Snow Survey Data for the Sagavanirktok River / Bullen Point Hydrology Study: Spring 2007

Hoar frost at bottom of snowpack, UAF Staff

by

Sveta Berezovskaya, Jeff Derry, Douglas Kane, Robert Geick, Michael Lilly, Dan White

July 2007

Sagavanirktok River/Bullen Point Hydrology Project

Report No. INE/WERC 07.18

Water and Environmental Research Center

Snow Survey Data for the Sagavanirktok River Bullen Point Hydrology Study: Spring 2007

by

Sveta Berezovskaya[1], Jeff Derry[2], Douglas Kane[1], Robert Geick[1], Michael Lilly[2], Dan White[1]

A report on research sponsored by the

Alaska Department of Transportation and Public Facilities

Alaska Department of Natural Resources

July 2007

Sagavanirktok River/Bullen Point Hydrology Project

Report Number INE/WERC 07.18

[1]University of Alaska Fairbanks, Water and Environmental Research Center
[2]Geo-Watersheds Scientific, Fairbanks, Alaska

Recommended Citation:

Berezovskaya, S.L., Derry, J.E., Kane, D.L., Geick, R.E., Lilly, M.R., and White, D.M., 2007. Snow Survey Data for the Sagavanirktok River Bullen Point Hydrology Study: Spring 2007. July 2007, University of Alaska Fairbanks, Water and Environmental Research Center, Report INE/WERC 07.18, Fairbanks, Alaska, 17 pp.

Fairbanks, Alaska
July 2007

For additional information write to:

Publications,
Water and Environmental Research Center
University of Alaska Fairbanks
Fairbanks, Alaska 99775
www.uaf.edu/water/

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the accuracy of the data presented herein. This research was funded by the Alaska Department of Natural Resources (ADNR) and the Alaska Department of Transportation and Public Facilities (AKDOT&PF). The contents of the report do not necessarily reflect the views of policies of the ADNR, AKDOT&PF or any local sponsor. This work does not constitute a standard, specification, or regulation.

The use of trade and firm names in this document is for the purpose of identification only and does not imply endorsement by the University of Alaska Fairbanks, Alaska Department of Natural Resources, Alaska Department of Transportation and Public Facilities, or other project sponsors.

UNITS, CONVERSION FACTORS, WATER QUALITY UNITS, VERTICAL AND HORIZONTAL DATUM, ABBREVIATIONS AND SYMBOLS

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (mm)
mile (mi)	1.609	kilometer (km)
	Area	
Acre	43559.826	square feet (ft^2)
Acre	0.407	hectare (ha)
square foot (ft^2)	2.590	square mile (mi^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	3785	milliliter (mL)
cubic foot (ft^3)	23.317	liter (L)
Acre-ft	1233	cubic meter (m^3)
	Velocity and Discharge	
foot per day (ft/d)	0.3048	meter per day (m/d)
Square foot per day (ft^2/d)	.0929	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/sec)
	Hydraulic Conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per day (ft/d)	0.00035	centimeter per second (cm/sec)
meter per day (m/d)	0.00115	centimeter per second (cm/sec)
	Hydraulic Gradient	
foot per foot (ft/ft)	5280	foot per mile (ft/mi)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Pressure	
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)

UNITS

For the purposes of this report, both English and Metric (SI) units were employed. The choice of "primary" units employed depended on common reporting standards for a particular property or parameter measured. Whenever possible, the approximate value in the "secondary" units was also provided in parentheses. Thus, for instance, snow density was reported in kilograms per cubic meter (kg m^{-3}) followed by the approximate value in slugs per cubic feet (slug ft^{-3}) in parentheses.

Vertical Datum:

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called *Sea Level Datum of 1929*.

Horizontal Datum:

The horizontal datum for all locations in this report is the North American Datum of 1983.

Abbreviations, Acronyms, and Symbols

AAS	Alaska's Arctic Slope
ADOT&PF	Alaska Department of Transportation and Public Facilities
DNR	Department of Natural Resources
F	Fahrenheit (^{o}F).
ft	feet
GWS	Geo-Watersheds Scientific
kg	kilograms
km^2	square kilometers
m	meters
NGVD	National Geodetic Vertical Datum
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
QA	quality assurance
QC	quality control
Slug	slug
Sag	Sagavanirktok River
UAF	University of Alaska Fairbanks
USGS	U.S. Geological Survey
WERC	Water and Environmental Research Center
WWW	World Wide Web
YSI	Yellow Springs Instruments

ACKNOWLEDGEMENTS

This project was funded by Alaska Department of Natural Resources and the Alaska Department of Transportation and Public Facilities. Ken Irving, Dan Reichardt, Greta Myerchin and many others participated in snow water equivalent data collection. Peter Prokein assisted with maps preparation. Logistical support was provided by BP Exploration (Alaska) Inc. Alaska. US Fish and Wildlife Surveys provided support and background data in the study area.

Snow Survey Data for the Sagavanirktok River Bullen Point Hydrology Study: Spring 2007

1. INTRODUCTION

This report discusses snow conditions that were observed during 2007 end-of-winter snow survey in the study area of the Sagavanirktok, Kadleroshilik, Shaviovik and Kavik River basins. Field studies primarily focused on assessment of maximum snow water equivalent (SWE) accumulated during the 2006 - 2007 winter. Field activities start at the end of April, because the snowpack virtually binds all precipitation falling during the period from October to April with no winter melt occurring on the Alaska's Arctic Slope (AAS) (Benson et al., 1986). Deficiencies in determining snow precipitation and sublimation imply that measurements of snow accumulated on the ground provide the most reliable observational component of winter water budget.

Assessment of maximum snow accumulation is critical input to snow hydrology studies. Seasonal snowpack constitutes winter detention storage for precipitation, induces considerable differences in surface energy balance and results in soil desiccation of the organic layer overlying permafrost (Kane et al., 1978). Water contained in snowpack ensures that snowmelt is a major hydrological event each year. Peak discharge, resulting from snowmelt, is the highest for many rivers on the North Slope, particularly for the basins of the Sagavanirktok, Canning and Kuparuk Rivers. These rivers drain a large area that extends from the Brooks Range through the Northern Foothills and across the Coastal Plain before discharging into the Arctic Ocean. Snow starts contributing to runoff in the southern mountainous province in May and only a month later it melts on Coastal Plain. Due to extremely high snowpack heterogeneity, knowledge on SWE spatial distribution is critical for understanding a river's hydrologic response during ablation.

