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Robert H. Swanson and Douglas R. Stevenson (1972)

MANAGING SNOW ACCUMULATION AND MELT UNDER LEAFLESS ASPEN TO ENHANCE WATERSHED VALUE.

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MANAGING SNOW ACCUMULATION AND MELT UNDER LEAFLESS ASPEN

TO ENHANCE WATERSHED VALUE

by

Robert H. Swanson* and Douglas R. Stevenson**

ABSTRACT

Photographic records from Streeter basin in Southern Alberta show that non-leaved cover influences both accumulation areas and ablation rate. Snow water equivalents in small natural openings one-half to five tree heights across were one-third more than under the surrounding canopy. Large clear areas not influenced by trees or topography were generally bare.

Snow ablated from small openings slower than under the canopy, and remained in the margins of treed areas longer than in adjacent clear areas.

Management implications are that total clearing of aspen and establishing grass in its stead is probably detrimental. Snow that should accumulate under aspen on the ridges is trapped in depressions, becoming direct runoff upon melting. The best range and watershed management combinations should be strip or block clearings to hold snow on ridges. This combination should yield more forage, distribute grazing animals and augment the local groundwater regime.

Subject index:

1. Snow management
2. Groundwater

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MANAGING SNOW ACCUMULATION AND MELT UNDER LEAFLESS ASPEN TO ENHANCE WATERSHED VALUE[1]

by

Robert H. Swanson and Douglas R. Stevenson[2]

INTRODUCTION

How does one manage a watershed? What practices are possible? Where should these practices be applied? What effects can be obtained? Why does one want to? These are valid questions facing the modern land manager. As pressure on the use of land increase, so must his decision-making capability. Rectangular blocks transverse of ridge and valley such as those in figure 1, may be easy to lay out on a map or on the ground, but their influence on the local hydrologic regimen and aesthetic value are suspect. Management that could be very general a few years ago, must now be very specific. Management goals must include both the physical capabilities of the land being managed and the physical, social, economic and emotional desires of the users.

The range lands of Southern Alberta are generally mixed aspen-willow and grass, figure 2. Some conifers are found in the upper reaches. Streeter basin in the Porcupine Hills south of Calgary, is a range watershed typical of most of the area. It is an area set aside for research into range management methods to enhance the water yielding characteristics and maintain high range productivity for both domestic livestock and wildlife. A common range management practice in Southern Alberta is to remove all shrub and tree vegetation although a few scattered trees are occasionally left for livestock shelter. The reasoning behind this practice is to increase the area for grass for grazing. This it most certainly does. However, this is not the only effect this practice has; it also has been reported that local groundwater discharges (springs), often cease flowing earlier in the year than prior to vegetation removal.

There are few facts in land management in Alberta. The observation that springs cease flowing after clearing operations is not documented. It is based on interviews with land managers from the area. Whether the problem existed in the beginning is not important. What is important is that research since has established that the hydrologic alteration is a valid probability.

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[1]Presented at the Western Snow Conference, Billings, Montana, April 20-22, 1971.

[2]Projects Coordinator, Forest Hydrology Research, Canadian Forestry Service, Edmonton, Alberta, and Hydrogeologist, Research Council of Alberta, Edmonton, Alberta, respectively.

Management of the aspen grasslands for range and water requires a knowledge of where management would have an influence and how to cause a desirable change. This means a knowledge of the local hydrogeology and the influence of vegetation in maintaining or enhancing it. The purpose of this paper is to document the importance of the leafless tree-shrub vegetation in distributing snow, and how it might be manipulated to achieve management goals.

HYDROGEOLOGY

Streeter basin is as complex hydrogeologically as one would wish to find. Four groundwater systems operate inter-dependently (figure 3). Three discharge locally and the fourth likely discharges into Willow Creek, the topographic low area in the vicinity of Streeter Basin.

The first local system,(a) discharges rapidly within a sub-basin. Recharge occurs through a thin surface mantle over slightly tilted shale or sandstone formation. Discharge occurs in response to snow melt or rain storms. Storage is low[3]; therefore the time interval between recharge and discharge is short (Figure 3e.) Most of the water discharged does not become surface flow but re-enters the soil mantle to become part of successive groundwater systems. Recharge and discharge often occur within the boundary formed by the topographic divide but not always. Recharge areas are well drained and may or may not be vegetated. Discharge areas usually have willows or other phreatophytic vegetation growing on them.

