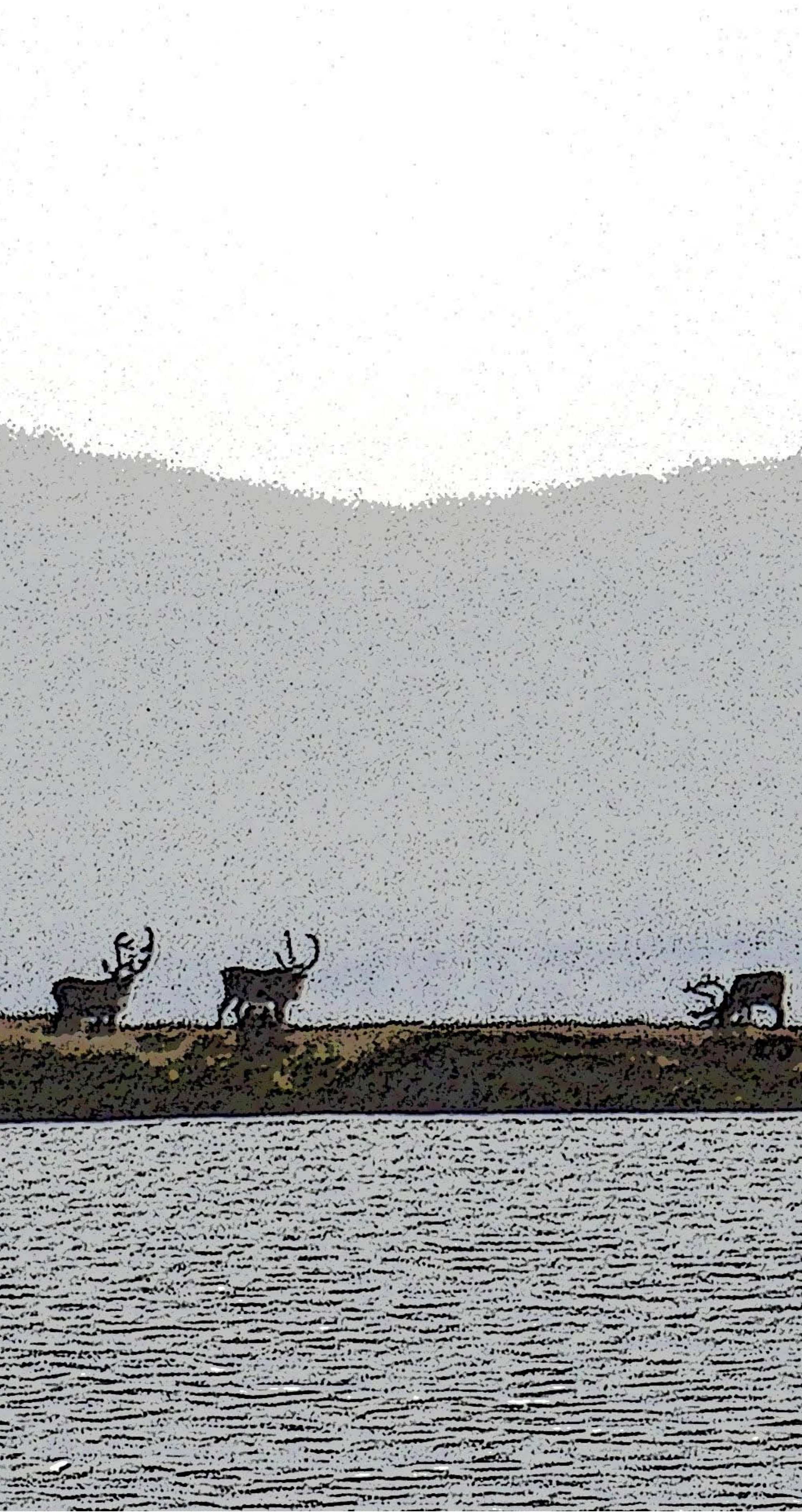

2006-2007 Alpine Drinking Water Lakes

Monitoring and Recharge Study

Prepared for

ConocoPhillips

Prepared by

Baker

Michael Baker, Jr., Inc.

108603-MBJ-RPT-001
January 2008

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1.0 Introduction

Water withdrawal from North Slope lakes is used for oil field facility and camp operation, and winter construction of ice roads for exploration and construction activities. Federal, state, and local agencies require permits for water withdrawal and stipulations in these permits require monitoring to determine the effects of water withdrawal on fish habitat. A number of fish species have been identified in the water source lakes since 1995; six species in Lake L9312 and seven species in Lake L9313 (Moulton 2004). The Alpine facility (CD1) relies on water withdrawal from Lakes L9312 and L9313 and is limited to a fixed volume of water withdrawn from these lakes by the following permits:

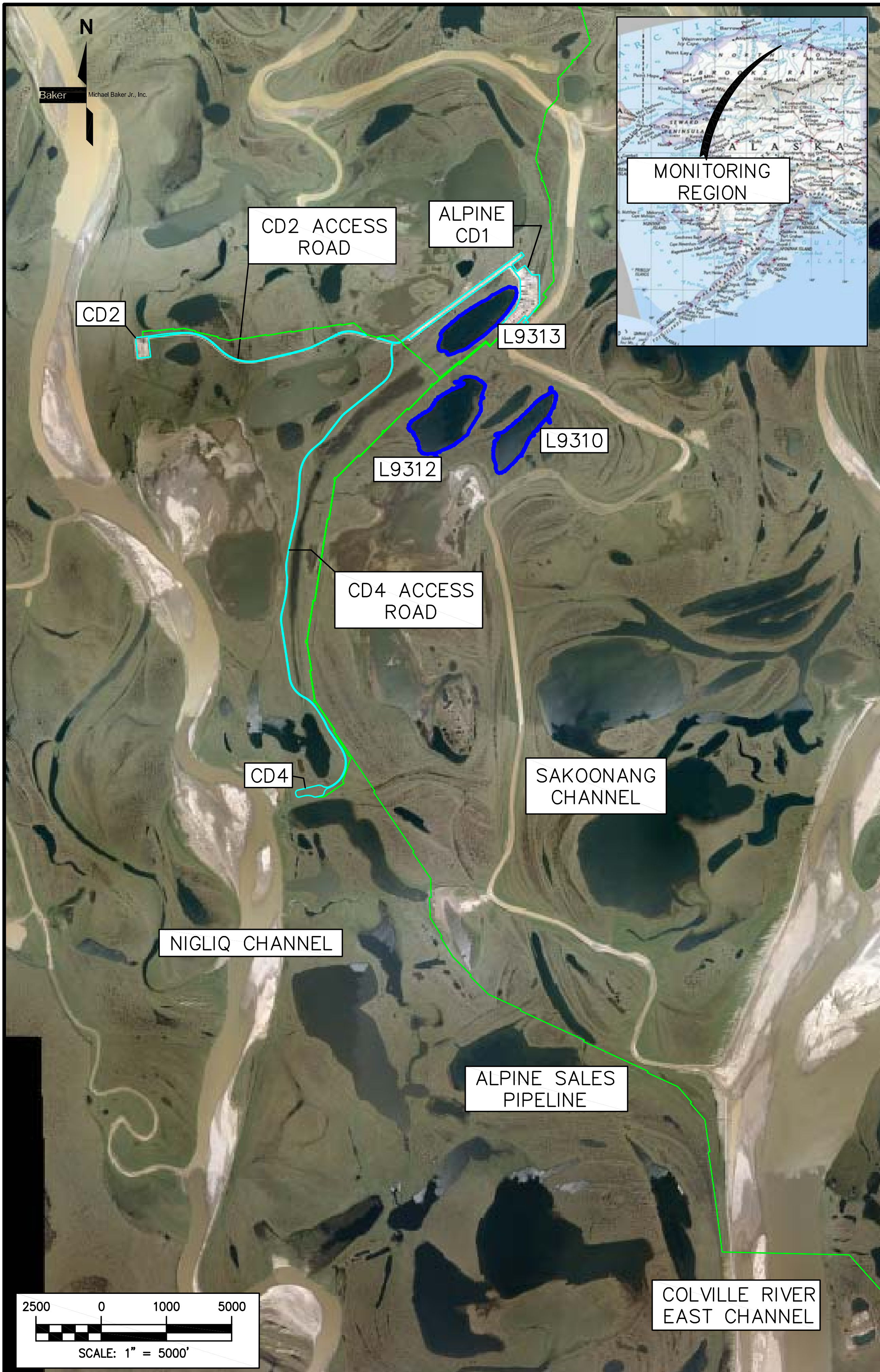
- L9312 Fish Habitat Permit (FG99-III-0051) Amendment #5
- L9313 Fish Habitat Permit (FG 97-III-0190) Amendment #5

The purpose of the 2006/2007 Alpine Drinking Water Lakes Monitoring and Recharge Study was to provide CPAI with methods and procedures for documenting the extent and impacts of water withdrawal from L9312 and L9313. To accomplish this, the physical conditions of water withdrawal Lakes L9312 and L9313 were compared to a control lake (L9310) of similar composition, having no water withdrawal.

This report summarizes hydrologic observations and measurements collected at Lakes L9313, L9312, and L9310 in 2006 and 2007 by Michael Baker Jr., Inc. (Baker). The study was conducted at the request of ConocoPhillips Alaska, Inc. (CPAI). The work is intended to supplement requirements of permit stipulations by gathering data with regard to water withdrawal, spring recharge, and water quality. Work consisted of seasonal water surface elevation (WSE) surveys, lake depth and ice thickness surveys, in situ water quality sampling, snow water equivalent (SWE) surveys, lake drainage basin delineations, and permit revision support. In addition, lake recharge observations were made pre- and post-spring breakup. The study area was limited to the three lakes listed above, located near Alpine facilities (Figure 1-1).

1.1 Acknowledgements

Sincere appreciation is given to CPAI, Kuukpik/LCMF, and Maritime Helicopters for their time, patience, and continuous support. They were instrumental in making this a safe and successful program.



2006/2007
ALPINE LAKES
STUDY OVERVIEW
FIGURE 1-1
(SHEET 1 OF1)

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2.0 Water Withdrawal and Lake Recharge

2.1 Historic Water Withdrawal

Water withdrawal from Alpine drinking water Lakes L9312 and L9313 has occurred since 1999 and 2002, respectively. The ADF&G Fish Habitat Permits were first issued to CPAI for Lake L9312 (FG99-III-0051) on March 30, 1999, and Lake L9313 (FG97-III-0190) on December 13, 1997. Since then, six amendments have been issued for each permit. Amendment #5 implemented on February 14, 2003 for both permits, stipulate that the allowable annual water withdrawal volumes for Alpine drinking water lakes as 30% of the volume of water present under seven-foot-thick ice cover at bankfull conditions less evaporation. This equates to 30 million and 6 million gallons of water available for withdrawal per water year from Lakes L9312 and L9313, respectively, assuming spring breakup recharge occurs. Amendment #6 to both permits did not change the established allowable withdrawal volumes.

ADF&G Fish Habitat permits define the water year as breakup-to-breakup regardless of date. Historic data were tabulated to quantify water withdrawal volumes based on a breakup-to-breakup water year. Field observations and past breakup studies in the Colville River Delta indicate that highwater and lake ice are present well into the month of June. Water withdrawal records are published quarterly with monthly withdrawal volumes. In this report, the water year is defined as July 1 to June 30. Table 2-1 and Table 2-2 present the monthly and annual withdrawal volumes for Lakes L9312 and L9313. The tabulated monthly and annual withdrawal volumes for Lakes L9312 and L9313 are presented graphically in Graph 2-1 and Graph 2-2. Each graph is cumulative and has a bolded line representing the current permitted water withdrawal volume.

Table 2-1 L9312 Historic Monthly Withdrawal Volumes

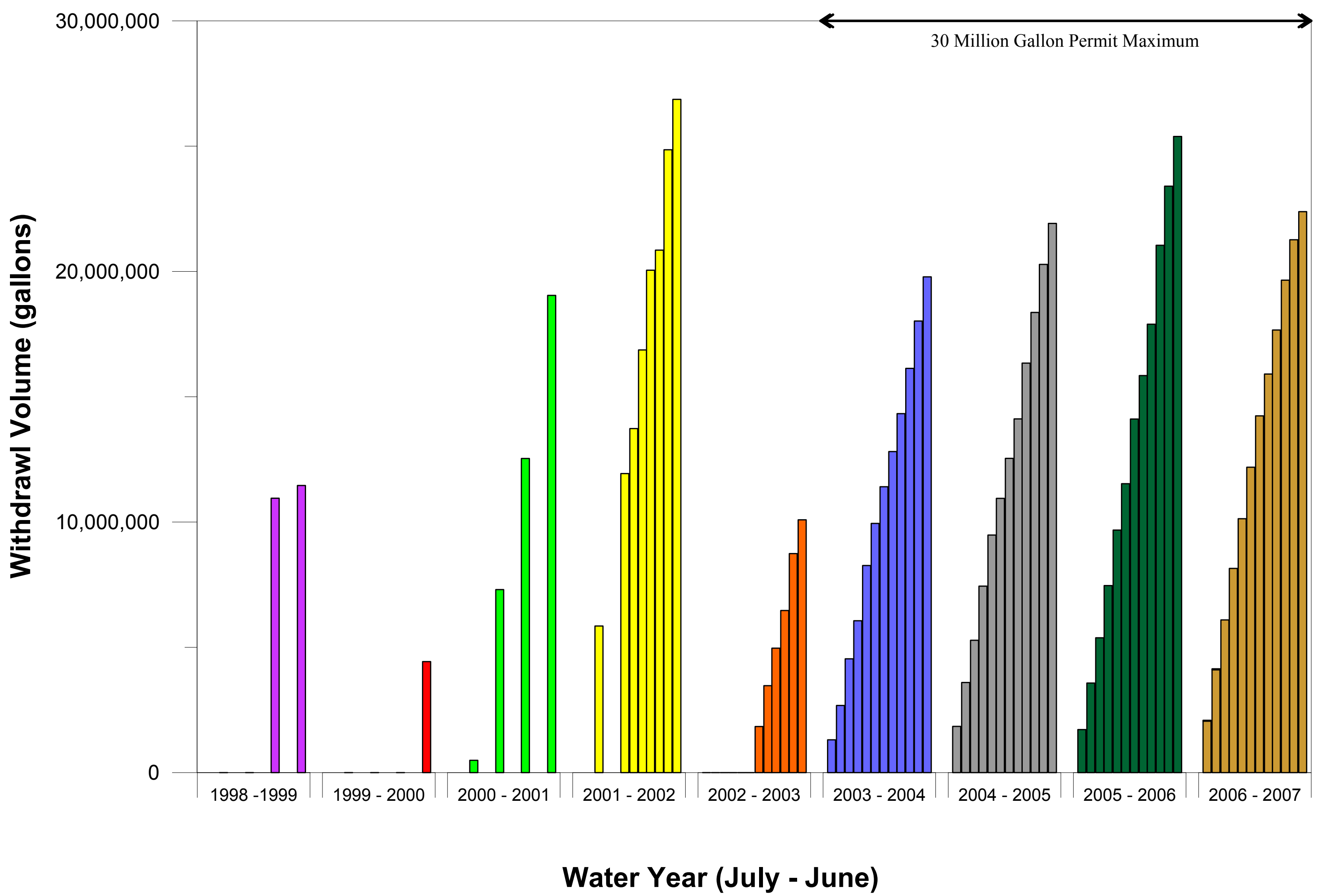
Water Year (July - June)	Withdrawal Volumes (gal.)												Total Annual Withdrawal (gal.)
	July	August	September	October	November	December	January	February	March	April	May	June	
1998 - 1999	x	x	x	x	x	x	—	—	10,947,695 [1]	—	—	513,260 [1]	11,460,955
1999 - 2000	—	—	0 [1]	—	—	0 [1]	—	—	0 [1]	—	—	4,437,361 [1]	4,437,361
2000 - 2001	—	—	495,300 [1]	—	—	6,809,520 [1]	—	—	5,228,100 [1]	—	—	6,512,600 [1]	19,045,520
2001 - 2002	—	—	5,850,800 [1]	—	—	6,083,500 [1]	1,798,000	3,137,100	3,180,400	799,167	4,006,020	2,011,700	24,854,987
2002 - 2003	0	0	0	0	0	0	1,841,900	1,626,800	1,503,100	1,499,400	2,271,000	1,346,800	10,089,000
2003 -2004	1,309,700	1,369,300	1,864,800	1,514,800	2,204,900	1,680,000	1,468,500	1,402,700	1,511,100	1,811,000	1,889,500	1,756,700	19,783,000
2004 - 2005	1,852,500	1,747,200	1,686,800	2,156,800	2,035,400	1,467,400	1,594,800	1,575,700	2,227,800	2,020,100	1,914,600	1,635,500	21,914,600
2005 - 2006	1,721,600	1,852,200	1,813,000	2,078,600	2,217,100	1,847,000	2,578,600	1,735,500	2,053,200	3,147,200	2,360,400	1,987,200	25,391,600
2006 - 2007	2,053,440	2,053,440	1,987,200	2,053,440	1,987,200	2,053,440	2,053,440	1,665,200	1,757,000	1,987,200	1,611,777	1,123,696	22,386,473

Notes: x Prior to initial water withdrawal from lake
— Withdrawal amount included in quarterly total
1 Quarterly withdrawl total

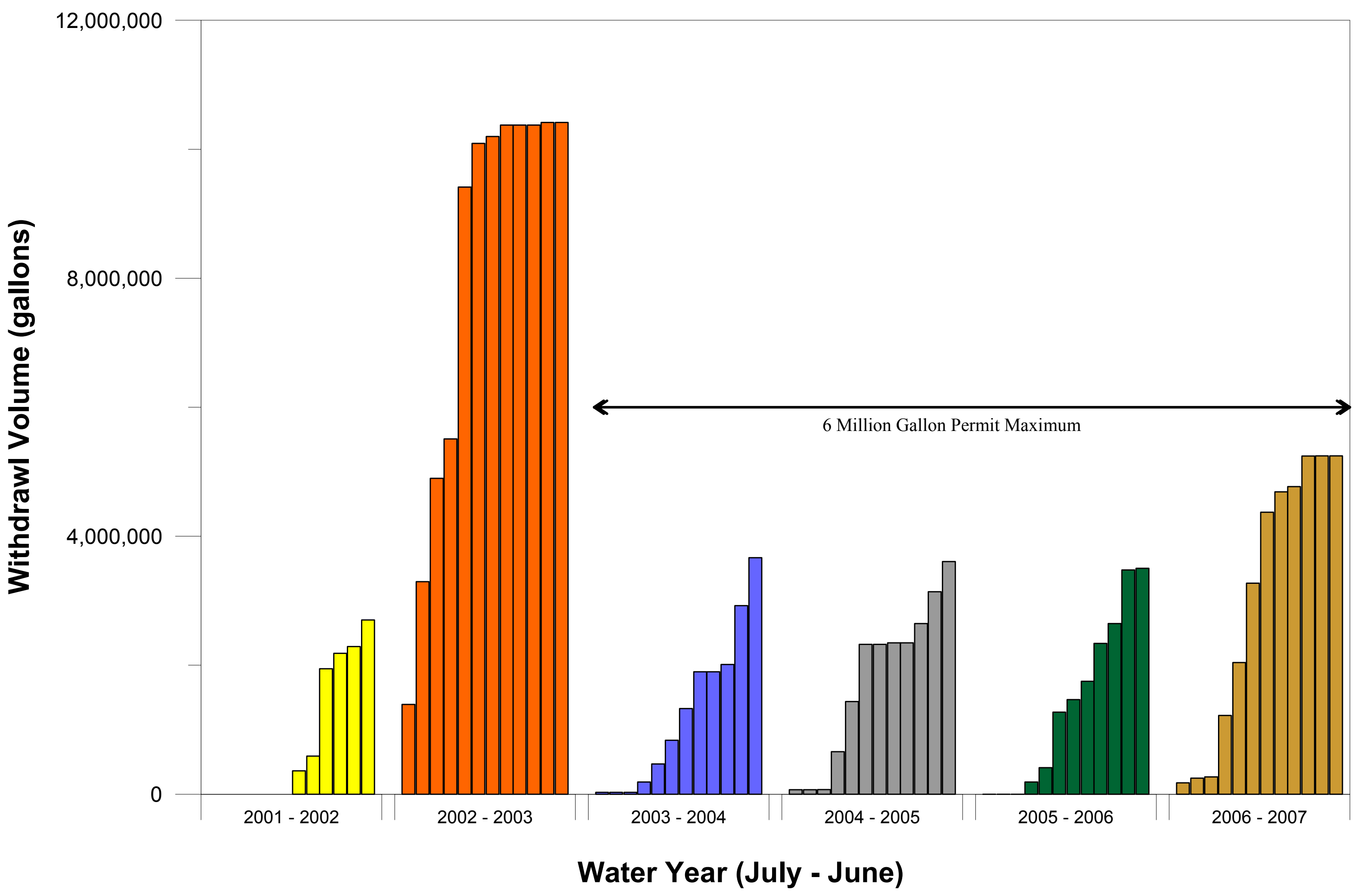
Table 2-2 L9313 Historic Monthly Withdrawal Volumes

