Table 4-8: 2008 – 2009 Study Area Water Level

Station	2008				2009					
	Aug	Sep	Oct	Nov - Apr	May	Jun	Jul	Aug	Sep	Oct
Thor Lake Level[1]										
Mean	0.321	0.304	0.353	nm	nm	0.441	0.415	0.340	0.341	0.361
Maximum	0.374	0.377	0.386	nm	nm	0.468	0.465	0.386	0.377	0.391
Minimum	0.279	0.257	0.304	nm	nm	0.411	0.353	0.282	0.273	0.332
Thor Lake Outlet[2]										
Mean	0.030	0.029	0.044	nm	0.213	0.456	0.466	0.203	0.250	0.401
Maximum	0.056	0.053	0.061	nm	0.226	0.575	0.546	0.343	0.411	0.415
Minimum	0.016	0.017	0.032	nm	0.191	0.217	0.328	0.129	0.147	0.384
Beaver Dam Level at Thor Lake[3]										
Mean	0.483	0.474	0.524	nm	0.706	0.646	0.619	0.562	0.570	0.598
Maximum	0.512	0.520	0.543	nm	0.742	0.742	0.669	0.608	0.616	0.613
Minimum	0.461	0.450	0.509	nm	0.656	0.591	0.558	0.526	0.536	0.581
Fred Lake Outlet[4]										
Mean	0.159	0.167	0.193	nm	0.372	0.507	0.463	0.261	0.264	0.309
Maximum	0.172	0.193	0.206	nm	0.388	0.561	0.560	0.324	0.321	0.323
Minimum	0.152	0.152	0.185	nm	0.361	0.377	0.311	0.238	0.243	0.289
Murky Lake Outlet[5]										
Maximum	–	0.109	0.123	nm	0.390	0.408	0.415	0.415	0.238	0.241
Mean	–	0.099	0.101	nm	0.348	0.331	0.286	0.286	0.173	0.225
Minimum	–	0.091	0.091	nm	0.323	0.238	0.180	0.180	0.124	0.212
Long Lake Outlet[6]										
Mean	0.192	0.178	0.223	nm	0.207	0.209	0.214	0.109	0.112	0.132
Maximum	0.223	0.219	0.240	nm	0.222	0.273	0.280	0.148	0.153	0.141
Minimum	0.167	0.156	0.207	nm	0.196	0.167	0.132	0.086	0.076	0.116
Long Lake Level[7]										
Mean	0.238	0.228	0.280	nm	0.311	0.316	0.314	0.206	0.212	0.234
Maximum	0.267	0.275	0.302	nm	0.327	0.548	0.380	0.250	0.255	0.246
Minimum	0.208	0.200	0.262	nm	0.297	0.269	0.230	0.171	0.170	0.223
Elbow Lake Level[8]										
Mean	–	–	–	–	–	0.425	0.396	0.328	0.318	0.322
Maximum	–	–	–	–	–	0.452	0.442	0.361	0.368	0.334
Minimum	–	–	–	–	–	0.410	0.343	0.300	0.272	0.309

Station	2008				2009					
	Aug	Sep	Oct	Nov - Apr	May	Jun	Jul	Aug	Sep	Oct
Cressy Lake Level[9]										
Mean	–	–	–	–	0.410	0.416	0.486	0.457	0.468	0.479
Maximum	–	–	–	–	0.422	0.495	0.515	0.480	0.504	0.489
Minimum	–	–	–	–	0.399	0.377	0.457	0.431	0.434	0.463

NOTES:
nm = no measurements at station
– = no station established
Dates of Operation:
1 – 8/10/08 – 10/10/08; 6/27/09 – 10/8/09
2 – 8/14/08 – 10/10/08; 5/26/09 – 10/8/09
3 – 8/14/08 – 10/9/08; 5/27/09 – 10/5/09
4 – 8/11/08 – 10/8/08; 5/26/09 – 10/8/09
5 – 9/25/08 – 10/8/08; 5/24/09 – 10/5/09
6 – 8/12/08 – 10/9/08; 5/27/09 – 10/5/09
7 – 8/12/08 – 10/9/08; 5/27/09 – 10/5/09
8 – 6/25/09 – 10/4/09
9 – 5/26/09 – 10/5/09

Table 4-9: 2008 – 2009 Study Area Discharge

	Month										
	Aug	Sep	Oct	Nov-Apr		May	Jun	Jul	Aug	Sep	Oct
Murky Lake Outlet											
Mean	–	0.004	0.004	nm	nm	0.097	0.090	0.071	0.071	0.023	0.045
Maximum	–	0.008	0.014	nm	nm	0.115	0.123	0.126	0.126	0.051	0.052
Minimum	–	0.000	0.000	nm	nm	0.087	0.051	0.026	0.026	0.003	0.040
Fred Lake Outlet											
Mean	0.005	0.010	0.025	nm	nm	0.068	0.200	0.165	0.008	0.014	0.050
Maximum	0.013	0.025	0.030	nm	nm	0.081	0.245	0.244	0.053	0.060	0.062
Minimum	0.001	0.001	0.021	nm	nm	0.059	0.072	0.043	0.000	0.000	0.034
Thor Lake Outlet											
Mean	0.0002	0.0002	0.0002	nm	nm	0.153	0.283	0.289	0.139	0.166	0.252
Maximum	0.0003	0.0003	0.0003	nm	nm	0.152	0.351	0.334	0.219	0.257	0.260
Minimum	0.0001	0.0001	0.0002	nm	nm	0.132	0.147	0.210	0.096	0.107	0.242

NOTES:
– = no station established
nm = no measurements at station

Table 4-10: 2008 – 2009 Study Area Stream Gauge Sites

Station	Date	Time	Discharge (m^3/s)	Stage (m)
Beaver Dam at Thor Lake	9-Oct-08	18:00	0.0013	0.548
	27-May-09	18:30	0.0350	0.675
	24-Jun-09	11:30	0.0594	0.678
Murky Lake Outlet	7-Oct-08	16:45	0.0026	0.103
	26-May-09	18:00	0.0719	0.335
	27-Jun-09	11:00	0.1274	0.372
	5-Oct-09	11:00	0.0344	0.232
Long Lake Outlet	9-Oct-08	16:45	0.0117	0.210
	27-May-09	16:30	0.0035	0.235
	24-Jun-09	10:45	0.0345	0.272
Thor Lake Outlet	9-Aug-08	8:20	0.0011	–
	12-Aug-08	14:00	0.0004	–
	14-Aug-08	14:25	0.0002	0.009
	24-Sep-08	15:30	0.0001	0.004
	26-Sep-08	8:30	0.0002	0.007
	7-Oct-08	16:45	0.0001	0.001
	9-Oct-08	12:15	0.0002	0.010
	26-May-09	10:00	0.1682	0.186
	28-May-09	16:30	0.1250	0.185
	26-Jun-09	16:45	0.3087	0.530
	27-Jun-09	18:30	0.3670	0.535
	3-Oct-09	15:45	0.1728	0.364
Fred Lake Outlet	12-Aug-08	15:50	0.0015	0.176
	8-Oct-08	17:30	0.0022	0.198
	26-May-09	14:45	0.0516	0.348
	28-May-09	18:30	0.0676	0.346
	26-Jun-09	18:00	0.2169	0.515
	3-Oct-09	17:00	0.0343	0.278

NOTE:
– Stage not established

Table 5-1: Regional Climate Data Stations

Station	Location			Years of Record*	Data
	Lat.	Long	Elevation (masl)		
Inner Whalebacks	61° 55.200' N	113° 43.800' W	165.2	1994 – 2009 (15)	T, R, S, W, G
Yellowknife A	62° 27.600' N	114° 26.400' W	205.7	1942 – 2009 (67)	T, P, R, S, SoG, W, G
Lutselk'e A	62° 25.200' N	110° 40.800' W	181.7	1999 – 2009 (10)	T, P, R, S, SoG
Fort Resolution A	61° 10.800' N	113° 41.400' W	160.3	1930 – 2009 (79)	T, P, R, S
Pine Point	60° 52.200' N	114° 22.200' W	224.0	1953 – 1965; 1975 – 1988 (25)	T, P, R, S, SoG
Fort Reliance (Aut)	62° 42.600' N	109° 10.200' W	167.6	1948 – 1991; 1996 – 2007 (54)	T, P, R, S, SoG
Camp Station	62° 07.290' N	112° 35.976' W	238.0	2008 – 2009	T, R, SoG, W, G

NOTES:
T = Temperature (°C)
P = Precipitation (mm)
R = Rainfall (mm)
S = Snowfall (cm)
SoG = Snow of Ground (cm)
W = Wind
G = Gust
*Some years may be partial years
Data available from Environment Canada

Table 5-2: Regional Annual Data Summary

Station	Location			Years of Record	Temperature (°C)		Precipitation (mm)			Rain (mm)			Snow Water Equivalent (mm)[2]		
	Lat.	Long.	Elevation (masl)		Max	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
Inner Whalebacks[1]	61° 55.200' N	113° 43.800' W	165.2	1994 – 2009 (15)	26.9	-38.8	188.5	166.4	0.0	161.1	108.0	0.0	70.5	64.6	0.0
Yellowknife A	62° 27.600' N	114° 26.400' W	205.7	1942 – 2009 (67)	32.5	-51.1	422.0	268.6	156.0	263.0	155.2	65.3	223.0	138.4	39.3
Lutselk'e A	62° 25.200' N	110° 40.800' W	181.7	1999 – 2009 (10)	31.5	-47.0	355.5	298.6	193.5	231.7	171.9	107.5	153.0	138.4	103.9
Fort Resolution A	61° 10.800' N	113° 41.400' W	160.3	1930 – 2009 (79)	35.0	-51.1	469.4	305.4	8.9	295.2	169.5	0.0	322.9	148.8	8.9
Pine Point[1]	60° 52.200' N	114° 22.200' W	224.0	1953 – 1965; 1975 – 1988 (25)	34.0	-51.0	488.9	326.3	48.5	289.3	199.0	0.0	199.6	127.3	0.0
Fort Reliance[1]	62° 42.600' N	109° 10.200' W	167.6	1948 – 1991; 1996 – 2007 (54)	34.3	-53.5	446.6	265.1	5.7	326.4	157.7	0.0	237.6	130.7	0.0

NOTES:
[1] - Data gaps in precipitation/rain/snow record
[2] - Estimate based on 10% density
masl - meters above sea level
°C - degrees Celsius
mm - millimeter

Table 5-3: Regional Monthly Temperatures

Station	Years of Record		Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inner Whalebacks	1994 – 2009	Maximum	2.1	-0.7	8.7	19.1	21.9	24.8	26.8	26.9	18.8	12.9	26.9	2.8
		Mean	-21.3	-20.9	-16.4	-4.2	1.7	9.0	14.0	11.8	6.1	1.1	-6.8	-16.8
		Minimum	-38.8	-37.2	-37.4	-28.7	-23.4	0.1	4.2	-6.0	-13.8	-15.6	-38.8	-35.3
Yellowknife A	1942 – 2009	Maximum	3.4	6.2	9.3	20.3	26.1	30.3	32.5	30.9	26.1	19.0	7.8	2.8
		Mean	-27.3	-24.3	-17.8	-6.4	4.7	12.9	16.5	14.1	7.0	-1.5	-13.7	-23.2
		Minimum	-51.1	-51.1	-43.3	-40.6	-22.8	-4.4	0.6	-0.6	-9.7	-28.9	-44.4	-48.3
Lutselk'e A	1999 – 2009	Maximum	3.0	4.0	14.0	14.5	26.0	31.0	31.5	31.0	23.1	18.5	4.5	2.0
		Mean	-24.3	-23.2	-17.1	-6.6	2.0	11.5	15.7	12.4	6.9	-2.1	-10.9	-19.7
		Minimum	-47.0	-44.5	-43.5	-32.0	-23.0	-5.5	-1.0	-3.5	-7.0	-30.0	-41.0	-41.0
Fort Resolution A	1930 – 2009	Maximum	5.0	9.4	12.0	23.5	30.9	31.7	35.0	33.0	27.2	22.6	8.9	9.5
		Mean	-25.4	-22.4	-16.1	-4.4	5.6	12.4	15.8	13.9	7.3	-0.1	-10.9	-20.7
		Minimum	-51.1	-48.9	-43.9	-37.2	-22.0	-6.0	-0.6	-3.3	-8.3	-26.0	-39.4	-46.7
Pine Point	1953 – 1965; 1975 – 1988	Maximum	9.5	10.5	14.0	22.5	29.5	31.7	33.5	34.0	24.4	19.5	16.0	10.0
		Mean	-21.3	-21.9	-14.1	-2.3	6.6	13.1	16.0	14.4	8.0	0.8	-11.3	-19.7
		Minimum	-51.0	-46.5	-43.5	-36.7	-33.9	-4.0	1.5	-5.0	-10.6	-24.0	-38.5	-45.6
Fort Reliance	1948 – 1991; 1996 – 2007	Maximum	2.1	6.1	10.1	18.4	26.1	29.4	34.3	32.7	27.2	17.9	6.7	4.1
		Mean	-28.5	-26.1	-20.8	-9.0	1.6	9.5	14.2	13.0	6.8	-2.0	-13.8	-23.3
		Minimum	-53.5	-51.1	-50.0	-41.1	-31.1	-7.2	-0.6	0.0	-7.8	-22.8	-43.3	-45.7

