MÉTAUXBLACKROCK

Environmental and Social Impact Assessment Statement

Iron Ore Mine – Lac Doré Geological Complex

Volume 2

(Chapters 8 to 15)

ENTRACO
Conseillers en environnement

Greenfield Park, November 2011
P0919

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8. AQUATIC ENVIRONMENT

Aquatic fauna surveys, as well as sampling of surface water and lake and stream sediments, can be used to determine the state of the aquatic environment prior to project development, and assess its fish habitat potential. This provides a context for determining how sensitive the environment is to anthropogenic changes arising from the project, based on the physicochemical properties of surface water, sediments and mining wastes.

8.1 METHODOLOGY

Aquatic environment field surveys were carried out in three stages. The first stage, which took place from March 21 to 25, 2011, was aimed at determining the capacity of water bodies in the project area to support fish populations in winter. According to Fisheries and Oceans Canada (DFO), water bodies capable of supporting fish populations, regardless of time of year, are classified as fish habitats.

The lakes targeted as part of this first stage program (Figure 8.1) were selected from 1:20,000 topographic maps. The deposit is located in the James Bay watershed, just inside the drainage divide between the St. Lawrence River and James Bay watersheds. Consequently, several of the surveyed lakes are headwater lakes or even ponds, and some are not linked to any structured drainage system.

Below the western side of the mineralized zone, the drainage system is more organized and larger lakes are present, including Lac Bernadette, lake A-1 and Lac Jean. These are located northwest of the BlackRock claims. Lac Denis, a mid-size lake, is located at the southern end of the mining property. Lac Yvette, which is quite removed from the other lakes, is southeast of the BlackRock project area. This headwater lake drains into Lac Bernadette. Physicochemical surveys were done for all these lakes in addition to the small lakes and ponds in the project area, as well as Lac Laugon and lake A-2, located immediately to the north of the mining project. Except for Lac Jean and Lac Denis, the large lakes mentioned above are not affected by the mining project.

A second field visit from May 19 to 28, 2011, was aimed at confirming walleye spawning activity in the control areas and other areas that might be affected by the project. The study area is within the James Bay watershed (Rivière Armitage and Ruisseau Villefagnan subsystems). Results of aquatic habitat photointerpretation were also verified during that field program. In addition, traditional land users and outfitters were consulted about fish species present and known spawning grounds. No walleye were caught in the project area even though a very effective capture method (experimental gill-netting) was used. The fish survey did, however, provide the basis for constraining the spatial distribution of the main species of fish present. Lines and creels were also used as fishing gear.

In the third field survey, which took place between July 3 and August 4, 2011, experimental fishing provided a more complete picture of the spatial distribution of fish species, and water and sediment samples were collected for analysis. Complementary depth and discharge surveys were also done. Laboratory analyses of water and sediment samples were performed at the Maxxam Analytics laboratory in Montreal.

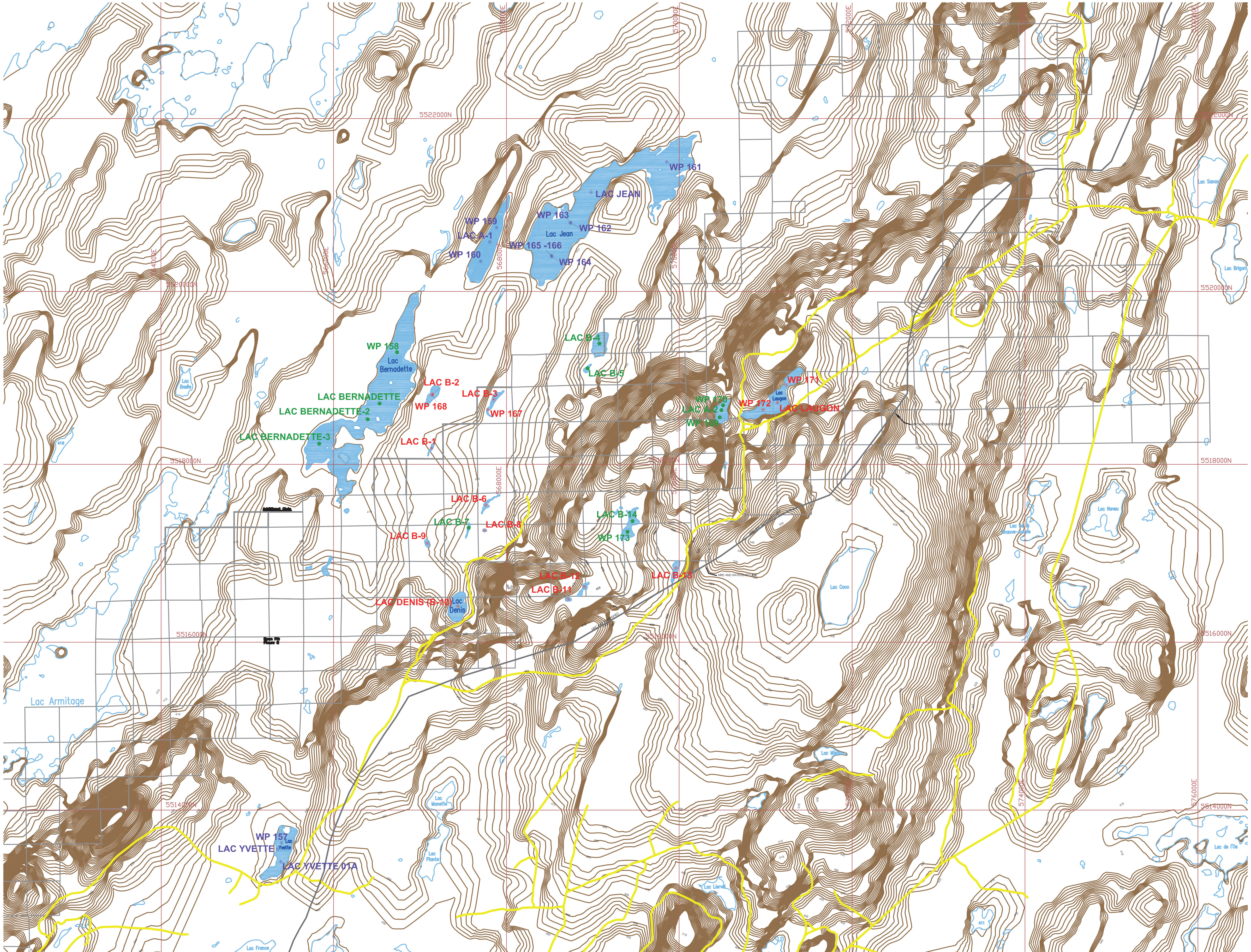
During the three field campaigns, a Hanna 9828 multiparameter meter was used to record the following *in situ* physicochemical parameters: temperature (^{o}C), pH, atmospheric pressure (mbar), conductivity at 25% (µs/cm), dissolved solids (tds), salinity, oxidation-reduction potential (ORP), dissolved oxygen (% and mg/L), resistivity (KΩ.cm) and ambient conductivity (µS/cmA).

Fish caught with a net were systematically measured, with very few exceptions. In a very small number of lakes, net fishing was not possible because of insufficient depth or because the lakes were bog pools. Creels were set in all open water bodies and even some bog lakes. A summary analysis of the stomach contents of most carnivorous fish caught and sacrificed was done to determine what foods were present, and observations were recorded. Except for a few cyprinids, none of the samples were preserved in formaldehyde.

An Ekman grab sampler was used for sediment sampling. In most cases, two or more samples were collected at each site. Samples were homogenized and plant debris was removed. Sediments were numbered and dated, then kept in cold storage (4ºC) until they were analyzed. Most sediment samples were collected at the mouth of the stream from which they came, at some distance from shore.

Surface water samples were also collected in some lakes for comprehensive laboratory analysis. Prescribed sample preservation times and conditions were complied with. All sampling locations are precisely recorded with GPS coordinates. Fishing gear used in the fish surveys and fishing times are reported in Appendix 8.1.

Discharge was measured in lake tributaries or emissaries. The method used during summer 2011 field work provides an order-of-magnitude estimate. It consists of using an object of slightly lower density than the water, which is mostly submerged, to estimate flow velocity. Flow must be uniform over the selected reach. Stream width and depth must be as similar as possible. Stream width is measured at two locations and a mean value is calculated. Depth is derived in the same way, by measuring along two cross-sections of the stream. The drift time of the floating object over a set distance is measured. This step is repeated three times. Flow velocity is also assessed at various points along a cross-section. A correction factor of 0.8 for fast sections with rocky and blocky beds and 0.9 for sections with smooth or sandy beds is applied. Discharge is calculated using the following formula: width x depth x correction factor x velocity.



BLACKROCK

Légende

- Sondage
- Limite de claim
- Chemin non pavé

Capacité de survie des poissons

- WP 157 Excellente à très bonne
- WP 157 Très faible à moyenne
- WP 157 Nulle à minimale

Dessiné à partir du plan : 3017001-000000-41-D09-0003
réalisé par BBA (février 2011)

Rév.	Description	Par/By	Date
–	–	–	–
–	–	–	–

ENTRACO
Conseillers en environnement

Dossier / File:
Projet minier BLACKROCK
Secteur Chibougamau

Dessin / Drawing:
Figure 8.1
Lacs inventoriés - Hiver 2011

Conçu par / Designed by: N.L.	Date 2011-04-01
Dessiné par / Drawn by: C.D.	Date 2011-04-20
Vérifié par / Verified by:	Date
Approuvé par / Approved by:	Date
No. dossier / File no.: P0919	Échelle / Scale:
No. dessin / Drawing no.:	Feuille / Sheet:

On June 11 and 12, 2011, a field survey took place specifically to measure discharge using a *Global Water* FP-111 flow probe at 24 stations, many of which were located at sites where less sophisticated measurements were also taken throughout the summer 2011 field program.

Discharge was calculated in cubic metres per second, using stream depth and width as well as mean flow velocity in metres per second. The following formula was used:

$$Q = V \times W \times D$$ (Chezy-Manning equation[1])

where:

Q: is the discharge in cubic meters per second (m^3/s);
V: is the mean flow velocity in m/s;
W: is the width (in metres);
D: is the depth (in metres).

Several measurements were taken at each site to ensure measurement repeatability and validity. Measurements were done by putting the flow meter in the middle of the stream, below the surface, about one third of the way down to the stream bed. At most sites located along roads, measurements were taken upstream and downstream from culverts, and at least 2 m from these structures. At undisturbed (natural) sites, measurements were taken in a representative section of stream. Discharge measurements are shown in Appendix 8.2.

Throughout the summer field campaign, photographs and videos were shot using a Canon EOS 5D digital camera, which produces 21 Mb raw data files and high resolution videos. Particular attention was paid to general site description. Files and photos were imported into Bridge software, which can recognize the exact date and time when a picture or video was shot. Descriptions and observations are supported by numerous photos and figures. A video record of the surveyed sites is also archived.

Figure 8.2 shows the location of sampling sites and the various activities undertaken at each site during the three field programs of 2011.

In addition to lacustrine and lotic ecosystems in the project area, adjacent control sites of similar nature were surveyed during the three field programs. Water and sediments were sampled in all representative sites in order to constrain background metal concentrations and physicochemical conditions at each site. Surveys were also done at sites where the implementation of compensation measures may be possible.

[1] Photo interpretation. J. Bédard, École polytechnique de Montréal, Département de génie minéral. September 1977.

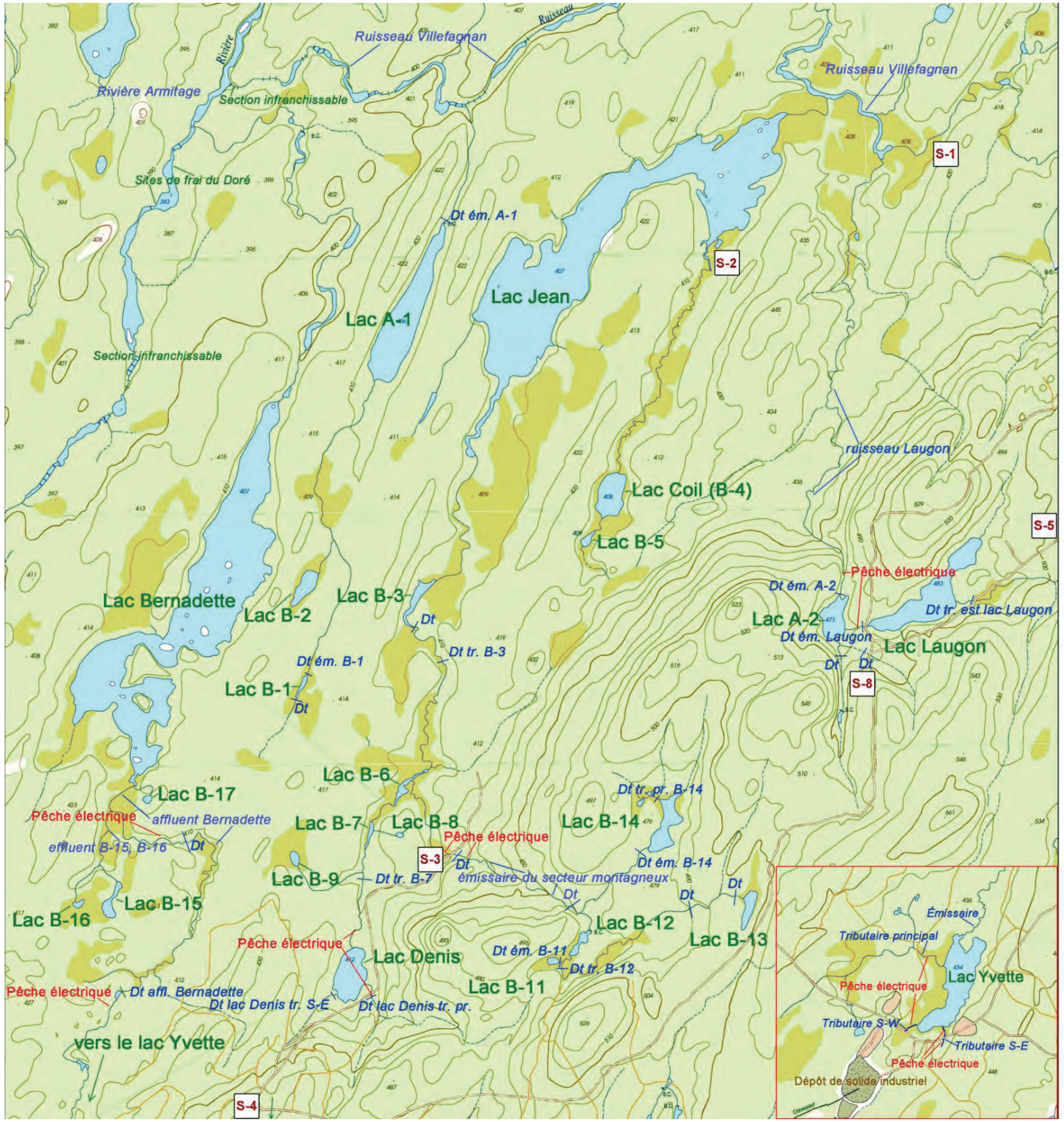
8.2 SURVEY OF FISH SPECIES

Fish catches during the two summer 2011 field programs confirmed the presence of 12 fish species. Table 8.1 shows a list of species, with numbers caught and catch locations. Table 8.2 shows the abbreviations used for the different species, along with their respective trophic groups, spawning seasons and interest for consumption. Finally, the relative abundance of each captured species is shown in Table 8.3. Among these species, yellow walleye, northern pike and brook trout are most sought-after by sport fishers. Native people also consume burbot. However, these species are far from abundant in the area of the mining project.

Line fishing was the only experimental fishing method used on Rivière Armitage, where the goal was mainly to confirm the presence of spawning activity on this river immediately upstream from its confluence with Ruisseau Villefagnan.

Total fishing times at stations shown in Table 8.1 were as follows: experimental net, 339 hours; creel, 1,657 hours; and line fishing, 12 hours. Electrofishing was done at 16 stations, where an electrical current was applied in the aquatic environment for a total of 2 hours and 37 minutes.

Figure 8.2 Aquatic Environment – Location of Sampling Stations



Lac, Rivière	Physico-chimie		Poissons	Sédiments	Débit	Bathymétrie
	Terrain	Labo	Inventaire			
Lac Bernadette	X	X	X	X		X
Affluent Pr. Bernadette			X		X X	
Lac B-15	X		X	X		X
Lac B-16	X					
Effluent de B-15 et B-16	X		X	X		
Lac B-17	X	X	X	X		X
Lac A-1	X		X	X	X Ém.	
Lac B-1	X		X	X	X Ém. X Tr.	X
Lac B-2	X					
Lac Jean	X		X	XX S-W, N-E		X
Lac B-4	X	X	X	X		X
Lac B-5	X	X	X	X		X
Lac B-3	X	X	X	X	X Tr. (2)	X
Lac B-6	X		X			
Lac B-7	X		X		X Tr. (2)	X
Lac B-8	X		X			
Lac Denis	X	X	X	X		X
Émissaire lac Denis			X			
Tr. S-E Lac Denis					X	
Tr. pr. Lac Denis			X		X	
Ém. Secteur montagneux			X			
Lac B-11	X	X	X		X Ém.	
Lac B-12	X	X	X		X Tr.	
Lac B-13	X		X	X	X Ém. (2)	X
Lac B-14	X		X	X	X Tr. X Ém.	X
Ruisseau Villefagnan	X		X			
Rivière Armitage	X		X	X		
Lac Laugon	X		X		X Tr. Pr.	X
Émissaire lac Laugon			X		X	
Lac A-2	X		X	X	X Tr.1 X Tr.2	X
Émissaire lac A-2			X		X	
Lac Yvette	X	X				
Tributaires Lac Yvette			X			

Les stations d'échantillonnage du secteur de BlackRock et de sa périphérie

Légende

***VERT:** lacs et secteurs étudiés*
***BLEU:** cours d'eau et les mesures de débit*
***ROUGE:** pêches électriques*
***S-1** : prélèvements de sol*

Abréviations
***Dt:** Mesure de débit*
***Ém. :** Émissaire*
***Tr. :** Tributaire*

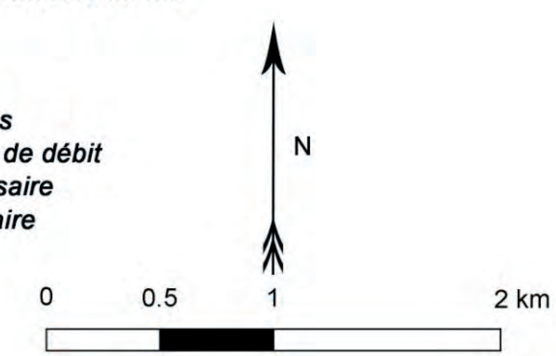


Table 8.1 Species Caught in Each Water Body

	ESLU	STVI	SAFO	PEFL	CACO	LOLO	MAMA	PHEO	PHEO MAMA	PHSP	RHCA	CUIN	COBA	SECO
Bernadette	12					1								
Bernadette tributary	2					2	7							
Bernadette tributary						7	7							
B-15														
B-17														
B-16 B-17 emissary														
A-1	6				2									
B-1							39	158				3		
Jean	4				21									
B-4	4			1	13									
B-5	2				37									
B-3	3				8									
B-6														
B-7	3				9									
B-8														
Denis	4													
Denis emissary					2		10			10				
Denis tributary														
B-11							5	20						
B-12			5				7	322						
B-13									677					
B-14			17				6		127					
Hills emissary			7							7				
Laugon							4		1,402			6		
Laugon emissary								5			8	3		
A-2							238	270				2		
A-2 emissary											4			1
Armitage	1	6												
Villefagnan														
Wynne	1				1	2	5	1			8		1	
Yvette tributary														
Pierre tributary E					2									
Pierre tributary N					7									
Total	**42**	**6**	**29**	**1**	**102**	**12**	**328**	**776**	**2,206**	**17**	**20**	**14**	**1**	**1**

See Table 8.2 for the meaning of abbreviations used.

Table 8.2 Species Tallied, Trophic Groups and Interest for Consumption

Common Name	Latin Name	Abbrev.	Trophic Group				Spawning Season	Interest
			Pisci-vorous	Benthi-vorous	Insecti-vorous	Plancto-nophage		
Mottled sculpin	Cottus Bairdii	COBA			X	Mottled sculpin	Cottus Bairdii	COBA
Yellow walleye	Stizostedion vitreum	STVI	X			Yellow walleye	Stizostedion vitreum	STVI
Brook stickleback	Culaea inconstans	CUIN			X	Brook stickleback	Culaea inconstans	CUIN
Northern pike	Esox lucius	ESLU	X			Northern pike	Esox lucius	ESLU
Burbot	Lota lota	LOLO	X		X	Burbot	Lota lota	LOLO
White sucker	Catostomus commersoni	CACO		X	X	White sucker	Catostomus commersoni	CACO
Pearl dace	Semotilus margarita	MAMA			X	Pearl dace	Semotilus margarita	MAMA
Longnose dace	Rhinichthys cataractae	RHCA		X	X	Longnose dace	Rhinichthys cataractae	RHCA
Brook trout	Salvelinus fontinalis	SAFO	X		X	Brook trout	Salvelinus fontinalis	SAFO
Fallfish	Semotilus corporalis	SECO			X	Fallfish	Semotilus corporalis	SECO
Yellow perch	Perca flavescens	PEFL	X		X	Yellow perch	Perca flavescens	PEFL
Northern redbelly dace *	Phoxinus eos	PHEO			X	Northern redbelly dace *	Phoxinus eos	PHEO
Northern redbelly dace or finescale dace (indeterminate)		PHSP			X	Northern redbelly dace or finescale dace (indeterminate)		PHSP

Table 8.3 Relative Abundance of Species Caught

Species	Number	Abundance %
Cyprinids PHEO & MAMA *	2,206	62.1
Northern redbelly dace (PHEO)	776	21.8
Pearl dace (MAMA)	328	9.2
White sucker	102	2.9
Northern pike	42	1.2
Brook trout	29	0.8
Longnose dace	20	0.6
Phoxinus sp	17	0.5
Brook stickleback	14	0.4
Burbot	12	0.3
Yellow walleye	6	0.1
Yellow perch	1	0.03
Mottled slcupin	1	0.03
Fallfish	1	0.03
Total	**3,555**	**100%**

*The northern redbelly dace (PHEO) accounts for more than two-thirds, and possibly up to 80%, of the fish caught.

Cyprinids were by far the most abundant family tallied. In the project area, they include the northern redbelly dace, finescale dace, pearl dace, longnose dace and fallfish. This family accounts for 92.4% of all catches, or 3,348 individuals out of a total of 3,555 fish caught. These numbers include 17 individuals in the Phoxinus genus, which are either northern redbelly dace or finescale dace.

In order of decreasing abundance, cyprinid species caught are the northern redbelly dace (±2,400), pearl dace (±925), longnose dace (20) and fallfish (1). The relative abundance of northern redbelly dace is very consistent with the habitat types surveyed at the project site. This species is particularly fond of calm water in beaver ponds and marshes with silty or humic bottoms. The pearl dace can also live in this type of habitat, but prefers clearer water. Its significant abundance reflects its adaptability.

The longnose dace, mottled sculpin and fallfish are at the other end of the spectrum, thriving in fast-moving, clear water with rocky or granular beds. The fact that they represent only 0.6%, 0.03% and 0.03%, respectively, of all catches indicates that they do not fare particularly well in this host environment.

Other than the above-mentioned forage fish, species at the top of the trophic chain are very scarce in water bodies at the mine site. Furthermore, the walleye caught (6) all came from Rivière Armitage, as these fish can not survive in the water bodies of the mine site. Predator species captured at the mine site were, in order of decreasing abundance, the northern pike (41), brook trout (29) and burbot (10), or 80 individuals (2.3 %) out of a total of 3,541 fish caught (these numbers do not include catches from Ruisseau Wynne and Rivière Armitage). The northern pike, which is the most abundant predator species, has a high tolerance for varied conditions, unlike the brook trout, which needs clear and very well oxygenated water to thrive. In fact, all brook trout catches are from two sites with favourable conditions. This is addressed later in the chapter.

The low relative abundance of predator species (2.3%) and the overabundance of species in other trophic levels (97.7%), most of which can tolerate marginal living conditions, are indicative of habitat quality. The following description of surveyed sites in the project area highlights these findings.

8.3 LAC JEAN DRAINAGE SYSTEM

All planned project infrastructures are within the Lac Jean watershed. From upstream to downstream, this includes Lac Denis and lakes B-9, B-8, B-7, B-6 and B-3, which flow south toward Lac Jean. It also includes a second chain of water bodies comprising lakes B-14, B-13, B-12 and B-11, which all flow into a common east-west trending tributary that in turn flows into lake B-6. From that point on, waters from both chains of lakes follow the same course to Lac Jean (Figure 8.2). All these lakes, as well as their tributaries and emissaries, are directly affected by the project.

8.3.1 Lac Jean

Through its main tributary, this large, 2.4-km long lake (Figure 8.2) drains two groups of lakes, the first one including lakes B-3, B-6, B-7, B-8 and Lac Denis, and the second, lakes B-11, B-12, B-13 and B-14. Lakes B-4 and B-5 drain into another tributary that flows into the bay at the northeast end of Lac Jean. Lac Jean itself is connected to Ruisseau Villefagnan via a very short emissary. The mean depth of Lac Jean is about 1 m and its maximum depth is 1.7 m. A bathymetric map of this lake is shown in Figure 8.3.

The southern part of Lac Jean comprises large grass beds, particularly near its main tributary, but also in its northeast bay, where abundant rush and large flood-prone areas are found. These make good breeding grounds for northern pike and feeding grounds for waterfowl, including Canada geese (seen), as well as for moose. This large mammal also benefits from the hilly areas nearby. Impassable beaver dams are found on the southern tributary (about 30-cm high) and on the northeast bay tributary (50-60-cm high). The beds of the Lac Jean tributaries and emissary are composed of organic matter colonized by aquatic plants. Large flood-prone ecotones line these streams.

Experimental fishing yielded five northern pike (Esox lucius) and 21 white sucker (Catostomus commersonii). Fishing time was 22 hours and 40 minutes. No fish were caught in any of the three creels set. The stomach of the one sacrificed pike only contained dragonfly larvae.

Ruisseau Villefagnan can be reached directly and without obstruction from Lac Jean. Because of the beaver dams, it is possible to reach lakes B-4, B-5 and B-3 by canoe through the northeast bay and south bay tributaries. These tributaries make good northern pike habitats, and moose make regular use of them.

This area is remarkably flat. The relief between the chains of lakes comprising the Lac Jean drainage system to Ruisseau Villefagnan does not exceed two metres. This area stretches over more than 8 km. This whole drainage system and the lentic portion of Ruisseau Villefagnan comprise a homogeneous environment in which beaver dams are the only obstacles to fish movement.

In winter, dissolved oxygen levels are very low to nil in some areas of the lake. However, because of the size of its watershed, water input into Lac Jean is large. The lake provides a good living environment for species such as northern pike and sucker, which have a high tolerance for variations in oxygen level. Walleye survival is limited by the shallow depth of the lake and its low dissolved oxygen content in winter.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.4. Sediments were sampled directly in Lac Jean downstream from each of its tributaries, namely in the south bay at 18U0568415, 5520106, and in the northeast bay at 18U0569709, 5521163.

Table 8.4 Lac Jean Physicochemical Parameters

Lac Jean					
Date	22/03/11	22/03/11	22/03/11	22/03/11	26/05/11
Longitude	18U0568979	18U0569856	18U0568740	18 U 568523	18U0568690
Latitude	5521148	5521500	5520793	5520407	5520409
Depth (m)	1.0	1.0	1.6	1.7	±1
Parameters:					
pH	8.14	9.03	8.74	9.02	7.83
°C	0.92	0.38	0.64	0.55	11.44
Atmospheric pressure (Mbar)	971.6	971.7	972	976.2	955
Conductivity at 25^{o} (µS/cm)	75	26	11	11	23
Total dissolved solids (TDS ppm)	38	13	6	5	13
Salinity (Sal)	0.03	0.01	0.00	0.00	0.01
Oxidation-reduction potential (ORP)	- 12.1	- 46.2	- 25	- 49	84.9
Dissolved oxygen (DO %)	0	0	5.7	15.7	75.7
Dissolved oxygen (DO mg/L)	0	0	0.75	2.16	7.79
Resistivity (KΩ. cm)					39.5
Ambient conductivity (µS/cmA)					19

Figure 8.3 Lac Jean Bathymetry

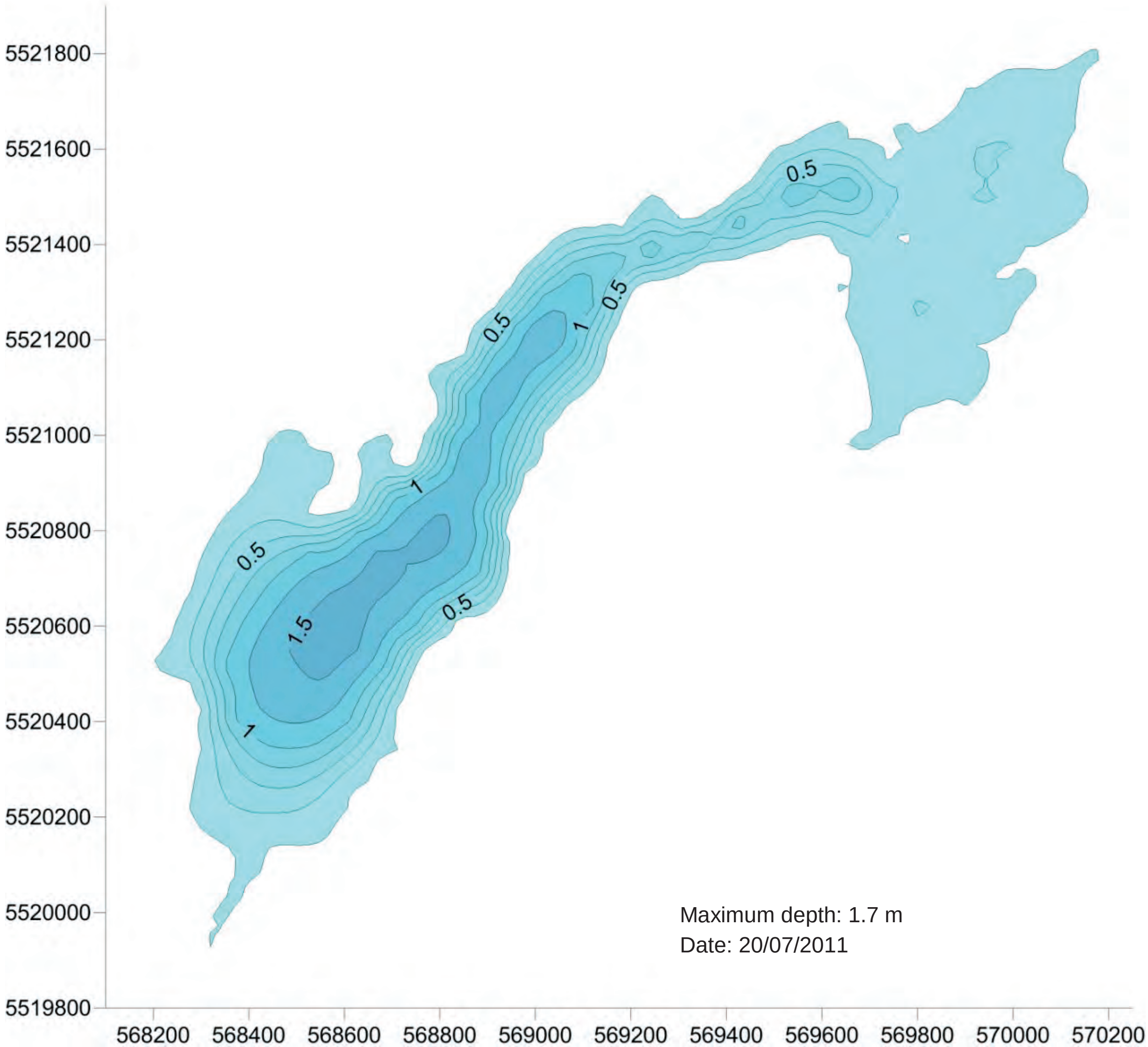


Photo 8.1: Main Lac Jean tributary, with flood-prone vegetation in springtime.

Photo 8.2: Beaver dam and flooded vegetation on main Lac Jean tributary (south).

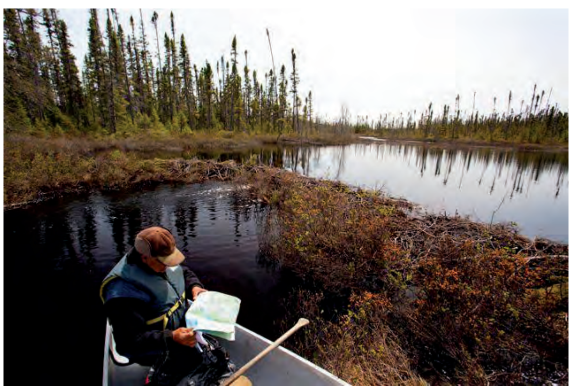


Photo 8.3: Beaver dam on northeast Lac Jean tributary

Photo 8.4: Lac Jean emissary

8.3.2 Lac Jean Lowlands Subsystem

The Lac Jean lowlands subsystem comprises, from upstream to downstream, Lac Denis and lakes B-9, B-8, B-7, B-6 and B-3, which flow one into the other before reaching Lac Jean. This area is generally very flat and characterized by multiple wetlands.