This report presents snow water equivalent observational data for the eastern part of the Alaskan Arctic. It summarizes data collection procedure, accuracy of observations and their spatial distribution.

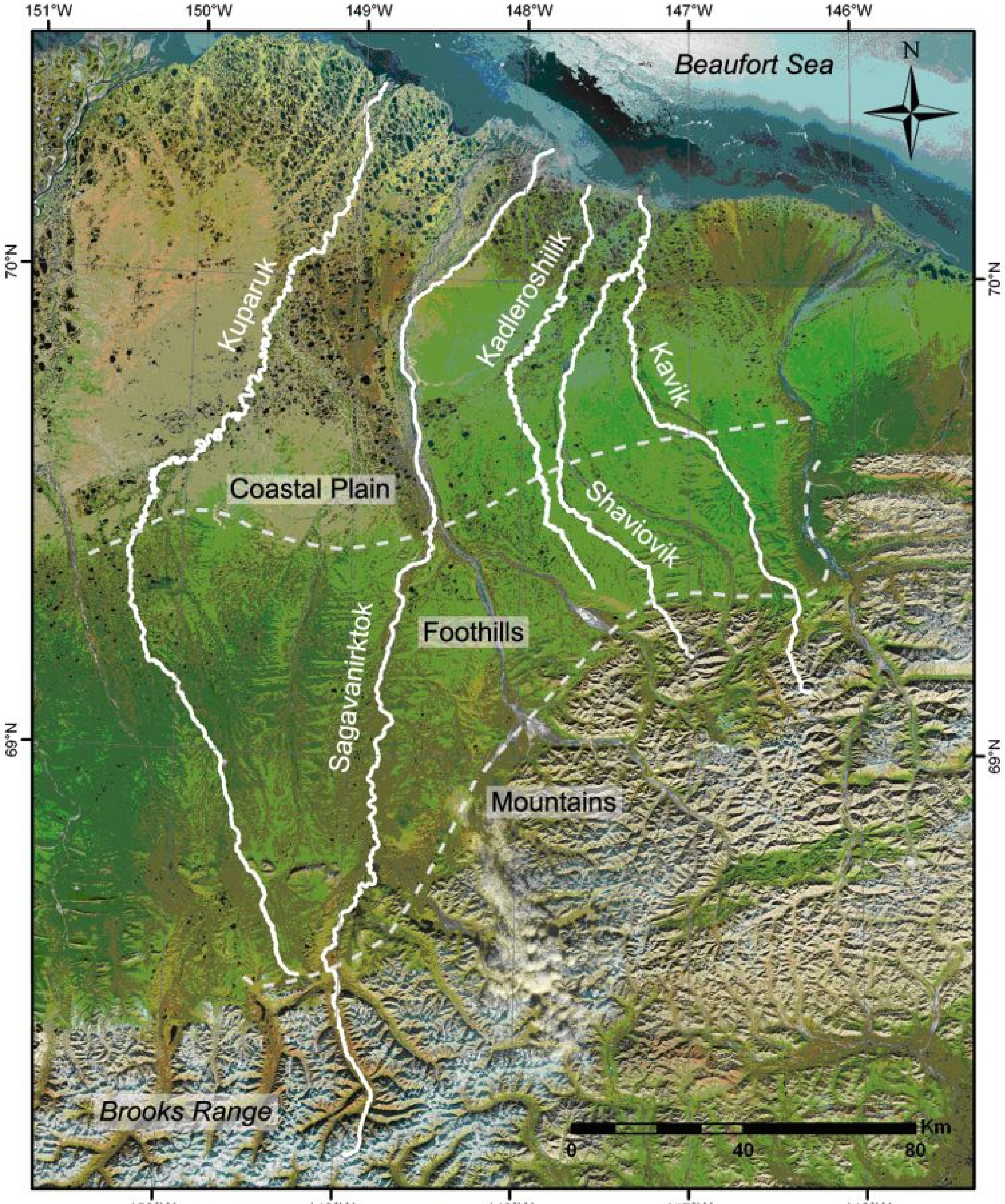

Figure 1. Geographical map of study area. Solid lines show major rivers; dashed lines represent approximate boundaries of the Coastal Plain, Foothills and Mountains regions.

2. AREA OF OBSERVATIONS

The study domain covers a 120 by 240 km region of the AAS that is bounded by the Brooks Range on the south and the Arctic Ocean on the north and includes the Sagavanirktok, Kadleroshilik, Shaviovik and Kavik River basins. The Sagavanirktok River is about 290 km long and has a drainage area of about 14,900 km^2. More than half (54 %) of the basin area occurs in the Brooks Range, and an additional 29% lies within the Foothills region. Only 17% of the basin falls within the Coastal Plain. Sagavanirktok River is constricted between the Kuparuk River basin to the east and Kadleroshilik and Shaviovik River basins to the west.

Approximately 90 % of the Kadleroshilik River basin consists of the Coastal Plain with remaining 10 % in the Foothills. The river is about 113 km in length encompassing over 1500 km^2 in drainage area. The Shaviovik River is located west of the Kadleroshilik River and is the largest river between the Sagavanirktok and Canning Rivers. The river is 137 km in length extending into the Brooks Range. The Shaviovik River drainage basin is approximately 4028 km^2 in size that includes the watershed of the Kavik River. The confluence of the Shaviovik and Kavik Rivers is located 18 km from the coast. The Kavik River extends 122 km to the south from this confluence reaching far into the Brooks Range.

The southern and northern boundaries of the domain are at 68° 10’ and 70° 15’ N latitude, respectively. The western and eastern boundaries of the domain are approximately at approximately 150° 00’ and 146° 30’ W longitude, respectively. The total elevation range within the study area is sea level to 2675 m (0 to 8025 ft). The topography is characterized by a flat northern portion, generally referred to as “Coastal Plain”, followed by gently rolling hills and valleys (“Foothills”) extending to the south and mountain ridges of the Brooks Range (“Mountains”) (Figure 1). More than half of the domain occurs in the Brooks Range.

Vegetation falls within a large region of sedge tussocks and mosses that cover much of northern Alaska. Occasional groupings of willows, approximately 40 cm high, occur in hillside water tracts and in the valley bottom. The surface organic soils vary from live organic material at the surface to partially decomposed organic matter between 10 and 20 cm in depth. Silt, overlying a glacial till, makes up the mineral soil in the glaciated areas (Kane et al, 1989). Overall, the topography and vegetation of the domain are representative of the AAS region.

