USING THE WRNSHYD PROCEDURE TO ESTIMATE LONG-TERM CUMULATIVE EFFECTS OF ASPEN CLEARCUTTING ON WATER YIELD IN ALBERTA

by

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ABSTRACT

Snow accumulation, evaporative loss of snow, summer evapotranspiration and ultimately water yield are affected by clearcut harvesting. As harvesting progresses through time, regrowth occurs that limits the effect that wind can have on the transport and redeposition of snow from clearcut areas. Basal area also increases, altering the effect on evapotranspiration. Regrowth can be estimated and input into the hydrology portion of the USFS Water Resources Evaluation of Non-point Silvicultural Sources (WRENSS) procedure to obtain an estimate of the cumulative effects of harvest through time.

The hydrology section of the WRENSS procedure indicates that if the height of regrowth is greater than the depth of the snowpack, wind driven snow transport and loss in transport are nil. This generally occurs by the second year after clearcutting in the boreal forest of Canada where aspen regrowth occurs rapidly from root sprouts after clearcutting. Basal area increases to about 30 $m^2\ ha^{-1}$ in the first 30 years after harvest and by year 20 is sufficiently high so that estimated increases in evapotranspiration are essentially nil. The net effect in WRENSS of the combined effects of clearcutting on snow accumulation, snow transport, loss in transport and evapotranspiration is zero for any *single* clearcut in aspen forests of this region by 25 years after harvest.

The cumulative effects of periodic harvests within a 546 km^2 watershed over various time intervals were estimated to determine possible harvesting regimes in order to maintain the annual water yield increase below 15% at the first significant user, a criterion established by Alberta Environment to minimize flooding impacts on downstream residents and water users. Three harvesting scenarios were simulated: 1) continuous harvest of 400,000 $m^3\ yr^{-1}$ until all of the merchantable timber is removed (approximately 15 years), 2) continuous harvest at 200,000 $m^3\ yr^{-1}$ for 30 years and 3) continuous harvest at 100,000 $m^3\ yr^{-1}$ over a 60 year rotation. The first scenario is the only one that resulted in a maximum increase (21%) in water yield greater than 15% at the boundary of the watershed. The other two scenarios resulted in maximum water yield increases of 11% and 6% respectively.

INTRODUCTION

Snow accumulation, evaporative loss of snow, summer evapotranspiration and ultimately water yield are affected by clearcut harvesting. As harvesting progresses through time, regrowth occurs on areas that were harvested earlier that limits the effect that wind can have on the transport, in situ evaporation and redeposition of snow from these clearcut areas. Basal area, stem density and root occupancy of the soil volume also changes and alters the effect on evapotranspiration. Aerodynamic roughness (height of regrowth) is a direct input into the snow accumulation and loss equations of the hydrology portion of the WRENSS (Water Resources Evaluation of Non-point Silvicultural Sources) procedure (USEPA 1980). Basal area was used by the developers of WRENSS as a surrogate for the combined effects of the remaining variables on evapotranspiration (although this is only implied, not stated in the WRENSS handbook). The combined effect of regeneration height and basal area increases on water yield can be therefore be estimated with the hydrology portion of the WRENSS procedure.

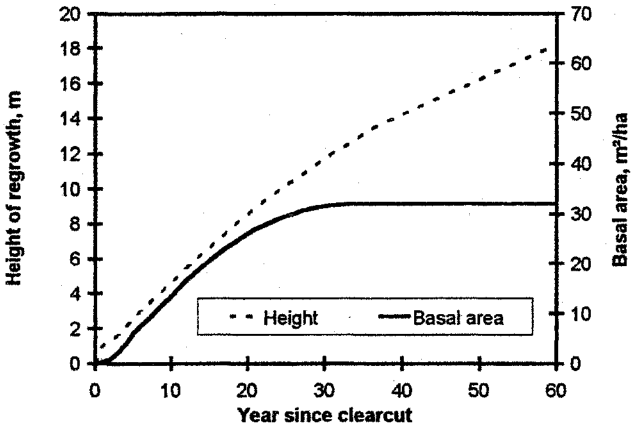

Figure 1. Increase in aspen height and basal area in the boreal forest of Alberta, Canada, as a function of time.

