The impact of depression/detention storage on the spring freshet, Clear Lake Watershed, Riding Mountain, Manitoba

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Abstract: Snowmelt studies in the Clear Lake watershed suggest that detention storage in small lakes, beaver ponds and wetlands can account for a significant attenuation in the spring lake levels. This project examines the impact of detention storage volumes retained within the Aspen Creek and Octopus Creek sub-basins of the Clear Lake Watershed. Detention storage in the Aspen Creek watershed is associated with numerous beaver pondings and beaver influenced small lakes and associated wetlands. In the Octopus Creek sub-basin small lakes represent the greatest volume of stored water and beaver pondings are of relatively little significance.

Mean annual water equivalent depth of snow measured in the Aspen Creak watershed is 12.0 cm and represents approximately 880 dm^3 of potential runoff. High water marks recorded in beaver pondings indicate that an additional 80 cm depth of runoff could be stored in the Aspen Creek beaver ponds throughout the summer. This value represents approximately 64 dm^3 of runoff. Consequently detention storage in beaver ponds represents approximately 7% of the potential spring runoff.

A more conservative 10 cm rise in water levels documented for small lakes and wetlands in Octopus Creek watershed represents approximately 675 dm^3 storage value. Mean annual water equivalent depth of snow measured in the Octopus Creek watershed is 9.0 cm and represents approximately 3089 dm^3 of potential runoff. In the Octopus Creak watershed detention storage accounts for 22% of the potential snowmelt runoff.

Introduction

The Clear Lake Watershed is centrally located on the Riding Mountain Uplands in southwestern Manitoba (Figure 1). The

