# SNOW COVER SURVEY 2009
## UPPER HUMBER RIVER WATERSHED

Water Resources Management Division
Department of Environment & Conservation
Government of Newfoundland & Labrador
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## INTRODUCTION

The Water Resources Management Division (WMRD), of the Newfoundland and Labrador Department of Environment and Conservation, is responsible for forecasting flood events for the Humber River. Snow cover maps derived from MODIS satellite imagery have proven to be beneficial for measuring percent snow cover within the Humber River Watershed and have improved forecasting river flow rates during springtime snow melt.

During the 2008-2009 snow season, three field visits were made to the Upper Humber River Watershed for the purpose of: (i) ground truthing snow cover maps derived from MODIS satellite imagery; (ii) measuring snow water equivalent of the snow pack; and (iii) measuring the effect of elevation on snowfall accumulation.

## STUDY AREA

The study area was located along the Upper Humber River, in a region accessible by a network of resource roads running west of Highway 420 (Figure 1). This area was selected for several reasons: (i) it is an area that retains its snow cover longer than other regions of the watershed and thus complete melting of snow in this area usually precludes the occurrence of any flood level flow rates in the Humber River; (ii) it is a area with no associated snow cover monitoring program, unlike the western portion of the Humber River Watershed; (iii) it contains a large elevation range (68m-523m), which is ideal for examining elevation effects on snowfall accumulation; and (iv) it contains black spruce (*Picea mariana* (Mill.) B.S.P.) dominant stand types and dense forest with crown closure greater than 75%, which are forest types known to be problematic for mapping snowcover using MODIS satellite data.

## SNOW STATION SETUP

The first of the three field visits took place from November 13-16, 2008. During this field visit, 20 stations were established to conduct snowcover surveys (Figure 1). There were four stations established at five different elevations (i.e. 100m, 200m, 300m, 400m, and 500m). Two of the 20 stations were situated outside the Humber River Watershed. These stations were highly accessibility by roadway and were assumed to be representative of snow conditions in similar elevation regions of the Upper Humber River Watershed. Both stations were located within a distance of 2.5 km from the Humber River Watershed boundary.

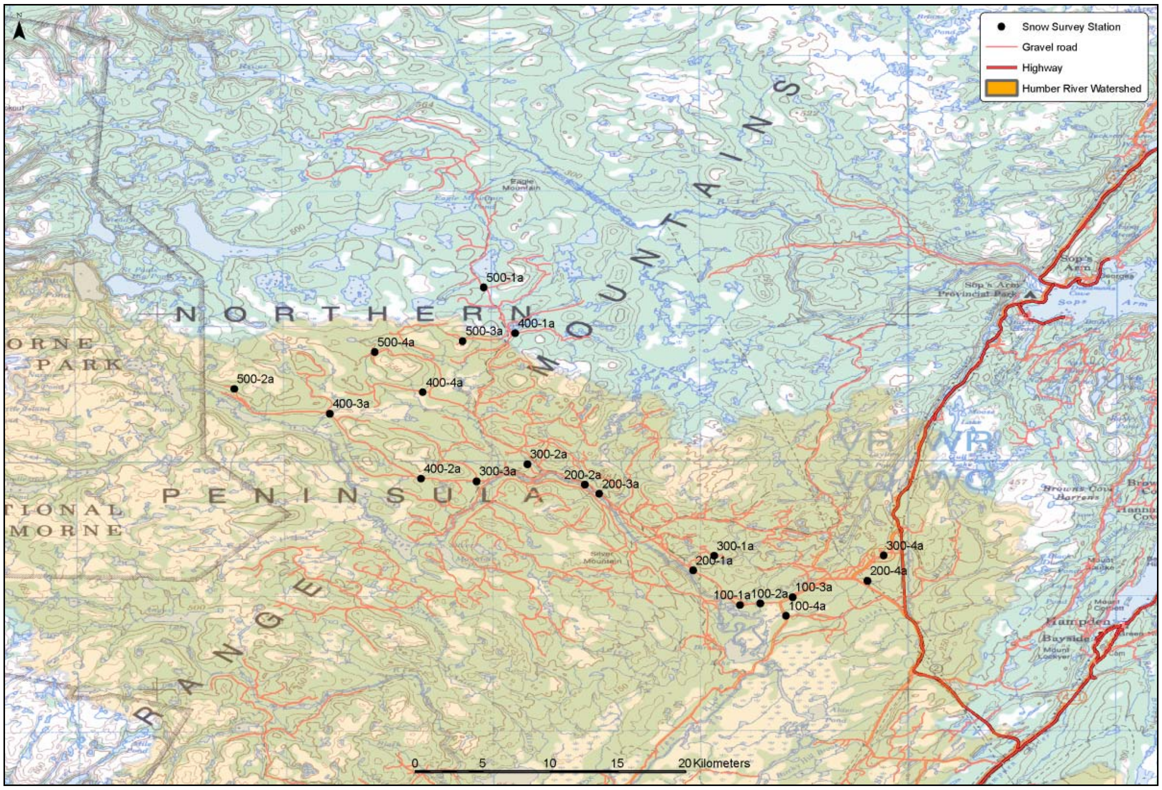


Figure 1. Map of study area and snow survey stations with elevation labels (100m-500m).