3. SAMPLING METHODS

Our snow surveys are made at designated stations throughout the domain to determine the depth, vertically integrated density and water equivalent (Figure 2). Most of the sites, except for ablation measurements (see section 3.2), are visited once a year near the peak of snow accumulation, the last week of April. Our observations in the Foothills showed that snow never melts before last week of April. Also, March, April and May are typically the months of lowest precipitation and, therefore, there is not much accumulation between the surveys and ablation.

In addition, meteorological stations are equipped with snow sensors that operate during the cold season and collect snow depth data at a point. Data can be collected in near real time or in the field directly from data logger.

3.1 Snow Survey

Our snow survey includes gravimetric SWE sampling and snow depth measurements collected over a 25 m by 25 m area; this technique is often referred to as “double sampling”. The Alaskan snowpack is extremely heterogeneous (Sturm and Benson, 2003). Usually, double sampling yields an areal SWE estimate with a lower variance than is possible by collecting snow cores only, because considerably more snow depths than SWE measurements can be made in a time increment. Rovansek et al. (1993) showed that double sampling provides improved SWE estimates and recommended sampling 12 to 15 snow depths for each snow core. However, this optimal ratio of snow depths to water equivalent appeared to vary greatly (from 1 to 23), depending on weather and snow conditions. Currently, we use an optimal ratio of 10; that is, 50 depths accompany five snow cores.

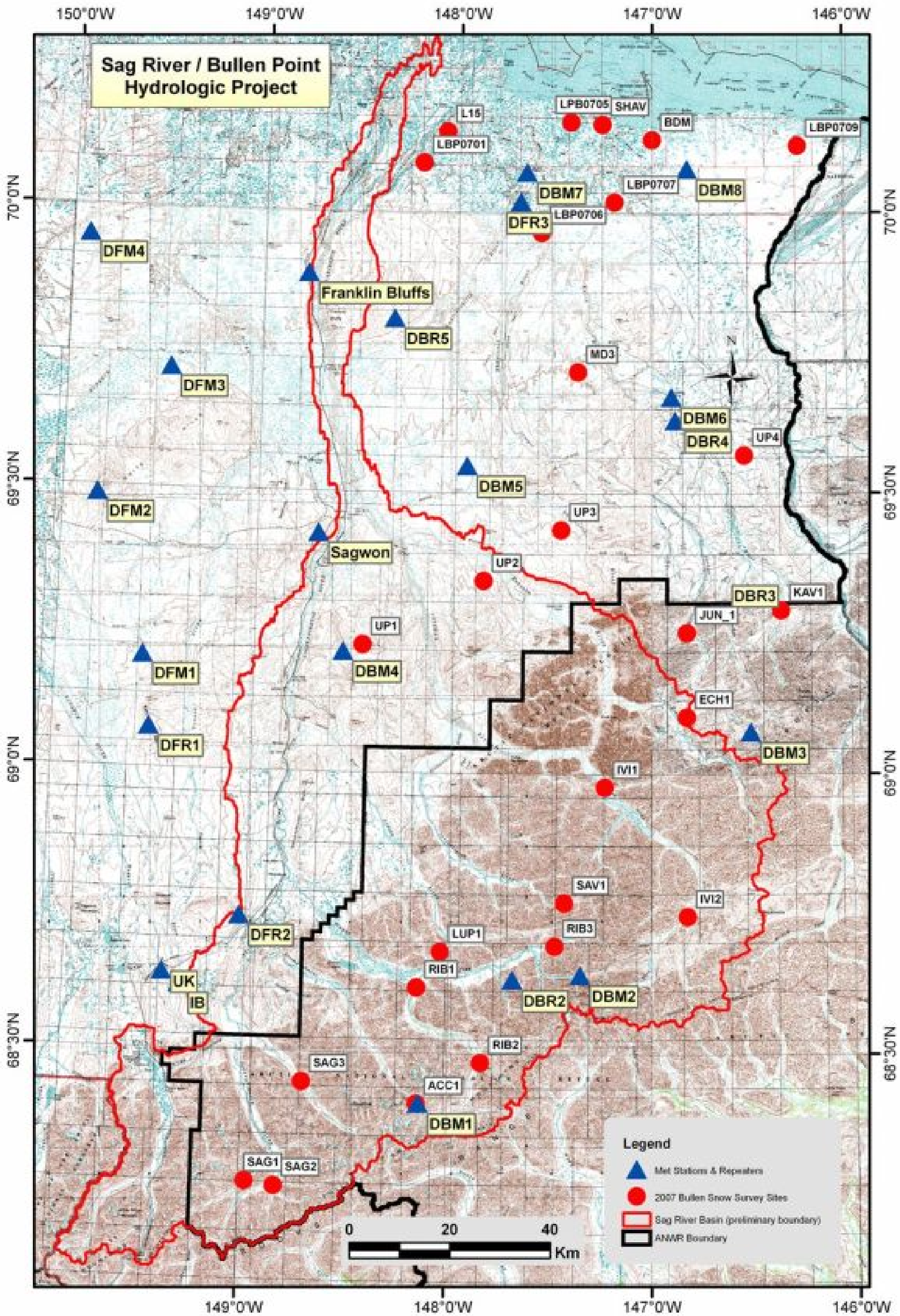

Figure 2. Location map of snow survey sites and meteorological stations.

Snow cores are sampled using fiberglass tube (“Adirondak”) with an inside area of 35.7 cm^2, equipped with metal teeth on the lower end to cut through dense layers of snow. The advantage of the Adirondak for shallow snowpack is that it has a larger diameter than many other types of snow tubes and thus provides a larger sample. To obtain a complete snow core, the Adirondak tube is pushed vertically through the snow while turning until soil is encountered; at this point the snow depth is recorded. The tube is then driven further into the organic layer and tipped sideways, retaining a vegetation plug that ensures the complete snow column was sampled. The vegetation plug is then removed and the snow is collected to be weighed later, in the laboratory. This procedure allows estimating both average snow density and snow water equivalent.

We use constant 50 m length for the snow depth course with a 1 m sampling interval along an L-shaped transect. Twenty five depth measurements are made on each leg of the L; this strategy is used to account for the presence of snowdrifts in the area of measurement. The directions of measurement are chosen randomly. Snow depth measurements are collected using a T-shaped graduated rod (T-probe). The probe is simply pushed through the snow to the snow-ground interface.

Snow water equivalent is defined as

$$SWE = (SD * \rho_s) / \rho_w \qquad (1)$$

where ρ_s is snow density, averaged from the 5 snow core samples, ρ_w is water density and *SD* is an average of 50 snow depths.