NOTES:
All values in degrees Celsius
Data from Environment Canada

Table 5-4: Regional Monthly Precipitation

Station	Years of Record		Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inner Whalebacks	1994 – 2009	Maximum	26.7	43.8	26.7	12.7	28.6	59.8	51.9	66.5	42.9	63.1	20.8	14.0
		Mean	8.9	14.6	9.6	5.2	10.8	14.7	25.6	29.0	12.8	19.7	8.6	7.0
		Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0
		% Distribution	5.3	8.8	5.7	3.1	6.5	8.8	15.4	17.5	7.7	11.8	5.2	4.2
Yellowknife A	1942 – 2009	Maximum	39.4	31.8	48.0	25.9	60.2	71.7	107.4	141.5	83.5	93.0	47.2	50.0
		Mean	14.0	12.5	12.7	10.6	17.2	22.0	36.1	39.6	31.8	31.3	23.6	17.3
		Minimum	0.0	1.6	0.8	0.0	0.0	0.5	4.1	4.0	3.3	5.3	2.5	4.3
		% Distribution	5.2	4.6	4.7	3.9	6.4	8.2	13.4	14.7	11.8	11.7	8.8	6.4
Lutselk'e A	1999 – 2009	Maximum	32.0	21.3	17.4	21.4	38.6	44.4	80.1	101.6	53.0	51.2	44.8	21.0
		Mean	14.5	10.2	12.8	9.1	20.7	19.8	38.9	60.0	36.0	27.9	32.9	15.9
		Minimum	4.7	1.6	4.6	2.2	1.0	0.0	6.9	19.8	22.2	12.0	21.6	7.5
		% Distribution	4.9	3.4	4.3	3.0	6.9	6.6	13.0	20.1	12.0	9.3	11.0	5.3
Fort Resolution A	1930 – 2009	Maximum	40.1	56.1	47.5	39.9	56.1	92.0	135.9	100.8	95.8	83.2	95.9	69.9
		Mean	16.0	12.5	12.3	12.1	17.1	25.6	37.3	36.7	39.9	36.4	40.3	19.2
		Minimum	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	10.2	6.4	12.8	0.0
		% Distribution	5.2	4.1	4.0	4.0	5.6	8.4	12.2	12.0	13.1	11.9	13.2	6.3
Pine Point	1953 – 1965; 1975 – 1988	Maximum	47.7	26.2	22.1	14.8	37.1	50.5	112.3	133.4	60.7	76.7	62.2	58.7
		Mean	20.6	11.2	13.3	5.6	21.1	29.1	37.8	60.4	35.8	33.1	36.9	21.4
		Minimum	0.6	0.3	2.4	0.4	1.7	3.8	14.2	5.1	15.7	3.2	6.6	5.6
		% Distribution	6.3	3.4	4.1	1.7	6.5	8.9	11.6	18.5	11.0	10.2	11.3	6.5
Fort Reliance	1948 – 1991; 1996 – 2007	Maximum	34.7	26.4	41.1	36.8	49.1	113.0	120.0	122.4	72.6	67.5	55.1	42.2
		Mean	12.3	10.8	11.3	13.2	15.5	28.9	36.3	43.4	30.4	27.3	21.2	14.4
		Minimum	1.6	1.6	0.9	1.8	0.0	3.4	0.3	5.5	4.6	4.3	6.2	3.3
		% Distribution	4.6	4.1	4.3	5.0	5.8	10.9	13.7	16.4	11.5	10.3	8.0	5.4

NOTES:
All values in millimeters
Data from Environment Canada

Table 5-5: Regional Monthly Rainfall

Station	Years of Record		Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inner Whalebacks	1994 - 2009	Maximum	0.0	0.0	0.0	8.2	28.6	59.8	51.9	66.5	42.9	19.4	12.0	0.0
		Mean	0.0	0.0	0.0	2.1	8.5	14.7	25.6	32.5	12.6	9.7	2.4	0.0
		Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		% Distribution	0.0	0.0	0.0	1.9	7.9	13.6	23.7	30.1	11.7	9.0	2.2	0.0
Yellowknife A	1942 - 2009	Maximum	5.4	0.8	3.4	14.4	55.6	71.7	107.4	141.5	73.4	52.8	10.8	4.4
		Mean	0.1	0.0	0.1	2.1	13.4	21.8	36.1	39.6	28.5	12.7	0.7	0.1
		Minimum	0.0	0.0	0.0	0.0	0.0	0.5	4.1	4.0	2.0	0.0	0.0	0.0
		% Distribution	0.1	0.0	0.1	1.3	8.7	14.1	23.3	25.5	18.3	8.2	0.4	0.1
Lutselk'e A	1999 - 2009	Maximum	0.0	0.0	0.0	6.6	27.0	44.4	80.1	101.6	53.0	13.6	0.7	0.0
		Mean	0.0	0.0	0.0	1.7	11.3	19.8	38.9	60.0	33.0	7.1	0.1	0.0
		Minimum	0.0	0.0	0.0	0.0	0.0	0.0	6.9	19.8	22.2	0.0	0.0	0.0
		% Distribution	0.0	0.0	0.0	1.0	6.6	11.5	22.6	34.9	19.2	4.1	0.1	0.0
Fort Resolution A	1930 - 2009	Maximum	0.0	0.6	2.6	33.3	42.3	92.0	135.9	100.8	94.5	44.4	5.4	1.8
		Mean	0.0	0.0	0.1	3.8	14.0	25.4	37.3	36.7	37.6	14.3	0.3	0.0
		Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0
		% Distribution	0.0	0.0	0.1	2.2	8.3	15.0	22.0	21.6	22.2	8.4	0.2	0.0
Pine Point	1953 - 1965; 1975 - 1988	Maximum	0.0	0.0	0.0	3.6	35.2	50.5	112.3	133.4	60.7	37.7	3.8	0.0
		Mean	0.0	0.0	0.0	0.6	18.0	29.1	37.8	60.4	34.9	17.9	0.3	0.0
		Minimum	0.0	0.0	0.0	0.0	0.0	3.8	14.2	5.1	13.6	2.5	0.0	0.0
		% Distribution	0.0	0.0	0.0	0.3	9.0	14.6	19.0	30.4	17.5	9.0	0.2	0.0
Fort Reliance	1948 - 1991; 1996 - 2007	Maximum	0.8	0.0	19.0	10.4	35.9	97.3	120.0	122.4	72.6	56.6	8.4	0.8
		Mean	0.0	0.0	0.4	1.9	9.5	27.9	36.3	43.4	27.5	10.3	0.4	0.0
		Minimum	0.0	0.0	0.0	0.0	0.0	3.3	0.3	5.5	3.8	0.0	0.0	0.0
		% Distribution	0.0	0.0	0.3	1.2	6.0	17.7	23.0	27.5	17.5	6.5	0.2	0.0

NOTES:
All data in millimeters
Data from Environment Canad

Table 5-6: Regional Monthly Snow Water Equivalent[1]

Station	Years of Record		Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inner Whalebacks	1994 - 2009	Maximum	26.7	43.8	26.7	12.7	11.3	0.0	0.0	0.0	0.7	25.8	20.8	14.0
		Mean	9.2	14.6	9.6	3.2	2.3	0.0	0.0	0.0	0.2	10.0	8.6	7.0
		Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
		% Distribution	14.3	22.6	14.8	4.9	3.5	0.0	0.0	0.0	0.3	15.4	13.3	10.8
Yellowknife A	1942 - 2009	Maximum	40.4	45.0	51.0	28.4	21.2	3.3	0.0	1.4	19.1	61.7	85.6	60.7
		Mean	17.2	15.9	15.6	9.6	3.8	0.1	0.0	0.0	3.1	20.3	30.6	22.1
		Minimum	0.0	2.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.5	4.3
		% Distribution	12.4	11.5	11.3	7.0	2.8	0.1	0.0	0.0	2.2	14.7	22.1	15.9
Lutselk'e A	1999 - 2009	Maximum	36.2	20.9	24.8	16.0	28.0	0.0	0.0	0.0	13.2	35.4	48.4	23.3
		Mean	16.7	11.1	14.0	7.6	9.2	0.0	0.0	0.0	3.0	21.4	38.5	17.1
		Minimum	3.8	3.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	8.8	24.4	9.5
		% Distribution	12.0	8.0	10.1	5.5	6.6	0.0	0.0	0.0	2.1	15.4	27.8	12.3
Fort Resolution A	1930 - 2009	Maximum	63.0	72.6	54.4	32.8	30.2	10.7	0.0	0.0	20.2	65.3	131.8	69.9
		Mean	18.2	14.2	13.7	8.9	3.1	0.2	0.0	0.0	2.2	22.6	45.4	20.3
		Minimum	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2	3.8
		% Distribution	12.2	9.5	9.2	6.0	2.1	0.1	0.0	0.0	1.5	15.2	30.5	13.7
Pine Point	1953 - 1965; 1975 - 1988	Maximum	47.7	26.2	22.1	11.2	22.6	0.0	0.0	0.0	7.9	47.2	62.2	58.7
		Mean	20.6	11.2	13.3	5.0	3.1	0.0	0.0	0.0	0.9	15.3	36.5	21.4
		Minimum	0.6	0.3	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.7	6.6	5.6
		% Distribution	16.2	8.8	10.5	4.0	2.4	0.0	0.0	0.0	0.7	12.0	28.6	16.8
Fort Reliance	1948 - 1991; 1996 - 2007	Maximum	35.4	40.3	48.8	36.6	29.1	15.2	0.0	0.0	41.1	56.4	67.8	51.8
		Mean	15.5	14.0	13.6	13.2	5.9	1.0	0.0	0.0	3.2	20.0	25.9	18.4
		Minimum	1.8	2.1	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.8	7.0	3.3
		% Distribution	11.9	10.7	10.4	10.1	4.5	0.7	0.0	0.0	2.4	15.3	19.8	14.1

NOTES:
1 - Estimates based on assumption of 10% snow density
All values in millimeters
Data from Environment Canada

APPENDIX B

Snow Pit Summary

Study Area Snow Pit Summary, 2009

<table>
<tr><th>Depth (cm)</th><th>Temp (°C)</th><th>Layer</th><th>Layer Depth (cm)</th><th>Layer Thickness</th><th>Snow Mass (g)</th><th>Density</th></tr>
<tr><td colspan="7">Snow Pit 1 – Weather Station</td></tr>
<tr><td>55</td><td>-13</td><td>9</td><td>51 – 55</td><td>4</td><td>40.7</td><td>0.12</td></tr>
<tr><td>50</td><td>-12</td><td>8</td><td>49 – 51</td><td>2</td><td>–</td><td>–</td></tr>
<tr><td>45</td><td>-12</td><td rowspan="2">7</td><td rowspan="2">36 – 49</td><td rowspan="2">13</td><td rowspan="2">68.6</td><td rowspan="2">0.20</td></tr>
<tr><td>40</td><td>-11</td></tr>
<tr><td>35</td><td>-11</td><td>6</td><td>30 – 36</td><td>6</td><td>–</td><td>–</td></tr>
<tr><td>30</td><td>-10</td><td>5</td><td>26 – 30</td><td>4</td><td>–</td><td>–</td></tr>
<tr><td>25</td><td>-9</td><td rowspan="2">4</td><td rowspan="2">16 – 26</td><td rowspan="2">10</td><td rowspan="2">101.0</td><td rowspan="2">0.29</td></tr>
<tr><td>20</td><td>-8</td></tr>
<tr><td>15</td><td>-7</td><td>3</td><td>10- 16</td><td>6</td><td>–</td><td>–</td></tr>
<tr><td>10</td><td>-6</td><td>2</td><td>4 – 10</td><td>6</td><td>101.8</td><td>0.30</td></tr>
<tr><td>5</td><td>-4</td><td rowspan="2">1</td><td rowspan="2">0 – 4</td><td rowspan="2">4</td><td rowspan="2">98.1</td><td rowspan="2">0.29</td></tr>
<tr><td>0</td><td>-4</td></tr>
<tr><td colspan="7">Snow Pit 2 – Thor Lake</td></tr>
<tr><td>55</td><td>-16</td><td>7</td><td>50 – 55</td><td>5</td><td>26.7</td><td>0.08</td></tr>
<tr><td>50</td><td>-14</td><td rowspan="2">6</td><td rowspan="2">40 – 50</td><td rowspan="2">10</td><td rowspan="2">–</td><td rowspan="2">–</td></tr>
<tr><td>45</td><td>-12</td></tr>
<tr><td>40</td><td>-11</td><td>5</td><td>35 – 40</td><td>5</td><td>87.5</td><td>0.26</td></tr>
<tr><td>35</td><td>-10</td><td rowspan="2">4</td><td rowspan="2">25 – 35</td><td rowspan="2">10</td><td rowspan="2">105.5</td><td rowspan="2">0.31</td></tr>
<tr><td>30</td><td>-9</td></tr>
<tr><td>25</td><td>-7</td><td rowspan="2">3</td><td rowspan="2">15 – 25</td><td rowspan="2">10</td><td rowspan="2">100.2</td><td rowspan="2">0.29</td></tr>
<tr><td>20</td><td>-5</td></tr>
<tr><td>15</td><td>-4</td><td rowspan="2">2</td><td rowspan="2">5 – 15</td><td rowspan="2">10</td><td rowspan="2">126.2</td><td rowspan="2">0.37</td></tr>
<tr><td>10</td><td>-3</td></tr>
<tr><td>5</td><td>-3</td><td rowspan="2">1</td><td rowspan="2">0 – 5</td><td rowspan="2">5</td><td rowspan="2">94.8</td><td rowspan="2">0.28</td></tr>
<tr><td>0</td><td>-3</td></tr>
<tr><td colspan="7">Snow Pit 3 – Dense forest between Thor and Long Lakes</td></tr>
<tr><td>77.5</td><td>–</td><td>6</td><td>69 – 77.5</td><td>8.5</td><td>19.6</td><td>0.07</td></tr>
<tr><td>70</td><td>-12</td><td>5</td><td>61 – 69</td><td>8</td><td>54.6</td><td>0.20</td></tr>
<tr><td>60</td><td>-11</td><td>4</td><td>53 – 61</td><td>8</td><td>71.2</td><td>0.26</td></tr>
<tr><td>50</td><td>-10</td><td rowspan="3">3</td><td rowspan="3">24 – 53</td><td rowspan="3">29</td><td rowspan="3">76.0</td><td rowspan="3">0.28</td></tr>
<tr><td>40</td><td>-9</td></tr>
<tr><td>30</td><td>-8</td></tr>
<tr><td>20</td><td>-8</td><td>2</td><td>11 – 24</td><td>13</td><td>95.0</td><td>0.34</td></tr>
<tr><td>10</td><td>-7</td><td rowspan="2">1</td><td rowspan="2">0 – 11</td><td rowspan="2">11</td><td rowspan="2">96.2</td><td rowspan="2">0.35</td></tr>
<tr><td>0</td><td>-6</td></tr>
</table>