The second local system,(b) may or may not discharge within the sub-basin it is recharged from. In general it does not. The usual case is for discharge to occur primarily in an adjacent sub basin. Recharge occurs from discharge by a first-order groundwater system, or from snow melt and rain via the surface soil mantle. The latter occurs primarily across basin boundaries. That is, the surface recharge area is in the sub basin adjacent to its discharge manifestation. The soil moisture in the recharge area may be quite high early in the spring. This helps it maintain a tree cover - usually aspen. The time scale between recharge and discharge is likely less than one year. Most of the late season "spring" discharge occurs from this type of system.

The third local system,(c) discharges outside of the sub basin and perhaps basin boundaries. This system is particularly operative in Streeter basin where the streamflow from the east sub basin is ten times that of the middle which is ten times that of the west. Recharge occurs from both the surface mantle and the discharge from preceding groundwater systems. Some of this recharge occurs after the flow from

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[3]Storage capacity may be high, however the water in storage at any one time is small because it is held in a permeable formation that is open at either end. Since it acts as an open drain, recharge water moves quickly through the system.

preceding springs has reached a stream channel. The time scale for total recharge-discharge is probably less than one year.

The fourth system (d) does not discharge visibly in the vicinity. Water entering this system finds its way into regional groundwater flow system which discharges into Willow Creek, the regionally low area. Land management practices may have far-reaching effects on the regional groundwater picture that are not envisioned during management prescriptions. Quite likely, any practice deleterious to the local groundwater regime is also harmful to the regional pattern.

The flow from all of these groundwater systems originates principally from snow melt and to a lesser extent from rain. Each system is affected by recharge either directly to it, or re-entry of discharge from a preceding system. Thus, any land use practice that alters snow accumulation and melt, changes the evaporation regime, or modifies the surface runoff-infiltration ratio, influences the total hydrologic regime. Vegetative manipulation is a land management tool that can be used to effect these alterations.

LEAFLESS TREES LOCALIZE SNOW ACCUMULATION

Aerial photographic records during the late winter - early spring period of 1968-69 snow season, show that treed areas hold snow longer than the adjacent untreed areas, figure 4. These photos plainly show the effectiveness of non-leaved trees in trapping and holding snow. Where the trees augment a natural terrain feature such as the leeward side of a ridge, or the windward side of a gully, the effectiveness is even greater.

In the large open areas free of trees, snow is retained in ground depressions to as great a degree as under the trees, but it has little opportunity to infiltrate to soil moisture because of its concentration in the saturated groundwater discharge zone and the rapidness with which it melts in the spring. Complete tree and shrub removal would augment the natural snow collection in such depressions. This would force more direct streamflow, which in our opinion is undesirable in this particular area.

Ground photos taken during winter and spring 1967 and 1968 show similar snow accumulation patterns (Figure 5). Chinook winds often force bare areas during the winter. It is interesting to note that even during strong chinook periods, 11-18 January, 1-8 February, 1968, the snow remained under the trees. According to Longley,[4] chinooks may be present on a third of the days December through February. It would be useful to determine the quantitative role of

[4] Longley, L.W. The frequency of winter chinooks in Alberta. Atmosphere. Canadian Met. Soc. 5(4):4-16. 1967.

tree cover in protecting the undercanopy surface from the full affects of this advective energy input.

Figure 6 is an aerial photo of Streeter basin in the summer. In general, the dark areas contain willows. Groundwater appears at the surface in these areas. When these areas are located in the upper reaches of a sub basin, they may indicate both groundwater discharge and recharge areas. In these upper loci, such as that at "E" which is already a natural snow accumulation area, they are particularly susceptible to management to enhance snow accumulation within them. Area "E" may also have a recharge area directly below it as there is no evidence of continuous streamflow from here to the main channel. It would be useful to know how much more water could infiltrate this recharge zone before surface runoff started.