3.2 Snow Depth Sensors

Eight meteorological stations located in the Sagavanirktok River /Bullen Point Project area are equipped with Sonic Ranger 50 (SR50) snow-depth sensors (Figure 2). The SR50 probe uses ultrasonic pulses to measure the distance from the sensor to the snow surface. Basically, SR50 sends out an ultrasonic pulse and times how long it takes to sense the pulse echo. Although the SR50 can measure the distance to any reflective surface like the ground or water, the sensitivity of the SR50 is designed for use in measuring distance to a snow surface.

The basic idea for measuring snow depth with the SR50 is simple subtraction. When there is no snow on the ground, the distance measured is the sensor's height above the ground. When snow has accumulated under the sensor the distance measured is to the snow surface. The difference between distance to the ground and distance to the snow surface is used to calculate snow depth. For example, if the sensor's height above the ground is 50 inches and 10 inches of snow accumulates, the new distance to surface will be 40 inches. Hence, 40 inches subtracted from 50 inches gives depth of the snow under the sensor of 10 inches.

The SR50 sampling method is point data that typically records measurements at hourly intervals. Thus, the SR50 has a low spatial coverage yet a high temporal resolution, while snow survey data has at higher spatial coverage yet at low temporal resolution. Snow sensor data used in conjunction with snow survey data can enhance and expand the limitations of each sampling method.

4. ACCURACY OF OBSERVATIONS

The problems of measuring and processing any observational data are critical to realize and address. This section provides the accuracy assessment of our observations, so this data can be utilized properly.

4.1 Snow-Water Equivalent

Core SWE often underestimates the water amount contained in the snowpack (our observations, personal communication with M. Sturm). In attempting to quantify underestimation in shallow tundra snowpack conditions, Woo et al. (1997) showed that a larger tube diameter increases the accuracy of density determination; he also showed that the Canadian sampler (similar to the Adirondak in diameter) captures snow density within 5% of snow pit estimates. Our comparison of Adirondak to snow pit density give similar results.

The accuracy of a single snow depth measurement is difficult to quantify. In the area of well-developed organics on top of the mineral soils, snow depth is often overestimated. While measuring, the probe can easily penetrate low-density organic material, so this additional depth is often inadvertently incorporated into the snow depth measurement. Any type of correction to existing snow depth records is difficult to perform, because the error varies strongly from observer to observer, as well as depending on the snow and soil conditions at each site.

Whereas snow depths show a systematic overestimation error, snow core densities tend to be close to, or to underestimate, SWE. The difficulty in SWE accuracy interpretations is that actual, accurate SWE is unknown. Comparing different sampling methods, Berezovskaya and Kane (2007a) suggest that SWE of the tundra snow estimated with double sampling technique has error of ± 10 %.

4.2 Snow-Depth Sensors

Diligent field practices are essential for accurate measurements. After the sensor is installed and subsequently every time the station is visited, the distance from the bottom of the sensor to five points (four distances at 20º angles around sensor, and one directly underneath) on the ground is measured. When snow is on the ground, five depth measurements are obtained as well as the distance from the sensor to the snow surface. This information is crucial for post processing data correction and QA/QC purposes.

Adjustments to data may vary according to the error tolerance and goals of the investigation, for this report QA/QC procedures are outlined below:

- Establish a baseline value that represents no snow on the ground.
- Manually review data (graphically), and replace erroneous values with the average from the first and last data value that is deemed reasonable.
- Adjust data to fit observed values in the field.
- Lastly, smooth the data and omit smaller, sporadic, data values. If the difference between a data point and the prior data point is greater than 1.5cm, and/or the difference between a data point and the following data point is greater than 1.5cm, then replace the data point

with the average of the prior 5 hours and following 5 hours of data. A 10-hour average helped smooth out blowing snow events and cold periods that may have altered readings.

- As to avoid an abrupt transition during accumulation and/or ablation periods, incrementally adjust data over a period of days.

Potential inherent errors exist. For example, since the speed of sound in air is affected by the temperature of the air it is traveling in, an air temperature measurement is required to correct the distance reading. Inaccuracies can be caused by poor calibration and/or neglecting periodic maintenance requirements. Physically related errors include blowing snow creating spurious data readings, difficulty in establishing a zero point due to tussocks, low shrubs, grass, etc., ground heave altering sensor height, changes in sensor height and angle as well as cable breakages due to wildlife curiosities.

5. SPATIAL DISTRIBUTION OF SNOW SITES

Snow survey sites are chosen to represent snow characteristics over a wide range of vegetation and terrain conditions. Snow water equivalents are measured at elevations from sea level to 4434 ft (0 to 1478 m) (Appendix A1-A3).

There are two distinctly different snow regimes across the domain, uplands and coastal (Liston and Sturm, 2002). To determine regional SWE, snow sites are classified as the Coastal Plain and uplands, the latter is separated into Foothills and Mountains. The coastal sites are the sites located below elevation isoline of 500 ft (152 m) and those above are referred to as uplands sites. Uplands snow sites are, in turn, separated into Foothills and Mountains based on elevation and surrounding topography (Appendix A1-A3). Elevation only is not representative for this purpose, because in the mountains most of the snow survey sites are located in the valley bottoms where helicopter can safely access the site.

Overall, 141 sites were visited in 2007. This number includes 41 sites within the frame of the Sagavanirktok River/ Bullen Point project and 100 sites within the Foothills Point project. 17

Bullen project sites are located in the Mountains, 9 sites are in the Foothills and 15 sites are on the Coastal Plain.

6. SUMMARY OF SNOW OBSERVATIONS

Average of Coastal Plain snow densities (0.453 slug ft-3 / 233 kg m-3) are higher than the Foothills (0.427 slug ft-3 / 220 kg m-3) and the Mountains (0.424 slug ft-3 / 219 kg m-3) (Appendix B1-B3).

The average of Coastal Plain SWE is 2.9 in (7.4 cm), and snow depth is 12.3 in (31 cm). Foothills average snow water equivalent is 3.6 in (9.2 cm), and snow depth average is 16.4 in (41.7 cm). Mountains average snow water equivalent (2.6 in / 6.7 cm) and snow depths (12.2 in/ 31.1 cm) are generally lower than those at the Coastal Plain and Foothills. By the end of April Foothills have the highest SWE accumulation and Mountains have the lowest average SWE.

Observations at the Coastal Plain have then been corrected for the heavy snowfalls in early May (section 8). The adjusted average Coastal Plain SWE is 3.0 in or 7.6 cm (Table 1). SWE data before and after storm are listed in Appendix B4.

Table 1. 2007 snow water equivalent analysis.

