CANADIAN HYDROLOGY SYMPOSIUM (CHS:86)
ASSOCIATE COMMITTEE ON HYDROLOGY
NATIONAL RESEARCH COUNCIL OF CANADA
JUNE 3 - 6, 1986
REGINA, SASKATCHEWAN

SYMPOSIUM CANADIEN D'HYDROLOGIE (CHS:86)
COMITE ASSOCIE D'HYDROLOGIE
CONSEIL NATIONAL DE RECHERCHES CANADA
LES 3 - 6 JUIN 1986
REGINA, SASKATCHEWAN

THE POTENTIAL FOR INCREASING WATER SUPPLY IN THE SASKATCHEWAN RIVER SYSTEM THROUGH WATERSHED MANAGEMENT

Robert H. Swanson and Pierre Y. Bernier[a]

ABSTRACT

The Eastern Rockies Forest Conservation Board was established in 1947 with a mandate for the conservation, development, maintenance and management of the forests in the eastern slopes watershed with a view to obtaining the greatest possible flow of water in the Saskatchewan River and its tributaries. Research studies were initiated in the Marmot and Streeter Experimental watersheds to learn how to accomplish such flow maximization. The results from these and other watershed studies indicate that increases in annual water yield vary greatly with wind speed and the size of clear-cut pattern imposed, ranging from an increase of 7 mm with 10 ha clear-cuts and wind speed of 5 m/s, to over 50 mm with 1 ha clearings under any wind regime.

The eastern slopes watershed contains approximately 22,946 km^2 of coniferous forest cover. If this were managed for maximum water yield, the increase in annual discharge would be 1,200,000 cubic decameters, an increase of about 7.5% in the average flow of the combined North and South Saskatchewan rivers. If the present system of forest management is sustained for 100 years, the increase in yield that will occur in any given year will depend upon that winter's wind regime and will be between 65,600 and 315,000 cubic decameters; representing increases in the average flow of 0.4 and 2% respectively.

[a] Project leader and Research Scientist, respectively, Northern Forestry Centre, Edmonton, Alberta.

RESUME

Le "Eastern Rockies Forest Conservation Board" fut établi en 1947 avec le mandat de conserver, développer, maintenir et gérer les forêts du versant est des Rocheuses dans le but d'obtenir le débit maximum de la rivière Saskatchewan et de ses tributaires. Des études furent entreprises aux bassins expérimentaux de Marmot et de Streeter afin d'apprendre comment maximiser les débits. Les résultats obtenus sur ces bassins et sur d'autres indiquent que l'augmentation annuelle des débits présente de fortes variations selon la vitesse des vents et la dimension des blocs de coupe, variations allant de 7 mm pour des blocs de 10 ha et des vents de 5 m/sec, à 50 mm pour des blocs de 1 ha, quel que soit le vent.

Les bassins du versant est des Rocheuses contiennent environ 22 946 km^2 de forêts résineuses. Si ces forêts étaient aménagées afin de maximiser les débits, l'augmentation annuelle serait de 1 2000 000 décamètres cubes, une augmentation d'environ 7,5% du débit moyen des rivières North et South Saskatchewan combinées. Si le système actuel d'aménagement forestier est maintenu pour les 100 prochaines années, l'augmentation annuelle des débits pour une année particulière dépendra du régime des vents durant l'hiver, et sera entre 65 600 et 315 000 décamètres cubes, représentant des augmentations du débit moyen de 0,4 et 2% respectivement.

THE EASTERN SLOPES WATERSHED

The eastern slopes of the Rocky Mountains in Alberta are the most important water-yielding portion of the Saskatchewan River watershed. The Eastern Rockies Forest Conservation Board (ERFCB) was constituted in 1947 in recognition of the special status that this area has with respect to water supply in the Saskatchewan River, which is vital to the water needs of southern Alberta and Saskatchewan (Canada 1947). "How to manage the conservation area for water production and water supply protection" was the question faced by the ERFCB. The joint provincial-federal Alberta Watershed Research Program (AWRP) was initiated during the period 1960 to 1963 with the establishment of experimental watersheds at Marmot Creek and Streeter Creek to examine the effects of forest cutting on streamflow (Jeffrey, 1964). A commercial clear-cut was established on Marmot Cabin Creek in 1974; small patch clear-cuts on Streeter Basin in 1976. The results of both of these experiments were reported by Swanson et al (1986). The effect of commercial clear-cutting operation on water yield was determined on a 7800 km^2 pulpwood lease near Hinton, Alberta (Swanson and Hillman 1977). The combination of these experimental results from Alberta and work done in similar vegetation types in the United States, is sufficiently general and conclusive so that the specification of timber cutting prescriptions to produce predictable increases in annual water yield from the Saskatchewan River headwaters are now possible.