8.3.2.1 Lac Denis

Lac Denis, approximately 400 metres long, is a headwater lake fed by two intermittent tributaries (Figure 8.2). Its emissary successively links lakes B-8, B-7, B-6, B-3 and Lac Jean. This is a clear-water lake generally less than one metre deep, although depths of 2 to 3.5 m are observed in some areas (Figure 8.4). The first tributary in the southeast is about 40 cm wide at its mouth and dies out in vegetation within 25 m of the lake. In the summer of 2011, its discharge was approximately 0.02 m^3/min. Its bottom consists of sand and mud, and it is lined with sweet gale and carex. The other tributary enters the lake in a small muddy bay. It is crossed by a logging road and has a cobbly bottom. A juvenile wood frog (Lithobathes sylvaticus) was spotted in it. The emissary had a discharge of 0.017 m^3/s in the summer of 2011. Two small pikes were spotted in the upper reach of this emissary, the first portion of which comprises large flood-prone grass beds. In March 2011, very low oxygen levels (0.6 and 0.39 ppm) were measured in the lake.

Experimental fishing was carried out in Lac Denis in 2001, during which 58 fish were caught, including, in order of decreasing abundance, northern pike, white sucker, yellow perch and fallfish.[2] Mathew Wapachee reported catching brook trout in Lac Denis a long time ago, which is consistent with the fact that the lake B-6 tributary supports a brook trout population. Also, with the exception of one beaver dam, there are no major obstacles between lake B-6 and Lac Denis.

In the summer of 2011, an experimental net and five creels were set in the lake. Two jack pike were spotted, one near a small grass bed and the other in the large rush bed located in the northern bay of the lake. A cyprinid school was also seen very far from the shore in this bay. During 18 hours and 48 minutes of fishing with an experimental net, four northern pike were caught with total lengths ranging from 537 to 695 mm (0.87 to 1.86 kg). The northern pike were in good condition. An 8-cm jack pike was found in the stomach of the largest one. The stomach content of another was nondescript, while the other two individuals had empty stomachs.

Electrofishing was carried out in the emissary and main tributary on the east side of the lake in August 2011. No fish were caught in the tributary, while the emissary yielded two white sucker (Catostomus commersonii), 10 pearl dace (Margariscus margarita) and 10 Phoxinus sp.

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[2] Page 124, projet minier Ressources McKenzie Bay Ltée, Mines de vanadium, Volume 1: inventaires et analyses, P33699-3/June 2003, Groupe-conseil Entraco

Despite its considerable size, Lac Denis appears to only support a limited northern pike population and very few forage fish. It does offer very nice grass beds for breeding, as well as abundant rush in the bay near the emissary, which make good nursery areas for northern pike.

The clear waters of Lac Denis offer any sucker and cyprinids that venture into it little chance of survival, as pikes can take advantage of troughs near small grass beds and the shoreline.

Flow in emissary and tributary streams can be quite low. On September 20, 2011, the discharge at the lake outlet was nil. This is the main piscifauna-limiting factor in the lake, because it affects survivability and strongly limits oxygenation in winter. Otherwise, the lake troughs and grass beds are good habitat features.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.5.

Table 8.5 Lac Denis Physicochemical Parameters

Lac Denis			
Date	25/03/11	25/03/11	05/07/11
Longitude	18U0567440	18U0567440	18U0567426
Latitude	5516359	5516359	5516362
Depth	1 M		80 CM
pH	< 6.8		8.36
°C	1.61		21.86
Atmospheric pressure (Mbar)	966.6		944.2
Conductivity at 25^{o} (µS/cm)	139		94
Total dissolved solids (TDS ppm)	69		46
Salinity (Sal)	0.06		0.04
Oxidation-reduction potential (ORP)	-16.8		38.2
Dissolved oxygen (DO %)	4.5 *	3.0 **	85.6
Dissolved oxygen (DO mg/L)	0.6 *	0.39 **	7.26
Resistivity (KΩ. cm)			10.6
Ambient conductivity (µS/cmA)			85

******Reading time: 2 minutes
***Reading time: 3 minutes

Figure 8.4 Lac Denis Bathymetry

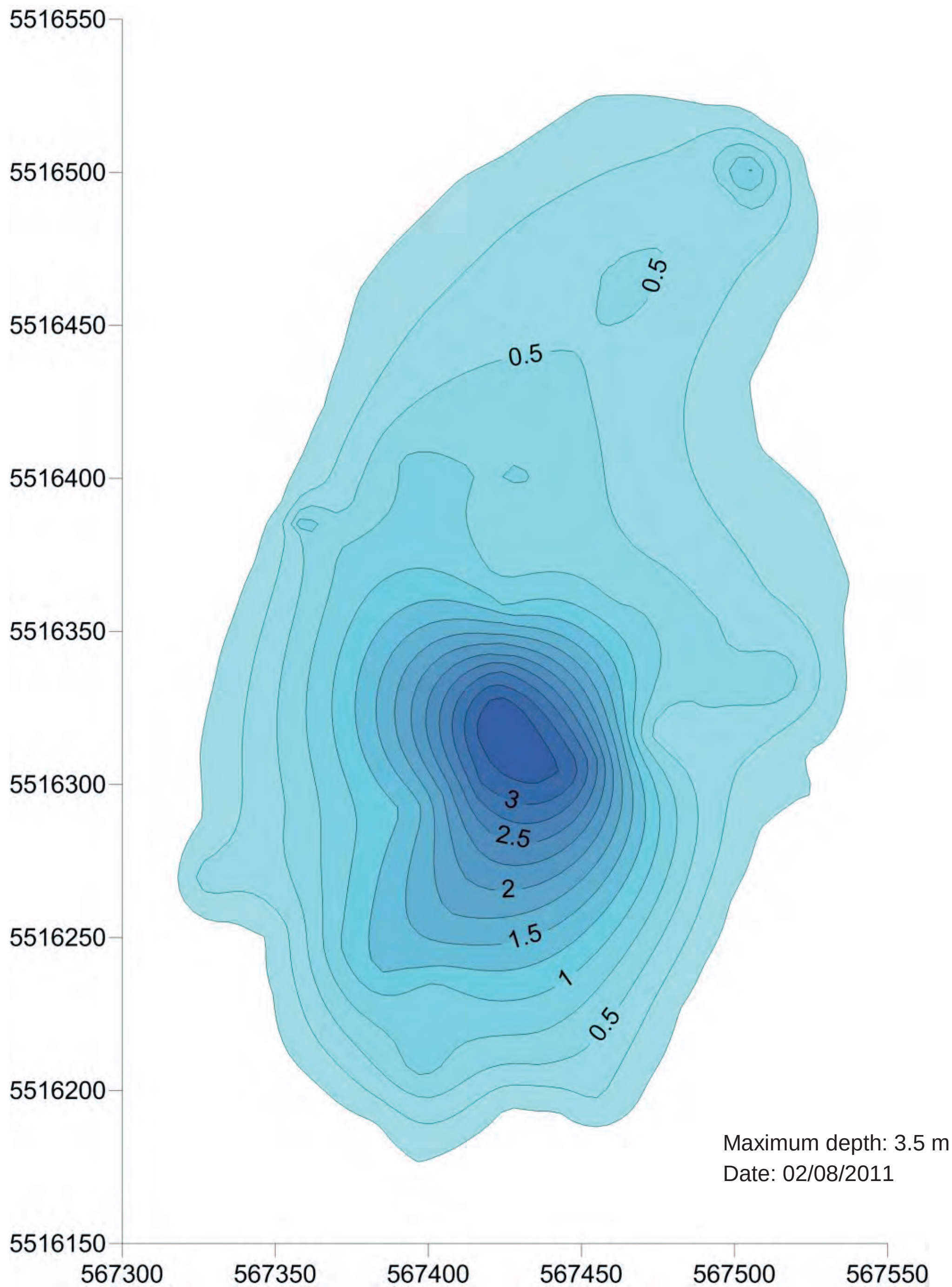

Photo 8.5: Lac Denis, from south shore near the smallest tributary. A few signs of beaver are visible, as well as aquatic vegetation comprising carex and water-lily, and flood-prone vegetation comprising carex and sweet gale. The low point on the horizon is the outlet area.

Photo 8.6: Start of north bay of Lac Denis. Rush covers all of the northern section up to the emissary.

Photo 8.7: Riparian vegetation comprising carex and some rush on west side of Lac Denis.

Photo 8.8: General view of Lac Denis from the south.

Photo 8.9: Northern pike in good condition, caught with a gill net.

Photo 8.10: Rush bay on north shore of lake, with flood-prone vegetation.

Photo 8.11: Lac Denis emissary and last rush section.

Photo 8.12: Small bay in which the main Lac Denis tributary flows; muddy bed and shores where leatherleaf and sweet gale grow.

Photo 8.13: Main Lac Denis tributary, downstream from road. Muddy bed and tangled trees.

Photo 8.14: Main Lac Denis tributary near the point where it enters the forest. A juvenile wood frog (Lithobathes sylvaticus) was spotted on one of the boulders.

8.3.2.2 Lake B-9

Lake B-9 is a bog pool located northwest of Lac Denis and west of lake B-7, in a large bog plain. This plain is located on the divide between the Lac Bernadette and Lac Jean watersheds. The pool is slightly closer to the Lac Denis emissary than to the main Lac Bernadette tributary.

The bog pool is approximately 70-m long by 50-m wide. Its depth does not exceed 50 cm. There are no streams flowing into or out of it. A small tributary of the Lac Denis emissary trends toward the pool but dies out in peat more than 300 m from it. In its northern section are vegetation islands that account for half of the pool surface area. The pool is strongly eutrophic and no fishing or analyses were done there. Lake B-9 is not amenable to fish survival. This bog pool will be backfilled to make way for the mine garage.

8.3.2.3 Lakes B-6, B-7 and B-8

These three lakes flow into lake B-3, which feeds into Lac Jean. Although the three lakes are less than 200 m apart, they are very separate water bodies. They are located precisely at the planned site of the waste rock platform for the coarse tailings pile. The platform will also cover the tributaries and emissaries of these lakes.

In March 2011, lake B-7 had the highest oxygen concentration (5.52 ppm) of all the lakes surveyed, lake B-6 was frozen to the bottom, and a strong sulphur smell emanated from lake B-8, which had a nill dissolved oxygen content.

Lake B-7

This narrow, roughly 200-m long lake flows into lake B-6. According to 1:20,000 maps, it receives the water from lake B-8. Water from Lac Denis also flows into it via a different tributary. An old beaver dam obstructs this second tributary. Measured depth in the lake is generally less than 1 m, although a small, 2.3-m deep trough was found (Figure 8.5). The bottom is essentially composed of organic matter.

At its outlet, a roughly 90-cm high beaver dam raises the lake water level. Abundant flooded vegetation comprising carex and sweet gale is found in the lake, and outward from this are leatherleaf and blue flag. Water-lily, rush and eelgrass make up the aquatic vegetation. The bottom of the emissary consists of mud and organic matter, and water-lily makes up the bulk of its aquatic vegetation. Riparian vegetation includes commonly flooded sweet gale and carex, as well as cinquefoil, alder and blue flag.

Because of the narrowness of the lake, only half of the experimental net was used. Two northern pike and nine white sucker were harvested after 20 hours and 55 minutes of experimental net fishing. The northern pike were 245 and 255 mm in total length and the white sucker were 172 to 269 mm long. One 98-mm long jack pike was caught in one of the five creels set.

The tributary mapped as flowing from lake B-8 does not exist. Lake B-8 flows under peat to lake B-7.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.6.

Table 8.6 Lake B-7 Physicochemical Parameters

Lake B-7			
Date	25/03/11	25/03/11	11/07/11
Longitude	18U0567563	18U0567563	18U0567544
Latitude	5517266	5517266	5517214
Depth (m)	1.2		0.80
pH	< 6.8		7.92
°C	0.35		16.2
Atmospheric pressure (Mbar)	966.0		958.7
Conductivity at 25^{o} (µS/cm)	107		52
Total dissolved solids (TDS ppm)	53		41
Salinity (Sal)			0.04
Oxidation-reduction potential (ORP)	- 40.8	- 19.0	278
Dissolved oxygen (DO %)	39.1	40.7	73.9
Dissolved oxygen (DO mg/L)	5.39 **	5.52 ***	7.02
Resistivity (KΩ. cm)			12
Ambient conductivity (µS/cmA)			68

** Reading after 2 minutes

*** Reading after 3 minutes

Figure 8.5 Lake B-7 Bathymetry

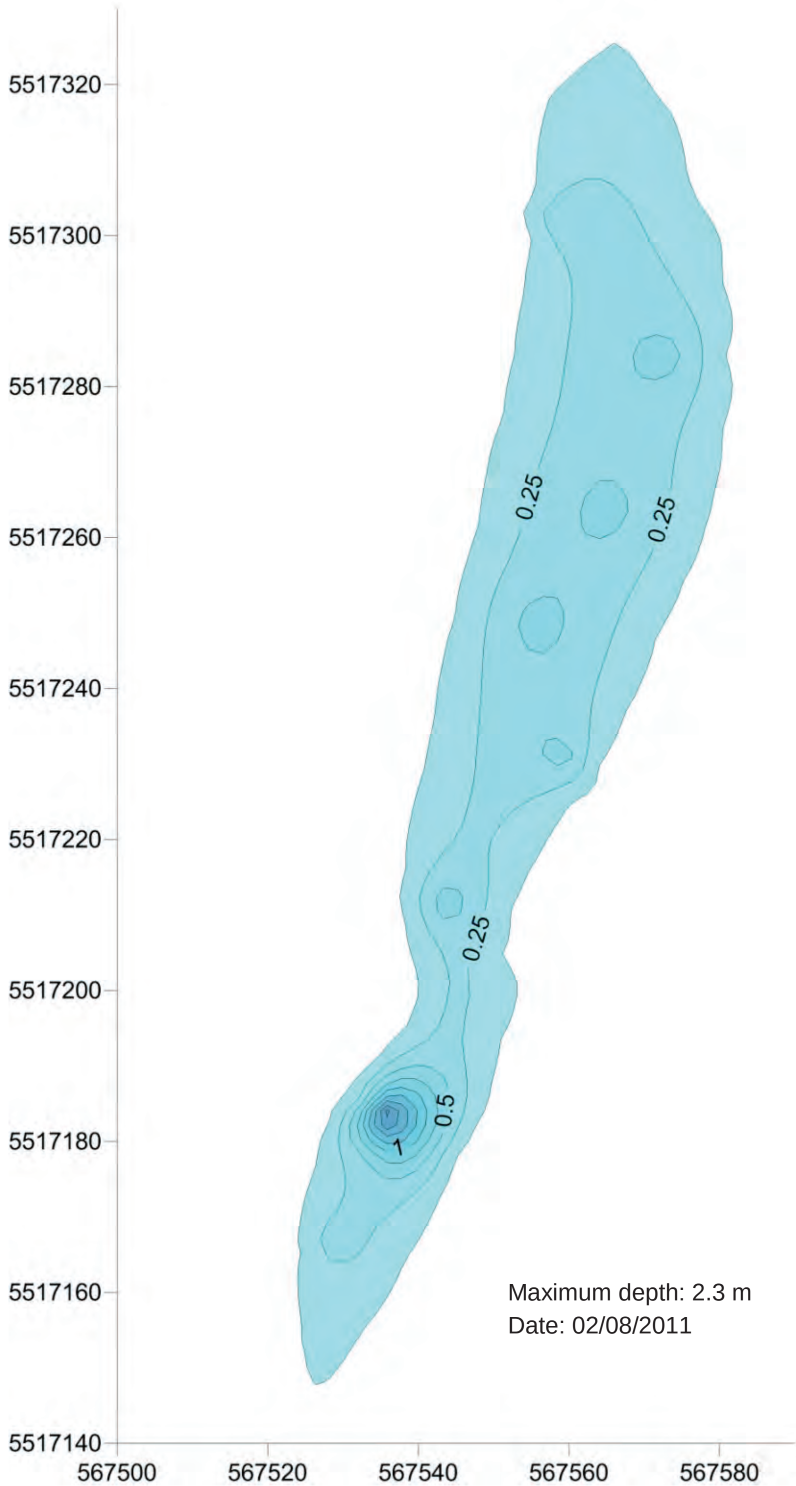

Photo 8.15: Main lake B-7 tributary; carex, sweet gale and blue flag are seen at edges.

Photo 8.16: General view of lake B-7 towards its emissary, with water-lily and rush in the foreground. At lake edge is a black spruce stand on organic rich substrate.

Photo 8.17: Beaver dam at lake B-7 outlet and emissary towards lake B-6. Dam height is approximately 90 cm.

Photo 8.18: Lake B-7 (looking towards main tributary); riparian vegetation comprising carex, leatherleaf, sweet gale and blue flag. Water-lily, eelgrass and rush make up the aquatic vegetation.

Photo 8.19: Lake B-7 (looking towards emissary); flooded riparian vegetation and aquatic vegetation.

Lake B-8

Lake B-8 is a classic bog pond. The creel set in it only yielded one large diving beetle. Water analysis results confirm its bog chemical signature: an acid pH of 6.68, a dissolved oxygen content of 2.10 ppm and an ORP of -78. Rich aquatic vegetation in the pond consists of water-lily, carex and buckbean (marsh trefoil). Riparian vegetation comprises sphagnum, carex, sweet gale, leatherleaf and abundant wild rose shrubs.

Water depth reaches 50 cm in the deepest part of the pond, near its western shore. About 30 m to the east of lake B-8 is another very similar albeit slightly shallower pond in a more open setting. This pond has no tributary or emissary, and does not appear on maps.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.7.

Table 8.7 Lake B-8 Physicochemical Parameters

Lake B-8		
Date	25/03/11	11/07/11
Longitude	18U0567749	18U0567733
Latitude	5517235	5517228
Depth (m)	1.0	30 CM
pH	< 6.8	6.68
°C	0.71	21.12
Atmospheric pressure (Mbar)	965.6	940.9
Conductivity at 25^{o} (µS/cm)	65	75
Total dissolved solids (TDS ppm)	33	78
Salinity (Sal)	0.03	0.03
Oxidation-reduction potential (ORP)	- 204	- 78
Dissolved oxygen (DO %)	0	11.4
Dissolved oxygen (DO mg/L)	0	2.10
Resistivity (KΩ. cm)		13.4
Ambient conductivity (µS/cmA)		70

Photo 8.20: Lake B-8; wild rose in the foreground. This lake is a bog pond without tributary or emissary.

Photo 8.21: Lake B-8; rich aquatic vegetation consisting of carex, water-lily and buckbean, with leatherleaf and sweet gale at edges

Photo 8.22: Lake B-8; aquatic vegetation consisting of carex, water-lily and buckbean.

Lake B-6

At the outlet to lake B-7, upstream from lake B-6, two successive beaver dams delineate a wide, 30- to 60-cm deep pool with abundant aquatic vegetation. Further downstream, the lake B-7 emissary narrows and seldom exceeds a depth of 30 cm. Aquatic vegetation is also abundant in this section, consisting of water-lily, eelgrass and carex on a muddy bottom. Fine sediments cover the bottom of the emissary immediately adjacent to lake B-6.

Lake B-6 is roughly 200-m long and no more than 30-cm deep. During the March 2011 physicochemical survey, mud was found immediately below the ice. Flood-prone vegetation and a few grass beds line this muddy lake. Aquatic vegetation comprises water-lily, carex, abundant pondweed and eelgrass. A second substantial tributary flows into the lake very near its outlet. This tributary drains the hilly area, more specifically waters from lakes B-11, B-12, B-13 and B-14. Electrofishing carried out on this stream further upstream confirmed the presence of brook trout.

Two small pikes were seen during the July 2011 field visit. Four creels set near grass beds remained empty after 84 hours. Because the average depth of the lake is 20 cm, experimental nets could not be set. Measured water temperature was 21.07ºC.

This lake can only serve as transitional grounds for fish. Its flood-prone vegetation, grass beds and aquatic vegetation provide good nursery areas for northern pike. The shallow depth of the lake means that larger individuals are vulnerable to predation.

Water depth increases downstream in the lake B-6 emissary, where grass beds, large pools and shrubby vegetation comprising sweet gale are found, providing an adequate setting for fish survival.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.8.

Table 8.8 Lake B-6 Physicochemical Parameters

Lake B-6		
Date	25/03/11	12/07/11
Longitude	18U0567763	18U0567742
Latitude	5517529	55174482
Depth (m)		0.20
pH		8.37
°C		21.07
Atmospheric pressure (Mbar)		942.0
Conductivity at 25^{o} (µS/cm)		99
Total dissolved solids (TDS ppm)		49
Salinity (Sal)		0.05
Oxidation-reduction potential (ORP)		310
Dissolved oxygen (DO %)		71.9
Dissolved oxygen (DO mg/L)		6.74
Resistivity (KΩ. cm)		9.3
Ambient conductivity (µS/cmA)		95

Photo 8.23: Lake B-6; large riparian vegetation area on east side of lake, comprising sphagnum, carex, sweet gale and leatherleaf. The lake is in the process of disappearing.

Photo 8.24: Lake B-6; eelgrass and water-lily in 20 cm of water on muddy bottom.

Photo 8.25: Lake B-6, at mouth of tributary from Lac Denis and lake B-7.

Photo 8.26: Lake B-6 tributary from Lac Denis and lake B-7. Muddy bottom with scattered rocks. Downstream from the second beaver dam, which is barely 30-cm high, dense aquatic vegetation comprises carex, water-lily and eelgrass. The second beaver dam is visible in the top middle left of the photo.

8.3.2.4 Lake B-3

Lake B-3, its tributary and the bulk of its emissary will be destroyed to make way for the waste rock and coarse tailings piles. From upstream to downstream, it drains the waters of Lac Denis and lakes B-8, B-7 and B-6. A second tributary drains lakes B-14, B-13, B-12 and B11. Lake B-3 is slightly more than 300-m long, and is surrounded by a large, well-drained plain consisting of flood-prone vegetation.

The lake B-3 tributary and emissary are both characterized by flood-prone vegetation that makes good breeding ground for northern pike, and aquatic vegetation comprising water-lily, pondweed and eelgrass. Watercourses are deeper, often twice as deep, as the lake: rivers are up to 1.4 m, while the maximum depth measured in the lake is 0.7 m (Figure 8.6). The lake bottom is composed of organic matter.

Fish can move freely at all times along the whole length of the emissary to the first rapid located some 400 m downstream. A beaver dam located at its mouth at Lac Jean is the only obstacle to fish movement, and even it is passable in periods of high water.

During field work in March 2011, the lake was frozen to the bottom at both sampling sites. No fish species can survive the winter in this lake. After 21 hours, experimental fishing with an experimental gill net in July 2011 yielded three northern pike (Esox lucius) and eight white sucker (Catostomus commersonii). The northern pike ranged in length from 265 to 340 mm, and the white sucker from 218 to 328 mm. No fish were caught in any of the five creels set. Local conditions in winter 2011 and fishing results in summer 2011 clearly show that fish are absent from lake B-3 in winter, only being found in its tributary and emissary. The lake offers seasonal survival conditions for a limited population of small northern pike. The lake’s hydraulogical system, particularly the presence of troughs and an abundant input of fresh water, plays an important role in fish survival. The emissary is closely linked to Lac Jean and provides good breeding grounds for northern pike.

On July 16, 2011, discharge measured in the tributary was 0.120 m^3/s at the small rapid located about 400 m from lake B-3. One sediment sample was collected in lake B-3, at 18U0567870, 5518796.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.9.

Table 8.9 Lake B-3 Physicochemical Parameters

Lake B-3	
Date	15/07/11
Longitude	18U0567879
Latitude	5518785
Depth (m)	45 CM
pH	7.82
°C	19.32
Atmospheric pressure (Mbar)	949.9
Conductivity at 25^{o} (µS/cm)	49
Total dissolved solids (TDS ppm)	25
Salinity (Sal)	0.02
Oxidation-reduction potential (ORP)	33.2
Dissolved oxygen (DO %)	91.1
Dissolved oxygen (DO mg/L)	7.76
Resistivity (KΩ. cm)	20.3
Ambient conductivity (µS/cmA)	44

Figure 8.6 Lake B-3 Bathymetry

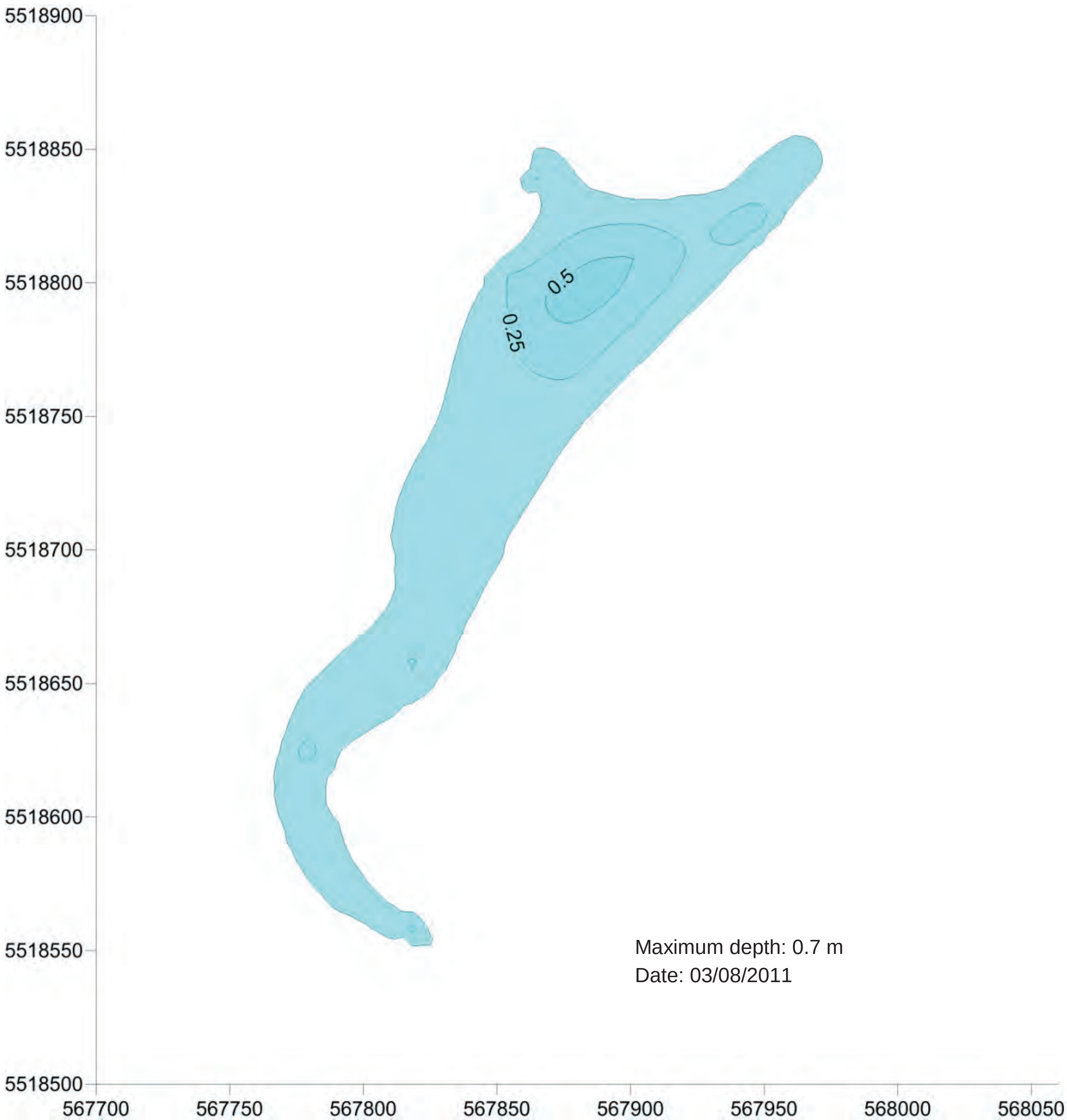

Photo 8.27: Lake B-3 from its western shore.

Photo 8.28: Lake B-3 from its eastern shore, looking towards the emissary.

Photo 8.29: Lake B-3, flood plain, eastern section (Mathew Wapachee).

Photo 8.30: Lake B-3; riparian vegetation comprising carex, leatherleaf and sweet gale.

Photo 8.31: Lake B-3 tributary (Matthew Wapachee); signs of moose are abundant in this area.

Photo 8.32: Lake B-3 tributary near its upper small rapid section; a flood plain is no longer present along the stream.

8.3.3 Mountains Subsystem

The Mountains subsystem is also associated with the Lac Jean drainage system. Its name comes from the fact that waters in this subsystem flow down some 65 m before reaching lake B-6 and joining the common tributary that flows towards Lac Jean. From upstream to downstream, this subsystem comprises lakes B-14, B-13, B-12 and B-11 (Figure 8.2).

8.3.3.1 Lake B-14

Lake B-14 along with its tributaries and emissary will disappear to make way for the fine tailings pond infrastructure. This lake, which is about 42 m long, is located in a hilly zone, more specifically at the foot of a high hill and northeast of Lac Denis. It is a headwater lake and has two tributaries, one of which drains two small fen ponds. Its emissary merges with waters flowing from lakes B-13, B-12 and B-11.

Except for its southern section, the lake is surrounded by a large flood-prone and flooded plain in which carex and sweet gale are submerged. Aquatic vegetation in the lake comprises water-lily, rush and eelgrass. Its northern section is a large marsh into which both tributaries flow. While water depth in this marsh does not exceed 10 cm or so, depth in the tributary channels, where aquatic vegetation comprises water-lily, ranges from 40 to 100 cm.

Conditions in these channels are independent from those in surrounding marshes. In winter, water freezes on the surface of the neighboring marsh, thus isolating the channels and preventing decomposition, and accounting for the high dissolved oxygen content (5.25 ppm) measured in lake B-14 in March 2011. Such oxygen contents allow the survival of fish such as brook trout.

The main tributary to the west is fed by two fen pools. From upstream to downstream, it flows over a bed of fine sediments, then cascades down into a very open area. In this roughly 100-m long section, the stream bed is composed of cobbles and gravel. Water discharge measured in the summer of 2011 was 0.026 m^3/s. Peatbogs located upstream act as sponges that slowly release water. Water is oxygenated as it flows downstream over small cascades. This tributary bed makes adequate spawning ground for brook trout.

A dam is located at the lake outlet. It is roughly 90-cm high and sticks out about 10 cm above the water surface. About 20 m downstream, a second dam forms a 20-m long by 7-m wide pool. Still further down, the stream becomes sinuous and shallow and flows over a rocky bed. Discharge measured in July 2011 was 0.060 m^3/s.

In summer 2011, experimental fishing, physicochemical measurements, sediment sampling and a bathymetric survey were done in this lake. A sediment sample was collected at coordinates 18U0569379, 5517233. Average water depth (Figure 8.7) was very small (0.7 m) and the maximum depth was 1.0 m.

One pearl dace (Margariscus margarita) and fourteen brook trout (Salvelinus fontinalis) were caught in the experimental net. The four creels yielded three other brook trout and 132 cyprinids (of which 127 came from a single creel). A species count of cyprinids was not performed. They included pearl dace (Margariscus margarita) and northern redbelly dace (Phoxinus eos). The fourteen brook trout individuals from the experimental net ranged in total length from 132 to 285 mm. One trout was released back into the lake. Of the thirteen that were kept, there were nine females, two males and two individuals of indeterminate gender. Insects were found in the stomachs of two trout. The eleven remaining trout had empty stomachs.

The lake B-14 ecosystem supports brook trout. Its shallow depth is not an impediment to survival for these fish, as they can take refuge in its channels in winter or during rare heat waves.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown inTable 8.10.