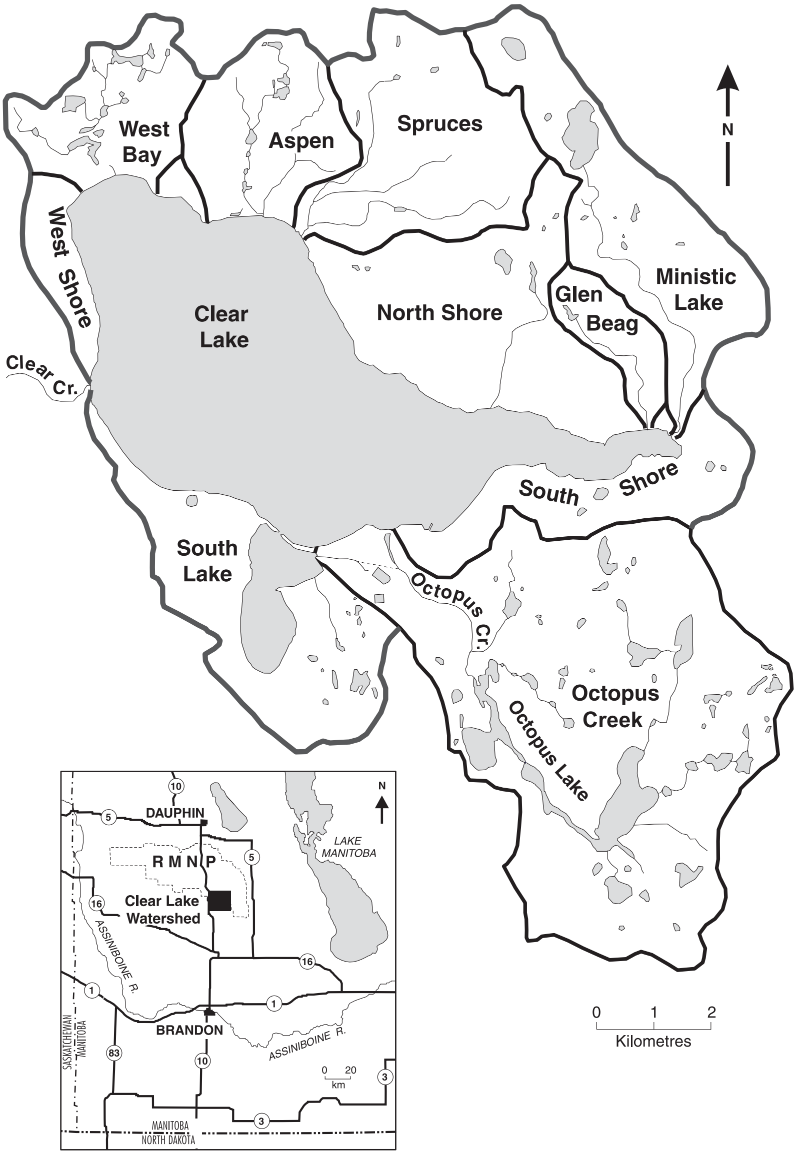

Figure 1: *Clear Lake watershed.*

watershed drains an area of 142.18 km^2 of which over 56 percent is located within Riding Mountain National Park. Approximately 46.0 km^2 of the Clear Lake watershed is classified as standing water and wetlands. This value represents 39% of the contributing drainage area for Clear Lake.

Snowmelt studies (McGuire 1997, McGinn and Rousseau 1997) in the Clear Lake watershed suggest that both detention storage and depression storage in beaver ponds, small lakes and wetlands can account for a significant attenuation in the spring lake levels.

Depression storage is defined as the volume of water (precipitation or snowmelt) required to fill all natural depressions in a watershed to their overflow levels. Depression storage does not contribute to runoff but ultimately infiltrates or evaporates (Lo 1992). Detention storage, a term often confused with depression storage, is the water on the ground above the overflow level of depression storage (Lo 1992) and includes surface and channel detention but does not include depression storage.

Objective

This paper focuses on the Aspen Creek and Octopus Creek sub-basins of the Clear Lake Watershed and examines:

1. depression storage volumes,
2. the significance of beaver pondings to the depression storage, and
3. the impact of depression storage on the snowmelt freshet.

The Study Basins

Aspen Creek watershed is located within the boundaries of Riding Mountain National Park (Figure 1). This sub-basin of the Clear Lake watershed has a drainage area of 7.325 km^2 (Table 1). Approximately 86% of the total area is covered in conifer, mixed and aspen forest while open meadows represent 3.16% of the cover. Surface water accounts for 8.74% (0.640 km^2) of the total area and wetlands, an additional 2.22% (0.163 $km^{2)}$. There are no developed lands or cultivated fields in the Aspen Creek watershed.

Table 1: *Cover types in the Clear Lake watershed: the Aspen Creek and Octopus Creek sub-basins.*

	SUB-BASINS	
Surface Cover	**Aspen Creek**	**Octopus Creek**
Conifer (km^2)	2.934	1.650
% Sub-basin	40.06	4.57
Mixed (km^2)	3.248	3.637
% Sub-basin	44.34	10.08
Deciduous (km^2)	0.108	10.510
% Sub-basin	1.48	29.14
Open (km^2)	2.31	1.362
% Sub-basin	3.16	3.77
Agriculture (km^2)	0.000	10.463
% Sub-basin	0.00	29.00
Wetlands (km^2)	0.163	4.485
% Sub-basin	2.22	12.43
Water (km^2)	0.640	2.268
% Sub-basin	8.74	6.29
Developed (km^2)	0.000	1.699
% Sub-basin	0.00	4.71
TOTAL (km^2)	7.325	36.073
% Sub-basin	100.00	100.00

Depression storage in the Aspen Creek watershed is associated with 24 beaver pondings constructed along the natural water courses and 13 beaver influenced small lakes and associated wetlands (Figure 2). An index of beaver activity within a watershed was developed by calculating the number of beaver ponds per unit area of watershed. In the Aspen Creek watershed the beaver pond density index was calculated to be 5.05 ponds km^{-1}.

Approximately 90% of the Octopus Creek watershed is located outside the park boundaries (Figure 1). This sub-basin of the Clear Lake watershed has a drainage area of 36.073 km^2 (Table 1). In contrast to the Aspen Creek sub-basin, only 43.79% of the Octopus Creek drainage area is forest covered, predominantly aspen woodlots. One-third of the total area of the Octopus Creek watershed is developed land and cultivated fields. Surface water covers 6.29% (2.268 $km^{2)}$ of the total drainage area and wetlands account for an additional 12.43% (4.485 km^2).

