AREVA

Kiggavik Project
Final Environmental Impact Statement

Tier 3 Technical Appendix 5P: Technical Assessments of Water Withdrawl Locations and Baker Lake Dock Site

September 2014

History of Revisions

Revision Number	Date	Details of Revisions
01	December 2011	Initial release Draft Environmental Impact Statement (DEIS)
02	September 2014	FINAL Environmental Impact Statement

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1 Potential Water Source Lakes-Mushroom and Siamese

1.1 Introduction

Golder Associates Ltd. (Golder) provided AREVA Resources Canada Inc. (AREVA) with an assessment of the potential impact that water withdrawal from Mushroom and Siamese lakes may have on resident lake trout (*Salvelinus namaycush*) populations. The focus of the assessment has been on potential impact to spawning habitat, as eggs and larval fish of this fall spawning species will be the most susceptible to changes in water levels. While the intake structures will be designed to minimize the alteration or loss of existing fish habitat in both lakes, the water removal during winter months may reduce the lake trout spawning habitat available in the water supply lakes. This technical memo includes discussions regarding the following subjects:

- factors potentially limiting lake trout spawning habitat selection;
- potential spawning habitat locations; and
- potential impact of removing water.

1.2 Factors Potentially Limiting Lake Trout Spawning Habitat Selection

Based on the work of Fitzsimons (1994), there are 31 factors potentially affecting lake trout spawning habitat selection. Fitzsimons study was intended to develop habitat criteria for detecting potential lake trout spawning habitat especially in the Great Lakes. The data used included a variety of lakes located mainly in North America, including Great Bear Lake, Northwest Territories (NT).

Fitzsimons separated the 31 factors into four categories: physical, chemical, biological, hydrological (Table 1-1). Then, the characteristics were separated into either important for the spawning process itself, or important for subsequent survival of eggs and larvae (Table 1-2; Fitzsimons 1994).

For the purpose of the assessment of the effects of water withdrawal, 12 factors required for spawning and optimal survival was selected (Table 1-3). The following sections will examine these 12 factors and use the available habitat data to determine potential lake trout spawning habitat in Mushroom and Siamese lake.

Table 1-1: Factors Potentially Affecting Lake Trout Spawning Habitat Selection

Physical	Chemical	Biological	Hydrological
substrate type	dissolved oxygen	predators	currents
size of cobbles	ammonia	competitors	fetch
shape of cobbles	hydrogen sulphide	macrophytes/*Cladophora*	seepage
depth of cobbles	odour substances	genetics/stocks	water depth
slope of cobbles	-	spawner density	temperature
colour of cobbles	-	proximity to stocking site	ice scour
type of cobble	-	-	lake size
infilling	-	-	proximity to tributaries
sedimentation rate	-	-	water level fluctuations
proximity to drop-off	-	-	-
light levels	-	-	-
interstitial space	-	-	-

Source: Fitzsimons 1994.
- = not applicable.

Table 1-2: An Overview of Lake Trout Spawning Habitat Characteristics in Inland and Great Lakes and Their Relative Importance

Factor Category	Factor Code	Factor	Similar for Inland and Great Lakes	Required for Spawning	Required for Optimal Survival	Related to
physical	P1	presence of 40 to 400 mm cobble/rubble	yes	yes	ND	-
	P2	multiple layers of cobbles	yes	yes	yes	P4
	P3	moderate to high slope of cobbles (10 to 45 degrees)	yes	yes	ND	H1
	P4	low sedimentation rate	ND	no	yes	C1,B3,H1
	P5	colour and type of cobbles	yes	no	no	-
	P6	moderate to large size shoal	yes	no	no	-
chemical	C1	high dissolved oxygen low ammonia	ND	no	yes	P2,P4,B3, H1
	C2	presence of conspecific odours	ND	no	no	-
biological	B1	low number of predators	yes	no	yes	-
	B2	low numbers of competitors	yes	no	yes	-
	B3	absence of macrophytes/*Cladophora*	ND	no	yes	P4,C1,H1
	B4	presence of native stocks	-	no	ND	-

Factor Category	Factor Code	Factor	Similar for Inland and Great Lakes	Required for Spawning	Required for Optimal Survival	Related to
	B5	high spawner density	ND	no	ND	-
	B6	close proximity to stocking site	yes	no	ND	-
hydrological	H1	presence of currents	ND	yes	yes	-
	H2	long fetch	no	no	no	P2,P4,C1
	H3	presence of seepage	yes	no	no	-
	H4	absence of ice scour and cover	ND	no	yes	-
	H5	remote from tributaries	no	no	ND	-
	H6	critical water depth	yes[a]	yes	yes	H7,H8
	H7	critical lake size	-	-	-	H6,H8
	H8	lack of water level fluctuations	ND	no	yes	H6,H7

Source: Fitzsimons 1994.
[a] Related to lake size.
ND = no data; - = not applicable

Table 1-3: Lake Trout Spawning Habitat Characteristics of Relevance to the Kiggavik Project

Factor Category	Factor Code	Factor	Required for Spawning	Required for Optimal Survival	Related to
physical	P1	presence of 40 to 400 mm cobble/rubble	yes	ND	-
	P2	multiple layers of cobbles	yes	yes	P4
	P3	moderate to high slope of cobbles (10 to 45 degrees)	yes	ND	H1
	P4	low sedimentation rate	no	yes	C1,B3,H1
chemical	C1	high dissolved oxygen low ammonia	no	yes	P2,P4,B3, H1
biological	B1	low number of predators	no	yes	-
	B2	low numbers of competitors	no	yes	-
	B3	absence of macrophytes/*Cladophora*	no	yes	P4,C1,H1
hydrological	H1	presence of currents	yes	yes	-
	H4	absence of ice scour and cover	no	yes	-
	H6	critical water depth	yes	yes	H7,H8
	H8	lack of water level fluctuations	no	yes	H6,H7

Source: Modified from Fitzsimons 1994.
ND = no data; - = not applicable.

1.3 Physical

The physical category includes substrate type and size (P1), depth of cobbles (P2), slope of cobbles (P3), and sedimentation rate (P4). Factors P1 to P3 are required for spawning, while factors P2 and P4 are also required for optimal survival of the eggs (Table 1-3).

1.3.1 Substrate Type and Size (P1)

Fitzsimons (1994) indicates that the presence of 40 to 400 mm cobble/rubble (or boulder) is an important requirement for spawning habitat (Table 1-3). Based on the substrate classification used in the Kiggavik field assessments, the preferred substrate size classes would include large gravel (i.e., 16 to 64 mm), cobble (i.e., 64 to 256 mm), and small boulder (i.e., >256 mm).

Mushroom Lake has an abundance of cobble/rubble/boulder (Table 1-4; Figure 1-1A). Golder estimated that 40% of the lake has cobble/rubble/boulder substrate (Table 1-5). This substrate combination was observed on the north end of the deep portion of the lake. On the south end of the deep portion of the lake, substrate consisted of a ripple train[1] of clean cobble/boulder alternating with large substrate embedded in sand. The ripples are generally perpendicular to the shoreline and often parallel to the predominant wind direction observed at the Kiggavik climate station in 2009 (i.e., north: 15.87%, NNW: 15.55%, NW: 10.92%, NNE: 8.58%; AREVA 2009). In the shallow bay, small sections of cobble/boulder mixed with sand were also observed.