Areas predominantly in aspen generally denote dry, well-drained sites ("F" on figure 6). These may or may not be groundwater recharge areas. However, any snow accumulated in these areas has a high infiltration opportunity. Even under rather intense cultivation to remove this vegetation, the surface runoff from these areas is slight. If all were managed as recharge areas, the probability of improved groundwater regime would be high.

The above photographic evidence indicates that areas with tree cover, even when the trees are leafless, are effective in trapping snow. It also indicates that the same leafless canopy provides some shelter from advective energy exchange. Such vegetated areas thus give potential for snow management.

LEAFLESS ASPEN ALTERS ACCUMULATION AND ABLATION

Streeter basin has three basic areal vegetation arrangements. Large areas without trees - clear area. Large sections mostly treed - treed area. And small openings within the treed area - openings. Each of these exhibit different characteristics in snow accumulation and ablation. The material reported below applies mainly to the treed-open contrast. The clear area is designated "G" on figure 6; "E" and "F" are treed; "A" - "D", the four small openings within the treed area.

Concerning these small openings: again these have three areas of influence, figure 7. Fringe - the area immediately surrounding and within the opening to a depth of one-tree height. Canopied - the area greater than one tree height into the surrounding trees. And, open - the area greater than one tree height toward the centre from the edge. These definitions will be used throughout the remainder of this paper.

Figure 8 shows the openings studied and a partial summary of the data from them. Their aspect-slope is generally N, 0 to 10°.

There are no replicates and no attempt was made to obtain representative data. The only purpose for the study was to determine if these openings in leafless aspen had any influence on snow accumulation and melt patterns within and around them. They do!

More snow accumulated in the open than in the treed areas (Treed average data from all four openings, open average data from openings A and D only). Between 5 March and 2 April, 3.3 inches (water equivalent) accumulated in the open, versus 2.5 inches under the canopy. Analysis of variance shows this difference significant at the 99% probability level.

Snow ablates slower in openings than under the trees. From 21 April to 5 May, 2.6 inches ablated from the openings compared to 3.5 under the canopy. This difference is likewise significant at the 99% level.

The surprising part of the above was the faster ablation rate under the canopy than in the open. Studies of snow ablation rates in openings in conifers have shown equal or greater rates in an opening of any size than under the canopy[5]. One plausible explanation for the above results is that long wave radiation under the leafless canopy is greater than in the open, even though short wave radiation is less[6]. Snow is highly reflective of short wave radiation, but highly absorptive of long wave. The leafless canopy is a source of long wave radiation because of heating from direct and reflected short wave radiation. Possibly, the amount of energy from long wave reradiation from the canopy plus direct short wave radiation to the snow surface is greater under the canopy than the amount of energy at the snow surface in the open supplied by direct short wave radiation alone. This needs further study.

Fringes of openings behaved somewhat disappointingly. The aerial photographs show snow remaining in the margin[7] of treed areas

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[5]Wilm, H.G. The influence of forest cover on snow-melt. Transactions, AGU, 29(4):547-557, August, 1948.

[6]Lull, H.W. and I.C. Reigner. Radiation measurements by various instruments in the open and in the forest. U.S. Forest Serv. Res. Paper NE-84, 21 pp. illus. 1967. Northeastern Experimental Station, Upper Darby, Pa.

[7]"Margin" refers to the portion of treed areas immediately adjacent to clear areas. Note that this is not the same as "fringe". The term "fringe" as used in this paper is applicable only to the 'area' one tree height within and immediately surrounding a small opening. It was anticipated that fringes and margins would exhibit similar characteristics. Apparently they don't.

for as much as two weeks longer than under the canopy. No ground measurements are available to substantiate that more snow did, in fact, accumulate in the margin. However, in the fringe area (as defined in figure 7f on this study) of the openings studied, accumulation amounts and ablation rates were not statistically different from those of the canopy, nor the open.

CONCLUSIONS

Leafless aspen and willow stands are important in localizing snow accumulation areas and altering the ablation rate. Observational evidence shows that snow under the canopy remains even during chinook periods that removes the total pack from clear areas. Some snow remains in the margin of treed areas up to two weeks longer in the spring than that in the clear area, or totally under the canopy.