Table 8.10 Lake B-14 Physicochemical Parameters

Lake B-14		
Date	23-03-11	08-07-11
Longitude	18U569401	18U569373
Latitude	55171219	5517214
Depth (m)	0.8	0.5
pH		8.77
°C	0.18	18.06
Atmospheric pressure (Mbar)		
Conductivity at 25^{o} (µS/cm)	77	56
Total dissolved solids (TDS ppm)	38	28
Salinity (Sal)	0.04	0.03
Oxidation-reduction potential (ORP)	-58.3	20.6
Dissolved oxygen (DO %)	38.3	70.1
Dissolved oxygen (DO mg/L)	5.25	6.52
Resistivity (KΩ. cm)		
Ambient conductivity (µS/cmA)		

Figure 8.7 Lake B-14 Bathymetry

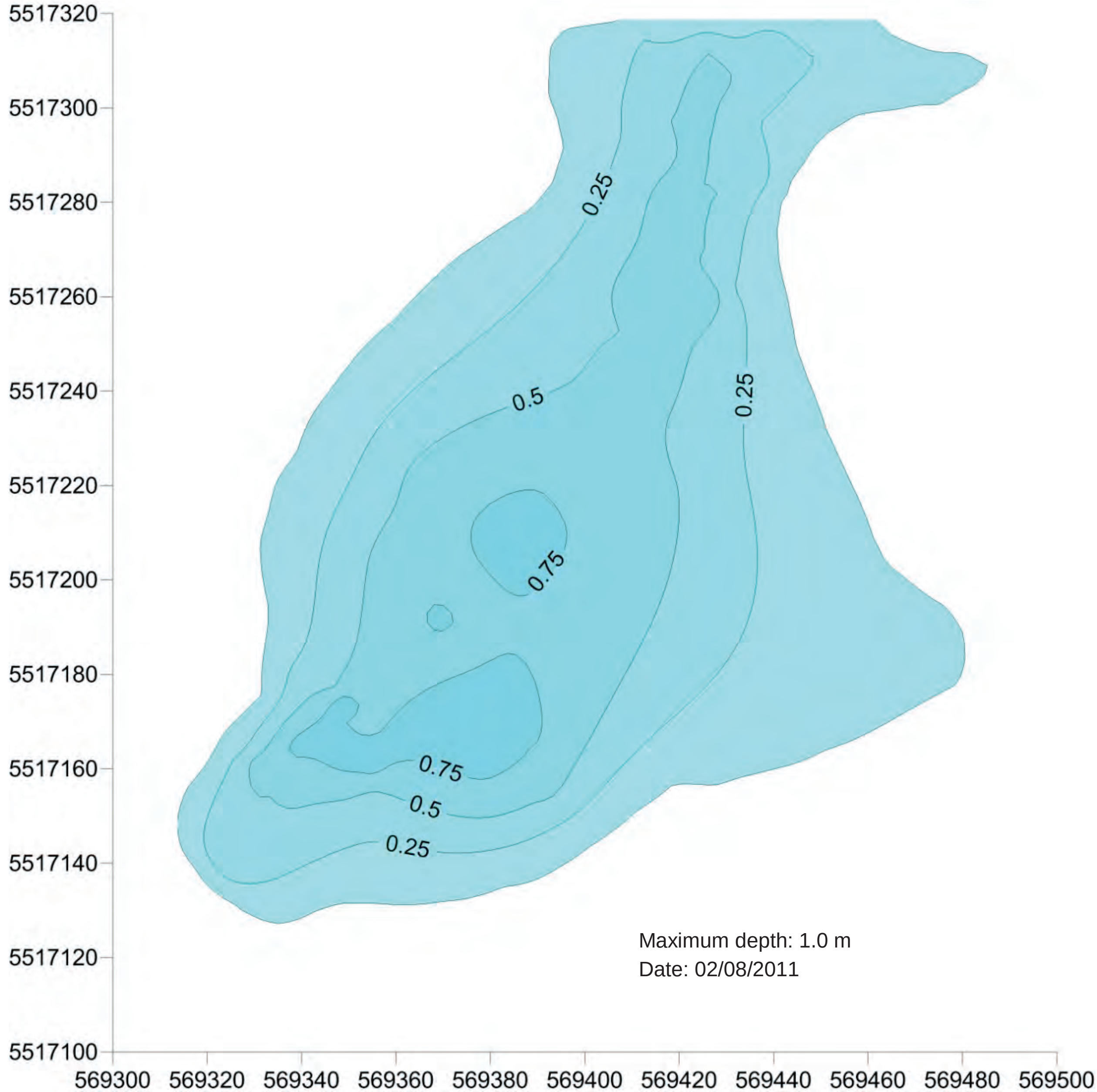

Photo 8.33: Beaver dam on lake B14 emissary

Photo 8.34: Some of the 17 brook trout caught in lake B-14; three were caught in creels and 14 in a net. Creels also produced 132 cyprinids.

Photo 8.35: View of the central and northern sections of lake B-14. Riparian vegetation is in a flood plain where carex and sweet gale emerge.

Photo 8.36: Channel of main lake B-14 tributary, lined with carex and sweet gale.

Photo 8.37: Lake B-14 main tributary; view looking upstream at fen draining into it and at hill feeding it.

Photo 8.38: Main tributary upstream from lake B-14 in open area. Clear water and rocky, gravelly bottom.

Photo 8.39: One of two fen pools that flow into a lake B-14 tributary.

8.3.3.2 Lake B-13

As the northern part of lake B-13 is in the line of the planned fine tailings pond dam, it will be backfilled.

Lake B-13, a headwater lake, is roughly 280 m long. It is surrounded by large flood meadows, particularly in its northern section. Its waters join up with lake B-12 waters before flowing down several rapids and cascades and into lake B-6. A very small, 5- to 20-cm wide tributary is located northeast of the lake. A thin sheet of water barely a few millimeters thick flows in it. Because of the shallow depth of the stream and the presence of plant debris, its discharge cannot be measured. The lake B-13 emissary is accessible via a channel to the west of the large flood meadow in the northern part of the lake. It first narrows then widens immediately ahead of a very old, overgrown beaver dam. In July 2011, emissary waters at the level of the dam were stagnant.

The average depth of the lake is approximately 1 m. There are, however, some troughs up to 2.9 m deep (Figure 8.8) that might provide ice-free, albeit not necessarily oxygenated, settings for fish in winter. In March 2011, a sulphur smell emanated from a hole cored through the lake B-13 ice and the dissolved oxygen reading from the multiparameter meter was 0.0 ppm. The ORP reading was -90.7. In summer 2011, a strong sulphur smell emanated when the mud was disturbed.

On July 4 and 5, an experimental net was set in a trough more than 1.5 m deep in the southern part of the lake. Five creels were also baited and set. Two pearl dace (Margariscus margarita) were caught in the net after 20 hours and 11 minutes. The five creels yielded 675 cyprinids. Most of these were released, but a few were preserved in formaldehyde for subsequent identification. Two species were present in the lake, namely pearl dace (Margariscus margarita) and northern redbelly dace (Phoxinus eos), the latter being by far the most abundant species caught.

Fish survival in this water body may depend on some local features such as deeper stream sections (which is not the case) or poorly-known physiological adaptations by some cyprinids.[3] This lake is a good example of why extreme caution must be exercised in assessing whether or not a given water body is conducive to fish survival.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.11.

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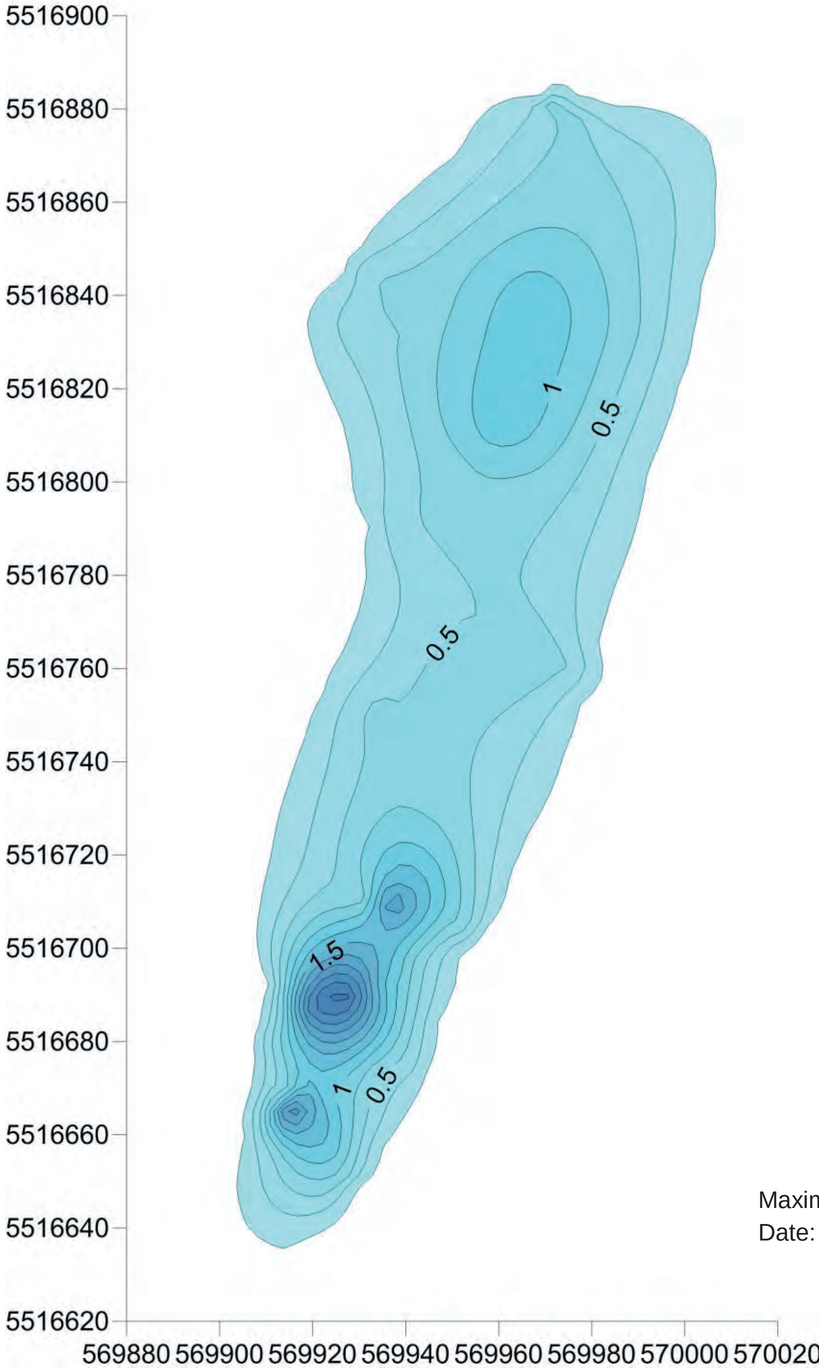
[3] In Europe, the crucian carp (a large cyprinid) survives deep pond freezing by burying itself in silt. http://sitewebseille.fr/pages_flash/poissons_seille.htm. “In winter, the crucian carp “hibernates”! It buries itself almost completely in silt and, in this way, can survive freezing down to the pond bottom. It nearly shuts down its vital functions and comes back to life with the coming of spring.”

Table 8.11 Lake B-13 Physicochemical Parameters

Lake B-13		
Date	29/03/11	04/07/11
Longitude		
Latitude		
Depth (m)	0.9	0.7
pH		8.56
°C	0.41	21.49
Atmospheric pressure (Mbar)		
Conductivity at 25° (µS/cm)	58	41
Total dissolved solids (TDS ppm)	29	21
Salinity (Sal)	0.03	0.02
Oxidation-reduction potential (ORP)	-90.7	45.1
Dissolved oxygen (DO %)		88.2
Dissolved oxygen (DO mg/L)		7.15
Resistivity (KΩ. cm)		
Ambient conductivity (µS/cmA)		

Figure 8.8 Lake B-13 Bathymetry



Maximum depth: 2.9 m
Date: 02/08/2011

Photo 8.40: Lake B-13; detail of carex and sweet gale flood plain. South bay of lake B-13. The plain in this lake is very boggy.

Photo 8.41: South bay of lake B-13; flood-prone vegetation comprising carex, sweet gale and leatherleaf; and view of whole length of lake.

Photo 8.42: Lake B-13; channel leading to old beaver dam at lake outlet. The waterbody ahead of the dam is a relict.

Photo 8.43: Lake B-13; flood plain in emissary area. Carex and sweet gale vegetation and springy soil (Matthew Wapachee).

Photo 8.44: Lake B-13; flood-prone vegetation in north bay of lake. Sheathed cottonsedge, leatherleaf, gale and carex.

Photo 8.45: Lake B-13; tributary to northeast of lake, lined by carex and sweet gale. The stream peters out before reaching the trees at the edge of the forest.

Photo 8.46: Lake B-13; northern redbelly dace and pearl dace.

Photo 8.47: Lake B-13; shore in west-central part of the lake (Charlie Bossum).

8.3.3.3 Lakes B-11 and B-12

These two contiguous lakes flow towards lake B-6. Lake B-11 is located in the line of the polishing pond dam and will therefore be covered by this structure. Lake B-12 overlaps both the line of the dam and the polishing pond worksite and will also be covered by these facilities.

Lake B-11

Lake B-11, the smaller of the two lakes, has all the characteristics of a bog lake. It does, however, have a small emissary that flows in the lake B-12 tributary. Lake B-11 has no structured tributary. It is an ovoid pond roughly 80 m in length, surrounded by a mat of sphagnum. The lake itself is a pool within this bog. In March 2011, ice was cored down to the mud without encountering water.

A second visit in the summer of 2011 confirmed that the lake is not more than 30 cm deep. Buckbean, carex, sweet gale, bladderwort and some leatherleaf line its edges. The springiness of the ground makes approaching the lake tricky. Carex and water-lily grow in the pool mud. The water between the tufts of vegetation is generally not more than 20 cm deep.

The emissary that links up with the lake B-12 tributary is roughly 50 metres long. At the lake outlet, it is 30 cm wide and its bed consists of mud. Measured discharge is 0.002 m^3/s.

A creel was set in a part of the pool that forms a small grassy enclave where drainage waters flow. The bottom of the lake consists of cracked mud that rises as plates: the lake seems to undergo severe low water periods. Its depth does not exceed 30 cm for the most part.

On July 31, 2011, 20 northern redbelly dace (Phoxinus eos) and five pearl dace (Margariscus margarita) were caught in the lake. Lake B-13 is a marginal aquatic habitat from which water is absent in winter as well as at certain times of the summer. Because it is linked to lake B-12, its very small emissary allows cyprinids to transit through this often inhospitable environment.

Photo 8.48: Lake B-11; pond in peatbog encased among hills. Carex, water-lily and some buckbean colonize the pond mud.

Photo 8.49: View of lake B-11 looking upstream. Sweet gale and leatherleaf grow on a springy mat.

Photo 8.50: Lake B-11 emissary; 30 cm wide and lined with carex, bladderwort and sweet gale.

Photo 8.51: Mud plates on bottom of deepest section of lake B-11 (30 cm).

Lake B-12

Lake B-12 is located in the same bog plain as lake B-11, about 50 m to the northeast (Figure 8.2). In March 2011, this lake, like lake B-11, was frozen to the bottom.

During the field visit in the summer of 2011, the water level in this water body, which appears on the map to be roughly 200 metres long, was abnormally low such that part of the bottom was exposed. Aquatic vegetation comprises pondweed, rush, water-lily and eelgrass. Its bottom consists of mud and rocks. In the section of the lake closest to its outlet, the water is deeper. The lake is narrower, and its depth reaches 60 cm. At the outlet, there is an old abandoned beaver dam. Water flows under it along the lake bottom.

At its mouth, the lake B-12 tributary that flows from lake B-13 has a rocky bed and flows into a bay in the southeast part of lake B-12. Farther upstream, it meanders through the bog on a bed that is richer in organic matter. Discharge at the junction with the lake B-11 emissary is 0.016 m^3/s. The tributary is often quite wide and remains unobstructed until it narrows near the edge of the forest, about 500 m upstream from lake B-12. Its bed mostly consists of cobbles and a little organic matter, as well as some gravel.

Part of an experimental net was set in the narrow, deep section upstream from the emissary. After 21 hours and 23 minutes, the net yielded four brook trout (Salvelinus fontinalis) ranging in total length from 185 to 200 mm. The four creels that were set yielded one 152-mm long brook trout, 322 northern redbelly dace (Phoxinus eos) and seven pearl dace (Margariscus margarita).

Lake B-12 is therefore a good environment for fish. Its tributary allows brook trout breeding and serves as a refuge or transition area for this species. The stream also allows habitat transitioning to lake B-11 for cyprinids.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters in lakes B-11, B-12, B-13 and B-14 are shown in Table 8.12.

Table 8.12 Physicochemical Parameters for Lakes in the Hilly Area of the Lac Jean Drainage System

LAKES	B-11	B-11	B-12	B-12	B-13	B-13	B-14	B-14
Date	23/03/11	30/07/11	23/03/11	30/07/11	23/03/11	04/07/11	23/03/11	08/07/11
Longitude	18U0568716	18U0568703	18 U 568919	18U0568904	18U0569961	18U056924	18 U 569401	18U0569373
Latitude	5516440	5516436	5516587	5516594	5516800	5516707	55171219	5517214
Depth (m)		20 CM		30 CM	0.9	70 CM	0.8	0.5
Parameters:	MUD		MUD					
pH		7.81		7.69	- 6.8	8.56	- 6.8	8.77
°C		18.68		19.56	0.41	21.49	0.18	18.09
Atmospheric pressure (Mbar)		944.6		943.1	956.0	937.2	958.3	939.2
Conductivity at 25^o (µS/cm)		93		74	58	41	77	56
Total dissolved solids (TDS ppm)		55		37	29	21	38	28
Salinity (Sal)		0.05		0.03	0.03	0.02	0.04	0.03
Oxidation-reduction potential (ORP)		35.1		35.7	- 90.7	45.1	- 58.3	20.6
Dissolved oxygen (DO %)		69.7		79.9	0	88.2	38.3	70.1
Dissolved oxygen (DO mg/L)		5.95		6.77	0	7.15	5.25	6.52
Resistivity (KΩ. cm)		10.8		11.9		24.6		18.9
Ambient conductivity (µS/cmA)		82		66		38		

Photo 8.52: General view of lake B-12 from upstream section to emissary. Water-lily and rush are the dominant aquatic vegetation species. Riparian vegetation mainly comprises carex and sweet gale.

Photo 8.53: Upstream portion of lake B-12. Low water level uncovers part of the lake bottom composed of mud and rocks. In this section, water depth does not exceed 30 cm.

Photo 8.54: Lake B-12; pondweed, eelgrass, water-lily and rush provide protection and food for cyprinid and brook trout populations

Photo 8.55: Lake B-12 section near emissary; although of significant depth (up to 60 cm), it is of limited aerial extent.

Photo 8.56: Lake B-12 tributary near its entrance into the lake. The bed is very rocky, while shores consist of peat and mud.

Photo 8.57: Lake B-12; further upstream, the tributary is deeper and meanders through the plain. Rush and pondweed make up the aquatic vegetation.

Photo 8.58: Lake B-12 outlet. In the brown section to the left covered by herbaceous vegetation, water escapes throught an old beaver dam.

Photo 8.59: Upper section of lake B-12 tributary, in the vicinity of its confluence with the lake B-11 emissary; bottom consisting of rock and sediments, peaty shores covered by gale and carex. This stream serves as passageway and refuge for lake B-11 cyprinids.

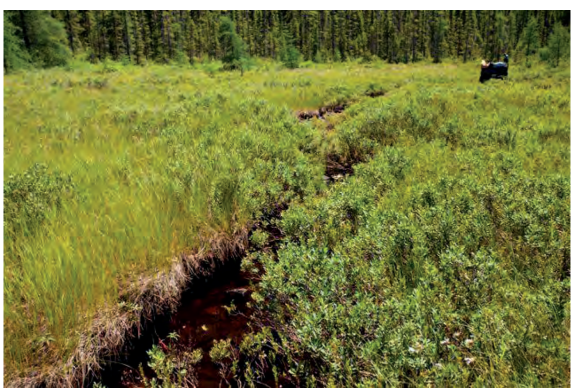


Photo 8.6: Upstream section of lake B-12 tributary where it flows among cobbles and becomes narrower, at edge of forest that lines the large peat bog in which lakes B-11 and B-12 are located.

8.3.3.4 Common Emmissary to Lakes B-11, B-12, B-13 and B-14

Some 150 m upstream from lake B-12, the waters of lakes B-11, B-12, B-13 and B-14 converge before continuing on to lake B-6. Fish are present in all these lakes, including brook trout populations in lakes B-12 and B-14. The emissary runs westward along rapids and cascades through a hilly area. Lakes B-12 and B-11 are at an elevation of approximately 465 m, lake B-13 is at 495 m (± 2 m), and lake B-14 is at 475 m (± 2 m). These lakes and their system will make way for the polishing pond facilities, the pit, a traffic area and the coarse tailings, which will be piled on a platform for possible future recovery.

Electrofishing was carried out in the stream on July 19, 2011. Fishing stations were located upstream and downstream from a logging road parallel to the pit at the foot of the hill. A large work area confined between the coarse tailings facility and the pit will occupy this zone.

Upstream from the road, an impassable waterfall prevents fish from running upstream. The stream bed consists of rubble, boulders (250 to 500 mm), cobbles (80 to 250 mm) and pebbles (40 to 80 mm). Downstream, the bed is composed of 80% sand and 20% gravel. Within the water body formed by a beaver dam, the bottom consists of organic matter.

Three brook trout (Salvelinus fontinalis) ranging in length from 61 to 150 mm were caught upstream from the logging road, and four brook trout ranging from 48 to 157 mm were caught downstream, along with seven cyprinids of indeterminate species but of genus Phoxinus. The cyprinids ranged in length from 63 to 68 mm.

The presence of brook trout in the catches is consistent with their presence in lakes B-14 and B-12. Their size, particularly for the smaller ones, indicates good breeding conditions for this species. This is the only stream in the project area that contains brook trout. It differs from all other streams in the area by its large vertical drop and stony bottom. It revives the waters of lake B-6.

Photo 8.61: Emissary to lakes B-11, B-12, B-13 and B-14. Electrofishing station upstream from forest road.

Photo 8.62: Emissary to lakes B-11, B-12, B-13 and B-14. Electrofishing station upstream from forest road.

Photo 8.63: Brook trout caught in emissary to lakes B-11, B-12, B-13 and B-14 (showing transverse stripes which are characteristic of fry).

Photo 8.64: Emissary to lakes B-11, B-12, B-13 and B-14. Electrofishing station upstream from forest road.

Photo 8.65: Emissary to lakes B-11, B-12, B-13 and B-14. Electrofishing station upstream from forest road.

Photo 8.66: Emissary to lakes B-11, B-12, B-13 and B-14 downstream from forest road.

Photo 8.67: Brook trout and Phoxinus sp. caught in emissary to lakes B-11, B-12, B-13 and B-14.

Photo 8.68: Emissary to lakes B-11, B-12, B-13 and B-14 downstream from forest road.

8.3.4 Lake A-1

Water released back into the environment from Lac Denis will flow into lake A-1 via lake B-1. Lake B-1 lies between the upper reach of the Lac Bernadette emissary and the southern portion of Lac Jean. It is roughly one kilometre long, and its emissary runs for one kilometre before its confluence with Ruisseau Villefagnan. Maximum depth recorded in the lake is 1.9 m. The lake A-1 drainage basin is very small. In March 2011, lakes B-1 and B-2, which feed lake A-1, were frozen or nearly frozen to the bottom and their oxygen concentration was nil. At the time, the maximum dissolved oxygen concentration measured in lake A-1 was 1.05 mg/L.

In May 2011, 21 hours and 25 minutes of experimental fishing yielded six northern pike (Esox lucius) and two white sucker (Catostomus commersonii). Three of the pikes were released without being measured because of precarious net-raising conditions in the canoe. Two of the pikes caught had been predigested by conspecific individuals. Those pikes that were measured had total lengths ranging between 330 and 562 mm. The two suckers caught were a very good size (508 and 580 mm in total length, TL) and in excellent condition. The 508-mm long sucker weighed 2.06 kg; the other one (580 mm) was released without being weighed. According to McPhail and Lindsey (1970), the maximum fork length (FL) for this species in Canada is 645 mm.[4]

This lake is not deep enough for walleye introduction, but does support survival of a northern pike population and white sucker growth. The lowest ratio of sucker to pike was recorded in this lake. The grass beds in the lake are relatively limited; a few are present near the lake outlet and, to a lesser extent, near the lake tributary. There are enough, however, to support northern pike breeding. This lake has limited potential for fish farming.

On July 27, 2011, a sediment sample was collected near the lake A-1 tributary flowing from lake B-1. Discharge was also measured, at 0.40 m^3/s. Physicochemical data measured *in situ* in March and May 2011 are shown in Table 8.13. It should be mentioned that, in addition to having a very small surface area, the lake A-1 drainage basin is in an organic environment. Although its pH is lower than that of most other water bodies in the area, it is still above 7.

[4] P 582 Scott and Crossman 1974

Table 8.13 Lac A-1 Physicochemical Parameters

LAKE A-1					
Date	22/03/11	22/03/11	22/03/11	20/05/11	(21/05/11)
Longitude	18U0567808	18U 567888	18 U 567704	18U0567562	18U0567870
Latitude	5520573	5520739	5520350	5520221	5520746
Depth (m)	1.9	1.9	1.2	0.7	0.7
Parameters:					
pH	7.06	7.99	8.03	7.21	7.39
°C	2.30	2.59	1.60	19.22	15.47
Atmospheric pressure (Mbar)	971.5	971.1	971.5	955.28	959.9
Conductivity at 25^{o} (µS/cm)	48	48	52	30	29
Total dissolved solids (TDS ppm)	24	24	26	15	14
Salinity (Sal)	0.02	0.02	0.02	0.01	0.01
Oxidation-reduction potential (ORP)	-13.9	- 46.4	-13.4	241.7	181.2
Dissolved oxygen (DO %)	7.0	0	8.2		85.9
Dissolved oxygen (DO mg/L)	0.94	0	1.05	9.47	8.14
Resistivity (KΩ. cm)				33.9	34.8
Ambient conductivity (µS/cmA)				26	24
Dissolved oxygen (DO %*2)	0		4.6		
Dissolved oxygen (DO mg/L*2)	0		0.61		

* Second reading

Photo 8.69: Shore of lake A-1; leatherleaf, heath, sweet gale and black spruce stand.

Photo 8.70: Riparian vegetation comprising leatherleaf and sweet gale, lake A-1 tributary.

Photo 8.71: Lake A-1; white sucker (Catostomus commersonii) in good condition.

Photo 8.72: Lake A-1 emissary in summer; aquatic vegetation comprising rush, carex and pondweed (July 2011).

8.3.4.1 Lakes B-1 and B-2

Lakes B-1 and B-2 are located to the west of the project area. These lakes and their watershed will be indirectly affected by the mining project, as excess Lac Denis water released back into the environment will go into the lake B-1 tributary. Lake B-1 is a small, narrow lake about 300 metres long. Its tributary is intermittent and its emissary joins the lake B-2 tributary. They both flow into lake A-1 (Figure 8.2).

In March 2011, lake B-1 was covered by 1.1 metres of ice and was frozen to the bottom. At the sampling location on lake B-2, a little water and mud were present under the ice. The multiparameter meter electrode froze, so that a pH reading could not be recorded. The lake B-1 depth survey done in July 2011 (Figure 8.9) revealed a maximum depth of 0.6 m.

In the summer of 2011, no fish were caught after 19 hours and 41 minutes of fishing with an experimental net in lake B-1. Five creels yielded 158 northern redbelly dance (Phoxinus eos), 39 pearl dace (Margariscus margarita), and three brook stickleback (Culea inconstans). Diving beetle larvae and adults, giant water bugs and leeches were also caught in the creels. Forage fish catches in settings considered completely marginal in winter were quite frequent in the lakes surveyed.

Discharge in the lake emissary at the time of the summer survey was approximately 0.006 m^3/s. Water was essentially stagnant in the tributary. Although no water could be seen to be moving, a strong sulphur smell emanated from the mud. Fresh moose tracks were spotted along the emissary as well as at the lake edge.

Lake B-1 is clearly eutrophic. Many of the plants that compose its vegetation, including carex, buckbean, sheathed cottonsedge and bladderword, are typical of peat bogs. In half of the lake, aquatic vegetation sheets float on the surface or are suspended in the water column. Although this lake is not a hospitable setting for game fish species, it is an interesting habitat for moose.

One sediment sample was collected at coordinates 18U0567130, 5518185. Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.14.

Lake B-2 was not surveyed in the summer of 2011.

Figure 8.9 Lake B-1 Bathymetry

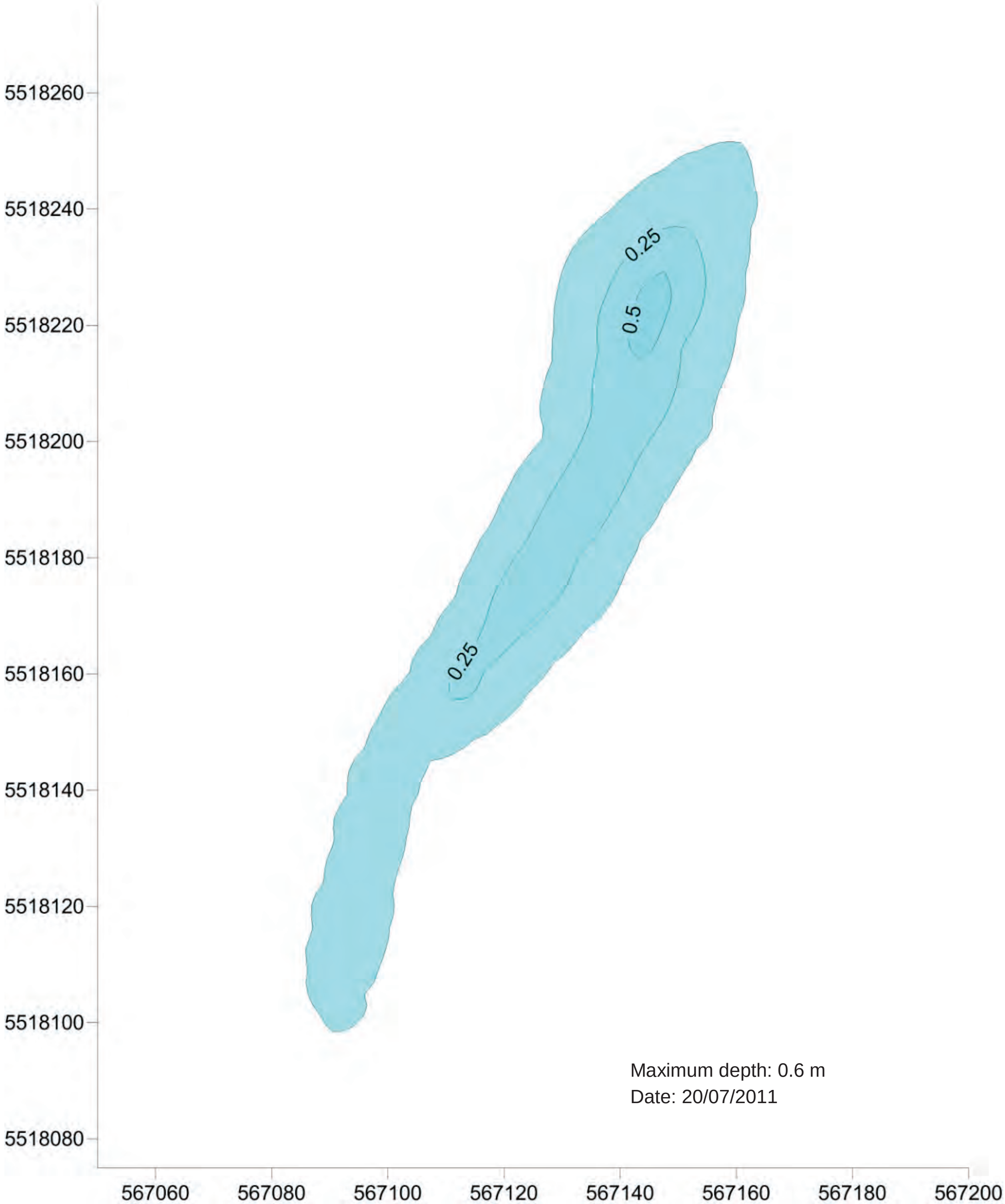


Table 8.14 Physicochemical Parameters of Lakes B1 and B2

Lakes B-1 and B-2	B-1	B-1	B-2
Date	22/03/11	20/07/11	22/03/11
Longitude	18U0567135	18U0567134	18U0567146
Latitude	5518189	5518203	5518809
Depth	1.1M ICE		1M ICE
Parameters:	*		**
pH		7.19	
°C		17.89	0.06
Atmospheric pressure (Mbar)		938.2	974.1
Conductivity at 25^{o} (µS/cm)		58	3
Total dissolved solids (TDS ppm)		28	2
Salinity (Sal)		0.03	0
Oxidation-reduction potential (ORP)		22.3	- 14
Dissolved oxygen (DO %)		70.2	0
Dissolved oxygen (DO mg/L)		6.15	0
Resistivity (KΩ. cm)		7.3	
Ambient conductivity (µS/cmA)		49	

* Frozen to the bottom.
** Frozen almost to the bottom. Mud and water. pH electrode froze.

Photo 8.73: Eastern shore of lake B-1; clearly eutrophic character of lake.

Photo 8.74: Lake B-1; sweet gale, leatherleaf and bladderwort; springy, water-soaked mat.

Photo 8.75: Lake B-1; fresh moose tracks in tributary.

Photo 8.76: Lake B-1 emissary in a long peat swamp.

8.3.5 Creeks in the Rail Transfer Site Area

In July 2011, electrofishing was done in the area of the rail transfer site. All stations were located near the railway track (see Figure 8.10).

Fishing at two stations adjacent to the eastern Lac Pierre tributary yielded two white sucker. The ditch bed consists of organic matter and is colonized by submerged plants. Fishing on the larger northern Lac Pierre tributary yielded seven white sucker upstream from the railway culvert. The stream bed consists of organic matter, as well as boulders, pebbles and gravel. No fish were caught downstream from the culvert where, from upstream to downstream, the stream bed consists of sand, gravel and organic matter. Habitats are characterized by the presence of grass beds and aquatic plants. Fishing carried out in ditches along the railway track yielded nothing.