Siamese Lake has an abundance of cobble/rubble/boulder (Table 1-4; Figure 1-2A). Golder estimated that approximately 59% of the lake has cobble/rubble/boulder substrate (Table 1-5). This substrate combination was observed all around the perimeter of the lake, with the exception of few areas with sand and boulder or cobble, and fewer areas of sand only.

1.3.2 Depth of Cobbles (P2)

Fitzsimons (1994) indicates that multiple layers of cobbles are an important requirement for spawning habitat and for optimal survival of the eggs (Table 1-3). This requirement corresponds to areas with the least amount of sediment infilling, and the greatest egg deposition (Marsden and Krueger 1991; Casselman 1989; Wagner 1981; as cited by Fitzsimons 1994). This factor is also related to factor P4 (sedimentation rate).

[1] Ripple train: series of ripples which lie one behind the other, as found on a rippled surface.

This characteristic, multiple layers of cobbles, was assumed in P1 areas with no sand in the two dominant substrate types and located in steeper slopes.

Mushroom Lake has multiple layers of cobbles (Table 1-4; Figure 1-1B). Golder estimated that 18% of the lake has multiple layers of cobble (Table 1-5). These were observed on the northern side of the deep basin of the lake. On the south and southeast sections, the cobble/boulder substrate is abundant; however, it is embedded in sand.

Siamese Lake has multiple layers of cobbles. Golder estimated that 40% of the lake has multiple layers of cobbles (Table 1-5). These were observed around the perimeter of the lake; however, several areas mainly near shoreline and often at proximity of inlets had a high proportion of sand and had a low slope, which allows for embeddedness of the cobbles (Table 1-4, Figure 1-2B).

Table 1-4: Lake Trout Spawning Habitat Characteristics Observed in Mushroom and Siamese Lakes

Factor Category	Factor Code	Factor	Mushroom Lake	Siamese Lake
physical	P1	presence of 40 to 400 mm cobble/rubble/ boulder	present in deep and shallow portions of lake	abundant around the lake and present in deep portions of lake
	P2	multiple layers of cobbles	assumed in section with little sand and steeper	assumed in section with little sand and steeper
	P3	moderate to high slope of cobbles (10 to 45 degrees)	five areas that range from 0 to 6 m deep	25 areas that range from 0 to 9 m deep
	P4	low sedimentation rate	ND	ND
chemical	C1a	high DO	high DO present between 2 and 7 m (May 2009)	high DO present between 2 and 5 m in the east basin, and between 2 and 4 m in the west basin (May 2009)
	C1b	low ammonia	low ammonia present in September 2008	low ammonia present in August 2008
biological	B1	low number of predators	round whitefish are known to eat lake trout eggs during and after spawning. Arctic grayling are known to be piscivorous	none known, due to limited sampling
	B2	low numbers of competitors	lake cisco and round whitefish	none known, due to limited sampling
	B3	absence of macrophytes/*Cladophora*	absent	occasional areas of inundated vegetation at the northern end of the western bay

Factor Category	Factor Code	Factor	Mushroom Lake	Siamese Lake
Hydrological	H1	presence of currents	one inlet at the NE end of the lake; predominant wind from the north	several inlets around the lake; predominant wind from the north
	H4	absence of ice scour and cover	ice cover is still present by the end of May 2010, but eggs should already have hatched	ice cover is still present by the end of May 2010, but eggs should already have hatched
	H6	critical water depth	-	-
	H8	lack of water level fluctuations	none at the present	none at the present

DO = dissolved oxygen; ND = no data; - = not applicable; m = metre.

Table 1-5: Lake Surface Area (m^2) Available for Lake Trout Spawning Habitat

Factor Code	Factor	Mushroom Lake (lake = 320,312 m^2)		Siamese Lake (lake = 27,921,900 m^2)	
		(m^2)	%	(m^2)	%
P1	presence of 40 to 400 mm cobble/rubble/boulder	127,612	40	16,505,305	59
P2	multiple layers of cobbles	56,828	18	11,242,190	40
P3	moderate to high slope of cobbles	5,127	1.6	226,749	0.81

m^2 = square metre; % = percent; mm = millimetre.

1.3.3 Slope of Cobbles (P3)

Moderate to high slope of cobbles (range from 10^o to 45^o) is an important requirement for spawning habitat (Fitzsimons 1994; Table 1-3). Lake trout tend to spawn either on the top of the slope or somewhere along the slope (Marsden and Krueger 1991; Casselman 1989; Wagner 1981; Peck 1986; Royce 1943, 1951; Sly and Widmer 1984; as cited by Fitzsimons 1994). The slope may also accommodate the quick movement of the emergent fry from shallower spawning ground to deeper nursery and rearing ground (Casselman 1991, as cited by Fitzsimons 1994). This factor is related to factor H1 (currents).

Mushroom Lake has five areas where the slope ranges between 10^o and 45^o (Figure 1-1C). Golder estimated that 1.6% of the lake has a moderate to high slope of cobbles (Table 1-5). These areas are located between 0 m and 6 m deep. The largest area is about 200 m long, the second area is about 100 m long, and the three shortest areas are between 30 and 40 m long.

Siamese Lake has 25 areas where the slope ranges between 10^o and 45^o (Figure 1-2C). Golder estimated that 0.81% of the lake has a moderate to high slope of cobbles (Table 1-5). These areas are located between 0 m and 9 m deep. The two largest areas are about 400 m long and the second largest area is about 300 m long. There are several smaller potential spawning areas that consist of pockets of substrate. The larger areas are about 250 m (n = 2) and 200m (n = 2); with the majority of the areas about 125 m in length (n = 13). The shortest areas are about 65 m in length (n = 5).

1.3.4 Sedimentation Rate (P4)

Fitzsimons (1994) indicates that low sedimentation rate is an important requirement for survival of lake trout eggs (Table 1-3). It is not a requirement for spawning, but a high sedimentation rate on a spawning ground would infill the cobble substrates, and cut the supply of dissolved oxygen (DO) to the eggs (Sly and Widmer 1984; as cited by Fitzsimons 1994). This factor is related to factor C1 (DO/ammonia), B3 (Macrophytes/*Cladophora*), and H1 (currents).

A direct measurement of the sedimentation rate was not done for lakes in the Kiggavik area (Table 1-4); however, based on the water clarity observed (e.g., secchi depth of 5.0 m for Mushroom Lake and 6.25 m for Siamese Lake) and the lack of fine organic substrates, sedimentation rates are very low.

1.4 Chemical

The chemical category includes DO (C1a) and ammonia (C1b). These factors are important requirements for optimal survival of the eggs (Table 1-3). These factors are related to factors P2 (depth of cobbles), P4 (sedimentation rate), B3 (macrophytes/*Cladophora*), and H1 (currents).

