planifier la réalisation du centre de ski de Nakiska. De plus, Marmot Creek et Streeter ont fourni des données utilisées dans le développement, la modification et la vérification de modèles de simulation hydrologique. Enfin, ces deux bassins ont fait l'objet de nombreuses thèses de maitrise et de doctorat.

Si un tel programme s'avérait encore nécessaire, les progrès dans les domaines de l'instrumentation et de la simulation permettraient d'accomplir plus avec moins de personnel et en moins de temps. On n'aurait jamais dû espérer obtenir de bassins tels que Marmot Creek et Streeter des résultats représentatifs d'effets obtenus ailleurs, ou même des résultats pouvant être appliqués directement. En fait, les bassins expérimentaux devraient servir à tester les modèles en comparant les résultats obtenus par simulation à ceux mesurés suite au traitement proposé, de façon à établir la crédibilité de ces modèles pour leur application à d'autres bassins.

NEED FOR RESEARCH

The eastern slopes of the Rocky Mountains in Alberta have long been recognized as an important watershed (Laycock, 1965). The Eastern Rockies Forest Conservation Board (ERFCB) was constituted in 1947 in recognition of the special status of this area with respect to water supply in the Saskatchewan River, which is vital to the water needs of southern Alberta and Saskatchewan. One of the ERFCB's principal functions was "...the conservation, development, maintenance and management of the forests in such area [the eastern slopes watershed] with a view to obtaining the greatest possible flow of water in the Saskatchewan River and its tributaries" (Canada, 1947). "How to manage this watershed for water production and water supply protection" was a question faced by the ERFCB. Upon its request, the joint provincial-federal Alberta Watershed Research Program (AWRP) was initiated during the period 1960-1963 with the establishment of experimental watersheds at Marmot Creek and Streeter Creek to examine the effects of forest cutting on streamflow and groundwater (Jeffrey, 1964, 1965).

OBJECTIVES

1. To provide climatic data in sufficient temporal and spatial resolution so that the impacts of forest cutting activities on microclimate and streamflow could be determined.
2. To investigate means to increase the quantity of runoff from the eastern slopes.
3. To ascertain if the streamflow hydrograph could be flattened out to obtain the same, or greater, quantity of snowmelt runoff over a longer period of time.
4. To determine if the harvesting guidelines of the Alberta Forest Service (AFS) (Alberta, 1971) for commercial cutting in spruce-fir forests were satisfactory for maintaining the volume of high quality-water that these watersheds yield.
5. To propose and test harvesting options specifically designed to alter streamflow.

Originally a similar set of objectives existed for Streeter Basin, but later these were reduced to a single more realistic objective of determining the effect of tree clearing above West Streeter spring upon its water yield and regime.

RESEARCH APPROACH

<u>Rational for research basin approach</u>:

The research basin approach was the technique most widely used and accepted for watershed management research at that time. *Results from plot studies* could be qualitatively interpreted, applied as forest cutting experiments, and quantitatively evaluated as an effect on streamflow.

Small watersheds or research basins were thought to be more representative of spatial variation than plot studies. The effect on streamflow was an integration of many individual soil, topographic and microclimatic situations.

Hydrologic simulation models were just beginning to appear on the research scene, and were not widely accepted as a valid way to emulate the behaviour of a complex watershed. *If* and when suitable models became available, the data from research basins could be used to test them.

<u>Why were Marmot and Streeter chosen</u>:

Marmot Marmot was chosen because it is a representative of the subalpine forest type. The subalpine vegetation type occurs just below timberline where snow accumulation is high and streamflow occurs throughout most of the snow-free season. Marmot's subalpine classification (Rowe, 1977) places it in the same vegetation-climate classification as the better-known Fool Creek watershed on the Fraser Experimental Forest in Colorado (Alexander & Watkins, 1977).

Streeter Streeter was chosen because it a representative of the aspen-grassland vegetation type. These grasslands are important to the ranching economy of the foothills of southern Alberta, and they occupy a significant portion of the Saskatchewan River headwaters. The woody vegetation (primarily *Populus* and *Salix* spp.) of them has been periodically removed to allow greater grass production and more grazing capacity. These clearing activities were thought to have an unknown but potentially serious impact on water yield, regime, and quality.