Due to the topography of the area, all 100m elevation stations were located within 5km of each other. The close proximity of these stations is undesirable from an experimental design perspective, since it is possible that any localized factors affecting snowfall accumulation in that region would affect the entire sampling group and not be representative of the larger population.

## DEER LAKE POWER SNOW SURVEY

On March 27, 2009 WRMD staff (i.e., Keith Abbott) accompanied the Deer Lake Power crew on their snow survey of the western portion of the Humber River Watershed, within the Grand Lake Watershed. This outing served as a training session, where information regarding sampling techniques and snow station layout and maintenance were shared to help develop a similar snow survey program for the Upper Humber River Watershed.

The Deer Lake Power survey program had established 19 snow sampling stations within the Humber River Watershed (Figure 2). Each station contains three substations, which were the locations to collect snow samples. The substations were typically small clearings in the forest that were on average 20m in diameter. The substations were spaced approximately 100m apart from each other. Figure 3 shows two Deer Lake Power employees weighting a snow sample at a substation. Three snow samples were collected at each substation, for a total of nine samples collected per station.

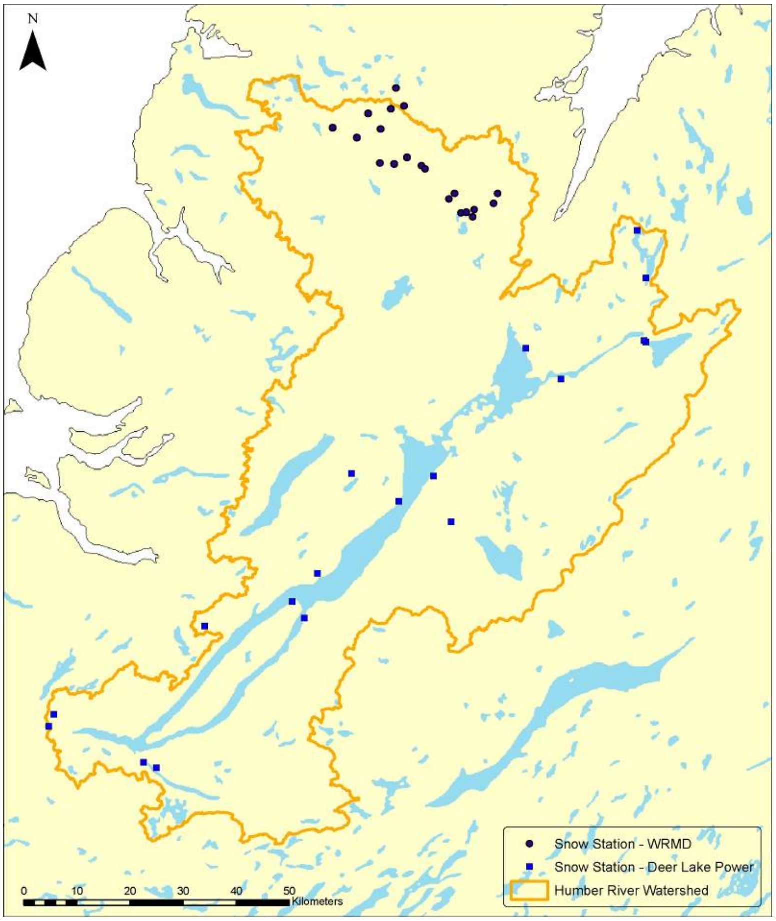


Figure 2. Snow survey stations established by Deer Lake Power and the Water Resources Management Division (WRMD) for the Humber River Watershed and surrounding area.

Figure 3. Jerry Smith (left) and Dawson Strangemore (right) of Deer Lake Power weight a snow sample at one of the Little Grand Lake (South) substations.