In this paper we have applied the results of ours and other's research (Bernier and Swanson 1986) to impose various forest clearing options on those headwaters. About 22,946 km^2 of the headwaters (exclusive of the National Parks) can support trees and would be available for some form of timber cutting activity to increase water yield. However, commercial forest harvest is allowed on only 18,742 km^2.

THE POTENTIAL FOR INCREASING YIELD

The potential for increasing water yield by manipulating a forested landscape is determined by the areal extent of tree-type vegetation, the amount and form of precipitation received, and factors that affect evaporation. Evaporation and/or transpiration (evapotranspiration, ET) must be reduced in order to increase water yield. Transpiration by the trees and evaporation from the foliage is reduced by removing the trees. However, reducing post-harvest evapotranspiration is not just a matter of removing trees. The physical conditions that favour high evaporation rates must also be altered.

Evaporation from the surface beneath a canopy of trees is always low because water vapour concentration is high and turbulent exchange is low. To some degree, these low evaporation conditions can be approached within clear-cuts if their size is sufficiently small so that the active boundary layer is maintained at the canopy level of the surrounding trees. Research has shown that if surface winds are low then evaporative losses are low too (Satterlund 1972). Our research has further shown that the wind speed in clearings with horizontal dimensions less than six times the height of the surrounding trees is less then one-tenth that above the canopy (Swanson 1980).

On subalpine and foothills watersheds, reductions in ET and subsequent increases in water yield, are better achieved through a patterned removal of some of the trees than by complete clear-cutting (Leaf 1975). In large clear-cuts, the increased exposure of the snow and ground surface to high winds will lead to some increased evaporation. With patterned clear-cutting, more snow will accumulate in the clearings than under the surrounding forest, and in small clearings, the snow will be sheltered from the wind as well.

WRENSS procedure to estimate water yield increase

The hydrology portion of WRENSS (Environmental Protection Agency 1980) can be used to estimate annual water yield from uncut and partially clear-cut watersheds. The portion of WRENSS that is applicable to Alberta is based on a simulation model (WATBAL) of the interaction between snowpack manipulation and ET that was derived from experimental watershed data in Colorado (Leaf and Brink 1975).

We use the WRENSS technique because it has produced reasonable estimates of actual annual water yield from both harvested and unharvested experimental watersheds in Alberta (Bernier and Swanson 1986). The similarity of climate and vegetation over the latitudinal range of the subalpine and foothills zones of the Rocky Mountains is the primary reason that this technique is usable to estimate the water yield increases that can be anticipated from Alberta's eastern slopes. WRENSS regions four and six produce reasonable results in application to the subalpine and foothills zones of Alberta. We have used region six in this paper.

Data requirements for WRENSS are minimal. The only climatic data input is annual precipitation divided into fall-winter, spring and summer groups. The only output is annual yield. WRENSS does not produce routed streamflow.

In order to estimate changes in yield that will occur under a forest management scheme, WRENSS is first used to calculate the annual yield for some baseline condition (usually fully treed). Then the annual yield under the same precipitation regime but with some clear-cutting of the forest is calculated. The difference between the two values is the potential change in annual yield. In both cases, seasonal evapotranspiration is estimated from vegetated cover density and seasonal precipitation. In the case with partial clear-cuts, WRENSS apportions differing amounts of precipitation to the cut and treed areas on the following bases:

1) in clear-cuts, with maximum windward dimensions less than approximately 15-tree heights, snow accumulates preferentially at the expense of the surrounding treed area;

2) in clear-cuts with windward dimensions greater than 15-tree heights, snow may be removed from the clearing by wind and either sublimate while in transport or be redeposited in the downwind treed areas;

3) if the surface of a clear-cut is aerodynamically rough, then snow may be retained in place regardless of the windward dimensions.