TOPICS RESEARCHED

Climate and Meteorology:

Emphasis during the early stages of the program was on the spatial variability of the monitored parameters. These included:

- A study to estimate precipitation variability over the basins.
- A series of raingauge intercomparison studies in mountainous terrain.
- An estimate of the variability of wind and temperature fields over the Kananaskis Valley.
- An estimate of radiative fluxes over the various topographic aspects of the watershed.
- An estimate of turbulence characteristics within the watersheds.
- A comparison of snow pillow and precipitation gauge measurements.
- An examination of the correlation between snow accumulation and elevation.
- A computation of water balances over the sub-basins.
- An evaluation of the impact or forest cutting practices on snow accumulation.
- An evaluation the influence of tree cutting patterns on windflow.

Hydrology:

- The evaluation of several streamflow watershed models. One of the models tested was the UBC watershed model and the wealth of data in the basin provided for a rigorous analysis and calibration of the model.

Forest cutting/water interactions:

- Effect of specialized forestry operations on annual water yield and seasonal streamflow (Marmot, Twin subbasin).
- Effect of commercial forestry practices on erosion and sedimentation (Marmot, Cabin subbasin).
- Effect of forestry practices on inorganic water quality.
- *Hydrologic processes effected by forest cutting:*
  - Local precipitation distribution and disposition.
  - Soil moisture and temperature.
  - Snow accumulation and melt.
  - Transpiration and evapotranspiration.
  - Subsurface water storage.
  - Soil water flux.
- Derivation and testing of simulation models (Dickinson, 1982).

DIFFICULTIES AND STUMBLING BLOCKS

The biggest stumbling block was a lack of knowledge of the time and resources that would eventually be required to complete the project. Some of the co-operative agencies were led to believe that the project could be completed in ten years: five years evaluation in the natural state and five years evaluation following treatment. It became apparent somewhat later that this 10-year time frame was unsuitable and there are some of us that contend that the eventual 25-year life of the project was not adequate because a forest cutting experiment should be run from prior to cutting the original forest to the same state in the replacement forest. This takes 80 to 200 years in Alberta. It does not mean that results cannot be used prior to the completion of the study, but it is not possible to estimate the duration of a treatment effect without some measure of that duration. Obviously a 25 year study is short term considering the long replacement time in this climate.

Other cooperators were led to believe that timber sale revenues would finance the harvesting, and were unprepared for requests for funding to subsidize the harvesting of timber from areas too small or on terrain too steep to make logging a paying proposition. It must be recognized that treatments cannot ordinarily be done without cost. Agencies set aside funds for personnel and equipment to evaluate a treatment and must be aware that they will also have to pay to have timber cut in an appropriate pattern.

Treatment plans must be clearly understood and agreed to by all participants. This was not always the case in Marmot and Streeter. A watershed treatment should be viewed as a single experiment. The plan must be fixed early in the experiment so that evaluation measures can coincide with both the spatial and temporal activities associated with the implementation of the treatment. If the treatment is subject to frequent review and change, then the evaluation will be difficult if not impossible.

The maintenance of equipment and the maintenance and quality control of databases are always areas of concern in meteorological studies. This program in particular was not immune to these problems as the rather ambitious monitoring was operated in an era when recording devices, the availability of manpower, especially students during the winter season, all proved to be major difficulties. Extraction of data from chart recording devices was also manpower intensive although much of the data was ultimately placed in computer-processible media.

Some data sets proved extremely difficult to collect. For example, wind measurement studies at higher elevations and estimates of snowpack in the alpine proved to be particularly troublesome.

The financial resources that the various agencies could devote to the project were severely reduced in 1978 as a result of a departmental "A Base Review" which forced the Atmospheric Environment Service to withdraw most of their services. Although key meteorological sites were maintained, this withdrawal created a data gap that could not be filled by any alternative means. Also, there was a lack of commitment by some of the early participating agencies which led to their termination of activities at an early date.