Water Year (July - June)	Withdrawal Volumes (gal.)												Total Annual Withdrawal (gal.)
	July	August	September	October	November	December	January	February	March	April	May	June	
2001 - 2002	x	x	x	x	x	x	362,800	228,000	1,355,300	238,200	106,060	411,090	2,701,450
2002 - 2003	1,392,750	1,902,400	1,602,200	611,599	3,905,968	676,320	107,600	177,000	600	300	38,900	0	10,415,637
2003 -2004	29,800	400	100	160,200	280,400	368,000	488,300	571,000	300	113,300	912,200	743,900	3,667,900
2004 - 2005	69,700	200	1,500	589,100	777,900	885,100	0	23,700	100	297,900	494,800	468,700	3,608,700
2005 - 2006	100	100	200	190,100	222,000	860,500	193,500	286,000	586,200	307,600	830,900	23,895	3,501,095
2006 - 2007	175,200	72,600	21,100	952,400	820,500	1,229,300	1,100,000	317,700	80,500	475,700	300	1,000	5,246,300

Notes: x Prior to initial water withdrawal from lake
1 Quarterly withdrawl total



Graph 2-1 Lake L9312 Cumulative Water Use History



Graph 2-2 Lake L9313 Cumulative Water Use History

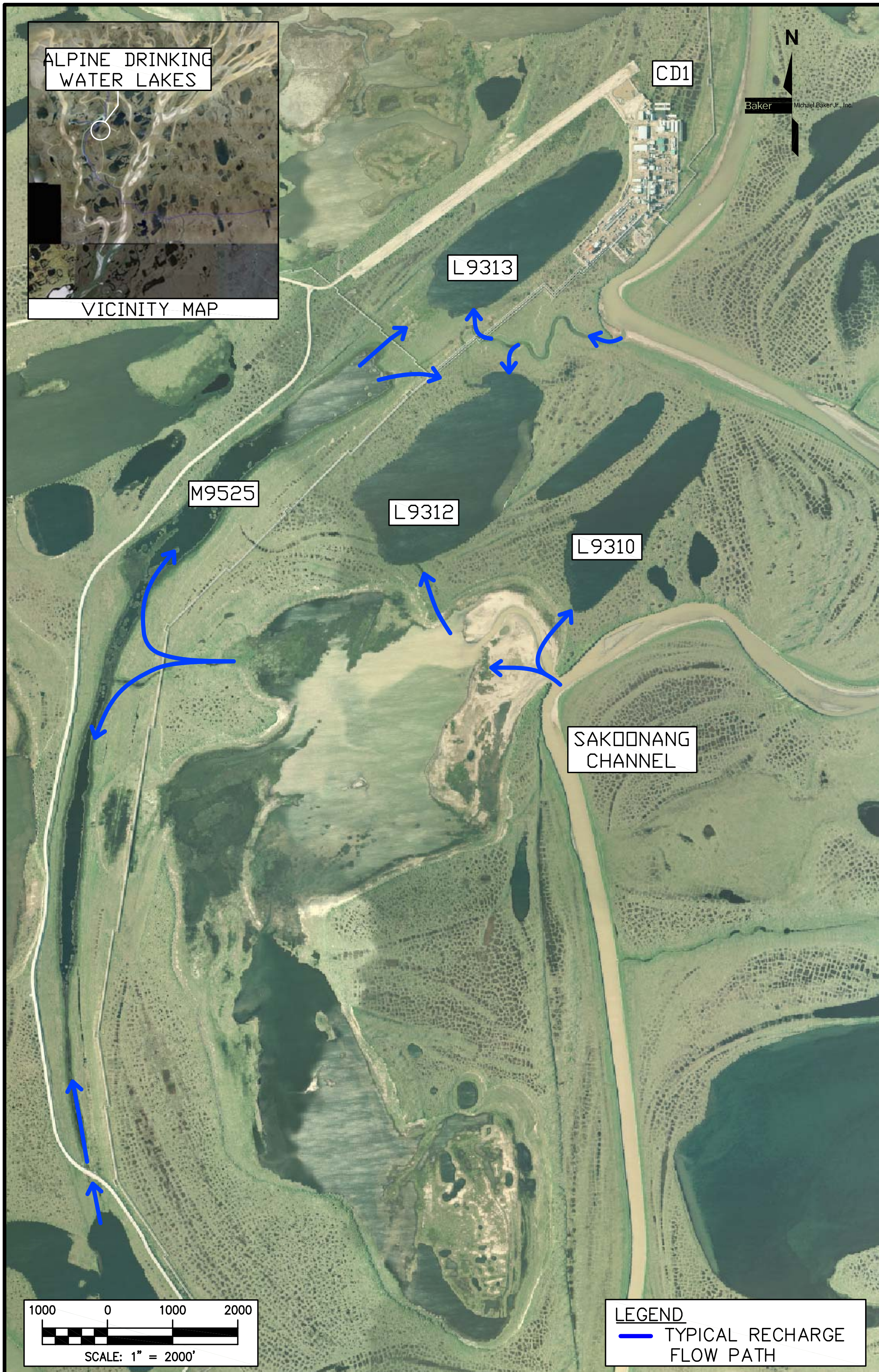
2.2 Historic Lake Recharge

Lake recharge observations have been conducted continuously for the last ten years at Lakes L9312 and L9313 (Table 2-3). Full lake recharge is defined as having achieved an established bankfull WSE (Baker 2002b) or having been inundated by floodwaters. Lake L9312 has fully recharged nine of the last ten years. Lake L9313 has fully recharged each year for this period of record Though no WSE is provided for 2000, visual observations made during breakup identify inundation of both lakes by floodwaters.

Table 2-3 Alpine Drinking Water Lake Historic Recharge

Year	Peak WSE (BPMSL-ft)		Bankfull Recharge		Floodwater Recharge		Reference
	L9312	L9313	L9312	L9313	L9312	L9313	
1998	8.35	7.35	✓	✓	✓	✓	Baker 1998
1999	7.93	6.14	✓	✓	-	-	Baker 1999
2000	-	-	✓	✓	✓	✓	Baker 2000
2001	7.55	8.31	-	✓	-	✓	Baker 2001
2002	8.21	8.90	✓	✓	✓	✓	Baker 2002a
2003	8.01	7.12	✓	✓	-	✓	Baker 2003
2004	8.37	9.40	✓	✓	✓	✓	Baker 2005a
2005	8.00	6.12	✓	✓	-	-	Baker 2005b
2006	9.55	9.95	✓	✓	✓	✓	Baker 2007a
2007	9.35	9.47	✓	✓	✓	✓	Baker 2007c
Notes:	Banfull recharge based on established bankfull water surface elevations: L9312 @ 7.8-ft BPMSL and L9313 @ 6.0-ft BPMSL (Baker 2002b)						

Floodwater recharge of the three study lakes is commonly routed through perennial lakes and channels from the Sakoonang Channel (Figure 2-1). Floodwater can also originate from the Nigliq Channel, though the extent of lake recharge is typically less. The source, timing, and extent of flooding are dependent upon the magnitude of ice jamming and annual high water. Inundation by floodwaters lifts intact lake ice, fully recharging the lake above established bankfull conditions.



2006/2007 ALPINE LAKES
TYPICAL FLOODWATER
RECHARGE FLOW PATH

FIGURE 2-1
(SHEET 1 OF 1)

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3.0 Water Quality

3.1 Methods

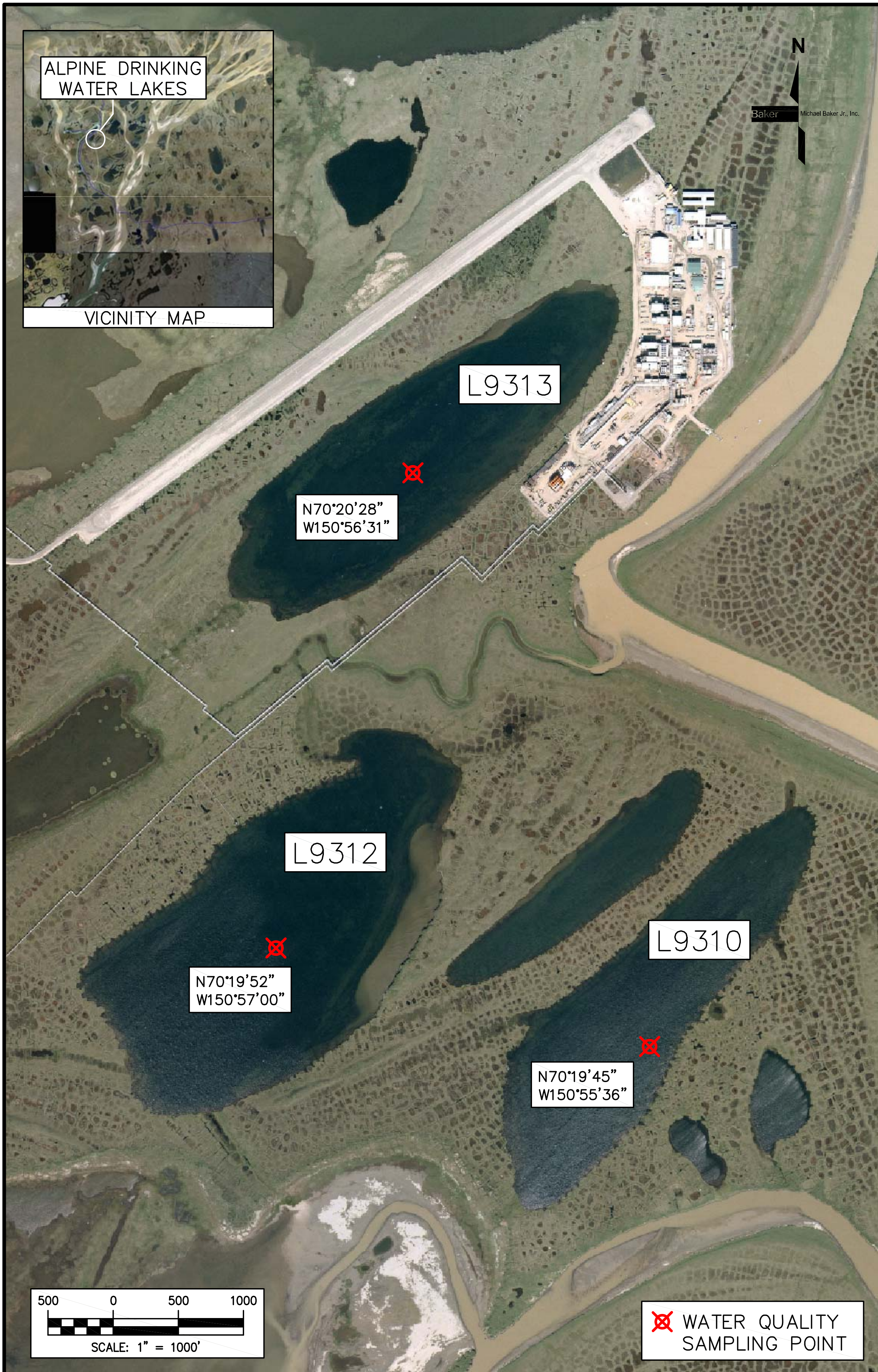
Water quality parameters include dissolved oxygen, temperature, conductivity, specific conductance, and salinity. Physical conditions of the lakes were also recorded, including water depth, freeboard, water surface elevation, and ice thickness. Historic water quality data was also compiled to help draw long-term conclusions on potential impacts of water withdrawal.

3.1.1 Physical Parameters

Water quality sampling was conducted at three predefined locations (Figure 3-1). Sample locations were targeted at the greatest lake depth based on available bathymetry and in-field sampling. Locations were recorded and identified using a hand-held global positioning system (GPS) unit referenced to North American Datum of 1983 (NAD83). Coordinates of sampling locations are presented in respective lake water quality data tables (Section 3.2). Winter access and transportation logistics were supported by Kuukpik/LCMF via snowmachine and Hagglund. Summer access to Lakes L9310 and L9312 was provided by Maritime Helicopters. Inflatable kayaks were subsequently used to reach sampling locations.

A standard level loop survey was tied to local temporary benchmarks (TBMs) to determine water surface elevation. Each TBM was tied to British Petroleum Mean Sea Level (BPMSL) datum. During the winter sampling events, the water surface elevation was calculated by subtracting measured freeboard, the distance from the top of ice to the water surface in the sample hole, from the surveyed ice surface elevation at the sample hole. During open water conditions, water surface elevation was calculated by adding water depth, measured on the survey rod, to the surveyed lake bed elevation near shore. Kuukpik/LCMF provided survey assistance. Water surface elevation surveys were conducted throughout the year on a monthly basis.

Water depth was measured using a weighted rag tape. During winter sampling events, an electric drill was used to auger a 2-inch (minimum) sampling hole through the ice. Freeboard was measured using the weighted rag tape when obtaining water depth. Ice thickness was measured using a graduated pole with a hook on the end. The pole was lowered into the water until the hook found the underside of the ice. The resultant ice thickness was measured from graduated marks along the pole.



2006/2007 ALPINE LAKES
WATER QUALITY
SAMPLING LOCATIONS

FIGURE 3-1
(SHEET 1 OF 1)

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3.1.2 In-Situ Parameters

The following in-situ water quality parameters were recorded using a YSI-30 meter:

- Temperature (°C)
- Conductivity (uS/cm)
- Salinity (ppt)

Additional in-situ parameters were recorded using a Hach HQ40d LDO meter. These include:

- Dissolved Oxygen Concentration (mg/L)
- Dissolved Oxygen Saturation (% air saturation)

Specific conductance was calculated from observed conductivity and temperature according to the formula specified by *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA and WEF 2005).

Monitoring took place approximately once a month during the winter season, and once during the summer season. In-situ conditions were sampled at a maximum interval of three-feet, between the bottom of ice (water surface in summer) and bottom of the lake. Given the extreme environmental conditions to which equipment was exposed, measures were taken to maximize the efficiency of field sampling and quality of resulting data, including equipment redundancy and pre-sampling calibration checks.

3.1.3 Instrument Calibration

All meters were calibrated according to the manufacturer's specifications. A summary of calibration checks and procedures are outlined below:

YSI 30

Daily: Prior to sampling, a calibration check was performed using a standard calibration solution provided by the supplier (TTT Environmental). If conductivity readings were inaccurate relative to the calibration solution, meter calibration was performed following the manufacturer's instructions.

Annual: Prior to the 2006/2007 sampling season, the meter was calibrated by TTT Environmental.

Hach HQ40d LDO

All HQ40d LDO meters were calibrated using water-saturated air by the manufacturer on an annual basis. According to the manufacturer, a single calibration, performed when a new sensor is installed, provides the best performance. Additional calibration is not suggested, nor required.

3.1.4 Historic Data Comparison

Data collected during the 2006/2007 hydrologic year was compared with data previously collected by Baker, URS, and MJM Research dating back to the summer of 1995. All water quality data referenced in this report, prior to 2004, has been previously compiled and published in tabular form (MJM Research 2004). Previously unpublished data was collected by Baker during the 2005/2006 hydrologic year and is presented here in both graphical and tabular form.

Variations in sampling location, technology, and methodology can introduce comparative errors which must be considered when reviewing historic data. Dissolved oxygen measurements have been problematic because of the historic use of membrane sensors. Poor accuracy and precision associated with membrane sensors, particularly under harsh conditions, can result in illegitimate data. Recently developed luminescent dissolved oxygen (LDO) probes have been used for DO measurements since 2005. LDO units have proven to be environmentally robust while providing superior precision and accuracy. Conductivity, salinity, and temperature sensors, on the other hand, have changed little over the period of record.

3.2 Results

In-situ water quality parameters were measured monthly during the winter, and once during the summer, at Lakes L9313, L9312, and L9310. Sampling took place at multiple discreet depths within the water column at a fixed sample location. Variation of observed parameters, with respect to depth, was significant during the winter months with ice cover acting as a barrier to wind induced mixing and gas transfer. During open water conditions, the lakes appeared well mixed with near-maximum levels of oxygen saturation and little variation in measured parameters with respect to depth. Water quality data collected from December 2005 to July 2007 are presented in Table 3-1 (L9313), Table 3-2 (L9312), and Table 3-3 (L9310).

Variation in the exact horizontal location and depth (particularly within close proximity of the lake bed) of sampling can cause differences between values at specific depths, and should be taken into account when looking at apparent anomalies in the data. Ultimately, it is the overall trend in water quality across the sampling year and between sampled lakes that is of particular interest. For this reason graphs provided in the following sections present the relative magnitude and trends of observed parameters with respect to depth, time, and location.

Table 3-1 Lake L9310 Water Quality Data (2005-2007)

Sample Location: N70°19'45" W150°55'36"										
Date	**Ice Thickness (ft)**	**Total Depth (ft)**	**Freeboard (ft)**	**Depth (ft)**	**Temperature (°C)**	**Salinity (ppm)**	**Conductivity (uS/cm)**	**Specific Condonductance (uS/cm)**	**Dissolved Oxygen (mg/L)**	**Dissolved Oxygen (%)**
12/19/2005	2.2	17.9	0.1	3	0.3	0.1	98	185	13.5	91.1
				5	0.6	0.1	98	184	13.4	91.2
				7	0.9	0.1	98	182	-	-
				9	1.3	0.1	97	178	12.6	86.2
				11	1.5	0.1	96	175	11.1	77.8
				13	1.6	0.1	96	174	9.9	69.6
				15	1.6	0.1	96	174	5.9	41.9
				17	1.6	0.1	96	173	5.7	40.5
1/17/2006	3.0	18.9	0.1	3	0.3	0.1	103	194	10.7	74.2
				6	0.7	0.1	102	189	10.1	71.1
				9	1.1	0.1	101	186	9.2	65.1
				12	1.6	0.1	100	181	7.5	53.7
				15	1.6	0.1	100	181	6.2	44.3
				18	1.7	0.1	104	187	4.2	30.4
2/14/2006	3.5	18.4	0.1	4	0.3	0.1	109	205	9.9	68.2
				6	0.6	0.1	109	203	9.6	66.2
				9	1.1	0.1	108	199	7.6	53.7
				12	1.5	0.1	107	194	5.9	42.0
				15	1.6	0.1	107	193	4.5	32.2
				18	1.8	0.1	109	196	2.6	18.9
4/4/2006	4.1	18.8	0.0	6	0.5	0.1	120	225	8.2	57.7
				9	1.0	0.1	119	220	7.8	54.5
				12	1.4	0.1	118	215	6.6	46.6
				15	1.5	0.1	123	223	5.0	35.8
				18	1.7	0.1	114	206	2.1	14.7
8/24/2006	-	20.6	-	2	6.2	0.1	95	148	12.1	110.7
				4	6.2	0.1	95	149	12.1	110.6
				6	6.2	0.1	95	148	12.0	110.5
				8	6.1	0.1	95	149	12.0	110.3
				10	6.1	0.1	95	149	12.0	110.3
				12	6.1	0.1	95	149	12.0	110.2
				14	6.1	0.1	95	149	12.0	110.1
				16	6.1	0.1	95	149	12.0	110.0
				18	6.1	0.1	95	149	12.0	109.8
				20	6.1	0.1	95	149	11.9	108.9
11/17/2006	1.0	19.5	0.0	3	0.6	0.1	89	166	14.3	97.7
				5	0.7	0.1	88	164	14.1	96.3
				7	0.9	0.1	87	162	13.6	93.9
				9	1.0	0.1	86	160	12.2	83.9
				11	1.2	0.1	86	158	11.7	80.1
				13	1.2	0.1	86	158	11.4	78.5
				15	1.3	0.1	87	158	11.1	75.9
				17	1.3	0.1	87	159	10.3	70.4
				19	1.3	0.1	87	160	9.7	66.4
11/30/2006	2.0	20.2	0.1	3	0.6	0.1	95	178	13.8	99.1
				6	1.1	0.1	94	172	13.1	94.9
				9	1.3	0.1	93	169	11.4	-
				12	1.6	0.1	92	166	9.1	67.3
				15	1.7	0.1	92	165	6.9	50.1
				18	1.8	0.1	93	167	5.6	41.5
				20	1.9	0.1	94	169	0.2	1.4
12/18/2006	2.5	20.2	0.1	3	0.3	0.1	88	167	-	-
				6	0.7	0.1	87	162	-	-
				9	1.0	0.1	86	159	-	-
				12	1.3	0.1	86	156	-	-
				15	1.5	0.1	86	155	-	-
				18	1.6	0.1	86	156	-	-
				20	1.6	0.1	88	159	-	-
1/2/2007	2.8	20	0.1	3	0	0.1	102	195	13.0	90.4
				6	0.3	0.1	90	171	11.9	83.9
				9	0.8	0.1	89	166	11.0	78.7
				12	1.3	0.1	88	161	9.1	65.5
				15	1.5	0.1	88	159	7.5	54.1
				18	1.6	0.1	89	160	5.2	37.9
				20	1.6	0.1	89	161	5.3	38.2

Table 3-1 Lake L9310 Water Quality Data (2005-2007) Cont.