Some evaporation may occur in situ from the surface of the snow accumulated within a clear-cut. This possibility was addressed by WRENSS in a manner that did not take into account local conditions. Evaporation from snow was either ignored or considered to be a constant. Neither approach is entirely satisfactory in Alberta's eastern slopes which have a reputation for windiness. We have therefore altered the WRENSS treatment of in situ evaporation from snow and made provision for various wind regimes to be included as options in a management plan. This has been accomplished by reducing the snowpack in clear-cuts by an amount evaporated which is a function of the wind speed in the clear-cut. Our studies have shown that the wind speed 2 m above the surface of clear-cuts greater than 30 tree heights across is the same as would occur at either 10 m above the canopy or in completely open situations (V_{open}) (Swanson 1980). In clear-cuts smaller than 30 tree heights across, wind speed in the clear-cut ($V_{clear-cut}$) is reduced as a function of clear-cut dimensions (H, in tree heights) in accordance with equation [1].

$$[1] \qquad V_{clear-cut} = (0.0214 + 0.0067H + 0.00084H^2)V_{open}$$

We have coupled 120 days of V_{open} wind speeds of 0, 1, and 5 m/sec, and a theoretical snow evaporation rate of 0.15 mm/day (relative humidity approximately 70%, air temperature -5 °C, V_{open} 1 m/sec: composite of information from Figure 1, Boyd[b]; and Table 8-5, Satterlund 1972), to estimate the loss from the snowpack of clear-cuts and the potential effect of such loss on water yield.

Estimated yield increase by vegetation zone

We have applied the WRENSS procedure to estimate the annual water

---

b From discussion on pages 311 to 314 in Proceedings of the First Canadian Conference on Microclimate, Part II. April 12-15, 1965, Toronto, Ontario, R. E. Munn, editor. Canada Department of Transport, Meteorological Branch, Toronto.

yield increase[c] that would result from clear-cutting one-half of the trees from a one square kilometre area. Originally, we divided the eastern slopes into vegetation zones and calculated yield increases separately for each of them with precipitation from years with high, low and average discharge. The yield increase, in millimeters, that would occur during high, low and average precipitation years was the same. Likewise, the difference in yield change between vegetation zones was generally less than 1 or 2 millimeters. Therefore water yield results obtained from simulation runs of the subalpine spruce-fir zone, (with average precipitation from the Marmot Experimental watershed of; Fall-Winter 197 mm, Spring 269 mm, and Summer 161 mm) were applied to all vegetation zones.

Innumerable sizes of clear-cuts and proportions of cleared/uncut area are possible. We have considered only two:

1) 50% clear-cut with uniformly distributed 1 hectare blocks;
2) 50% clear-cut with uniformly distributed 10 hectare blocks.

The wind speed associated with a clear-cut size is a function of the windward cross-sectional dimension in tree heights. With the 20 m tall trees of these forests, ten hectare square blocks are approximately 16 tree-heights across; one hectare blocks 5 tree-heights across.

The increase (mm) in annual yield estimated for the unit area has been multiplied by an applicable area to give an estimate of the change in annual discharge in cubic decameters. The physical significance of the estimated increase in discharge can be best appreciated when compared with the maximum, average and minimum annual discharge of the combined North and South Saskatchewan rivers during the period 1912 - 1984 which are 31,400,000, 15,930,000, and 6,970,000 cubic decameters respectively (Water Survey of Canada 1985). The conversion is direct as 1 millimetre increase in yield over a square kilometre equals 1 cubic decametre of discharge.

MANAGEMENT OF THE EASTERN SLOPES FOR WATER YIELD

The Eastern Rockies Forest Conservation Board's mandate to manage these forests to maximize flow can be interpreted in at least two ways. 1) To manage for maximum water production, that is, to physically arrange the trees so that the maximum amount of water would be released from the entire eastern slopes and to permit a forest industry <u>only</u> if it were permissable within that scheme. Or 2) to manage the eastern slopes primarily for sustained timber production with constraints on the form of harvest to ensure maximum water yield from those areas where cutting occurs.

---

c We have only shown increases. One can also simulate a decrease in yield by imposing a mean wind speed greater than 7 to 10 m/s.

