A WATERSHED MANAGEMENT PILOT PROJECT IN ALBERTA

by

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INTRODUCTION

The Province of Alberta commissioned a study team to look at possible ways to augment water supply in the Oldman River of southern Alberta (Oldman River Study Management Committee 1978). One method looked at was timber clearing or watershed management. The most important objection raised to the implementation of a watershed management scheme was that it has never been proven that the yield increases obtained from harvesting experiments on small catchments can be obtained from similar type of harvesting on the basins of major rivers. The study recommended that a management-scale test be conducted on a basin in the 100-200 square kilometre size range.

To be successful, watershed management techniques must be tailored to the climate and vegetation of the area managed. The annual hydrograph in Alberta's eastern slopes is dominated by the snowmelt event. Vegetation management for augmenting annual water yield therefore implies snow management. Research in Alberta and elsewhere has shown that clear-cutting increases water yield. In areas with snow dominated hydrographs, higher increases in yield occur from partial clear-cutting with small patch cuts, which preferentially trap and retain snow, rather than complete clear-cutting (Leaf 1975, Troendle 1983). In Alberta, the maximum cross-sectional dimension of clearings for preferential accumulation and retention of snow is about 4 to 8 tree heights (H) (Stanton 1966, Swanson and Stevenson 1971, Golding and Swanson 1978).

The imposition of harvesting practices to increase water yield on an operational scale involves much more than the relatively simple alteration of the vegetated landscape to enhance snow accumulation and reduce evapotranspiration loss. Compromises must be made among operating costs, concerns of other users, operating guidelines, etc. Our purpose in this paper is to indicate the processes that we have undergone to arrive at an operational watershed management plan. The plan has not yet been implemented; neither has it received final approval by the Alberta Forest Service or Alberta Environment.

SELECTION OF A SUITABLE BASIN

A planning committee was organized that included representatives from Alberta Environment, the water management agency; Alberta Forest Service, the land management agency; and the Canadian Forestry Service, the source of expertise on vegetation management for increasing water yield. Representatives from Alberta Fish and Wildlife were also included to insure that wildlife habitat was given due consideration in the plan.

The project was intended to be located in the headwaters of the South Saskatchewan river, with a preference for the Oldman River headwaters that serve areas where the demand for additional water is the highest. Both pre- and post treatment simulation and the paired basin approach are to be used to evaluate water yield during a pre-treatment, treatment and evaluation periods of about 5 years each. Initial screening for an appropriate basin was based on the following criteria:

1) The basin area had to exceed 125 km^2 above a point where an adequate gauging structure could be installed.

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2) The estimated increase in annual water yield had to be at least 15% with the removal of 50% of its forest cover in order to insure detectability of treatment effect.

3) A control basin had to be located nearby and have similar size and physical characteristics.

4) Both the control and treated basins had to be free of active timber cutting operations and the control basin had to remain so for the anticipated duration of the project (15 years).

5) Both basins had to be well defined with at least 90% of the total flow measurable at one surface outlet.

An initial screening to obtain candidate watersheds of suitable area, timber and topography was done from topographic and timber type maps. The increase in water yield that we could expect from these candidates was estimated with the USFS WRENSS procedure (Environmental Protection Agency 1982). The WRENSS procedure computes annual evapotranspiration as a function of seasonal precipitation, stand type, stand basal area, aspect of the land, the geometry of the cuts, and the intensity of clear-cutting imposed on the forest cover. The water yield from each candidate watershed was the summation of the estimated annual yield from several hypothetical sub-watersheds, each composed of one timber type or land use class (Table 1).

Table 1. Classification of areas by timber or disposition.

Class	Tree Height (metres)	Crown Density (percent closure)
Sawlog	18 < H	approximately 50
Roundwood	12 < H < 18	greater than 50
Unmerchantable	H < 12	greater than 50
Non forested -- no trees		
Non operable -- slopes greater than 45%		
Not available -- areas in private or otherwise dedicated holdings		

This first screening yielded a list of six basins in the South Saskatchewan River headwaters. None of these were located in the Oldman River basin because prior timber harvest or land use conflicts made it impossible to find a single treatable watershed larger than 50 km^2 there. The final choice among the six candidate basins was made according to arbitrarily-weighted criteria (Table 2) that took into account timber supply, possible environmental damage, and possible conflicts with other uses of the basin.