The height of aspen regrowth is high initially, generally achieving 1 m in the first year. It then tapers off to a fairly linear increase with time (Fig. 1). Basal area increases in a slightly different fashion, increasing slowly for the first 2-3 years, and then increasing quite

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rapidly to a constant value of about 30 m^2 ha^{-1} (Fig. 1). These curves, reproduced here from tabulated data in Peterson and Peterson (1992), are typical for an average aspen site. The rate of increase of both height and basal area would be somewhat faster on above average sites, and slightly slower on those below average. However, the general pattern of growth would remain the same.

I have used the WRNSHYD personal computer program (developed by Forestry Canada to simplify the use of the hydrology portion of the WRENSS procedure) to simulate the effects of regrowth on snow accumulation and evapotranspiration on a 546 km^2 watershed in northern Alberta and to estimate their effect on cumulative water yield increase over a 60-year rotation period. The WRNSHYD program requires only annual precipitation, seasonally distributed and forest cutting/regrowth information to operate. Annual precipitation in this area is approximately 580 mm (150 mm fall - early winter, 97 mm late winter - early spring and 334 mm growing season). The annual yield from this watershed is approximately 100 mm, most of which comes during a spring freshet resulting from combined snowmelt and rain. There are water users immediately below the downstream boundary of the area to be harvested.

SNOW ACCUMULATION AND LOSS IN ASPEN CLEARCUTS

According to the WRENSS procedure, snow accumulates preferentially in clearings as a function of the height of the surrounding trees. As regrowth occurs, the aerodynamic roughness of the clearing surface increases and prevents snow loss by wind transport. These effects combine to change the snow retention and subsequently the evapotranspiration regime of a clearcut as time progresses and regrowth occurs. I have used the snow distribution and loss portions of the WRNSHYD procedure to estimate the amount of snow that a clearcut with no regrowth (immediately after clearcutting) and one with 2-year old regrowth would have, relative to the uncut forest. The predicted and measured snow water equivalents are essentially the same, confirming, in this case, the usefulness of the WRNSHYD snow distribution functions (Fig. 2).

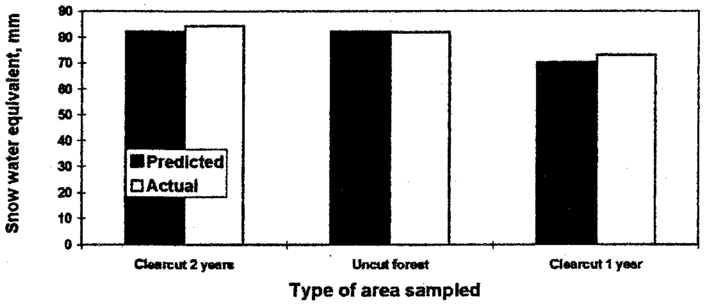

Figure 2. Amount of snow in aspen forest and clearcuts with two heights of regeneration

EVAPOTRANSPIRATION FROM ASPEN CLEARCUTS

Evapotranspiration in the snow dominated versions of the WRENSS hydrology procedure is a function of seasonal precipitation and the basal area of trees. Snow accumulates preferentially in clearcuts increasing the precipitation in these clearcuts (and reducing the precipitation in the treed areas), but also is subject to wind transport, loss during transport and redeposition in clearcuts with windward dimensions greater than 13 tree heights across. The average aspen tree height is 20 to 25 m and clearcut size in Alberta is about 30 ha with widths in most directions of 600 m, which greatly exceed 13 tree heights across. Therefore, the snow in these clearcuts is subject to wind-driven transport, evaporation and redeposition.