Octopus Lake, other small lakes and large wetland areas are major depression storage features in the Octopus Creek watershed (Figure 3). There are 14 beaver pondings in this watershed. These are of relatively little significance to the total volume of depression storage. Two dams positioned at the outlet of Octopus Lake, however, may be of importance, in that they act as a lake level control structure. The beaver pond density index for the Octopus Creek watershed is 0.388 ponds km^{-1}.

In summary, the two sub-basins of the Clear Lake watershed are characterized by different types of depression storage. The Aspen Creek watershed is a natural watershed in which depression storage is significantly influenced by beaver activity. The Octopus Creek watershed represents a developed drainage basin in which depression storage occurs in Octopus Lake, other small lakes and wetlands.

Procedures and Methodologies

The Manitoba Forest Inventory Cover Maps (1983) derived from 1979 aerial photographs, identify forty-four cover types in the Clear Lake watershed. These recognized cover types have been

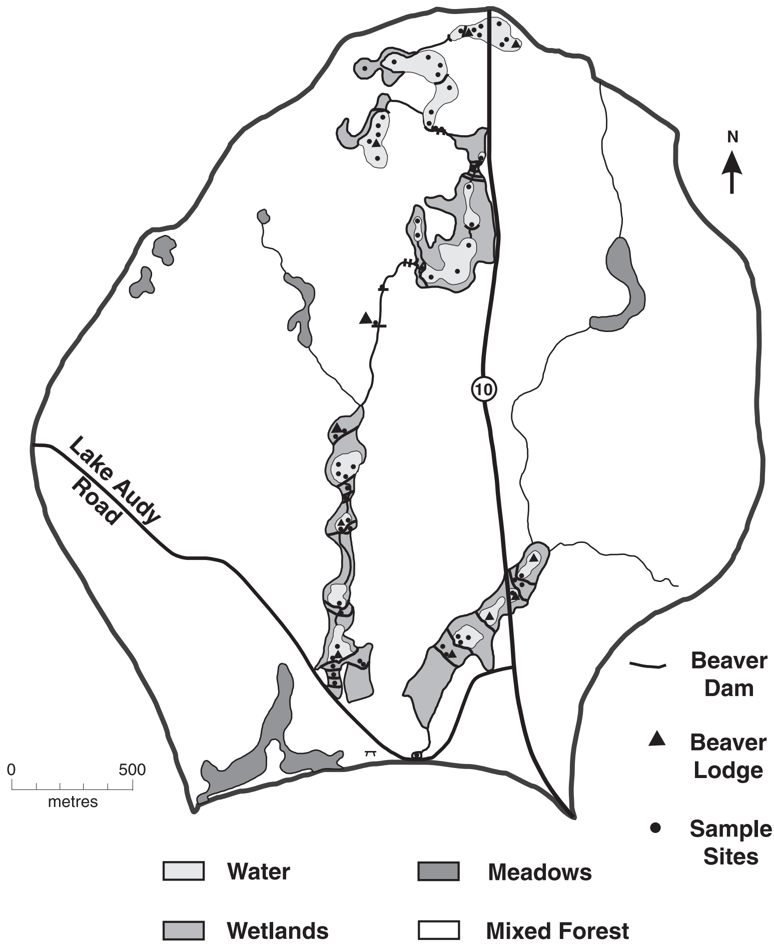