Region	Number of sites	SWE		Percent of last year	Percent of the Kuparuk SWE
		cm	in		
MOUNTAINS	17	6.7	2.6	92	106
FOOTHILLS	9	9.2	3.6	122	80
COASTAL PLAIN		7.4	2.9	85	91
	15	(7.6*)	(3.0*)	(87*)	(94*)
DOMAIN					
SUMMARY	41	7.8	3.0	98	90
		(7.9*)	(3.1*)	(100*)	(91*)

* indicates adjusted SWE (section 8).

Overall, snow accumulation over the domain is the same as last year (2006) (Table 1). Mountains, Foothills and coastal regions have accumulated 92 %, 121 % and 85 % of last year SWE (Table 1). These are the only observational SWE data available for the region.

7. SUMMARY OF SONIC SNOW DEPTH MEASUREMENTS

Of the eight meteorological stations in the Sagavanirktok River/Bullen Point region, four stations had continuous, good quality snow sensor data from the accumulation and ablation 2006-2007 season: Ribdon (DBM2), Sag-Ivishak (DBM4), Upper Kadleroshilik (DBM5), and Lower Kadleroshilik (DBM 7) (Figure 3A-3D).

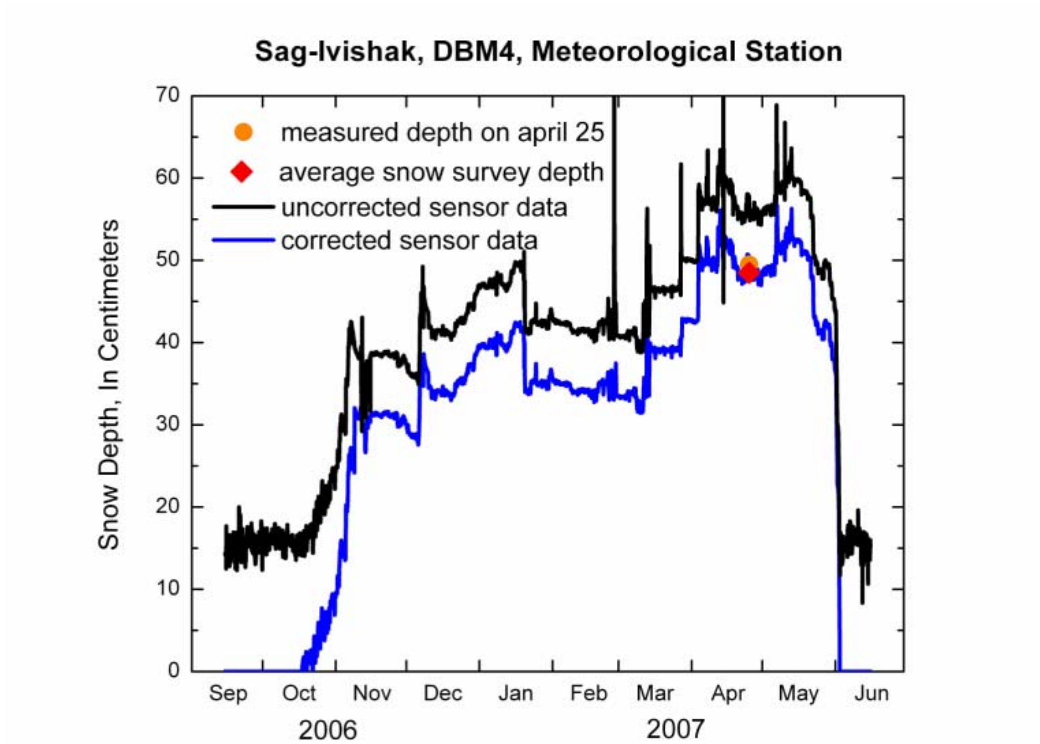

Figure 3. Corrected snow depth from Sonic Range S50 sensor installed at Sag-Ivishak, DBM4 meteorological station.

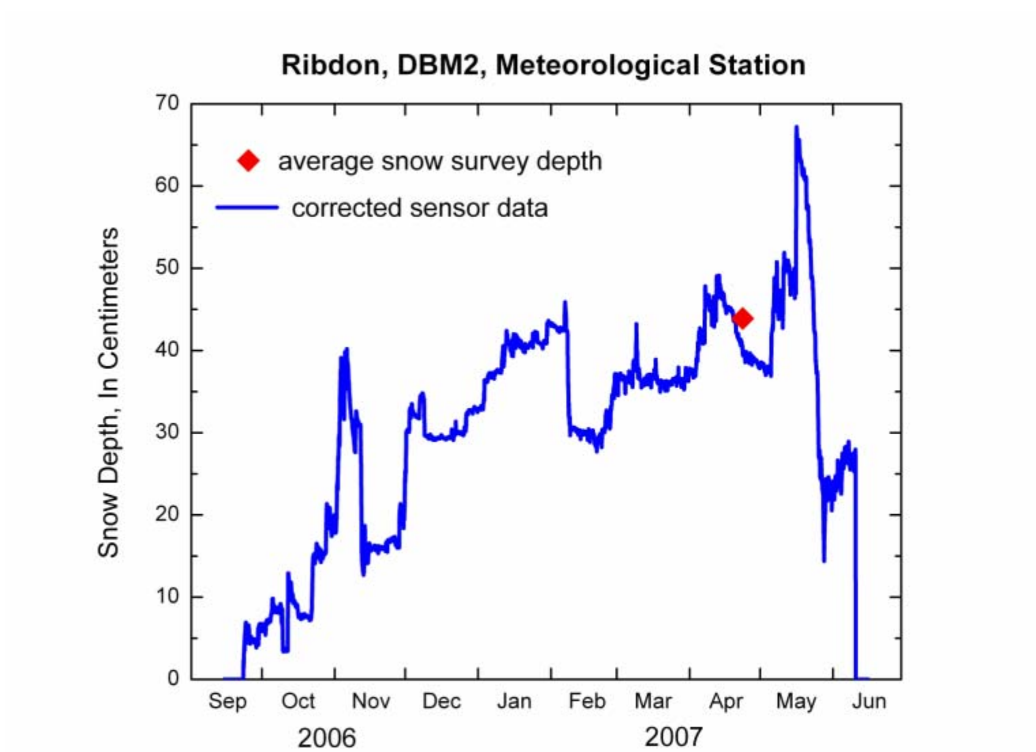

Figure 4. Corrected snow depth from Sonic Range S50 sensor installed at Ribdon, DBM2 meteorological station.