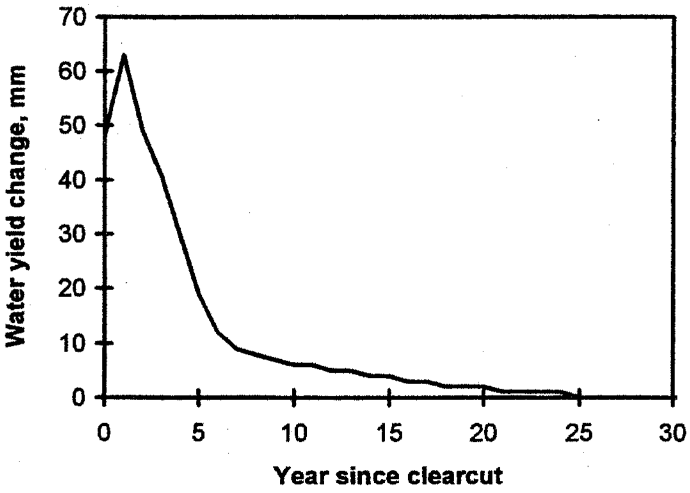

Figure 3. Water yield change of an individual clearcut block as snow accumulation and ET are affected by regrowth height and basal area increase.

During the first snow season after harvest, the height of regrowth is insufficient to retain all of the snow that accumulates. This condition changes the second year as regrowth is approximately 1 m high, (Fig 1) protruding well above the surface of the shallow snowpack depths of the Boreal forest region. This results in a water yield increase from each new harvest block that is slightly lower in the *initial* than the *second* year after harvest (Fig 3).

In Alberta's boreal forest, the increase in basal area (Fig 1) starts to take effect in year 3 and the increase yield from each individual clearcut is essentially zero at year 15 to 20 (Fig 3). The effect of any individual clearcut completely vanishes by year 30.

CUMULATIVE EFFECTS OF HARVEST OVER 30 YEARS

Forest harvest is a fact of life over much of Northern Alberta. The practice of clearcutting large tracts of land has been challenged by downstream water users, or those with farm lands on the floodplain because of their fear of increased flooding. Flooding is indeed a fairly common occurrence in the low-gradient streams of the boreal forest, and the possibility of forest cutting increasing either the frequency or magnitude of streamflow peaks during normal flooding periods is taken seriously by Alberta Environment. Through the use of various calculations, Alberta Environment has indicated that an increase in *annual* yield of 15% will not significantly alter the peak magnitude of storm events. Thus, forestry operations in some portions of the boreal forest are required to submit plans for harvest within their licensed areas that do not increase annual water yields by more than 15%.

There are several operational and managerial constraints that must be met in evaluating or prescribing an operational plan to limit water yield from a watershed. In this case, a volume of 100,000 m^3(the timber on approximately 364 ha), or more must be removed in any given harvesting operation in order to make the harvest economically feasible for a contractor. Secondly, the aspen on these areas is of fire origin and approximately 90 years old. This is beyond the age of maturity for aspen in this region, and the stands are beginning to show sign of deterioration from disease and age. It is estimated that if they are not harvested before they reach 120 years of age, that the timber will be of little value, and difficult to harvest because of death and decay. This means that, at least for this initial entry, the operators have approximately 30 years in which to remove all of the merchantable timber. The situation should improve considerably for the second and subsequent harvests after a 60 year rotation is established. Forty percent (21,840 ha) of the watershed area (56,600 ha) is considered operable or merchantable. Areas near stream channels, near lakes, on steep slopes, reserved for wildlife habitat, with traditional uses incompatible with harvest, in swamps, or in muskeg are considered inoperable.

With the above constraints in mind, I examined two harvesting scenarios[2] to remove all of the merchantable timber within 30 years and one which will reflect the state of affairs after the 60 year rotation is established. The first is the most drastic and would be unlikely to be adopted unless the condition of the trees deteriorated at a much faster rate than anticipated. The second is the most likely scenario, although year to year changes in the market for wood could cause some slight alteration from this plan. The third scenario should be fairly easy to maintain because there is some latitude for greater or lesser harvest each year than in the other two scenarios.

Scenario 1

Clearcut 1/15 of area each year until all merchantable has been harvested from the watershed. This scenario would remove all of the merchantable timber in 15 years, and harvesting 400,000 m^3 yr^{-1} would meet the volume constraint. It would also increase the annual water yield by an unacceptable amount above the 15% threshold established by Alberta Environment (Fig. 4).