Figure 2: *Depression storage in the Aspen Creek watershed.*

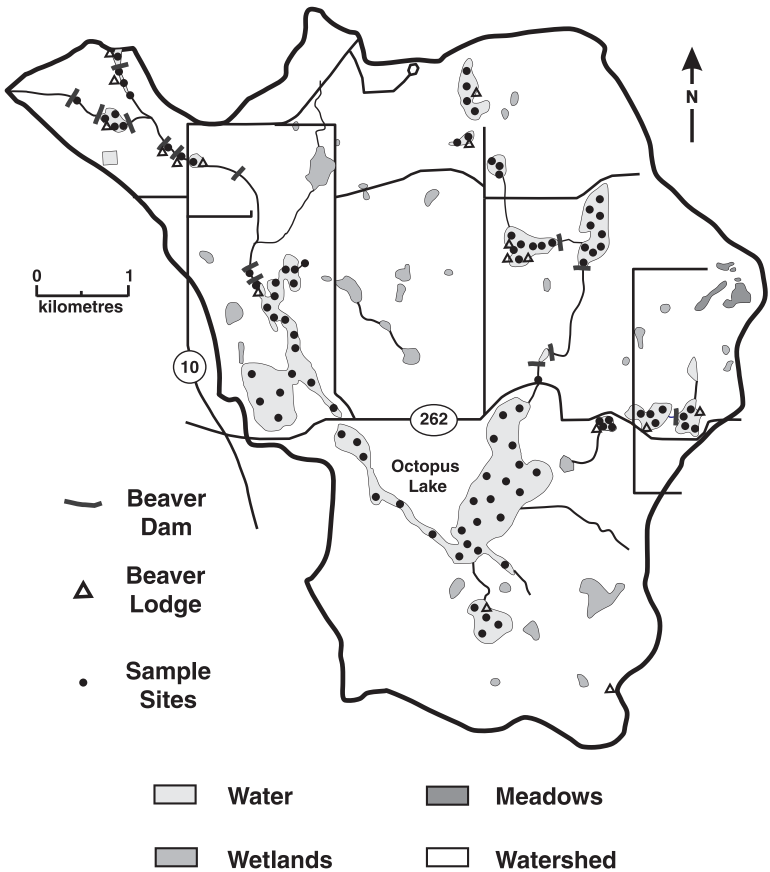

Figure 3: *Depression storage in the Octopus Creek watershed.*

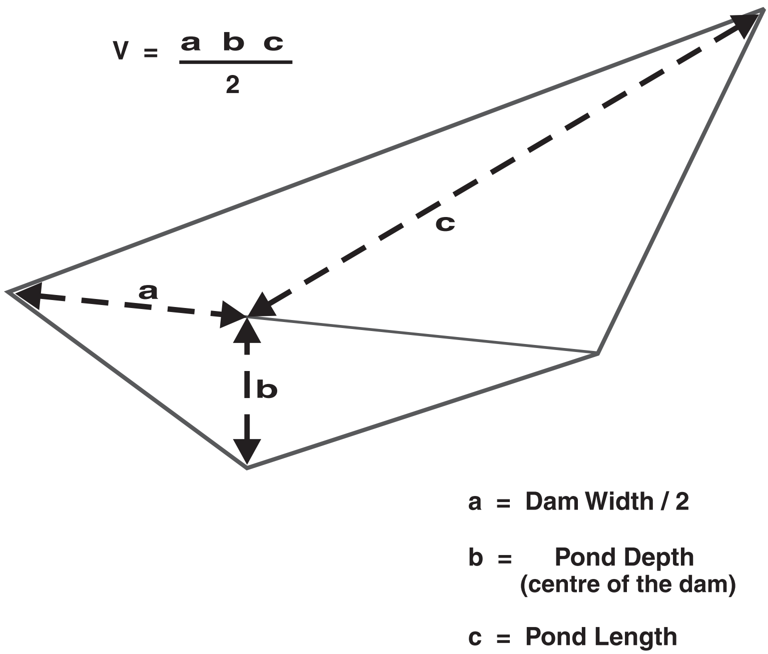

Figure 4: *Volumetric beaver pond model.*

grouped into eight natural vegetation associations (Table 1) and are described as follows:

1. Coniferous Forest (Conifer): white spruce, black spruce, balsam fir, and western larch.
2. Mixed Forest Parkland (Mixed): aspen, balsam popular, birch, and conifers. Some small open areas.
3. Deciduous Forest (Deciduous): aspen, birch, balsam popular, and shelter belts
4. Open: natural meadow.
5. Agriculture: cleared land, cropland, hayland, pastures, fence lines, ridge prairie and abandon land.
6. Wetlands: marsh, muskeg, moist prairie, wet meadow and drainage ditches. Species include willow, dwarf birch, and shrubs.
7. Water: lakes, streams, beaver ponds and dugouts.

8. Developed: townsite, beaches, cottage sub-divisions and summer camps.

Units 7 (standing water) and 6 (wetlands) are of the most concern in this paper. Surface areal measurements were derived from geographic information systems analysis (SPANS) of orthophotos.