Sample Location: N70°19'45" W150°55'36"										
Date	Ice Thickness (ft)	Total Depth (ft)	Freeboard (ft)	Depth (ft)	Temperature (ºC)	Salinity (ppm)	Conductivity (uS/cm)	Specific Condonductance (uS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
1/30/2007	3.6	20.8	0.2	4	0.1	0.1	116	220	11.2	82.0
				6	0.6	0.1	109	204	10.6	78.9
				9	1.3	0.1	108	197	9.6	72.5
				12	1.4	0.1	108	197	9.1	69.0
				15	1.5	0.1	110	199	6.3	48.4
				18	1.6	0.1	112	203	3.5	27.1
				20	1.9	0.1	118	211	1.9	15.0
3/1/2007	4.7	21.8	0.3	5	0.4	0.1	121	228	10.8	72.8
				6	0.7	0.1	121	226	10.3	70.8
				8	1.2	0.1	120	221	9.8	67.8
				10	1.4	0.1	120	218	9.2	63.7
				12	1.5	0.1	119	217	8.9	61.6
				14	1.6	0.1	120	216	8.7	60.0
				16	1.6	0.1	121	218	8.6	59.9
				18	1.7	0.1	123	221	4.0	28.2
				20	1.7	0.1	123	221	1.0	7.1
				21	1.8	0.1	124	222	0.9	6.2
3/24/2007	5.2	22.7	0.4	6	0.8	0.1	133	248	8.7	64.8
				8	1.5	0.1	133	242	8.3	61.5
				10	1.7	0.1	134	241	8.2	61.3
				12	1.7	0.1	134	242	8.4	63.0
				14	1.7	0.1	136	245	8.2	61.3
				16	1.7	0.1	138	248	6.0	44.9
				18	1.7	0.1	138	249	0.8	6.3
				20	1.9	0.1	139	249	0.1	0.9
				22	2.0	0.1	163	291	0.2	1.4
5/10/2007	-	19.0	0.4	6	0.7	0.1	140	261	10.2	72.2
				9	2.2	0.1	149	264	8.9	65.1
				12	2.6	0.1	152	265	8.2	61.4
				15	2.7	0.1	152	264	7.8	59.7
				18	2.8	0.1	152	265	7.4	56.6
7/17/2007	-	19.2	-	0	13.3	0.1	114	147	10.0	96.1
				4	13.2	0.1	114	147	10.0	95.9
				7	13.2	0.1	114	147	10.0	95.8
				10	13.2	0.1	114	147	10.0	95.7
				13	13.1	0.1	114	147	10.0	95.5
				16	13.1	0.1	114	147	10.0	95.2
				19	13.1	0.1	114	147	9.9	94.3

Table 3-2 Lake L9312 Water Quality Data (2005-2007)

Sample Location: N70°19'52" W150°57'00"										
Date	**Ice Thickness (ft)**	**Total Depth (ft)**	**Freeboard (ft)**	**Depth (ft)**	**Temperature (°C)**	**Salinity (ppm)**	**Conductivity (uS/cm)**	**Specific Condonductance (uS/cm)**	**Dissolved Oxygen (mg/L)**	**Dissolved Oxygen (%)**
12/19/2005	2.3	11.9	0.1	3	0.4	0.0	50	93	15.1	104.5
				4	0.7	0.0	49	92	14.9	103.7
				5	0.9	0.0	49	92	14.8	103.1
				6	1.3	0.0	49	90	14.6	102.2
				7	1.4	0.0	49	90	14.1	99.6
				8	1.5	0.0	49	89	13.5	95.8
				9	1.9	0.0	49	88	8.5	61.1
				10	2.1	0.0	52	92	7.3	52.5
				11	2.4	0.0	56	99	1.7	11.9
1/17/2006	3.1	11.8	0.1	4	0.7	0.0	53	99	14.6	74.2
				6	1.2	0.0	53	97	13.9	71.1
				8	1.7	0.0	53	95	12.4	65.1
				10	2.1	0.0	56	100	3.8	53.7
				11	2.1	0.1	66	117	2.2	44.3
8/24/2006	-	12	-	2	5.7	0.0	50	78	12.3	111.5
				4	5.7	0.0	50	78	12.3	111.3
				6	5.7	0.0	50	78	12.3	111.3
				8	5.7	0.0	50	78	12.3	111.4
				10	5.7	0.0	50	78	12.3	111.6
				12	5.8	0.0	49	78	12.7	115.3
11/17/2006	1	11.9	0.05	2	0.5	0.0	46	87	14.9	101.3
				3	0.7	0.0	46	85	14.7	100.0
				4	0.8	0.0	45	84	14.5	99.0
				5	0.8	0.0	45	84	14.3	97.5
				6	0.8	0.0	45	84	13.9	95.1
				7	0.9	0.0	45	83	13.2	90.4
				8	1.2	0.0	45	82	11.6	79.7
				9	1.3	0.0	46	83	9.8	67.6
				10	1.4	0.0	46	84	9.3	64.1
				11	1.4	0.0	46	84	9.8	67.1
2/14/2006	3.7	11.6	0.1	4	0.5	0.0	58	109	15.5	106.7
				6	0.9	0.0	58	107	15.0	104.4
				8	1.5	0.0	57	104	13.8	97.7
				10	1.7	0.0	57	103	4.3	29.9
				11	2.1	0.1	72	128	0.8	5.7
11/30/2006	1.7	11.7	0.1	3	0.4	0.0	50	95	15.5	109.4
				5	0.7	0.0	50	93	15.4	108.3
				7	1.0	0.0	49	91	14.2	102.0
				9	1.6	0.0	48	87	6.7	49.4
				11	2.0	0.0	56	100	0.2	1.1
12/18/2006	2.2	11.6	0.1	3	0.3	0.0	48	92	-	-
				6	1.0	0.0	48	88	-	-
				9	1.6	0.0	48	86	-	-
				11	2.9	0.0	56	97	-	-
1/2/2007	2.9	12.1	0.1	3	0.2	0.1	49	93	15.1	108.3
				6	0.5	0.1	49	92	15.1	109.5
				9	1.5	0.1	49	88	8.2	61.1
				12	2.3	0.1	65	115	0.4	3.0
1/30/2007	3.8	11.9	0.2	4	0.2	0.0	62	119	15.2	111.4
				6	0.7	0.0	62	115	14.7	109.2
				8	1.2	0.0	62	113	12.9	97.2
				10	1.8	0.0	60	108	7.2	55.4
				11	2.1	0.0	62	111	4.5	34.3
				12	2.2	0.0	82	145	0.2	1.3
3/1/2007	4.4	11.9	0.3	5	0.5	0.1	69	130	14.7	14.7
				7	1.2	0.1	69	127	13.9	13.9
				9	1.8	0.1	69	124	10.3	10.3
				11	2.1	0.1	70	124	3.5	3.5
				12	2.1	0.1	76	134	0.2	0.2
3/24/2007	5.3	12.05	0.4	6	0.6	0.1	79	148	13.0	95.2
				8	1.7	0.1	79	143	12.1	90.5
				10	2.2	0.1	83	146	9.0	67.8
				12	2.1	0.1	87	155	0.2	1.6
5/10/2007	5.3	12.05	0.4	6	0.9	0.1	63	117	15.3	108.7
				7	1.4	0.1	90	164	14.6	106.7
				8	2.2	0.1	91	160	14.8	100.2
				9	2.7	0.1	91	158	14.1	107.4
				10	3.0	0.1	94	162	12.3	95.5
				11	3.1	0.1	96	165	6.9	53.5
7/17/2007		7.87		0	13.5	0.0	59	76	10.0	96.2
				3	13.4	0.0	59	76	10.0	95.8
				6	13.4	0.0	59	76	9.9	95.1
				9	13.2	0.0	59	76	9.8	93.4
				12	13.2	0.0	59	76	0.1	0.9

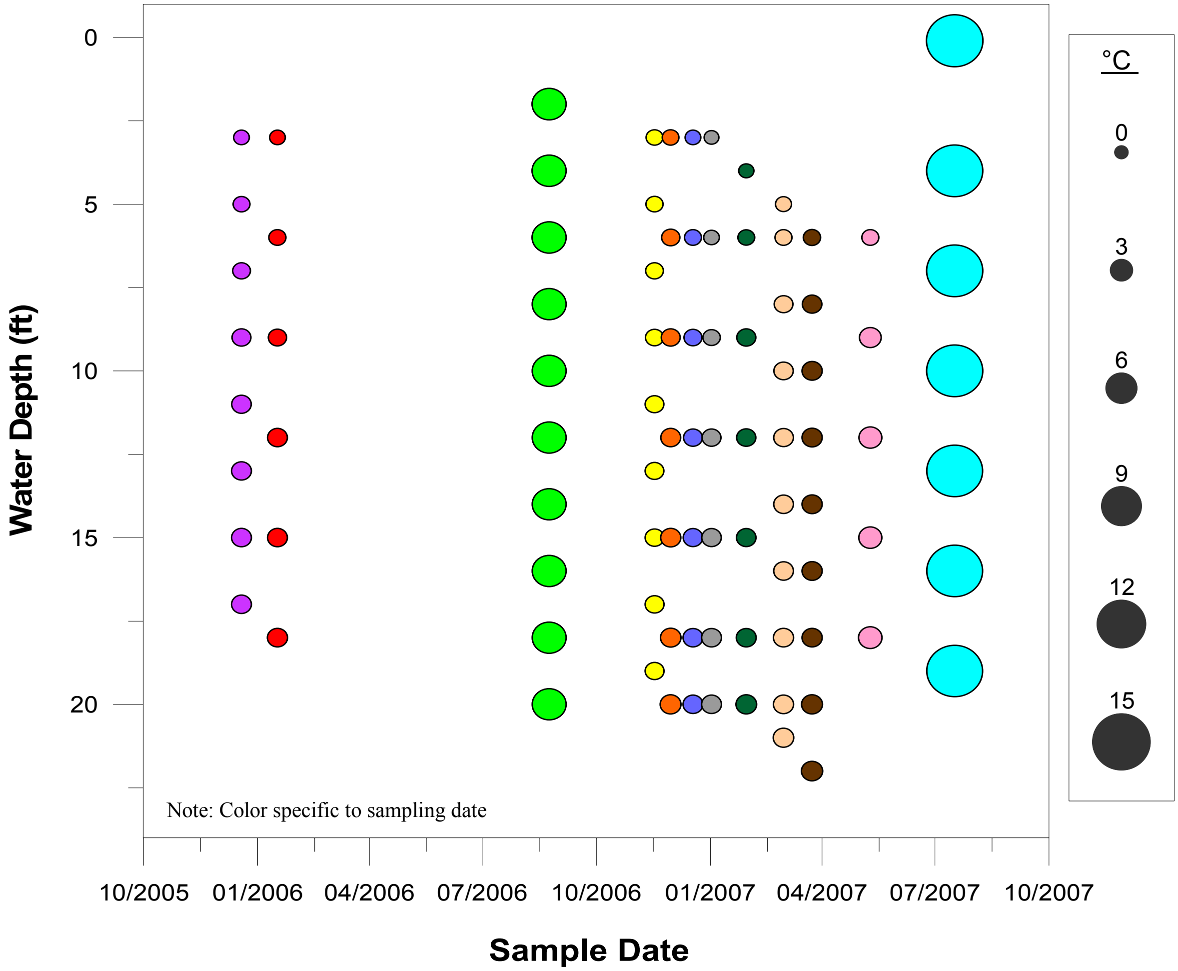
Table 3-3 Lake L9313 Water Quality Data (2005-2007)

Sample Loctaion: N70°20'28" W150°56'31"										
Date	Ice Thickness (ft)	Total Depth (ft)	Freeboard (ft)	Depth (ft)	Temperature (ºC)	Salinity (ppm)	Conductivity (uS/cm)	Specific Condonductance (uS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
12/19/2005	2.3	9.2	0.1	3	0.4	0.2	193	363	13.5	94.3
				4	0.8	0.2	194	360	13.5	94.3
				5	1.3	0.2	195	356	13.4	94.2
				6	1.4	0.2	195	356	13.0	92.5
				7	1.7	0.2	196	354	10.9	78.1
				8	1.8	0.2	197	353	5.0	35.8
				9	2.2	0.2	200	354	3.0	21.5
1/17/2006	2.8	9.6	0.1	3	0.4	0.0	212	399	11.4	78.8
				4	0.8	0.0	213	395	11.3	79.3
				6	1.4	0.0	215	391	10.6	75.3
				8	1.8	0.0	211	379	8.5	58.2
8/24/2006	-	9.1	-	2	5.6	0.1	139	221	12.5	103.0
				4	5.6	0.1	139	221	12.5	99.8
				6	5.6	0.1	139	221	12.5	90.0
				8	5.6	0.1	139	221	12.5	90.0
				9	5.7	0.1	139	220	13.1	90.0
11/17/2006	1.1	9.0	0.0	2	0.5	0.1	142	267	14.0	95.8
				3	0.7	0.1	142	265	13.8	94.9
				4	0.8	0.1	142	264	13.6	94.2
				5	1.1	0.1	142	262	13.2	91.7
				6	1.3	0.1	143	261	11.7	82.1
				7	1.4	0.1	143	260	9.6	68.0
				8	1.6	0.1	144	260	5.7	40.4
				9	1.9	0.1	148	265	5.4	39.1
11/30/2006	1.7	9.3	0.1	3	0.6	0.1	161	302	14.3	103.0
				5	1.1	0.1	162	298	13.5	99.8
				7	1.6	0.1	164	296	11.9	90.0
				9	1.9	0.1	162	290	1.2	9.1
12/18/2006	2.3	7.2	0.1	2	0.1	0.1	165	315	-	-
				4	0.5	0.1	166	311	-	-
				6	0.9	0.1	168	312	-	-
				7	1.7	0.1	176	317	-	-
1/2/2006	2.6	9.3	0.1	3	0.3	0.1	160	303	12.4	92.9
				6	1.2	0.1	161	295	11.7	88.8
				9	2.0	0.1	163	291	0.2	1.8
1/30/2007	3.6	9.1	0.15	4	0.6	0.2	204	382	9.9	73.0
				6	1.1	0.2	205	378	9.2	69.1
				8	1.8	0.2	206	369	2.5	2.5
				9	1.9	0.2	208	373	0.2	1.1
3/1/2007	4.6	9.3	0.3	5	0.7	0.2	247	460	7.4	51.1
				7	1.6	0.2	250	452	6.9	48.7
				9	1.7	0.2	257	463	0.3	2.1
3/24/2007	5.1	9.3	0.3	5	0.3	0.3	315	597	5.8	42.4
				7	1.3	0.3	317	578	4.8	36.7
				9	1.7	0.3	326	587	0.1	1.0
5/10/2007	-	9	0.3	6	0.9	0.3	346	642	6.8	49.3
				7	1.9	0.3	352	630	6.8	50.1
				8	2.3	0.3	363	641	6.1	45.5
7/17/2007	-	9.3	-	0	14.3	0.1	154	194	10.2	99.6
				3	14.2	0.1	154	193	10.1	99.1
				6	14.1	0.1	153	194	10.1	98.3
				9	13.9	0.1	154	196	8.0	78.6

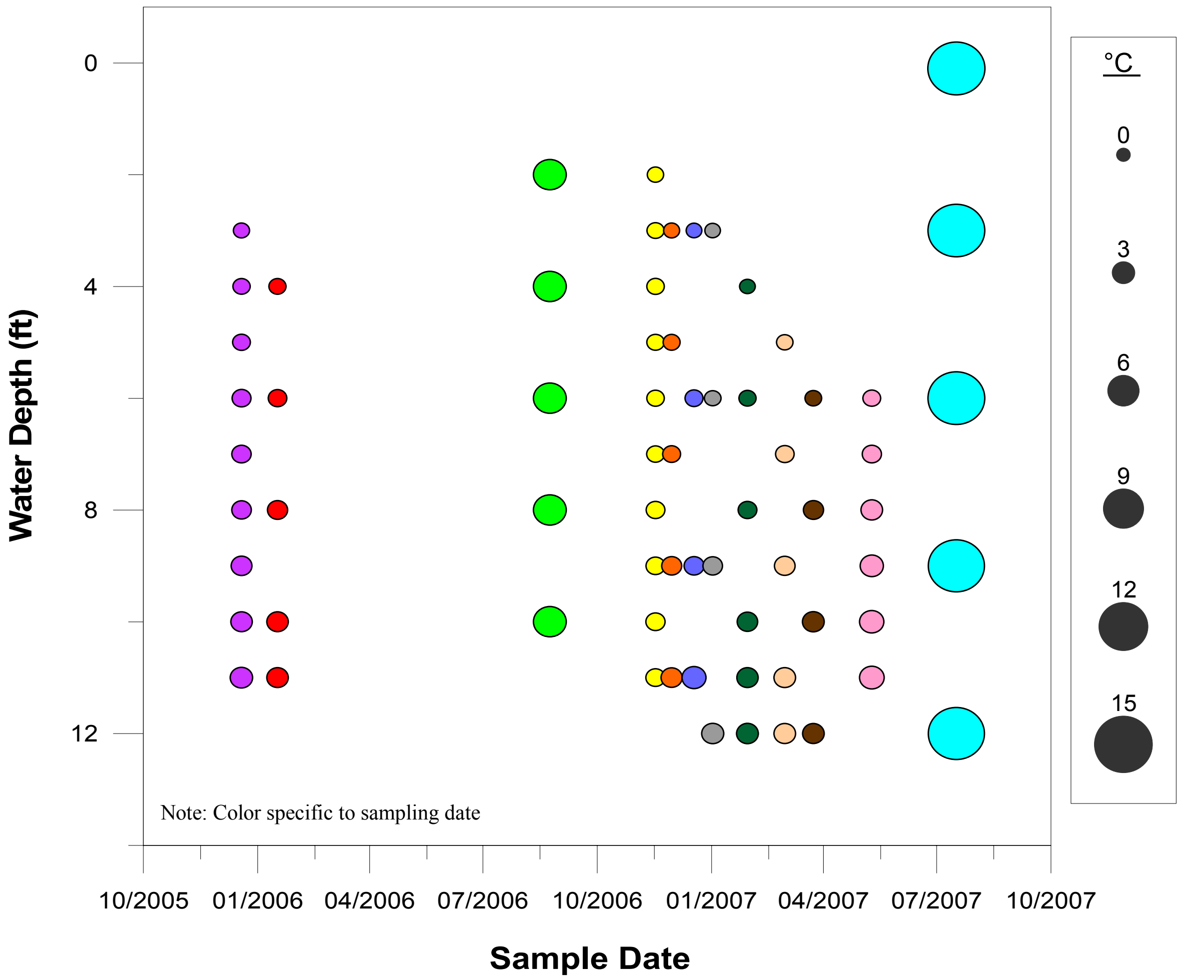
3.2.1 Water Temperature

Water temperature distributions observed in Lakes L9310, L9312, and L9313 are presented in Graph 3-1, Graph 3-2, and Graph 3-3, respectively. Water temperatures differed little between lakes during the summer months. Lakes L9313, L9312, and L9310 averaged 5.6°C, 5.7°C, and 6.1°C, respectively, in August of 2006. Temperatures were higher in July of 2007, with average lake temperatures ranging from 13.2°C to 14.1°C. During the winter months, water temperature remained consistent between lakes, but developed a gradient relative to depth as the season progressed. Water temperatures achieved a linear trend in December of 2006 in all three lakes, as temperatures gradually increased with depth. By February, a weak stratification in water temperature became apparent, with temperatures increasing little below a depth of 10 feet. In February of 2007, temperatures ranged from approximately 0.0°C (below ice) to 2.0°C (lake bottom), independent of total lake depth. The two sampling events in early 2006 had similar temperature values with gradients and weak stratification of similar magnitude. Temperature gradients are muted in the graphs by the large summer temperature values.