## UPPER HUMBER RIVER SNOW SAMPLING

Snow sampling for the Upper Humber River Watershed occurred on April 1-2, 2009. Snow samples were collected using the Model 3600 Federal or Mt. Rose Snow Sampling Tube, which is used to measure the depth, snow water equivalent (SWE) and density of the snowpack. Depth measurements are made by inserting the tube into the snowpack in the direction of nadir. The depth is read directly from the graduated measure on the outside of the tube. The snow tube is then removed with the snow contents and weighted. The digital scale weights the tube and contents in units of ounces, pounds, grams or kilograms. The weight of the empty tube is subtracted from the total weight to obtain the weight of the sampled snow. The SWE is than computed by converting the weight (g) of the snow to SWE (cm) using the conversion factor 0.08959cm/g where:

$$\text{SWE (cm)} = \text{weight (g)} \times 0.08959\text{cm/g} \qquad [1]$$

Density is computed using the equation:

$$\text{Density (\%)} = \text{SWE (cm)} / \text{depth (cm)} \times 100\% \qquad [2]$$

Twenty stations were established within the Upper Humber River region, with one substation for each station. Beginning next year in 2010, two additional substations will be established at each station, giving it a similar sampling design as the Deer Lake Power Snow Survey. Table 1 displays the mean depth, snow water equivalent (SWE), and density of snow sampled at each substation. The mean depth, SWE and density for all substations (n = 60) was 121.07cm (SD = 30.65), 35.78cm (SD = 14.87) and 29.54% (SD = 8.43), respectively.

Table 1. Mean depth, snow water equivalent (SWE) and density of snow sampled at each substation in April 2009 (n = 3), with corresponding standard deviation (SD).

| Date | Station | Depth (cm) | | SWE (cm) | | Density (%) | |
|---|---|---|---|---|---|---|---|
| | | Mean | ±SD | Mean | ±SD | Mean | ±SD |
| 2009-04-02 | 100-1a | 92.33 | 7.57 | 31.66 | 4.60 | 34.20 | 2.68 |
| 2009-04-02 | 100-2a | 90.67 | 0.58 | 28.97 | 2.25 | 31.95 | 2.46 |
| 2009-04-02 | 100-3a | 91.00 | 4.36 | 25.98 | 3.23 | 28.71 | 5.03 |
| 2009-04-02 | 100-4a | 96.67 | 2.08 | 34.05 | 5.45 | 35.26 | 5.94 |
| 2009-04-02 | 200-1a | 102.33 | 3.79 | 29.27 | 2.25 | 28.58 | 1.41 |
| 2009-04-02 | 200-2a | 121.67 | 15.50 | 32.55 | 3.39 | 27.11 | 5.12 |
| 2009-04-02 | 200-3a | 108.00 | 5.20 | 40.91 | 2.88 | 37.89 | 2.14 |
| 2009-04-02 | 200-4a | 109.00 | 12.29 | 39.12 | 1.03 | 36.19 | 4.02 |
| 2009-04-02 | 300-1a | 129.67 | 9.24 | 55.25 | 8.97 | 42.47 | 4.65 |
| 2009-04-01 | 300-2a | 113.33 | 2.08 | 28.37 | 9.58 | 24.96 | 8.07 |
| 2009-04-01 | 300-3a | 145.67 | 10.07 | 30.76 | 7.51 | 21.41 | 6.75 |
| 2009-04-02 | 300-4a | 105.67 | 14.57 | 34.94 | 5.88 | 33.04 | 2.65 |
| 2009-04-02 | 400-1a | 204.33 | 8.50 | 69.29 | 17.93 | 34.08 | 9.41 |
| 2009-04-01 | 400-2a | 143.00 | 16.09 | 32.25 | 13.56 | 22.14 | 7.23 |
| 2009-04-01 | 400-3a | 137.33 | 15.53 | 29.86 | 2.59 | 21.80 | 0.79 |
| 2009-04-01 | 400-4a | 128.00 | 12.53 | 27.48 | 9.58 | 22.03 | 9.75 |
| 2009-04-01 | 500-1a | 99.33 | 8.39 | 17.89 | 1.58 | 18.13 | 2.57 |
| 2009-04-01 | 500-2a | 137.33 | 18.01 | 38.53 | 12.32 | 28.12 | 9.23 |
| 2009-04-01 | 500-3a | 174.33 | 6.11 | 66.00 | 16.28 | 37.67 | 7.92 |
| 2009-04-01 | 500-4a | 91.67 | 6.66 | 22.40 | 9.35 | 25.04 | 12.53 |

**ELEVATION AFFECT ON SNOW ACCUMULATION**

Table 2 shows mean depth, SWE and density of snow sampled at each elevation. This information is also depicted in Figure 4.