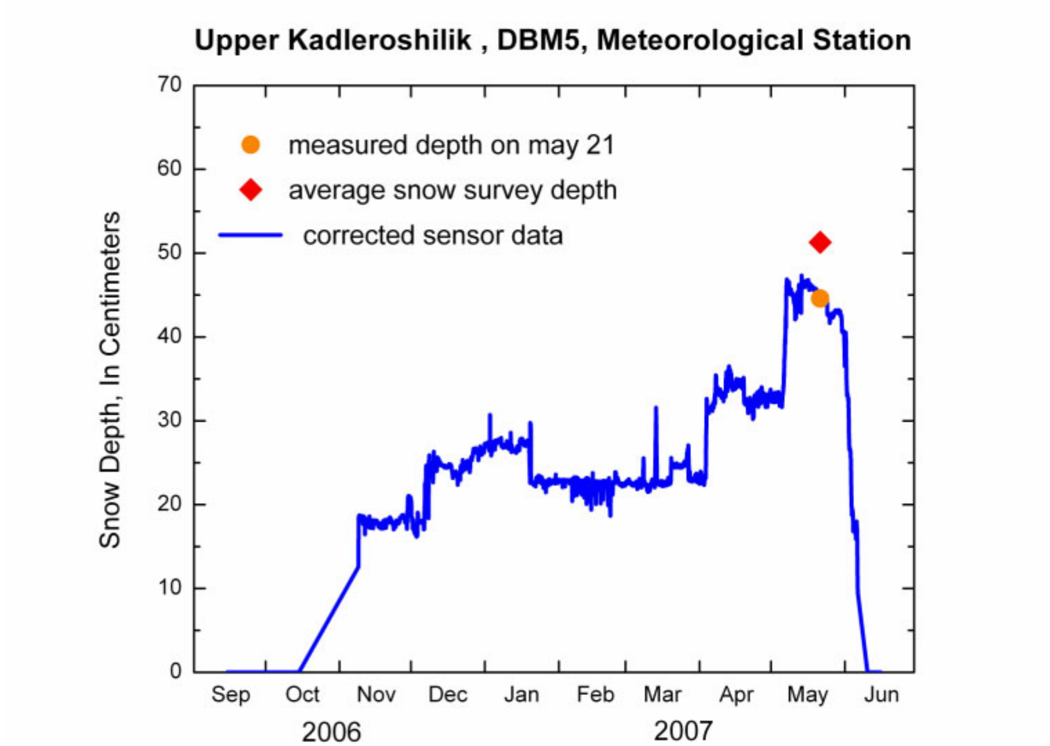

Figure 5. Corrected snow depth from Sonic Range S50 sensor installed at Upper Kadleroshilik, DBM5 meteorological station.

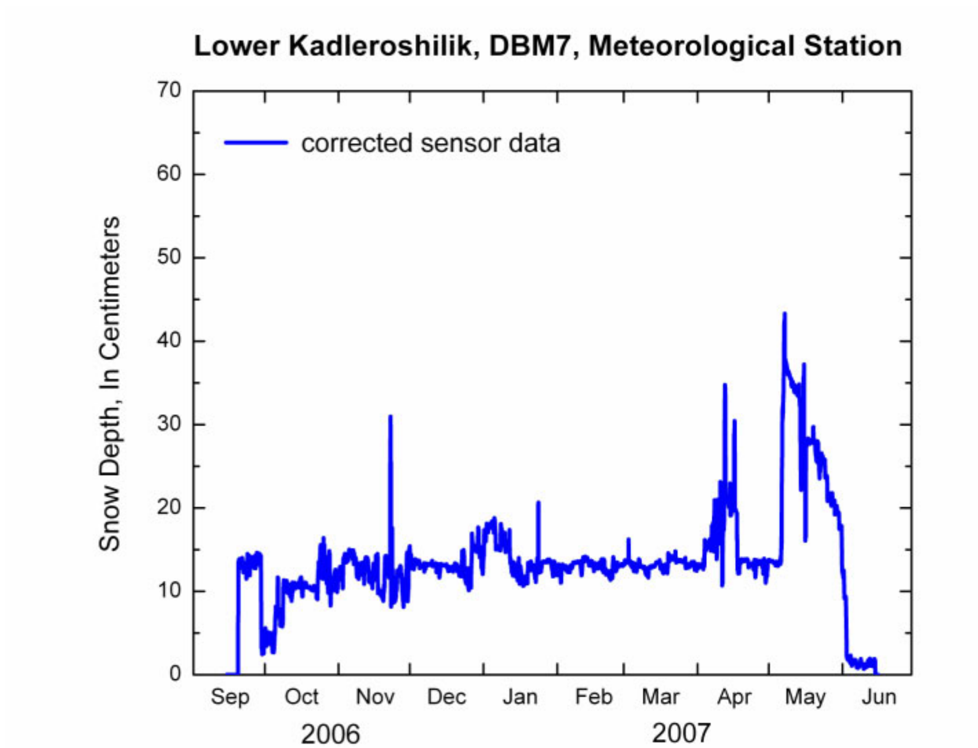

Figure 6. Corrected snow depth from Sonic Range S50 sensor installed at Lower Kadleroshilik, DBM7 meteorological station.

DBM 1, DBM 3, DBM 6, and DBM 8 station records showed uncorrectable errors due to a several of reasons; such as the sensor was pushed over or the data cable was severed by an animal, sensor malfunction and calibration issues. Sonic snow depth records at the other four stations were adjusted to account for field observations and anomalous data points (section 3.3). As an example, the Sag-Ivishak station demonstrates data before and after it was corrected for periods when no snow was on the ground as well as differences with observed snow depth (Figure 3).

Corrected snow depth sensor records agree well with snow surveys conducted at the meteorological stations (Figure 3-6). Fifty snow survey depths vary within 10 to 80 cm for Ribdon, 30 to 63 cm for Sag-Ivishak, and 32 to 66 cm for Upper Kadleroshilik. Average snow survey depths is 43.9 for Ribdon, 48.5 cm for Sag-Ivishak, and 51.3 cm for Upper Kadleroshilik, and sensor depths were 39.6cm, 50cm, and 44.5cm, respectively. The maximum difference between survey and sensor data is being 6.8 cm at Upper Kadleroshilik.

The advantage of snow sensor information is high temporal resolution, which can capture the timing and relative magnitude of snow events. Our records show that snow accumulation began approximately the latter part of September for Lower Kadleroshilik and Ribdon, and mid-October for Upper Kadleroshilik and Sag-Ivishak. All snow sensors to some degree reflect major snow accumulation events occurred late October, late November - early December, late March - early April and heavy snowfalls in May. Stations show an increase ranging from 5% - 63% to the late spring storm occurring approximately from May 5 to May 8. Snow was no longer on the ground by June 2 to 10 for all four stations.