Management for maximum water yield

In their present state the forests of the eastern slopes could be harvested in a manner that would produce maximum water yield. Theoretically, all of the eastern slopes area that is presently treed, or will have trees within an acceptable time period, that is 22,946 square kilometers, could be manipulated to increase water yield. A mosaic of clear-cut patches, with maximum dimensions of approximately 5 tree heights, interspersed with an equal number and size of uncut blocks, would increase annual water yield by approximately 60 mm (Table 1, option 1a); larger clear-cut blocks would result in smaller yield increases (Table 1, option 1b). Since this type of cutting need not depend upon commercial use of the material removed, it could be applied to all vegetated areas except barren rock or above timberline with equal effectiveness. With 5 m/s winds, 1 ha clear-cutting would produce an increase in annual discharge of 1,193,190 dam^3, an increase of 7.5% in the mean flow of the North and South Saskatchewan Rivers (Table 1, option 1a).

Clearing to create this maximum water yielding state could be done over a short time period if desired. The clearings would have to be maintained by reclearing about every 10 years. Much of the material cleared could not be used by the existing forest products industry. Both the initial clearing and subsequent maintenance clearing would have to be heavily subsidized by water users. Unless some alternative use were found for the timber, this type of watershed management would result in considerable waste and probably be socially unacceptable, regardless of the value of the water.

Water yield increase under present forest management

The forests of the eastern slopes watershed are currently managed to produce a sustainable volume of usable timber in perpetuity, not to maximize water yield. One goal of the existing forest management system is to create a mosaic of differing ages of trees in order to provide a harvestable crop each year in the future. This is being accomplished by clear-cutting areas that are widely dispersed over the total forest area within a 100-year time frame that will allow the growth of a replacement crop. No cutting is allowed in areas that are too steep, too wet, or that lie above a "watershed protection contour". These inoperable areas where cutting is not allowed make up 30 to 50% of the 18,742 km^2. Within the remaining 50 to 70% operable portion, the allowable harvest (the annual allowable cut) is one percent of the total volume of the operable area each year.

The eastern slopes forests are further subdivided into 18 approximately equal-sized areas which are managed individually on a sustained-yield basis, each with its own annual allowable cut. These areas are further divided into operating units which provide a 20-year supply of timber for a local industrial operator. The operating units with the oldest trees are harvested first. This is done to avoid over-cutting in accessible areas while more remote timber decays. At the end of the first 100-years of harvest, each of the 18 areas should contain an even distribution of trees ranging from 0 to 100 years old. A sustained yield of products from each unit ensures that harvesting operations are not concentrated in any one portion of the eastern slopes and promotes the establishment of permanent manufacturing facilities with stable communities.

The clear-cutting in each operating unit is done in two stages. In the first stage, blocks are clear-cut that are roughly 10 ha in size. These are separated from each other by similarly-sized uncut blocks. In the second ten years (subject to suitable replacement trees and growth on the blocks cleared earlier), the uncut blocks are removed, starting with those adjacent to the blocks cleared earliest in the first ten years. An entire operating unit will have been clear-cut at year twenty. This sequence is repeated five times so that at the end of the first 100 years, all of the timber from the operable portions of a sustained yield unit will have been harvested. The trees on inoperable areas are never cut. At year 100 several water yield possibilities exist (Table 1, option 2b):

1) if wind speed is near zero, the yield increase is 27 mm;

2) if wind speed is moderate (assuming an average V_{open} of 5 m/s from November through March) then the yield increase is 7 mm as the block size is too large for the surrounding old trees to have more than a minor effect on wind speed in the cleared area, and sublimation losses from the winter snow pack are barely offset by reduced transpiration;

3) if wind speed is low (wind approximately 1 m/s), then an intermediate yield increase of 24 mm occurs.

If we assume that all 18 units of the eastern slopes forests are being fully harvested at allowable cut (assuming 70% of the unit is operable), then the increased in discharge is:

1) with zero wind -- 354,220 dam^3 -- a 2.2% increase in the average flow of the combined North and South Saskatchewan Rivers as measured at Prince Albert and Saskatoon.

2) with winds 5 m/s -- 91,840 dam^3 -- an increase of only 0.6% in the average flow of the combined rivers.