Table 2. Mean depth, snow water equivalent (SWE) and density at five different elevations (n = 12) sampled in April 2009, with corresponding standard deviation (SD).

| Elevation (m) | Depth (cm) | | SWE (cm) | | Density (%) | |
|---|---|---|---|---|---|---|
| | Mean | ±SD | Mean | ±SD | Mean | ±SD |
| 100 | 92.67 | 4.58 | 30.16 | 4.68 | 32.53 | 4.50 |
| 200 | 110.25 | 11.54 | 35.46 | 5.41 | 32.44 | 5.71 |
| 300 | 123.58 | 18.24 | 37.33 | 13.06 | 30.47 | 9.85 |
| 400 | 153.17 | 33.41 | 39.72 | 20.75 | 25.01 | 8.54 |
| 500 | 125.67 | 35.69 | 36.20 | 21.89 | 27.24 | 10.51 |

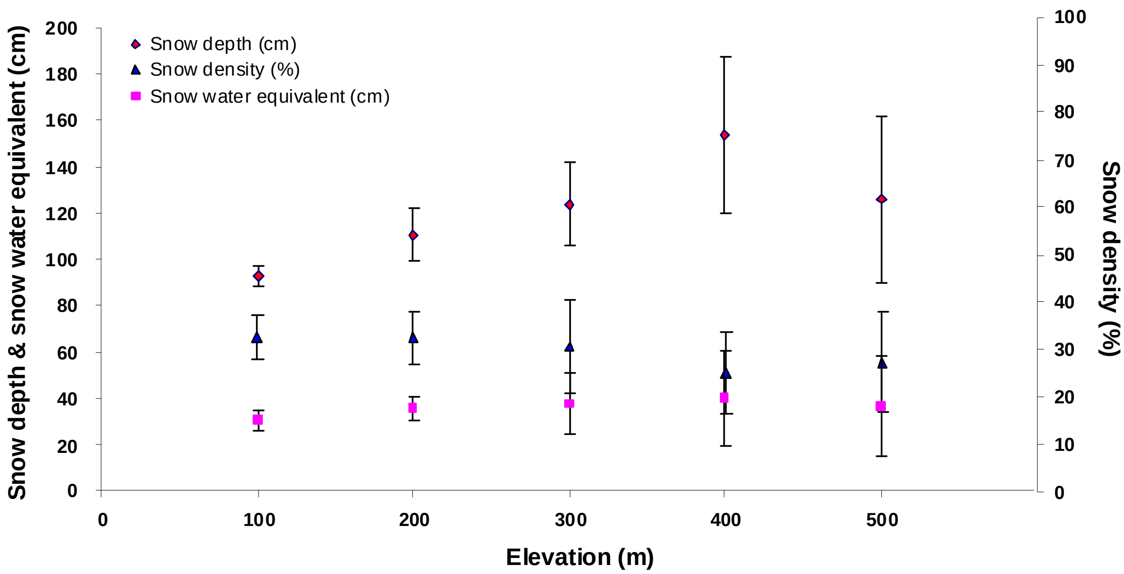


Figure 4. Mean depth, snow water equivalent (SWE) and density at five different elevations (n = 12) sampled in April 2009, with standard deviation error bars.

With an increase in elevation from 100m-to-400m, there was an increase in mean snow depth from 93cm to 153cm and an increase in mean SWE from 30cm to 40cm. This shows that snowfall accumulation was greater at higher elevations. For the same increase in elevation, the density of snow decreased from 33% to 25%. This decrease in snow density at higher elevations could have resulted from a higher frequency of melting events at lower elevations where temperatures are typically lower due to the principle of lapse rate. Also due to lapse rate there is a higher probability that precipitation events could fall as rain at lower elevations and as snow at higher elevations. Such a weather event occurred during the second day of sampling on April 2, 2009. Rainfall at lower elevations had made the snow wet and heavy, increasing the density of the snow. It is important to note that from January 1, 2009 to March 31, 2009, there were six days and two days where mean temperature was higher than freezing ($0^{o}$C), as measured by Environment Canada's at the Deer Lake (elevation 21.9m) and Daniels Harbour (elevation 19.0m) weather stations, respectively.

Snow samples collected at 500m elevation varied from the depth, SWE and density trends described above. With an increase in elevation from 400m to 500m, mean snow depth and SWE decreased from 153cm to 126cm and 39.7cm to 36.2cm, respectively. For this same elevation increase, snow density had increased from 25% to 27%. It was assumed that the 500m elevation substations were typically in highly exposed areas, not sheltered by vegetation and as a result the effects of wind had displaced snow to more sheltered areas and higher sun exposure at these substations had promoted an icy granular layer to form near the snow surface. Thus the effects of wind would have reduced snowfall accumulation at higher elevation, resulting in decreased snow depth and SWE, and the effects of sun exposure forming an icy granular surface layer would have increased the density of the snowpack. A snow pit dug near substation 500-1a revealed that the top 11cm of snow consisted of this icy granular layer of high water content (Figure 5). No other snow pits were dugs, but plans for subsequent snow surveys will involve snow pits dug at each 100m elevation increment.