8. SPRING STORM SUMMARY

Following the initiation of April snow surveys, a storm event occurred approximately from May 5 to May 8, 2007. It brought heavy snowfalls and caused an additional snow accumulation throughout the Coastal Plain. The dominant wind direction was the northeast. According to sonic sensor data, the major portion of snow accumulation occurred from May 5 to May 7 in the Bullen Point Region, roughly a day ahead of sites located in the Kuparuk Foothills Region to the west. Inclement weather before, during, and after the storm delayed accessing coastal survey sites via helicopter the majority of the first part of May.

To assess the storm impact on maximum SWE, we compared observations collected before and after this storm (Table 2). The difference was attributed 1) to localize the extent and magnitude of the event and 2) to adjust maximum winter snow accumulation (Appendix B4).

Table 2. Observed SWE in close proximity to the Sagavanirktok River/Bullen Point Region. Sites listed in order by location going from north to south..

Site	Data source	SWE before storm Date	SWE before storm cm	SWE after storm Date	SWE after storm cm	Difference %
Franklin Bluffs	Snow survey	4/27	6.6	5/17	8.7	24
Upper Kadleroshilik, DBM5	Snow sensor	5/5	7.4	5/7	10.5	30
Sagwon	Snow survey	4/25	7.5	5/17	7.3	-03
Sag-Ivishak, DBM4	Snow sensor	5/4	11.3	5/7	11.8	05
Ribdon, DBM2	Snow sensor	5/4	8.7	5/7	10.6	17
Happy Valley	Snow survey	4/25	7.3	5/17	8.1	10
Upper Kuparuk	Snow survey	4/24	11.9	5/16	14.2	16

The evaluation considers the change in SWE at snow survey sites and meteorological stations. To convert snow sensor depth to SWE, an average density of 230 kg/m³ from snow surveys taken near the same time and location is used. Data show that the storm extends from the coast to approximately 69º50’N, affecting Franklin Bluffs, Lower Kadleroshilik and Upper Kadleroshilik snow records. The Lower Kadleroshilik SWE increase is difficult to quantify, because snow density required to convert snow depth to SWE for this site was not measured. After the snowfall it can be as low as 25 kg/m3 (density of freshly fallen snow) and, then, it can evolve with time to

300 kg/m^3. A station located to the west of lower Kadleroshilik near the Nuiqsut (not shown) shows a 22 % increase.

An accumulation gradient from north to south is seen for the Coastal Plain (Table 2), with higher accumulation in the north decreasing towards the south. Approximately at the latitude of 69º25’N there was no new snow accumulation recorded.

The SWE increase on the Coastal Plain as a result of the storm ranges from 11% to 30%. This range is based on observation for both Bullen project and Foothills project (Berezovskaya et al., 2007b). Most of the snow survey sites on Coastal Plain were visited after this storm. Only two sites are adjusted an amount relative to their position in the watershed (Appendix B4). The Franklin Bluffs correction factor was used. Adjusted SWE estimations resulted in an average SWE for the Coastal Plain of 7.6 cm (3.0 in) or a 3 % increase (Table 1).

REFERENCES

Benson, C.S., W. Harrison, J. Gosink, L. Mayo and D. Trabant (1986). The role of glacierized basins in Alaskan Hydrology, in Kane, D.L., ed., Symposium: Cold Regions Hydrology: American Water Resources Assoc., 471-483

Berezovskaya S. and D.L. Kane (2007a) Strategies for measuring snow water equivalent for hydrological applications: part 1, accuracy of measurements. Nordic Hydrology (in press)

Berezovskaya S., Jeff Derry, Douglas Kane, Robert Geick, Michael Lilly, Dan White (2007b) Snow survey data for the Kuparuk Foothills Hydrology Study: Spring 2007. July 2007, University of Alaska Fairbanks, Water and Environmental Research Center, Report INE/WERC 07.17, Fairbanks, Alaska, 41 pp.

Kane, D.L., Hinzman, C. S. Benson and K. R. Everett (1989) Hydrology of Imnavait Creek, an arctic watershed. Holarctic Ecology 12, 262-269

Kane, D.L., J.N. Luthin and G.S. Taylor (1978) Heat and mass transfer in cold regions soils. IWR-65, Institute of Water Resources, UAF

Liston, G. E., and M. Sturm (2002) Winter Precipitation Patterns in Arctic Alaska Determined from a Blowing-Snow Model and Snow-Depth Observations. Journal of Hydrometeorology, vol. 3, 646–659.

Rovansek, R.J., D.L. Kane and L.D. Hinzman (1993) Improving estimates of snowpack water equivalent using double sampling. Proceedings of the 61st Western Snow Conference, 157-163

Sturm, M., and C. S. Benson (2004). Scales of Spatial Heterogeneity for Perennial and Seasonal Snow Layers. Annals of Glaciol. 38, 253–260

Woo, M-K (1997) A guide for ground based measurement of the arctic snow cover. Canadian Snow Data CD, Meteorological Service of Canada, Downsview, Ontario, p.30

APPENDIX A. LIST OF THE SNOW SURVEY SITES IN 2007

Appendix A1. Elevation and coordinates of the sites located in the Mountains

№	ID	ELEV m	LAT decimal degree	LON decimal degree
1	ACC1	1391	68.4102	-148.145
2	RIB1	609	68.6174	-148.153
3	RIB2	800	68.4848	-147.836
4	RIB3	918	68.6931	-147.478
5	SAG1	730	68.2667	-148.967
6	SAG2	868	68.2597	-148.826
7	SAG3	830	68.4462	-148.704
8	SAV1	955	68.7705	-147.432
9	ECH1	868	69.1022	-146.825
10	IVI1	521	68.9767	-147.234
11	IVI2	810	68.7464	-146.823
12	JUN_1	615	69.2526	-146.823
13	KAV1	733	69.2920	-146.348
14	LUP1	747	68.6817	-148.041
15	DBM1	1474	68.4116	-148.137
16	DBM2	1478	68.6425	-147.352
17	DBM3	1319	69.0762	-146.505