1.4.1 Dissolved Oxygen (C1a)

Low DO may limit the survival of eggs, but do not appear to control spawning (Fitzsimons 1994). Active spawning has been observed in lakes where DO values were below levels considered lethal to lake trout embryos (Sly 1988, as cited by Fitzsimons 1994). At water temperature between 7 and 10^{o}C, Marcus et al. 1984 report DO levels below 6 mg/L as affecting lake trout embryo development and survival (Carlson and Siefert 1974, as cited by Marcus et al. 1984). Between 2 and 3 mg/L, most salmonid embryos will hatch successfully, but will produce small and underdeveloped larvae that are viable and not deformed (CCME 1999). Furthermore, at low DO concentrations, hatching of lake trout was delayed (Carlson and Siefert 1974, as cited by CCME 1999). For cold-water ecosystem, the Canadian water quality guidelines for the protection of aquatic life (CCME 1999) reports lowest acceptable DO concentration guideline values of 9.5 mg/L for early life stages and 6.5 mg/L for other life stages. These guidelines are based on the U.S. Environmental Protection Agency's "slight production impairment" estimates (USEPA 1986, as cited in CCME 1999), with an additional 0.5 mg/L to estimate threshold DO concentrations (CCME 1999). The guideline for early life stages was established to protect salmonid larvae in their redds (CCME 1999), because in redds intragravel DO concentrations are lowered due to sediment oxygen demand and fish embryos respiration. Therefore, 3 mg/L were added to the guidelines for early life stages (CCREM 1987, as cited by CCME 1999). Because this technical memo is adapted to lake trout, which are fish species that do not build redds, but broadcast their eggs over cobble/boulder substrate, Golder used the 6.5 mg/L limit to identify where successful spawning can occur.

Mushroom Lake had DO concentrations that ranged from 9.6 mg/L at 7 m deep to 12.29 mg/L at 2 m deep (i.e., immediately below the ice) during winter limnology sampling (May 2009). All values were above 6.5 mg/L, which signifies that eggs can survive anywhere in the entire lake. However, to be conservative, in case the DO concentrations below 7 m was less than 6.5 mg/L, the lake stratum identified ranged from 2 to 7 m (Tables 1-4 and 1-6; Figure 1-1D). Golder estimated that 34% of the volume of the lake has high DO concentration (Table 1-7).

Siamese Lake had DO concentrations that ranged from 0.2 mg/L at the bottom of the east basin to 17.49 mg/L immediately below the ice, during winter limnology sampling (May 2009). On Siamese Lake, the ice depth ranged from 1.8 to 2.1 m (Table 1-6). In the deepest basin (east), DO values equal or above 6.5 mg/L were measured between 2 and 5 m. In the west basin, DO values equal or above 6.5 mg/L were measured between 2 and 4 m (Tables 1-4 and 1-6; Figure 1-2D). Golder estimated that 38% of the volume of the lake has high DO concentration (Table 1-7).

Table 1-6: Range of Depth (m) Versus Dissolved Oxygen Concentration (mg/L) Collected in May 2009

Waterbody	Station Number	Ice Thickness (m)	Maximum Depth of Station (m)	Depth (m) with Dissolved Oxygen (mg/L)		
				Above 9.5	Between 6.5 and 9.5	Below 6.5
Mushroom Lake	1	2	7.3	2.0 to 7.0	-	-
Siamese Lake	1	1.8	11.3	2.0 to 4.0	5	6.0 to 11.0
	2	1.8	9.7	2.0 to 3.0	4	5.0 to 9.0
	3	2	7.8	2.0 to 5.0	-	6.0 to 7.0
	4	2.1	3.1	2.5 to 3.0	-	-
	5	2	4.1	2.5 to 4.0	-	-

m^3 = cubic metre; % = percent.

Table 1-7: Lake Volume (m^3) Available for Lake Trout Spawning Habitat

Factor Code	Factor	Mushroom Lake (lake = 590,452 m^3)		Siamese Lake (lake = 114,648,400 m^3)	
		(m^3)	%	(m^3)	%
C1a	high dissolved oxygen	198,371	34	43,442,125	38
C1b	low ammonia	590,452	100	114,648,400	100

m^3 = cubic metre; % = percent.

1.4.2 Ammonia (C1b)

According to Fitzsimons (1994), high ammonia may limit the survival of eggs, but do not appear to control spawning. The Canadian water quality guidelines for the protection of aquatic life (CCME 2000) report highest acceptable total ammonia concentration for summer conditions (10°C and pH 7) to be 10.3 mg NH_3/L, which is the equivalent of 8.2 mg N/L. For fall and winter conditions (5°C and pH 7), that maximum total ammonia concentration is 15.3 mg NH_3/L, which is the equivalent of 12.2 mg N/L.

Mushroom Lake had ammonia concentration of <0.01 mg N/L in early September 2008 with temperature of 8.21°C and pH of 6.96. Ammonia concentration was not available for the winter sampling session (May 2009). The September 2008 ammonia N value is below both highest acceptable total ammonia concentrations for summer, fall, and winter conditions; therefore, ammonia concentration is not a limiting factor for the survival of the eggs in Mushroom Lake (Table 1-4).

Siamese Lake had ammonia concentrations of 0.07 mg N/L in the deepest basin (east) and 0.02 mg N/L in the west basin in late August 2008 with temperatures between 10.61 and 10.76°C and pH between 6.62 and 6.79. Ammonia concentration was not available for the winter sampling session (May 2009). The August 2008 ammonia N values are below both highest acceptable total ammonia concentrations for summer, fall, and winter conditions; therefore, ammonia concentration is not a limiting factor for the survival of the eggs in Siamese Lake (Table 1-4).

1.5 Biological

The biological category includes predators (B1), competitors (B2), and macrophytes/*Cladophora* (B3). These factors are an important requirement for optimal survival of the eggs, but are not required for spawning (Table 1-3).

1.5.1 Predators (B1)

According to Fitzsimons (1994), low number of predators is required for optimal survival of eggs. Potential predators during and after spawning include crayfish, slimy sculpin, white suckers, brown bullheads, burbot, round goby, and mottled sculpin (Martin and Olver 1980, as cited by Fitzsimons 1994; Claramunt et al 2005). Round whitefish have been observed eating lake trout eggs during spawning activities (Fitzsimons 1994).

Based on the sampling in the local study area (LSA), lake trout are the most widely distributed piscivore. Slimy sculpin, which will selectively feed on eggs when they are available have a limited distribution in the LSA and have not been found in either lakes during the 2007 to 2009 sampling.

Mushroom Lake has four fish species captured, including Arctic grayling, lake cisco, lake trout, and round whitefish (Table 1-4). Round whitefish likely eat lake trout eggs. Arctic grayling are primarily insectivores (McPhail 2007), but they can be piscivorous. Lake cisco are primarily planktivores (McPhail 2007).

Siamese Lake has only a population of lake trout; based on the limited sampling (Table 1-4). However, Siamese Lake should be able to sustain other fish species. The absence of fish species other than lake trout in the captures may be the result of sampling bias. Therefore, potential predation on eggs could not be evaluated.

1.5.2 Competitors (B2)

According to Fitzsimons (1994), low number of competitors is required for optimal survival of eggs. Competitors must be a fall spawning fish species, which require similar substrate sizes.

Mushroom Lake contains two other fall spawner species, lake cisco and round whitefish. Lake cisco spawn late fall (McPhail 2007). They will spawn over sandy and gravel shoals, but may also use cobble and gravel shoals (McPhail 2007). Round whitefish spawn from early September to December depending on the location (McPhail 2007). They will spawn over silt to coarse gravel substrates as well as over boulders (McPhail 2007). It would be assumed that lake cisco and round whitefish would likely select different spawning locations compared to lake trout, because of their preferences for smaller size substrate (Table 1-4).

Siamese Lake has only a population of lake trout; based on the limited sampling (Table 1-4). However, Siamese Lake should be able to sustain other fish species. The absence of fish species other than lake trout in the captures may be the result of sampling bias. If other fall spawning species are present, differences in habitat preferences would likely limit inter-species competition for spawning substrate (see above).