Depth measurements were obtained during winter while the small lakes, beaver ponds, and wetlands were accessible over the ice cover. In small lakes depth measurements were spatially distributed so as to provide reasonable bathometric coverage. Volumetric storage values were calculated on the basis of areal measurements and the lake bathometry.

In beaver ponds depth measurements were sounded at several spatially separate sites and provided an estimate of mean pond depth. Maximum depths were recorded adjacent to the planometric centre of the dam structure. A model was developed to estimate the storage waters retained in the beaver ponds. The model is based on the accepted calculations for the volume of a four sided pyramid

($V = a \cdot b \cdot c$). Applying the model to beaver pond morphology (Figure 4),

$$V = a \cdot b \cdot c/3, \text{ where:}$$

a represents one half of the dam width,
b is water depth adjacent to the centre of the dam, and
c is the planometric length of the pond.

Aerial photographs were used to measure dam width and pond length.

High water markings on drowned trees were recorded. These markings provided evidence of historic water levels and were later used to estimate depression storage depths.

Results and Discussion

Aspen Creek Watershed:

Mean annual water equivalent depth of snow measured in the Aspen Creek watershed is approximately 12.0 cm and represents 880 dm^3 of potential runoff (McGuire 1997, McGinn and Rousseau 1997). During the winter months 511 dm^3 of water are normally held in depression storage. Beaver ponds contribute an additional 211 dm^3 (30%) to this value.

High water marks recorded in the beaver pondings indicate an addition 70-120 cm depth of runoff could be stored in the Aspen Creek beaver ponds and associated wetlands throughout the summer. This value represents approximately 168-289 dm^3 of runoff. Other measurements suggest that the more conservative 20 cm rise in the small lakes could store an additional 112 dm^3 of runoff. Consequently, in the Aspen Creek watershed, depression storage in small lakes, beaver pond and beaver influenced wetlands represents approximately 32-46% of the potential spring runoff. Aho (1997) suggests that up to 50% of potential runoff infiltrates. When maximized infiltration losses are considered, the detention storage in the Aspen Creek watershed could represents 64-92% of the total spring runoff.

Octopus Creek Watershed:

Mean annual water equivalent depth of snow measured in the Octopus Creek watershed is approximately 9.0 cm and represents 3247 dm^3 of potential runoff (McGuire 1997; McGinn and Rousseau 1997). Depression storage held in the Octopus Creek sub-basin during the winter months is calculated to be 3010 dm^3. A 20 cm rise in water levels, documented for Octopus Lake and applied to other small lakes and wetlands in the watershed, represents approximately 1433 dm^3 of surface runoff. In the Octopus Creek watershed depression storage accounts for 44% of the total potential snowmelt runoff. Mean maximum spring infiltration losses (50% of total runoff; Aho 1997) increase the significance of depression storage held in small lakes and wetlands. In the Octopus Creek watershed it has been calculated that on average 12% of the total potential snowmelt runoff enters Clear Lake during the melt season. Freshet runoff measurements taken on Octopus Creek near the outlet into Clear Lake over the last three years support this observation. Significant runoff was recorded during spring 1995, when the Octopus Creek watershed received 29% (2.6 cm) more snow than normal. There was no measurable runoff from the Octopus Creek sub-basin for years of average snowpack accumulation (1995-96 and 1996-97).

Conclusion

Depression storage can account for a significant attenuation of spring lake levels in Clear Lake. Depression storage in the Aspen Creek sub-basin is significantly influenced by beaver activity. In this watershed the beaver pond density index is 5.05 ponds km^{-1} and beaver impoundments represent at least 30% of the total depression storage in the watershed.

In the Octopus Creek sub-basin the beaver pond density index is 0.388 ponds km^{-1} representing only 14 beaver impoundments in over 36 km^2. Spring runoff depression storage is held in Octopus Lake, other small lakes and wetlands. Two beaver dams are significant in that they act as a water level control structure at the outlet of Octopus Lake.

When potential infiltration losses (50% of potential runoff) are considered, approximately 64-96% of snowmelt runoff from the Aspen Creek sub-basin is held as depression storage. In the Octopus Creek sub-basin, 88% of snowmelt runoff is retained in Octopus Lake, other small lakes and wetlands.

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