Depth (cm)	Temp (°C)	Layer	Layer Depth (cm)	Layer Thickness	Snow Mass (g)	Density
Snow Pit 4 – Slope above Great Slave Lake landing						
63	-13	5	50 – 63	13	33.8	0.11
60	-10					
50	-8	4	43 – 50	7	65.8	0.21
40	-6	3	30 – 43	13	87.0	0.27
30	-5	2	11 – 30	29	82.6	0.26
20	-4					
10	-3	1	0 – 11	11	110.9	0.35
0	-2					

APPENDIX C

Snow Sensor Data

Snow Sensor Data

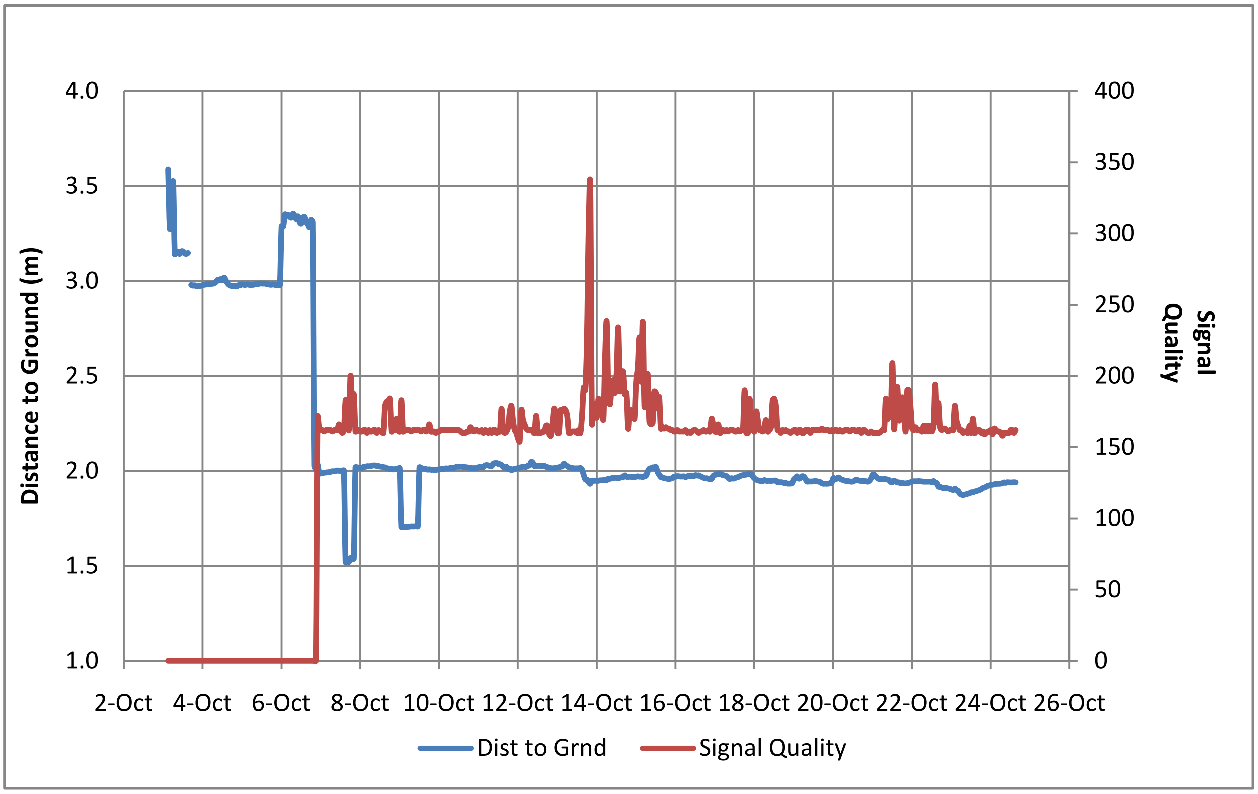
Analysis of the 2008-2009 snow sensor data indicated that the sensor was not recording accurate information. This was attributed to three reasons. First, data noise was common in the data record because of vegetation beneath the sensor. Secondly, the area beneath the sensor was disturbed during the winter and the snowpack was compacted. Finally, the sensor was positioned above its ideal operational elevation when installed in June 2008 resulting in less accurate measurements. As a result, the snow sensor data from the winter of 2008 – 2009 were not reportable.

As noted above, the snow sensor was repositioned in October 2009 to 2.06 m above ground, which is within the ideal operational elevation range (0.5 – 2.5 m above ground) of the sensor. A snowboard was installed beneath the sensor to provide a consistent ground elevation. Finally, the program was updated to include a sensor quality measurement parameter.

Snow sensor data, including sensor distance above ground and signal quality from October 3 to 24 2009, are listed in Table C-1. Signal quality readings between 160 and 210 are of good quality, readings greater than 210 are less desirable.

Figure C-1 depicts the temporal sequence of the sensor record during this period. The data demonstrate the sequence of sensor testing and the high quality of the sensor data. This plot shows the changes in the height of the snowboard during the period October 6 to October 9. Variability in the signal quality is related to changes in the snowboard position or snow accumulation (after October 10th). With the exception of the period October 14 – 15, the signal quality of the sensor data is all relatively strong. The poorer signal quality from October 14 to 15th reflects a snow fall event and a gradual accumulation of a few centimeters of snow. Signal quality values tend to worsen during snow events or when the surface beneath the sensor is disturbed.

Figure C-1: Snow Sensor Readings October 2009



Blue lines are sensor distance to ground and reflects snow accumulation; Red lines represent signal quality (see text for details)