Thin oily films on the surface of closed pools were noted in a ditch along the railway track.

Figure 8.10 Electrofishing – Rail Transfer Site Area

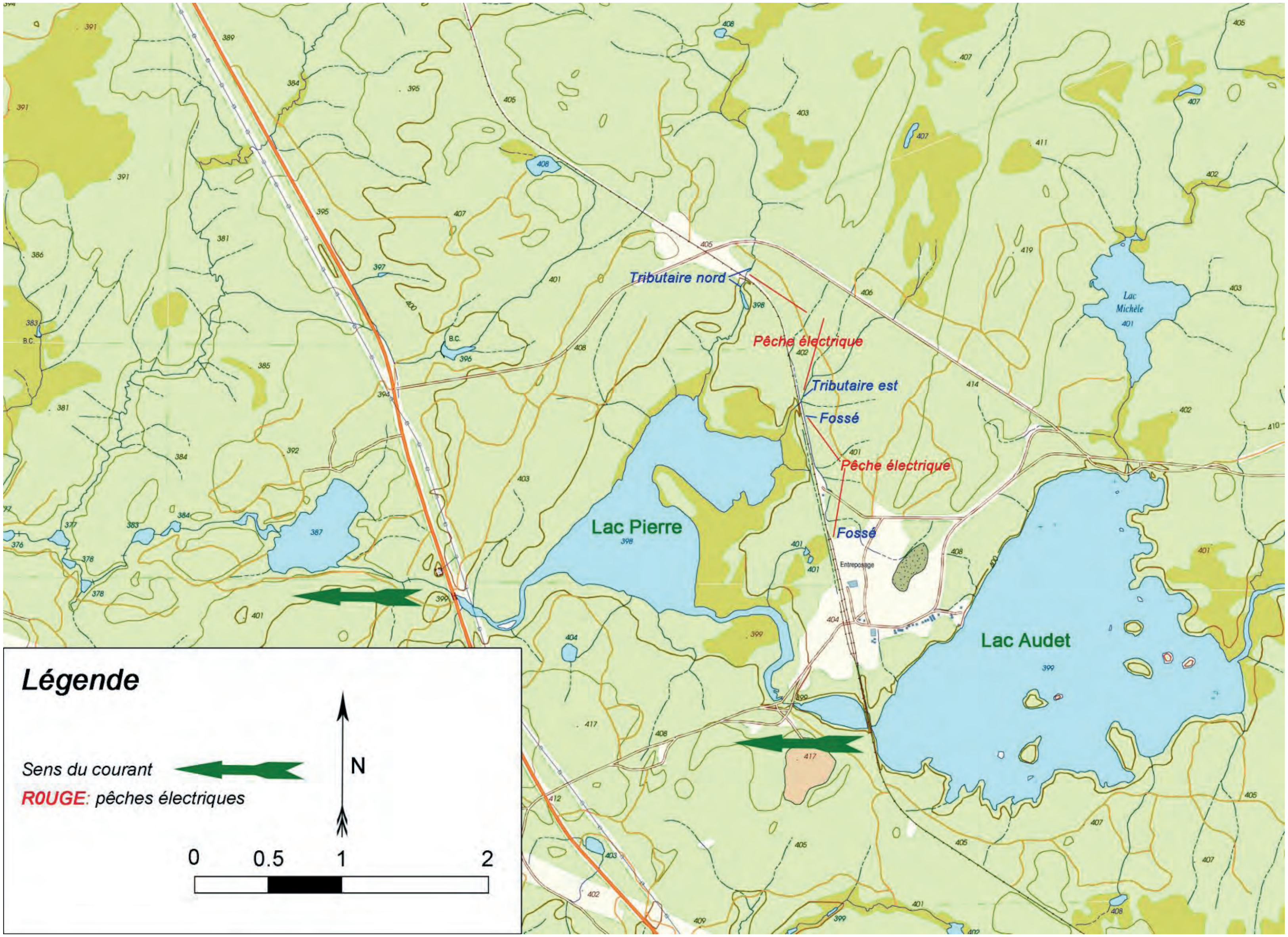


Photo 8.77: Lac Pierre east tributary

Photo 8.78: Lac Pierre east tributary.

Photo 8.79: Lac Pierre north tributary, upstream from culvert.

Photo 8.80: Lac Pierre north tributary, downstream from culvert.

8.3.6 Creek at the Future Construction Camp Site

There is an intermittent creek (Figure 8.11) at the site of the planned construction camp. It is less than 20 cm wide and only flows for a few metres before disappearing under peat. Given its size, the lack of a structured bed and the tangled shrubbery around it, it can be considered uninhabitable by fish.

8.3.7 Lac Yvette Tributaries

Electrofishing was done in the three Lac Yvette tributaries. The fishing stations are located near the network of roads that surround Lac Yvette (inset in Figure 8.2). These sites were surveyed because the access road that will be upgraded in this area could go on either side of the lake.

The first two fishing stations lie south of the lake. They are on small tributaries that form bays where they enter the lake. They are located to the northeast of a rehabilitated Lemoine Mine tailings deposit. The fishing station in the southeast tributary is located approximately 200 metres from these tailings. The southwest bay station is 400 metres away. The last fishing station is to the northwest, on the main Lac Yvette tributary.

Water at all three stations was reddish in colour. Repeated overloads[5] resulted in electrofisher power down. Water conductivity at all three sites was too high to allow the use of electrofishers.

No fish were caught. The high conductivity is related to a high concentration of ions, which in turn may be related to local geological conditions.

[5] Technically, an overload occurs when the electrofishing power output power exceeds 2,000 Watts. The strength of the current was reduced several times without success; the overload continued to exceed 2,000 Watts.

Figure 8.11 Intermittent Creek at the Future Construction Camp Site

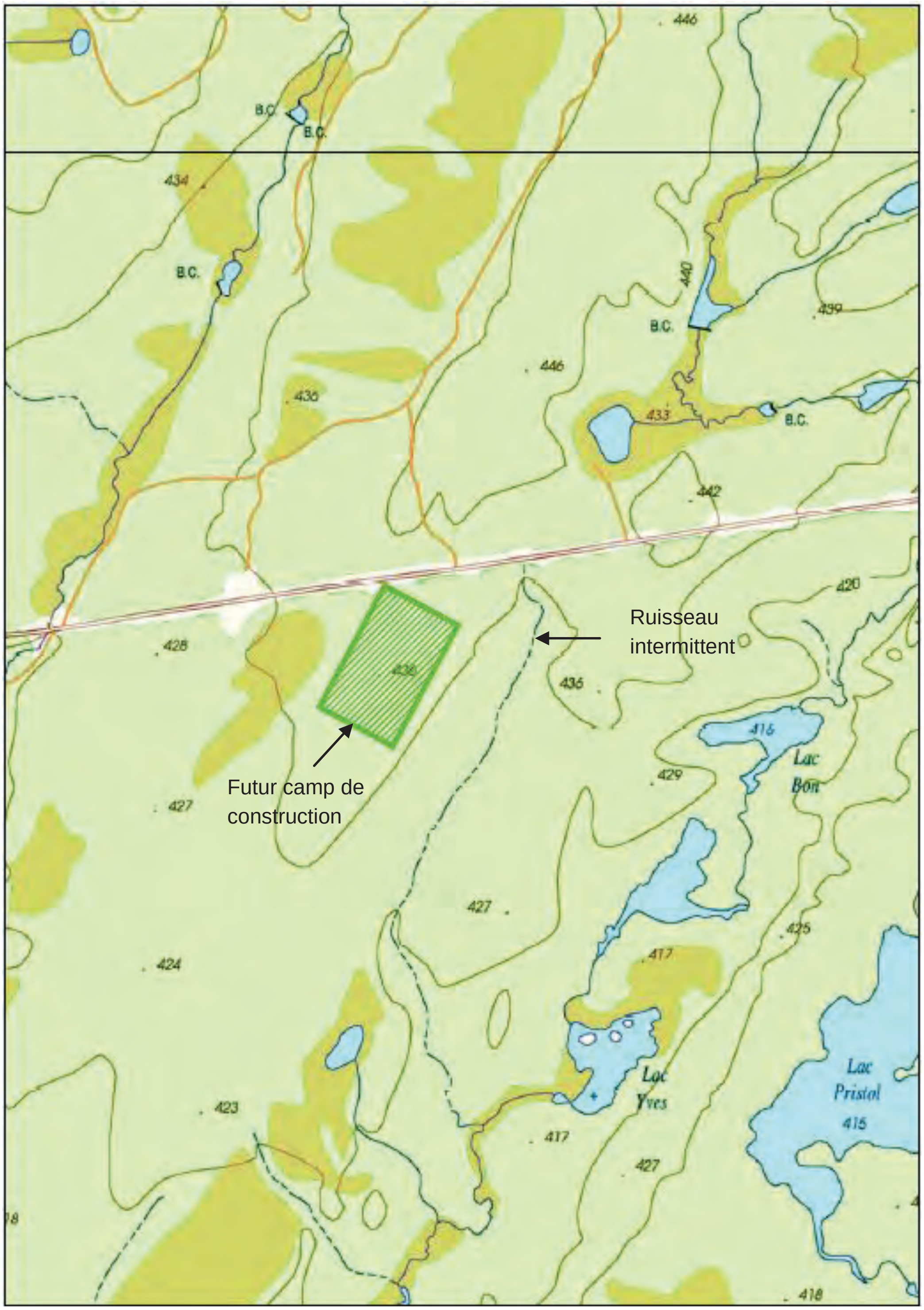


Photo 8.81: Lac Yvette tributary.

Photo 8.82: Lac Yvette tributary.

8.4 REFERENCE DRAINAGE SYSTEMS

There are three reference drainage subsystems in close proximity to the project: the Lac Bernadette, Lac Coil–B-5 and Ruisseau Villefagnan systems. The three subsystems differ both in the size of their catchments and in the species they host. They contain both lentic (Bernadette, Lac Coil–B-5) and lotic (Ruisseau Villefagnan) habitats. Although Ruisseau Villefagnan is classified as a control site, it is described in Section 8.9, which deals with compensation measure implementation areas.

8.4.1 Lac Bernadette

Lac Bernadette is located west of the mining infrastructure development area and is not affected by the project. From upstream to downstream, this 2.4-km long lake drains Lac Yvette and lakes B-15, B-16 and B-17. Its emissary flows into Rivière Armitage (Figure 8.2).

In March 2011, oxygen levels recorded in Lac Bernadette were between 1.82 and 3.40 mg/L, which is sufficient for winter survival of several species and is clearly related to the fact that the lake has a large watershed.

In May 2011, fishing with an experimental net, creels and lines was carried out in the lake, and major physicochemical parameters were recorded *in situ* (Table 8.15). Experimental net fishing time was 22 hours and 30 minutes, during which 12 northern pike ranging in length from 507 to 637 mm and weighing between 0.69 and 1.38 kg were caught. Line fishing yielded nothing and creels yielded one burbot (Lota lota) roughly 100 mm long, and a number of dragonfly larvae. Identifiable stomach contents in the 12 northern pike (Esox lucius) consisted of 65% dragonfly larvae, in addition to four fish of indeterminate species, one small northern pike (Esox lucius) and one 120-mm burbot. The fact that only 12 northern pike (Esox lucius) and one burbot (Lota lota) were caught points to a very low abundance of forage fish. The relative abundance of dragonfly larvae and the presence of one pike and one burbot in the stomach contents, as well as the relatively small and uniform size of northern pike individuals, all seem to confirm this gap in the trophic chain.

Electrofishing done on July 20, 2011, at two stations along the main tributary revealed the presence of numerous burbot and pearl dace (Margariscus margarita), as well as jack pike. The two tributaries and the emissary contain large grass beds and flood-prone vegetation that are very good for northern pike breeding. An otter family is active in the main tributary and one beaver was also spotted there. This tributary has rich aquatic vegetation (water-lily, eelgrass, pondweed). Ripples caused by small northern pike were spotted often. As in other neighbouring streams, flood-prone vegetation consists of carex and grasses. Riparian shrub vegetation is dominated by sweet gale and leatherleaf. There is a beaver dam at the outlet.

In July 2011, a sediment sample was collected in the southeast bay of the lake, near the island located at the mouth of the tributary. A depth survey of the south bay of the lake was also done.

Depth was generally less than 1 m, although a reading of 2.6 m was recorded. The bathymetric map of the southern part of the lake is shown in Figure 8.12.

Aside from the possible absence of forage fish, this lake is a good setting for northern pike. Its shallow depth does, however, limit walleye adaptation. Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters in Lac Bernadette are shown in Table 8.15.

Figure 8.12 Bathymetry of the South Part of Lac Bernadette

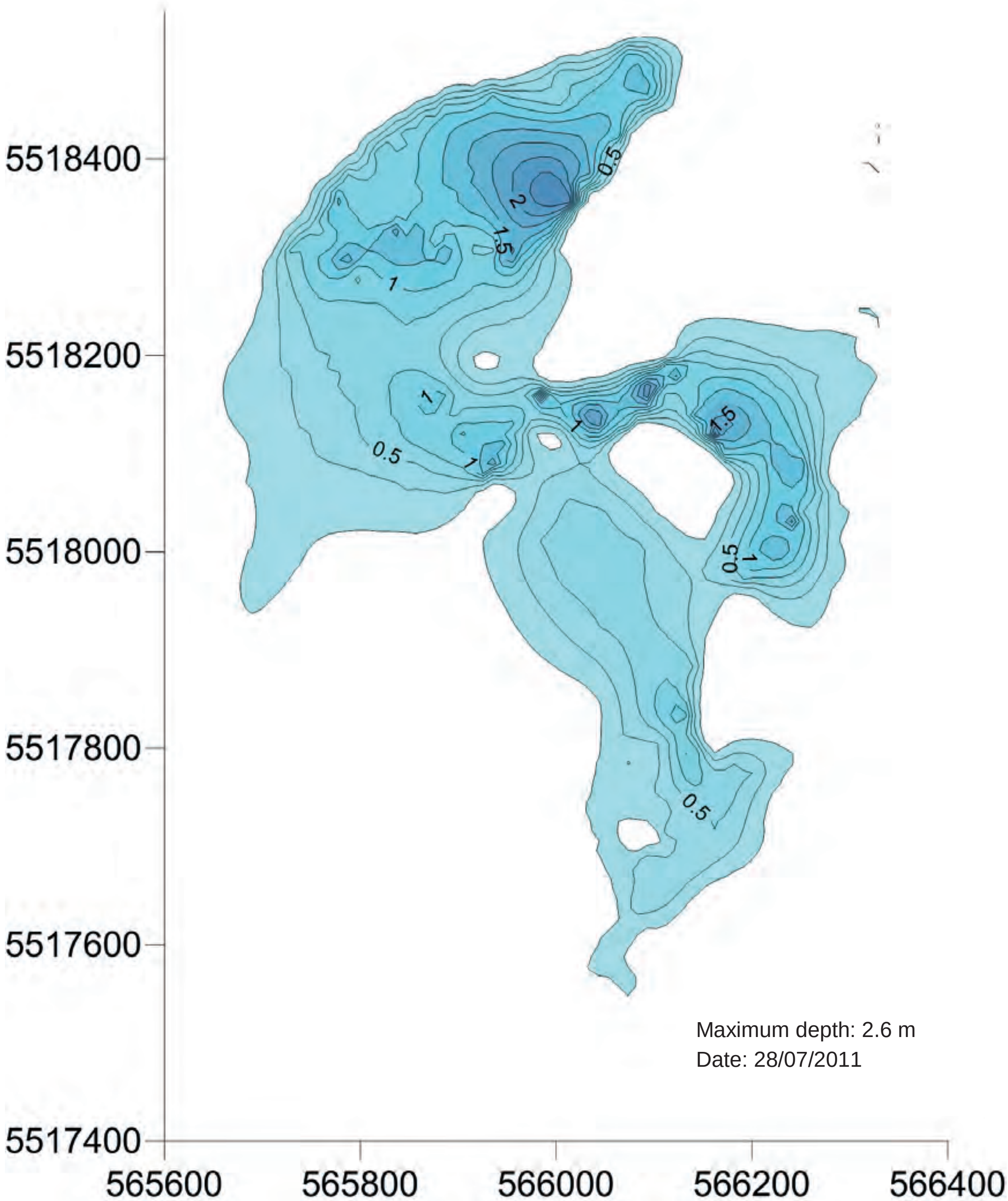


Table 8.15 Lac Bernadette Physicochemical Parameters

Lac Bernadette							
Date	21/03/11	21/03/11	21/03/11	21/03/11	22/05/11	22/05/11	22/05/11
Longitude	18U0566533	18U566395	18U565834	18U566734	18U0566446	18U0566518	18U0566949
Latitude	5518704	5518521	5518239	5519297	5518824	5518342	5519961
Depth (m)	2.05	1.9	0.9	1.8	0.60	0.60	0.60
Parameters:							
pH	8.99	7.84	7.25	7.20	7.27	7.33	7.5
°C	2.99	1.72	1.27	1.14	16.34	14.77	16.91
Atmospheric pressure (Mbar)	968.4	968.2	962	967.9	955.3	953.3	951.9
Conductivity at 25° (µS/cm)	92	81	104	81	37	64	47
Total dissolved solids (TDS ppm)	46	41	52	41	19	32	24
Salinity (Sal)	0.04	0.04	0.05	0.04	0.02	0.03	0.02
Oxidation-reduction potential (ORP)	- 8.6	- 54.7	- 84.7	- 91.9	105.5	64.2	12.0
Dissolved oxygen (DO %)	14.6	16.2	25.8	16.9	82.8	79.2	75.0
Dissolved oxygen (DO mg/L)	1.82	2.15	3.40	2.22	7.73	7.63	6.70
Resistivity (KΩ. cm)					27.6	15.6	21.5
Ambient conductivity (µS/cmA)					31	51	40

Photo 8.83: Lac Bernadette south tributary, with flood-prone vegetation.

Photo 8.84: Flood-prone vegetation around Lac Bernadette, near its emissary, and aquatic vegetation on bottom.

Photo 8.85: Beaver dam and flood-prone vegetation at outlet to Lac Bernadette.

Photo 8.86: Northern pike from Lac Bernadette, small and of same age group.

8.4.1.1 Lakes B-15, B-16 and B-17 and Their Emissaries, and Ruisseau Bernadette

Lakes B-15, B-16 and B-17 are not affected by project development. Lakes B-15 and B-16 are east of the project area and south of Lac Bernadette (Figure 8.2). Their respective emissaries converge before flowing into Ruisseau Bernadette roughly 200 m upstream from where it flows into the lake of the same name. This brook is the main Lac Bernadette tributary, as it drains Lac Yvette, which is a headwater lake located much further to the south. Lake B-17 is a very small pond located south of Lac Bernadette. It has no emissary and its waters flow through the vegetation mat into the south bay of Lac Bernadette.

Lake B-15

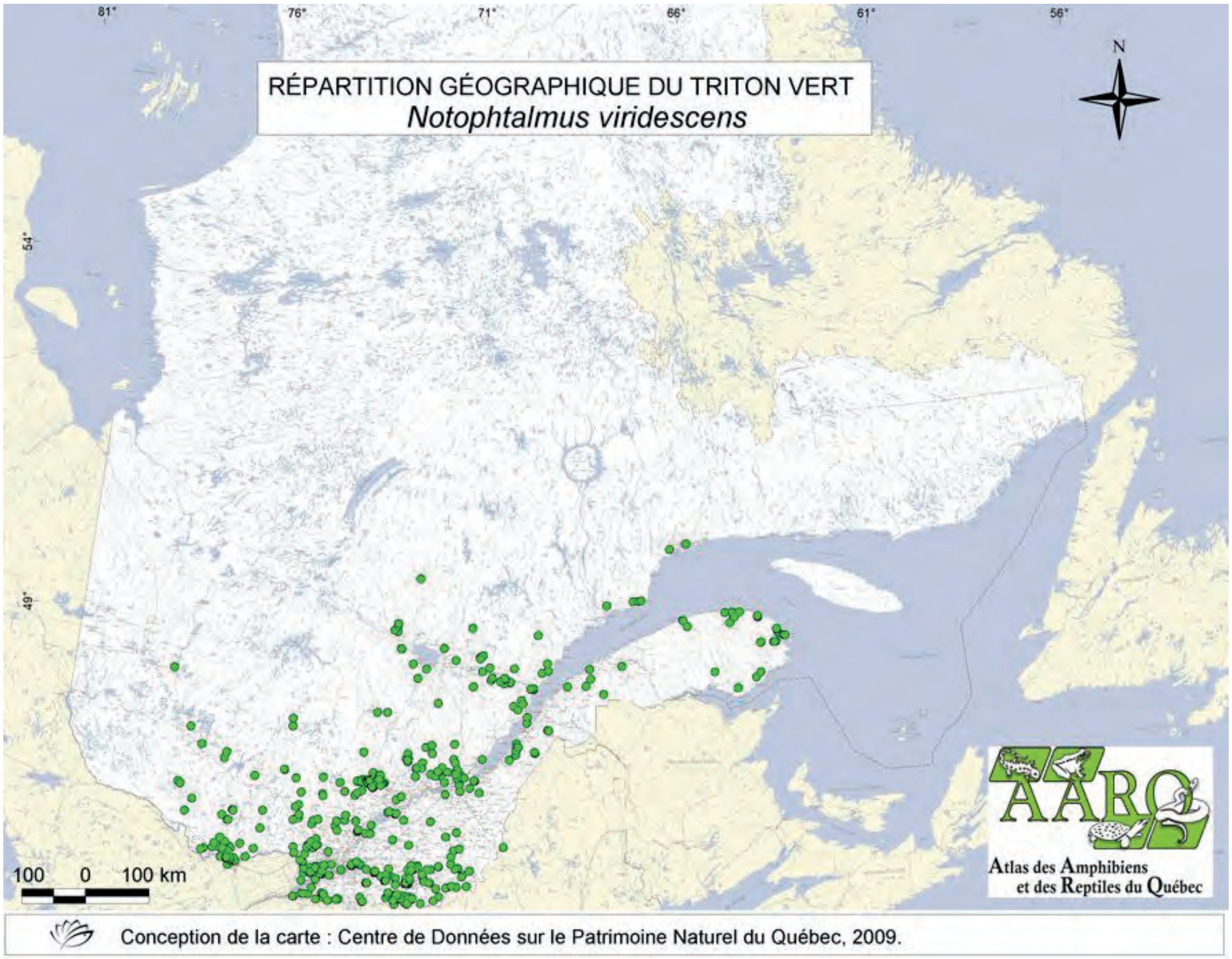
This lake is about 300 m long. It has no tributary, and its emissary disappears in peat then reappears about 200 m further, near its junction with the lake B-16 emissary. Lake B-15 is surrounded by floating peatland. It is divided in two parts: the first is open and ovoid and the second, northern part is a small elongate bay.

One experimental net and five creels were set on July 14, 2011. No fish had been caught in the net after 22 hours. A creel set near the lake outlet did yield an eastern newt (Notopthalmus viridescens viridescens). This species is common but had not yet been reported from the Lac Chibougamau region (Figure 8.13). Formal identification was performed by Sébastien Rouleau, M.Sc. Biologist, research and conservation coordinator at the Saint-Lawrence Valley Natural History Society.

A depth survey was also done in July 2011 (Figure 8.14), which showed that depth is generally less than one metre in the small bay in the northern section of the lake, but that there is a 5.2-m deep trough in the main part of the lake. Physicochemical measurements were done at a single location at two different depths, 0.3 m and 3.6. Sediment samples were collected near shore. Interestingly, temperature ranged from 19.86ºC at the surface to 8.70ºC at a depth of 3.6 m. At the two different depths, ORP values were 30.9 and -131 and dissolved oxygen concentrations were 6.23 ppm and 1.72 ppm, with saturation values of 72.6% and 0.3%. It is therefore impossible for fish to live in the deep part of this water body. Stratification of the water column is also observed for conductivity, TDS and salinity. Results of *in situ* measurements taken in the summer of 2011 for major physicochemical parameters in lake B-15 are reported in Table 8.16.

The lake B-15 emissary starts out very narrow then opens up before disappearing completely. No discharge can be measured. It is a residual emissary covered by sphagnum, which includes a few scattered water holes linking up under peat with the channel formed by its confluence with waters flowing from lake B-16. Lake B-15 waters flow out of the surrounding bog. Deep lake B-15 waters are captive as their level is much lower than the water level in Lac Bernadette located downstream. The lake is a large, deep bog pool.

Figure 8.13 Geographic Distribution of the Eastern Newt (Notophatlmus viridescens)



This map is from the Atlas of Amphibians and Reptiles of Québec (AARQ) website.

Figure 8.14 Lake B-15 Bathymetry

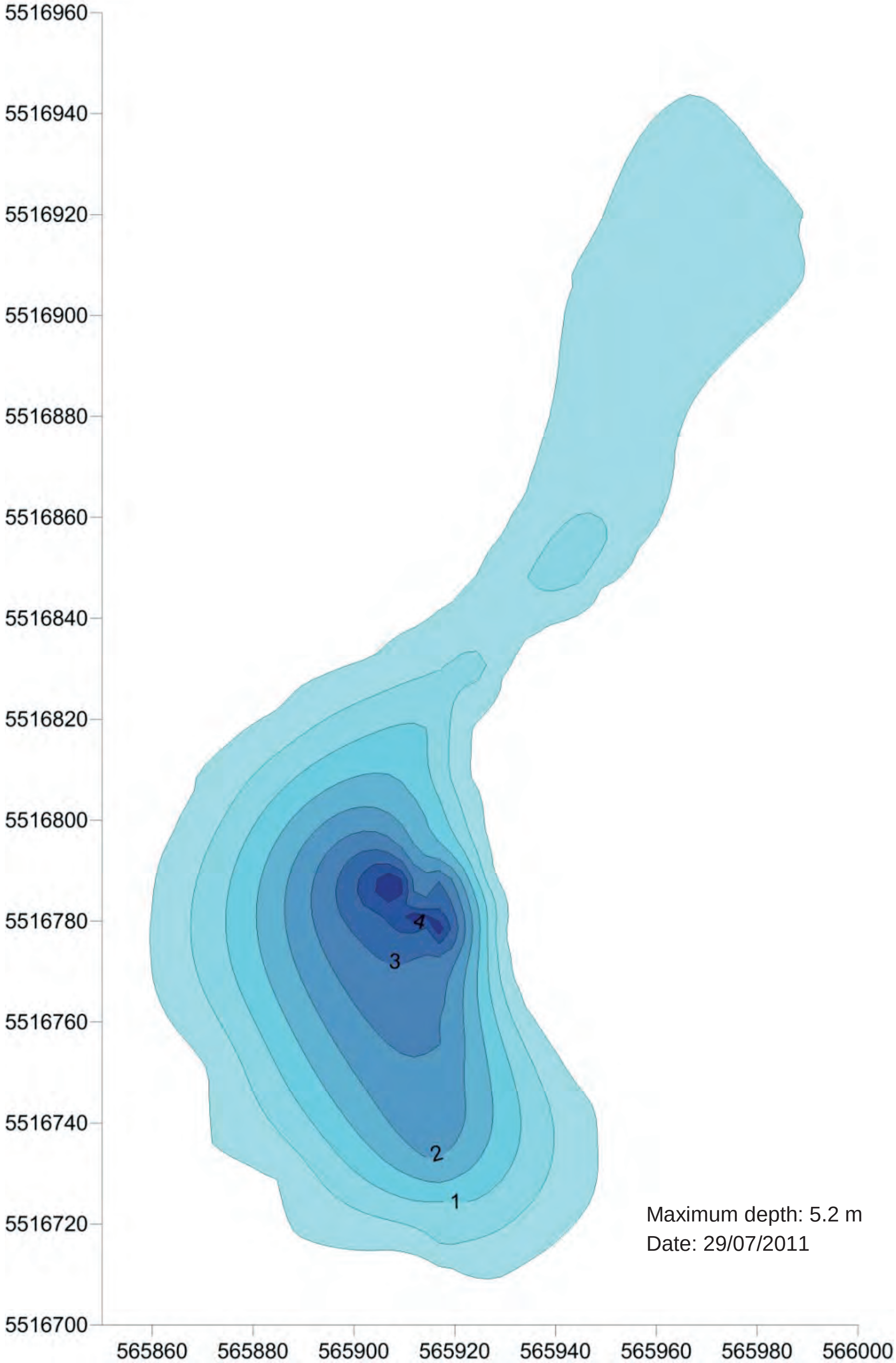


Table 8.16 Lake B-15 Physicochemical Parameters

Lake B-15		
Date	14/07/11	14/07/11
Longitude	18U056592	18U056592
Latitude	5516717	5516717
Depth (m)	3.6	0.30
pH	7.84	7.85
Parameters:		
°C	8.70	19.86
Atmospheric pressure (Mbar)	955.2	955.1
Conductivity at 25^{o} (µS/cm)	324	124
Total dissolved solids (TDS ppm)	164	62
Salinity (Sal)	0.13	0.06
Oxidation-reduction potential (ORP)	-131	30.9
Dissolved oxygen (DO %)	0.3	72.6
Dissolved oxygen (DO mg/L)	1.72	6.23
Resistivity (KΩ. cm)	15.9	8.1
Ambient conductivity (µS/cmA)	227	112

Photo 8.87: Lake B-15 and its peatbog setting. Shores are floating on water. Leatherleaf, sweet gale, laurel and carex make up the riparian vegetation, with black spruce and several other typical peatbog plants.

Photo 8.88: Eastern newt.

Lake B-16

Lake B-16 is roughly 120 m to the east of lake B-15, from which it is separated by a bog. Lake B-16 has no emissary or tributary *per se*. It drains out under peat and its waters infiltrate through sphagnum to join up with an emissary located about 200 m further. Depth in this roughly 100-m pond does not exceed 50 cm, and its surface is punctuated by several sphagnum islands colonized by typical bog vegetation.

This lake is characterized by advanced eutrophication. No fishing was done in lake B-16. This is a bog pond and cannot support fish.

Results of *in situ* measurements taken in the summer of 2011 for major physicochemical parameters are shown in Table 8.17.

Table 8.17 Lake B-16 Physicochemical Parameters

Lake B-16	
Date	15/07/11
Longitude	18U056933
Latitude	5516799
Depth (m)	0.25
pH	7.16
Parameters:	
°C	21.98
Atmospheric pressure (Mbar)	954.6
Conductivity at 25^{o} (µS/cm)	496
Total dissolved solids (TDS ppm)	216
Salinity (Sal)	0.21
Oxidation-reduction potential (ORP)	13.6
Dissolved oxygen (DO %)	70.8
Dissolved oxygen (DO mg/L)	5.89
Resistivity (KΩ. cm)	2.2
Ambient conductivity (µS/cmA)	476

Photo 8.89: B-16 pond and islands. The shore rests on a very thick sphagnum mat. Aquatic vegetation comprises water-lily and buckbean. In the foreground are carex and sheathed cottonsedge.

Photo 8.90: B-16 pond; older stunted spruce and larch on a mat of sphagnum, carex and leatherleaf, and rich aquatic vegetation. Sphagnum islands are visible in pond.

8.4.1.2 Emissary Common to Lakes B-15 and B-16

Lakes B-15 and B-16 no longer have structured emissaries; the lake B-15 emissary is non-existent and the lake B-16 emissary is residual. Both lakes flow out under peat and form short channels that converge in a main channel.

The course of this common channel is surrounded by flood-prone vegetation, particularly in the lower section near its mouth, but also in its upper reaches. Riparian vegetation essentially comprises leatherleaf and carex. The stream ranges in depth from 30 to 60 cm. Its bed is essentially composed of organic matter. Young northern pike were spotted in the lower third of its course.

On July 27, 2011, two creels were set in the channel. After 34 hours and 49 minutes, they remained empty. Physicochemical parameters were measured (Table 8.18) and one sediment sample was collected. This sample contained abundant decomposing organic matter. Measuring discharge was not possible because no flow could be detected.

Table 8.18 Physicochemical Parameters – B-15 and B-16 Common Emmissary

Lakes B-15 and B-16	
Date	28/07/11
Longitude	18U0565795
Latitude	5517003
Depth (m)	
pH	7.93
Parameters:	
°C	14.56
Atmospheric pressure (Mbar)	948.8
Conductivity at 25° (µS/cm)	67
Total dissolved solids (TDS ppm)	34
Salinity (Sal)	0.03
Oxidation-reduction potential (ORP)	21.3
Dissolved oxygen (DO %)	24.6
Dissolved oxygen (DO mg/L)	2.39
Resistivity (KΩ. cm)	
Ambient conductivity (µS/cmA)	

Photo 8.91: Upper section of brook flowing from lakes B-15 and B-16, about 200 m southwest of lake B-16; abundant flood-prone vegetation. Leatherleaf makes up the bulk of the shrubby vegetation, which is typical of peat bogs.

Photo 8.92: Emissary common to lakes B-15 and B-16, near second creel station.