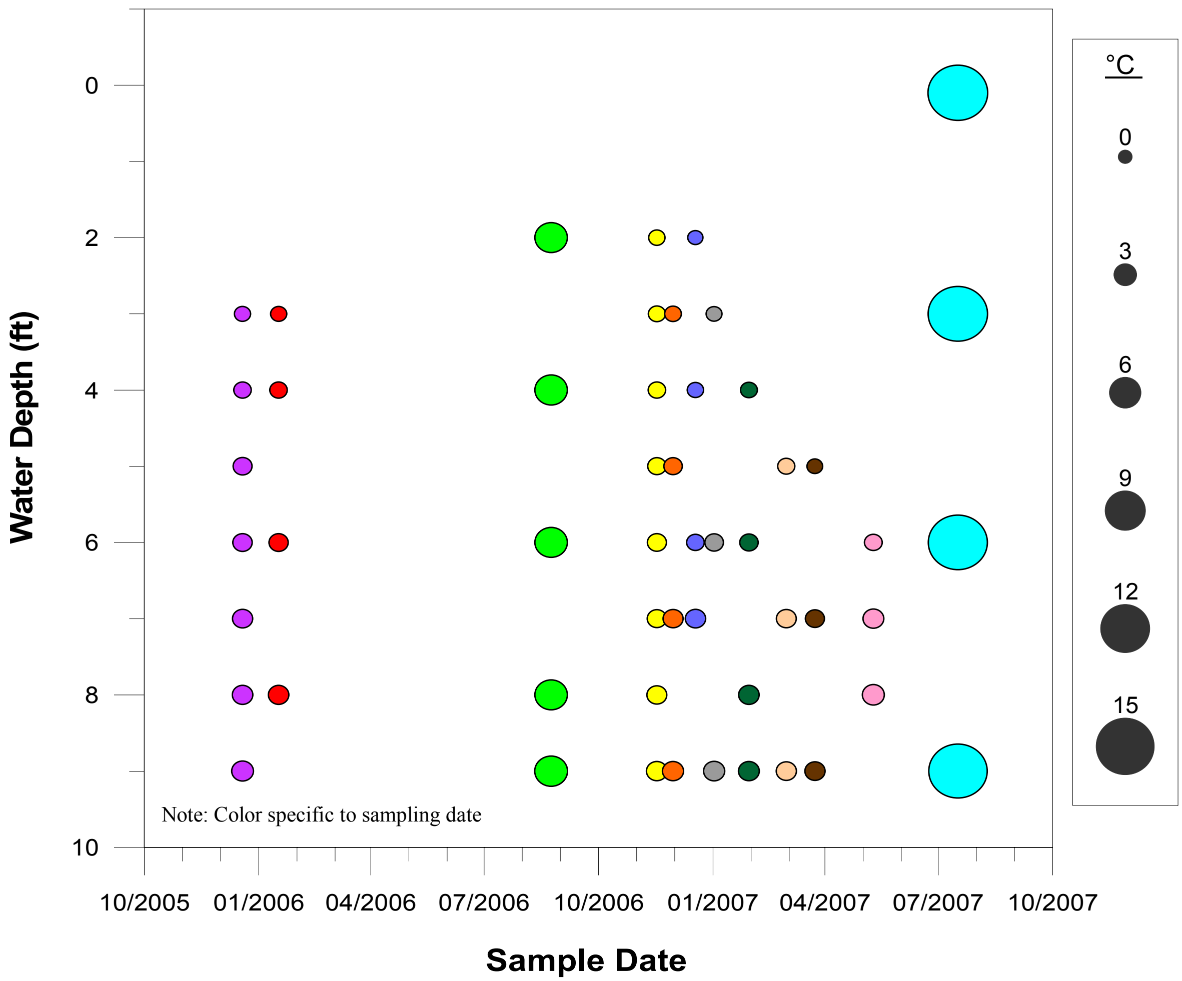
Water withdrawal from Lakes L9313 and L9312 did not impact water temperatures or the development and stability of temperature gradients when compared to the Lake L9310.



Graph 3-1 Lake L9310 Water Temperature (°C)



Graph 3-2 Lake L9312 Water Temperature (°C)



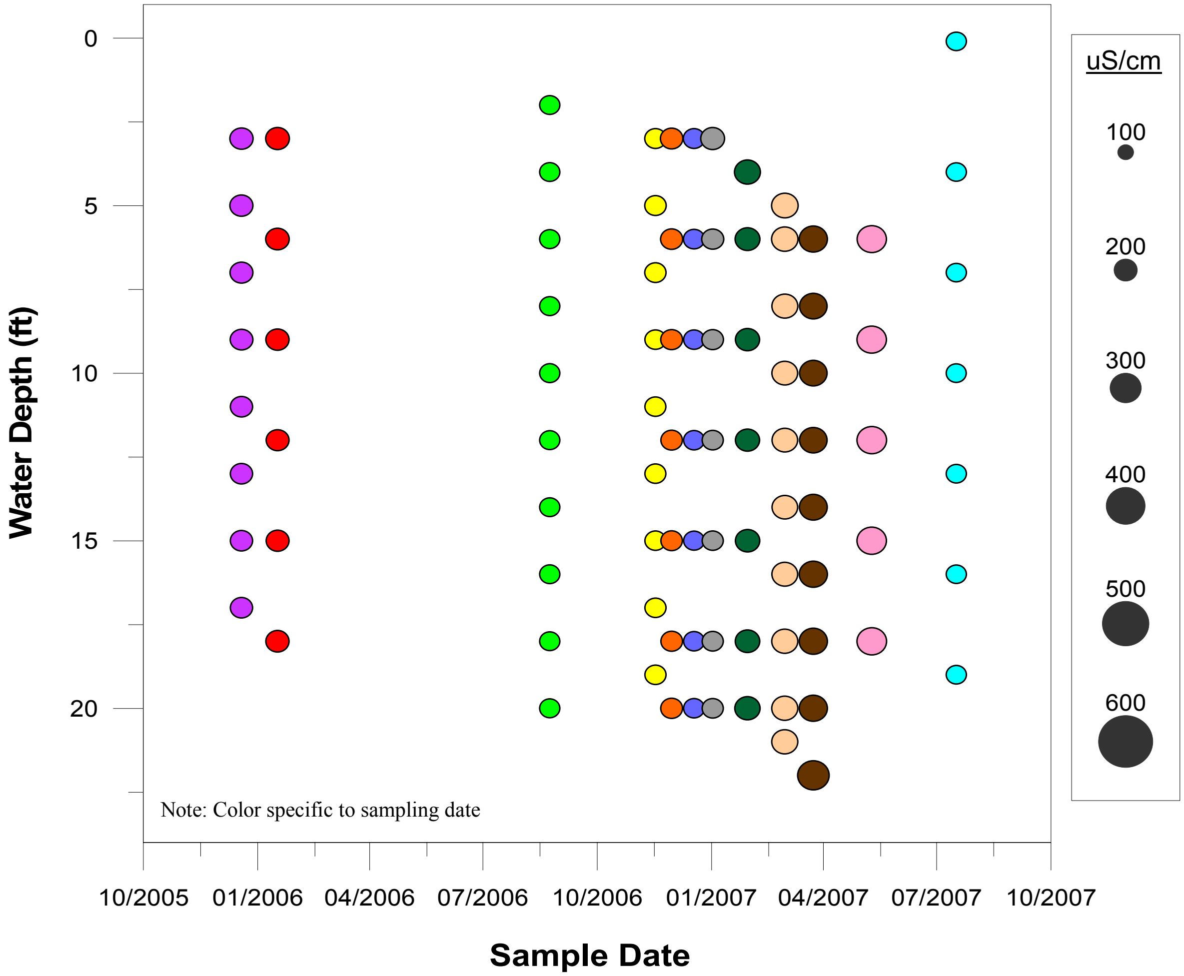
Graph 3-3 Lake L9313 Water Temperature (°C)

3.2.2 Conductivity/Specific Conductance

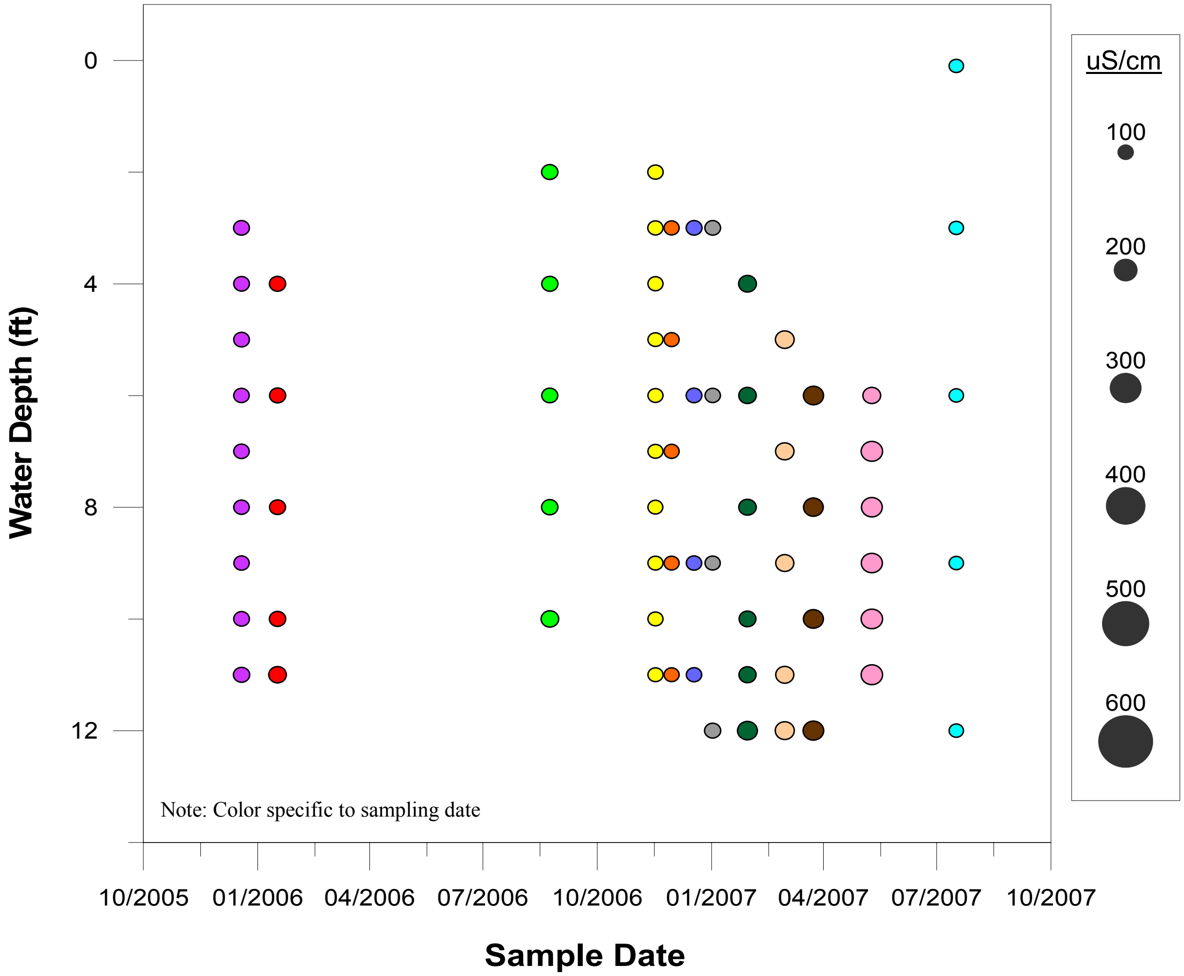
Conductivity is an approximate measurement of total dissolved solids (TDS), effectively measuring the ions, dissolved ionized solids, and carbon dioxide in solution. Specific conductance (conductivity at standard temperature, 25°C) was calculated from measured conductivity, temperature, and a standard temperature correction coefficient of 0.0191 (APHA, AWWA and WEF 2005). The effect of depth related temperature variation observed in all three lakes is quite small, resulting in a relatively consistent relationship between conductivity (AC) and specific conductance (SC); with SC = 1.92AC(0°C) and SC = 1.78AC(2°C). Even differences between seasonal temperatures result in limited variation between sampling events. Due to the similarity of SC and conductivity trends over the sampling period, specific conductance will primarily be discussed hereafter.

Observed SC of Lakes L9310, L9312, and L9313 are presented in Graph 3-4, Graph 3-5, and Graph 3-6, respectively. A general trend was observed during the 2006/2007 sampling season, with SC remaining relatively constant from the August 2006 measurements to those taken in early January 2007, after which an increase in SC occurred in all three lakes. This change was relatively similar across all three lakes, increasing 22% in L9312 and L9310 and 28% in L9313 over the month of January. By the March 2007 monitoring event, rates of increase dropped to roughly 8.5% in L9312 and L9310, yet remained high in L9313 at 22%. Specific conductance in January 2006 varied little from that observed in January 2007.

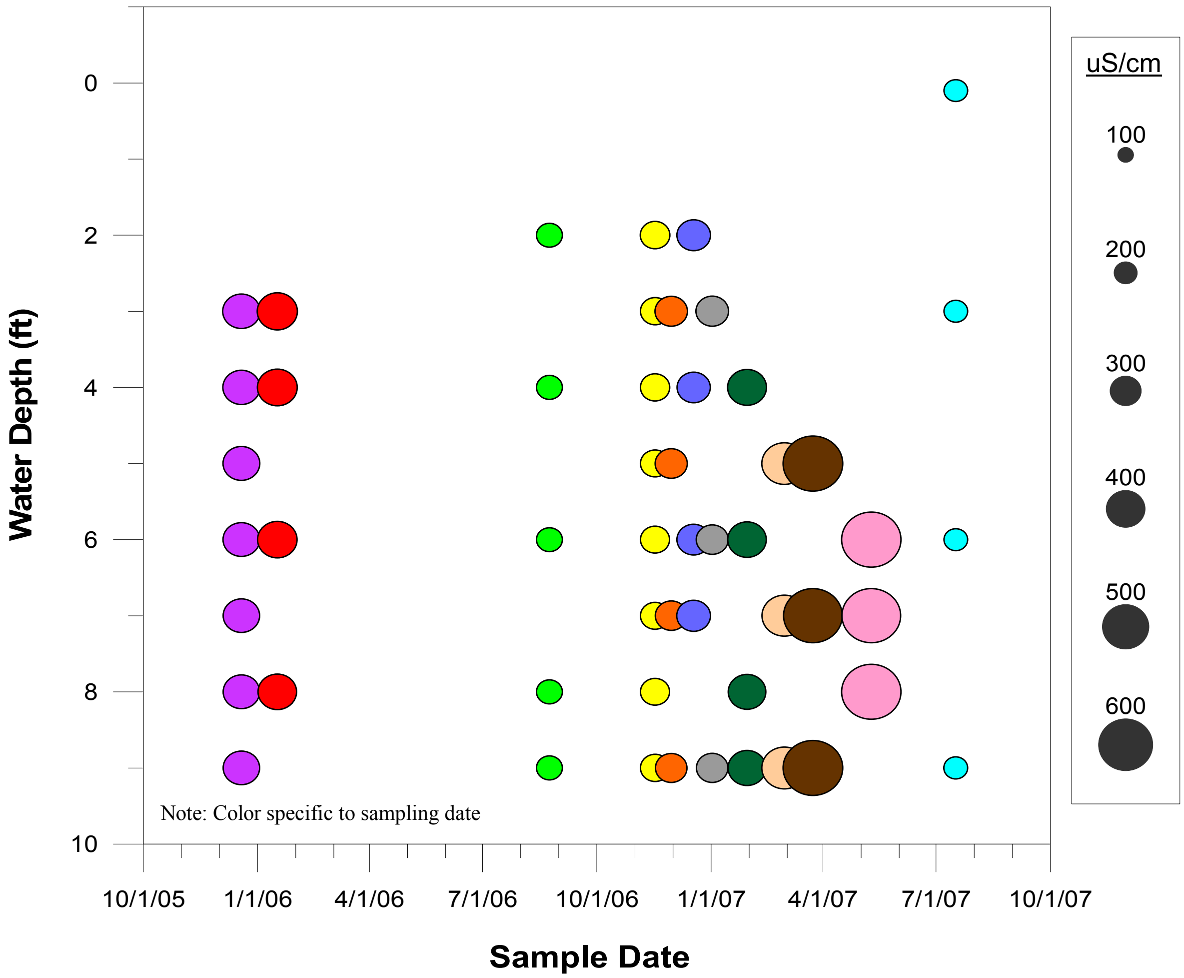
Though specific conductance varied between lakes, a comparison of trends in L9313 and L9312 to those in L9310 does not suggest a direct impact from water withdrawal. Lake L9313 did maintain a rapid increase in specific conductance between January and April; however, this cannot be directly correlated to water withdrawal from the lake. A comparison of historic data in Section 3.3.2 supports this finding.