Table C-1: Snow Sensor Data, October 2009

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/3/2009 3:10	3.588	-	
10/3/2009 4:10	3.275	-	
10/3/2009 5:10	3.281	-	
10/3/2009 6:10	3.525	-	
10/3/2009 7:10	3.142	-	
10/3/2009 8:10	3.152	-	
10/3/2009 9:10	3.153	-	
10/3/2009 10:10	3.143	-	
10/3/2009 11:10	3.156	-	
10/3/2009 12:10	3.156	-	
10/3/2009 13:10	3.146	-	
10/3/2009 14:10	3.143	-	
10/3/2009 15:10	3.148	-	
10/3/2009 16:10		-	Box (0.33m height) placed beneath sensor
10/3/2009 17:10	2.98	-	
10/3/2009 18:10	2.976	-	
10/3/2009 19:10	2.978	-	
10/3/2009 20:10	2.974	-	
10/3/2009 21:10	2.973	-	
10/3/2009 22:10	2.974	-	
10/3/2009 23:10	2.976	-	
10/4/2009 0:10	2.979	-	
10/4/2009 1:10	2.981	-	
10/4/2009 2:10	2.982	-	
10/4/2009 3:10	2.985	-	
10/4/2009 4:10	2.983	-	
10/4/2009 5:10	2.986	-	
10/4/2009 6:10	2.986	-	
10/4/2009 7:10	2.989	-	
10/4/2009 8:10	2.995	-	
10/4/2009 9:10	3.006	-	
10/4/2009 10:10	3.004	-	
10/4/2009 11:10	3.011	-	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/4/2009 12:10	3.005	-	
10/4/2009 13:10	3.018	-	
10/4/2009 14:10	3.003	-	
10/4/2009 15:10	2.989	-	
10/4/2009 16:10	2.98	-	
10/4/2009 17:10	2.976	-	
10/4/2009 18:10	2.974	-	
10/4/2009 19:10	2.976	-	
10/4/2009 20:10	2.972	-	
10/4/2009 21:10	2.973	-	
10/4/2009 22:10	2.979	-	
10/4/2009 23:10	2.979	-	
10/5/2009 0:10	2.983	-	
10/5/2009 1:10	2.981	-	
10/5/2009 2:10	2.98	-	
10/5/2009 3:10	2.983	-	
10/5/2009 4:10	2.981	-	
10/5/2009 5:10	2.98	-	
10/5/2009 6:10	2.98	-	
10/5/2009 7:10	2.981	-	
10/5/2009 8:10	2.983	-	
10/5/2009 9:10	2.985	-	
10/5/2009 10:10	2.985	-	
10/5/2009 11:10	2.988	-	
10/5/2009 12:10	2.987	-	
10/5/2009 13:10	2.987	-	
10/5/2009 14:10	2.987	-	
10/5/2009 15:10	2.984	-	
10/5/2009 16:10	2.983	-	
10/5/2009 17:10	2.981	-	
10/5/2009 18:10	2.981	-	
10/5/2009 19:10	2.983	-	
10/5/2009 20:10	2.98	-	
10/5/2009 21:10	2.98	-	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/5/2009 22:10	2.979	-	
10/5/2009 23:10	2.98	-	
10/6/2009 0:10	3.288	-	Removed box beneath sensor
10/6/2009 1:10	3.287	-	
10/6/2009 2:10	3.351	-	
10/6/2009 3:10	3.345	-	
10/6/2009 4:10	3.349	-	
10/6/2009 5:10	3.338	-	
10/6/2009 6:10	3.335	-	
10/6/2009 7:10	3.355	-	
10/6/2009 8:10	3.343	-	
10/6/2009 9:10	3.326	-	
10/6/2009 10:10	3.341	-	
10/6/2009 11:10	3.309	-	
10/6/2009 12:10	3.303	-	
10/6/2009 13:10	3.335	-	
10/6/2009 14:10	3.337	-	Sensor height measured to 3.35m above ground
10/6/2009 15:10	3.311	-	
10/6/2009 16:10	3.298	-	
10/6/2009 17:10	3.284	-	
10/6/2009 18:10	3.323	-	
10/6/2009 19:10	3.31	-	
10/6/2009 20:10	2.029	-	Lowered sensor to 2.06m above ground
10/6/2009 21:10	2.009	-	
10/6/2009 22:10	2.034	171	Changed program - added Msmt 2 to Msg 4; changed sensor height expression to 2.06m
10/6/2009 23:10	1.988	162	Snowboard under sensor
10/7/2009 0:10	1.988	162	
10/7/2009 1:10	1.989	162	
10/7/2009 2:10	1.991	161	
10/7/2009 3:10	1.992	162	
10/7/2009 4:10	1.993	162	
10/7/2009 5:10	1.994	162	
10/7/2009 6:10	1.996	162	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/7/2009 7:10	1.999	161	
10/7/2009 8:10	1.998	162	
10/7/2009 9:10	2	162	
10/7/2009 10:10	2.003	162	
10/7/2009 11:10	2.001	166	
10/7/2009 12:10	2.001	162	
10/7/2009 13:10	2.002	160	
10/7/2009 14:10	2.002	162	
10/7/2009 15:10	1.52	183	Raised snowboard to 1.512m below sensor
10/7/2009 16:10	1.52	182	
10/7/2009 17:10	1.521	162	
10/7/2009 18:10	1.542	200	
10/7/2009 19:10	1.536	180	
10/7/2009 20:10	1.539	187	Returned to sensor - snowboard blown off supports (likely between 17:00-18:00 UTC) - snowboard was sticking up (off nadir) below sensor which explains the poorer signal quality
10/7/2009 21:10	2.019	161	Returned snowboard to ground, 2.02m below sensor
10/7/2009 22:10	2.019	162	
10/7/2009 23:10	2.018	162	
10/8/2009 0:10	2.017	161	
10/8/2009 1:10	2.017	161	
10/8/2009 2:10	2.022	162	
10/8/2009 3:10	2.022	162	
10/8/2009 4:10	2.025	160	
10/8/2009 5:10	2.025	162	
10/8/2009 6:10	2.025	161	
10/8/2009 7:10	2.028	161	
10/8/2009 8:10	2.029	162	
10/8/2009 9:10	2.029	162	
10/8/2009 10:10	2.026	160	
10/8/2009 11:10	2.026	162	
10/8/2009 12:10	2.023	161	
10/8/2009 13:10	2.023	161	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/8/2009 14:10	2.02	160	
10/8/2009 15:10	2.019	179	
10/8/2009 16:10	2.015	182	
10/8/2009 17:10	2.013	182	
10/8/2009 18:10	2.01	184	
10/8/2009 19:10	2.011	161	
10/8/2009 20:10	2.008	162	
10/8/2009 21:10	2.01	162	
10/8/2009 22:10	2.01	170	
10/8/2009 23:10	2.012	162	
10/9/2009 0:10	2.015	161	
10/9/2009 1:10	1.705	183	Raised snowboard to 1.70m below sensor
10/9/2009 2:10	1.705	161	
10/9/2009 3:10	1.705	162	
10/9/2009 4:10	1.705	162	
10/9/2009 5:10	1.706	162	
10/9/2009 6:10	1.707	162	
10/9/2009 7:10	1.708	161	
10/9/2009 8:10	1.708	162	
10/9/2009 9:10	1.708	162	
10/9/2009 10:10	1.71	162	
10/9/2009 11:10	1.709	162	
10/9/2009 12:10	2.019	162	Returned snowboard to ground, 2.02m below sensor
10/9/09 13:10	2.016	161	
10/9/09 14:10	2.013	162	
10/9/09 15:10	2.012	162	
10/9/09 16:10	2.01	161	
10/9/09 17:10	2.007	162	
10/9/09 18:10	2.009	166	
10/9/09 19:10	2.006	161	
10/9/09 20:10	2.007	161	
10/9/09 21:10	2.005	161	
10/9/09 22:10	2.005	160	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/9/09 23:10	2.008	161	
10/10/09 0:10	2.008	161	
10/10/09 1:10	2.01	162	
10/10/09 2:10	2.011	162	
10/10/09 3:10	2.011	162	
10/10/09 4:10	2.014	162	
10/10/09 5:10	2.013	162	
10/10/09 6:10	2.014	162	
10/10/09 7:10	2.016	162	
10/10/09 8:10	2.015	162	
10/10/09 9:10	2.017	162	
10/10/09 10:10	2.02	162	
10/10/09 11:10	2.023	162	
10/10/09 12:10	2.022	162	
10/10/09 13:10	2.023	161	
10/10/09 14:10	2.022	160	
10/10/09 15:10	2.021	160	
10/10/09 16:10	2.02	160	
10/10/09 17:10	2.019	161	
10/10/09 18:10	2.017	161	
10/10/09 19:10	2.016	164	
10/10/09 20:10	2.015	162	
10/10/09 21:10	2.015	161	
10/10/09 22:10	2.015	162	
10/10/09 23:10	2.016	162	
10/11/09 0:10	2.02	161	
10/11/09 1:10	2.021	161	
10/11/09 2:10	2.02	162	
10/11/09 3:10	2.021	160	
10/11/09 4:10	2.029	162	
10/11/09 5:10	2.031	161	
10/11/09 6:10	2.029	160	
10/11/09 7:10	2.026	162	
10/11/09 8:10	2.026	160	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/11/09 9:10	2.039	162	
10/11/09 10:10	2.041	162	
10/11/09 11:10	2.042	160	
10/11/09 12:10	2.037	161	
10/11/09 13:10	2.036	161	
10/11/09 14:10	2.031	177	
10/11/09 15:10	2.021	161	
10/11/09 16:10	2.018	160	
10/11/09 17:10	2.022	161	
10/11/09 18:10	2.01	164	
10/11/09 19:10	2.013	175	
10/11/09 20:10	2.004	179	
10/11/09 21:10	2.009	168	
10/11/09 22:10	2.011	162	
10/11/09 23:10	2.013	160	
10/12/09 0:10	2.015	156	
10/12/09 1:10	2.018	154	
10/12/09 2:10	2.02	176	
10/12/09 3:10	2.023	169	
10/12/09 4:10	2.022	166	
10/12/09 5:10	2.022	163	
10/12/09 6:10	2.028	162	
10/12/09 7:10	2.03	162	
10/12/09 8:10	2.048	162	
10/12/09 9:10	2.043	161	
10/12/09 10:10	2.026	160	
10/12/09 11:10	2.025	172	
10/12/09 12:10	2.028	160	
10/12/09 13:10	2.027	160	
10/12/09 14:10	2.026	160	
10/12/09 15:10	2.027	161	
10/12/09 16:10	2.027	161	
10/12/09 17:10	2.022	165	
10/12/09 18:10	2.02	165	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/12/09 19:10	2.017	159	
10/12/09 20:10	2.015	158	
10/12/09 21:10	2.014	166	
10/12/09 22:10	2.015	177	
10/12/09 23:10	2.016	173	
10/13/09 0:10	2.018	160	
10/13/09 1:10	2.019	160	
10/13/09 2:10	2.024	176	
10/13/09 3:10	2.024	175	
10/13/09 4:10	2.038	177	
10/13/09 5:10	2.031	176	
10/13/09 6:10	2.026	172	
10/13/09 7:10	2.02	160	
10/13/09 8:10	2.018	160	
10/13/09 9:10	2.016	161	
10/13/09 10:10	2.014	161	
10/13/09 11:10	2.014	161	
10/13/09 12:10	2.014	160	
10/13/09 13:10	2.014	162	
10/13/09 14:10	2.016	160	
10/13/09 15:10	2.007	172	
10/13/09 16:10	1.98	192	
10/13/09 17:10	1.956	190	
10/13/09 18:10	1.955	226	
10/13/09 19:10	1.942	302	
10/13/09 20:10	1.933	334	
10/13/09 21:10	1.949	167	
10/13/09 22:10	1.948	180	
10/13/09 23:10	1.95	174	
10/14/09 0:10	1.948	171	
10/14/09 1:10	1.949	184	
10/14/09 2:10	1.951	177	
10/14/09 3:10	1.951	182	
10/14/09 4:10	1.952	170	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/14/09 5:10	1.952	213	
10/14/09 6:10	1.952	238	
10/14/09 7:10	1.96	186	
10/14/09 8:10	1.959	180	
10/14/09 9:10	1.962	194	
10/14/09 10:10	1.964	197	
10/14/09 11:10	1.964	188	
10/14/09 12:10	1.965	202	
10/14/09 13:10	1.961	234	
10/14/09 14:10	1.965	190	
10/14/09 15:10	1.967	203	
10/14/09 16:10	1.968	203	
10/14/09 17:10	1.977	187	
10/14/09 18:10	1.97	188	
10/14/09 19:10	1.969	163	
10/14/09 20:10	1.97	176	
10/14/09 21:10	1.969	173	
10/14/09 22:10	1.968	172	
10/14/09 23:10	1.969	170	
10/15/09 0:10	1.97	196	
10/15/09 1:10	1.972	206	
10/15/09 2:10	1.97	227	
10/15/09 3:10	1.971	196	
10/15/09 4:10	1.968	238	
10/15/09 5:10	1.973	179	
10/15/09 6:10	1.975	187	
10/15/09 7:10	1.997	201	
10/15/09 8:10	2.012	168	
10/15/09 9:10	2.013	166	
10/15/09 10:10	2.019	167	
10/15/09 11:10	2.018	189	
10/15/09 12:10	2.021	188	
10/15/09 13:10	1.995	177	
10/15/09 14:10	1.981	185	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/15/09 15:10	1.968	163	
10/15/09 16:10	1.966	164	
10/15/09 17:10	1.962	163	
10/15/09 18:10	1.961	164	
10/15/09 19:10	1.959	163	
10/15/09 20:10	1.958	163	
10/15/09 21:10	1.96	162	
10/15/09 22:10	1.963	162	
10/15/09 23:10	1.97	161	
10/16/09 0:10	1.97	161	
10/16/09 1:10	1.973	162	
10/16/09 2:10	1.972	161	
10/16/09 3:10	1.971	161	
10/16/09 4:10	1.971	161	
10/16/09 5:10	1.972	161	
10/16/09 6:10	1.968	162	
10/16/09 7:10	1.972	160	
10/16/09 8:10	1.974	161	
10/16/09 9:10	1.974	160	
10/16/09 10:10	1.973	161	
10/16/09 11:10	1.973	162	
10/16/09 12:10	1.978	162	
10/16/09 13:10	1.976	161	
10/16/09 14:10	1.977	160	
10/16/09 15:10	1.972	161	
10/16/09 16:10	1.968	161	
10/16/09 17:10	1.964	162	
10/16/09 18:10	1.961	161	
10/16/09 19:10	1.962	161	
10/16/09 20:10	1.959	162	
10/16/09 21:10	1.958	161	
10/16/09 22:10	1.959	170	
10/16/09 23:10	1.975	165	
10/17/09 0:10	1.979	161	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/17/09 1:10	1.985	161	
10/17/09 2:10	1.985	166	
10/17/09 3:10	1.988	160	
10/17/09 4:10	1.981	162	
10/17/09 5:10	1.978	162	
10/17/09 6:10	1.976	161	
10/17/09 7:10	1.973	162	
10/17/09 8:10	1.964	161	
10/17/09 9:10	1.958	162	
10/17/09 10:10	1.962	162	
10/17/09 11:10	1.96	162	
10/17/09 12:10	1.962	161	
10/17/09 13:10	1.966	161	
10/17/09 14:10	1.968	162	
10/17/09 15:10	1.972	161	
10/17/09 16:10	1.976	162	
10/17/09 17:10	1.978	162	
10/17/09 18:10	1.98	190	
10/17/09 19:10	1.981	160	
10/17/09 20:10	1.984	160	
10/17/09 21:10	1.985	184	
10/17/09 22:10	1.984	164	
10/17/09 23:10	1.971	162	
10/18/09 0:10	1.961	161	
10/18/09 1:10	1.955	175	
10/18/09 2:10	1.951	169	
10/18/09 3:10	1.949	162	
10/18/09 4:10	1.947	162	
10/18/09 5:10	1.947	161	
10/18/09 6:10	1.952	164	
10/18/09 7:10	1.949	169	
10/18/09 8:10	1.948	161	
10/18/09 9:10	1.949	162	
10/18/09 10:10	1.948	164	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/18/09 11:10	1.949	183	
10/18/09 12:10	1.95	184	
10/18/09 13:10	1.949	179	
10/18/09 14:10	1.941	162	
10/18/09 15:10	1.941	162	
10/18/09 16:10	1.941	160	
10/18/09 17:10	1.94	162	
10/18/09 18:10	1.937	161	
10/18/09 19:10	1.937	162	
10/18/09 20:10	1.934	161	
10/18/09 21:10	1.934	161	
10/18/09 22:10	1.934	160	
10/18/09 23:10	1.937	161	
10/19/09 0:10	1.956	162	
10/19/09 1:10	1.964	162	
10/19/09 2:10	1.972	160	
10/19/09 3:10	1.96	162	
10/19/09 4:10	1.963	162	
10/19/09 5:10	1.972	160	
10/19/09 6:10	1.971	160	
10/19/09 7:10	1.96	162	
10/19/09 8:10	1.945	162	
10/19/09 9:10	1.945	162	
10/19/09 10:10	1.945	160	
10/19/09 11:10	1.945	162	
10/19/09 12:10	1.946	162	
10/19/09 13:10	1.947	162	
10/19/09 14:10	1.946	162	
10/19/09 15:10	1.944	162	
10/19/09 16:10	1.942	162	
10/19/09 17:10	1.936	163	
10/19/09 18:10	1.933	162	
10/19/09 19:10	1.934	162	
10/19/09 20:10	1.933	162	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/19/09 21:10	1.934	162	
10/19/09 22:10	1.935	161	
10/19/09 23:10	1.939	162	
10/20/09 0:10	1.962	161	
10/20/09 1:10	1.959	162	
10/20/09 2:10	1.959	162	
10/20/09 3:10	1.966	161	
10/20/09 4:10	1.96	162	
10/20/09 5:10	1.955	161	
10/20/09 6:10	1.952	161	
10/20/09 7:10	1.949	162	
10/20/09 8:10	1.948	162	
10/20/09 9:10	1.947	162	
10/20/09 10:10	1.945	161	
10/20/09 11:10	1.944	162	
10/20/09 12:10	1.945	162	
10/20/09 13:10	1.95	162	
10/20/09 14:10	1.955	161	
10/20/09 15:10	1.951	162	
10/20/09 16:10	1.949	162	
10/20/09 17:10	1.948	160	
10/20/09 18:10	1.948	162	
10/20/09 19:10	1.947	162	
10/20/09 20:10	1.946	161	
10/20/09 21:10	1.944	160	
10/20/09 22:10	1.949	160	
10/20/09 23:10	1.961	161	
10/21/09 0:10	1.98	160	
10/21/09 1:10	1.98	160	
10/21/09 2:10	1.971	160	
10/21/09 3:10	1.962	160	
10/21/09 4:10	1.958	160	
10/21/09 5:10	1.958	161	
10/21/09 6:10	1.956	162	

Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/21/09 7:10	1.958	162	
10/21/09 8:10	1.957	184	
10/21/09 9:10	1.955	170	
10/21/09 10:10	1.952	174	
10/21/09 11:10	1.942	173	
10/21/09 12:10	1.941	209	
10/21/09 13:10	1.949	163	
10/21/09 14:10	1.945	184	
10/21/09 15:10	1.94	192	
10/21/09 16:10	1.94	169	
10/21/09 17:10	1.936	177	
10/21/09 18:10	1.937	185	
10/21/09 19:10	1.935	180	
10/21/09 20:10	1.935	161	
10/21/09 21:10	1.936	190	
10/21/09 22:10	1.938	190	
10/21/09 23:10	1.941	178	
10/22/09 0:10	1.944	163	
10/22/09 1:10	1.946	162	
10/22/09 2:10	1.946	164	
10/22/09 3:10	1.946	162	
10/22/09 4:10	1.947	162	
10/22/09 5:10	1.946	162	
10/22/09 6:10	1.945	161	
10/22/09 7:10	1.944	165	
10/22/09 8:10	1.944	161	
10/22/09 9:10	1.944	165	
10/22/09 10:10	1.944	161	
10/22/09 11:10	1.944	165	
10/22/09 12:10	1.942	161	
10/22/09 13:10	1.947	165	
10/22/09 14:10	1.939	194	
10/22/09 15:10	1.936	168	
10/22/09 16:10	1.918	181	