Figure 6 displays snow depth, SWE and density variations with elevation for the 19 stations surveyed by Deer Lake Power in the Grand Lake Watershed in March 2009. The trends were somewhat similar to what was observed in the Upper Humber River Watershed, with the exception of snow depth, which also increased with elevation; like the snow depth and SWE variables. It is possible that the decrease in density with elevation, as observed for the Upper Humber River Stations, was due to the time of sampling, where the second day of sampling (April 2, 2009) involved visiting the lower elevation sites when weather conditions were rainy.

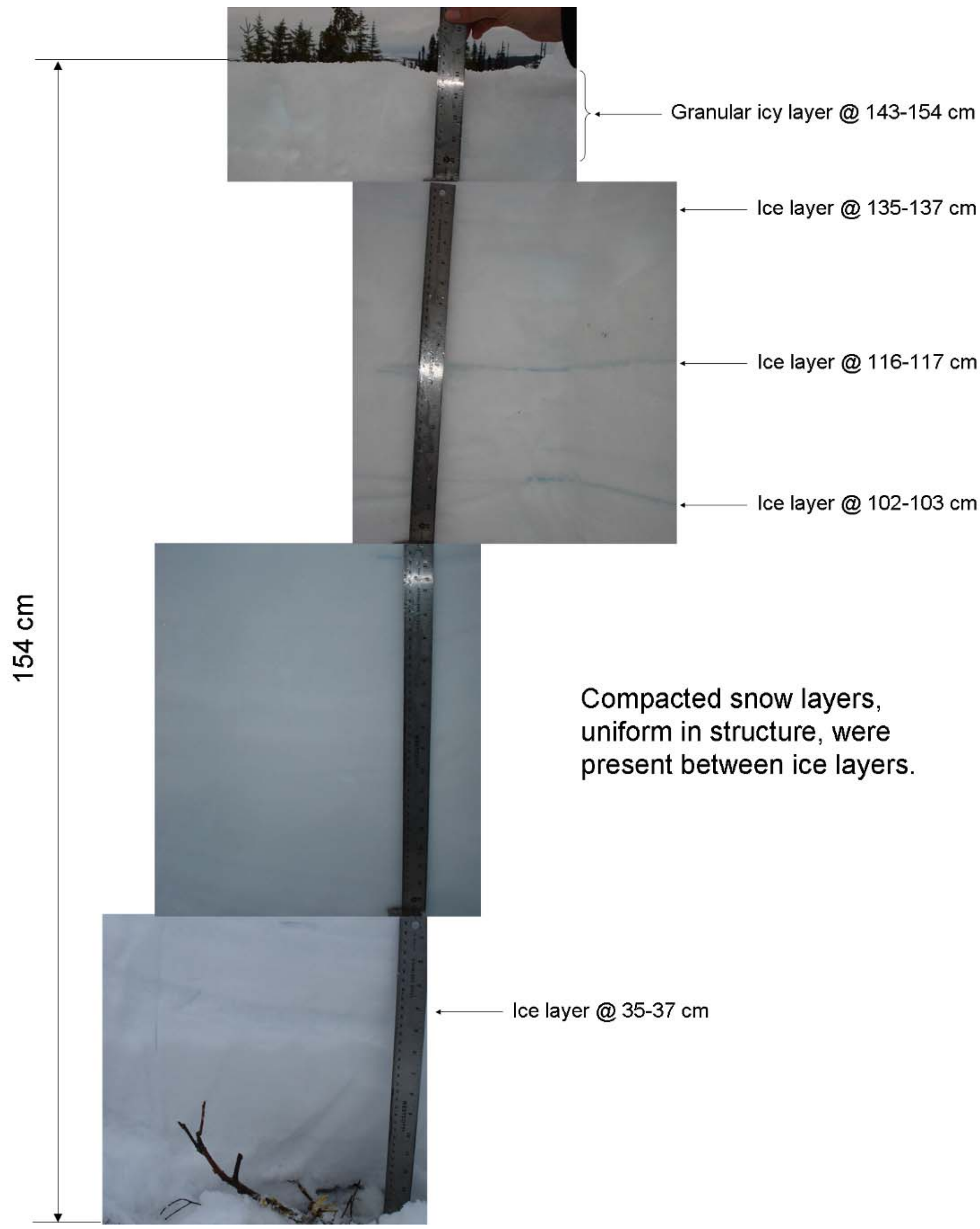


Figure 5. Snow pit dug near substation 500-1a revealed four thin sub-surface ice layers and a thick surface granular ice layer.