Graph 3-4 Lake L9310 Specific Conductance (uS/cm)



Graph 3-5 Lake L9312 Specific Conductance (uS/cm)



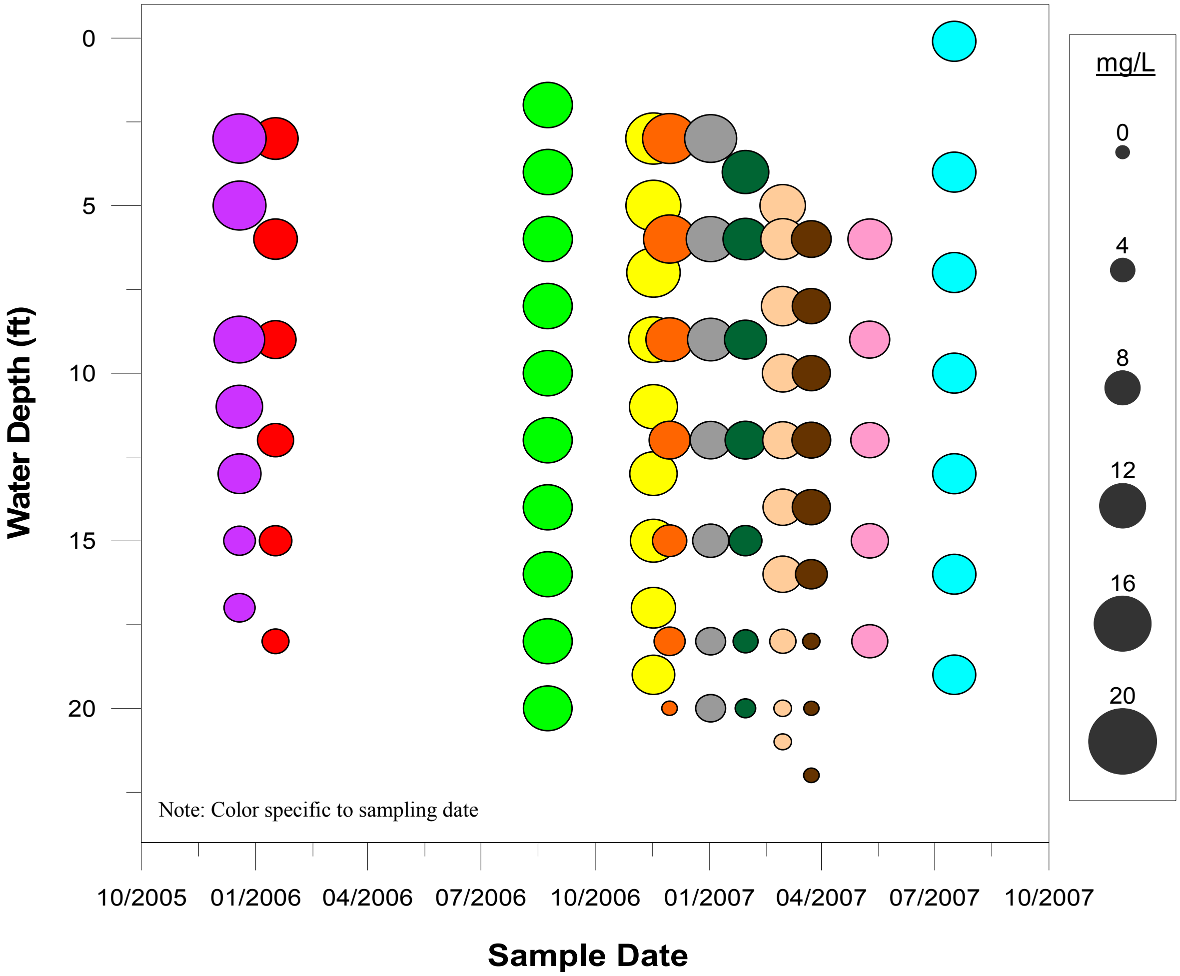
Graph 3-6 Lake L9313 Specific Conductance (uS/cm)

3.2.3 Dissolved Oxygen

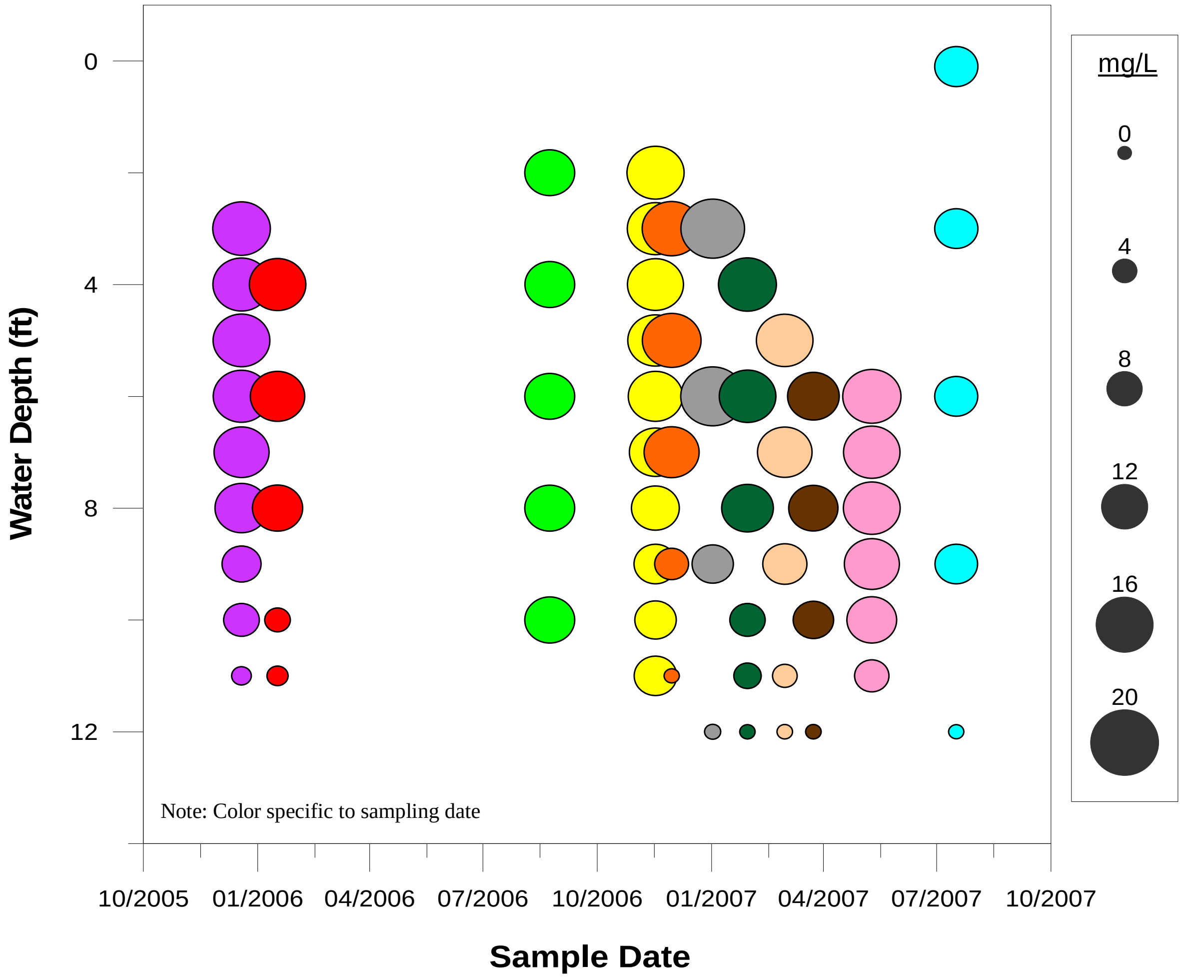
Open water conditions and summer winds result in well mixed waters, particularly in the relatively shallow lakes on the North Slope. Dissolved oxygen (DO) concentrations are replenished during this open water season due to increased photosynthetic activity, air/water diffusion, and wind-wave aeration. Dissolved oxygen concentrations (mg/L) and associated %-air saturation values measured at Lakes L9310, L9312, and L9313 in August 2006 and July 2007 reveal that the entire water column of each lake was near saturation. Relative DO concentrations are presented in Graph 3-7, Graph 3-8, and Graph 3-9.

Early winter DO concentrations in the shallower portions of the water column remained relatively consistent with observed open water concentrations. However, a gradient developed by late November 2006, with lower concentrations appearing at depth. Concentrations as low as 0.2 mg/L were observed at the lake bottom, with values increasing by as much as 6 mg/L within 2 feet of the lake bottom, suggesting a highly active benthic zone. This trend toward a decreased DO concentration continued throughout the ice-cover season, with values decreasing higher in the water column over time. In May of 2007, prior to any apparent opening of surface ice, the oxygen gradient became less apparent with values increasing at depth. These trends were observed in all three lakes, including the control lake.

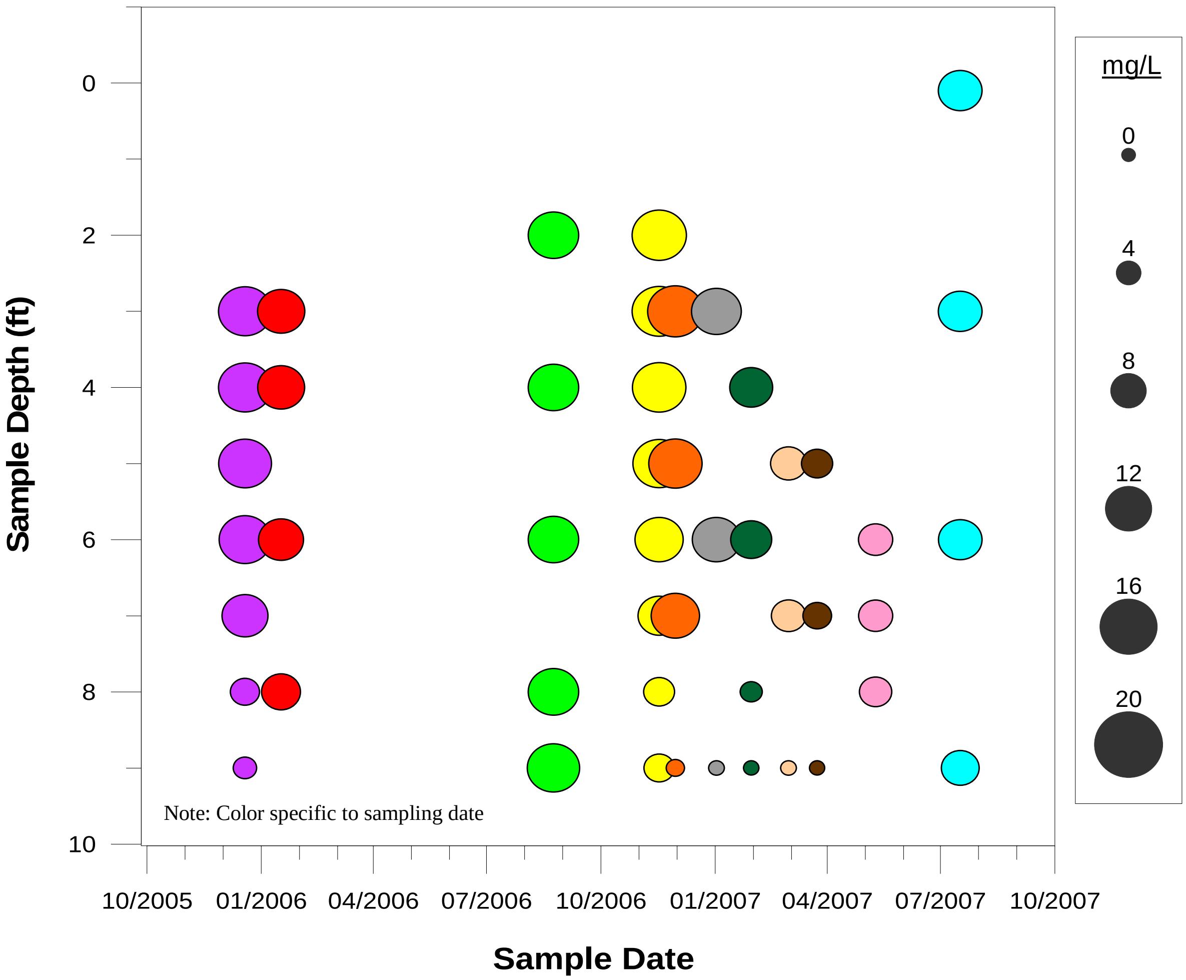
Lake L9313 had the greatest decrease in dissolved oxygen at the ice/water interface. The same amount of oxygen depletion was observed in Lake L9310 at an equivalent depth from the lake bottom. This suggests that the rapid decrease of oxygen at the ice/water interface is a result of lake morphology, and more specifically, lake depth. No significant difference in observed dissolved oxygen could be attributed to water withdrawal during the 2006/2007 monitoring season.



Graph 3-7 Lake L9310 Dissolved Oxygen (mg/L)



Graph 3-8 Lake L9312 Dissolved Oxygen (mg/L)



Graph 3-9 Lake L9313 Dissolved Oxygen (mg/L)

3.3 Discussion

3.3.1 2005–2007 Water Quality

During the open water season, wind-induced mixing results in a homogeneous distribution of water temperature, specific conductance, and dissolved oxygen. Winter ice cover and low temperatures cause near quiescent water. Specific conductance varied little within the water column, while gradients in temperature and dissolved oxygen progressively formed throughout the winter season. Specific conductance did, however, increase as a whole in the three lakes during the winter of 2006/2007. This rapid increase in specific conductance, and the striking similarity between L9312 and L9310, suggests a natural shift in conductivity independent of water withdrawal.

During the winter months, most lakes behave as closed systems, specifically with regard to oxygen. Consequently, the oxygen content of an ice and snow covered lake is essentially a function of the initial oxygen storage shortly after freeze-up and the rate of depletion. Most oxygen consumption in lakes is due to bacterial respiration, decomposition, and chemical oxidation at the sediment/water interface (oxidized microzone). A smaller portion of oxygen is consumed in the water column via bacterial respiration and fish, though fish contribute minimally to winter oxygen depletion (Ellis and Stefan 1989). Additionally, removal of water from the lake equates to the removal of total available oxygen from the "closed" system. The total concentration of oxygen removed is a function of both withdrawal location and volume.

Once a lake freezes over, it becomes inversely stratified, with deeper water temperatures at or near 4°C and sub-ice water dropping to approximately 0°C. As the winter season progresses, a defined temperature gradient throughout the water column develops. In the absence of wind induced mixing, the weak temperature (density) stratification is sufficient to suppress nearly all vertical transport (Ellis and Stefan 1989). As a result of negligible vertical transport and the fact that most oxygen consumption occurs at the sediment surface, an oxygen gradient (oxycline) develops. Over the winter season, this gradient becomes more pronounced throughout the water column as oxygen diffuses laterally to the sloping lake bed and vertically via limited transport. Lateral convective exchange of both oxygen and water temperature between the shallow and deep regions of a lake is thus dependent on overall lake geometry. This expected trend in both temperature and DO was observed in all three of the monitored lakes during the 2006/2007 ice-cover season.

3.3.2 Historic Water Quality Comparison

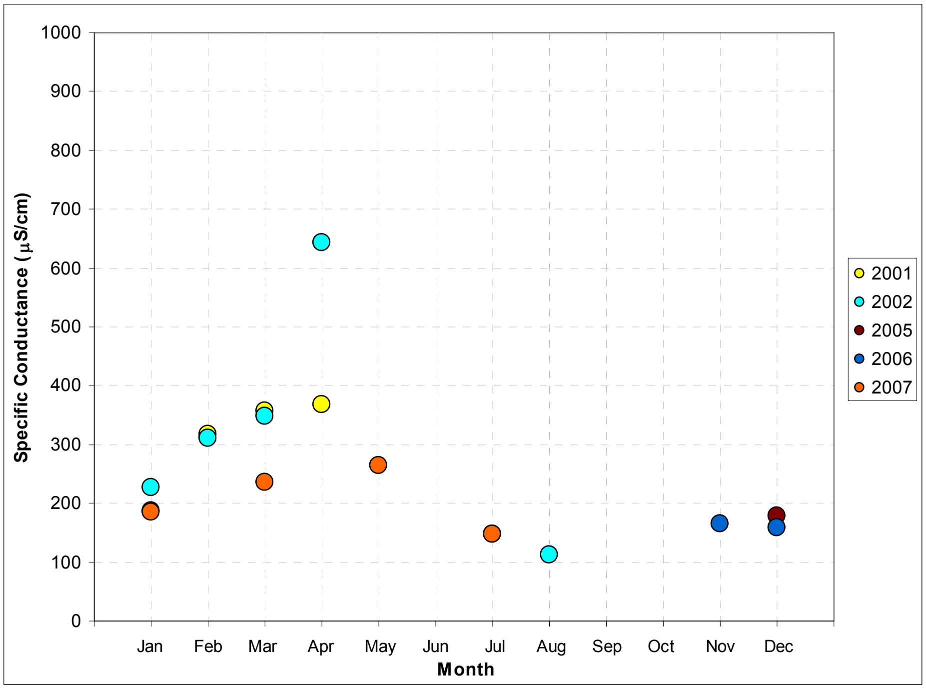
Water temperatures differed little between lakes during the summer months. Lakes L9313 and L9312 averaged 5.6°C and 5.7°C in August of 2006. Lake L9310 had an average water temperature of 6.1°C in August 2006. Historic records identify average August water temperatures of 4.5°C and 6.0°C in 2000 and 2001 respectively, while during the month of July, water temperatures were nearly double this value, averaging 10.5°C (2000) and 13°C (2001).

Winter temperatures and the formation of temperature gradients within the water column were typical for the period of record. Below ice temperatures were approximately 0.0°C to 0.5°C in all lakes. Bottom temperatures were less stable, varying with time and between lakes. Values commonly ranged from 2.0°C to 4.5°C having no obvious correlation with water withdrawal.

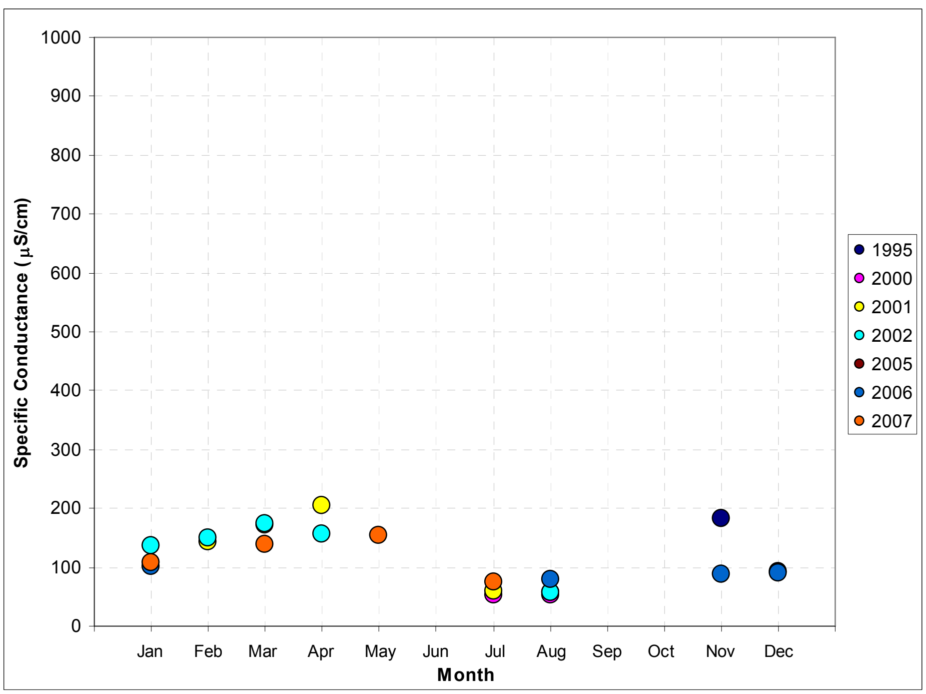
Historic SC values, averaged across the water column, are presented in Graph 3-10 (L9310), Graph 3-11 (L9312), and Graph 3-12 (L9313). Maximum winter SC values at all three lakes occur in the month of

April. Seasonal values of SC have remained relatively stable in Lakes L9310 and L9312 over the period of record. A significant rise in SC was noted in Lake L9310 in April 2002. Being a control lake having no historic water withdrawal, the rapid rise was not a result of withdrawal. Lake L9313 has had a wide range of historic SC values during winter ice cover seasons. Though maximum SC varied between years, there has always been an increasing trend over the winter. The rate of increase and maximum observed values could not be correlated with water withdrawal volumes. The greatest volume withdrawn from Lake L9313 took place between July and December of 2002 equaling approximately 10.1 million gallons (MG). Following this withdrawal, in April of 2003, the average observed SC of 730 uS/cm was only marginally greater than the April 2001 baseline value of 675 uS/cm. In April of 2002, average SC reached a maximum historic value of 988 uS/cm following a total annual withdrawal volume of only 2.0 MG.