A conflict existed between ease of access, operability and representativeness in the selection of Marmot. Early in the program it was realized that Marmot might not be the most representative basin, but that the proximity of the Kananaskis Forest Research Station made it attractive from an operational aspect. However, Marmot contained a marginal amount of timber to cut, in that 40 to 50% of the basin is alpine and not harvestable. Furthermore, about 40% of the timbered area was at an elevation where harvesting was prohibited by regulations (which were waived for the Cabin Creek treatment).

Conflict with changing forestry operations. It takes 10 to 15 or more years of records after calibration and treatment to evaluate the effect of a forest clearing operation on streamflow. By the time the results are in, the practice being used may have changed. For instance, commercial practice at the time Marmot was started was to completely clear all standing timber from a cut block. By the time Cabin Creek was clear-cut, the practice was to leave non merchantable trees standing. These two differ in the microclimate and energy transfer characteristics at the snow and underlying vegetation surfaces.

Numerous other operational problems were encountered. For example:

- During the latter period of the study, 'glaciation' occurred at the Cabin Creek hydrometric station, which led to some record loss during low flow periods.
- Hydrometric stations were much more difficult and expensive to install than originally envisioned.
- As time progressed, rehabilitation work was required on some of the control structures, and if not carried out promptly, some record loss was incurred.
- A coal lease existed in Marmot which threatened its existence as a research area.
- Lastly, an area adjacent to Marmot was selected for the 1988 Olympics. Although the Olympic site was completely outside of Marmot, the Province's desire to allow for expansion of the ski runs into the watershed forced Marmot's closure in October 1986.

ACCOMPLISHMENTS

The extensive hydrometeorological data sets for the basin (Davis, 1964) were very useful in testing and calibrating watershed simulation models. The major benefit to the Water Resources Branch, which originally wasn't envisioned, was acquiring an excellent knowledge of various control structures, and enabled the Branch to improve its operational capabilities, both locally and nationally.

An aspect which can be readily overlooked is the personal contact benefits of a multi agency project. These contacts, which have been generated over a period of 25 years, have been very beneficial to the majority of participants in the research basins.

The Marmot Creek Basin has also served as a showplace for international and national visitors, although the magnitude of the project may have led some to believe that much more was being accomplished than actually occurred.

For the most part, the meteorological studies (Ferguson & Storr, 1972) successfully achieved their objectives (Storr, 1977). The precipitation data were successfully analyzed to show the relationship between snowpack accumulation and altitude (Golding, 1974), and similar relationships between evaporation and elevation were also demonstrated.

Photogrammetry proved to be somewhat successful for estimating the snow in Marmot basin and a new technique was developed to extract radiation data from recording charts (Storr, 1972). In experiment undertaken to examine the siting of precipitation gauges in mountainous terrain, Storr (1966) found that the criteria recommended by the World Meteorological Organization resulted in serious undercatch of precipitation in the Marmot Basin.

Clear-cut harvesting of 23% of the area of the Cabin Creek subbasin of Marmot in 10 ha commercial-sized blocks increased annual water yield by 35.7 dam³ (17 mm) or 6% greater than predicted if left uncut (Swanson et al., 1986). Erosion was not a problem on the stable soils of Cabin Creek; neither did suspended sediment load increase as a result of this timber harvest.

Clear-cutting 50% of the vegetated portion of the west subbasin of Streeter in a pattern designed to augment snow accumulation and retention of snow on site increased water yield from a small contact spring, during April through October, by 6.3 dam³ (82 mm) or 175% more than predicted if left uncut (Swanson et al., 1986). More importantly, flow continued throughout the summer of 1977, the second driest year on record in southern Alberta, even though predicted flow was zero if left uncut.

IMPACT OF RESULTS ON WATER MANAGEMENT

There is a conflict within this research program, and among the coauthors of this paper, as to the objectives of the Marmot, Cabin Creek subbasin treatment and the statistical significance of the results. Differing interpretation of the treatment and its results continue to affect the way the results are viewed and used by research agencies and water management agencies.