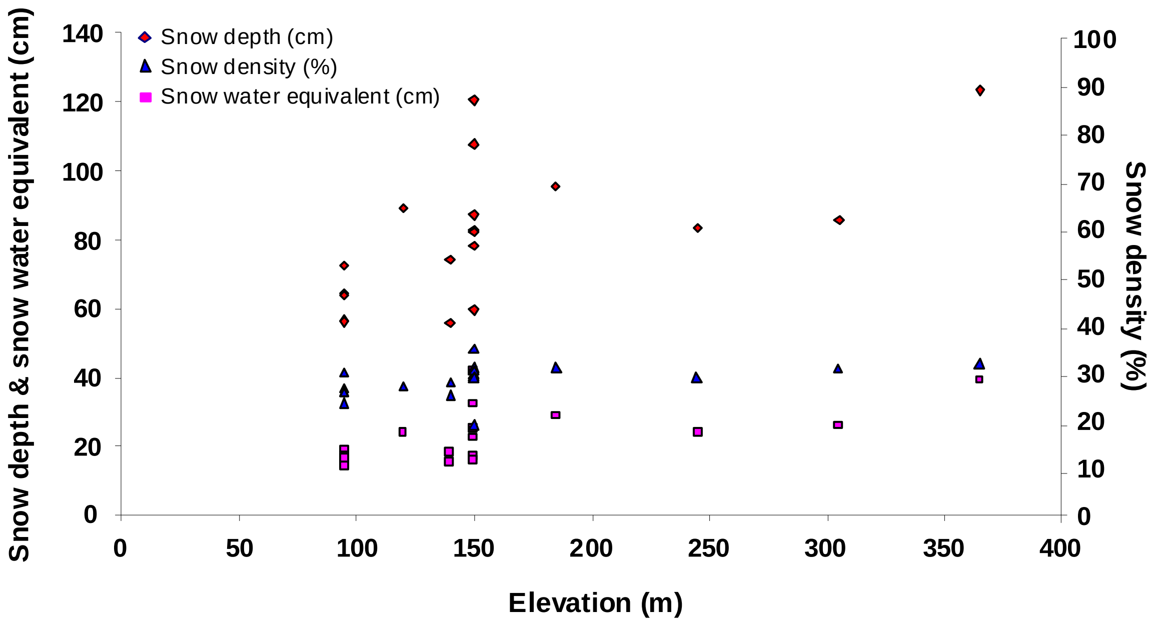


Figure 6. Mean depth, snow water equivalent (SWE) and density varies with elevation (n = 19) for the Deer Lake Power snow survey stations sampled in March 2009.

## PARTIAL SNOW COVER SURVEY

Snowcover mapping often omits thinner snowcover layers found on the perimeter of the snowpack from being classified as snow. On May 28, 2009, a third field study was conducted to visit three sites of partial snowcover for the purpose of ground truthing the Humber River snowcover maps. These three areas were located in a transition zone between snow and snow-free areas according to snowcover conditions mapped on May 16, 2009 (Figure 7). The three areas were also selected due to there accessibility by roadways. It was beneficial to visit these areas of transition and document snow conditions (i.e., % snowcover & location) with a camera and GPS.

From the time of selecting the Areas of Interest (AOI) on May 16, 2009 to actually visiting these areas on May 28, 2009, 12 days had passed and much of the snow cover had receded as shown in Figure 7. Photographs were still taken at these areas with the exception of Area B, where the gravel road leading to this area was too rough to travel for the vehicle used. Instead, photographs were taken in a northwesterly direction from the nearby community of Cormack. Figure 8 shows some pictures captured at or near these AOI.

The snow had receded as much as 15km from Area A. The ground conditions at this site showed some remnant patches of snow under forest canopy (Figure 8). Based on a visual estimate of snow cover in this area, it seemed most of the ground had no snowcover and thus the snowcover map for May 28, 2009 was correct for this area.

Area B was not accessible by car. However, a picture taken 10km southwest of Area B shows some remnant patches of snow in the direction of Area B (Figure 8). It was determined based on visual inspection that this small amount of snowcover did not warrant Area B to be classified as snow covered, and so the snowcover map for May 28, 2009 was correct for this area.