Table 2. Weighted criteria used in the final basin selection.

	criteria	weight
1)	Basin with the highest simulated yield increase	13
2)	Basin with the most merchantable timber	12
3)	Basin with the most similar control	12
4)	Basin with the best unit breakdown	10
5)	Basin with the most healthy timber	9
6)	Basin with the least erodible soils	9
7)	Basin with the least conflict for recreation	9
8)	Basin with the least potential for flood damage	9
9)	Basin with the most stable stream banks	7
10)	Basin with least conflicts with fish and wildlife	7
11)	Basin with most existing climate stations	6
12)	Basin with most existing hydrometric stations	6
13)	Basin with least conflicts with grazing	3
14)	Basin with least conflicts with mining	3
15)	Basin with least conflicts with gas and oil	3

DESCRIPTION OF THE BASIN TO BE TREATED

The treatment basin selected is 157 km^2 in area with large flat valleys, rolling hills, sharp ridges, and flat plateaus. Vegetation consists of mature stands of Engelmann spruce (Picea engelmanii Parry) and lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) at various levels of maturity (Table 3). Slopes greater than 45% are classified by the Alberta Forest Service as inoperable. Stands of grass or shrubs cover recent cuts and some of the valley bottoms. The basin receives an annual precipitation of about 550 mm, roughly half of which falls as snow. Dominant winds are westerly. Summer precipitation is mostly in the form of thundershowers. Regional annual water yield is about 150 mm.

Table 3. Timber utilization classes within the treatment basin.

Classification	Area	% Total
Total basin	157 km^2	100
Forested	115	73
Operable forested	98	62
Sawlog	34	22
Roundwood	51	32
Unmerchantable	13	8

Since only 62% of the basin is operable, a 50% harvest will clear-cut 31% of the total basin. The effect of treatment per unit area treated must therefore be very high in order to achieve a basin-wide 15% water yield increase. Secondly, most of the timber on the basin is in the roundwood and unmerchantable classes. Because of the limited local market for small diameter trees, little revenue is expected from operation in these classes, and costs will be incurred for the disposal of the trees.

DETERMINING CLEAR-CUT DESIGN

The removal of the forest cover decreases water losses through reduced transpiration and interception loss. In Alberta, wind is a major climatic factor. Evaporation from the snow in large clear-cuts has the potential to negate some of the gains in water yield resulting from reduced transpiration and interception loss. Therefore, large clear-cuts have the potential to reduce the efficiency of the treatment for water yield augmentation. The most obvious effect of wind on exposed snow packs is the pick up and transport of snow. Water losses are greatest while the snow is airborne. Tabler (1975) estimates that blowing snow completely sublimates if transported approximately 3000 m. Typically, commercial cutblocks in Alberta are 20 ha with a windward length of about 440 m (22 H) assuming a square cut block. Although winds speeds may be fairly high in cutblock of this size, the sheltering effect of debris and regrowth in the cuts reduces the probability of pickup. This, coupled with the relatively short 440 m transport distance, probably negates the possibility of high in-transport sublimation losses, even from these relatively large clear-cuts.

A more important source of snow loss in Alberta may be in situ sublimation from the snowpack surface. Computations based on Sverdrup's equations (Ashwell and Marsh 1967) using local meteorological conditions show average daily sublimation rates of up to 0.45 mm/day under exposed conditions. In situ loss seems to be linearly dependent on wind speed which indicates that shelter from wind should reduce it.

It appears that the best way to insure that there is no negative effect due to either transport or in situ snow loss is to reduce the exposure to wind of the snow surface within a clear-cut. This can be accomplished by creating fairly small clearings. Equation (1), (Swanson 1980) expresses wind speed at 2 m height in circular clearings, relative to that 10 m above the canopy, as a function of clear-cut diameter in units of the surrounding tree's height (H):

$$R = 0.0214 + 0.0067H + 0.00084H^2 \quad (H \leq 30) \qquad (1)$$

where R is the ratio of surface wind speed at 2 m above the ground in the opening to wind speed at 10 m above the canopy.

We have assumed that equation (1) can also be applied to determine the surface wind speed in clear-cuts which are rectangular where H is the windward length of the opening

expressed in terms of the height of the surrounding trees. Given this assumption, at an average above-canopy wind speed of 5 m/s for 120 winter days, timber harvest produces essentially no increase in water yield if clear-cuts have windward dimensions greater than 15 H, compared to an almost-maximum increase if windward dimensions are 5 H (Swanson and Bernier 1986).