The Research Coordinating Committee, under whose auspices the Cabin Creek treatment was conducted, changed the objectives of this treatment from one to evaluate the effect on water yield and sediment to one of sediment only. This was done because the members of the committee recognized that the area to be treated on Cabin Creek was small, and that the statistical errors in evaluation were large, so that an effect on streamflow would be difficult if not impossible to detect. We also recognized that variation in sediments must be large if they are to be detected as the errors in measuring sediment are normally greater than those in measuring streamflow.

On the other hand, the effect on streamflow was a major objective of the program that had to be met. The research coordinator (Swanson) felt that data from the Cabin and Twin Creek treatments could be combined with data from plot studies done elsewhere in Alberta, Canada and the United States, to derive a simulation model to meet the "effect" on streamflow objective.

The selection of Mount Allan as the site for the 1988 Olympics, and the threat to the research program that this selection posed forced premature evaluation of the Cabin Creek treatment. An extended period of below normal snowfall years following treatment, fairly high standard errors in the paired watershed regressions and the 1986 closure of Marmot prevented us from obtaining a sufficient number of years of data (Kovner & Evans, 1954) to conduct a satisfactory statistical evaluation of either the Cabin or Twin Creek treatments. However, statistical evaluation of the Cabin Creek data was attempted, but at a lower confidence level (80%) than that normally used in research studies (95 to 99%, Freese, 1967), by Swanson et al. (1986), who determined that an increase in yield of 17 mm was statistically significant at the 90% level. The same data were examined under contract from the Water Resources Branch by Hydrocon Engineering (Continental) Ltd (1985), who concluded that the increase in streamflow on Cabin Creek was not statistically significant at the 95 to 99% level, and therefore was non existent.

Thus one major point of contention within the Marmot program is whether or not streamflow on Cabin creek was actually increased by the clear-cutting that occurred. Since the treatment of Cabin was intended to emulate existing commercial harvesting practice and not to optimize water yield and the evaluation period was curtailed, those of us in research were delighted that an increase could be detected at any reasonable level of probability. We all agree that the increase that occurred as a result of the Cabin Creek treatment is physically insignificant in terms of water management of the eastern slopes.

On the other hand, those of us in research contend that clear-cutting specifically designed to increase water yields would produce physically significant gains in streamflow from the eastern slopes watersheds. The WRENSS (Troendle & Leaf, 1980) procedure simulates increases of 50 to 60 mm over most of the eastern slopes watershed if 1 hectare clearings are created (Swanson & Bernier, 1986). The simulated increase in yield with 1 ha clear-cuts is roughly 3 times the 17 mm observed at Cabin Creek where 10 hectare clearings were created, approximately 2 times the 41 mm obtained from 16 to 1400 ha clear-cut under a primarily spring rain dominated precipitation regime at Hinton, Alberta, (Swanson & Hillman, 1977) but somewhat less than the 80 mm observed at Streeter Basin where 1/2 hectare clearings were created. WRENSS simulations for Streeter, Hinton and Marmot Cabin are 82 mm, 33 mm and 11 mm respectively.

Regardless of the foregoing, the bottom line is that the impact of the Marmot and Streeter projects on water management in Alberta and within the eastern slopes watershed is non-existent. The primary reason for this is the changing use and management pattern within the eastern slopes watershed, which to date has frustrated our efforts to put in place a recommended (Northwest Hydraulics Consultants Ltd., 1977) demonstration or operational watershed management project (Bernier & Swanson, 1986). We realize that land managers in the eastern slopes watershed must consider uses other than water production when making decisions. It is presumed to be more expensive to harvest timber from the small clear-cuts that our's and other's results (Leaf, 1975; Troendle, 1983) indicate to be most effective in enhancing water yield than from those presently used. An economical means to harvest timber in order to maintain a supply of logs for the wood products sector of the economy continues to be important in Alberta. It is likely that recreational use and the maintenance of wildlife habitat within the eastern slopes watershed will assume *increasing* importance in the future. Many areas of the watershed that could have been managed for water yield improvement have *already been* harvested in the less-efficient (for water yield increase) larger clear-cuts and a new stand of merchantable trees will not be available for 100 or more years. Other areas are being set aside for uses not compatible with any type of timber harvesting. Therefore, even though water yield improvement is technically feasible, it is extremely improbable that forest cutting specifically designed to augment water yields from the eastern slopes will ever take place.