1.5.3 Macrophytes/Cladophora (B3)

According to Fitzsimons (1994), absence of macrophytes and *Cladophora* is required for optimal survival of eggs. Macrophytes do not prevent spawning activities, but the decaying of the plant will fill the interstitial space, reduce DO, and elevate ammonia (Sly 1988, as cited by Fitzsimons 1994). *Cladophora* is a macrophyte filamentous green algae (Dodds 2001) which grows on submerged rocks in shallow lakes and streams (Allaby 1992). *Cladophora* blooms are linked to high phosphorus levels in the water mainly as result of humane activities like inadequate sewage treatment and detergents containing phosphorus (http://www.glwi.uwm.edu/research/aquaticecology/cladophora accessed 1 June 2010). Extensive coverage of *Cladophora* has been observed on spawning material during summer months (Fitzsimons 1994); however, strong waves and currents remove them by spawning time. This factor is related to factors P4 (sedimentation rate), C1 (DO/ammonia); and H1 (currents).

<u>Mushroom Lake</u> has no macrophytes. *Cladophora* was not observed; total phosphorus and dissolved phosphorus levels in water from Mushroom Lake were low in early September 2008 (i.e., both at <0.01 mg/L). Macrophytes and *Cladophora* are not a limiting factor for optimal survival of lake trout eggs in Mushroom Lake.

<u>Siamese Lake</u> has few beds of inundated vegetation located at the northern end of the west basin. *Cladophora* was not observed; total phosphorus and dissolved phosphorus levels in water from Siamese Lake were low in late August 2008 (i.e., 0.02 mg/L and 0.04 mg/L in the east basin, respectively; <0.01 mg/L in both samples from the west basin). Macrophytes and *Cladophora* are not a limiting factor for optimal survival of lake trout eggs in Siamese Lake.

1.6 Hydrological

The hydrological category includes currents (H1), ice scour and cover (H4), water depth (H6), and water level fluctuations (H8). These factors are an important requirement for optimal survival of the eggs, but only H1 and H6 are required for spawning (Table 1-3).

1.6.1 Currents (H1)

According to Fitzsimons (1994), the importance of currents is suggested by the occasional river spawning fish (Loftus 1954, as cited by Fitzsimons 1994); by the clean interstitial spaces in area of significant sedimentation and infilling (Sly 1988, as cited by Fitzsimons 1994); and by the egg deposition pattern. Although maximum egg deposition occurred at the top of a shoal, elevated egg peak deposition could be followed downslope in a 2 m wide swath for a distance of approximately 15 m in a near straight line (Fitzsimons 1994). Corbett and Parsons (2008) observed during underwater surveys that over 90% of the eggs were recorded in depths ranging from 0.5 to 2 m, but were also occasionally found in depths exceeding 15 m. These situations occurred mainly with steep profile shoals. Corbett and Parsons (2008) suspected that the eggs were deposited in shallow water but “rolled” down to deeper depths. The Corbett and Parsons study does not report a presence of current in the area, other than the shorelines studied were exposed to fetches greater than 0.5 m.

Mushroom Lake has no currents information available. Localized current may occur at the inlet located at the northeast end of the lake (Figure 1-2C). At the Kiggavik climate station in 2009, the predominant winds were registered from the north (15.87%), NNW (15.55%), NW (10.92%), and NNE (8.58%) (AREVA 2009).

Siamese Lake has no currents information available. Localized currents may occur near the inlet streams located around the lake (Figure 1-2C). As for Mushroom Lake, the predominant winds recorded at the Kiggavik climate station in 2009, were from the north (15.87%), NNW (15.55%), NW (10.92%), and NNE (8.58%) (AREVA 2009).

1.6.2 Ice Scour and Cover (H4)

According to Fitzsimons (1994), extensive ice scour has been noted on spawning shoals. Therefore, its absence does not appear to be a pre-requisite for spawning, although it may limit survival by dislodging eggs prior to hatching (Fitzsimons 1994).

Mushroom Lake has a thick ice cover at least until the end of May 2009, Golder measured ice thickness on Mushroom Lake in May at 2.0 m. Additionally, ice thickness was modeled for Mushroom Lake. These modeled ice thicknesses are based upon the historical climate record for Baker Lake and lake geometry and temperature data that were collected for Mushroom Lake. Mean, minimum, and maximum monthly ice thickness values are presented in Table 1-8. Maximum ice thickness occurs in May; however, it is not known if eggs would have hatched or if eggs deposited in the ice zone would have been frozen. Therefore, it is assumed that there is no egg survival in the ice zone.

Table 1-8: Modeled Monthly Ice Thickness for Mushroom Lake

Month	Monthly Ice Cover Thickness (m)		
	Minimum	Mean	Maximum
January	0.65	1.26	1.86
February	0.8	1.55	1.87
March	0.87	1.78	1.87
April	1.03	1.87	1.87
May	1.11	1.87	1.87
June	0	1.51	1.87

m = metre

Siamese Lake has a thick ice cover at least until the end of May. Ice thicknesses that were measured on Siamese Lake in 2009 ranged between 1.8 to 2.1 m. As for Mushroom Lake, ice thicknesses were modeled for Siamese Lake. Mean, minimum, and maximum monthly ice thicknesses are presented in Table 1-9. Maximum ice thickness occurs in May; however, it is not known if eggs would have hatched or if eggs deposited in the ice zone would have been frozen. Therefore, it is assumed that there is no egg survival in the ice zone.

Table 1-9: Modeled Monthly Ice Thickness for Siamese Lake

Month	Monthly Ice Cover Thickness (m)		
	Minimum	Mean	Maximum
January	0.65	1.25	1.86
February	0.79	1.54	2.12
March	0.87	1.78	2.31
April	1.02	1.94	2.43
May	1.11	2.01	2.48
June	0	1.5	2.47
July	0	0.09	1.92
August	0	0	0
September	0	0	0.06
October	0	0.13	0.55
November	0.09	0.52	1
December	0.47	0.9	1.46

m = metre

1.6.3 Water Depth (H6)

Water depth is an important factor in selection of lake trout spawning locations. Fitzsimmons (1994) identified a trend of increasing spawning depth with increasing lake size;

$$\text{Spawning depth [m]} = 0.07 + 0.93 \log (\text{lake size [km}^2\text{]}) \quad (r^2 = 0.79).$$

The Fitzsimmons relationship does not fit well for small lakes such as Mushroom and Siamese lakes. In addition, avoidance of areas where ice accumulation and freezing of substrate and eggs occurs would likely have a greater influence on the viability of lake trout populations. Therefore, this criterion was not used.

1.6.4 Water Level Fluctuations (H8)

According to Fitzsimons (1994), the absence of water level fluctuation is not required for spawning, but is required for egg survival (Table 1-3).

During the fall and winter, incubating lake trout eggs are vulnerable to impacts from reservoir drawdown and fluctuating water levels (Ford et al. 1995). Effects of drawdown identified by Martin (1955, 1957, as cited by Ford et al. 1995) include spawning beds dewatered, eggs desiccated or frozen, and access of preferred spawning site lost. Lake trout may also be forced to select spawning sites of lower qualities (i.e., sub-optimal temperature, higher sediment loads, different substrate, and different depth; Martin 1955 and 1957, as cited by Ford et al. 1995).