Small openings in the leafless canopy are effective snow traps. An average of one-third more snow accumulated in two small openings than under the surrounding leafless canopy. The snow within these openings ablated thirty percent slower than that under the leafless canopy. Openings physically oriented and of a size designed to maximize accumulation and minimize ablation rate would improve groundwater recharge opportunity if created on recharge areas.

If aspen stands are present on groundwater recharge zones, then their complete removal will create an unfavorable hydrologic regime. They should be left to maintain groundwater recharge-discharge patterns. It should also be possible to enhance groundwater recharge through manipulation of aspen stands growing on recharge areas to increase snow accumulation and retard ablation.

ACKNOWLEDGEMENT

~~I~~ we wish to acknowledge with thanks the field work by Collin Cumberland, Larry Lafleur and Zdenek Fisera during the winters of 1967-1970.

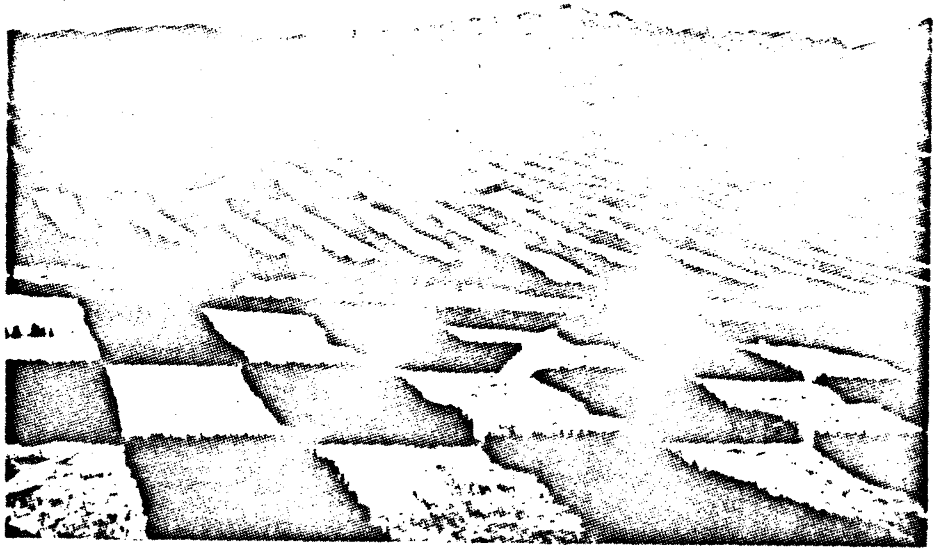


Figure 1. Uniform placement of land management unit boundaries is not necessarily suited to watershed management. Portions of cuts on discharge areas tend to cause more surface runoff from storms. Practices denuding large sections of recharge area may reduce length of time stream flow occurs in late summer.

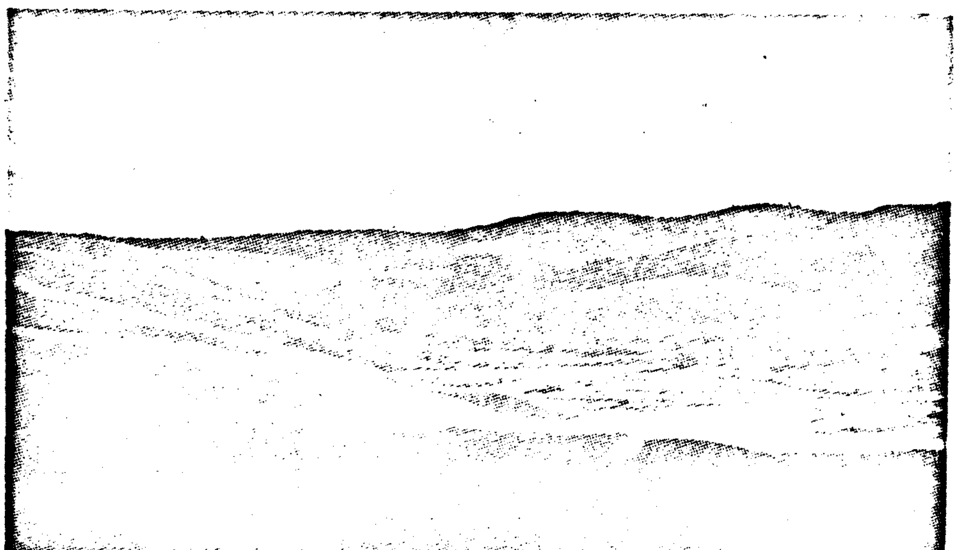


Figure 2. Rangeland watersheds of Southern Alberta. Vegetation is mixed aspen-willow-grass.