AVAILABILITY OF RESULTS

Hydrology:

All streamflow data is available in the annual "Surface Water Data Alberta" publications produced by Environment Canada (e.g. Water Survey of Canada, 1987a & b). These data are also available on tape and microfiche. A limited quantity of the annual compilations of hydrometeorological data are available for Marmot for the years 1962 to 1980, and for Streeter for the years 1964 to 1977, from Canada Water Resources Branch, Calgary.

Climate and meteorology:

The meteorological data sets have been archived and a documentation of their status was completed by Mann (1984a). The studies were well documented in the proceedings of numerous hydrology workshops and various Western Snow Conferences, as well as in several refereed journals. A comprehensive survey of all of these reports was completed by Mann (1984b).

Forest cutting/water interactions:

The WRENSS procedure (Troendle & Leaf, 1980) has been tested against Marmot Cabin Creek and Streeter Basin data. This procedure provides an objective way to propose and evaluate the effects of various forest clear-cutting treatments on annual water yield. It has been programmed for use on a microcomputer (IBM PC compatible; Bernier, 1986) and is available upon request from the Canadian Forestry Service, free of charge.

The results of clear-cutting portions of the Marmot Cabin Creek and Streeter Basin watersheds, and the streamflow data upon which those results are based, are available in a single publication (Swanson *et al.*, 1986). Most of the research done on Marmot and Streeter Basins were catalogued in a symposium proceedings in 1977 (Swanson & Logan, 1977). We plan to publish an updated annotated bibliography in the near future. At the present time, these combined research basin programs have resulted in over 87 published reports.

ARE RESULTS BEING USED?

Hydrology:

The data have been used to conduct watershed modelling studies. It has also been utilized to make the decision that the results can't be used operationally to increase water yield on the eastern slopes.

The major use has been by university students. Countless numbers of requests were filled for these users, who utilized the information for papers and theses.

Climate and meteorology:

The Marmot data sets have proven valuable for the recreational development which proceeded subsequently in the Kananaskis Valley. Most of this work has focused on preparations for the 1988 Winter Olympics, and the Marmot snow, wind, and temperature data have been used in preparing climatologies for the neighbouring Nakiska ski area. In addition, the development of techniques used in the weather forecasting program for the ski area would have been much less successful than they were had the 20-year Marmot database and the resultant research reports been unavailable.

Forest cutting/water interactions:

Yes, the results are being used primarily for model development and verification. Both Marmot and Streeter have provided valuable hydrologic process and treatment effects data for developing, modifying and testing watershed simulation models. The most fully developed model application is the simplified WRENSS (Troendle & Leaf, 1980; Bernier, 1986) procedure which is currently being used by the Alberta Forest Service to estimate the effects of various controversial harvests on streamflow. WRENSS is also being used to design or evaluate treatments in other situations where forest cutting is being considered as one of several alternatives to augment water yield, e.g. Lenosee Lake watershed in Saskatchewan.

WOULD YOU DO IT ALL THE SAME AGAIN?

Hydrology:

It is obvious that the answer is no. From a water management agency's perspective, the most significant negative is that even if water yields could have been quadrupled, the results probably couldn't be applied.

Climate and meteorology:

From the meteorological perspective the answer is maybe. Monitoring technologies have improved markedly since the Marmot and Streeter programs were started. Should the need for another similar program be demonstrated, current technologies would permit accomplishing more with less manpower. This was in fact recently proven during the 1988 Winter Olympics when an extensive wind and precipitation network was established on the southeast shoulder of Mount Allan and successfully operated essentially unattended for the last two years. Remote sensing technologies and reliable hardware have greatly reduced manpower needs for programs of this type.