In addition to protecting the snow surface from evaporative loss, small clearings, less than 15 H in diameter, also trap snow that would have otherwise fallen into the adjacent treed areas. The relative efficiency of openings in trapping snow compared to the uncut forest can be expressed as a function of opening diameter (equation 2):

$$E = 1 + (-0.0405H + 0.5812\ (1 - \exp(H)^{-1}) \qquad (2)$$

where H is defined as above and E is the ratio of snow water equivalent in the opening to snow water equivalent within the forest on an uncut site. Equation (2) was derived from data from Swanson and Golding (1982) (0 to 6 H), and forced through E = 1 at approximately 15 H in accordance with the curve published in the WRENSS procedural handbook (Environmental Protection Agency 1980). The treed areas around the openings are the source of that extra snow, and the trapping efficiency of the openings decreases if cutting intensity is greater than 50% (Environmental Protection Agency 1980).

From the standpoint of trapping and retaining snow, the ideal opening diameter for increasing water yield in Alberta is approximately 5 H, which in the 20 m tall timber of the project area suggests a maximum-sized clearing of approximately 1 ha. The economics of timber harvesting disfavour such small-sized cuts as costs for roading, flagging of cut boundaries and moving the machinery increase with decreasing cut size. In the context of a water yield augmentation scheme, such as this proposal, the best opening size (windward length and shape) should be determined by a cost/benefit analysis. Unfortunately, the project's benefit -- extra cubic decameters (dam^3) of water -- does not generate revenue. However, harvest costs are real. This ratio of real costs to perceived benefits will always dictate less-than-optimum compromises for water yield augmentation until a real value is applied to the water also.

Economic pressures have dictated a compromise clear-cut size for this project. Openings will be rectangular with an east-west (windward) dimension not to exceed 8H. Where possible, north-south oriented strip cuts will be used so that block size can be large in order to reduce operating costs. The strips will be of irregular shape with reduced sight lines in order to accommodate moose habitat requirements and to reduce transport of snow if strong wings do occur in the north-south axis.

The use of larger openings in the form of narrow strips is probably reasonable if one is certain that winds will blow across the short axis rather than down the long one. Winds are generally westerly along the Alberta foothills. However, we do not have local wind data for the project area. Wind data from climate stations operating during the pretreatment period may indicate some alteration of the final clear-cutting design.

ESTIMATING THE INCREASE IN WATER YIELD

Table 4. Estimated change in annual water yield due to 50% removal of forest cover from the proposed pilot watershed management area.

Timber classification	uncut	Windward dimension/Wind speed												
		4H				8H				15H				
		0	1	5	10	0	1	5	10	0	1	5	10	m/s
Sawlog	142	209	209	207	204	205	205	201	197	195	193	187	179	mm
Roundwood	154	214	214	211	209	212	211	208	205	201	199	193	185	
Unmerchantable	207	239	239	237	234	236	235	232	228	228	226	219	211	
Total for basin	186	222	222	221	219	221	220	218	216	214	213	209	204	mm
Percent increase	--	19	19	19	18	19	18	17	16	15	15	12	10	%

After the choice was made to use this particular treatment basin, we went through a second exercise of evaluating the increase in annual water yield due to treatment. The analysis was carried out on over 300 stands with sizes ranging from 1 to 908 ha. Cut blocks within each stand were laid out on 1:15000 maps so that their aspect, windward (east-west) length and areas could be measured. The remainder of the information necessary to drive the WRENSS procedure was taken from the Alberta Forest Service timber inventory database. Results show an 18% increase due to treatment with wind speed of 1 m/s; a much smaller increase due to treatment with a wind speed of 10 m/s (Table 4).

DISCUSSION

Concern was expressed in the Oldman River Study Management Committee's (1978) report regarding claims that higher water yield occurred from forested than from non forested watersheds as reported by Rachkmanov (1970). Leyton and Rodda (1970) point out that most such claims were from regions in which snow forms a major part of the annual precipitation. Annual hydrographs from the Oldman River basin, as well as the entire eastern slopes portion of the Saskatchewan River headwaters, exhibit a snowmelt dominated characteristic, so the concern expressed is certainly relevant to watershed management in this portion of Alberta.

As water resources researchers, we feel only marginally happy with the compromise reached on cut block size and shape for this proposed project. Eight tree-height wide cuts are not the optimum for maximum snow accumulation and sheltering from the wind. Furthermore, it is possible that surface winds will be channeled in a more north-south axis by the strong north-south ridge and valley pattern that exists in the basin. In that case, in spite of irregularities left in the strips, the windward lengths would easily become 15 to 20 H with little protection for the snow surface from high winds. In such a scenario, the increase in water yield from the project area would likely fall short of the 15% needed to ensure reliable evaluation. It would therefore seem wise to establish a network of wind measurement stations during the pretreatment phase of the project so that cut block design could be adjusted in accordance with local wind data prior to the implementation of any clear-cutting.

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