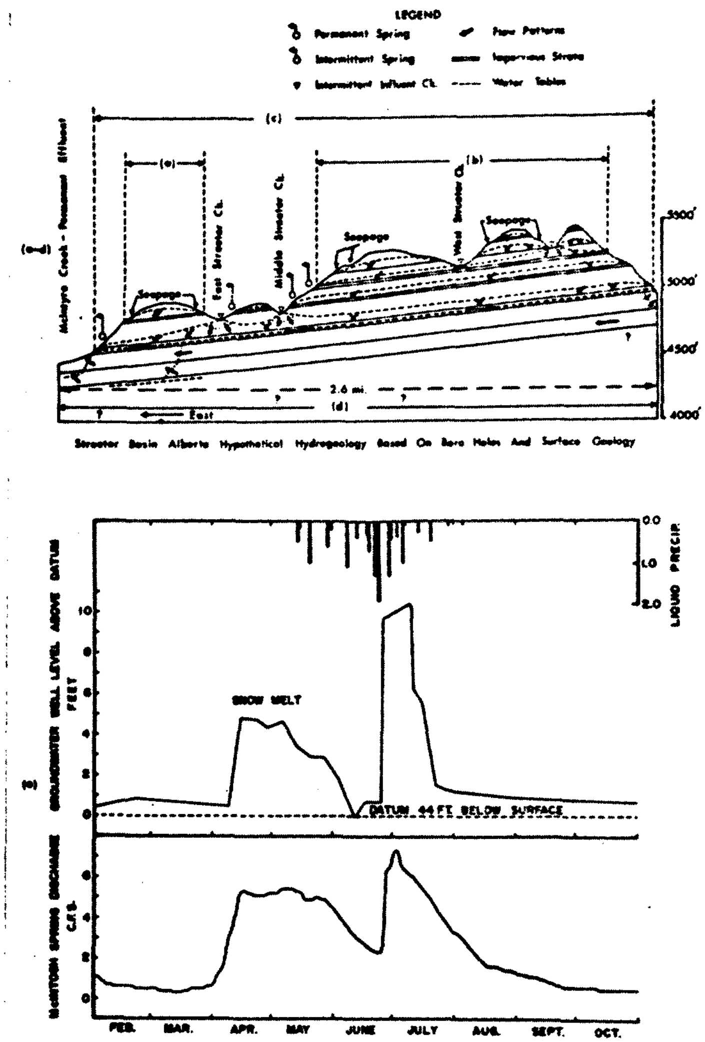


Figure 3. Underlying geological structure of Streeter experimental watershed: (a) first order local groundwater system; (b) second order system; (c) third order system; (d) fourth order system; (e) "spring" discharge hydrograph and position of groundwater table for first order local system at (a).