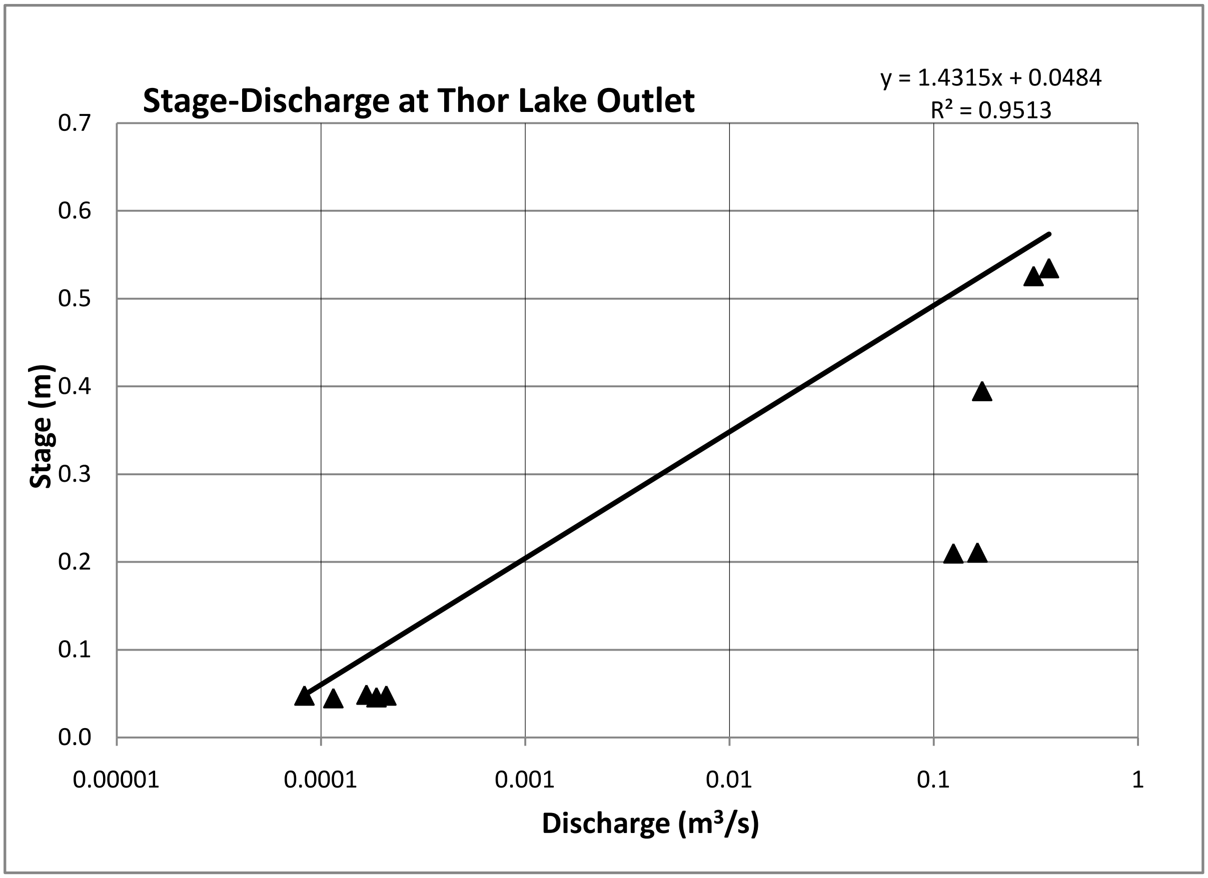
Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/22/09 17:10	1.917	164	
10/22/09 18:10	1.913	162	
10/22/09 19:10	1.91	163	
10/22/09 20:10	1.91	163	
10/22/09 21:10	1.91	162	
10/22/09 22:10	1.908	161	
10/22/09 23:10	1.906	162	
10/23/09 0:10	1.903	162	
10/23/09 1:10	1.9	162	
10/23/09 2:10	1.907	179	
10/23/09 3:10	1.9	169	
10/23/09 4:10	1.895	165	
10/23/09 5:10	1.881	162	
10/23/09 6:10	1.876	162	
10/23/09 7:10	1.874	160	
10/23/09 8:10	1.876	161	
10/23/09 9:10	1.878	161	
10/23/09 10:10	1.881	160	
10/23/09 11:10	1.883	165	
10/23/09 12:10	1.888	160	
10/23/09 13:10	1.888	170	
10/23/09 14:10	1.892	160	
10/23/09 15:10	1.894	162	
10/23/09 16:10	1.897	162	
10/23/09 17:10	1.9	162	
10/23/09 18:10	1.904	160	
10/23/09 19:10	1.91	161	
10/23/09 20:10	1.913	159	
10/23/09 21:10	1.917	160	
10/23/09 22:10	1.922	161	
10/23/09 23:10	1.924	161	
10/24/09 0:10	1.927	162	
10/24/09 1:10	1.928	159	
10/24/09 2:10	1.93	163	

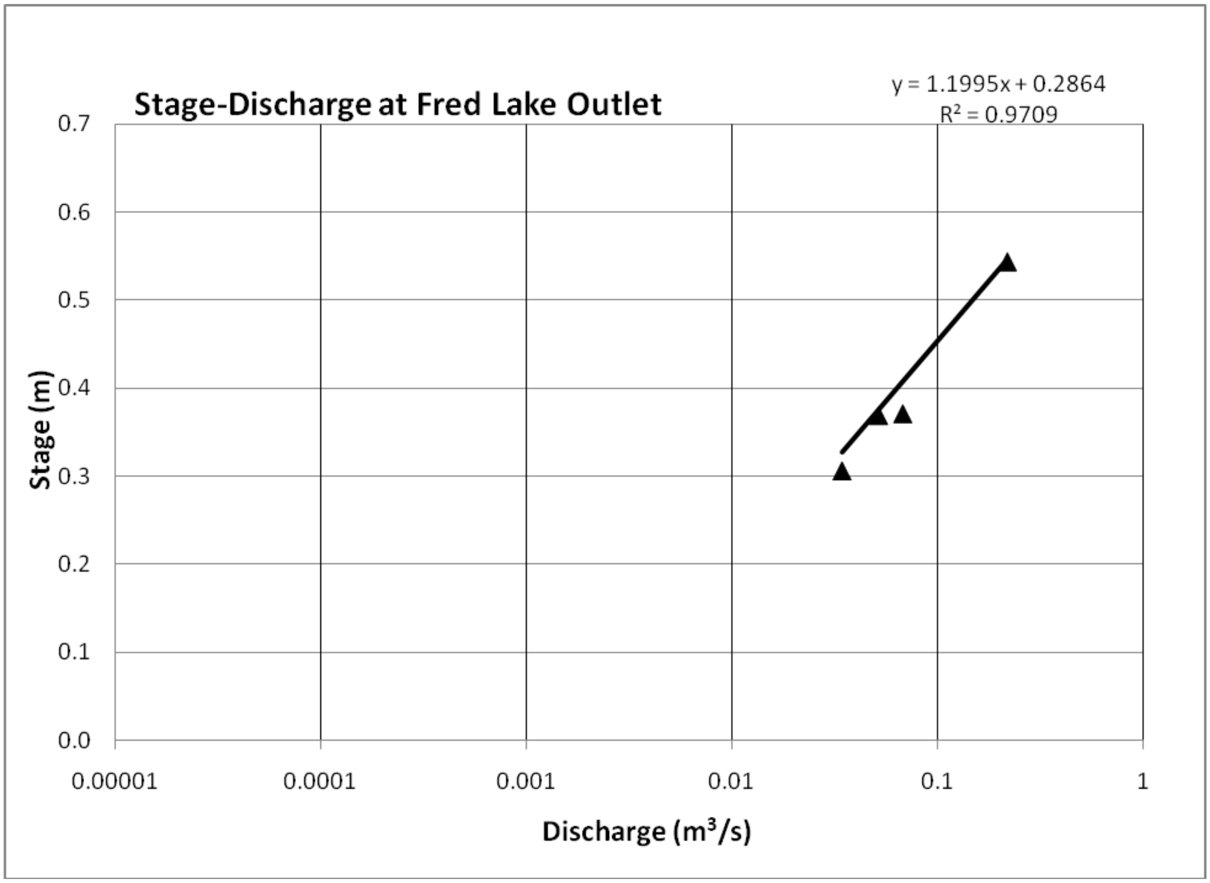
Date/Time (UTC)	Distance to Ground (m)	Signal Quality	Comments
10/24/09 3:10	1.932	162	
10/24/09 4:10	1.933	161	
10/24/09 5:10	1.933	161	
10/24/09 6:10	1.934	160	
10/24/09 7:10	1.936	158	
10/24/09 8:10	1.94	160	
10/24/09 9:10	1.938	160	
10/24/09 10:10	1.941	160	
10/24/09 11:10	1.94	160	
10/24/09 12:10	1.94	162	
10/24/09 13:10	1.94	162	
10/24/09 14:10	1.941	160	
10/24/09 15:10	1.94	162	

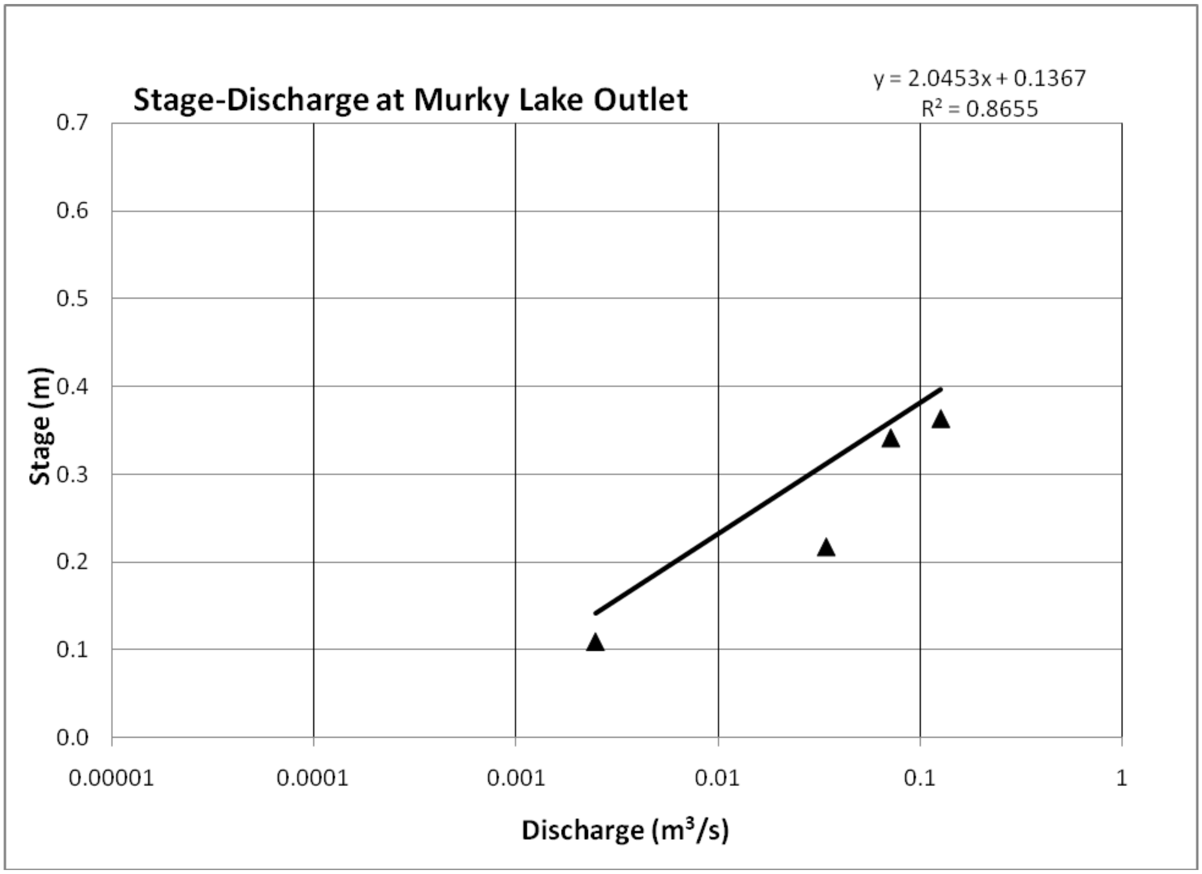
NOTES:
Sensor quality is defined as follows:
0 = no reading obtained
160 - 210 = good reading
210 - 300 = less accurate reading
300 - 600 low accuracy reading