8.4.1.3 Lake B-17

Lake B-17 is a small, roughly 75-m long bog lake. Its shape is that of a triangle with very rounded apices. The lake has no tributary or emissary, although at the mouth of Ruisseau Bernadette, a relict tributary trends towards it, and the MNRF 1:20,000 map shows the presence of a tributary. As with lakes B-15 and B-16, lake B-17 waters flow very slowly through the surrounding bog. Aquatic vegetation comprises water-lily, buckbean and carex. The riparian vegetation zone is very narrow, comprising carex and abundant leatherleaf. The bog is surrounded by a black spruce stand.

Net and creel fishing were carried out in the lake in July 2011. Physicochemical measurements (Table 8.19), sediment sampling and a full depth survey (Figure 8.15) were also done. Compared to neighbouring lakes, lake B-17 is surprisingly deep, with a maximum depth of 3.2 m.

Twenty-one hours and 24 minutes of fishing with an experimental net produced no catch, nor were there any fish in any of the three creels set, which did, however, yield one large tadpole, two hymenoptera of the Lethocerus genus and three eastern newts (Notopthalmus viridescens viridescens). The newts caught were among the first individuals of this species reported from the region north of Chibougamau.

Table 8.19 B-17 Physicochemical Parameters

Lake B-17	
Date	27/07/11
Longitude	18U0567489
Latitude	5517466
Depth (m)	2.0
pH	8.18
°C	19.56
Atmospheric pressure (Mbar)	445.1
Conductivity at 25^{o} (µS/cm)	117
Total dissolved solids (TDS ppm)	57
Salinity (Sal)	0.05
Oxidation-reduction potential (ORP)	33.2
Dissolved oxygen (DO %)	84.2
Dissolved oxygen (DO mg/L)	7.05
Resistivity (KΩ. cm)	8.5
Ambient conductivity (µS/cmA)	104

Figure 8.15 Lake B-17 Bathymetry

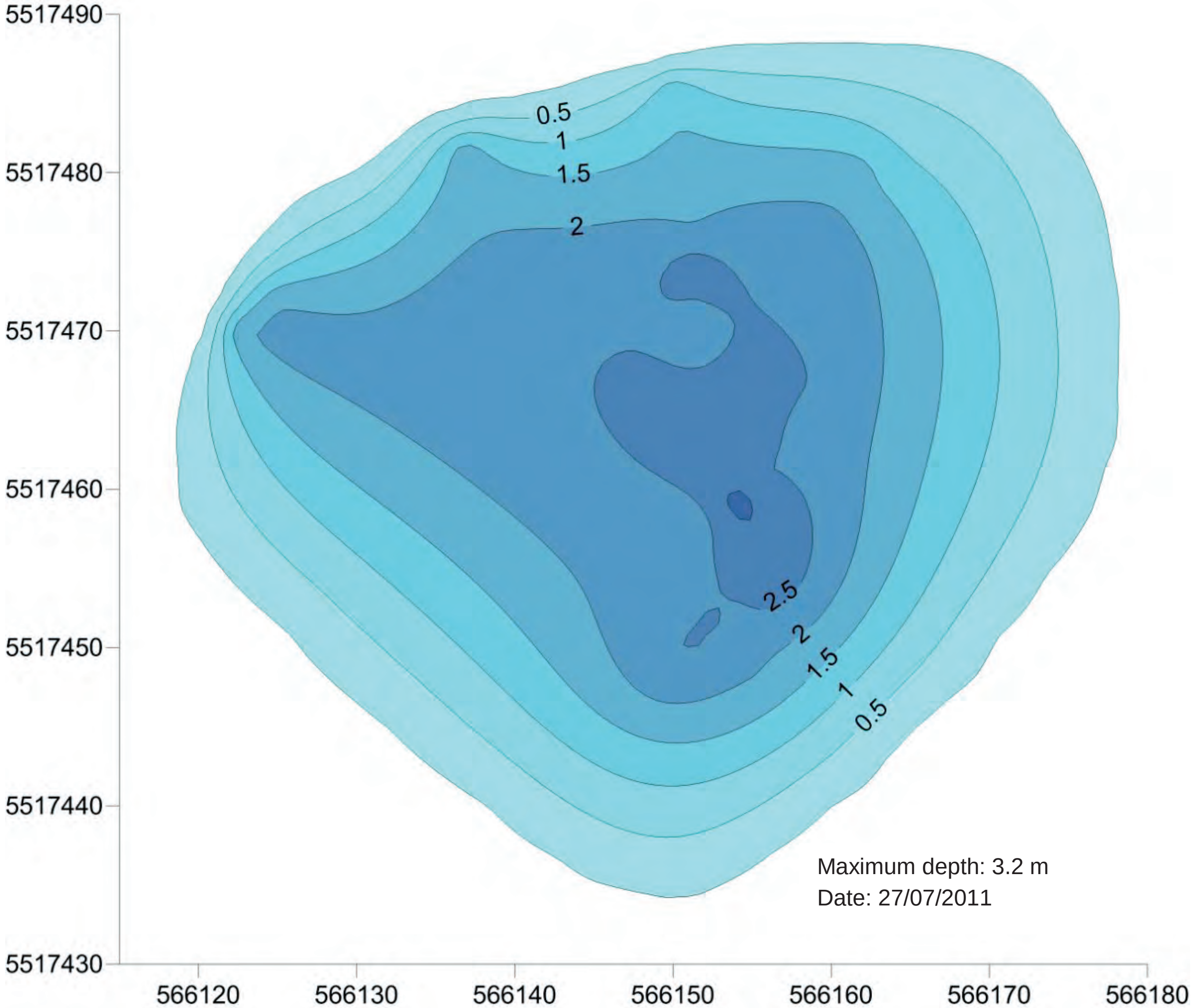


Photo 8.93: Lake B-17; leatherleaf and carex comprise the bulk of the transition zone between shore and forest. Buckbean, bladderwort and water-lily colonize the lake bottom.

8.4.1.4 Ruisseau Bernadette

Ruisseau Bernadette drains Lac Yvette waters and waters from small lakes located along its course. The brook flows over very flat terrain. It is the main Lac Bernadette tributary.

In its upstream section, Ruisseau Bernadette plays an important role in the Lac Bernadette ecology. Its lower part is the most favorable setting for northern pike breeding. Two otters were spotted there, as well as a beaver lodge and one beaver a little further upstream. This section of the tributary has rich aquatic vegetation (water-lily, eelgrass and pondweed). As in neighbouring streams, there is also flood-prone vegetation comprising carex and grasses, and riparian shrub vegetation comprising sweet gale and leatherleaf, with a few larches in open areas.

Several small northern pike were spotted in this stream. Discharge measured on July 29, 2011, was 0.171 m^3/s. Electrofishing was done at two points along the stream. At the first station (upstream), it yielded seven pearl dace (Margariscus margarita) ranging in total length from 42 to 101 mm and seven burbot (Lota lota) from 116 to 147 mm in total length. At the second station further downstream, two pearl dace, two burbot and two northern pike (Esox lucius) were caught, the latter 78 and 79 mm long. These observations confirm the fact that pike (Esocidae) breed in the Lac Bernadette area.

Photo 8.94: Pool along Ruisseau Bernadette.

Photo 8.95: Fishing station on Ruisseau Bernadette, downstream section.

8.4.2 Lac Coil (B-4) and Lake B-5

Lac Coil (B-4) and lake B-5 are at the northern edge of the mine site area. Neither the lakes nor their small watershed are affected by the project. They are contiguous and contain similar habitats, and water flows unobstructed between the two. They form a chain of lakes that also includes Lac Jean and lakes B-3, B-6, B-7 and B-8, as well as part of Ruisseau Villefagnan. This system comprises a large biotic set with no major obstacles.

Water from Lac Coil and lake B-5 drains into the northeast bay of Lac Jean through a small meandering stream with a beaver dam near its mouth. This dam raises the water level in the stream by at least 60 cm, widening it considerably and making it canoeable up to lake B-5, upstream from lake B-4. The stream is roughly two kilometres long.

Lac Coil is roughly 280 metres long and shaped like a rounded rectangle. Lake B-5 streches over 180 metres and is ovoid in shape, and much smaller than its neighbour. As seen on the bathymetric map (Figure 8.16), water depth in Lac Coil is generally less than one metre and reaches a maximum of 1.9 m. Lake B-5 has a mean depth of 0.5 m (Figure 8.17), locally reaching 1.4 and 1.5 m. The bottoms of these lakes are essentially composed of mud and organic matter.

In March 2011, measured oxygen levels were 3.34 ppm in lake B-4 and 3.39 ppm in lake B-5. These were among the higher oxygen levels recorded in all the lakes surveyed.

Experimental nets and creels were set in these water bodies. In lake B-4, four northern pike (Esox lucius), 13 white sucker (Catostomus commersonii), and one yellow perch (Perca flavescens) were caught after 23 hours and 15 minutes. Pike total length ranged from 290 to 491 mm, and their weight ranged from 170 to 800 grams. A sucker was present in the stomach of the largest northern pike, while the other pikes had empty stomachs. Sucker length ranged from 168 to 242 mm. The yellow perch was 194 mm in total length. Although the creels turned up no fish, one creel set in lake B-4 yielded two eastern newts (Notopthalmus viridescens viridescens).

An osprey (Pandion haliatus) busy productively fishing was spotted several times at Lac Coil. Its activity was observed for about an hour. A pair or a brood is likely present nearby. The osprey or its mate returned shortly after each fishing session. Mathew Wapachee also noted fresh, clear tracks left by two moose.

At lake B-5, 21 hours and 32 minutes of fishing yielded 37 white sucker and two northern pike. Several of the white sucker had been predigested by northern pike. The northern pike were 296 and 450 mm in length and weighed 190 and 910 g, respectively. The larger one had a sucker in its stomach. The 34 sucker measured had lengths ranging from 180 to 300 mm.

Results of *in situ* measurements taken in the winter and summer of 2011 for major physicochemical parameters are shown in Table 8.20.

Sediment samples were collected in both lakes at the following locations: 18U0569078, 5519425 for lake B-4 and 18U0568929, 5519106 for lake B-5.

Table 8.20 Physicochemical Parameters of Lac Coil (B-4) and Lake B-5

Lakes	Coil (B-4)		Coil (B-4)	B-5	B-5
Date	25/03/11		21/07/11	25/03/11	22/07/11
Longitude	18U0569077		18U0569060	18U0568939	18U0568929
Latitude	5519398		5519360	5519111	5519095
Depth (m)	0.8			0.9	0.60
pH	*	**			
Parameters:	<6.8		8.48	<6.8	7.71
°C	0.25		19.19	0.56	17.85
Atmospheric pressure (Mbar)	965.1		936.7	965.3	942.7
Conductivity at 25° (µS/cm)	94		83	93	72
Total dissolved solids (TDS ppm)	47		42	46	37
Salinity (Sal)	0.04		0.04	0.04	0.03
Oxidation-reduction potential (ORP)	- 22.1		18.6	- 205	23.8
Dissolved oxygen (DO %)	23.4	24.2	82	26.1	72
Dissolved oxygen (DO mg/L)	3.24	3.34	7.06	3.49	6.35
Resistivity (KΩ. cm)			12.0		14.1
Ambient conductivity (µS/cmA)			74		63

*Reading time: 2 minutes
** Reading time: 3 minutes
*** Frozen to the bottom, solid
**** Frozen to the bottom, liquified mud

Figure 8.16 Lac Coil (B-4) Bathymetry

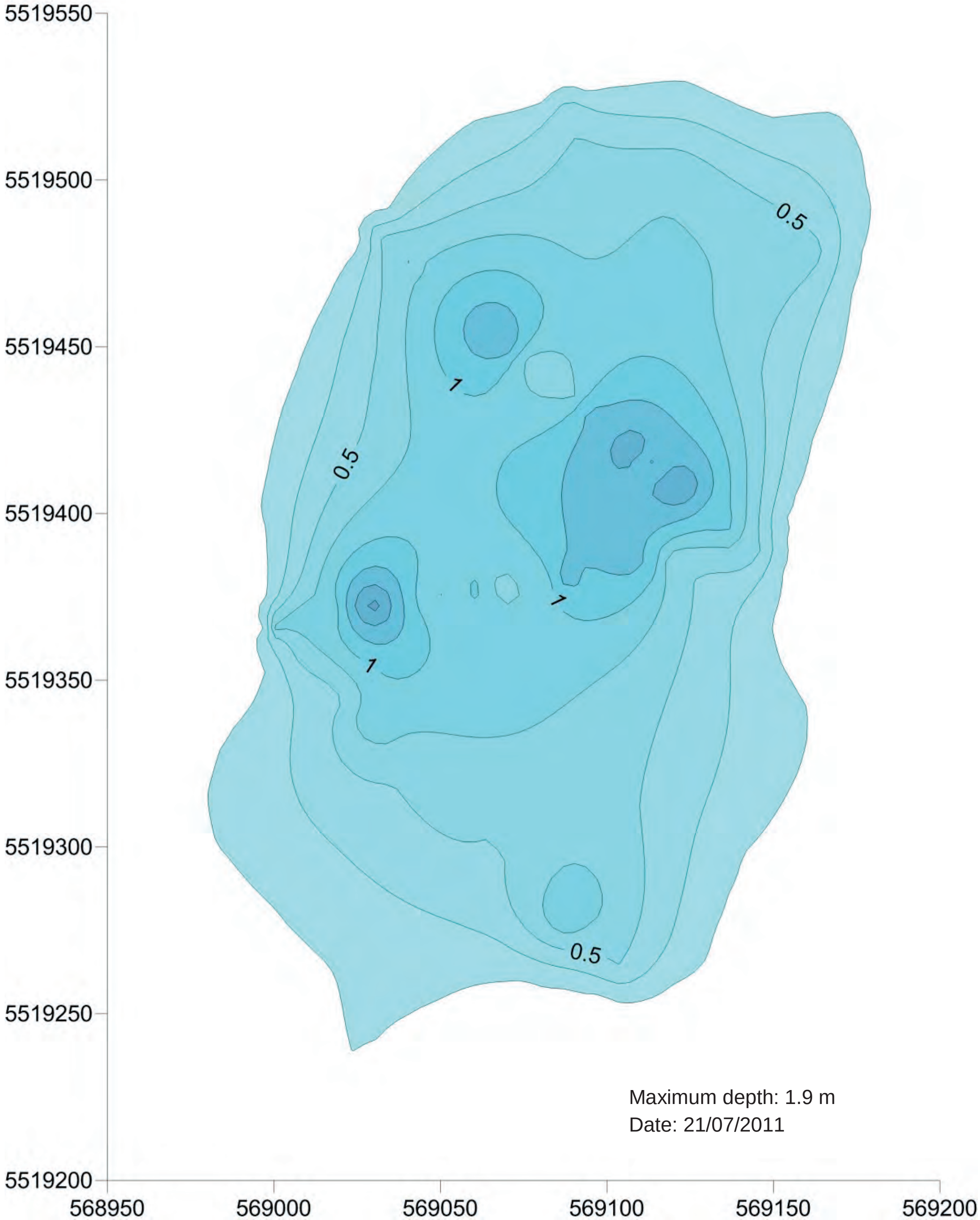
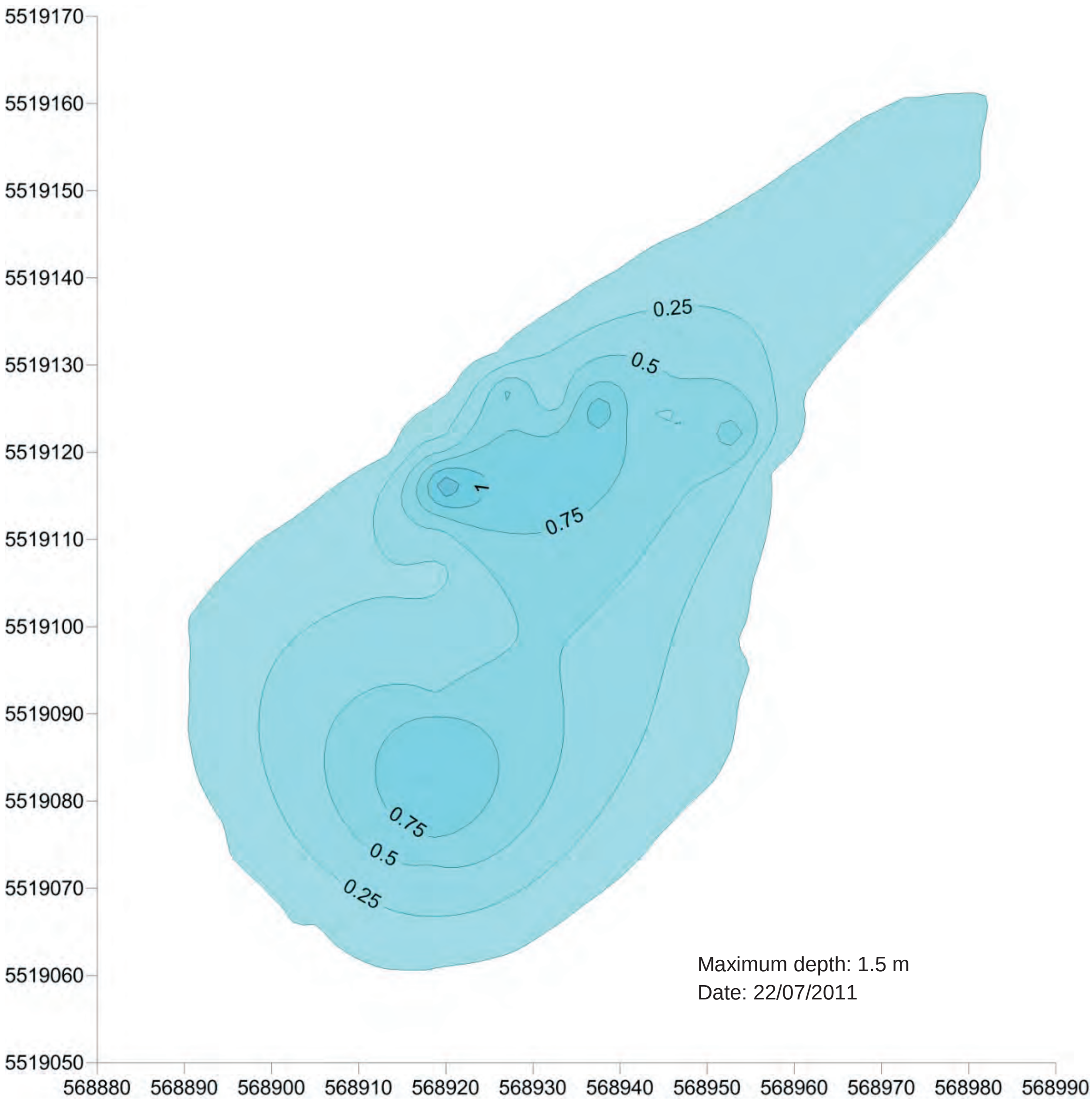


Figure 8.17 Lake B-5 Bathymetry



8.4.2.1 Lac Coil (B-4) and Lake B-5 Emissaries and Tributaries

Upstream from the beaver dam at Lac Jean, the Lac Coil emissary is deeper than Lac Jean directly downstream, its depth commonly exceeding 1.3 m and rarely falling below 0.60 m. Its bed consists of organic matter and fine sediments, and there is abundant aquatic vegetation comprising water-lily and eelgrass. Ripples caused by small northern pike were frequently spotted.

Riparian vegetation is flooded and comprises carex, gale and leatherleaf. Flooding has killed the surrounding conifers. The stream is commonly very wide in its lower half, narrows two-thirds of the way up then widens again close to Lac Coil.

The lake B-5 emissary is similar, albeit generally shallower (approximately 50 cm). It is surrounded by peatland that is similar to that surrounding Lac Coil and lake B-5, but where shrubs are more abundant and dried-out trees very few in number. It is roughly 1.5-m wide. One branch running down from the hill of the deposit joins up with the main trunk in its lower third section.

Although the lake B-5 tributary is much smaller than the emissary, its facies is similar. It also splits into two small branches.

These streams are extensions of fish habitats found in lakes B-4 and B-5.

Photo 8.96: Lac Coil (B-4) near its outlet; flood-prone vegetation comprising carex and sweet gale.

Photo 8.97: Riparian vegetation strip around Lac Coil; sweet gale, cinquefoil in bloom, carex and black spruce stand.

Photo 8.98: Two adult eastern newts (Notophthalmus viridescens viridescens) caught and released at Lac Coil.

Photo 8.99: Approach to western shore of Lac Coil; typical peatbog vegetation, with leatherleaf, bladderword, sphagnum and carex.

Photo 8.100: Beaver dam at mouth of Lac Coil emissary into Lac Jean; at left, water level downstream from dam.

Photo 8.101: Lake B-5 emissary and its readily-canoeable channel. Shore with arborescent vegetation comprising gale and leatherleaf.

Photo 8.102: Flood-prone vegetation plain at edge of lake B-5.

Photo 8.103: Fishing in lake B-5 (Mathew Wapachee); flood-prone vegetation and steep shoreline.

Photo 8.104: Lake B-5 tributary, immediately upstream from the lake. Bed consists of organic sediments and mud. Depth is approximately 40 cm.

Photo 8.105: Branch of small, tortuous lake B-5 tributary.

8.5 PHYSICOCHEMICAL QUALITY OF SURFACE WATERS

Results of *in situ* surface water analyses for the 22 sampling stations (lacustrine and lotic settings) are shown in Table 8.21. More detailed results for the eight stations for which laboratory analyses were performed are shown in Table 8.22.

8.5.1 pH and Mineralization Parameters

The average of pH values measured at the sampling stations is 7.85, which points to a strong capacity of bicarbonates to neutralize acidic inputs from human activity or precipitation. Sampling in 251 lakes in the Canadian Shield performed by Langlois et al. (1985) also highlights this regional disparity; the 30 lakes sampled in the Chapais-Chibougamau area have a mean pH value of 7.1, which is higher than mean values for all other Quebec regions (which have mean pH values between 5.5 an 6.8), except for the Lac Albanel region. A mean pH of 7.85 in the project area is therefore clearly exceptional.

Waters in the study area, which have a mean conductivity value of 83 µS/cm, are weakly mineralized and of bicarbonate-calcic type, bicarbonates being the most abundant ions in these waters, followed by calcium, magnesium and sodium. In these oligotrophic waters, alkalinity is proportional to total inorganic carbon, which is the sum of carbonates, bicarbonates and carbonic acid.

For the eight stations whose surface waters underwent laboratory analyses, mean values for alkalinity, calcium, magnesium and sodium are 27 mg/L and 10.5, 2, and 1 ppm, respectively. These values are representative for water flowing on a granitic substrate (mean values of 24 mg/L for alkalinity and 13.43 ppm for total organic carbon).

Major cations, including calcium, magnesium and sodium, are derived from rock alteration and mineral dissolution (ferromagnesian minerals, feldspars and amphibolites) by carbonic acid resulting from carbon dioxide dissolution.

Table 8.21 Results of *In Situ* Surface Water Measurements (Summer 2011)

Lake	Depth (m)	pH	°C	µS/cm	TDS ppm	Sal	ORP	DO %	DO mg/L	KΩ. cm	µS/cmA
Lac Bernadette subsystem											
Bernadette 1	0.6	7.27	16.34	37	19	0.02	105.5	82.8	7.73	27.6	31
Bernadette 2	0.6	7.5	14.77	64	32	0.03	64.2	79.2	7.63	15.6	51
Bernadette 3	0.6	7.5	16.91	47	24	0.02	12.0	75.0	6.70	21.5	40
B-15	3.6	7.84	8.70	324	164	0.13	- 131	0.3	1.72	15.9	227
B-15	0.3	7.85	19.86	124	62	0.06	30.9	72.6	6.23	8.1	112
B-16	0.25	7.16	21.98	496	216	0.21	13.6	70.8	5.89	2.2	476
B-17	2	8.18	19.56	117	57	0.05	33.2	84.2	7.05	8.5	104
Lake A-1 subsystem											
A-1	0.7	7.21	19.22	30	15	0.01	241.7		9.47	33.9	26
A-1	0.7	7.39	15.47	29	14	0.01	181.2	85.9	8.14	34.8	24
B-1	0.5	7.19	17.89	58	28	0.03	22.3	70.2	6.15	17.3	49
Lac Jean subsystem											
Jean	1.0	7.83	11.44	23	13	.01	84.9	75.7	7.79	39.5	19
B-4		8.48	19.19	83	42	0.04	18.6	82.0	7.06	12.0	74
B-5	0.6	7.71	17.85	72	37	0.03	23.8	72.0	6.35	14.1	63
B-3	0.45	7.82	19.32	49	25	0.02	33.2	91.1	7.76	20.3	44
B-6	0.25	8.37	21.07	99	49	0.05	310	71.9	6.74	9.3	95
B-7	0.8	7.92	16.2	52	41	0.04	278	73.9	7.02	12	68
B-8	0.3	6.68	21.12	75	78	0.03	-78	11.4	2.10	13.4	70
Denis	0.8	8.36	21.86	94	46	0.04	38.2	85.6	7.26	10.6	85
B-11	0.2	7.81	18.68	93	55	0.05	35.1	69.7	5.95	10.8	82
B-12	0.3	7.69	19.56	74	37	0.03	35.7	79.9	6.77	11.9	66
B-13	0.7	8.56	21.49	41	21	0.02	45.1	88.2	7.15	24.6	38
B-14	0.5	8.77	18.09	56	28	0.03	20.6	70.1	6.52	18.9	
Ruisseau Villefagnan subsystem											
Villefagnan 1	0.6	7.43	17.54	30	15	0.01	122.1	82.6	7.69	33.6	26
Villefagnan 2	1.5	7.75	9.62	32	16	0.01	82.5	77.2	8.47	31.5	23
Laugon	2.0	8.13	8.13	56	28	0.03	26.2	90.6	8.71	18.0	50
A-2	0.6	8.26	20.37	70	40	0.04	20.5	90.2	7.52	12.7	73
Rivière Armitage system											
Armitage 1	0.6	7.16	14.0	22	14	0.01	99.6	79.0	7.74		23
Armitage 2	0.6	7.74	13.32	30	15	0.01	76.2	76.7	7.48	33.7	23
Armitage 3	0.6	7.94	12.54	32	16	0.01	87.2	79.4	8.02	30.9	21

Table 8.22 Results of Surface Water Laboratory Analyses (Summer 2011)

Sampling Date		09-08-11	10-08-11	09-08-11	09-08-11	09-08-11	09-08-11	09-08-11	29-08-11	RDL
PARAMETER	UNITS	Lac Jean Subsystem						Lac Bernadette Subsystem		
		Lake B-3	Lac Coil	Lake B-5	Lake B-11	Lake B-12	Lac Denis	Lake B-17	Lac Yvette	
pH	-	-	-	-	-	-	-	-	7,15	N/A
Total organic carbon	mg/L	14	11	18	14	19	6.1	8.3	17	0.4
Total inorganic carbon	mg/L	2.6	3.5	2.3	4.1	4	3.9	2.7	-	0.8
Total cyanides	mg/L	-	-	-	-	-	-	-	<0.003	0.003
Mercury (Hg)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		0.0001
Aluminium (Al)	mg/L	0.09	0.16	0.18	0.13	0.23	0.07	0.09	0.05	0.03
Calcium (Ca)	mg/L	9	11	9	8	6	14	14	13	1
Antimony (Sb)	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	-	0.006
Magnesium (Mg)	mg/L	2	3	2	<1	<1	3	6	-	1
Silver (Ag)	mg/L	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0003
Total hardness ($CaCO_3$)	mg/L	31	41	31	21	15	50	61	-	1
Arsenic (As)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Barium (Ba)	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03
Cadmium (Cd)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Chromium (Cr)	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03
Cobalt (Co)	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03
Copper (Cu)	mg/L	<0.003	<0.003	<0.003	<0.003	0.003	<0.003	0.003	0.006	0.003
Lead (Pb)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Manganese (Mn)	mg/L	0.035	0.013	0.049	0.008	0.023	0.014	0.008	0.037	0.003
Molybdenum (Mo)	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03
Nickel (Ni)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Selenium (Se)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Sodium (Na)	mg/L	0.8	0.8	0.7	0.6	0.6	1.0	2.1	1.4	0.2
Zinc (Zn)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.028	0.019	0.005
Tin (Sn)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	0.05
Boron (B)	mg/L	-	-	-	-	-	-		<0.05	0.05
Iron (Fe)	mg/L	-	-	-	-	-	-		0.2	0.1
Potassium (K)	mg/L	-	-	-	-	-	-		<0.2	0.2
Strontium (Sr)	mg/L	-	-	-	-	-	-		<0.05	0.05
Titanium (Ti)	mg/L	-	-	-	-	-	-		<0.05	0.05
Vanadium (V)	mg/L	-	-	-	-	-	-		<0.01	0.01
Beryllium (Be)	mg/L	-	-	-	-	-	-		<0.002	0.002

RDL: reportable detection limit

Calcium is one of the most common alkaline-earth metals and cations in surface and groundwaters. Calcium found in many rock types is easily dissolved and leached out of soils. Silicate minerals such as pyroxenes and amphiboles, as well as sedimentary deposits composed of calcite and dolomite, gypsum and mineral apatite, can release large amounts of calcium in water. Calcium concentrations measured in the study area (average of 10.5 mg/L) are typical of the Canadian Shield, as they are less than 15 mg/L. This metal is essential to humans and animals. Like other mineralization parameters, calcium generally reduces metal toxicity to fish (Pagenkopf et al., 1974; Chakoumakos et al., 1979), except for vanadium.

Like calcium, magnesium is a common component of natural waters. It is one of the main metals used to define total hardness, the other being calcium. Magnesium salts are very soluble and tend to stay in solution after calcium salts have precipitated. Ferromagnesian minerals, igneous rocks and dolomitic sedimentary rocks are the main sources of magnesium in water. Magnesium is non-toxic and poses no danger to humans or to aquatic biotic communities. The average magnesium concentration measured was 2.0 mg/L.

Ionic sodium (Na^+) is present in all surface waters. Nearly all sodium compounds are soluble and tend to stay in aqueous solution. Clay minerals, feldspars, halite and mirabilite are all possible sources of sodium. Calculated sodium concentrations were relatively low, their average being 1.0 mg/L.

In general, pH, conductivity, alkalinity and total inorganic carbon, as well as calcium, magnesium and sodium concentrations, are much higher in the study area than anywhere else in the Quebec portion of the Canadian Shield. Of 251 Canadian Shield lakes sampled in all Quebec regions by Langlois et al. (1985), the 30 lakes located in the Chapais-Chibougamau area show higher values than those from other regions of Quebec. These parameters (conductivity, alkalinity, total inorganic carbon, calcium, magnesium and sodium) reflect bedrock leaching and the buffer capacity of water, or its capacity to neutralize acidic inputs from precipitation or various anthropogenic sources.

Thus, from an ecotoxicological standpoint, because of their peculiar properties, waters in the study area can play a role in minimizing potential impacts of mining activities. Alkalinity, for instance, is an important factor for both fish and benthic species, because for one thing, it tends to buffer water pH, and for another, its major constituents (carbonates and bicarbonates) complex with most metals, thereby reducing their toxicity. These local conditions must therefore be considered in assessing ecotoxicological risks related to the mining project.

8.5.2 Organic Carbon

Total organic carbon is an indicator of the abundance of organic debris in water; values of this parameter ranged from 6.1 to 19 mg/L, for an average of 12.2 mg/L. The highest values are from bog lakes and the lowest value was measured in Lac Denis.

It should be mentioned that metal toxicity is significantly reduced in the presence of organic matter in natural waters, a fact that has been demonstrated for aluminium in particular by Brouard (1988). Thus, in natural waters, organic matter, for which metals have an affinity, plays a protective role by reducing metal ecotoxicity to fish. This is not true for mercury, however, because it is the organic form of this metal (methylmercury, CH_3Hg^+) that accumulates in living beings and is known to be toxic above certain exposure levels.

8.5.3 Metals

Apart from calcium, magnesium and sodium, over half of the 18 elements analyzed in the laboratory in 2011 had concentrations below the analytical detection limit. Parameters with concentrations above the analytical detection limit are summarized in Table 8.23 and are discussed below. Results of analyses done in the same area in 2001 (Entraco 2003) are also discussed; these results are more precise for trace metals, their concentrations having been measured at the µg/L level.

Aluminium

In relatively aluminosilicate-rich soils such as those in the Canadian Shield, H^+ ions from precipitation displace not only cations (Ca^{+2}, Mg^{+2}, Na^+ and K^+), but also aluminium and, secondarily, other trace metals. This leads to excess aluminium in surface water. Although setting guideline values for diverse aquatic settings under natural conditions is no easy task, the MDDEP has set a value of 0.75 mg/L for acute aluminium toxicity when pH values are between 6.5 and 9.0, as is the case for the study area. The criterion for chronic toxicity set by the MDDEP only applies to surface waters with a pH of around 6. None of the lakes sampled in 2011 exceed this limit.