Raising water levels may not have as much impact as a reservoir drawdown because lake trout may increase their vertical spawning distribution in response to raised water level (Rawson 1961, as cited by Ford et al. 1995). Furthermore, Wilton (1985, as cited by Fitzsimons 1994) reported spawning in Bark Lake to be at approximately 1 m deep in the late 1930's prior to increase the water level by 11 m. After the water level was raised, lake trout continued to spawn at approximately 1 m deep, which is now 11 m higher than the original site.

Currently, water fluctuations within Mushroom and Siamese lakes are influenced by natural variation in the hydrograph. Instantaneous water elevation measurements were recorded on Mushroom Lake in2009 and 2010 and on Siamese Lake between 2007 and 2010. All water elevations were recorded during the open water period.

1.7 Potential Spawning Habitat locations

According to the criteria discussed in Section 1.2, moderate to high slope of cobbles (P3), high DO (C1a), and multiple layer of cobbles (P2) appear to be the limiting factors for lake trout spawning habitat in Mushroom and Siamese lakes.

1.7.1 Mushroom Lake

Mushroom Lake has four areas where lake trout spawning habitat and optimal egg survival requirements are met (Figure 1- 3). These areas represent approximately 1.3% of the lake area. These areas are located between 2 and 6 m deep. The largest area is about 200 m long and ranged from 2 m to 5 m deep. The second area is about 100 m long and ranged from 2 m to 6 m. The two shortest areas are 30 m long and ranged from 2 to 6 m deep (Figure 1-3).

1.7.2 Siamese Lake

Siamese Lake has 17 areas where lake trout spawning habitat and optimal egg survival requirements are met (Figure 1-4). These areas represent approximately 0.27% of the lake area. These areas are located between 2 m and 5 m deep. The largest area is about 400 m long and ranged from 3 m to 5 m deep. The two second largest areas are about 200 m long and ranged from 2 m to 5 m deep. The majority of the areas are between 200 m and 60 m long and ranged from 2 to 3 m (n=8) and 3 to 5 m (n=2) deep. The four shortest areas are about 60 m long and ranged from 2 to 3 m (n=3) and 4 to 5 m (n=1) deep (Figure 1-4).

1.8 Potential Impact of Removing Water

Lake bathymetry for Mushroom and Siamese lakes were collected in 2009 and 2008, respectively. From the bathymetric data, stage-storage volume-area curves were created. Lake volumes below the 2 m depth line were used as the assumed initial winter volume. The estimated drops in lake elevations over the winter were based upon subtraction of the winter usage volumes presented in the Project Proposal (AREVA 2008) from the volume associated with 2 m depth. Linear interpolation of the curves was used to estimate the change in under-ice volume. Table 1-8 provides the winter water level fluctuation for Mushroom and Siamese lakes.

1.8.1 Mushroom Lake

Golder (2010) estimates that the winter water level fluctuation for Mushroom Lake necessary to provide water for the proposed infrastructures located north of Andrew Lake will be approximately 10 cm (Table 1-10). Potential spawning habitat in Mushroom Lake has been identified between 2 m and

6 m deep (refer to Section 1.7.1). A 10 cm decrease in the water level will slightly reduce the spawning area, but there will still be habitat available in deeper portions of the spawning areas.

Table 1-10: Calculated Winter Water Level Fluctuations for Mushroom and Siamese Lakes

Waterbody	Condition	Water Level Fluctuation
Mushroom Lake	unique source	10 cm decrease
Siamese Lake	unique source	5 cm decrease
	in combination with water from the East Pit	3 cm decrease
West Basin of Siamese Lake	unique source	12 cm decrease
	in combination with water from the East Pit	6 cm decrease

Source: Golder (2010).
cm = centimetre.

1.9 Siamese Lake

Water from Siamese Lake may be removed to provide water for the proposed infrastructures located north of Pointer Lake; however, it will be done either as the sole source of water or in conjunction with water removed from the east pit. Golder (2010) estimated that the winter water level fluctuation for Siamese Lake will be approximately 5 cm if it is the sole source of water and 3 cm drop if it is used in conjunction with the East Pit (Table 1-8).

The maximum depth of the shallow region between the east and west basins of Siamese Lake was measured to be 2.5 m during the bathymetric survey that was conducted in 2008. Although it is unlikely that the two basins would become isolated from one another during the period of ice cover, an assessment of water withdrawal was conducted for the west basin, assuming complete isolation from the east lobe. The estimated drops in winter water levels in the west basin of Siamese Lake (assuming isolation) are 12 cm or 6 cm, depending on whether Siamese Lake is used as a unique source for water supply or if it is supplemented by water from East Pit.

Potential spawning habitat in Siamese Lake has been identified between 2 m and 5 m deep (refer to Section 2.2). A 3 to 5 cm drop in the water level will slightly reduce the area in the majority of spawning locations, but there will still be habitat available in deeper portions of spawning areas. Furthermore, the longest spawning area is located between 3 and 5 m, which will not be affected by the water level fluctuations as it is located below the 3 m contour.

The majority of the habitat features, which combine to create suitable spawning areas, appear to be located in the west basin (Figure 1-2A to 1-2C). In the event that the two basins become isolated in the later winter and there is a 12 cm reduction in the west basin water levels; the majority of the potential spawning areas appear to be located in 3 to 5 m of water (refer to Section 1.7.2). Therefore, a change in under ice water levels of 12 cm would not affect these areas.

1.10 Conclusion

Based on the location of potential spawning areas and the estimated water level reduction in the lakes as a result of water consumption, there is a potential to dewater small areas of potential spawning areas. These represent a small percentage of available habitat; therefore, the potential impacts on spawning and egg/embryo development should be low.

To further evaluate potential impacts, it is recommended that timing of decrease in under ice water elevation be compared with timing of larval emergence and transformation to free swimming state. If water level decrease occurs after larval fish are in a free swimming state, then impacts of water withdrawal to egg/embryo development would likely be negligible.

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Statistics at Time of Survey	
Elevation	N/A
Maximum Length	1.13 km
Surface Area	320,312 sq. m.
Volume	590,452 cu.m.
Mean Depth	1.89 m
Maximum Depth	8.90 m
Perimeter, Main Shore	3,416 m
Perimeter, Islands	N/A