Forest cutting/water interactions:

From the forestry research perspective the answer is no. There was no firm commitment by the forest management agency to implement water yield improvement practices within the eastern slopes watershed. Furthermore, it has taken so long to obtain locally-derived results that the management opportunities have slipped away. The science of forest hydrology was well enough advanced in 1960 so that a cutting pattern could have been proposed and tested as a pilot treatment. The advice of those experienced in watershed management research in the United States was to initiate such a pilot program, using a cutting pattern similar to that on the Fool Creek watershed in Colorado. Our findings still point to this type of cutting pattern as being the most suitable for application to increase water yield from the subalpine and foothills forests. In retrospect, this advice should have been followed. Fortunately for us, none of the current research or management personnel were part of the decision process at that time.

In 1960, no acceptable hydrologic simulation model was available. This has changed radically since then. We now have a number of reasonably good models to choose from. If starting again, we would recommend that we adopt one of these and develop it as a tool for transferring the results of small watershed and plot experiments to operational situations. The emphasis would be on making the model usable with a minimum amount of data on ungauged watersheds. Experimental watersheds such as Marmot and Streeter would not have been expected to be representative of any particular zone, but would be regarded as places to test simulation results from proposed treatments in order to establish the credibility of the model.

The Marmot and Streeter basin studies provide contrasting examples of how not to approach a research study, i.e., to choose research sites without due and full consideration of all of the ultimate research objectives. In the case of Streeter, a poor choice was overcome by modifying the objectives to make them fit the physical realities of the basin. However, the physical problems encountered in Marmot were not as readily evident as those in Streeter, and even though the Cabin Creek treatment objectives were modified to meet research objections, the modifications were not totally agreed to by the management agencies involved.

REFERENCES

Alberta (1971) Timber management regulations. Regulation 60/73. Office Consolidation. Department of Lands and Forests, Edmonton, Alberta.

Alexander, R. R. & R. K. Watkins (1977) The Fraser Experimental Forest, Colorado. U. S. Department of Agriculture, Forest Service. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. General Technical Report RM-40. 32 pp.

Bernier, P.Y (1986) A programmed procedure for evaluating the effect of forest management on water yield. Canadian Forestry Service, Northern Forestry Centre, Edmonton, Alberta. Forest Management Note No. 37. 12 p.

Bernier, P.Y. & R.H. Swanson (1986) A watershed management pilot project in Alberta. pp. 87-92 *In: Proceedings 54th Annual Meeting, Western Snow Conference*, 15-17 April 1986, Phoenix Arizona.

Canada (1947) An act respecting the protection and conservation of the forests on the Eastern Slope of the Rocky Mountains. Parliament of Canada, Ottawa. Chapter 59, 311-327.

Davis, D. A. (1964) Collection and compilation of streamflow data in Marmot Creek basin. *Research Watersheds, Hydrology Symposium No. 4*. National Research Council, Ottawa. pp. 105-116.

Dickinson, W. T. (1982) Distributed watershed models for the Marmot basin. *Hydrological Processes of Forested Areas, Canadian Hydrology Symposium CHS-82*. National Research Council of Canada, Ottawa. pp. 441-462.

Ferguson, H.L. & D. Storr (1972) Hydrometeorological network design for basin studies. National Research Council of Canada, Associate Committee on Hydrology, Canadian National Committee for the International Hydrological Decade workshop on Hydrological Data Collection, Ottawa.

Freese, F. (1967) *Elementary Statistical Methods for Foresters*. U.S. Department of Agriculture, Forest Service, Washington, D.C. Agriculture Handbook 317. 87 pp.

Golding, D.L. (1974) The correlation of snowpack with topography and snowmelt runoff on Marmot Creek, Alberta. *Atmosphere* 12:31-38.

Hydrocon Engineering (Continental) Ltd. (1985) Marmot Creek watershed study. File report No. 216-26.3. Prepared for Water Survey of Canada, Calgary, Alberta.

Jeffrey, W. W. (1964) Watershed research in the Saskatchewan River headwaters. *Research Watersheds, Hydrology Symposium No. 4*. National Research Council, Ottawa. pp. 79-104.

Jeffrey, W. W. (1965) Experimental Watersheds in the Rocky Mountains, Alberta, Canada. International Association of Scientific Hydrology Publication No. 66. pp. 502-521.

Kovner, J.L. & T.C. Evans (1954) A method for determining the minimum duration of watershed experiments. *Trans. Amer. Geophys. Union*, 53(4):608-612.