The average aluminium concentration calculated in 2011 for the study area is 0.125 mg/L. The maximum value of 0.189 mg/L is from lake B-5. In 2001, Ruisseau Villefagnan had the highest aluminium concentration, at 0.19 mg/L. Organic aluminium is the dominant form of aluminium in the natural waters of the Canadian Shield (Baker and Schofield, 1980; Campbell et al., 1982 and 1984). Bioassays performed by Brouard (1988) have shown that aluminium toxicity to brook trout (Salvelinus fontinalis) is significantly reduced in the presence of organic matter, and that a concentration of 0.3 mg/L at a pH of 5.5 does not pose a sublethal ecotoxicity risk for salmonids. It is therefore clear that, for the average pH value of 7.85 calculated for the study area, measured aluminium concentrations (0.125 mg/L) do not pose a problem.

Manganese

Manganese concentrations were also above the detection limit. Although this element may be present in its manganous form (Mn^{+2}), it is easily oxidized to its manganic form (Mn^{+4}). Soils, sediments and metamorphic and sedimentary rocks are important sources of manganese. Ferromagnesian minerals such as black mica and amphibole contain abundant manganese. In surface waters of Eastern Canada (7,504 samples analyzed), manganese concentrations range from 0.01 to 3.80 mg/L (NAQUADAT, 1985).

Langlois et al. (1985) reported an average manganese concentration for 30 lakes in the Chapais area of 13.6 µg/L, which is less than the average of values measured in the study area in 2011 (23.4 µg/L). The highest manganese concentration measured in 2001 (33 µg/L) was from Ruisseau Villefagnan. The three highest values measured in 2011 (35, 37 and 49 µg/L) are well below the 470 µg/L limit set by the MDDEP for chronic toxicity at a total hardness of 20 mg/L $CaCO_3$. The mean hardness recorded in the study area was 36 mg/L $CaCO_3$.

Barium

Maximum barium concentrations measured in 2001 were from Ruisseau Villefagnan (5.3 µg/L). Concentrations measured in 2011 are below the detection limit (30 µg/L). These concentrations are below values normally observed under natural conditions in Eastern Canada, which range from 20 to 1,000 µg/L (NAQUADAT).

Cobalt

Cobalt is a heavy metal with similar chemical properties to nickel, although it is more soluble in surface water. Smaltite and cobaltite are natural sources of cobalt. Weathering of igneous and sedimentary rocks (especially shales) also releases cobalt in water. Cobalt background concentrations in natural settings are less than 1 µg/L for Eastern Canada (NAQUADAT, 1985), and the chronic toxicity threshold is set at 100 µg/L (MDDEP, 2008). The maximum cobalt concentration measured in 2001 (0.4 µg/L) is well below this limit. Concentrations measured in the study area in 2001 ranged from 0.1 to 0.4 µg/L.

Iron

Iron, whether in its ferrous (Fe^{2+}) or ferric (Fe^{3+}) form, is the fourth most abundant element in the Earth's crust. Weathering naturally releases iron from the crust, particularly from igneous rocks and sulphide ores such as pyrite and pyrrhotite. Iron can also come from sedimentary and metamorphic rocks. Sandstones subjected to leaching can release iron oxides such as hematite (Fe_2O_3) and magnetite (Fe_3O_4), as well as iron hydroxides such as goethite ($HFeO_2$). When iron salts concentrations are high enough, they may precipitate in contact with air and thus impact aquatic communities. This is why the MDDEP has set an interim iron concentration threshold of 1.3 mg/L (SAVEX 2000) to protect aquatic life (chronic effects).

Iron concentrations measured from Lac Jean, Ruisseau Villefagnan (2001) and Lac Yvette (2011) (0.17, 0.31 and 0.20 mg/L, respectively) are below Quebec government threshold values. The average concentration for these three stations (0.226 mg/L) was slightly higher than that reported by Langlois et al. (1985) for 30 lakes in the Chapais area (0.188 mg/L).

Iron concentrations in the study area are related to the geological setting and the presence of organic matter. Values measured from Eastern Canada (6,449 samples) range from 0.01 to 90 mg/L in surface waters (NAQUADAT, 1985). Iron toxicity depends on several factors, such as pH, the metal's ionic form (Fe^{+2} or Fe^{+3}), its state of complexing with organic matter and its mode of occurrence in the water column (dissolved or suspended).

Measured iron concentrations do not pose an ecotoxicity risk, mainly because, in the presence of organic matter, iron is mostly present in colloidal form (particles roughly 50 microns in diameter), as opposed to other soluble (<1 micron) or suspended (>100 microns) forms. It should be noted that colloidal and suspended forms of iron are generally composed of several metals in the form of oxides, hydroxides and silicates, or as clay, silica or organic matter particles that bind the metals by adsorption, ionic exchange or complexation.

Thus, surface waters can show high iron concentrations without posing an ecotoxicity risk for aquatic fauna. Many authors, including Rand and Petrocelli (1985), have highlighted the fact that various abiotic factors, such as pH, the presence of organic matter, and water hardness and alkalinity, reduce the toxicity of some inorganic substances to fish. Thus, in surface waters with relatively high pH (average value of 7.85) and in the presence of organic matter, metallic ions generally form organic ligands, thereby reducing their bioavailability to fish.

Table 8.23 Summary of Analytical Results for Surface Water Parameters above Detection Limits

Parameter	Station							
	Lac Jean Subsystem						Lac Bernadette Subsystem	
	B-3	Coil	B-5	B-11	B-12	Denis	B-17	Yvette
Total organic carbon	14	11	18	19	14	6.1	8.3	17
Total inorganic carbon	2.6	3.5	2.3	4.0	4.1	3.9	2.7	
pH	7.82	8.48	7.71	7.81	7.69	8.36	8.18	7.15
Calcium (ppm)	9	11	9	6	8	14	14	13
Magnesium (ppm)	2	3	2	<1	<1	3	6	
Sodium (ppm)	0.8	0.8	0.7	0.6	0.6	1.0	2.1	1.4
Metals								
Al (mg/L)	0.09	0.16	0.18	0.23	0.13	0.07	0.09	0.05
Cn (mg/L)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.006
Mn (mg/L)	0.035	0.013	0.049	0.023	0.008	0.014	0.008	0.037
Fe (mg/L)								
Zn (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.019

Molybdenum

Molybdenum concentrations measured in 2001 were, for most stations, below analytical detection limit, except for stations in Lac Laugon, Lac Denis, Lac Jean and Ruisseau Villefagnan, where concentrations ranged from 0.3 to 0.7 µg/L. These values are well below the 3.2 mg/L chronic toxicity threshold set by the MDDEP (2008) for protection of aquatic life.

Lead

Lead is a major constituent of more than 200 types of minerals. In surface waters in Canada (229 samples analyzed), lead concentrations range from 1 to 41 µg/L (NAQUADAT, 1985). For a hardness of 20 mg/L $CacO_3$, the MDDEP set the lead concentration threshold for protection of aquatic communities (chronic effects) at 0.41 µg/L. The highest concentration recorded in 2001 in Ruisseau Villefagnan is 1.0 µg/L, which is above the MDDEP threshold. This limit is currently being reassessed. Lead toxicity to fish is inversely proportional to water hardness and dissolved oxygen content.

In summary, of the metals analyzed, aluminium, barium, cobalt, iron, manganese and lead are the only ones with concentrations higher than their respective analytical detection limits. These metals are generally present in concentrations below theoretical criteria set for protection of aquatic communities. Interestingly, Ruisseau Villefagnan, an exceptional environment both in terms of habitat quality and biodiversity, is the water body with the highest metal concentrations.

Because of their peculiar properties (high pH values and mineralization parameters compared to other regions of Quebec), the waters of the study area can play a role in minimizing the potential toxicity of certain metals. The same is true for organic matter, which plays a protective role by making metals less bioavailable, thus reducing their ecotoxicity to fish. These factors must be taken into consideration in the assessment of environmental risks associated with the mining project, as they imply that the receiving environment has a specific ability to respond to various anthropogenic sources of contamination.

8.6 PROPERTIES OF SEDIMENTS AND SOILS

The physicochemical quality of surface waters depends largely on sediments and soils. For this reason, chemistry, mineralogy and grain size of sediments and soils in the project area were characterized in 2001. The six soil samples selected from the area in the immediately vicinity of the BlackRock project provide a picture of local background conditions. Nineteen sediment samples were also collected during summer 2011, both in control areas and in areas directly affected by the project. Soil and sediment analyses were performed by Maxxam Analytics using methods approved by the MDDEP and the *Centre d'expertise en analyse environnementale du Québec*. Certificates of analysis and methods used are provided in Appendix 8.3, and sample locations are shown in Figure 8.2.

8.6.1 Physicochemical and Granulometric Properties of Sediments

Chemical and granulometric analyses of sediments were done to constrain background conditions and physical properties of particles. These data can be used to constrain potential future inputs from mining operations. Results for Lac Jean and Lac Bernadette clearly show that these lakes are sediment reservoirs. Final mine effluent will be routed to Lac Jean, while Lac Bernadette, which is very similar and adjacent, will serve as a representative control setting.

In the southeast bay of Lac Jean, where the largest tributary enters the lake, 33% of sediment particles are of silt and clay size. Sediments in the northeast bay have less abundant fines (21.7%). This bay collects waters from a much smaller system (Lac Coil and lake B-5). Sediments sampled in Lac Bernadette downstream from its tributary also contained a large proportion of fines, with a 34% silt- and clay-size fraction.

Sediments in most small water bodies upstream from these two large basins also contain abundant fines (26 to 48% equal in size or finer than silt). At the other end of the spectrum, sediments sampled in Rivière Armitage only contained 0.2% fines of that size.

In a natural setting, mainly as a result of geochemical processes, some substances are introduced into aquatic ecosystems and enter the particulate phase to then act as reservoirs of chemicals. Because sediments are an important component of aquatic systems and serve as habitat for a large number of benthic and epibenthic organisms, exposure to certain chemicals present in sediments may have an impact not only on these organisms, but also on fish species that feed on them. For this reason, governments have set specific sediment quality guidelines.

As with other guidelines pertaining to environmental quality, those relating to sediments have wide-ranging potential applications. However, guidelines for sediment quality are most often used as control tools for assessing the potential risk of exposure to chemicals in specific locations. To this end, analytical results were compared to the Canadian Council of Ministers of the Environment Guidelines for the Protection of Aquatic Life (CCME 2001).

Analytical results (Table 8.24) serve to constrain background concentrations for several metals, as well as pH values, some mineralization parameters (calcium, magnesium, potassium and sodium), and total organic carbon, total phosphorus and total cyanides. Of the metals analyzed, arsenic, cadmium, chromium, copper, lead and zinc are the only ones to which CCME guidelines apply. For the 14 stations sampled, mean concentrations calculated for these metals are below suggested interim sediment quality guidelines, which are concentrations above which adverse biological effects are frequently observed.

The finest particles in sediments have a high specific surface area, which enhances contaminant adsorption. Because of their high fines content, sediments in the project area have a higher capacity to bind potential contaminants derived from the ore concentration process. In addition, the high organic matter content in sediments in all the small water bodies in the study area enhances adsorption of metals on organic matter, thereby reducing their bioavailability to fish. Total organic carbon concentrations in sediments range from 130,000 to 400,000 mg/kg for small lentic bodies. By comparison, in Baie Girard in Lac Chimougamau, the organic carbon concentration is only 7,400 mg/kg. Organic carbon concentration was also low at the sampling station on Rivière Armitage, at 3,300 mg/kg.

Table 8.24 Analytical Results for Sediments Sampled in the BlackRock Project Area in 2011

Sampling Date		05-07-11	11-07-11	08-07-11	04-07-11	12-07-11	16-07-11	12-07-11	22-07-11	16-07-11	20-07-11	15-07-11	15-07-11	RDL
PARAMETER	UNITS	Lac Jean Subsystem									Lake A-1 Subsystem		Lac Bernadette Subsystem	
		LAC DENIS	LAKE B-7	LAKE B-14	LAKE B-13	LAKE B-6	LAC JEAN NORTHEAST BAY	LAKE B-4	LAKE B-5	LAC JEAN SOUTHEAST BAY	LAKE B-1 Emissary	LAKE B-3	LAKE B-15	
Moisture content	%	94	84	90	95	87	92	91	94	88	95	90	96	N/A
pH	pH	7.17	6.22	6.3	6.16	6.92	6.44	6.94	7.12	6.26	6.44	6.15	6.41	N/A
Total cyanides	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Total organic carbon	mg/kg	130,000	130,000	140,000	210,000	140,000	220,000	130,000	180,000	150,000	220,000	140,000	270,000	500
Silver (Ag)	mg/kg	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2
Arsenic (As)	mg/kg	<1	11	<1	<1	<1	5	4	6	5	4	5	7	1
Barium (Ba)	mg/kg	36	32	25	58	30	43	25	21	39	45	52	34	5
Cadmium (Cd)	mg/kg	0.4	0.7	<0.2	0.9	0.6	0.7	0.3	0.5	0.9	0.2	1.1	1.3	0.2
Cobalt (Co)	mg/kg	4	5	4	6	6	11	8	12	9	<2	18	7	2
Chromium (Cr)	mg/kg	48	8	6	9	13	15	12	18	13	4	17	11	2
Copper (Cu)	mg/kg	30	27	13	55	15	33	37	25	19	8	18	18	1
Tin (Sn)	mg/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5
Manganese (Mn)	mg/kg	57	790	68	100	590	630	59	100	1100	30	1300	210	1
Molybdenum (Mo)	mg/kg	<2	<2	<2	3	2	2	2	14	<2	<2	<2	<2	2
Nickel (Ni)	mg/kg	15	8	7	11	7	15	14	11	10	9	12	13	1
Lead (Pb)	mg/kg	9	8	<5	33	6	16	8	13	11	<5	19	46	5
Selenium (Se)	mg/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Zinc (Zn)	mg/kg	71	55	37	66	52	63	48	47	62	37	97	87	5
Aluminium (Al)	mg/kg	19,000	4,700	6,300	8,200	6,600	9,700	7,000	14,000	7,800	2,000	13,000	3,200	20
Beryllium (Be)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Boron (B)	mg/kg	<5	<5	<5	<5	<5	<5	<5	5	<5	<5	<5	5	5
Calcium (Ca)	mg/kg	8,600	3,300	3,400	6,100	6,000	9,900	6,000	11,000	7,000	5,900	5,500	12,000	30
Iron (Fe)	mg/kg	5,000	4,100	2,900	3,600	5,600	11,000	6,500	10,000	5,700	920	10,000	4,300	10
Magnesium (Mg)	mg/kg	1,400	680	360	410	1,200	1,700	860	1,700	1,300	1,000	1,400	2,000	10
Potassium (K)	mg/kg	200	64	67	170	110	140	110	180	100	70	140	190	10
Sodium (Na)	mg/kg	54	22	28	41	37	89	38	67.0	44	100	58	120	10
Strontium (Sr)	mg/kg	12	<10	<10	15	<10	18	13	22	14	18	12	13	10
Titanium (Ti)	mg/kg	170	89	92	150	110	140	96	150	160	47	170	50	1
Vanadium (V)	mg/kg	10	8	5	12	8	18	10	22	17	6	30	13	1
Total phosphorus	mg/kg	560	300	250	490	350	440	250	480	450	200	530	540	20
Grain size (silt and clay)	%	29.0	48.0	34.0	37.0	26.0	21.7	15.5	19.4	33.0	45.0	38.0	32.3	

RDL: reportable detection limit
N/A = not applicable

Table 8.24 Analytical Results for Sediments Sampled in the BlackRock Project Area in 2011 (cont'd)

Sampling Date		28-07-11	28-07-11	27-07-11	31-07-11	4-07-11	04-07-11	27-07-11	
PARAMETER	UNITS	Lac Bernadette Subsystem			Rivière Armitage Subsystem		Lac Chibougamau	Lake A-1 Subsystem	RDL
		LAC BERNADETTE	B15-B16 EMISSARY	B17	A-2	RIVIERE ARMITAGE	BAIE GIRARD	A-1	
Moisture content	%	92	92	97	93	22	30	91	N/A
pH	pH	6.17	6.33	6.46	6.37	6.07	6.12	6.28	N/A
Total cyanides	mg/kg	<0.5	1.2	<1	0.6	<0.5	<0.5	<0.5	0.5
Total organic carbon	mg/kg	160,000	370,000	400,000	180,000	3,300	7,400	200,000	500
Silver (Ag)	mg/kg	<20	<20	<20	<20	<20	<20	<20	20
Arsenic (As)	mg/kg	<10	<10	<10	<10	<10	<10	10	10
Barium (Ba)	mg/kg	<50	<50	<50	<50	<50	<50	<50	50
Cadmium (Cd)	mg/kg	<2	<2	<2	<2	<2	<2	<2	2
Cobalt (Co)	mg/kg	<20	<20	<20	30	<20	<20	<20	20
Chromium (Cr)	mg/kg	<20	<20	<20	23	<20	<20	<20	20
Copper (Cu)	mg/kg	23	<10	17	34	<10	<10	13	10
Tin (Sn)	mg/kg	<50	<50	<50	<50	<50	<50	<50	50
Manganese (Mn)	mg/kg	850	300	51	350	420	150	480	10
Molybdenum (Mo)	mg/kg	<20	<20	<20	<20	<20	<20	<20	20
Nickel (Ni)	mg/kg	12	<10	<10	18	13	<10	<10	10
Lead (Pb)	mg/kg	<50	<50	<50	<50	<50	<50	<50	50
Selenium (Se)	mg/kg	<100	<100	<100	<100	<100	<100	<100	100
Zinc (Zn)	mg/kg	190	<50	87	150	59	<50	79	50
Aluminium (Al)	mg/kg	5,500	2,000	990	15,000	5,100	2,100	3,700	200
Beryllium (Be)	mg/kg	<5	<5	<5	<5	<5	<5	<5	5
Boron (B)	mg/kg	<50	<50	<50	<50	<50	<50	<50	50
Calcium (Ca)	mg/kg	8,200	21,000	14,000	12,000	1,500	1,000	10,000	300
Iron (Fe)	mg/kg	7,500	6,000	1,500	16,000	11,000	3,100	5,100	100
Magnesium (Mg)	mg/kg	1,500	2,500	1,900	1,500	4,000	1,000	2,000	100
Potassium (K)	mg/kg	160	100	150	170	210	100	130	100
Sodium (Na)	mg/kg	<100	<100	<100	<100	<100	<100	<100	100
Strontium (Sr)	mg/kg	<100	<100	<100	<100	<100	<100	<100	100
Titanium (Ti)	mg/kg	130	59	35	230	280	120	180	10
Vanadium (V)	mg/kg	24	23	18	77	28	16	<10	10
Total phosphorus	mg/kg	480	350	410	790	290	<200	450	200
Grain size (silt and clay)	%	34.0	15.5	17.9	4.1	0.2	4.5	4.4	

RDL: reportable detection limit

N/A = not applicable

Results from analyses performed in 2001 on sediments from water bodies in the area of the mine site are reported in Table 8.25. This data, as well as the 2011 data for which precise geographical coordinates of sampling sites were recorded (Table 8.26), will be used to monitor changes in physicochemical and granulometric parameters in the project area.

Table 8.27 shows results from leach tests done in 2001 on sediments collected in the project area. These tests serve to constrain the concentration of metals that sediments can theoretically release under extreme pH conditions. It is therefore important to note that leach tests were done at a pH of 4.9, which is three orders of magnitude more acidic than pH values measured *in situ* (mean value of 7.85) in surface waters in the project area.

Table 8.25 Analytical Results for Sediments Sampled in the Project Area in 2001

PARAMETER	DETECTION LIMIT	UNITS	Lac Laugon	Lac Denis	Lac Jean	Ruisseau Villefagnan		
pH	0.01		6.43	6.47	6.41	6.39	6.73	5
Moisture content	0.5	%	95	89	74	50	50	27
Total organic carbon	0.2	%	190,000	180,000	120,000	140,000	5,000	5,000
Grain size*			COARSE	COARSE	INTER	INTER	INTER	INTER
Total phosphorus	20	mg/kg	730	570	450	360	430	510
Total cyanides	0.3	mg/kg	< 10	< 2.2	3.1	< 0.4	< 0.5	<
Calcium	50	mg/kg	15,000	3,000	6,100	2,300	3,400	2,900
Magnesium	20	mg/kg	1,800	1,900	1,500	1,300	1,600	5,000
Sodium	50	mg/kg	130	110	57	<	<	62
Aluminium	20	mg/kg	15,000	6,000	10,000	3,200	3,600	11,000
Silver	2	mg/kg	<	<	<	<	<	<
Arsenic	0.1	mg/kg	1.9	0.7	0.7	0.5	5	2.7
Barium	10	mg/kg	42	34	40	13	13	37
Beryllium	2	mg/kg	<	<	<	<	<	<
Boron	2	mg/kg	6	2		<	<	<
Cadmium	0.5	mg/kg	1.1	<	<	<	<	<
Chromium	5	mg/kg	21	11	15	8	10	25
Cobalt	2	mg/kg	13	4	7	4	6	14
Copper	5	mg/kg	34	10	36	<	6	12
Tin	2	mg/kg	3	<	3	<	<	<
Iron	50	mg/kg	12,000	11,000	8,600	4,400	8,200	21,000
Manganese	10	mg/kg	190	220	200	200	72	970
Molybdenum	1	mg/kg	2	<	<	<	2	<
Nickel	5	mg/kg	19	7	17	<	6	18
Lead	5	mg/kg	25	8	<	<	<	9
Potassium	100	mg/kg	260	270	150	<	120	260
Selenium	0.5	mg/kg	1.2	<	<	<	<	<
Titanium	10	mg/kg	250	320	170	150	180	350
Vanadium	10	mg/kg	35	14	11	<	<	23
Strontium	5	mg/kg	18	11	22	8	12	12
Zinc	5	mg/kg	110	44	66	27	31	94

NOTES: < value below analytical detection limit
Inter: intermediate fraction 38 – 999 µm
C-F: bimodal (coarse, fine)
*Coarse: coarse fraction ≥ 1,000 µm
Fine: fine fraction < 38 µm

Table 8.26 Location of Sediment Sampling Stations – Summer 2011

LAKE, RIVER	LONGITUDE	LATITUDE	DATE
LAC BERNADETTE	18U0566140	5517760	28/07/11
A-1	18U0567620	5520189	27/07/11
LAC JEAN SW BAY	18U0568415	5520106	16/07/11
LAC JEAN NE BAY	18U0569709	5521163	16/07/11
LAKE A-2	18U0570475	5518553	31/07/11
LAKE B-1	18U0567130	5518185	20/07/11
LAKE B-3	18U0567870	5518796	15/07/11
LAKE B-4	18U0569078	5519425	21/07/11
LAKE B-5	18U0568929	5519106	22/07/11
LAC DENIS	18U0567452	5516295	05/07/11
LAKE B-14	18U0569379	5517233	08/07/11
LAKE B-15	18U0565922	5516717	14/07/11
LAKE B-17	18U0566153	5517453	27/07/11
LAC CHIBOUGAMAU, BAIE GIRARD	18U0567735	5524414	04/08/11
RIVIÈRE ARMITAGE	18U0568430	5522429	04/08/11

Table 8.27 Results of Leach Tests Performed in 2001 on Sediments from the BlackRock Project Area

PARAMETER	DETECTION LIMIT	UNITS	UNITS	Lac Laugon	Lac Denis	Lac Jean	Ruisseau Villefagnan		
Phosphorus	0.2		mg/L	<	<	<	<	<	<
Calcium	0.5	mg/kg	mg/L	23	33	36	22	36	9.1
Magnesium	0.5	mg/kg	mg/L	2.1	2.7	8.5	3.9	5.0	1.1
Sodium	50	mg/kg	mg/L	-	-	-	-	-	-
Aluminium	0.1	mg/kg	mg/L	0.2	0.2	0.1	0.3	0.3	0.4
Silver	0.1	mg/kg	mg/L	<	<	<	<	<	<
Arsenic	0.005	mg/kg	mg/L	<	<	<	<	0.018	<
Barium	0.2	mg/kg	mg/L	<	<	0.2	<	0.3	0.2
Beryllium	0.01		mg/L	<	<	<	<	<	<
Boron	0.2		mg/L	<	<	<	<	<	<
Cadmium	0.005	mg/kg	mg/L	<	<	<	<	<	<
Chromium	0.05	mg/kg	mg/L	<	<	<	<	<	<
Cobalt	0.02	mg/kg	mg/L	<	<	<	<	0.03	0.02
Copper	0.05	mg/kg	mg/L	<	<	<	<	<	<
Tin	0.1		mg/L	<	<	<	<	<	<
Iron	0.2	mg/kg	mg/L	<	<	<	<	<	0.3
Manganese	0.05	mg/kg	mg/L	0.23	0.11	0.24	2.8	0.39	4.3
Molybdenum	0.1	mg/kg	mg/L	<	<	<	<	<	<
Nickel	0.05	mg/kg	mg/L	<	<	<	<	<	<
Lead	0.05	mg/kg	mg/L	<	<	<	<	<	<
Potassium	2		mg/L	<	<	<	<	<	<
Selenium	0.005	mg/kg	mg/L	<	<	<	<	<	<
Titanium	0.1	mg/kg	mg/L	<	<	<	<	<	<
Vanadium	0.05	mg/kg	mg/L	<	<	<	<	<	<
Zinc	0.2	mg/kg	mg/L	<	<	<	<	0.2	0.2

NOTES:
< value below analytical detection limit
Leach test done at a pH of 4.9

Leach test results indicate that only a very small proportion of metals present in the sediments is dissolved, even under acidic conditions. Excluding major cations such as calcium and magnesium, all metals analyzed had concentrations below the analytical detection limit, with the exception of the following: aluminium, arsenic (Ruisseau Villefagnan), barium, cobalt, iron, manganese and zinc. Leach test results shown in Table 8.27 reflect extreme theoretical conditions and are not representative of conditions normally encountered in lakes and watercourses in the study area.

In summary, the analysis of metals in sediments highlights the fact that all metals for which the CCME has set guidelines (arsenic, cadmium, chromium, copper, lead and zinc) have concentrations below these limits. Metal solubilization generally increases with decreasing pH. The low proportion of metals released at a pH of 4.9 suggests a relatively low risk of sudden release of metals, particularly during spring snowmelt, compared to other lakes and watercourses in Quebec. The relatively high pH of waters in the study area (average pH of 7.85), relative abundance of organic matter (198,000 mg/kg organic carbon on average) and sediment grain size (27% of particles, on average, the size of silt and clay) are all factors that significantly limit metal bioavailability.

8.6.2 Chemical Characteristics of Soils

Six soil samples collected in 2001 in the project area were analyzed by Maxxam Analytics for 27 metals, using the Centre d'Expertise Environnementale du Québec's analytical method (method MA 200-Mét, 1.0) for heavy metal contaminated soils. Sampling stations were all located in the vicinity of the project area, as shown in Figure 8.2. Metal concentrations in soils are reported in Table 8.28.

Soil samples were collected from tills that make up the overburden in the area. Results were assessed using heavy metal criteria defined in the Quebec Government Soil Protection and Contaminated Sites Rehabilitation Policy. Other elements not covered in the policy were analyzed to constrain background concentrations in the soil prior to the start of mining operations.

A sample collected south of Lac Laugon shows the highest concentrations of copper, lead, zinc, selenium and mercury. Most of the samples had high copper and lead concentrations and in some cases exceeded limit values. Copper and lead concentrations are clearly linked to the many sulphide showings in the area. Analytical results show that six of seven samples analyzed had copper concentrations exceeding the Superior Province background concentration of 50 mg/kg, while copper concentration in the seventh sample (48 mg/kg) was similar to background. As for lead, five of the seven samples exceed the background concentration for the Superior Province (40 mg/kg). Zinc concentrations in soil are generally below background for the Superior Province (120 mg/kg), a single sample having a concentration equal to this value. No samples were collected directly from the mineralized zone.

Table 8.28 Metal Concentrations in Soil

Parameter	Detection limit	Units	Soil 1 (023792 02)	Soil 2 (023793 02)	Soil 3 (023794 02)	Soil 4 (023795 02)	Soil 5 (023796 02)	Soil 6 (023797 02)	Background concentration in the Superior Province
Moisture	0.5	%	1.5	0.8	0.5	1.0	1.3	<	
Metal									
Aluminium	20	mg/kg	1,700	820	1,900	9,900	13,000	1,000	
Silver	2	mg/kg	<	<	<	<	<	<	0.5
Arsenic	0.5	mg/kg	<	<	<	1.5	0.9	<	0.5
Barium	10	mg/kg	11	<	<	18	13	<	200
Beryllium	2	mg/kg	<	<	<	<	<	<	
Boron	2	mg/kg	<10	<10	<10	<10	<10	<10	
Cadmium	0.5	mg/kg	<	<	<	<	<	<	0.9
Calcium	50	mg/kg	2,700	1,500	920	2,000	1,500	610	
Chromium	5	mg/kg	6	<	7	24	25	<	85
Cobalt	2	mg/kg	11	<	3	5	6	<	20
Copper	5	mg/kg	120	92	76	94	65	48	50
Tin	2	mg/kg	5	6	3	4	2	<	5
Iron	50	mg/kg	3,200	1,200	6,600	13,000	17,000	2,200	
Magnesium	20	mg/kg	840	320	640	2,800	2,200	250	
Manganese	10	mg/kg	72	17	27	120	200	13	1,000
Mercury	0.02	mg/kg	0.04	<	<	0.03	0.04	<	0.3
Molybdenum	1	mg/kg	<	<	<	<	<	<	6
Nickel	5	mg/kg	5	<	<	12	9	<	50
Phosphorus	20	mg/kg	250	46	96	420	680	45	
Lead	5	mg/kg	45	46	43	49	22	22	40
Potassium	100	mg/kg	130	<	120	240	170	<	
Selenium	0.5	mg/kg	<	<	<	<	<	<	3
Sodium	50	mg/kg	800	410	320	270	290	170	
Strontium	5	mg/kg	11	8	8	13	8	<	
Titanium	10	mg/kg	65	220	800	470	530	340	
Vanadium	10	mg/kg	<	<	33	25	35	<	
Zinc	10	mg/kg	120	85	46	74	58	30	120

8.6.3 Summary Comparison of Chemical Parameters for Soils, Sediments and Water

Average copper concentrations in soils (±82.5 mg/kg) are roughly 3.5 times higher than in sediments (±23.3 mg/kg) in the lakes of the study area. Copper concentrations in water are below the detection limit of 0.003 mg/L.

Average lead concentrations in soils (±37.8 mg/kg) are roughly 2.6 times higher than in sediments (±14.5 mg/kg) in the lakes of the study area. Lead concentrations in water are below the detection limit of 0.001 mg/L.

Zinc concentrations in sediments are slightly higher than in soils (±73.7 mg/kg vs ±68.8 mg/kg). Zinc concentrations in surface water are generally below the detection limit, except for two stations where measured concentrations were 0.028 and 0.019 mg/L.

Vanadium concentrations appear on average to be slightly higher in sediments than in soils (±18.4 mg/kg vs 16.1 mg/kg). Vanadium concentrations in surface water are below the detection limit of 0.01 mg/L.

According to the Soil Protection and Contaminated Sites Rehabilitation Policy criteria, several natural soil samples could be considered contaminated, as their copper (50 mg/kg) and lead (40 mg/kg) concentrations were above Superior Province background values. Some caution must be exercised in interpreting these criteria as they apply to the study area and the Chibougamau region. For instance, simply grinding the ore could theoretically produce local concentrations that exceed guidelines but are still similar to concentrations observed under natural conditions.

8.7 ANALYSIS OF METALS IN BIOMASS (FISH AND BENTHOS)

Biomass analyses done at the mine site in 2001 were reviewed to assess the potential for metals to enter the food chain. Two species of fish were selected for assessment of metals in biomass: the northern pike, a piscivorous species, and the white sucker, a benthivorous and insectivorous species.

Table 8.29 shows biomass metal concentrations for Lac Denis, Lac Jean and Ruisseau Villefagnan (average, maximum), as well as the average length of analyzed individuals and their total number for each station (N).

Of the 17 metals analyzed (Hg, V, Al, Fe, Mn, Se, As, Cd, Cr, Co, Cu, Ni, Pb, Ti, Zn, Mo, and Sr), mercury, vanadium, aluminium, iron, manganese, selenium and arsenic showed concentrations above the analytical detection limit.