100 0 100
SCALE 1:5,000 METRES

Reference:
NTS Mapsheet 66A05

PROJECT
AREVA
KIGGAVIK
EVALUATION OF POTENTIAL
WATER SUPPLY LAKES

TITLE
MUSHROOM LAKE
PRESENCE OF 40 TO 400 mm SUBSTRATES

DRAFT

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0610		FILE No.	
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CADD	AKG	08/06/10	**FIGURE: 1-1A**	
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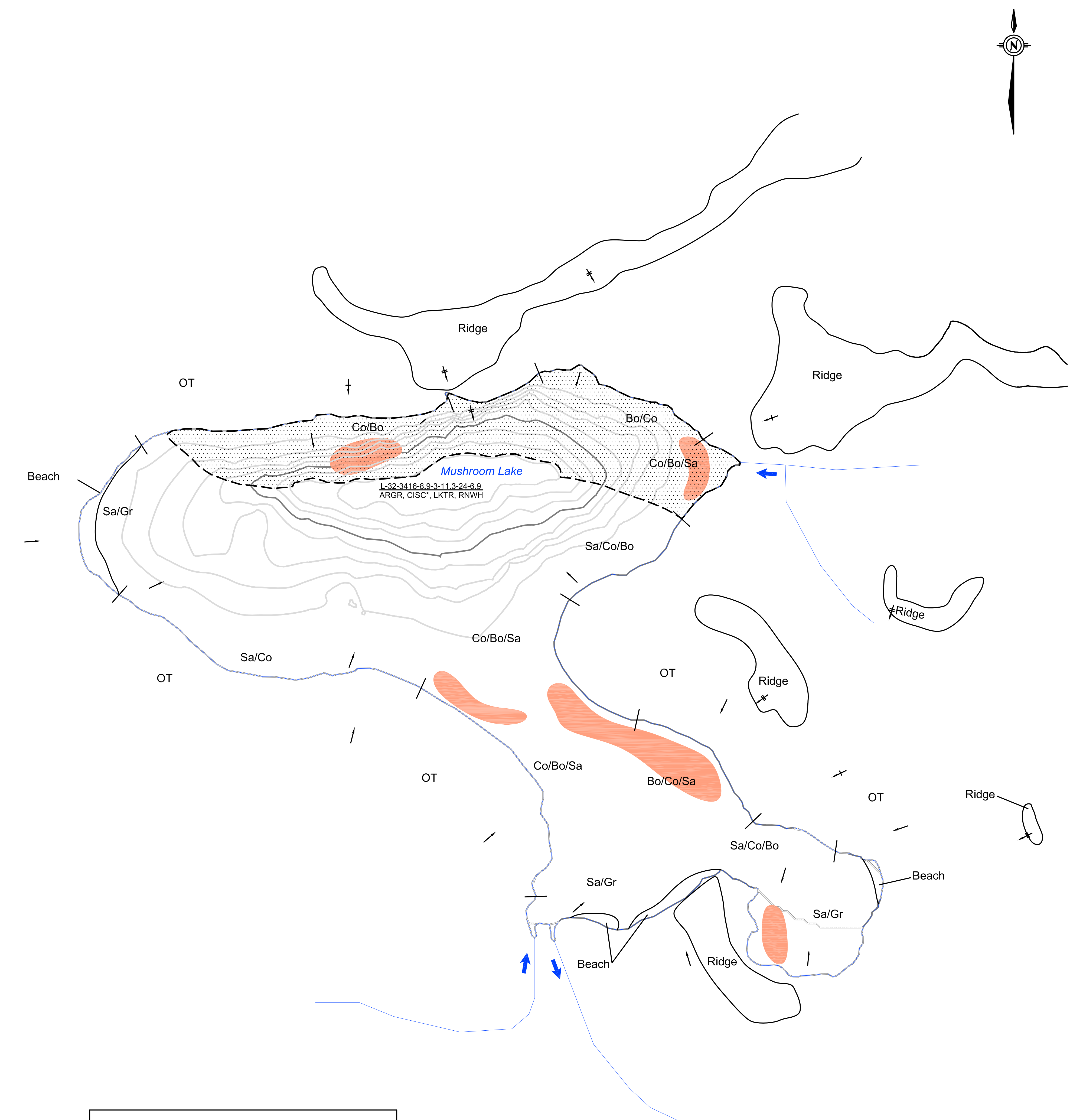
REVIEW				



Statistics at Time of Survey	
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Perimeter, Main Shore	3,416 m
Perimeter, Islands	N/A

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SCALE 1:5,000 METRES

PROJECT
AREVA
KIGGAVIK
EVALUATION OF POTENTIAL
WATER SUPPLY LAKES

TITLE
MUSHROOM LAKE DEPTH OF COBBLES

DRAFT

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0610	FILE No.		
DESIGN		SCALE	AS SHOWN	REV. 0
CADD	AKG	08/06/10		
CHECK				
REVIEW				

FIGURE: 1-1B

Reference:
NTS Mapsheet 66A05

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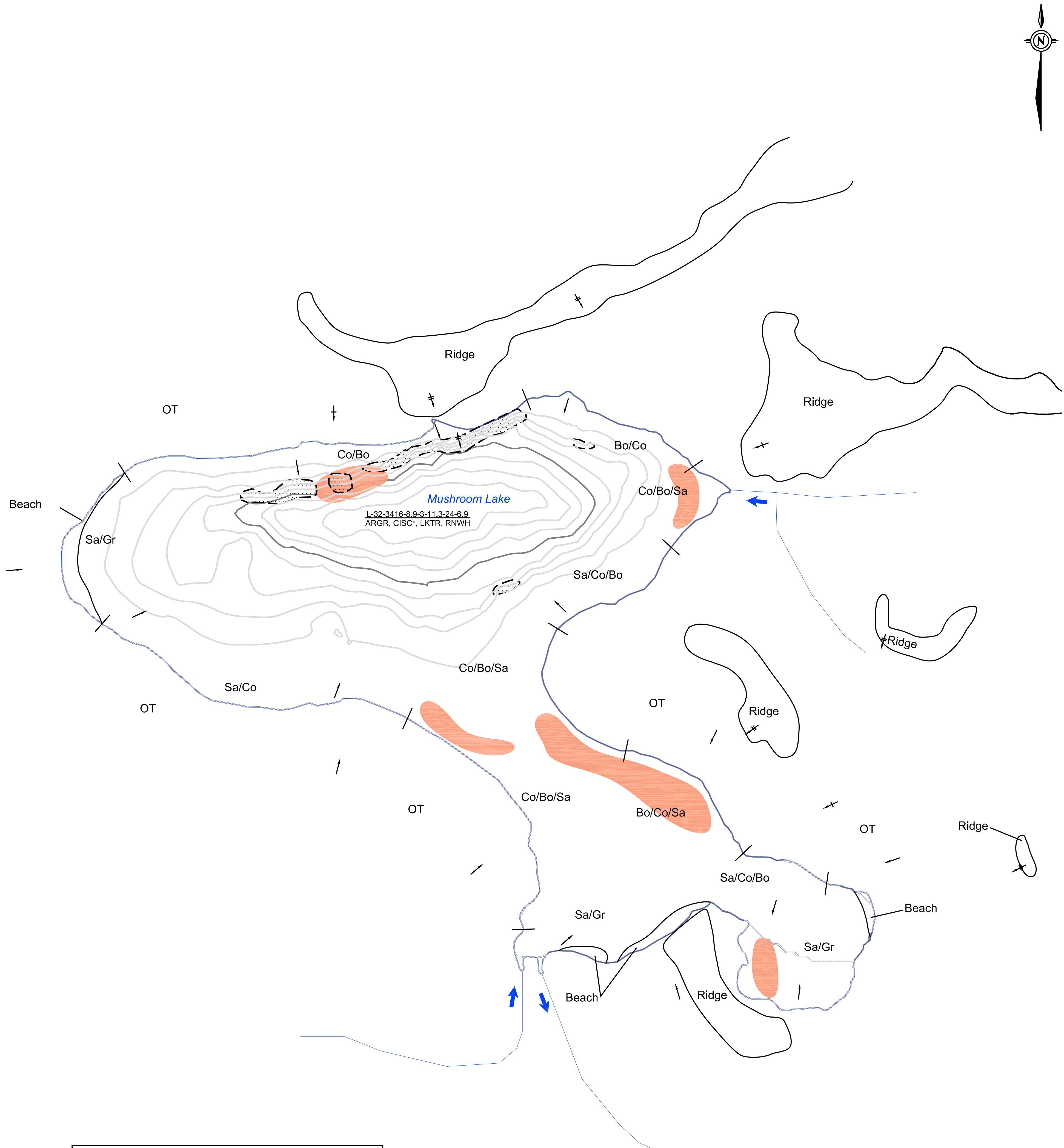