Area C still had some snowcover, as mapped by the May 28, 2009 snowcover map (Figure 7) and as observed on the ground (Figure 8). It seems the presence of snow, even if in patches, can dominant the reflectance of a MODIS ground sampling unit or pixel. Thus, a mixed pixel that captures both forest canopy and patchy snow cover will likely be classified as snowcover. Further investigation is required to support this observation.

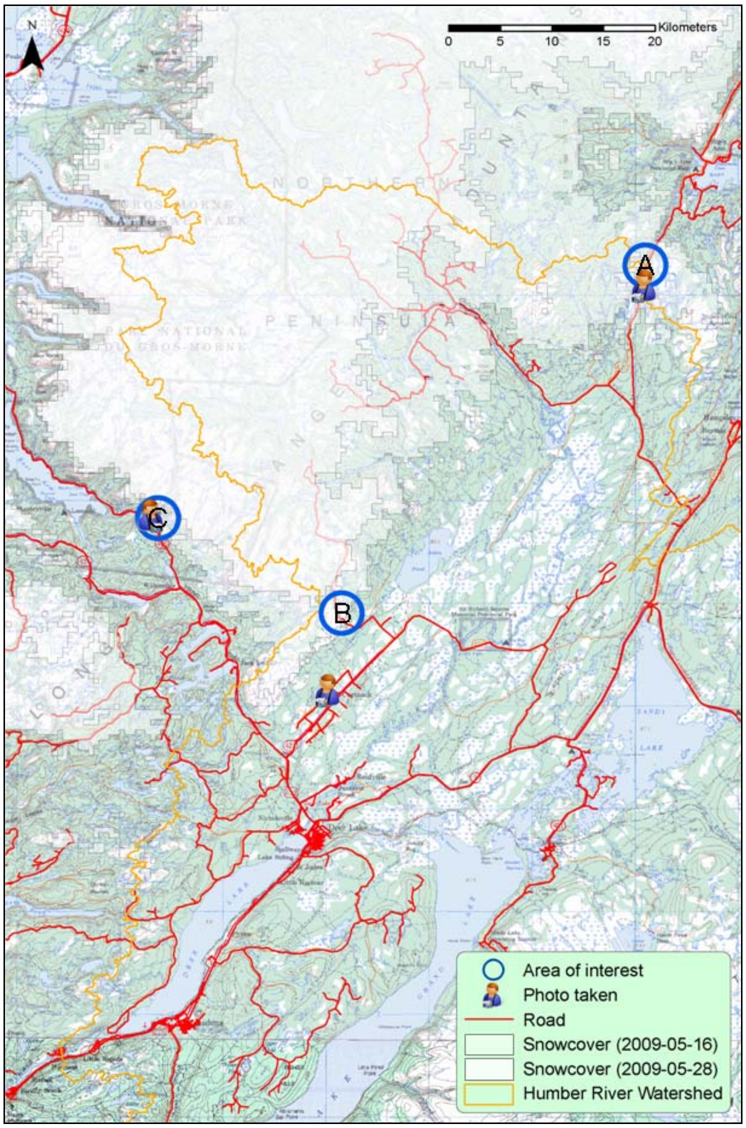


Figure 7. Three sampling areas with roads layer (yellow/black line), Humber Watershed boundary (blue line) and snowcover layer (red).

**Area: A**
Direction: Northwest
Filename: PAR-02-01

**Area B**
Direction: Northwest
Filename: PAR-12-04

**Area C**
Direction: Northeast
Filename: PAR-15-06

Figure 8. Ground truth photographs taken of partial snow cover for three areas of interest.

## DIGITAL SCALE VERSUS SPRING SCALE

The Deer Lake Power survey crew uses a spring scale to weight their snow samples. The spring scale measures SWE directly in units of centimeters. A digital scale was supplied with the Model 3600 Mt. Rose Snow Sampling Tube purchased by the WRMD. The digital scale can weight snow samples in units of pounds, ounces, kilograms or grams. These weights then have to be converted to SWE (cm) using Equation [1].