Table 8.29 Average Metal Concentrations (Maximum Values in Parentheses) Measured from the Flesh of Two Species of Fish Caught in the Project Area in 2001

SPECIES	STATION	N	Avg. LENGTH	Mercury	Vanadium	Aluminium	Iron	Manganese	Selenium	Arsenic
			(mm)	(mg/kg*)	(mg/kg*)	(mg/kg*)	(mg/kg*)	(mg/kg*)	(mg/kg*)	(mg/kg*)
Detection limit (mg/kg)				0.05	0.2	2	2	0.5	0.2	0.2
Northern pike	Lac Denis	5	556	0.23 (0.38)	< 0.2	≤ 2	2.5 (3.5)	< 0.5	0.4 (0.5)	0.2 (0.5)
	Lac Jean	5	472	0.23 (0.47)	< 0.2	< 2	3.0 (9.7)	0.6 (1.6)	0.4 (0.4)	< 0.2
	Ruisseau Villefagnan: lotic	5	556	0.33 (0.53)	≤ 0.2	< 2	1.2 (2.2)	0.6 (1.8)	0.4 (0.6)	0.2 (0.8)
	Ruisseau Villefagnan: lentic	5	325	0.14 (0.18)	≤ 0.2	< 2	2.9 (5.7)	1.3 (3.6)	0.4 (0.7)	< 0.2
White sucker	Lac Jean	5	445	0.16 (0.32)	< 0.2	< 2	3.1 (6.5)	< 0.5	0.4 (0.5)	< 0.2
	Ruisseau Villefagnan: lotic	5	243	0.08 (0.11)	≤ 0.2	< 2	2.2 (3.5)	0.3 (0.5)	0.4 (0.6)	< 0.2
	Ruisseau Villefagnan: lentic	5	233	0.09 (0.11)	< 0.2	3	4.9 (13)	< 0.5	0.5 (1.1)	0.2 (0.5)

NOTE:

- Numbers in parentheses are maximum values measured
- All other metals analyzed have concentrations below the analytical detection limit and are not reported in the Table;
- Other metals analyzed and corresponding detection limits (in mg/kg) are: cadmium (0.5), chromium (5), cobalt (2), copper (5), nickel (5), lead (5), titanium (2), zinc (10), molybdenum (1) and strontium (1)

* Wet weight

N = number of individuals analyzed

For northern pike, average mercury concentrations ranged from 0.14 to 0.33 mg/kg, with a maximum value of 0.53 mg/kg in one individual caught in Ruisseau Villefagnan. White sucker have average mercury concentrations ranging from 0.08 to 0.16 mg/kg, with a maximum value 0.32 mg/kg from the Lac Jean station.

Measured mercury levels for the two species of fish caught in the study area are within the ranges described by Brouard et al. (1990) for 29 natural lakes in the James Bay watershed.

For other metals, including vanadium, aluminium, iron, manganese, selenium and arsenic, concentrations measured from the dorsal muscles of fish are very close to or below the detection limit.

For benthos, analyses of metal concentrations were done for Lac Jean and for lotic and lentic stations along Ruisseau Villefagnan. Most of the 13 metals analyzed have concentrations below the analytical detection limit, except for aluminium, vanadium and zinc (Table 8.30). Metals in sediments seem to have limited availability for benthic invertebrates and hence for benthivorous fish and their predators.

Results of analyses of metals in fish show that mercury is the only metal with concentrations significantly higher than the analytical detection limit. However, measured mercury concentrations are similar to reported background concentrations for 29 natural lakes in the James Bay watershed. For benthic organisms, aluminium and zinc have concentrations significantly above detection limits.

The very high pH of water bodies in the study area and the abundance of bicarbonates, cations like calcium and organic carbon result in a decrease in metal toxicity to aquatic fauna. In general, metals are complexed before reaching the aquatic fauna. Physicochemical characteristics of surface waters in the study area are distinctly different from those in the Province of Quebec as a whole.

Table 8.30 Metal Concentrations Measured in Benthos from the Project Area

PARAMETER	DETECTION LIMIT	UNITS	STATION		
			Lac Jean	Ruisseau Villefagnan lotic	Ruisseau Villefagnan lentic
Mercury	0.05	mg/kg	<	<	<
Aluminium	2	mg/kg	79	180	130
Cadmium	0,5	mg/kg	<	<	<
Chromium	5	mg/kg	<	<	<
Cobalt	2	mg/kg	<	<	<
Copper	5	mg/kg	8	<	<
Nickel	5	mg/kg	<	<	<
Lead	5	mg/kg	<	<	<
Iron	10	mg/kg	-	-	-
Manganese	10	mg/kg	-	60	-
Titanium	2	mg/kg	<	<	<
Vanadium	0.2	mg/kg	<	0.5	0.4
Zinc	10	mg/kg	<	24	12

NOTES:
- Dash (-) indicates that data is not available
- Concentrations are in mg/kg wet weight

8.8 COMPARATIVE ASSESSMENT OF THE LAC DENIS AND RUISSEAU VILLEFAGNAN ECOSYSTEMS

Benthic communities at Lac Denis and in lotic and lentic habitats in Ruisseau Villefagnan were characterized with a view towards implementing compensation measures at Lac Denis and Ruisseau Villefagnan. The Shanon-Weaver (1963) diversity index for benthos underscores the poverty of the Lac Denis ecosystem and the contrasting richness of the lotic and lentic habitats in Ruisseau Villefagnan. This diversity index, which ranges from 0 to 5, is an indicator of ecosystem health. A value higher than 3 reflects high diversity and therefore implies that local conditions are conducive to the survival of many species, even though the density of some may be low. The evenness index also reflects the relative abundance of different species, and more specifically the distribution of individuals in different taxa. Values of this index range from 0 to 1, a higher value indicating that several species are equally abundant in a given setting; in other words, there are no dominant species. Diversity index values for Ruisseau Villefagnan stations are greater than 4. At Lac Denis, a diversity index of 2.615 reflects an overrepresentation of amphipod crustaceans (52.14%), which generally tolerate to low dissolved oxygen concentrations. As part of environmental monitoring activities at Lac Denis and Ruisseau Villefagnan, the structure of benthic communities will have to be assessed in order to constrain their evolution. There is good reason to believe that construction of a reservoir at Lac Denis could improve the quality and productivity of this habitat. The corresponding decrease in discharge in Ruisseau Villefagnan downstream from Lac Jean and its effect on lentic and lotic habitats in this area should also be monitored. In this way, it should be possible to constrain the effect of flow reduction, as well as the potential for implementing compensation measures both upstream and downstream from the Lac Jean emissary.

The relative abundance of the various families of benthic organisms in control lakes and in areas exposed to final effluent will also have to be constrained. Characteristics of dominant taxonomic groups in benthic communities in Lac Denis and lotic and lentic sections of Ruisseau Villefagnan downstream from Lac Jean are provided in Table 8.31.

Table 8.31 Characteristics of Benthic Communities in Lac Denis and Ruisseau Villefagnan and Dominant Taxonomic Groups – Entraco 2001

	Lac Denis STATION	Ruisseau Villefagnan Lentic STATION	Ruisseau Villefagnan Lotic STATION
Total by sample *****	468	490	591
Total number of taxa *****	16	35	49
Density (number of individuals/0.05 m^2)	234	245	295
Diversity index (Shanon-Weaver)	2,615	4,471	4.861
Evenness index (Pielou's "J")	0.654	0.858	0.861
Relative abundance (%)			
Gastropoda	0.85	2.45	3.38
Bivalves	14.53	3.27	4.06
Oligochaeta	0.00	6.94	12.86
Crustacea **(1)**	63.25	22.45	25.89
Insects **(2)**	16.24	64.90	53.30
Other	5.13	0.00	0.51
(1) Crustacea distribution (%)			
Cladocera	11.11	2.86	11.51
Copepoda	0.00	0.00	2.03
Amphipods	52.14	19.59	12.35
(2) Insect distribution (%)			
Beetles	0.00	0.00	1.86
Diptera	12.82	32.65	35.03
Ephemeroptera	3.42	21.43	13.71
Caddisflies	0.00	8.16	1.35
Other	0.00	2.65	1.35
TOTAL (Crustaceans and insects in %)	79.5	87.3	79.2

***** Excluding nematods and oligochaeta fragments

8.9 COMPENSATION MEASURE IMPLEMENTATION AREAS

In light of the loss of aquatic faunal habitats resulting from the project, closer attention was paid to four specific areas. These habitats are not directly affected by project activities. However, the use of water from the Ruisseau Villefagnan watershed, specifically from Lac Jean, may result in reduced discharge in this watercourse, as water required for ore processing is taken from the Lac Jean subsystem and recycled through the concentration circuit. A reduction in flow is therefore expected in the lower section of Ruisseau Villefagnan, which has potential for the implementation of compensation measures for yellow walleye, brook trout and northern pike.

The three other potential areas for implementation of compensation measures are Rivière Armitage, which plays a particularly important role in Lac Chibougamau ecology, Ruisseau Wynne and Lac Denis. Ruisseau Wynne collects waters from Lac Pillow and feeds Lac Stella, which flows into Lac Armitage. As for Lac Denis, its level will be raised so that it can serve as a source of process water. A significant increase in its volume coupled with fish management measures could result in a good habitat for northern pike.

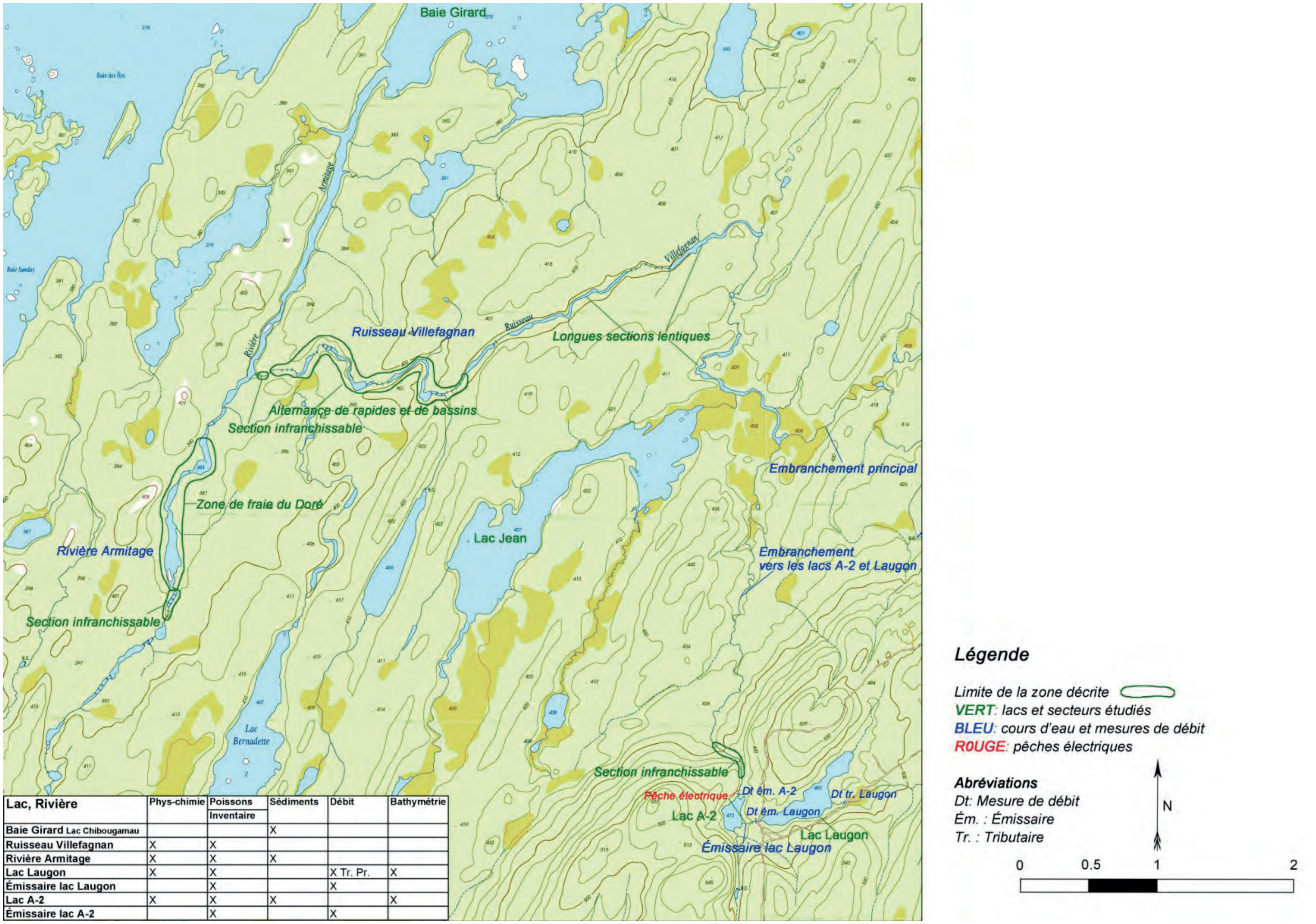
8.9.1 Rivière Armitage

This watercourse is sourced in Lac Armitage and flows directly into Lac Chibougamau. Experimental fishing was done in Rivière Armitage on May 21, 24 and 28, 2011, to check for the presence of yellow walleye and assess fry development. The spawning ground is located roughly 500 m upstream from the mouth of Ruisseau Villefagnan (Figure 8.18).

On May 21, 2011, line fishing yielded no walleye. A single northern pike was caught and released. The northern portion of Lac Chibougamau, through which walleye transit on their way to Rivière Armitage, lost its ice cover on May 23, 2011. One fallfish, one northern pike and two male yellow walleye were caught with a line, all in the upper section of the spawning ground. Development of sexual maturity in the two males was limited. Walleye total lengths were 434 and 418 mm, and their weights were 580 and 560 g, respectively. On May 28, water temperature was 12.54°C. Four walleye were caught, including three from the lower section of the spawning ground. Total lengths ranged from 390 to 441 mm, and the fish ranged in weight from 510 to 720 g. All were mature males, and a slight pressure applied to their abdomens was sufficient to release milt. The three sacrificed walleye had empty stomachs. The absence of females or large spawners in the spawning ground suggests that spawning had only just begun.

To assess the potential for implementation of compensation measures for walleye further upstream, photos and videos were shot of the impassable barrier located upstream from the spawning ground, where the river mainly flows around a rocky island. On the eastern branch of the river, sills are lower and there are bedrock grooves. Also on the east side, a small stream seems to act as a secondary channel, diverting Rivière Armitage waters.

Figure 8.18 Possible Compensation Areas – Rivière Armitage, Ruisseau Villefagnan and Lake A-2



Lac, Rivière	Phys-chimie	Poissons Inventaire	Sédiments	Débit	Bathymétrie
Baie Girard Lac Chibougamau			X		
Ruisseau Villefagnan	X	X			
Rivière Armitage	X	X	X		
Lac Laugon	X	X		X Tr. Pr.	X
Émissaire lac Laugon		X		X	
Lac A-2	X	X	X		X
Émissaire lac A-2		X		X	

During the last visit to Rivière Armitage, on August 4, 2011, the water level was much lower. Distincly impassable barriers more than 1.4-m high were noted east of the island. There are even higher sills on the west side. Another visit to the east side of the river might be warranted to determine whether a passageway towards potential spawning grounds upstream is possible. Nothing conclusive could be found on 1:20,000 air photos and topographic maps.

Videos and photos shot during field visits give ecosystem managers a good sense of the river and its impassable section. The potential for compensation measures would be along the eastern shore, where sills are not as high and grooves in the bedrock might facilitate fish movement. It should also be noted that potential measures to this end are closely linked to a more global view of Lac Chibougamau walleye population dynamics, in particular the need to increase recruitment, which falls under MRNF jurisdiction.

Physicochemical parameters measured *in situ* during the various Rivière Armitage visits are recorded in Table 8.32. It is interesting to note the changes in pH and conductivity between May 21 and 28, 2011. The decrease in flow over that interval seems to have resulted in an increase in ion abundance and water buffering capacity.

Table 8.32 Rivière Armitage Physicochemical Parameters

Rivière Armitage	**	**	*
Date	21/05/11	24/05/11	28/05/11
Longitude	18U0566555	18U0554350	18U056770
Latitude	5521921	5510939	5522405
Depth	0.6 m	0.6 m	0.6 m
Parameters:			
pH	7.16	7.74	7.94
°C	14.0	13.32	12.54
Atmospheric pressure (Mbar)	962.4	946.0	958.9
Conductivity at 25^{o} (µS/cm)	22	30	32
Total dissolved solids (TDS ppm)	14	15	16
Salinity (Sal)	0.01	0.01	0.01
Oxidation-reduction potential (ORP)	99.6	76.2	87.2
Dissolved oxygen (DO %)	79.0	76.7	79.4
Dissolved oxygen (DO mg/L)	7.74	7.48	8.02
Resistivity (KΩ. cm)		33.7	30.9
Ambient conductivity (µS/cmA)	23	23	21

* At first rapid upstream from the mouth of Ruisseau Villefagnan

** 600 m downstream from Ruisseau Villefagnan

Photo 8.106: Rivière Armitage across from mouth of Ruisseau Villefagnan – May 2011.

Photo 8.107: Walleye spawning ground area in Rivière Armitage, lower rapid of impassable section – May 2011.

Photo 8.108: Rivière Armitage; impassable section in springtime – May 2011.

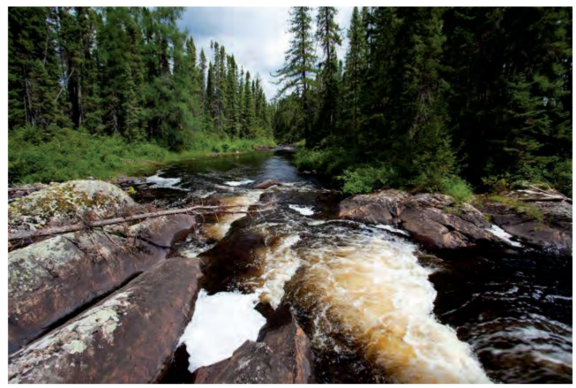


Photo 8.109: Rivière Armitage; grooves on east side of impassable section on August 4, 2011.

8.9.2 Ruisseau Villefagnan

This watercourse drains a 28-km^2 watershed and flows into Rivière Armitage near the yellow walleye spawning ground, approximately 2.5 km upstream from where it enters Lac Chibougamau (Figure 8.18). Ruisseau Villefagnan collects waters from lake A-1, Lac Jean, lake A-2 and Lac Laugon, and consists of a succession of pools, meanders and channels, with bed sediments dominated by rather coarse particles in its lower section. Species caught in this watercourse (Entraco 2003) are those found in Rivière Armitage that run up the accessible section of Ruisseau Villefagnan to the first impassable waterfall. Brook trout are found upstream from this area. This information was confirmed by former O-59 trapline tallyman, Matthew Wapachee.

In the summer of 2011, a study of the stream was carried out to constrain its potential for brook trout populations and eventually improve the yellow walleye breeding areas in the Lac Chibougamau region.

The stream bed in its lower section near its confluence with Rivière Armitage comprises rubble and rock and makes a good walleye breeding ground. This first section ends upstream from a very long, gently-sloping rapid, at two rapids that are impassable for walleye. On May 21, 2011, white sucker (Catostomus commersonnii) were seen spawning there, while walleye spawning had not yet begun in Rivière Armitage. Black bear trails are found nearby, for obvious reasons.

The section located upstream up to the confluence with the lake A-1 emissary was also visited. This section has long pools with beds comprising organic-rich sediments and cobbles. While these pools offer favorable conditions for northern pike, they also make viable grounds for brook trout. The pools are intercalated with rapids in which flow was very strong during the spring freshet of 2011. The stream bed in rapid sections comprises rubble of various sizes and bedrock outcrops. These rapid sections, in which flow is too strong for northern pike, are often a good setting for brook trout.

The last visited section of Ruisseau Villefagnan begins upstream from the rapid adjacent to the lake A-1 emissary. This is a meandering, lentic section about 2 kilometres long. The bed mainly comprises fine sediments and organic matter, along with some rubble. In springtime, its depth ranges from 0.5 to 1.5 m. The lentic section provides a good setting for northern pike. The shallowness of long sections and their lentic nature do not meet the needs of walleye and trout. There are no obstacles between this stretch of Ruisseau Villefagnan and Lac Jean.

The upper reaches of the lentic section split into two branches, one of which drains Lac Laugon and lake A-2 waters through hilly terrain. Mr. Wapachee reports having caught brook trout in this area. The other branch is larger and physiographically similar, and undoubtedly contains brook trout habitats.

Line fishing done between May 21 and 27, 2011, in the visited sections of Ruisseau Villefagnan produced no fish. No other fishing gear was used.

Results of *in situ* measurements taken in the summer of 2011 for major physicochemical parameters are shown in Table 8.33.

Table 8.33 Ruisseau Villefagnan Physicochemical Parameters

Ruisseau Villefagan		*****
Date	21/05/11	27/05/11
Longitude	18U0567207	18U 0570456
Latitude	5522199	5521917
Depth	0.6 m	1.5 m
Parameters:		*
pH	7.43	7.75
°C	17.54	9.62
Atmospheric pressure (Mbar)	961.4	959.5
Conductivity at 25^{o} (µS/cm)	30	32
Total dissolved solids (TDS ppm)	15	16
Salinity (Sal)	0.01	0.01
Oxidation-reduction potential (ORP)	122.1	82.5
Dissolved oxygen (DO %)	82.6	77.2
Dissolved oxygen (DO mg/L)	7.69	8.47
Resistivity (KΩ. cm)	33.6	31.5
Ambient conductivity (µS/cmA)	26	23

* Ruisseau Villefagnan near confluence with Lac Jean emissary

Various habitats are found in Ruisseau Villefagnan. Its uppermost section should be studied to constrain the extent of its brook trout population, as well as its spawning grounds, carrying capacity and potential for compensation measures.

The rapids located between the lake A-1 emissary and Ruisseau Villefagnan are very fast flowing. Along with the small intervening pools, they make a good setting for brook trout. Northern pike can only pass through the rapids, mainly in the downstream direction. However, northern pike and brook trout can coexist in the large intervening pools.

The bed of the lowermost section of Ruisseau Villefagnan, near the impassable sections for walleye, provides a suitable setting for walleye breeding. In addition, this section is near Rivière Armitage, where this species is abundant. Possible compensation measures for walleye at this locality should be examined more closely.

Photo 8.110: Ruisseau Villefagnan at 18U0567207, 5522199. Impassable section for yellow walleye.

Photo 8.111: Ruisseau Villefagnan at 18U0568015, 5522093. Lower pool with bed of rubble, gravel, and tree trunks

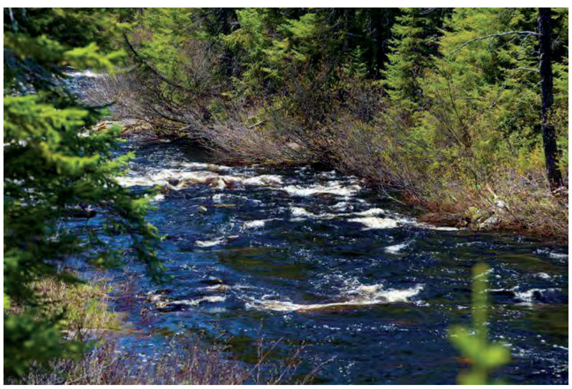


Photo 8.112: Ruisseau Villefagnan at 18U0567658, 5521898. Rapids and falls, fast moving section with rubble.

8.9.3 Lac Laugon and Lake A-2

Lac Laugon and lake A-2 are located northeast of the mining project and outside its boundaries. Lac Laugon connects with lake A-2 via a short emissary. The two lakes feed into one of the two branches of Ruisseau Villefagnan. These branches flow through hilly terrain favorable to brook trout before reaching a lentic area into which Lac Jean waters flow.

Lac Laugon

Lac Laugon is a roughly 1-km long headwater lake with two intermittent tributaries. Its level is raised by a large beaver dam located at its outlet. The dam is about 2.5 metres high and raises the lake level accordingly.

Riparian and forest vegetation that includes sweet gale and leatherleaf, as well as black spruce, is flooded. Beavers have also taken up residence upstream from the main tributary on the eastern side of the lake and created a large pond there. The tributary offers no breeding grounds for salmonids. Its bed is muddy and mainly composed of organic matter and a little sand. The small intermittent tributary in the northern section of Lac Laugon flows over a muddy bed. During a site visit on August 1, 2011, no flow was detected in this tributary.

During March 2011 field work, no traces of dissolved oxygen were recorded at any of the three sampling stations in the lake. In light of results gathered in winter 2011 and the presence of brook trout in Ruisseau Villefagnan, a fish survey was done in Lac Laugon in July 2011 and major physicochemical parameters were measured (Table 8.34). After 19 hours and 26 minutes of fishing with an experimental net, four pearl dace (Margariscus margarita) and one brook stickleback (Culea inconstans) were caught.

Five creels were set in which a total of 1,402 cyprinids were caught, as well as five brook stickleback (Culea inconstans). A species-specific tally was not done so that fish could be released alive. However, a few individuals were kept for identification purposes. Based on the size and colouring of captured individuals, it can be stated that at least two thirds if not 80% of cyprinids are northern redbelly dace (Phoxinus eos). Pearl dace (Margariscus margarita) were the second most numerous species. These results clearly indicate that winter oxygen levels in the lake only allow survival of very tolerant species.

In its natural state, salmonid survival is not possible in Lac Laugon. The lack of oxygen in winter and the absence of appropriate tributaries and spawning grounds make brook trout survival and breeding impossible.

Lac Laugon Emissary

Although it is not a permanent structure, the beaver dam located at the lake outlet is an impassable obstacle for brook trout. Downstream and near Lac Laugon, a few rapids can also impede brook trout movement in periods of low flow. Under normal flow conditions, these obstacles are not impassable. At mid-course, the emissary consists of a succession of small cobbly rapids with a little gravel, and pools with cobbly bottoms. Fine sediments and mud are also present and line the bottom in some reaches. Sediments are colonized by aquatic vegetation comprising eelgrass and poodweed, as well as rush and water-lily. In the upper fourth of the course, there is a small, 1.4-m high impassable waterfall. Some gravel is present where the Lac Laugon emissary enters lake A-2.

On July 6, 2011, water discharge in the stream was 0.092 m^3/s. Electrofishing was carried out in the emissary on July 21, 2011, which yielded eight longnose dace (Rhinicthys cataractae), three brook stickleback (Culea inconstans) and five northern redbelly dace (Phoxinus eos).

Figure 8.19 Lac Laugon Bathymetry

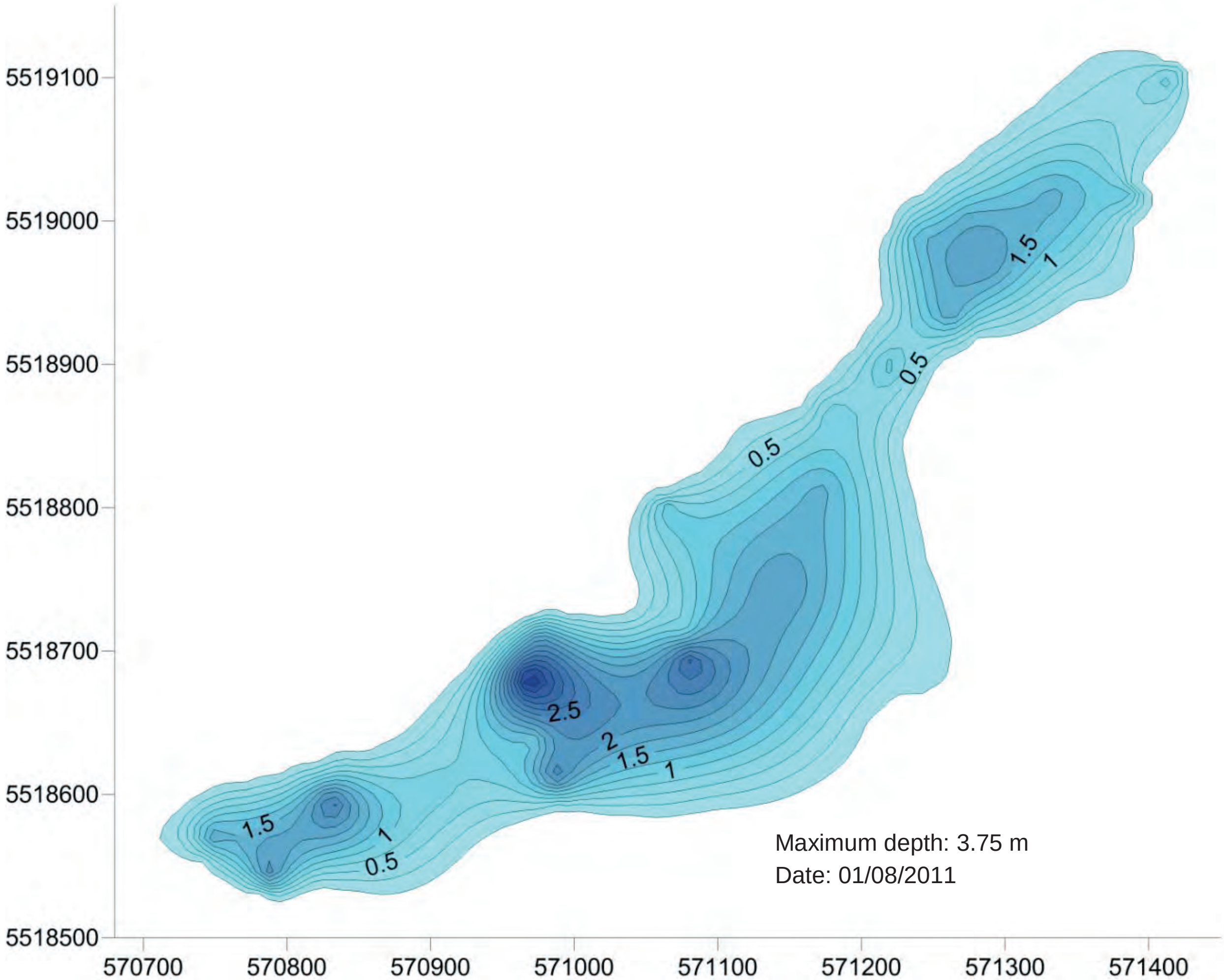


Table 8.34 Lac Laugon Physicochemical Parameters

Lac Laugon					
Date	23/03/11	23/03/11	23/03/11	23/03/11	06/07/11
Longitude	18U0571136	18U0571136	18U0571237	18U0570970	18U0570772
Latitude	5518715	5518715	5518919	5518634	55188569
Depth (m)	3	1.65	1.7	3.3	2.0
Parameters:					
pH	< 6.8		< 6.8	< 6.8	8.13
°C	2.87	1.39	1.97	3.39	18.83
Atmospheric pressure (Mbar)	958.2	958.2	958.0	957.8	937.9
Conductivity at 25^{o} (µS/cm)	96	76	75	95	56
Total dissolved solids (TDS ppm)	48	38	38	48	28
Salinity (Sal)	0.05	0.04	0.03	0.04	0.03
Oxidation-reduction potential (ORP)	-33.7	-18.8	-83	-73.7	26.2
Dissolved oxygen (DO %)	0	0	0	0	90.6
Dissolved oxygen (DO mg/L)	0	0	0	0	8.71
Resistivity (KΩ. cm)					18.0
Ambient conductivity (µS/cmA)					50

Photo 8.113: Lac Laugon; flooded vegetation in eastern tributary bay; living vegetation essentially comprises sweet gale, carex and some leatherleaf. Black spruce along the shore has not survived flooding.

Photo 8.114: More than two thirds of the 1402 cyprinids caught in Lac Laugon were northern redbelly dace (Phoxinius oes). Pearl dace (Margariscus margarita) were the other cyprinids present.

Photo 8.115: Aquatic vegetation comprising eelgrass and pondweed in small bay in northeast section of Lac Laugon. Flooded vegetation comprises carex and gale.

Lake A-2

Lake A-2 is roughly 300 metres long. It is fed by two tributaries, the main one being the Lac Laugon emissary. The second tributary, which splits into two branches, is located south of the lake. Its eastern branch was dry in August 2011. The main branch, which flows in a south-north direction, is slow-flowing and meandering. The fines tailings pond dam will transect its upper section. This stream is surrounded by flood-prone vegetation comprising carex and gale. The lake bottom comprises fine sediments, while further upstream, cobbles are abundant. During the site visit on July 31, 2011, no flow was perceptible in the stream.

Many cyprinids and one stickleback were spotted near shore. The shores of the lake are cobbly, and its waters are very clear. A large bed of rush and carex is found in the southern part of the lake. Only very small grass beds are found in other areas, and there is a narrow transition zone where riparian vegetation comprising a few carex and shrubs such as sweet gale connects the cobbly shore to the forest. Depth survey results (Figure 8.20) show that depth is most often less than 1.1 m, although there is a 3.25-m deep trough in the northern part of the lake.

Fishing with an experimental net over 19 hours and 3 minutes yielded 21 pearl dace (Margariscus margarita). Five creels yielded 217 pearl dace (Margariscus margarita), 270 northern redbelly dace and two brook stickleback (Culea inconstans). Electrofishing in the Lac A-2 emissary produced four longnose dace (Rhinicthys cataractae), a species typical of fast flowing sections of rivers.

A beaver dam constructed of mud, branches and numerous cobbles blocks the outlet. The abundance of cobbles confirms the minerotrophic nature of the lake. Its emissary flows on a bed of cobbles and gravel, and becomes steeper and faster-flowing downstream. Cascades and waterfalls prevent the upstream run of brook trout from Ruisseau Villefagnan.

Fish populations in lake A-2 seem to be less than the carrying capacity of the lake, which could likely host brook trout. Dissolved oxygen levels are appropriate, and there are abundant forage fish as food supply. The presence of longnose dace in the tributary of the lake A-2 emissary is also a positive indicator. Furthermore, the downstream section of the Lac Laugon emissary is a potential spawning ground for brook trout.