Statistics at Time of Survey	
Elevation	N/A
Maximum Length	1.13 km
Surface Area	320,312 sq. m.
Volume	590,452 cu.m.
Mean Depth	1.89 m
Maximum Depth	8.90 m
Perimeter, Main Shore	3,416 m
Perimeter, Islands	N/A

100 0 100
SCALE 1:5,000 METRES

PROJECT
AREVA
KIGGAVIK
EVALUATION OF POTENTIAL
WATER SUPPLY LAKES

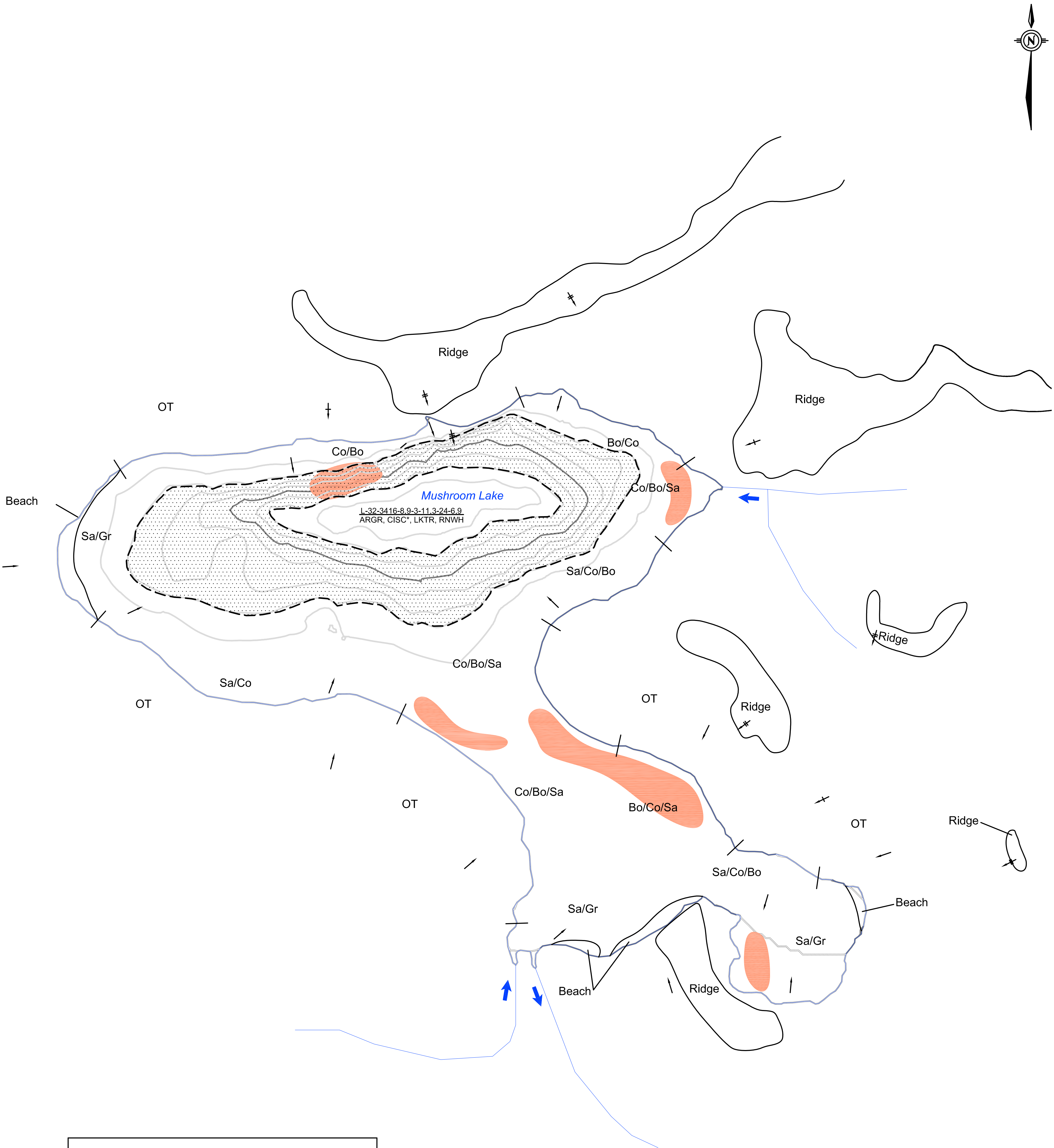
TITLE
MUSHROOM LAKE
MODERATE TO HIGH SLOPE COBBLES

DRAFT

Golder Associates
Saskatoon, Saskatchewan

PROJECT		09-1362-0610	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	AKG	08/06/10	**FIGURE: 1-1C**	
CHECK				
REVIEW				

Reference:
NTS Mapsheet 66A05



Statistics at Time of Survey	
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Surface Area	320,312 sq. m.
Volume	590,452 cu.m.
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Maximum Depth	8.90 m
Perimeter, Main Shore	3,416 m
Perimeter, Islands	N/A