Laycock, A. H. (1965) The need for a regional approach in watershed management planning. Proceedings First Annual Meeting American Water Resources Association, December 1-3, 1965. Chicago, Illinois. pp. 146-154.

Leaf, C. F. (1975) Watershed Management in the Rocky Mountain Subalpine Zone: the Status of our Knowledge. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-137. 31 pp.

Mann, A.S. (1984a) Alberta Watershed Research Program - Hydrometeorological Data Reports, 1963-1982.

Mann, A.S. (1984b) Alberta Watershed Research Program - Summary of Hydrometeorological Project Reports, 1963-1982.

Northwest Hydraulics Consultants Ltd. (1977) Watershed management for increased water yield. Report prepared for the Oldman River Basin Study management Committee, Edmonton, Alberta. 62pp.

Rowe, J. S. (1977) *Forest Regions of Canada*. Canada Department of the Environment, Canadian Forestry Service, Ottawa. Publication 1300. 172 pp.

Storr, D. (1966) A raingauge comparison in a mountainous area. Environment Canada, Atmospheric Environment Service, Downsview, Ontario. Technical Memorandum 617.

Storr, D. (1972) A revised radiation scale. Environment Canada, Atmospheric Environment Service, Downsview, Ontario. Technical Memorandum 776. 11 p.

Storr, D. 1977. Some preliminary water balances of Marmot Creek subbasins. *Alberta Watershed Research Program Symposium Proceedings, 1977*. R. H. Swanson and P. A. Logan, compilers. Fisheries and Environment Canada, Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta. Information Report NOR-X-176. pp. 159-177.

Swanson, R.H. & P.Y. Bernier (1986) The potential for increasing water supply in the Saskatchewan River system through watershed management. *In*: *Canadian Hydrology Symposium CHS:86*, June 3-6, 1986, Regina, Saskatchewan, p, 485-596. National Research Council of Canada, Associate Committee on Hydrology, Ottawa.

Swanson, R. H. & G. R. Hillman (1977) Predicted Increased Water Yield After Clear-cutting Verified in West-central Alberta. Canada Department of Fisheries and Environment, Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta. Information Report NOR-X-198. 40 pp.

Swanson, R.H. & P.A. Logan, Editors (1977) Alberta Watershed Research Program Symposium Proceedings, 1977. Fisheries and Environment Canada, Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta. Information Report NOR-X-176.

Swanson, R.H., D.L. Golding, R.L. Rothwell & P.Y. Bernier (1986) Hydrologic effects of clear-cutting at Marmot Creek and Streeter watersheds, Alberta. Canadian Forestry Service, Northern Forestry Centre, Edmonton, Alberta. *Information Report NOR-X-278*. 27 p.

Troendle, C. A. (1983) The potential for water yield augmentation from forest management in the Rocky Mountain region. *Water Resources Bulletin*, 19:359-373.

Troendle, C. A. & C. F. Leaf (1980) Hydrology, Chapter III, p. III-1 to III-173. *In*: *An approach to water resources evaluation of non-point silvicultural sources (a procedural handbook)*. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia. EPA-600/8-80-012. 861 pp.

Water Survey of Canada (1987a) *Historical Streamflow Summary Alberta to 1986*. Environment Canada, Inland Waters Directorate, Ottawa.

Water Survey of Canada (1987b) *Surface water data Alberta - 1987*. Environment Canada, Inland Waters Directorate, Ottawa.

National Research Council Canada
Conseil national de recheres Canada

ASSOCIATE COMMITTEE ON HYDROLOGY
COMITE ASSOCIE D'HYDROLOGIE

PROCEEDINGS OF THE CANADIAN HYDROLOGY SYMPOSIUM No 17 - 1988

Canadian Research Basins: Successes, Failures and Future

COMPTES RENDUS DU SYMPOSIUM CANADIEN D'HYDROLOGIE No 17 - 1988

Les Bassins de Recherche canadiens: Succès, Eches et Futur

CHS
88
SCH

Banff, Alberta
May 9-11 Mai 1988

NRCC No. 30416

ISBN 0-660-54946-8