The allowable cut is not being harvested nor is 70% of the land operable in all units; therefore the water yield increase will always be less than these estimates under the existing forest management system. It should also be noted that under this system, the amount of clear-cutting in any moderate sized watershed that has occurred to date is to small for any increases in yield to be noted.

Table 1. Estimated increase in annual water yield and discharge[1] from the Saskatchewan river headwaters at full implementation of several forest cutting options. See section in text on present forest management for description of operable land.

Option	Wind speed (m/s)	Increased yield (mm)	Increased watershed discharge Cubic Decameters	
1.	Water yield only, no regrowth of trees, total area 22,946 km^2			
a.	1 hectare clear-cut blocks, maintenance after establishment			
	0	60	1,376,760	
	1	58	1,330,870	
	5	52	1,193,190	
b.	10 hectare clear-cut blocks, maintenance after establishment			
	0	45	1,032,570	
	1	42	963,730	
	5	32	734,270	
2.	Commercial forestry, regrowth starting year 1, manageable area 18,742 km^2 of which 50 to 70% is operable.			
a.	1 hectare clear-cut blocks, 20 year cutting cycle.			
			(70%)	(50%)
	0	31	406,700	290,500
	1	29	380,460	271,760
	5	21	275,510	196,790
b.	10 ha clear-cut blocks, 20 year cutting cycle.			
	0	27	354,220	253,020
	1	24	314,870	224,900
	5	7	91,840	65,600
c.	1 ha clear-cut blocks, 50 year cutting cycle.			
	0	30	393,580	281,130
	1	29	380,460	271,760
	5	26	341,100	243,650
d.	10 ha clear-cut blocks, 50 year cutting cycle.			
	0	26	341,100	243,650
	1	22	288,630	206,160
	5	8	104,960	74,970

Suggested alterations to existing practice for greater water yield

From the standpoint of increasing water yield, the biggest problem with the existing management scheme is the size of the clear-cut patches. A 10 ha square block clear-cut in 20 m tall trees has a windward dimension of 16 tree-heights and the wind speed at the surface is about 34% of that found in the open. During the second ten years of a 20-year cycle, the surrounding trees are 2 m tall, and clearings created from year 11 to 20 have a windward dimension of 200 tree heights. Wind speed in a 200 H clearing is the same as that in the open.

The same volume of timber could be removed from the identical total area if the size of each clear-cut was reduced to 1 ha (Table 1, option 2a). The increase in yield from 1 ha clear-cuts with calm winds would only be marginally greater than that occurring with the 10 ha blocks (31 mm versus 27 mm). With wind speed 5 m/s' the change would be three times as great (21 mm versus 7 mm with 10 ha blocks).

A slightly greater increase (26 mm instead of 21 mm at 5 m/s wind speed) would result if both 1 ha blocks were cleared and the cutting cycle was lengthened to 100 years with the intervening blocks removed at year 50 (Table 1, option 2c). The longer regrowth period would allow the surrounding trees to attain a height of 10 m. The 1 ha blocks are 10 tree heights across when this occurs, which offer considerably better protection from the effects of high winds than the 2 m tall trees of the 20 year cycle. However, lengthening the cutting cycle to 100 years with 10 hectare blocks only improves yield over the 20 year cycle at a wind speed of 5 m/s (Table 1, option 2d), and results in slightly lower increases at the lower wind speeds.

DISCUSSION AND CONCLUSIONS

It is possible to increase water yield from the Saskatchewan River headwaters. This can be accomplished by clear-cutting some of the forest. However, local wind conditions greatly influence the resultant yield. We have simulated the results at wind speeds of 1 and 5 m/s. Data from the Marmot Experimental Watershed indicate an average open wind speed of 4.2 m/s for 1970-1980. Therefore, our estimates at 5 m/s are probably not to far from the yield changes that should be anticipated. We recommend that clear-cut size not exceed 1 ha if the clear-cutting is to produce dependable water yield increases over a range of unknown climatic conditions.

Regrowth on clear-cuts, in terms of increasing basal area, generally starts slowly, reaches a maximum at middle age and declines toward maturity. In the WRENSS procedure, once basal area reaches half it maximum value, evapotranspiration returns to its preharvest level. We have imposed linear regrowth over the entire 100 years. This causes WRENSS to overestimate evapotranspiration during the first 50 years of regrowth. In our simulations, at age 50, basal area is one-half maximum and WRENSS calculations of evapotranspiration are not affected by further regrowth. Therefore, our estimates of water yield increase are generally conservative.