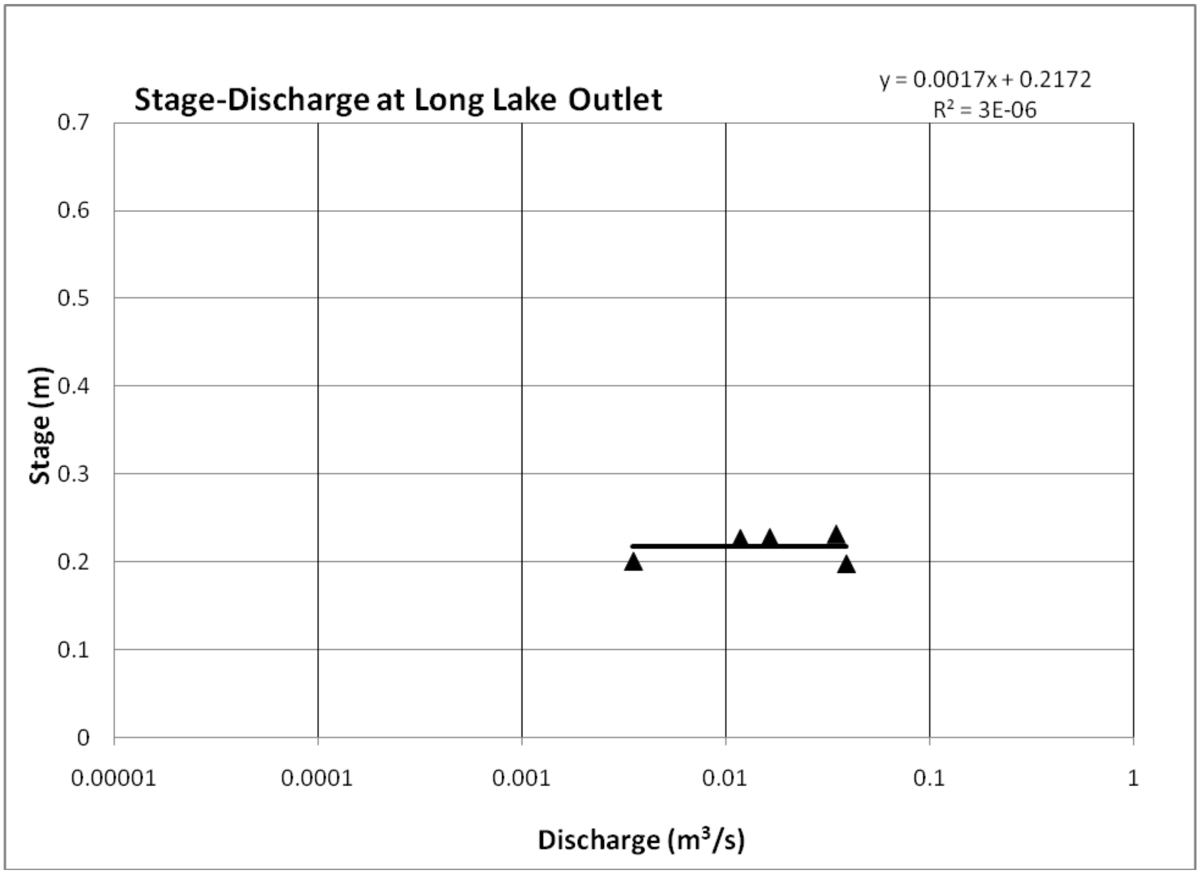
APPENDIX D

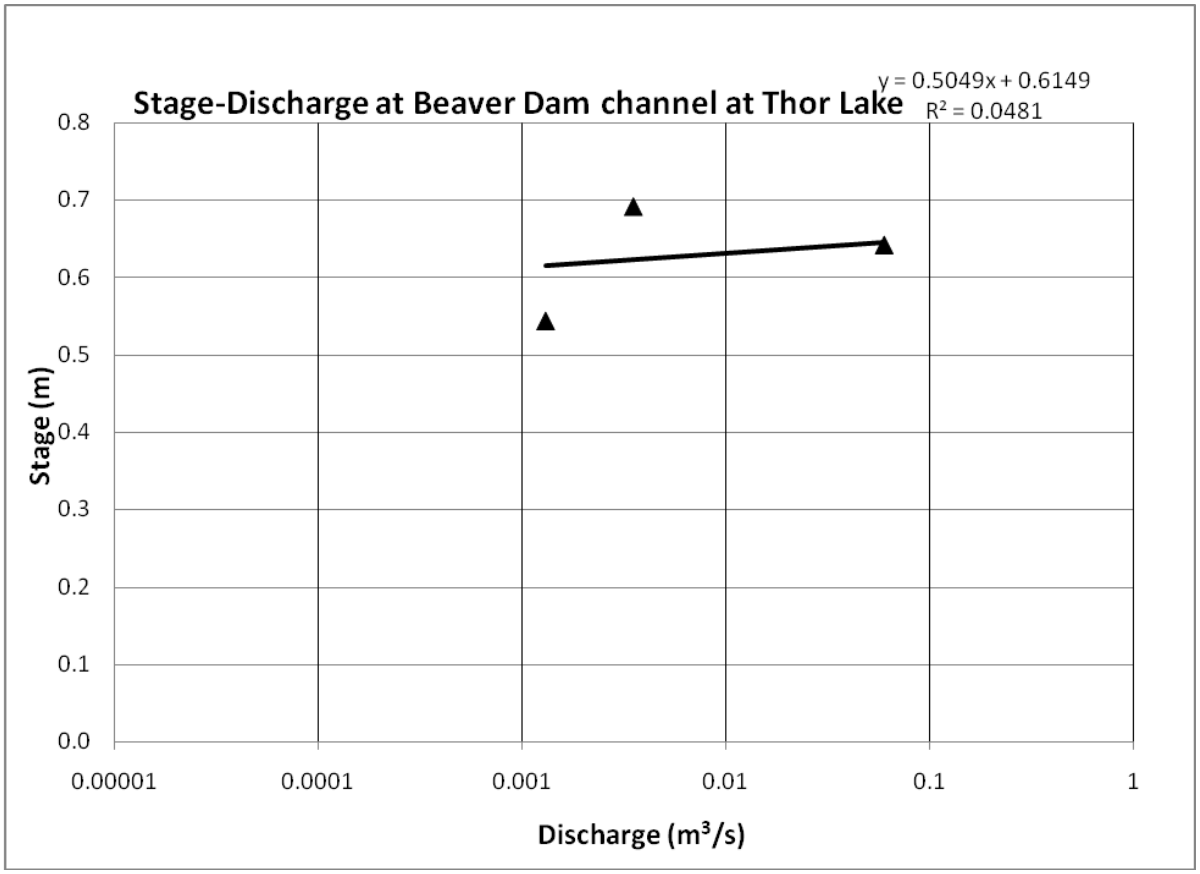
Stage Discharge Plots, 2008 – 2009


Stage-Discharge at Thor Lake Outlet
y = 1.4315x + 0.0484
R² = 0.9513
Stage (m)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00001
0.0001
0.001
0.01
0.1
1
Discharge (m³/s)


Stage-Discharge at Fred Lake Outlet
y = 1.1995x + 0.2864
R² = 0.9709
Stage (m)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00001
0.0001
0.001
0.01
0.1
1
Discharge (m³/s)


Stage-Discharge at Murky Lake Outlet
y = 2.0453x + 0.1367
R² = 0.8655
Stage (m)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00001
0.0001
0.001
0.01
0.1
1
Discharge (m³/s)


Stage-Discharge at Long Lake Outlet
y = 0.0017x + 0.2172
R² = 3E-06
Stage (m)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00001
0.0001
0.001
0.01
0.1
1
Discharge (m³/s)


Stage-Discharge at Beaver Dam channel at Thor Lake
y = 0.5049x + 0.6149
R² = 0.0481
Stage (m)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00001
0.0001
0.001
0.01
0.1
1
Discharge (m³/s)

Appendix A.3

Thor Lake Rare Earth Metals Baseline Project Environmental Baseline Report: Volume 2 – Hydrogeology 2010

THOR LAKE RARE EARTH METALS BASELINE PROJECT

Environmental Baseline Report: Volume 2 – Hydrogeology

FINAL INTERIM REPORT

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1231-10431

December 2010

Stantec

Stantec

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Tobi Gardner, Ph.D. .... Field Assistant
Steve Wilbur, Ph.D,, P.Geo. .... Senior Review

EXECUTIVE SUMMARY

This report presents methods and results for the baseline hydrogeology studies conducted from 2008 through 2010 for Avalon Rare Metals Inc (Avalon), related to their Thor Lake Project (Project). The objectives were to:

- Describe hydrogeologic and hydrostratigraphic units and their spatial variability
- Measure occurrence of groundwater
- Quantify hydraulic properties of the hydrostratigraphic units
- Sample, analyze and summarize groundwater chemistry.

The 2008, 2009 and 2010 field programs consisted of; drilling and installing wells, developing, hydraulic testing, measuring groundwater levels, and sampling monitoring wells for select analytical parameters.

During the field programs, borings were drilled and monitoring wells were installed which penetrated bedrock; monitoring wells were completed to depths ranging from 8.2 to 99.7 m below ground surface (m bgs). Surficial material in the study area has been interpreted to generally consist of an upper organic rich horizon overlying till, with bedrock outcrops dominating the landscape. The surficial material thickness and physical properties varies significantly throughout the Project area. Generally groundwater elevation has been measured to be near the ground surface in all wells, although the monitoring wells have not been measured frequently enough to observe seasonal effects. Two methods of hydraulic tests were performed (packer and recovery tests) over the Project area. The results of hydraulic testing of the site indicate a range of hydraulic conductivity from 10^{-5} m/s – 10^{-8} m/s. All groundwater quality were tabulated and summarized. Results of analysis for wells sampled over multiple years were generally in the same range, and no seasonal trends were apparent.

Groundwater quality data has been compared to federal, Canadian Council of Ministers of Environment (CCME) Canadian Water Quality Guidelines for the protection of Aquatic Life (December 2007), and to the British Columbia Contaminated Sites Regulation (CSR) Schedule 6 Generic Numerical Water Standards for the protection of Freshwater Aquatic Life (January, 2009). The following parameters exceeded the CCME and/or CSR guidance parameters in the Project area: aluminum, cadmium, copper, iron, lead, and/or silver. These exceedances of the CCME and/or CSR guidelines do not imply that the groundwater at the study area is currently contaminated; only that background concentrations of these parameters are higher than typically found in groundwater at other natural sites in Canada. These background groundwater quality results merely reflect the natural geologic and hydrogeologic conditions within these specific areas of the property.

A preliminary hydrogeologic conceptual model has been developed and assumes a near-surface (within active thaw zone) aquifer perched on permafrost. A deeper bedrock aquifer is present below permafrost; the depth of permafrost is estimated to be approximately 60 to 80 m bgs in the general area based on thermistor readings collected from a single borehole and the production of groundwater from two deep (~95 m bgs) wells. The range and spatial distribution of groundwater occurrence, hydrostratigraphy, hydraulic properties, permafrost distribution, hydraulic connectivity and hydrogeochemistry can only be generally described or are not known at this time.

ABBREVIATIONS AND ACRONYMS

CCME........Canadian Council of Ministers of Environment
cm .... centimeter
CSR .... Contaminated Sites Registry
K........hydraulic conductivity
km ....kilometer
m .... meters
m asl........ meters above sea level
m bgs ....meters below ground surface
meq ....milliequivalent
mg/L ....milligram per liter
mm ....millimeter
m/s .... meters per second
MW........ Monitoring well
N.A. .... Not applicable
nm .... not measured
PVC........ Polyvinly chloride
QA/QC........Quality Assurance, Quality Control
TDS........total dissolved solids
µm .... micrometer
µS/cm........Microsiemens per centimeter

TABLE OF CONTENTS

List of Appendices

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1 INTRODUCTION

Avalon Rare Metals Inc (Avalon) is currently assessing the feasibility of developing the Nechalacho Rare Earths Deposit, located on mineral leases it holds at its Thor Lake site in the Northwest Territories. The deposit is located approximately 100 km southeast of Yellowknife and 4 km north of the Hearne Channel of Great Slave Lake. The Thor Lake site has been subject to mineral exploration by others since the 1970s. Previous exploration focused on beryllium resources in the T-zone (approximately 1 km north of Thor Lake) and included drilling and bulk sampling. Since acquiring the property in 2006, Avalon has focused on delineating the rare earth resource within the Nechalacho Deposit, which is not part of the T-zone. Development concepts being considered during the PFS include development of an underground mine, mineral concentration, tailings disposal, waste rock disposal, fuel and concentrate storage, power generation and transportation infrastructure (airstrip, upgraded site roads, wharf on Great Slave Lake). Concentrate would be shipped off-site for refinement into a marketable rare earth product.

The Thor Lake site is within the Taiga Shield ecozone, characterized by Precambrian bedrock outcrops with many lakes and wetlands in glacially carved depressions.

The Thor Lake site is located within the Akaitcho Territory, an area currently under negotiation of a comprehensive land claim between the federal government and the Akaitcho First Nations, representing First Nations in LutselK’e, Fort Resolution, Ndilo and Dettah. Thor Lake lies within the Mackenzie Valley region of the NWT and is, therefore, subject to the provisions of the *Mackenzie Valley Resource Management Act* (MVRMA) in addition to other federal and territorial legislation.