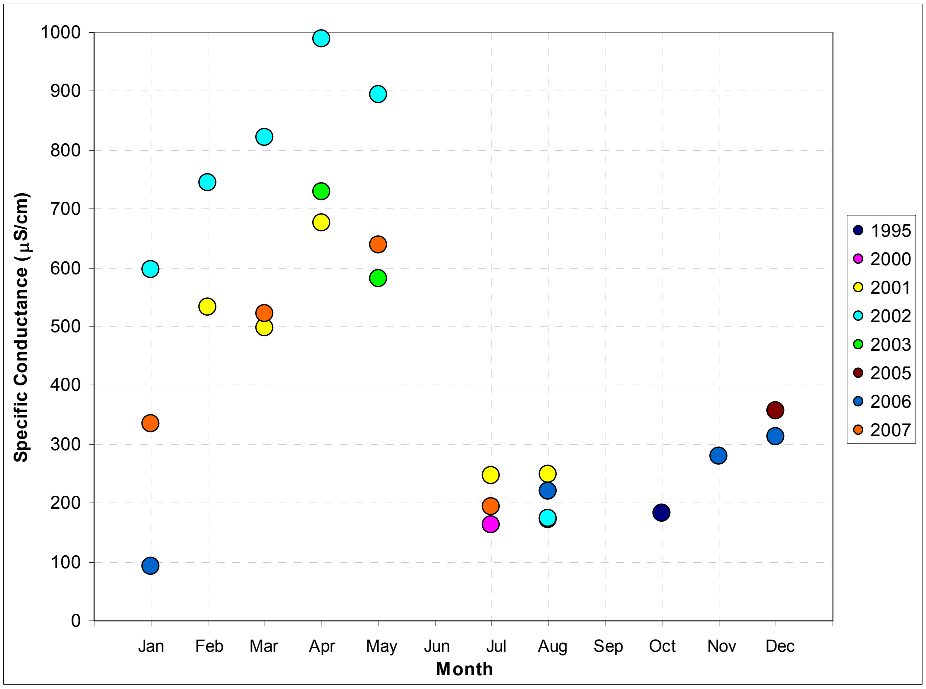
Variations in reported DO concentration can occur from year to year due to sampling methods/technology, activity and size of local biological community, organic loading, and sampling location. Historic DO data is difficult to compare without accounting for these mechanisms; however, a similar trend is obvious in those years where data was collected throughout the ice-cover season. In early 2001, 2002, 2006, and 2007, DO concentrations dropped, initially at the lake bottom and gradually within the water column, climbing to a maximum value near the ice/water interface. Low values of maximum DO consistently occurred in early April, with the lowest measured peak value being 0.1 mg/L at 6.8 feet in L9313 (April 7, 2002). Of the historic data, Lake L9313 had the most rapid decline and lowest observed maximum DO concentrations at shallow depth. Maximum monthly DO concentrations have consistently remained higher in L9312 than in L9310 or L9313 throughout the winter season over the period of record.



Graph 3-10 Lake L9310 Historic Average Specific Conductance



Graph 3-11 Lake L9312 Historic Average Specific Conductance



Graph 3-12 Lake L9313 Historic Average Specific Conductance

4.0 Lake Water Recharge

Previous studies have estimated that mean summer precipitation is very near the evaporative loss of lakes during the open water season, making lake water recharge largely dependent on snowmelt runoff and floodwater (Baker 2002b). For this study, catchment basin delineations and snow surveys were performed to identify potential recharge volumes from snowmelt runoff. Resulting values were compared with the permitted withdrawal volumes to determine the possibility of adequate recharge in years of no floodwater recharge.

4.1 Catchment Basin Delineation

The primary focus of the catchment basin delineation was to ensure accurate estimates of catchment size as it relates to lake recharge via precipitation and snowmelt. The catchment basin area for each Alpine drinking water lake was delineated using 1999 and 2004 AeroMap 2-foot contours and spot elevations. The vertical accuracy of the elevation data was equal to half the contour interval. The extent of lake margins between years was compared using 2004 and 2005 aerial photography; no significant changes were noted. Field observations were used to verify the catchment basin delineations.

4.2 Snow Water Equivalent and Recharge from Runoff

4.2.1 Snow Survey Methods

Snow water equivalent surveys were conducted within the delineated catchment basins of the Alpine drinking water Lakes L9312 and L9313 on May 10, 2007. Lake L9310 was also sampled on that date.

Sampling Transects and Points

Lake-water perimeter and the lake's associated catchment basin were delineated using aerial imagery, topographic contours, and spot elevations provided by CPAI. Data specific to each terrain type was then identified including respective area, shape, relief, and potential locations for drift formation. Most lake catchment basins in the Colville River Delta have a boundary ridge encircling the lake body, thus transects were positioned perpendicular to local relief radiating from a central location on the lake. Additional transects were positioned to cover irregularities of a typical "bowl" shape. Irregularities can include drainage gullies, pingos and mounds, or basin arms. In the arctic, where vegetation is not a major factor affecting snow distribution, terrain has a major effect. Thus, terrain-based snow surveys allow the determination of mean catchment snow values and produce sufficient spatial snow information for most hydrologic studies (Woo 1997).

Sampling points along each transect were identified. Initial point locations were selected independent of local topography and terrain type to maintain random sampling along transects. In the case of adjoining transects, like those radiating from a single location, a point was positioned at their intersection, with successive points positioned a fixed distance from the initial point. Uniform spacing of points was necessary to provide systematic sampling. The number of depth measurements was dependent on transect length and the variability of snow within the terrain unit. The number of depth measurements included those taken to determine snow density, of which there was no less than two points per transect (Woo 1997).

DOUBLE SAMPLING METHOD

At each of the three study lakes, a double sampling method snow survey was conducted measuring snow pack in two separate ways: (1) by measuring snow depth and mass at a smaller number of points, and (2) by measuring only snow depth at a large number of points. Sampling points were located along predetermined transects. Each terrain type that was covered by a single transect contained at least one snow mass sampling point.

The double sampling method was selected based on the limited depth of snow cover characteristic of the arctic. Goodison, Ferguson, and McKay (1981) suggest that in shallow snowpacks (less than 1 meter), depth and density have been found to be essentially independent and there is typically less temporal and spatial variability in density than in depth. Additionally, Rovansek, Kane, and Hinzman (1993) found that snow water equivalent estimates resulting from double sampling methods have less variance than when measuring snow mass and depth at every location. The double sampling method can also accelerate the speed at which a sampling program is executed, with depth measurements taking a fraction of the time required for measuring both depth and sample weight.

SAMPLING

Density measurements were conducted according to procedures outlined in the Natural Resources Conservation Service (NRCS) *Snow Survey Sampling Guide* (NRCS 2007a) and *British of Columbia Snow Survey Manual* (BC Ministry of Environment 1981), using a $1^{5}/_{8}$-inch ID Model 3600 Mt. Rose (Standard Federal) snow sampling tube and scale. This particular sampler was chosen based on its common acceptance and use by the NRCS.

Snow depth alone was sampled using a graduated snow pole. In addition, if shallow snow was encountered having a SWE of less than 2 inches, a bulk sampling was conducted (NRCS 2007a). A bulk sampling is a grouping of multiple samples collected in the immediate area of the sample point, recording sample depth of each sample and weighing the combined core samples.

SNOW WATER EQUIVALENT (SWE) COMPUTATIONS

Methods used in computing snow density and SWE are described in *2007 Colville River Delta Lakes Recharge Monitoring and Analysis* (Baker 2007b). Calculations were based on those presented by Woo (1997) with consideration of those presented by Rovansek, Kane, and Hinzman (1993). For each terrain type, an average snow depth, snow density, and SWE were calculated at each lake. An area weighted SWE was also calculated for each lake's associated catchment basin.

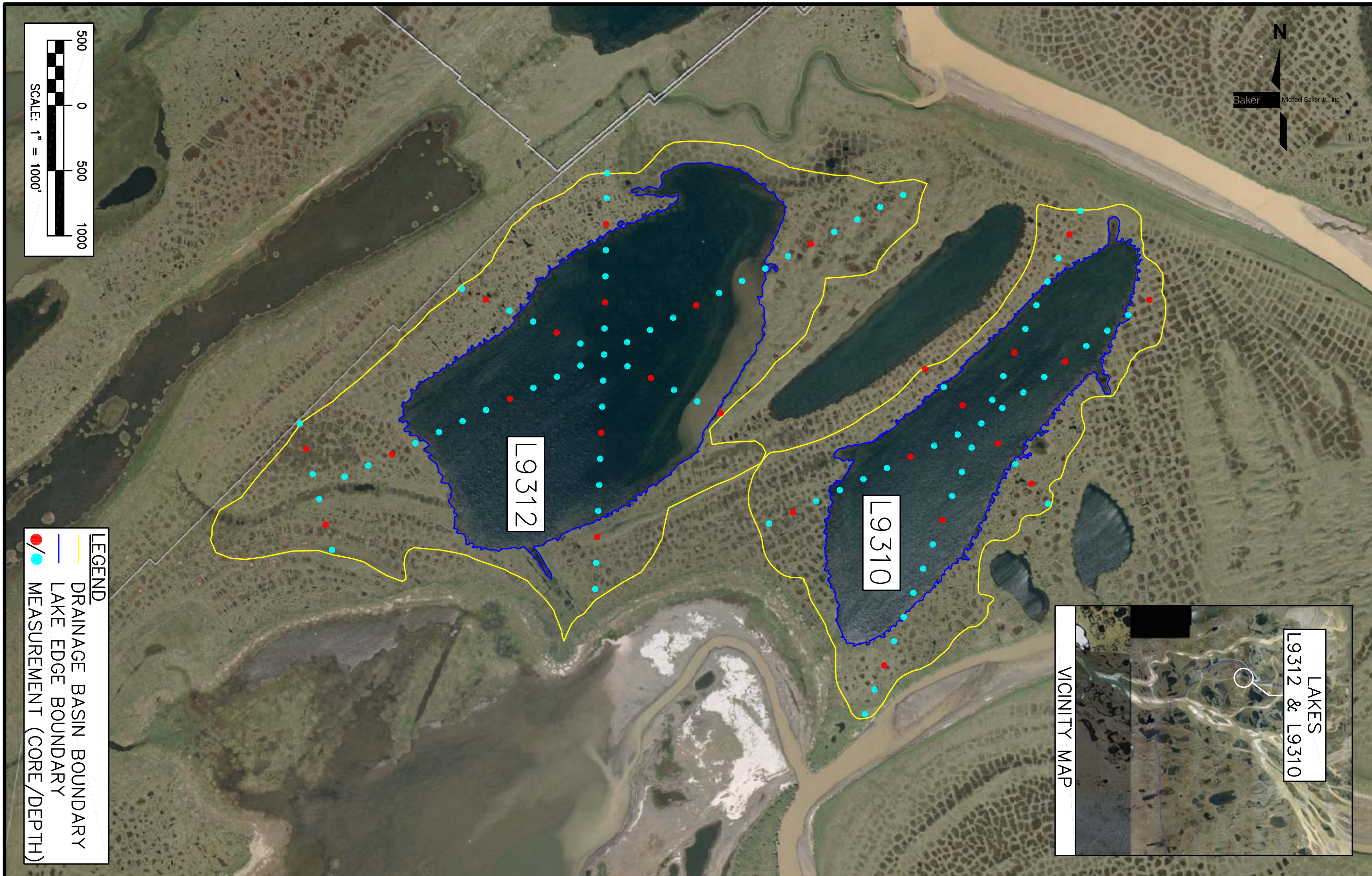
4.2.2 Results

Snow surveys were conducted prior to breakup at the Alpine drinking water Lakes L9312, L9313, and control Lake L9310. Figure 4-1 and Figure 4-2 present the sample locations and the catchment basin boundaries for each lake. The snow survey field data is presented in Appendix A.

Terrain specific snow depth, snow density, SWE and area weighted SWE results are presented in Table 4-1. The results were used to estimate the amount of snowmelt water potentially available for lake recharge. Associated volumes are also presented in Table 4-1. The potential recharge volume estimates assume the presence of permafrost which inhibits notable loss of water to infiltration. The potential recharge volume for each lake was computed using the lake's corresponding area weighted SWE and is independent of the other sample lakes.

Table 4-1 Alpine Lakes Snow Survey Results – May 10, 2007

Lake Name	Drainage Area (ft^2)		Snow Density (lb/in^3)		Snow Depth (in)		Snow Water Equivalent (in)			Estimated Recharge Volume (million gallons)
	Lake	Tundra	Lake	Tundra	Lake	Tundra	Lake	Tundra	Area Weighted	
L9310	2,874,000	2,517,000	0.004	0.006	5.59	13.46	0.69	2.38	1.48	4.96
L9312	4,861,000	4,944,000	0.007	0.007	5.3	12.3	1.05	2.22	1.64	10.03
L9313	3,382,000	3,131,000	0.007	0.006	6.1	13.8	1.23	2.18	1.69	6.86



ConocoPhillips Alaska, Inc.

DATE:	12/11/2007	PROJECT:	108603
DRAWN:	OOO	FILE:	SSL9313_L9312_L9310.DWG
CHECKED:	MDM	SCALE:	AS SHOWN

Baker

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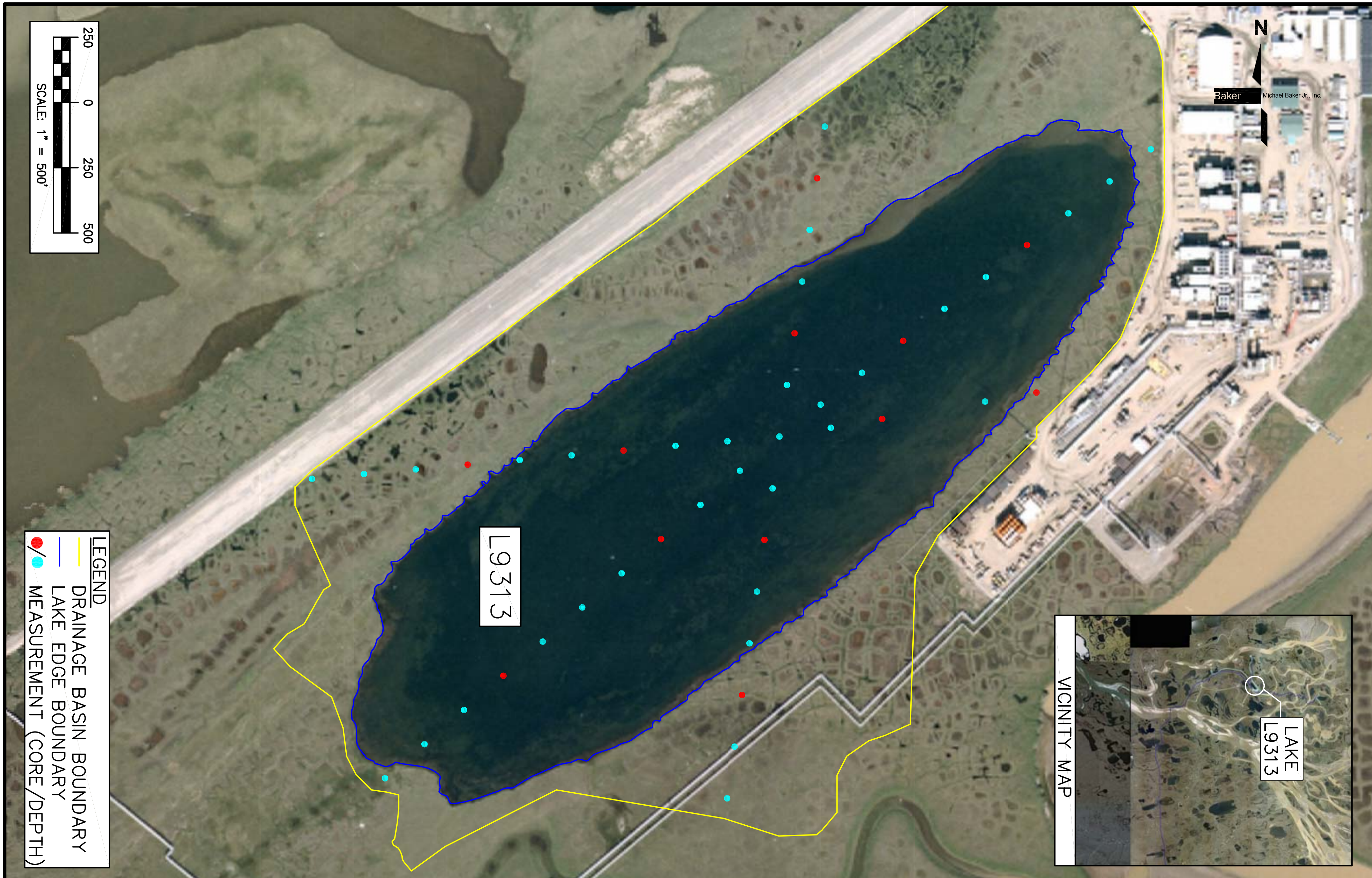
2006/2007 ALPINE LAKES
L9312 AND L9310 CATCHMENT
BASINS & SNOW SURVEY POINTS

FIGURE 4-1
(SHEET 1 OF 1)



ConocoPhillips Alaska, Inc.

DATE: 12/11/2007	PROJECT: 108603
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2006/2007 ALPINE LAKES
L9313 CATCHMENT BASIN
& SNOW SURVEY POINTS

FIGURE 4-2
(SHEET 1 OF 1)

4.2.3 Discussion

The estimated snowmelt runoff recharge volume of Lake L9313 suggests adequate recharge of the maximum allowable withdrawal volume of 6 MG. Lake L9312 is considerably lower, at 10 MG, than the permitted withdrawal volume of 30 MG. According to the May 2007 NRCS Snowpack Map, North Slope snowpack conditions were 70-89% of normal. The NRCS Basin Outlook Report for April 1, a month which yielded little precipitation, estimated that winter precipitation in Prudhoe Bay was 68% of normal (NRCS 2007b,c). These estimates suggest that potential recharge volumes calculated from 2007 snow water equivalence underestimate normal recharge potential. Assuming the snowpack conditions were 70% of normal, potential normal recharge of L9312 would still be below the permitted water withdrawal volume.

Snow surveys were also performed in 2006 at the Alpine drinking water lakes (but not L9310) to supplement the 2006 spring breakup and hydrologic assessment (Baker 2007a). Resulting snow water equivalence at Lakes L9312 and L9313 would yield estimated potential recharge volumes of 14.7 and 11.4 MG, respectively. The May 1, 2006, NRCS Snowpack Map estimated North Slope snowpack conditions at 70-89% of normal (NRCS 2007c), similar to those in 2007.

5.0 Conclusions

This study finds that water withdrawal appears to have had no direct impact on the water quality parameters measured. Moulton concluded in 2004 that historic water withdrawal did not appear to negatively impact resident fish populations, based on historic fish surveys and water quality monitoring. Historic water withdrawal has had no definitive impact on specific conductance or dissolved oxygen. Though Lake L9313 has historically seen lower dissolved oxygen during winter months it is likely related to the shallowness of the lake and not water withdrawal.

Lake L9313 has recharged to a defined bankfull WSE every spring for the last ten years with floodwaters having recharged it eight out of ten years. Lake L9312 has recharged to a bankfull WSE nine out of ten years while being recharged by floodwater six out of the tens years of record. In 2005 neither lake recharged from floodwater, yet both lakes achieved peak water surface elevations above their respective bankfull elevation.

6.0 References

American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF). 2005. Standard Methods for the Examination of Water and Waste Water. 21st Edition.

BC Ministry of Environment. 1981. British Columbia Snow Survey Manual.

Ellis, C.R. and H.G. Stefan. 1989. Oxygen demand in ice-covered lakes as it pertains to winter aeration. Water Res. Bul., 25(6), pp. 1169-1176.

Goodison, B.E., Ferguson H.L. and McKay, G.A. (1981). Measurement and Data Analysis. Chapter 6 in Handbook of Snow, Gray, D.M. and Male, D.H. (Eds.), Pergamon Press Canada Ltd., pp. 191-274.

Michael Baker Jr., Inc. (Baker). 1998. 1998 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. Prepared for ARCO Alaska, Inc.

—— 1999. 1999 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. Prepared for ARCO Alaska, Inc.