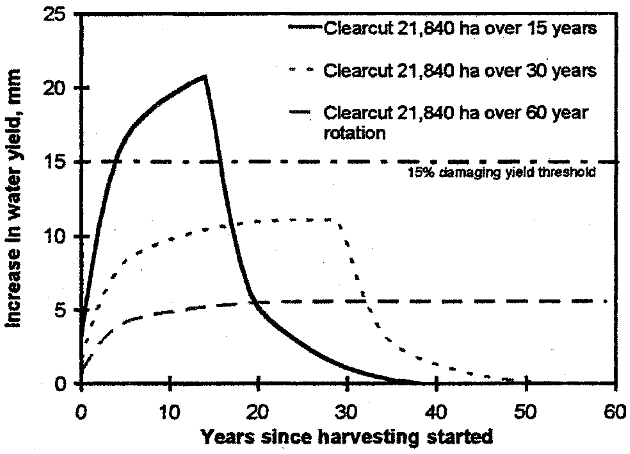

Figure 4. Cumulative watershed yield change under three harvesting regimes, each removing the same volume of timber but over differing time intervals.

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[2] These were not the only scenarios examined. Although factual, the scenarios presented here are hypothetical and not necessarily those that would be presented to the Government of Alberta as part of the annual operating plan for any forest industry operation.

Scenario 2

Clearcut 1/30 of the area each year until all of the merchantable timber has been harvested from the watershed. This scenario would remove all of the merchantable timber within the 30 year time constraint, and the removal of 200,000 m^3 yr^{-1} would allow a contractor to work well within the volume constraint The annual yield increase of 11% is within the Alberta Environment threshold for the average runoff year (Fig 4). Unfortunately, it remains at a fairly high level for approximately 20 years, raising the possibility that the increase may exceed the threshold in a sequence of wetter years.

Scenario 3

This is a scenario which could be followed after the initial harvest to bring the area under a 60 year rotation. Each year 1/60 of the volume would be removed. This volume is still 100,000 m^3 yr^{-1} and would meet the volume constraint. The annual yield increases by about 5% and will remain there as long as harvesting continues (Fig 4). This increase should allow a margin of safety for extremely wet years, or extended sequences of above normal precipitation.

DISCUSSION AND CONCLUSIONS

The cumulative effects of subsequent harvests at various time intervals were estimated to maintain the annual water yield increase below 15% at the first significant user, a criterion established by Alberta Environment to minimize flooding impacts on downstream residents and water users. Over a 30-year time span, only the 15-year rapid cutting scenario resulted in a maximum increase greater than 15% at the boundary of the watershed.

These simulations are relatively easy to perform once one has an estimate of height and basal area regrowth with time. These data are entered directly into the WRNSHYD program to calculate the change in water yield with regrowth for an individual management unit through the desired time interval. If each management unit is the same size, then it is a simple matter to use a spreadsheet to start the water yield information for each cutting unit at it's appropriate harvest year and to sum the resultant cumulative effect. If each management unit is not equal in size, than it is only slightly more work to use the WRNSHYD program on each unit and enter its individual characteristics into a spreadsheet for cumulative summation.

The hydrology portion of the WRENSS procedure has been tested on several experimental watersheds in the United States and Canada. If the precipitation data that is used in it is truly representative of that for the area in question, then the procedure gives results very close to the long term average water yield for that area. The WRNSHYD program is easy to use, but does require a fair degree of hydrologic knowledge to interpret the results. It's results should not be accepted blindly under any circumstances and should be examined to see if they are reasonable in the light of other hydrologic data for the area. One need not refrain from estimating the cumulative hydrological effects of forest harvest because of inadequate tools. The hydrology portion of the WRENSS procedure is a powerful tool, given its extremely low data requirements and proven capabilities.

LITERATURE CITED

Peterson, E.B. and Peterson, N.M., 1992. "Ecology, management, and use of aspen and balsam poplar in the Prairie Provinces, Canada,", Forestry Canada, Northwest Region, Northern Forestry Centre, Edmonton, Alberta, Special Report No. 1, 252pp.

USEPA, 1980, "Water resources evaluation of non-point silvicultural sources (a procedural handbook)", Unites States Environmental Protection Agency. Environmental Research Laboratory, Athens, Georgia, EPA-600/8-80-012. 860pp.