Stantec (formerly Jacques Whitford AXYS Ltd.) initiated environmental baseline studies at the Thor Lake project site in fall 2008. This Technical Data Report (TDR) presents background information, methods and results of the data collected for the hydrogeological studies during 2008-10. A data gap analysis was completed during 2008 (JWA 2008) and was used to help determine scope for this work. The objectives were to:

- Describe hydrogeologic and hydrostratigraphic units and their spatial variability
- Measure occurrence of groundwater
- Quantify hydraulic properties of the hydrostratigraphic units
- Sample, analyze, and summarize groundwater chemistry.

2 BACKGROUND

2.1 Study Area

The study area is located approximately 100 km east of Yellowknife, approximately 4 km north of the Hearne Channel in the Great Slave Lake (Figure 1, Appendix A). The local study area lies between Thor Lake and Long Lake (Figure 2, Appendix A).

2.1.1 Physical Setting

The regional area lies within the Tazin Lake Upland Ecoregion of the Taiga Shield Ecozone as defined in the National Ecological Framework for Canada (1996). The region is characterized by rolling Precambrian bedrock outcrops with many lakes and wetlands in glacially carved depressions. The study area is relatively flat with maximum elevation change of approximately 50 m. Lowlands tend to have poor drainage and are commonly wet for prolonged periods. Permafrost is discontinuous but widespread.

The property is located approximately 230 m asl, approximately 80 m in elevation above Great Slave Lake. Drainage in the area appears to flow in a variety of directions but is expected to eventually reach Great Slave Lake.

2.1.2 Surficial Geology

The study area was covered by the Laurentide ice sheet during the last glaciation, during Late Wisconsinan (10,000 years BP). During maximum glaciation, the dominant ice flow direction was southwest and retreated to the northeast of the study area. Glacial meltwater impounded along this margin and, formed Glacial Lake McConnell. Modern remains of this lake are the separated and present day Great Bear Lake, Great Slave Lake, and Lake Athabasca (Dyke and Dredge 1989; Lemmen, *et al.* 1994; Fulton 1995).

Glaciation produced a thin and discontinuous till veneer covering bedrock, as depicted on the existing map for the study area (1:5 000 000) (Fulton 1995). Figure 3 (Appendix A) shows the mapped surficial geology for the study area.

2.1.3 Bedrock Geology

The Project is located within the Archean Slave Structural Province, near the contact with the Churchill Province, Figure 4 (Appendix A).

Specifically, the property is situated on a roughly semi-circular plutonic complex approximately 40 km in diameter, as mapped by Henderson (1985), belonging to the Early Proterozoic Blachford Lake Intrusive Suite. This suite can be divided into two portions: a western, less alkaline series of gabbro anorthosites, granites and syenites, and an eastern peralkaline granite-syenite and silica-undersaturated system (Davidson 1982).

The property is predominately situated on the Thor Lake Syenite (Henderson 1985), consisting of zoned, coarse-to medium-granied, dark green, faylite-hedenbergite syenite, coarse-grained ferrorichterite syenite, and inequigranular ferrorichterite syenite. Grace Lake Granite also outcrops; where it is a light grey to pale greenish grey, massive, coarse-grained, equigranular, riebeckite-bearing granite. Small dykes and sheets of diabase and gabbro are scattered thoughout the pluton (Henderson 1985). Emplacement of both the Grace Lake Granite and the Thor Lake Syenite was followed by a body of nepheline syenite, ijolite and urtite under the lake zone on the property (Pinckston and Smith 1991).

The Blatchford Lake plutonic complex is surrounded by Archean rocks belonging to the Burwash Formation, Duncan Lake Group, Yellowknife Supergroup (Henderson 1985). These rocks are typically psammitic to pelitic schists, interlayered with amphibolite grade greywacke and siltstones. Textures are typically coarsely porphyroblastic, and the rocks contain various assemblages of quartz-plagioclase-biotite-muscovite-cordierite-andalusite-sillimanite-staurolite-garnet.

3 METHODS

The 2008, 2009, and 2010 field programs consisted of drilling and installing wells, developing, hydraulic testing, measuring groundwater levels, and sampling monitoring wells for select analytical parameters.

3.1 Monitoring Well Drilling and Installation

3.1.1 Well Drilling

During the Summer 2008 and Winter 2009 exploration program, eight coreholes were drilled as multipurpose holes; five were installed as monitoring wells (MW08-127, MW08-128, MW08-130, MW09-151, and MW09-152), two were left as open coreholes (L08-123 and L08-124), and a thermistor was installed in one (L08-134). All 2008 coreholes were cored by Peak Drilling of Yellowknife, NWT, using a diamond drill and NW-sized drilling tools. The borehole diameter was 89 mm and the core diameter 76 mm. The 2009 boreholes were drilled by Foraco Drilling Ltd. (Foraco) of Yellowknife, NWT, using a diamond drill and NQ-sized drilling tools. The borehole diameter was 78 mm and the core diameter 48 mm.

All core logging was completed by Avalon, after the coreholes were drilled. Stantec later reviewed the core and borehole logs to evaluate hydrostratigraphy and help design the monitoring wells. Borehole logs are in Appendix B. Depending on ground conditions, the following parameters were recorded:

- Run depth
- Run length
- Lithology

- Recovery (length and %)
- Alteration and weathering.

3.1.2 Well Completion

Due to the drilling schedule, three monitoring wells installations were overseen by a Stantec hydrogeologist (MW09-127, MW09-151, and MW09-152) and the remaining wells were designed by Stantec and installed by Avalon (MW09-128 and MW08-130), (Figure 5, Appendix A). Monitoring well completion details are in Appendix A.

The 2008 boreholes were completed as monitoring wells using 51 mm diameter schedule 40 PVC well materials. The 2009 boreholes were completed as monitoring wells using 25 mm diameter schedule 40 PVC well materials. The screen sections for both diameter monitoring wells had slot openings of 0.25 mm (0.010 inch or 10 slot). The lengths of the screened intervals ranged from 2.3 m to 15.0 m depending on well depth, water levels and hydrostratigraphic variations.

A silica sand pack (#10-20, grain size 1 mm) was placed around the screen, 0.5 m to 5.0 m above the screen section of each well. The annulus was then sealed with bentonite chips. Caution was exercised to install proper seals to prevent bridging of the bentonite chips, borehole instability and collapse, and/or to prevent surface water from entering the borehole. The seal was achieved by pouring the bentonite chips very slowly and regularly checking the depth to the bentonite seal using a downhole measuring tape.

One thermistor string was installed in one of the boreholes (L08-134) during the 2009 field program. The thermistor was installed inside 51 mm diameter schedule 40 PVC and backfilled with sand to hold it in place. Ground temperature readings were collected with a TH2016 (RST Instruments Inc.) portable thermistor readout unit.

3.2 Groundwater Level Measurements

Instantaneous groundwater levels were recorded at monitoring wells using a Solinst water level meter. Groundwater levels were measured at various dates during August – October 2008, March and June – October 2009, and May – October 2010.

Groundwater elevations at the 2008 well locations were surveyed using ground-based differential GPS methods. The casing stick-up and ground elevation was measured at each monitoring well location and groundwater elevation was calculated.

3.3 Hydraulic Testing

Hydrualic tests were conducted in all new monitoring wells to determine the hydraulic conductivity of the hydrogeologic units. Two types of hydraulic tests were performed: hydraulic recovery tests and packer tests.

3.3.1 Recovery Tests

Hydraulic recovery tests were performed during the 2008 field program in the 2008 monitoring wells to determine the hydraulic conductivity of hydrogeological units. All wells were developed prior to testing to remove suspended sediments, develop the sand pack, and remove possible drill water that had been lost into the formation during drilling. Tests were performed once the wells had been developed and recovered to static water levels. For this project the slug was a one meter, single use bailer. A minimum of three rising head tests were performed on each well. To ensure the most accurate results possible, all testing was done in the following manner:

- A Solinst pressure transducer was placed one meter below the bottom of the slug and was used to continuously record the changes in water levels.
- Approximately 10 minutes after the pressure transducer was installed, and water levels had stabilized, tests were performed.
- Water level readings were confirmed with manual measurements taken with the Solinst water level meter.

The hydraulic recovery test results were interpreted using methods within the Aquifer Test version 3.0 software by Waterloo Hydrogeologic (now Schlumberger Water Services).

Hydraulic conductivity was estimated using an analytical relation between the instantaneous displacement of water in a well bore and the resulting rate of head change. These analyses were based on Bouwer and Rice (1976) for fully or partially penetrating wells in unconfined aquifers. Both methods of analysis used a modified version of the Theim equation (Freeze and Cherry, 1979) to estimate hydraulic conductivity:

$$K = \frac{r_c^2 \ln(^{R_e}/_{r_w})}{2L} \frac{1}{t} ln \frac{y_0}{y_t}$$

Where:

K = hydraulic conductivity [L/T]

r_c= radius of the well casing [L]

R_e= effective radial distance over which the head difference is dissipated [L]

r_w = radial distance between well center and undisturbed aquifer [L]

L = screened interval [L]

y_0 = difference between static (undisturbed pre-test) and slug displaced water level at time 0 [L]

y_t = difference between static (undisturbed pre-test) and slug displaced water levels at time t [L]

t = time [T].

The equation assumes that the aquifer over the test section is homogeneous and isotropic, the water level change around the well is negligible, and no water flows through an unsaturated material above the water table. In general, this assumption implies that groundwater flow is primarily through bedrock fractures which are distributed more or less similarly across the hydrostratigraphic unit.

3.3.2 Packer Tests

Packer tests were performed in March 2009 to determine in-situ hydraulic conductivity of a rock mass over a specific interval under constant pressure head conditions. Packer tests were performed in one of the 2009 boreholes (MW09-152) over selected and representative intervals. The packer test intervals were selected after an inspection of the drill core to determine representative depth intervals for lithology, fracture frequency, and fault zones over the entire depth of the borehole.

The packer test system was composed of the following three main components:

- A downhole assembly of two or three inflatable packer glands used to seal the tested interval within the borehole
- A packer inflation system that used nitrogen to inflate the packer glands and seal the test section
- A water pressure system that facilitated water injection at a constant pressure (head) into the tested interval and provided a measurement of the flow rate.

The tests were conducted after the borehole was completed. The drill rods were pulled back to allow water levels to stabilize. The water level was used to determine the maximum (P^{max}) and minimum (P^{min}) inflation pressure to be applied over the tested interval, calculated as follows:

$$P^{max} = P_{hydrostatic} + P_{packer}$$

$$P^{min} = P_{hydro-test} + P_{infl} + P_{seal} + P_{gauge\ max}$$

Where,

$P_{hydrostatic}$ = the hydrostatic pressure prior to the test at packer (psi)

P_{packer} = maximum inflation pressure of the packer (from manufacturers curve) (psi)

$P_{hydro\text{-}test}$ = the hydrostatic pressure during test with zero gauge pressure (psi)

P_{infl} = pressure inflate the packer (from manufacturers curve) (psi)

P_{seal} = pressure to seal/seat the packer (from manufacturers curve) (psi)

$P_{gauge\ max}$ = maximum pressure of injected water at gauge during tests (psi).

The packer inflation pressures insure that the tested interval is properly sealed, prevents slippage, and avoids damage to the packer gland.

The borehole was thoroughly flushed with water until clear, prior to testing to ensure the hole was free of any cuttings. The downhole assembly was lowered through the drill rods into the open borehole. The packer glands were slowly inflated using nitrogen gas; once inflated the water pressure system was connected to the system. Water was injected down the rods into the tested interval under staged but a constant pressure. The injected rate was measured using a flow meter and recorded for selected pressures. The packer tests were conducted in stages where the maximum injection pressure increased from 25%, 50%, 75%, to 100%. The data collected from these stages was then used to calculate the hydraulic properties of the rock mass within the test interval.

3.4 Groundwater Sampling

Groundwater samples were collected from existing and new monitoring wells during August – October 2008, March and June – October 2009, and May – October 2010 using disposable bailers. Sample bottles were provided by ALS Laboratory Group (ALS). Non-powdered nitril gloves were worn at all stages of the sampling procedure to prevent sampling contamination.

The samples were analyzed for physical parameters, nutrients, total metals, dissolved metals, and total organic carbon. The samples to be analyzed for dissolved metals were filtered using a 0.45 µm sterilized membrane in the field. The appropriate preservatives were added to the samples, as outlined by ALS. The samples were labeled and stored in a chilled cooler with ice packs while transported to the lab. A chain of custody form detailing the sampling handling information and analysis required was prepared and included with the samples prior to shipping via air cargo to ALS in Vancouver, BC. All samples were received by lab within QA/QC protocol.

Field and duplicate samples were also collected based on standard QA/QC protocols.

4 RESULTS

4.1 Geologic Setting

The 2008 and 2009 borings penetrated unconsolidated surficial material and/or bedrock with boring depths ranging from 193.9 m bgs to 215.2 m bgs; a summary of boring logs is available in Table 1, Appendix C. Additional surficial geology information was available from the concurrent baseline studies regarding soils and terrain which are reported in a separate technical data report, the following information, from the Terrain and Permafrost Interim Report – Volume 4, is available here. Surficial material in the study area has been interpreted to generally consist of an upper organic rich horizon overlying till.

Organic deposits generally occupy topographic lows and either rest directly on bedrock or overlie poorly drained surficial deposits (lacustrine, glaciolacustrine material or fine grained till deposits). Due to the poor drainage, the accumulations form bogs and fens varying in thickness.

Till is the dominant unconsolidated surficial deposit, consisting of material deposited by ice due to lodgement, melt out, or post-melt out gravity flow. Facies vary throughout the study area but generally consist of poorly compact, stony matrix supported diamicton. Deposits are generally discontinuous veneers and blankets directly overlying the bedrock.