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SCALE 1:5,000 METRES

PROJECT
AREVA
KIGGAVIK
EVALUATION OF POTENTIAL
WATER SUPPLY LAKES

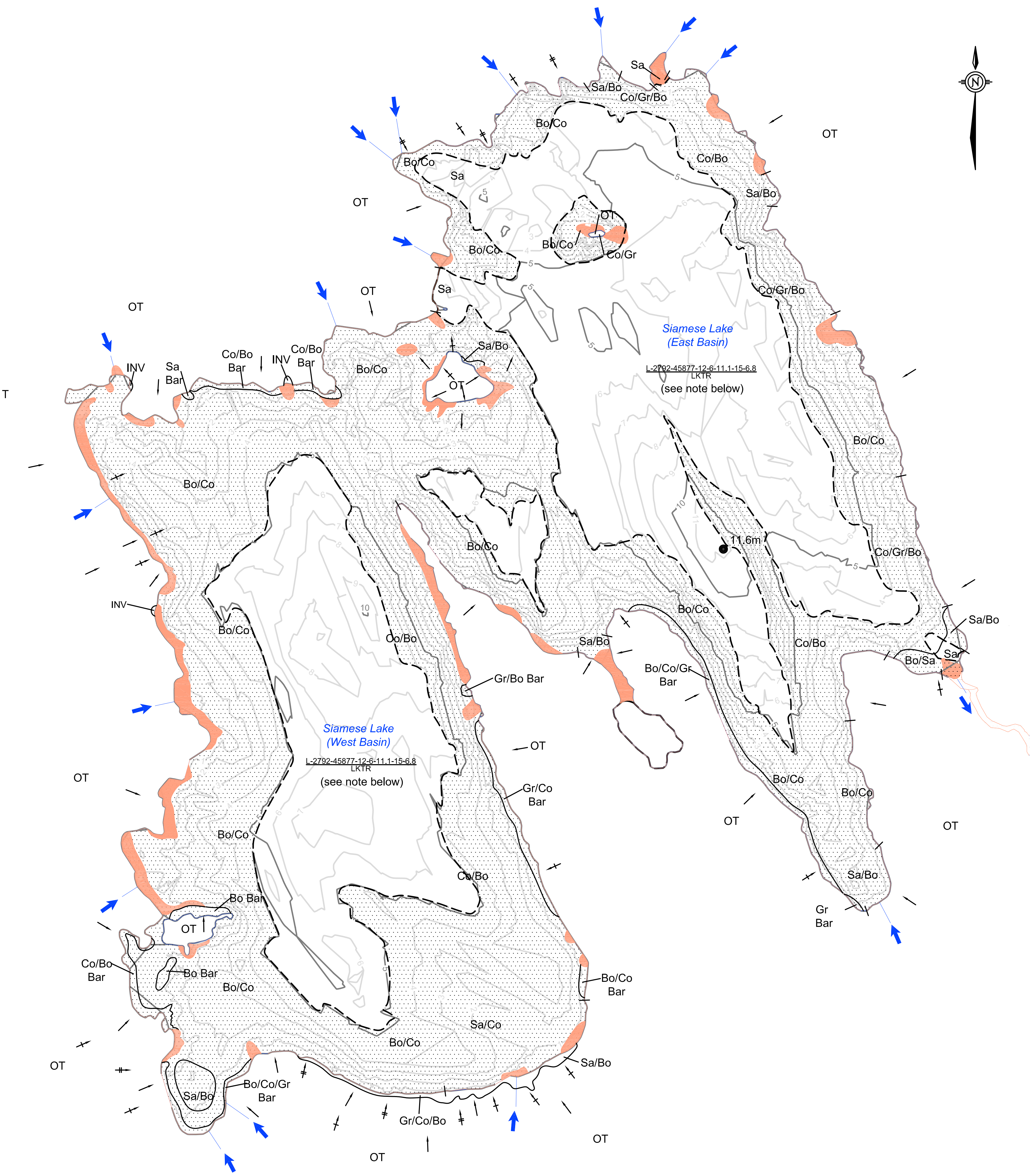
TITLE
MUSHROOM LAKE
HIGH DISSOLVED OXYGEN

DRAFT

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0610		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	AKG	08/06/10	FIGURE: 1-1D	
CHECK				
REVIEW				

Reference:
NTS Mapsheet 66A05



Statistics at Time of Survey	
Elevation	160 m
Maximum Length	8.7 km
Surface Area	27,921,900 sq. m.
Volume	114,648,400 cu.m.
Mean Depth	4.10 m
Maximum Depth	11.6 m
Perimeter, Main Shore	45,877 m
Perimeter, Islands	3,325 m

Note:
Site Summary Symbol numbers represents the entire lake.

Reference:
NTS Mapsheet 66A05

PROJECT
AREVA
KIGGAVIK
EVALUATION OF POTENTIAL WATER SUPPLY LAKES

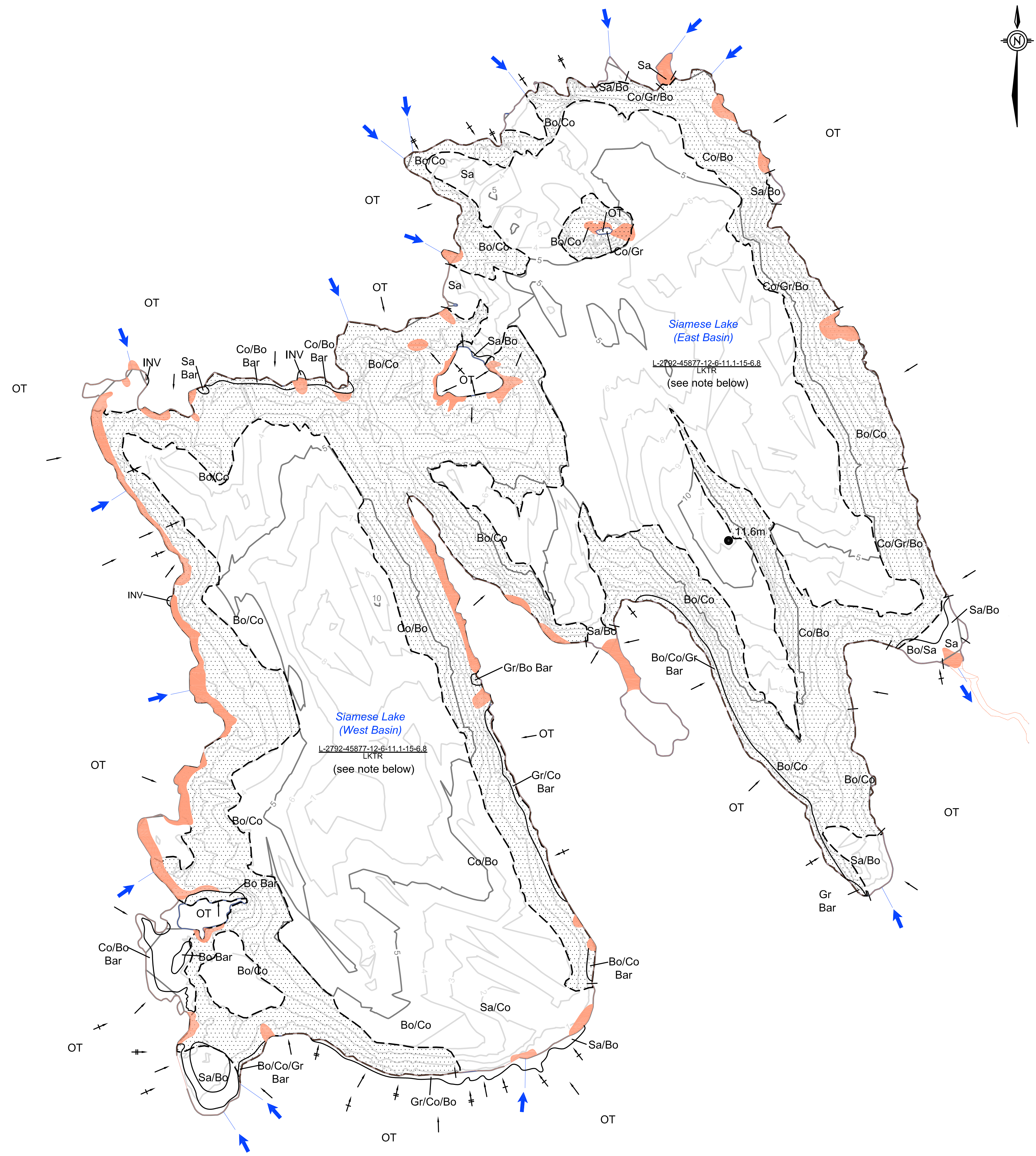
TITLE
SIAMESE LAKE
PRESENCE OF 40 TO 400 mm SUBSTRATES

DRAFT

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0610		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	TAH/AKG	20/05/10	FIGURE: 1-2A	
CHECK				
REVIEW				

\\golder.gds\gal\Saskatoon\GGIS\2009\1362\09-1362-0610 AREVA Kiggavik Baseline and EIA\KI\08_Environment\C_Aquatics\CAD\Task 9600 - Drawing file: 09-1362-0610-9600-AQUA Siamese Bathy_Habitat Revised 2010.dwg



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Reference:
NTS Mapsheet 66A05

PROJECT
AREVA
KIGGAVIK
EVALUATION OF POTENTIAL
WATER SUPPLY LAKES

TITLE
SIAMESE LAKE
DEPTH OF COBBLES

DRAFT

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0610	FILE No.	
DESIGN		SCALE AS SHOWN	REV. 0
CADD	TAH/AKG 20/05/10	FIGURE: 1-2B	
CHECK			
REVIEW			