—— 2000. Alpine Facilities Spring 2000 Breakup Monitoring and Hydrologic Assessment. Prepared for Phillips Alaska, Inc.

—— 2001. Alpine Facilities Spring 2001 Spring Breakup and Hydrologic Assessment. Prepared for Phillips Alaska, Inc.

—— 2002a. Alpine Facilities Spring 2002 Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2002b. Alpine Water Supply Risk Assessment 2002 Update. Prepared for ConocoPhillips Alaska, Inc.

—— 2003. Alpine Facilities Spring 2003 Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2005a. Alpine Facilities 2004 Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2005b. Colville River Delta and Fish Creek Basin 2005 Spring Breakup and Hydrological Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2007a. 2006 Colville River Delta and Fish Creek Basin Spring Breakup and Hydrological Assessment. January 2007. Prepared for ConocoPhillips Alaska, Inc.

—— 2007b. Colville River Delta Lakes Recharge Monitoring and Analysis. Prepared for ConocoPhillips Alaska, Inc.

—— 2007c. 2007 Colville River Delta Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

Moulton, L.L. 2004. Monitoring of Water-source Lakes in the Alpine Development Project: 1999-2003. Prepared for ARCO Alaska, Inc.

National Resources Conservation Services (NRCS), United States Department of Agriculture. 2007a. Snow Survey Sampling Guide. Website accessed spring 2007. (http://www.wcc.nrcs.usda.gov/factpub/ah169/ah169.htm)

—— 2007b. Alaska Basin Outlook Reports. Accessed summer 2007. (http://www.wcc.nrcs.usda.gov/cgibin/bor.pl)

—— 2007c. Alaska Snowpack Maps. Accessed summer 2007. (http://www.wcc.nrcs.usda.gov/cgibin/ak_snow.pl?state=alaska)

Rovansek, R.J., DSL Kane, and LED. Hangman. 1993. Improving Estimates of Snowpack Water Equivalent Using Double Sampling, Proceedings of the Eastern and Western Snow Conference, Quebec City.

Woo, Ming-ko. 1997. Arctic Snow Cover Information for Hydrological Investigations as Various Scales, Proceedings of the Northern Res. Basin Symposium/Workshop. Nordic Hydrology, 29 (4/5), 245 – 266.

Appendix A Snow Survey Field Sheets

Snow Survey Data Sheet

Date: 5/10/2007 | **Start Time:** 8:13 | **End Time:** 11:15 | **Observers:** MDM, OOO

Catchement Basin: L9310 | **Driving Wrench Used:** Yes | **Tube Section Used:** 1

Snow Sample No.	Sample Type	Terrain Type	Snow Depth (in)		Core Length (in)	Tube & Core Weight (lb)	Empty Tube Weight (lb)	Water Equivalent (in)	Density (lb/in^3)
			w/ Dirt Plug	w/o Dirt Plug					
SS1*	Core	Lake	—	5.2	—	2.18	1.96	0.59	0.004
SS2*	Core	Tundra	—	9.4	—	2.28	1.96	1.07	0.004
SS3*	Core	Lake	—	5.0	—	2.24	1.98	0.69	0.005
SS4	Core	Tundra	18.5	17.3	—	2.28	1.98	4.01	0.008
SS5*	Core	Lake	—	4.3	—	2.22	1.98	0.64	0.005
SS6	Core	Tundra	20.5	18.0	—	3.08	2.74	4.54	0.009
SS7*	Core	Lake	—	5.0	—	2.20	2.00	0.53	0.004
SS8*	Core	Tundra	—	10.2	—	2.30	1.94	1.20	0.004
SS9*	Core	Lake	—	4.5	—	2.14	1.98	0.43	0.003
SS10*	Core	Tundra	—	16.2	—	2.58	1.98	2.00	0.004
SS11*	Core	Lake	—	5.0	—	2.16	1.96	0.67	0.005
SS12*	Core	Tundra	—	10.8	—	2.56	1.84	2.40	0.008
SS13	Depth	Lake	—	6.0					
SS14	Depth	Lake	—	7.1					
SS15	Depth	Lake	—	4.8					
SS16	Depth	Lake	—	5.0					
SS17	Depth	Tundra	—	10.8					
SS18	Depth	Lake	—	6.2					
SS19	Depth	Tundra	—	14.8					
SS20	Depth	Lake	—	5.5					
SS21	Depth	Lake	—	7.8					
SS22	Depth	Lake	—	7.2					
SS23	Depth	Lake	—	5.8					
SS24	Depth	Tundra	—	7.2					
SS25	Depth	Tundra	—	12.0					
SS26	Depth	Tundra	—	16.3					
SS27	Depth	Tundra	—	7.8					
SS28	Depth	Tundra	—	15.8					
SS29	Depth	Lake	—	4.2					
SS30	Depth	Lake	—	5.8					
SS31	Depth	Lake	—	4.8					
SS32	Depth	Lake	—	5.4					
SS33	Depth	Lake	—	4.2					
SS34	Depth	Lake	—	7.2					
SS35	Depth	Tundra	—	12.0					
SS36	Depth	Tundra	—	11.4					
SS37	Depth	Tundra	—	19.4					
SS38	Depth	Tundra	—	21.6					
SS39	Depth	Lake	—	4.2					
SS40	Depth	Lake	—	5.5					
SS41	Depth	Lake	—	4.8					
SS42	Depth	Lake	—	8.4					
SS43	Depth	Lake	—	4.8					
SS44	Depth	Tundra	—	10.8					
SS45	Depth	Tundra	—	13.8					
SS46	Depth	Lake	—	7.2					

Snow Survey Calculations

Average Area:	Tundra =	2516717 ft^2
	Lake =	2874091 ft^2
Average SWE:	Tundra =	2.38 in
	Lake =	0.69 in
Average Snow Depth:	Tundra =	13.46 in
	Lake =	5.59 in
Average Density:	Tundra =	0.006 lb/in^3
	Lake =	0.004 lb/in^3
Catchement Basin Weighted SWE =		1.48 in

NOTES:

* Pooled sample measurement conducted, snow depth without dirt plug, SWE, and density represents the average of pooled samples.

Pooled Snow Survey Data Sheet

Date: 5/10/2007 | **Start Time:** 8:13 | **End Time:** 11:15 | **Observers:** MDM, OOO

Catchement Basin: L9310 | **Driving Wrench Used:** Yes | **Tube Section Used:** 1

Snow Sample No.	Pooled Sample #	Terrain Type	Snow Depth (in)		Core Length (in)	Bucket & Core Weight (lb)	Empty Bucket Weight (lb)	Water Equivalent (in)	Density (lb/in^3)
			w/ Dirt Plug	w/o Dirt Plug					
SS1	1	Tundra	—	5.0	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.5	—	—	—	—	—
	4	Lake	—	5.5	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**26.0**		2.18	**0.22**	—	—
			Average =	**5.2**			**0.04**	0.59	0.004
SS2	1	Tundra	11.0	9.0	—	—	1.96	—	—
	2	Tundra	12.0	10.5	—	—	—	—	—
	3	Tundra	11.0	9.5	—	—	—	—	—
	4	Tundra	11.0	8.5	—	—	—	—	—
			Sum =	**37.5**		2.28	**0.32**	—	—
			Average =	**9.4**			**0.08**	1.07	0.004
SS3	1	Lake	—	5.0	—	—	1.98	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**25.0**		2.24	**0.26**	0.69	0.005
			Average =	**5.0**			**0.05**		
SS5	1	Lake	—	4.0	—	—	1.98	—	—
	2	Lake	—	4.0	—	—	—	—	—
	3	Lake	—	4.4	—	—	—	—	—
	4	Lake	—	4.4	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**21.3**		2.22	**0.24**	—	—
			Average =	**4.3**			**0.05**	0.64	0.005
SS7	1	Lake	—	5.2	—	—	2.00	—	—
	2	Lake	—	4.8	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	4.9	—	—	—	—	—
	5	Lake	—	4.9	—	—	—	—	—
			Sum =	**24.8**		2.20	**0.20**	—	—
			Average =	**5.0**			**0.04**	0.53	0.004
SS8	1	Tundra	12.0	11.1	—	—	1.94	—	—
	2	Tundra	12.5	7.0	—	—	—	—	—
	3	Tundra	12.5	10.5	—	—	—	—	—
	4	Tundra	12.5	12.0	—	—	—	—	—
			Sum =	**40.6**		2.30	**0.36**	—	—
			Average =	**10.2**			**0.09**	1.20	0.004
SS9	1	Lake	—	4.5	—	—	1.98	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	4.5	—	—	—	—	—
	4	Lake	—	4.5	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**22.5**		2.14	**0.16**	—	—
			Average =	**4.5**			**0.03**	0.43	0.003
SS10	1	Tundra	17.0	15.8	—	—	1.98	—	—
	2	Tundra	17.0	16.5	—	—	—	—	—
	3	Tundra	18.0	16.5	—	—	—	—	—
	4	Tundra	17.5	16.0	—	—	—	—	—
			Sum =	**64.8**		2.58	**0.60**	—	—
			Average =	**16.2**			**0.15**	2.00	0.004
SS11	1	Lake	—	5.0	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
			Sum =	**20.0**		2.16	**0.20**	—	—
			Average =	**5.0**			**0.05**	0.67	0.005
SS12	1	Tundra	—	9.8	—	—	1.84	—	—
	2	Tundra	—	9.9	—	—	—	—	—
	3	Tundra	12.0	10.0	—	—	—	—	—
	4	Tundra	15.0	13.5	—	—	—	—	—
			Sum =	**43.2**		2.56	**0.72**	—	—
			Average =	**10.8**			**0.18**	2.40	0.008

Snow Sample #	Catchement Basin	Sample Type	Lat. (NAD 83)	Long. (NAD 83)
SS1	L9310	Core	N 70° 19' 48.16"	W 150° 55' 29.17"
SS2	L9310	Core	N 70° 19' 45.20"	W 150° 55' 21.51"
SS3	L9310	Core	N 70° 19' 54.42"	W 150° 55' 14.34"
SS4	L9310	Core	N 70° 19' 59.21"	W 150° 54' 55.73"
SS5	L9310	Core	N 70° 19' 55.07"	W 150° 55' 25.78"
SS6	L9310	Core	N 70° 20' 04.04"	W 150° 55' 13.85"
SS7	L9310	Core	N 70° 19' 51.0"	W 150° 55' 37.22"
SS8	L9310	Core	N 70° 19' 53.71"	W 150° 55' 45.77"
SS9	L9310	Core	N 70° 19' 42.33"	W 150° 55' 41.26"
SS10	L9310	Core	N 70° 19' 31.30"	W 150° 55' 53.88"
SS11	L9310	Core	N 70° 19' 47.06"	W 150° 55' 48.65"
SS12	L9310	Core	N 70° 19' 42.74"	W 150° 56' 14.87"
SS13	L9310	Depth	N 70° 19' 49.66"	W 150° 55' 32.95"
SS14	L9310	Depth	N 70° 19' 50.87"	W 150° 55' 28.32"
SS15	L9310	Depth	N 70° 19' 52.04"	W 150° 55' 23.60"
SS16	L9310	Depth	N 70° 19' 53.24"	W 150° 55' 18.97"
SS17	L9310	Depth	N 70° 19' 55.63"	W 150° 55' 09.71"
SS18	L9310	Depth	N 70° 19' 56.83"	W 150° 55' 05.08"
SS19	L9310	Depth	N 70° 19' 58.0"	W 150° 55' 00.36"
SS20	L9310	Depth	N 70° 19' 51.47"	W 150° 55' 30.56"
SS21	L9310	Depth	N 70° 19' 53.25"	W 150° 55' 28.17"
SS22	L9310	Depth	N 70° 19' 56.85"	W 150° 55' 23.40"
SS23	L9310	Depth	N 70° 19' 58.66"	W 150° 55' 21.01"
SS24	L9310	Depth	N 70° 20' 00.44"	W 150° 55' 18.62"
SS25	L9310	Depth	N 70° 20' 02.26"	W 150° 55' 16.23"
SS26	L9310	Depth	N 70° 20' 05.82"	W 150° 55' 11.46"
SS27	L9310	Depth	N 70° 19' 46.63"	W 150° 55' 25.20"
SS28	L9310	Depth	N 70° 19' 43.70"	W 150° 55' 17.73"
SS29	L9310	Depth	N 70° 19' 47.84"	W 150° 55' 35.05"
SS30	L9310	Depth	N 70° 19' 45.99"	W 150° 55' 37.15"
SS31	L9310	Depth	N 70° 19' 44.18"	W 150° 55' 39.16"
SS32	L9310	Depth	N 70° 19' 40.48"	W 150° 55' 43.37"
SS33	L9310	Depth	N 70° 19' 38.66"	W 150° 55' 45.47"
SS34	L9310	Depth	N 70° 19' 36.81"	W 150° 55' 47.57"
SS35	L9310	Depth	N 70° 19' 34.96"	W 150° 55' 49.68"
SS36	L9310	Depth	N 70° 19' 33.15"	W 150° 55' 51.78"
SS37	L9310	Depth	N 70° 19' 29.48"	W 150° 55' 55.89"
SS38	L9310	Depth	N 70° 19' 27.63"	W 150° 55' 57.99"
SS39	L9310	Depth	N 70° 19' 48.82"	W 150° 55' 38.21"
SS40	L9310	Depth	N 70° 19' 47.94"	W 150° 55' 43.38"
SS41	L9310	Depth	N 70° 19' 46.22"	W 150° 55' 53.91"
SS42	L9310	Depth	N 70° 19' 45.34"	W 150° 55' 59.17"
SS43	L9310	Depth	N 70° 19' 44.46"	W 150° 56' 04.44"
SS44	L9310	Depth	N 70° 19' 43.62"	W 150° 56' 09.61"
SS45	L9310	Depth	N 70° 19' 41.87"	W 150° 56' 20.14"
SS46	L9310	Depth	N 70° 19' 52.37"	W 150° 55' 41.49"

Snow Survey Data Sheet									
Date: 5/10/2007			**Start Time:** 13:00		**End Time:** 15:30		**Observers:** MDM, OOO		
Catchement Basin: L9312			**Driving Wrench Used:** Yes				**Tube Section Used:** 1		
Snow Sample No.	**Sample Type**	**Terrain Type**	**Snow Depth (in)**		**Core Length (in)**	**Tube & Core Weight (lb)**	**Empty Tube Weight (lb)**	**Water Equivalent (in)**	**Density (lb/in^3)**
			w/ Dirt Plug	**w/o Dirt Plug**					
SS47*	Core	Tundra	—	12.5	—	2.9	1.98	3.07	0.009
SS48*	Core	Lake	—	5.0	—	2.24	1.98	0.69	0.005
SS49*	Core	Tundra	—	11.1	—	2.24	1.96	0.93	0.003
SS50*	Core	Lake	—	4.7	—	2.26	1.96	0.80	0.006
SS51*	Core	Lake	—	8.0	—	2.68	1.96	1.92	0.009
SS52	Core	Tundra	15.5	13.5	—	2.12	1.96	2.14	0.006
SS53	Core	Tundra	17.2	14.2	—	2.22	1.98	3.20	0.008
SS54*	Core	Lake	—	7.2	—	2.74	1.96	2.08	0.010
SS55*	Core	Lake	—	4.0	—	2.14	1.96	0.48	0.004
SS56*	Core	Lake	—	4.1	—	2.3	1.96	0.91	0.008
SS57	Core	Tundra	17.2	16.7	—	2.3	1.98	4.27	0.009
SS58*	Core	Tundra	—	8.9	—	2.26	1.98	0.93	0.004
SS59	Core	Tundra	16.0	15.0	—	2.22	1.98	3.20	0.008
SS60*	Core	Tundra	—	12.4	—	2.56	1.98	1.94	0.006
SS61	Depth	Lake	—	8.4					
SS62	Depth	Lake	—	5.4					
SS63	Depth	Tundra	—	15.0					
SS64	Depth	Tundra	—	10.8					
SS65	Depth	Lake	—	9.6					
SS66	Depth	Lake	—	4.8					
SS67	Depth	Lake	—	3.8					
SS68	Depth	Lake	—	5.8					
SS69	Depth	Lake	—	4.8					
SS70	Depth	Lake	—	4.8					
SS71	Depth	Lake	—	5.0					
SS72	Depth	Lake	—	5.3					
SS73	Depth	Lake	—	7.0					
SS74	Depth	Lake	—	4.0					
SS75	Depth	Lake	—	4.8					
SS76	Depth	Lake	—	3.6					
SS77	Depth	Tundra	—	11.0					
SS78	Depth	Tundra	—	19.0					
SS79	Depth	Tundra	—	8.6					
SS80	Depth	Tundra	—	15.6					
SS81	Depth	Tundra	—	19.0					
SS82	Depth	Tundra	—	26.4					
SS83	Depth	Lake	—	4.6					
SS84	Depth	Lake	—	3.6					
SS85	Depth	Lake	—	4.8					
SS86	Depth	Tundra	—	7.4					
SS87	Depth	Tundra	—	4.8					
SS88	Depth	Lake	—	6.0					
SS89	Depth	Lake	—	4.1					
SS90	Depth	Tundra	—	6.0					
SS91	Depth	Tundra	—	9.6					
SS92	Depth	Lake	—	4.1					
SS93	Depth	Lake	—	3.8					
SS94	Depth	Lake	—	3.6					
SS95	Depth	Lake	—	5.4					
SS96	Depth	Lake	—	7.4					
SS97	Depth	Lake	—	8.3					
SS98	Depth	Tundra	—	13.2					
SS99	Depth	Tundra	—	13.2					
SS100	Depth	Tundra	—	10.8					
SS101	Depth	Tundra	—	9.6					
SS102	Depth	Tundra	—	8.4					
SS103	Depth	Tundra	—	13.6					
SS104	Depth	Tundra	—	5.4					

Snow Survey Calculations

Average Area:	Tundra =	4943536	ft^2
	Lake =	4860982	ft^2
Average SWE:	Tundra =	2.22	in
	Lake =	1.05	in
Average Snow Depth:	Tundra =	12.3	in
	Lake =	5.3	in
Average Density:	Tundra =	0.007	lb/in^3
	Lake =	0.007	lb/in^3
Catchement Basin Weighted SWE =		1.64	in

NOTES:

* Pooled sample measurement conducted, snow depth without dirt plug, SWE, and density represents the average of pooled samples.