Bedrock outcrops are the dominant landscape elements throughout the region and within the study area. Evidence of former ice-flow patterns is found throughout the area, including striations, crag-and-tail hills, glacially-smoothed outcrops, and roche moutonnées. Outcrops show variable degree of weathering in relation with surficial processes associated with thermal expansion (freeze and thaw cycles, frost heave).

4.2 Boring and Monitoring Well Logs

In 2008 and 2009 eight borings were cored for both exploration and groundwater study purposes in the general area between Thor Lake and Long Lake. Monitoring wells were installed in five of these borings. Locations are shown on Figure 5, Appendix A. Wells were completed in bedrock with total well depths ranging from 10.3 m bgs to 99.7 m bgs; Table 1, Appendix C is a summary of boring logs and well completion data. Borehole logs are in Appendix B.

In September/October 2008, three monitoring wells (MW08-127, MW08-128, and MW08-130) were completed as shallow wells in bedrock. The depths of completion ranged from 10.3 m bgs to 16.1 m bgs.

In March 2009, two deep monitoring wells (MW09-151 and MW09-152), were completed to 95.2 m bgs and 99.7 m bgs to evaluate sub-permafrost aquifer conditions.

Two 2008 coreholes (L08-123 and L08-124) were left as open wells to collect samples and measure water levels. A thermistor was installed in another 2008 corehole (L08-134) to provide data on permafrost temperature and depth.

4.3 Groundwater Elevation

Groundwater level measurements were collected in the seven monitoring wells from seven to ten separate times, depending on well conditions (presence of ice), during 2008 (September and October), 2009 (March, June and October), and 2010 (May, June, September, and October) (Table 2). Groundwater levels in the seven wells have fluctuated from 0.24 m (MW08-127) to 3.67 m (MW09-152). The presence of ice in the wells has affected water level fluctuations in L08-123, MW08-130 and MW09-152, and may have affected water levels in MW08-128 and MW09-151. Ice does not seem to have affected water levels in L08-124 and MW08-127. In March 2009 ice was encountered in the five 2008 wells at ~1.0 to 3.0 m below the previous autumn water-level measurement. Subsequent groundwater levels measured in June and/or October 2009 were similar to those measured in the previous autumn, but in some cases these water levels were measured on top of ice in the well. During the 2010 field program, ice measurements collected in June were in some cases approximately 1.0 to 3.0 m below the March 2009 measurements. By September and October the depth to ice was in some cases approximately 8 to 10 m deeper. The presence of shallow ice in the wells is likely due primarily to seasonal freezing, whereas the presence of ice deeper in the wells is likely due to permafrost. The variable depth of thaw in each well is likely a combination of seasonal thaw, the area of disturbed ground around the well, and the relatively higher thermal conductance of the well (or open borehole) compared to the surrounding ground.

Generally groundwater elevation has been measured to be near the ground surface (0.7 m bgs to 4.5 m bgs) in all the wells. Although the monitoring wells have not been measured frequently enough to observe seasonal effects or responses to extended wet or dry periods, groundwater levels are expected to have some seasonal response so that higher groundwater levels would be expected during the spring freshet, and lower groundwater levels related to late summer.

Due to the general shallow depths to groundwater in all the wells, the relatively long distance between wells and the small overall difference in depths to groundwater levels, horizontal gradients (and as a result flow directions) are expected to follow the general topographic surface.

4.4 Ground Temperature

Near surface ground temperatures can vary substantially and are subject to seasonal temperature variations. Below the level of zero annual amplitude (i.e., below the depth of penetration of seasonal temperature variations), ground temperatures and permafrost thickness generally reflect the mean annual air temperature and local physical conditions. The depth of zero annual amplitude and thickness of permafrost also varies depending on local environmental conditions (soil properties, land cover, vegetation, insulation, proximity to large water bodies, and other factors). At some depth, the effect of the geothermal gradient is greater than the effect of surface effects, and ground temperatures steadily increase with further increasing depth.

Thermistor readings were collected in L08-134 during the 2009 and 2010 field programs. The thermistor reading in October 2009 had a minimum temperature of -0.75 °C at 14 mbg which was at the end of the string. The minimum temperature (also at 14 mbg) was slightly warmer in October 2010. The temperature-depth data from both years data indicates that the permafrost temperature is rather warm (< 1 ºC), and appears to approach isothermal character with depth (below approximately 7.0 mbg). A minimum permafrost thickness of 44 to 59 m at this location is estimated by assuming ground temperatures increase from -0.75 ºC at -14.0 mbgs based on a geothermal gradient of 1ºC per 30 to 60 m (Lachenbruch, 1968). Further, two of the deeper monitoring wells (i.e., MW09-151 and MW09-152) obtained groundwater from the 80 to 100 mbg range, indicating that in those locations permafrost thickness was no deeper than approximately 80 m. Thus, it is reasonable to assume an approximately 60 to 80 m permafrost thickness at these well locations.

The active layer is defined as the shallow soil zone that freezes and thaws with the changing seasons. The 2009 readings and the majority of the 2010 readings indicate subzero ground temperatures were reached at approximately 2 to 3 mbg, perhaps indicative of the thickness of the active layer. (Figure 6, Appendix A). Readings in September and October of 2010, however, indicate subzero ground temperatures were reached between 4 – 6 mbg. By comparing the 2009 October reading with the 2010 October reading, there is an apparent warming trend, which may reflect a deeper thaw attributed to the extent of disturbed ground in the vicinity of the well. More detailed observations of the depth of the active layer were made as part of the soils and terrain baseline assessment (see Terrain and Permafrost Interim Report – Volume 4).

4.5 Hydraulic Tests

Results of the hydraulic tests have been summarized in Tables 3 and 4, Appendix C. Detailed results of the 2008 and 2009 hydraulic tests are presented in Appendix D.

4.5.1 Recovery Tests

Recovery tests were performed in the three shallow monitoring wells (MW08-127, MW08-128, and MW08-130) and two open boreholes (L08-123, and L08-124) during the 2008 field program. All three shallow monitoring wells were completed in bedrock. The data were analyzed with methods applicable to fully penetrating and partially penetrating wells in unconfined aquifers as described above in Section 3.3.1. Although it is likely that the assumptions regarding isotropic, homogenous, and fully penetrating conditions are not likely met, the curves generated by the analytical methods described in Section 3.3.1 match fairly well to the observed conditions, so that the calculated hydraulic conductivities are reasonable as bulk (or average) conductivities over the screen length.

In the area of study, estimated hydraulic conductivity values in bedrock varied over three orders of magnitude 6.06 x 10^{-8} m/s to 3.08 x 10^{-5} m/s.

4.5.2 Packer Tests

One borehole was tested over five depth intervals in the local study area, during the 2009 winter field program. The test intervals ranged from 3.3 m to 139.4 m in length, and the depth of the test intervals ranged from 20.0 m bgs to 208.6 m bgs. Table 3, Appendix C is a summary of the packer test results. In general, hydraulic conductivity decreased with depth; this was expected due to the higher density of vugs in bedrock near surface, and the decreasing fractures and joints with depth. . Based on the method of analyses described above, the hydraulic conductivities were estimated to range from to 1.66 X 10^{-6} m/s in tests performed near surface and 2.90 x 10^{-8} m/s at depth.

4.5.3 Summary of Hydraulic Tests

The results of hydraulic testing of the wells suggest a range of hydraulic conductivity from 2.90 x 10^{-8} to 3.08 x 10^{-5} m/s. The variable hydraulic conductivity seen in the bedrock is typical of vuggy crystalline rock (Freeze and Cherry, 1979), which also showed decreasing hydraulic conductivity with depth. There are insufficient data to distinguish between the hydraulic conductivities of bedrock types, variability spatially throughout the study area, and with depth.

4.6 Hydrogeochemistry

All groundwater quality data have been compared to federal, Canadian Council of Ministers of Environment (CCME), Canadian Water Quality Guidelines for the protection of Aquatic Life (December 2007). In addition, data has been compared to the British Columbia Contaminated Sites Regulation (CSR), Schedule 6 Generic Numerical Water Standards for the protection of Freshwater Aquatic Life (January, 2009). These criteria were selected due to the absence of any other existing federal or territorial guidelines for groundwater quality. These criteria are meant to represent approximate background concentrations to a representative ambient level which may reflect natural geologic variations in relatively undeveloped areas. In addition, these criteria are to provide general guidance only and have been used for comparison to existing background groundwater quality conditions at the study area.

Monitoring wells were sampled up to three times during the 2008, 2009, and 2010 field programs. The analytical results of all groundwater samples collected as part of the hydrogeology field program are presented in Table 5-7, Appendix C. Laboratory certificates are provided in Appendix F.

Results of analysis for wells sampled over multiple events were generally in the same range. Although no seasonal trends were apparent this may be due to short term and infrequent data collection.

4.6.1 General and Physical Parameters, Major Ion Chemistry, and Hydrochemical Facies

Groundwater is classified based on major ion chemical compositions, while taking into account major anions and cations exceeding 10 meq-%. The water type (hydrochemical facies) is determined by listing the ions with concentrations greater than 10 meq-% in decreasing order (cations are listed first). Charts 1 – 5, Appendix E, show the major ion chemistry and hydrochemical facies.

Chart 6 (Appendix E) is a Piper Diagram which shows cations (represented on the right triangle), anions (represented on the left triangle), and both cations and anions in the diamond. Cations typically indicate mixing, solubility, and ion exchange processes; anions typically indicate solubility and precipitation reactions. The diamond field is used to represent waters of two or more chemistries. Groundwater samples plotted from the study area suggest two groundwater sources; one consisting of samples from L08-124, MW08-128, and MW08-130, and the second consisting of samples from MW09-152. The chemistry indicates the samples from L08-124, MW08-128, and MW08-130 are in a near surface oxidizing environment. The chemistry for MW09-152 suggests a deeper more oxygen reducing environment (Pyne, 1995). The presence of ice in wells MW08-127 and MW09-152 may have isolated the screen from the collection depth and thus affected the water chemistry data. The grouping of the deep and shallow aquifers is consistent with that of the hydrogeochemical facies from Charts 1 – 5 (Appendix E) and as summarized in Table 8, Appendix C.

Magnesium is the dominating cation in two of the monitoring wells sampled (L08-124 and MW08-130), while sodium dominates in one of the sample locations (MW09-152).Both sodium and magnesium dominate MW08-128 depending on the sampling event. Carbonate was the dominating anion in all samples. A shift in the major ion chemistry was observed from October 2009 to October 2010 for MW08-127; the October 2008 and 2009 samples are sodium and potassium dominant and likely reflect a near surface oxidizing environment while the October 2010 sample is magnesium dominant and likely reflects a deeper more oxygen reducing environment. It is unclear what caused the shift, but may be due to the much deeper depth to ice in October 2010. All groundwater samples were analyzed for their concentrations of total and dissolved metals. The measured dissolved metal concentrations were compared to CSR and CCME water quality guidelines for the protection of aquatic life. The CSR guideline values apply to both surface and groundwater, whereas the CCME guidelines only apply to surface water. However, as groundwater ultimately discharges to surface water bodies, the CCME guideline values are included here for reference. All exceedances are marked in Tables 5 – 7, Appendix C.

These exceedances of the CCME and/or CSR guidelines do not imply that the groundwater at the study area is currently contaminated; only that background concentrations of these parameters are higher than typically found in groundwater at other natural sites in Canada. These background groundwater quality results merely reflect the natural geologic and hydrogeologic conditions within these specific areas of the property.

4.6.2 QA/QC of Analytical Results

The duplicate samples MW09-152 (June and October) had very similar analytical results for most analyzed species. Notable differences are only present in concentrations low and close to the detection limits of the analytical method. The field duplicate results are within acceptable limits of reproducibility for the purpose of this study.

In addition, a QA/QC procedure has been implemented by ALS, and all analytical results have been approved by a laboratory representative.

5 DISCUSSION

Based on analyses and interpretation of the information gathered during the 2008, 2009, and 2010 field programs, the local hydrogeological conceptual model of the area between Thor Lake and Long Lake consists of shallow (perched) and deep aquifers separated by permafrost. The shallow aquifer is composed of unconsolidated surficial material and, in some places the bedrock is porous and vuggy, perched on the permafrost. The deep aquifer likely occurs below permafrost and is comprised of different bedrock lithologies in which groundwater flow mainly occurs along fractures and other rock discontinuities. Although this conceptual model can likely be extrapolated to other places in the proposed project footprint, more data (i.e., greater spatial – both vertically and horizontally - coverage of groundwater elevations and hydraulic properties) and information (i.e., surficial and bedrock maps, distribution of permafrost map) would be required to develop a more detailed concept. The following summarizes our understanding of the hydrogeology based on the data gathered to date.

5.1 Shallow Aquifer

The shallow aquifer is composed of unconsolidated surficial material and, where spatially present, porous and vuggy bedrock within the active zone, which has been interpreted to be perched on the permafrost. The unconsolidated surficial material mainly consists of till and organic deposits in topographically low areas. The till varies throughout the study area but generally consists of a poorly compact, stony, matrix supported diamicton. The organic deposits are poorly drained fine materials.

Recovery tests performed in shallow monitoring wells showed a hydraulic conductivity range over several orders of magnitude, from 7.56 x 10-7 m/s to 3.08 x 10-5 m/s. There is little spatial