Digital and spring scales measurements of SWE were compared for a total of 32 snow samples (Figure 9). For heavier snow samples the digital scale tends to measure higher SWE values than the spring scale. Scale calibration is required using predefined weights to determine scale accuracy. GeoScientific Ltd. provides the following values to calibrate the digital scale:[1]

100 grams = 8.96 cm SWE
250 grams = 22.40 cm SWE
500 grams = 44.80 cm SWE
1000 grams = 89.60 cm SWE
2000 grams = 179.20 cm SWE
3000 grams = 268.80 cm SWE

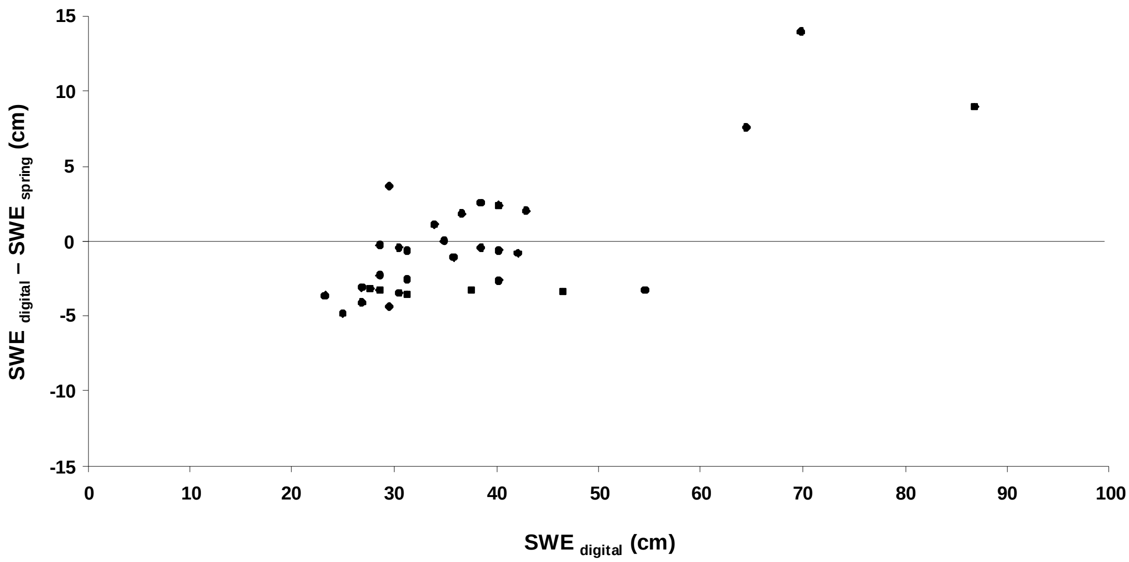


Figure 9. Differences between SWE estimates made by the digital scale ($SWE_{digital}$) and spring scale ($SWE_{spring}$) show that for heavier snow samples the digital scale tends to measure higher SWE values than the spring scale.

[1] Note: The 3 meter SWE scale has a built in tare weight to accommodate some of the weight of the empty snow sampler. Approximately 600 grams is required to break the tare weight. Therefore put approximately 600 grams on the scale to get it moving, and then each of the above weights should increase the scale reading by the corresponding SWE value.

**RECOMMENDATIONS**

The following are some recommendations for subsequent field visits:

- Do not collect snow samples in wetland areas. Ground surface in often unfrozen and thus can melt the snowpack from below. Also, a snow tube inserted into a bog can get stuck from suction created and near to impossible to remove (Figure 10).
- Purchase a winch with straps for safe snow mobile travel
- Purchase calibration weights for digital scale
- Purchase silicone spray for snow tubes to prevent snow from sticking to the inside of the tube
- Purchase driving wrench and cleaning knife for snow tube
- Space the 100m elevation stations further apart
- Partial snow cover visit should take place near the beginning of May month to better capture the snowcover boundaries
- One snow pit should be dug at each elevation increment
- Two additional substations should be established at each station to match the sampling design of the Deer Lake Power survey

Figure 10. Paul Taylor of Parks & Natural Areas Division displays a snow tube section, recovered after a two hour struggle to retrieve it from a bog.

**APPENDIX A**

**SUPPLY LIST FOR SNOW SAMPLING SURVEY**

Supplies for a five night snow survey field trip include:

1. food and food coolers;
2. 4x4 vehicle to transport gear from Corner Brook to Study Area;
3. two snowmobiles;
4. trailer to transport snowmobiles;
5. two snowmobile sleds;
6. 20 L of gasoline for each snow snowmobile;
7. 3 L of oil for each snowmobile;
8. rope and tarpaulin to cover sleds;
9. winch and straps to move snowmobile when stuck in snow;
10. 10 L of kerosene for oil stove at camp;
11. 25 pounds of propane for camp stove and lights;
12. bucksaw and axe for cutting wood for camp wood stove;
13. small shovel to dig snow pits, dig out camp, and to dig out snowmobile when stuck.

Figure 1. Two snowmobiles were used for transportation in the study area and to transport supplies to Russell's Roost (i.e., Wildlife Division Cabin) located at the following coordinates: 49.778773N, 57.290411W.