Appendix A2. Elevation and coordinates of the sites located in the Foothills

№	ID	ELEV m	LAT decimal degree	LON decimal degree
1	MD3	319	69.7170	-147.380
2	UP1	194	69.2276	-148.454
3	UP2	318	69.3439	-147.850
4	UP3	393	69.4356	-147.460
5	UP4	350	69.5689	-146.530
6	DBM4	431	69.2156	-148.552
7	DBM5	209	69.5495	-147.942
8	DBM6	198	69.6734	-146.901
9	DBR5	267	69.8106	-148.326

Appendix A3. Elevation and coordinates of the sites located on the Coastal Plain

№	ID	ELEV m	LAT decimal degree	LON decimal degree
1	L15	11	70.1438	-148.068
2	SHAV	5	70.1586	-147.259
3	SHAV-L	5	71.1586	-146.259
4	BDM	4	70.1310	-147.000
5	BDM-L	4	71.1310	-146.000
6	LBP0701-L	13	69.0879	-149.189
7	LBP0701	13	70.0879	-148.189
8	LPB0705-L	8	70.1625	-147.422
9	LPB0705	8	70.1625	-147.422
10	LBP0709-L	4	69.1201	-147.240
11	LBP0709	4	70.1201	-146.240
12	LBP0707-L	21	70.0200	-147.195
13	LBP0707	21	70.0200	-147.195
14	LBP0706-L	45	69.9653	-147.573
15	LBP0706	45	69.9653	-147.573

APPENDIX B. AVERAGE SNOW DENSITY, SNOW DEPTH AND SNOW WATER EQUIVALENT

Appendix B1. Summary for the sites located in the Mountains

№	ID	SWE		SNOW DEPTH		SNOW DENSITY	
		cm	in	cm	in	kg/m^3	$slug/ft^3$
1	ACC1	4.9	1.9	20.8	8.2	240	0.466
2	RIB1	5.3	2.1	25.9	10.2	210	0.407
3	RIB2	5.4	2.1	27.2	10.7	198	0.384
4	RIB3	8.8	3.5	45.5	17.9	190	0.369
5	SAG1	0.3	0.1	1.2	0.5	250	0.485
6	SAG2	12.8	5.0	43.2	17.0	300	0.582
7	SAG3	6.8	2.7	27.7	10.9	280	0.543
8	SAV1	8.7	3.4	46.6	18.3	190	0.369
9	ECH1	6.4	2.5	37.1	14.6	172	0.334
10	IVI1	5.2	2.0	20.0	7.9	260	0.504
11	IVI2	7.0	2.8	39.3	15.5	180	0.349
12	JUN_1	7.7	3.0	39.6	15.6	196	0.380
13	KAV1	1.8	0.7	11.0	4.3	166	0.322
14	LUP1	8.4	3.3	44.5	17.5	190	0.369
15	DBM1	9.4	3.7	36.9	14.5	254	0.493
16	DBM2	12.0	4.7	43.9	17.3	274	0.532
17	DBM3	3.1	1.2	18.4	7.2	166	0.322
	Average	6.7	2.6	31.1	12.2	219	0.424

Appendix B2. Summary for the sites located in the Foothills.

№	ID	SWE		SNOW DEPTH		SNOW DENSITY	
		cm	in	cm	in	kg/m^3	slug/ft^3
1	MD3	7.5	3.0	32.2	12.7	230	0.446
2	UP1	7.6	3.0	37.3	14.7	200	0.388
3	UP2	6.2	2.4	40.7	16.0	150	0.291
4	UP3	10.0	3.9	47.5	18.7	210	0.407
5	UP4	13.2	5.2	52.2	20.6	250	0.485
6	DBM4	9.3	3.7	48.5	19.1	191	0.371
7	DBM5	14.3	5.6	51.3	20.2	278	0.539
8	DBM6	4.8	1.9	19.7	7.8	246	0.477
9	DBR5	10.3	4.1	45.6	18.0	226	0.438
	Average	9.2	3.6	41.7	16.4	220	0.427

Appendix B3. Summary for the sites located in the Coastal Plain.

№	ID	SWE		SNOW DEPTH		SNOW DENSITY	
		cm	in	cm	in	kg/m^3	slug/ft^3
1	L15	8.0	3.1	30.4	12.0	260	0.504
2	SHAV	8.2	3.2	49.8	19.6	170	0.330
3	SHAV-L	9.5	3.7	42.9	16.9	223	0.433
4	BDM	3.5	1.4	24.5	9.6	140	0.272
5	BDM-L	2.2	0.9	14.6	5.7	154	0.299
6	LBP0701-L	6.6	2.6	17.4	6.9	380	0.737
7	LBP0701	6.4	2.5	21.3	8.4	300	0.582
8	LPB0705-L	6.2	2.4	32.0	12.6	200	0.388
9	LPB0705	5.4	2.1	31.2	12.3	170	0.330
10	LBP0709-L	-	-	18.5	7.3	-	-
11	LBP0709	8.3	3.3	46.0	18.1	180	0.349
12	LBP0707-L	10.3	4.1	32.5	12.8	320	0.621
13	LBP0707	14.3	5.6	50.6	19.9	280	0.543
14	LBP0706-L	5.2	2.0	22.9	9.0	230	0.446
15	LBP0706	9.0	3.5	34.1	13.4	260	0.504
	Average	7.4	2.9	31	12.3	233	0.453

Appendix B4. Adjusted SWE for the sites located in the Coastal Plain.

№	ID	OBSERVED SWE		CORRECTION FACTOR	ADJUSTED SWE	
		cm	in		cm	in
1	L15	8.0	3.1	not applicable	8.0	3.1
2	SHAV	8.2	3.2	not applicable	8.2	3.2
3	SHAV-L	9.5	3.7	not applicable	9.5	3.7
4	BDM	3.5	1.4	not applicable	3.5	1.4
5	BDM-L	2.2	0.9	not applicable	2.2	0.9
6	LBP0701-L	6.6	2.6	1.31	8.7	3.4
7	LBP0701	6.4	2.5	1.31	7.4	3.3
8	LPB0705-L	6.2	2.4	not applicable	6.2	2.4
9	LPB0705	5.4	2.1	not applicable	5.4	2.1
10	LBP0709-L	-	-	not applicable	-	-
11	LBP0709	8.3	3.3	not applicable	8.3	3.3
12	LBP0707-L	10.3	4.1	not applicable	10.3	4.1
13	LBP0707	14.3	5.6	not applicable	14.3	5.6
14	LBP0706-L	5.2	2.0	not applicable	5.2	2.0
15	LBP0706	9.0	3.5	not applicable	9.0	3.5
	Average	7.4	2.9		7.6	3.0

Sites that were sampled after storm are marked as “not applicable”, i.e. correction is not needed.