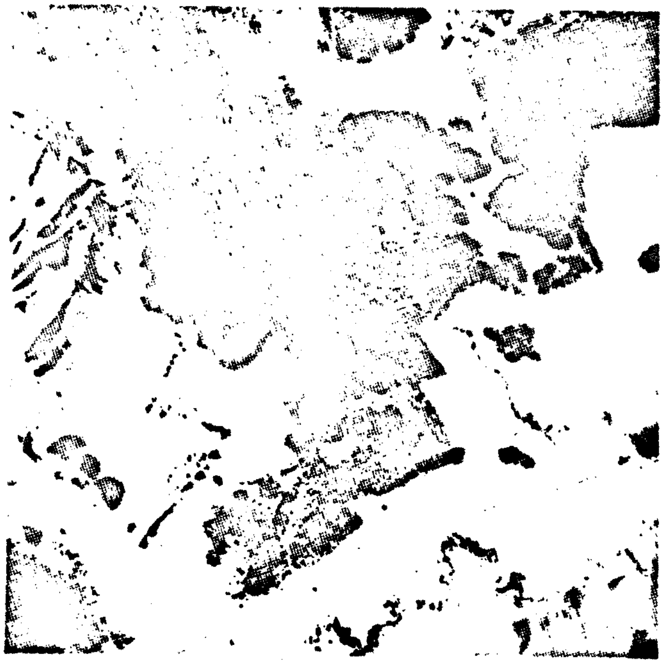
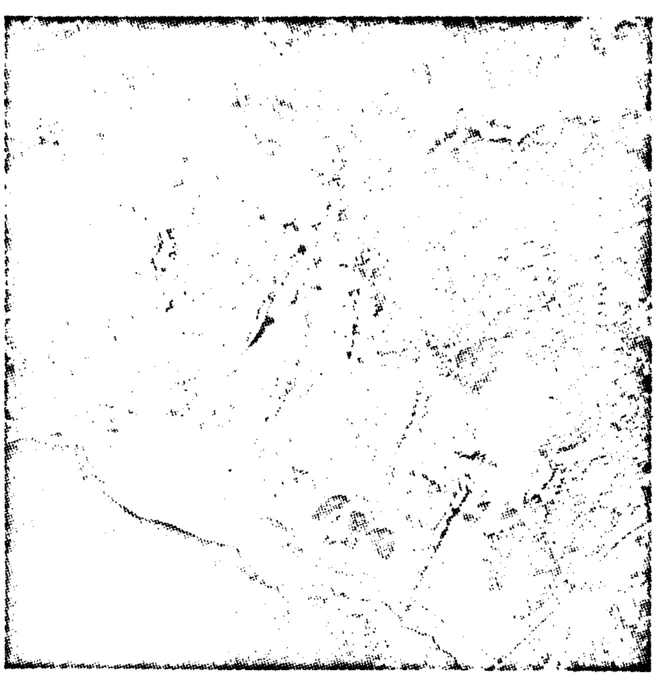


Figure 4. Streeter experimental watershed aerial photography, spring 1969.