Our simulations indicated nearly identical water yield increases during low, high and average precipitation years. This occurs because evapotranspiration is relatively constant from year to year. In real situations, soil water deficits that exist at the start of the spring runoff season must be met before any water yield occurs. WRENSS does not allow one to carry either deficits or surpluses from year to year, and is thus somewhat unrealistic. We would expect to get lower yield increases in sequences of years with low precipitation, and higher yield increases during sequences of years with high precipitation.

The estimates for water yield increases under commercial forest management are based on harvesting trees from the land presently designated as operable. Operability is a function of both administrative decisions and harvesting technology. For example, in the central portion of the eastern slopes, all land above approximately 1800 m elevation was set aside as a watershed protection zone and is therefore inoperable. However, there is no physical reason why forest harvest to increase water yield could not occur in this zone. A second example is a rule against operating on 45% slopes. This is a machine limitation. Harvesting methods that use cable rather than ground-based skidding equipment can operate on these and much steeper slopes without damage to either the watershed or danger to the operator. Removal of these constraints could raise expected yield increases by as much as 50%.

We have not addressed the cost of increasing water yield through forest harvest. Existing commercial operations with 10 ha clear-cuts will probably continue at the same rate so that an increased yield between 7 and 24 mm will occur by the year 2070 at no cost to water users. All of the higher yield options require much smaller clear-cuts to produce dependable results. It is more difficult to harvest in 1 than in 10 hectare clear-cuts. Smaller clear-cuts require a much greater road density to extract the timber. They also cost more to layout on the ground. Forest managers should not impose these additional operating costs on operators to produce a product from which they receive no remuneration. If water users within the Saskatchewan River basin want Alberta's eastern slopes to be managed to increase water yield, then those users should be prepared to pay the additional costs associated with such management.

LITERATURE CITED

BERNIER, P. Y. AND R. H. SWANSON. (In review 1986). Evaluation and modifications of the USFS WRENSS procedure for estimating water yield from forested watersheds. To be submitted to Canadian Water Resources Journal.

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.

ENVIRONMENTAL PROTECTION AGENCY. 1980. An approach to water resources evaluation of non-point silvicultural sources (A procedural handbook). United States Environmental Protection Agency Environmental Research Laboratory, Athens, Georgia. EPA-600/8-80-012. 861 pp.

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

LEAF, C. F. 1975. Watershed management in the Rocky Mountain subalpine zone: the status of our knowledge. United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-137. 31 pp.

LEAF, C. F. AND G. E. BRINK. 1973. Hydrologic simulation model of Colorado subalpine forest. United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, Research Paper RM-107. 23 pp.

SATTERLUND, DONALD R. 1972. Wildland watershed management. The Ronald Press, New York. Table 8-5, p166.

SWANSON, R. H. 1980. Surface wind structure in forest clearings during a chinook. Proceedings, Western Snow Conference. 48th Annual Meeting. Laramie, Wyoming. April 15-17, pp. 26-30.

SWANSON, R. H. AND 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., D. L. GOLDING, R. L. ROTHWELL, AND P. Y. BERNIER. (In press 1986). The hydrologic effects of clear-cutting at Marmot Creek and Streeter watershed, Alberta. Agriculture Canada, Northern Forestry Centre, Edmonton, Alberta, Information Report.

WATER SURVEY OF CANADA. 1985. Historical streamflow summary Saskatchewan to 1984. Environment Canada, Inland Waters Directorate, Ottawa. 397 pp.

National Research Council Canada

Conseil national de recherches Canada

ASSOCIATE COMMITTEE ON HYDROLOGY

COMITE ASSOCIE D'HYDROLOGIE

PROCEEDINGS OF THE CANADIAN HYDROLOGY SYMPOSIUM No 16 - 1986

DROUGHT: The Impending Crisis?

COMPTES RENDUS DU SYMPOSIUM CANADIEN D'HYDROLOGIE No 16 - 1986

LA SECHERESSE: La Crise Est-Elle Imminente?

Regina, Saskatchewan
June 3-6, 1986 / 3-6 juin, 1986

NRCC No. 25514

ISBN 0-660-53262-X