Pooled Snow Survey Data Sheet									
Date: 5/10/2007			**Start Time:** 13:00		**End Time:** 15:30		**Observers:** MDM, OOO		
Catchement Basin: L9312			**Driving Wrench Used:** Yes				**Tube Section Used:** 1		
Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Core Length (in)**	**Bucket & Core Weight (lb)**	**Empty Bucket Weight (lb)**	**Water Equivalent (in)**	**Density (lb/in^3)**
			w/ Dirt Plug	**w/o Dirt Plug**					
SS47	1	Tundra	14	12.5	—	—	1.98	—	—
	2	Tundra	14	13.0	—	—	—	—	—
	3	Tundra	13.5	13.5	—	—	—	—	—
	4	Tundra	13	11.0	—	—	—	—	—
			Sum =	**50.0**		2.9	**0.92**	—	—
			Average =	**12.5**			**0.23**	3.07	0.009
SS48	1	Lake	—	4.8	—	—	1.98	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**24.8**		2.24	**0.26**	—	—
			Average =	**5.0**			**0.05**	0.69	0.005
SS49	1	Tundra	14	11.7	—	—	1.96	—	—
	2	Tundra	13.5	11.0	—	—	—	—	—
	3	Tundra	13	10.5	—	—	—	—	—
	4	Tundra	13	11.0	—	—	—	—	—
			Sum =	**44.2**		2.24	**0.28**	—	—
			Average =	**11.1**			**0.07**	0.93	0.003
SS50	1	Lake	—	4.8	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	4.6	—	—	—	—	—
	4	Lake	—	4.6	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**23.5**		2.26	**0.3**	—	—
			Average =	**4.7**			**0.06**	0.80	0.006
SS51	1	Lake	—	8.0	—	—	1.96	—	—
	2	Lake	—	8.0	—	—	—	—	—
	3	Lake	—	8.0	—	—	—	—	—
	4	Lake	—	8.0	—	—	—	—	—
	5	Lake	—	8.0	—	—	—	—	—
			Sum =	**40.0**		2.68	**0.72**	—	—
			Average =	**8.0**			**0.14**	1.92	0.009
SS54	1	Lake	—	7.0	—	—	1.96	—	—
	2	Lake	—	7.5	—	—	—	—	—
	3	Lake	—	7.5	—	—	—	—	—
	4	Lake	—	7.0	—	—	—	—	—
	5	Lake	—	7.0	—	—	—	—	—
			Sum =	**36.0**		2.74	**0.78**	—	—
			Average =	**7.2**			**0.16**	2.08	0.010
SS55	1	Lake	—	4.0	—	—	1.96	—	—
	2	Lake	—	4.0	—	—	—	—	—
	3	Lake	—	4.0	—	—	—	—	—
	4	Lake	—	4.0	—	—	—	—	—
	5	Lake	—	4.0	—	—	—	—	—
			Sum =	**20.0**		2.14	**0.18**	—	—
			Average =	**4.0**			**0.04**	0.48	0.004
SS56	1	Lake	—	4.0	—	—	1.96	—	—
	2	Lake	—	4.0	—	—	—	—	—
	3	Lake	—	4.2	—	—	—	—	—
	4	Lake	—	4.2	—	—	—	—	—
	5	Lake	—	4.2	—	—	—	—	—
			Sum =	**20.6**		2.3	**0.34**	—	—
			Average =	**4.1**			**0.07**	0.91	0.008
SS58	1	Tundra	11.5	9.0	—	—	1.98	—	—
	2	Tundra	11	9.0	—	—	—	—	—
	3	Tundra	11	9.0	—	—	—	—	—
	4	Tundra	11	8.5	—	—	—	—	—
			Sum =	**35.5**		2.26	**0.28**	—	—
			Average =	**8.9**			**0.07**	0.93	0.004
SS60	1	Tundra	12	11.0	—	—	1.98	—	—
	2	Tundra	13.5	13.0	—	—	—	—	—
	3	Tundra	13.5	12.5	—	—	—	—	—
	4	Tundra	13.6	13.0	—	—	—	—	—
			Sum =	**49.5**		2.56	**0.58**	—	—
			Average =	**12.4**			**0.15**	1.94	0.006

Snow Sample #	Catchement Basin	Sample Type	Lat. (NAD 83)	Long. (NAD 83)
SS47	L9312	Core	N 70° 20' 03.02"	W 150° 56' 11.68"
SS48	L9312	Core	N 70° 19' 58.24"	W 150° 56' 37.19"
SS49	L9312	Core	N 70° 19' 50.13"	W 150° 56' 31.39"
SS50	L9312	Core	N 70° 19' 52.70"	W 150° 56' 47.14"
SS51	L9312	Core	N 70° 19' 58.38"	W 150° 56' 57.60"
SS52	L9312	Core	N 70° 20' 04.26"	W 150° 56' 57.58"
SS53	L9312	Core	N 70° 19' 40.66"	W 150° 56' 58.51"
SS54	L9312	Core	N 70° 19' 48.53"	W 150° 56' 58.01"
SS55	L9312	Core	N 70° 19' 56.04"	W 150° 57' 08.28"
SS56	L9312	Core	N 70° 19' 50.96"	W 150° 57' 18.57"
SS57	L9312	Core	N 70° 19' 46.64"	W 150° 57' 44.79"
SS58	L9312	Core	N 70° 19' 58.45"	W 150° 57' 24.34"
SS59	L9312	Core	N 70° 19' 41.28"	W 150° 57' 59.42"
SS60	L9312	Core	N 70° 19' 46.98"	W 150° 58' 03.93"
SS61	L9312	Depth	N 70° 19' 51.0"	W 150° 56' 36.57"
SS62	L9312	Depth	N 70° 19' 51.87"	W 150° 56' 41.85"
SS63	L9312	Depth	N 70° 19' 36.72"	W 150° 56' 58.81"
SS64	L9312	Depth	N 70° 19' 38.69"	W 150° 56' 58.71"
SS65	L9312	Depth	N 70° 19' 42.63"	W 150° 56' 58.41"
SS66	L9312	Depth	N 70° 19' 44.59"	W 150° 56' 58.31"
SS67	L9312	Depth	N 70° 19' 46.56"	W 150° 56' 58.11"
SS68	L9312	Depth	N 70° 19' 50.50"	W 150° 56' 57.91"
SS69	L9312	Depth	N 70° 19' 52.47"	W 150° 56' 57.71"
SS70	L9312	Depth	N 70° 19' 54.44"	W 150° 56' 57.61"
SS71	L9312	Depth	N 70° 19' 53.57"	W 150° 56' 52.33"
SS72	L9312	Depth	N 70° 19' 55.38"	W 150° 56' 52.53"
SS73	L9312	Depth	N 70° 19' 56.32"	W 150° 56' 47.45"
SS74	L9312	Depth	N 70° 19' 57.30"	W 150° 56' 42.27"
SS75	L9312	Depth	N 70° 19' 59.19"	W 150° 56' 32.11"
SS76	L9312	Depth	N 70° 20' 00.16"	W 150° 56' 26.93"
SS77	L9312	Depth	N 70° 20' 01.10"	W 150° 56' 21.84"
SS78	L9312	Depth	N 70° 20' 02.05"	W 150° 56' 16.76"
SS79	L9312	Depth	N 70° 20' 03.96"	W 150° 56' 06.50"
SS80	L9312	Depth	N 70° 20' 04.91"	W 150° 56' 01.42"
SS81	L9312	Depth	N 70° 20' 05.88"	W 150° 55' 56.33"
SS82	L9312	Depth	N 70° 20' 06.82"	W 150° 55' 51.25"
SS83	L9312	Depth	N 70° 19' 56.41"	W 150° 56' 57.60"
SS84	L9312	Depth	N 70° 20' 00.35"	W 150° 56' 57.59"
SS85	L9312	Depth	N 70° 20' 02.29"	W 150° 56' 57.59"
SS86	L9312	Depth	N 70° 20' 06.23"	W 150° 56' 57.58"
SS87	L9312	Depth	N 70° 20' 08.13"	W 150° 56' 57.58"
SS88	L9312	Depth	N 70° 19' 55.24"	W 150° 57' 02.99"
SS89	L9312	Depth	N 70° 19' 56.85"	W 150° 57' 13.67"
SS90	L9312	Depth	N 70° 19' 57.62"	W 150° 57' 18.96"
SS91	L9312	Depth	N 70° 19' 59.22"	W 150° 57' 29.64"
SS92	L9312	Depth	N 70° 19' 53.56"	W 150° 57' 02.87"
SS93	L9312	Depth	N 70° 19' 52.72"	W 150° 57' 08.14"
SS94	L9312	Depth	N 70° 19' 51.84"	W 150° 57' 13.31"
SS95	L9312	Depth	N 70° 19' 50.12"	W 150° 57' 23.83"
SS96	L9312	Depth	N 70° 19' 49.24"	W 150° 57' 29.10"
SS97	L9312	Depth	N 70° 19' 48.36"	W 150° 57' 34.36"
SS98	L9312	Depth	N 70° 19' 47.52"	W 150° 57' 39.53"
SS99	L9312	Depth	N 70° 19' 45.76"	W 150° 57' 50.06"
SS100	L9312	Depth	N 70° 19' 44.92"	W 150° 57' 55.32"
SS101	L9312	Depth	N 70° 19' 43.17"	W 150° 58' 00.86"
SS102	L9312	Depth	N 70° 19' 39.36"	W 150° 57' 57.88"
SS103	L9312	Depth	N 70° 19' 45.06"	W 150° 58' 02.40"
SS104	L9312	Depth	N 70° 19' 48.87"	W 150° 58' 05.47"

Snow Survey Data Sheet									
Date:	5/10/2007		Start Time:	16:00	End Time:	18:00	Observers:	MDM, OOO	
Catchement Basin:		L9313	Driving Wrench Used:		Yes		Tube Section Used:		1
Snow Sample No.	Sample Type	Terrain Type	Snow Depth (in) w/ Dirt Plug	Snow Depth (in) w/o Dirt Plug	Core Length (in)	Tube & Core Weight (lb)	Empty Tube Weight (lb)	Water Equivalent (in)	Density (lb/in^3)
SS105*	Core	Lake	—	3.5	—	2.28	1.98	0.80	0.008
SS106	Core	Tundra	17.0	16.0	—	2.2	1.98	2.94	0.007
SS107*	Core	Lake	—	5.0	—	2.24	1.96	0.75	0.005
SS108*	Core	Tundra	—	6.9	—	2.16	2.02	0.47	0.002
SS109*	Core	Lake	—	7.2	—	2.4	1.96	1.17	0.006
SS110*	Core	Lake	—	8.5	—	2.98	2.12	2.30	0.010
SS111*	Core	Lake	—	5.1	—	2.34	1.98	0.96	0.007
SS112*	Core	Tundra	—	9.4	—	2.5	1.96	1.80	0.007
SS113*	Core	Lake	—	4.5	—	2.32	1.96	0.96	0.008
SS114*	Core	Lake	—	4.4	—	2.28	1.96	0.85	0.007
SS115*	Core	Lake	—	5.0	—	2.34	1.96	1.01	0.007
SS116*	Core	Tundra	—	10.0	—	2.54	1.98	1.87	0.007
SS117	Depth	Lake	—	6.4					
SS118	Depth	Lake	—	8.4					
SS119	Depth	Lake	—	10.2					
SS120	Depth	Lake	—	7.8					
SS121	Depth	Lake	—	6.6					
SS122	Depth	Lake	—	7.3					
SS123	Depth	Lake	—	7.3					
SS124	Depth	Lake	—	8.4					
SS125	Depth	Lake	—	14.6					
SS126	Depth	Tundra	—	9.8					
SS127	Depth	Lake	—	6.6					
SS128	Depth	Lake	—	4.2					
SS129	Depth	Tundra	—	12.6					
SS130	Depth	Tundra	—	12.6					
SS131	Depth	Lake	—	4.2					
SS132	Depth	Lake	—	3.6					
SS133	Depth	Lake	—	4.2					
SS134	Depth	Tundra	—	12.0					
SS135	Depth	Tundra	—	14.2					
SS136	Depth	Lake	—	4.8					
SS137	Depth	Lake	—	7.8					
SS138	Depth	Lake	—	6.0					
SS139	Depth	Lake	—	4.8					
SS140	Depth	Lake	—	4.2					
SS141	Depth	Lake	—	5.4					
SS142	Depth	Lake	—	4.8					
SS143	Depth	Tundra	—	20.6					
SS144	Depth	Lake	—	4.2					
SS145	Depth	Lake	—	3.6					
SS146	Depth	Lake	—	7.2					
SS147	Depth	Tundra	—	14.6					
SS148	Depth	Tundra	—	18.6					
SS149	Depth	Tundra	—	19.8					
SS150	Depth	Tundra	—	16.6					
SS151	Depth	Lake	—	6.2					

Snow Survey Calculations

Average Area: Tundra = 3131338 ft^2
Lake = 3382142 ft^2

Average SWE: Tundra = 2.18 in
Lake = 1.23 in

Average Snow Depth: Tundra = 13.8 in
Lake = 6.1 in

Average Density: Tundra = 0.006 lb/in^3
Lake = 0.007 lb/in^3

Catchement Basin Weighted SWE = 1.69 in

NOTES:

* Pooled sample measurement conducted, snow depth without dirt plug, SWE, and density represents the average of pooled samples.

Pooled Snow Survey Data Sheet									
Date: 5/10/2007			**Start Time:** 16:00		**End Time:** 18:00		**Observers:** MDM, OOO		
Catchement Basin: L9313			**Driving Wrench Used:** Yes				**Tube Section Used:** 1		
Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Core Length (in)**	**Bucket & Core Weight (lb)**	**Empty Bucket Weight (lb)**	**Water Equivalent (in)**	**Density (lb/in^3)**
			w/ Dirt Plug	**w/o Dirt Plug**					
SS105	1	Lake	—	3.5	—	—	1.98	—	—
	2	Lake	—	3.5	—	—	—	—	—
	3	Lake	—	3.5	—	—	—	—	—
	4	Lake	—	3.5	—	—	—	—	—
	5	Lake	—	3.5	—	—	—	—	—
			Sum =	**17.5**		2.28	**0.3**	—	—
			Average =	**3.5**			**0.06**	0.80	0.008
SS107	1	Lake	—	4.5	—	—	1.96	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	5.5	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.5	—	—	—	—	—
			Sum =	**25.0**		2.24	**0.28**	—	—
			Average =	**5.0**			**0.06**	0.75	0.005
SS108	1	Tundra	9	8.5	—	—	2.02	—	—
	2	Tundra	8.5	8.0	—	—	—	—	—
	3	Tundra	8.5	5.5	—	—	—	—	—
	4	Tundra	8.5	5.5	—	—	—	—	—
			Sum =	**27.5**		2.16	**0.14**	—	—
			Average =	**6.9**			**0.04**	0.47	0.002
SS109	1	Lake	—	7.5	—	—	1.96	—	—
	2	Lake	—	7.0	—	—	—	—	—
	3	Lake	—	7.0	—	—	—	—	—
	4	Lake	—	7.5	—	—	—	—	—
	5	Lake	—	7.0	—	—	—	—	—
			Sum =	**36.0**		2.4	**0.44**	—	—
			Average =	**7.2**			**0.09**	1.17	0.006
SS110	1	Lake	—	8.5	—	—	2.12	—	—
	2	Lake	—	8.5	—	—	—	—	—
	3	Lake	—	8.5	—	—	—	—	—
	4	Lake	—	8.5	—	—	—	—	—
	5	Lake	—	8.5	—	—	—	—	—
			Sum =	**42.5**		2.98	**0.86**	—	—
			Average =	**8.5**			**0.17**	2.30	0.010
SS111	1	Lake	—	5.0	—	—	1.98	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.5	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**25.5**		2.34	**0.36**	—	—
			Average =	**5.1**			**0.07**	0.96	0.007
SS112	1	Tundra	12.5	10.5	—	—	1.96	—	—
	2	Tundra	11.5	9.5	—	—	—	—	—
	3	Tundra	11	9.5	—	—	—	—	—
	4	Tundra	11	8.0	—	—	—	—	—
			Sum =	**37.5**		2.5	**0.54**	—	—
			Average =	**9.4**			**0.14**	1.80	0.007
SS113	1	Lake	—	4.5	—	—	1.96	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	4.5	—	—	—	—	—
	4	Lake	—	4.5	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**22.5**		2.32	**0.36**	—	—
			Average =	**4.5**			**0.07**	0.96	0.008
SS114	1	Lake	—	4.5	—	—	1.96	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	4.5	—	—	—	—	—
	4	Lake	—	4.5	—	—	—	—	—
	5	Lake	—	4.0	—	—	—	—	—
			Sum =	**22.0**		2.28	**0.32**	—	—
			Average =	**4.4**			**0.06**	0.85	0.007
SS115	1	Lake	—	5.0	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**25.0**		2.34	**0.38**	—	—
			Average =	**5.0**			**0.08**	1.01	0.007
SS116	1	Tundra	14	13.0	—	—	1.98	—	—
	2	Tundra	10	9.0	—	—	—	—	—
	3	Tundra	10	8.0	—	—	—	—	—
	4	Tundra	12	10.0	—	—	—	—	—
			Sum =	**40.0**		2.54	**0.56**	—	—
			Average =	**10.0**			**0.14**	1.87	0.007

Snow Sample #	Catchement Basin	Sample Type	Lat. (NAD 83)	Long. (NAD 83)
SS105	L9313	Core	N 70° 20' 30.42"	W 150° 56' 40.96"
SS106	L9313	Core	N 70° 20' 29.81"	W 150° 56' 58.38"
SS107	L9313	Core	N 70° 20' 34.95"	W 150° 56' 21.99"
SS108	L9313	Core	N 70° 20' 40.80"	W 150° 56' 19.77"
SS109	L9313	Core	N 70° 20' 34.72"	W 150° 56' 09.83"
SS110	L9313	Core	N 70° 20' 38.40"	W 150° 55' 56.12"
SS111	L9313	Core	N 70° 20' 31.77"	W 150° 56' 12.04"
SS112	L9313	Core	N 70° 20' 32.86"	W 150° 55' 54.76"
SS113	L9313	Core	N 70° 20' 27.11"	W 150° 56' 36.59"
SS114	L9313	Core	N 70° 20' 21.88"	W 150° 56' 54.0"
SS115	L9313	Core	N 70° 20' 27.14"	W 150° 56' 24.98"
SS116	L9313	Core	N 70° 20' 21.29"	W 150° 56' 27.30"
SS117	L9313	Depth	N 70° 20' 31.42"	W 150° 56' 17.74"
SS118	L9313	Depth	N 70° 20' 32.12"	W 150° 56' 06.25"
SS119	L9313	Depth	N 70° 20' 32.48"	W 150° 56' 00.56"
SS120	L9313	Depth	N 70° 20' 32.27"	W 150° 56' 18.90"
SS121	L9313	Depth	N 70° 20' 33.51"	W 150° 56' 14.36"
SS122	L9313	Depth	N 70° 20' 35.95"	W 150° 56' 05.19"
SS123	L9313	Depth	N 70° 20' 37.16"	W 150° 56' 00.66"
SS124	L9313	Depth	N 70° 20' 39.64"	W 150° 55' 51.48"
SS125	L9313	Depth	N 70° 20' 40.85"	W 150° 55' 46.95"
SS126	L9313	Depth	N 70° 20' 42.09"	W 150° 55' 42.41"
SS127	L9313	Depth	N 70° 20' 32.99"	W 150° 56' 22.76"
SS128	L9313	Depth	N 70° 20' 36.91"	W 150° 56' 21.21"
SS129	L9313	Depth	N 70° 20' 38.84"	W 150° 56' 20.44"
SS130	L9313	Depth	N 70° 20' 42.77"	W 150° 56' 18.99"
SS131	L9313	Depth	N 70° 20' 29.10"	W 150° 56' 24.21"
SS132	L9313	Depth	N 70° 20' 25.21"	W 150° 56' 25.75"
SS133	L9313	Depth	N 70° 20' 23.25"	W 150° 56' 26.52"
SS134	L9313	Depth	N 70° 20' 19.36"	W 150° 56' 27.97"
SS135	L9313	Depth	N 70° 20' 17.39"	W 150° 56' 28.74"
SS136	L9313	Depth	N 70° 20' 29.72"	W 150° 56' 27.89"
SS137	L9313	Depth	N 70° 20' 28.42"	W 150° 56' 32.24"
SS138	L9313	Depth	N 70° 20' 25.80"	W 150° 56' 40.94"
SS139	L9313	Depth	N 70° 20' 24.49"	W 150° 56' 45.29"
SS140	L9313	Depth	N 70° 20' 23.19"	W 150° 56' 49.65"
SS141	L9313	Depth	N 70° 20' 20.57"	W 150° 56' 58.35"
SS142	L9313	Depth	N 70° 20' 19.27"	W 150° 57' 02.70"
SS143	L9313	Depth	N 70° 20' 17.93"	W 150° 57' 07.05"
SS144	L9313	Depth	N 70° 20' 30.84"	W 150° 56' 29.31"
SS145	L9313	Depth	N 70° 20' 30.65"	W 150° 56' 35.18"
SS146	L9313	Depth	N 70° 20' 30.23"	W 150° 56' 46.73"
SS147	L9313	Depth	N 70° 20' 30.0"	W 150° 56' 52.61"
SS148	L9313	Depth	N 70° 20' 29.59"	W 150° 57' 04.16"
SS149	L9313	Depth	N 70° 20' 29.39"	W 150° 57' 10.03"
SS150	L9313	Depth	N 70° 20' 29.17"	W 150° 57' 15.81"
SS151	L9313	Depth	N 70° 20' 31.06"	W 150° 56' 23.53"