14 March - snow cover appears uniform.

4 April - bare patches appearing in untreated areas except for depressions in topography.



16 April - snow gone from all but timber margins and topographic depressions.

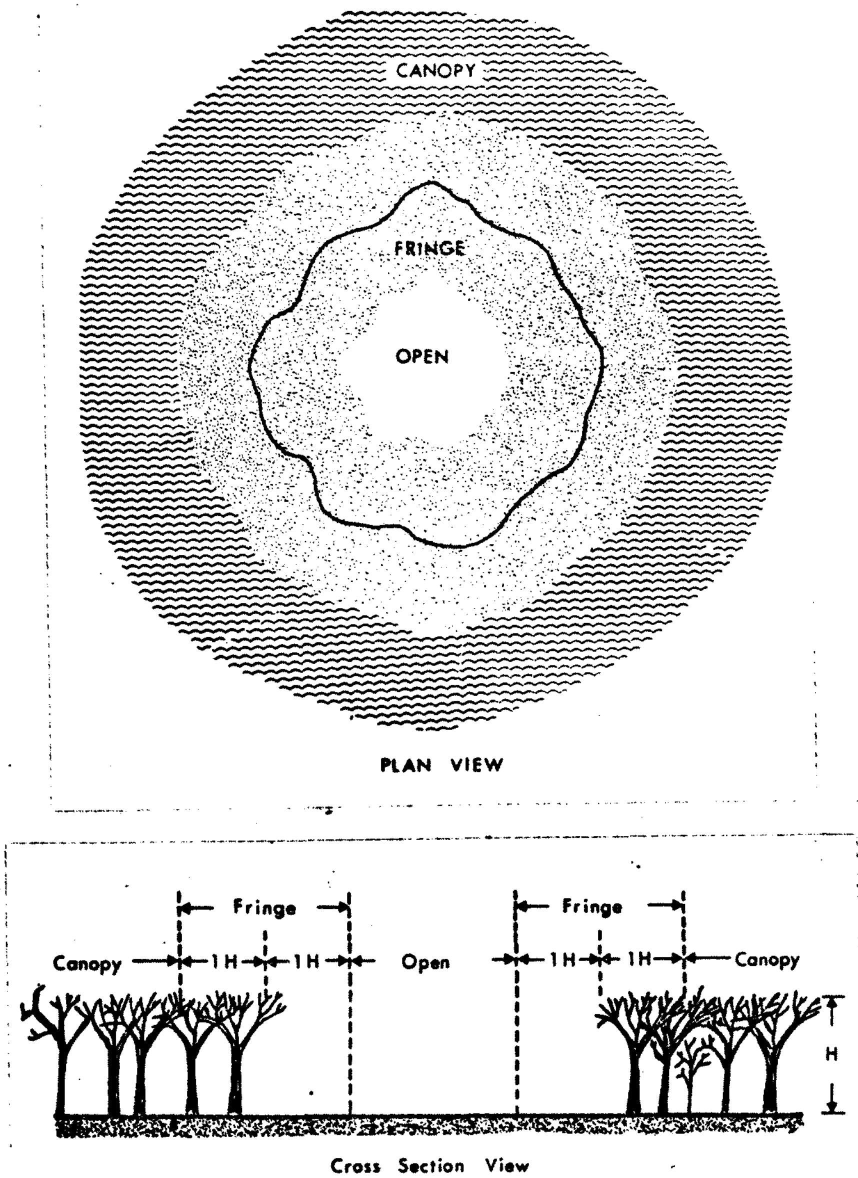
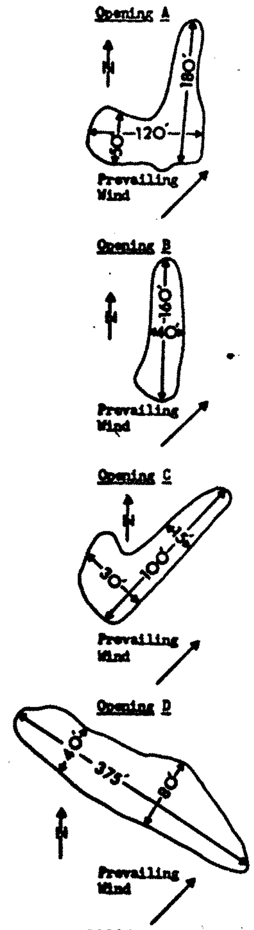


Figure 7. Diagramatic sketch of opening, fringe, canopy definitions. (a) Plan view. (b) Cross section.



Opening A

Aspect; NE — Slope; 10°

Surrounding trees aspen, 15-25 feet tall.

Snow data	Canopy	Fringe	Open
Accumulation 5 Mar - 2 Apr	2.5	3.1	4.4
Ablation 21 Apr - 5 May	4.2	3.7	3.0
Residual snow on 13 May	0.2	0.8	0.1

Opening B

Aspect; NNW — Slope; 4°

Surrounding trees aspen, 30-40 feet tall.

Snow data	Canopy	Fringe*
Accumulation 5 Mar - 2 Apr	1.9	3.0
Ablation 21 Mar - 5 May	5.3	2.7
Residual snow on 13 May	0.5	1.3

* no portion classifiable as open.

Opening C

Aspect; NE — Slope; 10°

Surrounding trees Aspen, 25-40 feet tall.

Snow data	Canopy	Fringe*
Accumulation 5 Mar - 2 Apr	4.0	3.5
Ablation 21 Apr - 5 May	3.8	2.5
Residual snow on 13 May	0.0	0.6

* no portion classifiable as open.

Opening D

Aspect; N — Slope; Level

Surrounding trees aspen, 30-60 feet tall.

Snow data	Canopy	Fringe	Open
Accumulation 5 Mar - 2 Apr.	1.6	2.2	2.4
Ablation 21 Apr - 5 May	4.0	2.8	2.9
Residual snow on 13 May	0.4	0.7	0.4

Figure 8. Physical and snow data, 1970, on openings studied. All quantities water equivalents in inches. Accumulation and ablation increment change during period indicated, not condition at end of period.