The stocking of several hundred individuals and implementation of minor accommodations downstream from the Lac Laugon emissary should be considered as a possible compensation measure. To ensure their hardiness and avoid contamination by parasites or illnesses, stocked fish could be taken from Ruisseau Villefagnan. Winter oxygen levels and flow constancy in the Lac Laugon emissary are the two main factors which could limit the effectiveness of such measures. Oxygen levels measured at three different stations in lake A-2 in March 2011 ranged from 0 to 5.02 ppm. The higher concentration allows for salmonid winter survival.

Sediment sampling was carried out in lake A-2 downstream from its tributary, at 18U0570475, 5518553. Results of *in situ* measurements taken in March and July 2011 for major physicochemical parameters are shown in Table 8.35

Table 8.35 Lake A-2 Physicochemical Parameters

Lake A-2						
Date	23/03/11	23/03/11	23/03/11	23/03/11	23/03/11	31/07/11
Longitude	18U0570488		18U0570507	18U570507		18U0570445
Latitude	5518627		5518544	55186544		5518603
Depth (m)	2.5	1.2	0.9	2	1.6	0.60
Parameters:						
pH	6.8 SURFACE		6.8	6.8		8.26
°C	4.19	1.57	0.11	1.31	2.15	20.37
Atmospheric pressure (Mbar)	960.2	960.0	956.9	959.8		936.4
Conductivity at 25^{o} (µS/cm)	140	113	88	110		70
Total dissolved solids (TDS ppm)	70	57	44	55		40
Salinity (Sal)	0.07	0.05	0.04	0.05		0.04
Oxidation-reduction potential (ORP)	51.8	78.6	-8.7	-64.3		20.5
Dissolved oxygen (DO %)	0	11.5	37.0	20.7	6.7	90.2
Dissolved oxygen (DO mg/L)	0	1.43	5.02	2.76	0.87	7.52
Resistivity (KΩ. cm)						12.7
Ambient conductivity (µS/cmA)						73

Figure 8.20 Lake A-2 Bathymetry

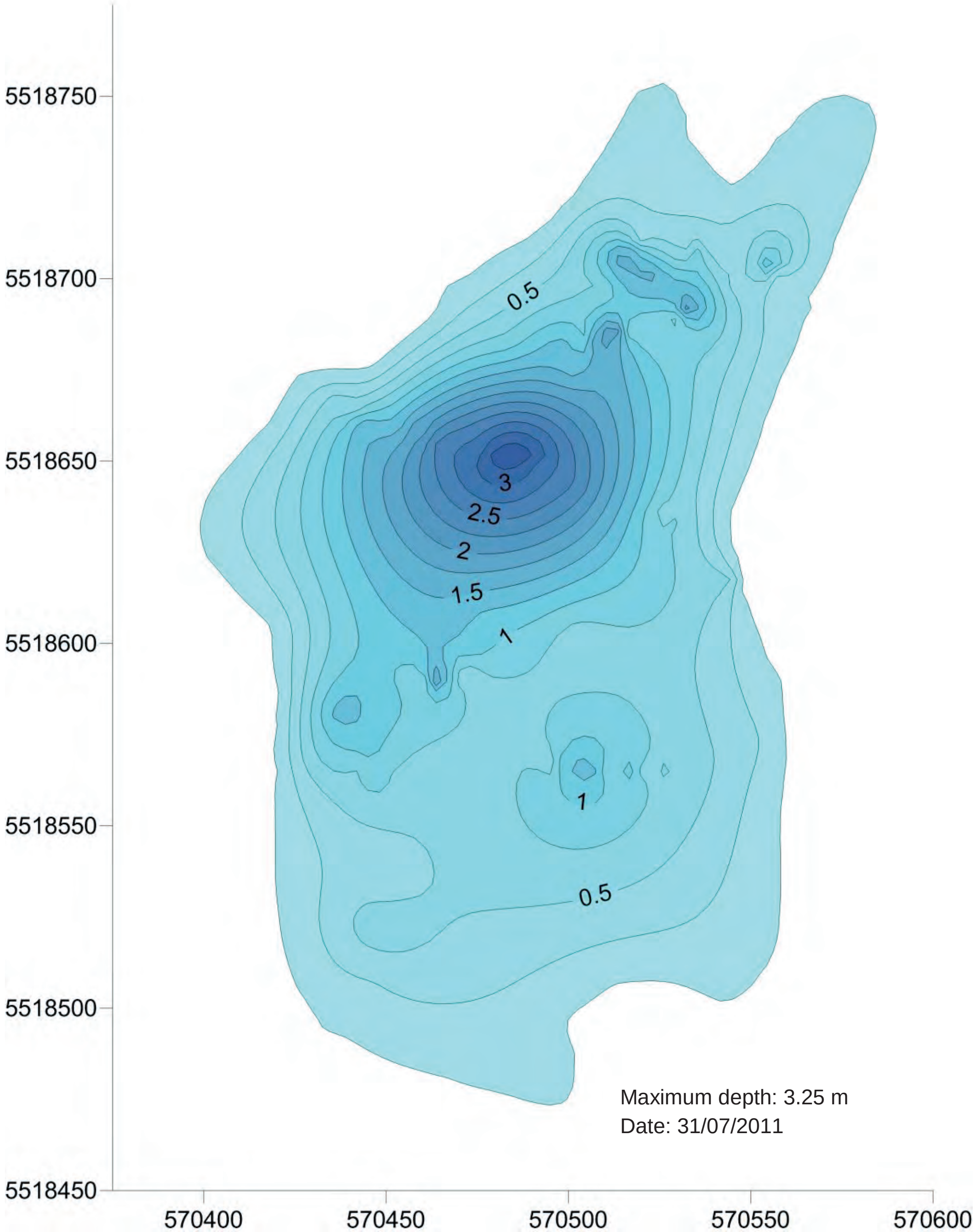


Photo 8.116: Aquatic and flooded vegetation in southern part of lake A-2. Gale and carex in foreground, with rush and water-lily behind.

Photo 8.117: Lake A-2 south bay; a rush and water-lily strip provides a good habitat for the many cyprinids found in the water body.

Photo 8.118: Beaver dam at the lake A-2 outlet. Note rocky and gravelly bottom of both lake and emissary.

Photo 8.119: Lake A-2 emissary immediately downstream from beaver dam. Cobbly and coarse gravelly bed.

8.9.4 Ruisseau Wynne

Ruisseau Wynne is an important watercourse in the Rivière Armitage watershed (Figure 8.21). It collects waters from Lac Pillow and flows to Lac Stella, which drains into Lac Armitage. Ruisseau Wynne crosses logging road 210 very near the southwestern boundary of the BlackRock claims block.

Mathew Wapachee pointed to the presence of a whitefish spawning ground upstream from the road. According to him, the stretch of Ruisseau Wynne near Lac Stella is also a springtime breeding area for yellow walleye and chub sp. (Figure 8.22).

Electrofishing was carried out in Ruisseau Wynne both downstream and upstream from the road 210 culvert. Downstream from the culvert, one 61-mm northern pike (Esox lucius), two burbot (Lota lota) 128 mm and 138 mm long, four pearl dace (Margariscus margarita) with lengths ranging from 47 to 75 mm, and one 54-mm mottled sculpin (Cottus bairdii) were tallied. The stream bed comprises large boulders, rubble and cobbles, and aquatic vegetation is limited.

Upstream from the culvert, the electrofishing catch included one 186-mm long white sucker (Catostomus commersonii), eight longnose dace (Rhynichthys cataractae) ranging in length from 51 to 94 mm, one 17 mm pearl dace, and one 46 mm Phoxinus sp. The stream bed comprises large boulders, cobbles and about 10% organic matter along the shoreline.

From a compensation standpoint, these electrofishing results provide information about local habitat quality and aquatic fauna. The seven species of fish caught reflect a rich habitat with high biodiversity. Forage fish are well-represented, as well as game fish. The presence of longnose dace and mottled sculpin indicates that this is a high quality watercourse with several habitat types.

Figure 8.21 Electrofishing: Ruisseau Wynne and Intermittent Creek at the Construction Camp Site

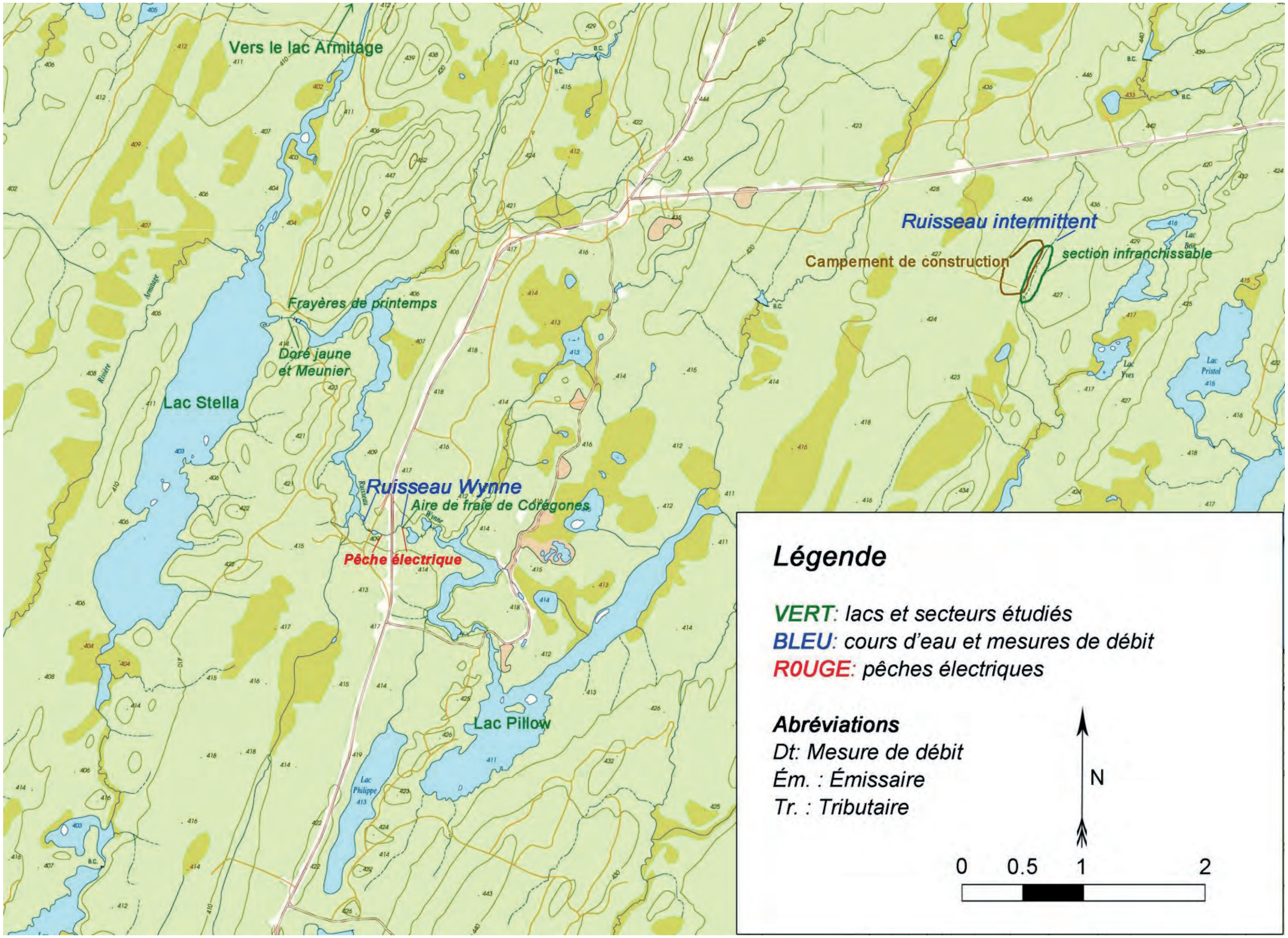


Photo 8.120: Ruisseau Wynne downstream from road 210.

Photo 8.121: Ruisseau Wynne downstream from road 210.

Photo 8.122: Ruisseau Wynne; looking downstream from road 210, and part of culvert.

Photo 8.123: Ruisseau Wynne upstream from road 210.

Photo 8.124: Ruisseau Wynne upstream from road 210; pools, boulders, water-lily and rush.

Photo 8.125: Ruisseau Wynne upstream from road 210; pool and rush.

Photo 8.126: Ruisseau Wynne upstream from road 210; bed comprises boulders and large boulders.

8.9.5 Validation of Potential Compensation Areas

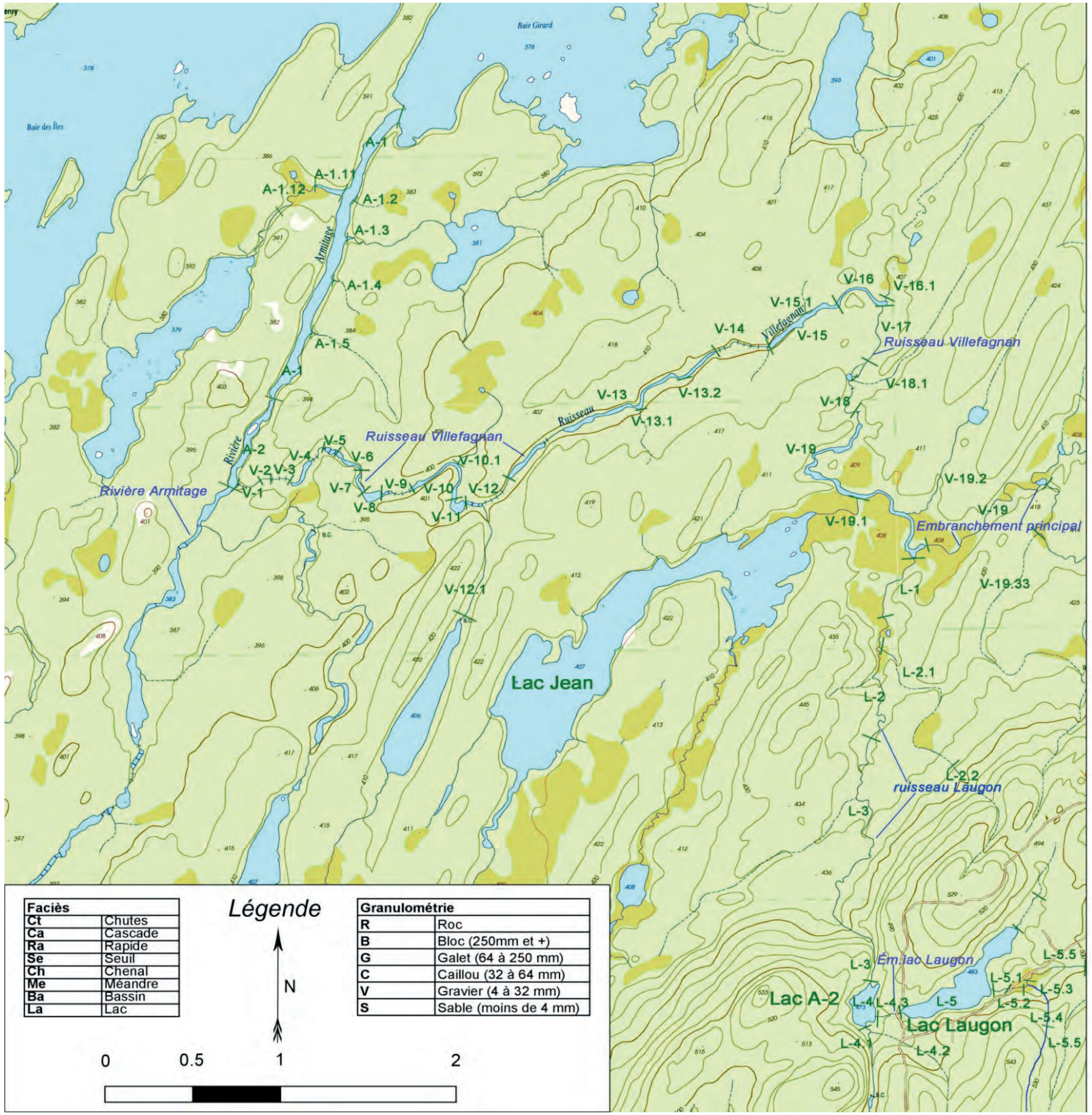
Photointerpretation of the main watercourses within the study area was performed to constrain the importance of aquatic habitats for breeding and the life cycle of some game species, such as walleye and brook trout. Photointerpretation results are shown in Figure 8.22. Based on such results, a watercourse can be subdivided into homogeneous reaches. A homogenous reach is defined as a section of a watercourse with homogeneous flow facies (fall, cascade, rapid, sill, channel, meander, pool, lake) and grain size distribution (bedrock, boulders, cobbles, pebbles, gravel, sand). As each species prefers certain types of habitats during different parts of its life cycle, it is then possible to theoretically assess the potential of a watercourse for breeding of species such as walleye or brook trout. Systematic field visits of all lotic and lentic settings were done to round out the results of this theoretical assessment. The data presented in Figure 8.22 is therefore very reliable.

Photointerpretation and field work results indicate that, although walleye are absent from Ruisseau Villefagnan, this watercourse shows very good potential for this species (Figure 8.23). Given that walleye are fond of habitats with coarse-grained beds for breeding (10 to 25 cm cobbles among boulders), good habitats for this species would mainly be in the lower section of Ruisseau Villefagnan, namely in the V1, V3, V5 and V9 reaches, which represent a total theoretical surface area of 5,875 m^2.

The work highlights the importance of opening up Ruisseau Villefagnan to walleye by modifying the waterfall located 300 m upstream from its mouth. Potential brook trout breeding areas are scattered about the various sections of the watercourse, adjacent to small sills where sand and gravel are found. Measures could be implemented to make these settings attractive to brook trout.

Provided that the water sent to Lac Denis meet release parameters, transformation of this water body into a reservoir should improve its biological diversity and productivity.

Figure 8.22 Facies and Grain Size in Potential Compensation Areas



Rivière Armitage

Segment	Km	Faciès	Granulo	Largeur (m)	Longueur (m)	Surface	Commentaire
A-1	0	Ch	SV	70	2000	140000	Très lent
A-2	2	Ch	SV	50	600	30000*	Très lent

Tributaires de la rivière Armitage

Segment	Km	Faciès	Granulo	Largeur (m)	Longueur (m)	Surface	Commentaire
A-1.11	0,7	Ba	SV	30	150	4500	
A-1.12	0,95	Me	SV	10	270	2700	Eutrophe
A-1.2	0,7	Ch	SV	10	200	2000	Lent
A-1.3	0,9	Me	SV	10	600	6000	Lent
A-1.4	1,2	Ch	SV	10	300	3000	Lent
A-1.5	1,6	Ch	SV	15	700	10500	Lent

Ruisseau Villefagnan

Segment	Km	Faciès	Granulo	Largeur (m)	Longueur (m)	Surface	Commentaire
V-1	0	Ca	RBG	20	50	1000	Delta
V-2	0,05	Ba	SV	50	100	5000	
V-3	0,15	Ca/Ra	RBG	15	100	1500	
V-4	0,25	Me	SV	20	300	6000	
V-5	0,55	Ra	RBG	15	75	1125	
V-6	0,62	Me	SV	20	200	4000	
V-7	0,82	Ch	SV	15	150	2250	
V-8	0,97	Ba	SV	60	125	7500	
V-9	1,1	Ra	RBG	15	150	2250	
V-10	1,23	Ch	SV	20	550	11000	
V-11	1,8	Ba	SV	50	50	2500	
V-12	1,85	Ra	BCV	20	350	7000	
V-13	2,65	Ch/Ra	SVB	25	1600	40000	
V-14	4,25	Ra	BVS	20	200	4000	
V-15	4,45	Ch	SV	30	400	12000	
V-16	3,85	Me	SVB	15	400	6000	
V-17	4,75	Me	SVB	20	400	8000	
V-18	5,1	Ch+Ba/ Se	SVR	20	350	7000	
V-19	5,45	Me/Ba	SV	25	3100	77500	

Tributaires du ruisseau Villefagnan

Segment	Km	Faciès	Granulo	Largeur (m)	Longueur (m)	Surface	Commentaire
V-10.1	1,45	Me	SV	10	550	5500	
V-12.1	1,9	Ch	SVB	10	850	8500	Exutoire
V-13.1	3	Me	SVB	10	450	4500	Intermittent
V-13.2	3,4	Ch	SVB	10	1000	10000	
V-15.1	4,3	Ch	SVB	10	500	5000	Intermittent
V-16.1	4,85	Me	SVB	10	300	3000	Eutrophe
V-18.1	5,5	Ch	SVB	40	400	16000	Intermittent
V-19.1	1,3	Me	SV	10	400	4000	Exutoire
V-19.2	1,65	Me	SVB	10	700	7000	
V-19.33	3,1	Me	BVS	5	1400	7000	Eutr-interm.

Ruisseau du Lac Laugon

Segment	Km	Faciès	Granulo	Largeur (m)	Longueur (m)	Surface	Commentaire
L-1	0	Ch	SV	10	300	3000	
L-2	0,3	Me	SV	5	800	4000	
L-3	1,1	Me	SVB	5	1800	9000	Exutoire B-2
L-4	2,9	La	SVB	150	200	30000	Lac B-2
L-5	3,2	La	SVB	120	850	102000	Lac Laugon

Tributaires du ruisseau Laugon et du lac Laugon

Segment	Km	Faciès	Granulo	Largeur (m)	Longueur (m)	Surface	Commentaire
L-2.1	0,55	Me	SVB	5	900	4500	Intermittent
L-2.2	1,4	Ra	BVR	5	1200	6000	Intermittent
L-4-1	3,1	Me	BVS	5	1200	6000	Intermittent
L-4.2	3,1	Me	BVR	5	700	3500	Intermittent
L-4.3	3,1	Ch	BVS	5	100	500	Laugon/A-2
L-5.1	3,75	Ch	SVB	10	100	1000	
L-5.2	3,85	Ba	SVB	15	100	1500	Eutrophe
L-5.3	3,95	Ca	BVS	5	200	1000	Intermittent
L-5.5	3,95	Me	SVB	5	450	2250	Intermittent

9. CHARACTERIZATION OF THE ORE, SOLID WASTES AND PROCESS WATER

Physicochemical characterization of the solid and liquid wastes is required to determine the environmental effects of the BlackRock project and set the conditions for its implementation, in order to obtain the environmental permits for the project. In addition to meeting regulatory requirements, characterization activities are aimed at determining the chemical composition and identifying the mineralogy of the solids. The concentrations of metals and suspended solids and the biological toxicity of the process water are also compared to the applicable regulations. This makes it possible to anticipate whether the final effluent will comply with operating standards.

The first stage of waste characterization work was done in December 2010 using five representative samples selected by BlackRock and sent to Corem for preliminary pilot testing. This material is identical to the material analyzed in 2010 at SGS Laboratories in Lakefield and the samples given to BlackRock's Chinese partners. It was on the basis of this material that the Chinese steel plants and financial companies became involved in the project.

The characterization work done using the 2010 samples was as follows:

- identification of the rocks in the mineralized zone;
- determination of radiation level and quantity of radioactive elements in the ore;
- diffraction of the ore, the waste rock composite and the concentrator tailings;
- comparative analysis of the solid wastes in relation to background levels in the Superior geological province;
- comparative analysis of the leachate in relation to groundwater contamination criteria.

The second portion of the characterization work began in April 2011, using the same material Corem used to carry out pilot testing in February 2011. The material is from a single 400-kg bulk sample taken by BlackRock Metals. According to Corem's analyses, the February 2011 pilot feed was similar in composition to three of the five samples used in preliminary pilot testing in October 2010. At that time, the process operating parameters were as described in Chapter 4.

The characterization work done using the 2011 samples was as follows:

- characterization of the particle size distribution of the solid wastes;
- analysis of metals in process water;
- determination of settling rate and the main parameters affecting it;
- determination of process water toxicity to Daphnia magna.

9.1 CHARACTERIZATION OF THE ORE AND WASTE ROCK

BlackRock geologists have identified four representative rock types for the mineralized zone: anorthosite, gabbro, pyroxenite and the diabase dyke. The results of quantitative analysis of the mineralized zone rocks are shown in Table 9.1. These results are consistent with characterization data published in the literature for similar rocks. These rocks are rich in aluminum, iron, calcium and magnesium. The important elements for the project, particularly iron and titanium, are abundant in the pyroxenite and the diabase dyke. Vanadium is present in higher concentrations in the diabase dyke than in other rock types. Heavy and trace metals, including arsenic, uranium and thorium, are also shown in Table 9.1.

The Quaternary Applied Research Centre (QARC) conducted tests on ore samples from the deposit in relation to radioactive elements. These tests were performed at the BlackRock core shack on three randomly-selected boxes of drill core. Table 9.2 shows the results obtained, which indicate that the radiation dose per hour and the concentration of radioactive elements (K, U and Th) in the ore is less than the background level in Chibougamau. Correspondence from the QARC on this subject is provided in Appendix 9.1.

Table 9.1 Analysis of the Ore using 4-Acid Digestion – ICP DES Finish (2010)

Element	Units	LDR	ENBR-1 Anorthosite	ENBR-2 Gabbro	ENBR-3 Pyroxenite	ENBR-4 Diabase Dyke
Si	%	0.005	19.824	19.967	14.269	17.484
Al	%	0.01	6.90	5.45	3.37	4.70
Fe	%	0.01	7.66	6.25	18.0	11.2
Ca	%	0.01	8.40	5.71	4.07	4.40
Na	%	0.01	2.30	0.89	0.76	1.24
K	%	0.01	0.08	<0.01	0.08	0.17
Mg	%	0.01	0.86	1.41	3.55	2.13
Ti	%	0.005	0.62	0.48	1.91	1.63
Mn	ppm	1	1540	2040	3580	3150
V	ppm	0.5	469	387	441	1110
S	ppm	50	190	330	1950	610
As	ppm	0.2	<0.2	0.4	1.1	<0.2
Cd	ppm	0.02	0.02	0.04	0.10	0.07
Co	ppm	0.05	33.9	32.6	141	116
Cr	ppm	0.5	57.0	80.9	<0.5	75.2
Cu	ppm	0.2	39.6	26.9	38.6	40.7
Ni	ppm	0.2	59.6	28.2	9.5	67.6
Pb	ppm	0.1	1.0	2.0	1.0	1.5
Zn	ppm	0.5	52.4	99.2	307	161
Th	ppm	0.1	<0.1	<0.1	<0.1	0.2
U	ppm	0.005	0.031	0.018	0.010	0.057

Note: The analysis protocol (four-acid digestion) is different from the one provided for in *Directive 019* (MA.200 - Met.1.2) for soil contamination.

Table 9.2 Ore Radiation Level and Radioactive Element Content – Quaternary Applied Research Centre, September 2010

Box No.	Radiation Dose Rate $nSvh^{-1}$	K (%)	U (ppm)	Th (ppm)
1	25.7	0.8	0.8	2.9
2	16.6	0.5	0.0	2.9
3	18.3	0.4	0.0	3.1
Chibougamau background level	45.8	1.8	1.5	3.2

9.2 GRANULOMETRIC PROPERTIES OF THE SOLID WASTES

In addition to the waste rock generated by mining, two types of solid waste are produced by the concentration process, namely coarse tailings with a D_{80} of 1,065 µm and fine tailings with a D_{80} of 75 µm. Tailings analyzed for size distribution were from pilot testing by Corem in 2011 (Table 9.3). These tailings, which were received in slurry form, were homogenized and screened to determine their size distribution and relative abundance of the fractions. The slurry from the primary magnetic separator collected after screening totalled 8,096 grams of solids. The secondary magnetic separator only yielded 572.5 grams of solids. The small quantity of solids available for the secondary magnetic separator would be due to pilot plant losses.

As shown in Table 9.3, the coarse fraction over 75 µm is only 69.22% by weight of the primary separator sample. A spiral classifier must be used to separate this coarser fraction from the fines. Fine particles from the primary and secondary separators will be combined and sent to the tailings pond.

Table 9.3 Screening of Tailings, Abundance and Size Distribution

Primary Separator		Screen Size (µm)	Secondary Separator	
Weight Fraction (g)	Percentage Fraction		Weight Fraction (g)	Percentage Fraction
4,973	61.42	150		
631	7.8	75		
1,131	13.97	38	246.5	43.06
490.4	6.05	20	108	18.86
86	1.06	6	17	2.97
785	9.70		201	35.11
8,096	100	**Total**	572.5	100

The project design criteria calls for 80% of the coarse tailings from the primary separator to have a grain size of less than 1,065 µm, and 80% of the fine tailings to have a grain size of less than 75 µm.

The material obtained from Corem did not demonstrate the type of clear separation that can be achieved with a spiral classifier. The coarse tailings from the primary separator contained too much fine material, and the fine tailings from the secondary separator were smaller than expected: 100% of the fine tailings were smaller than 75 µm. The pilot conditions were unable to reproduce the desired split between the coarse and fine tailings. It should be noted, however, that a spiral classifier was not used in the pilot work, but will be used during the operation phase.

The clear separation of coarse particles during operations is very important for coarse tailings facility management, as grain size control is essential to maintaining the quality of the runoff from the coarse tailings pile.

The higher quantity of fines generated by the pilot work allowed extreme conditions to be created for the process water. It would in fact be reasonable to presume that there was a higher concentration of dissolved metals and suspended solids in the pilot water than there will be during operations (see Section 9.5).

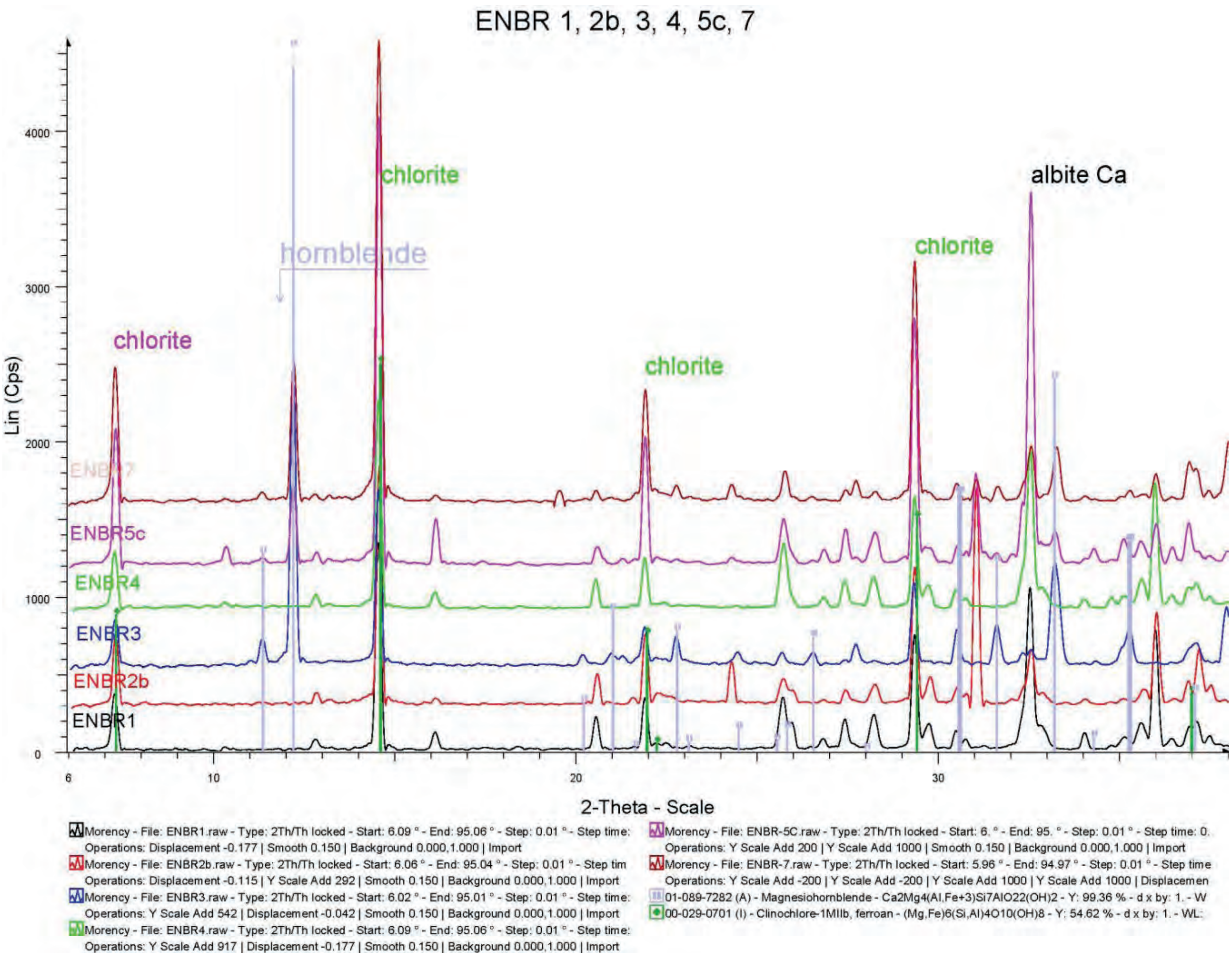
9.3 DIFFRACTION OF THE ORE, WASTE ROCK AND TAILINGS

The diffractograms in Figure 9.1 are from the 2010 samples and identify the mineralogical phases. The intensity of the diffraction peaks allows the modal (virtual) abundance of the minerals to be estimated. The diffractogram results are summarized in Table 9.4. They confirm the presence of chlorite in all rocks of the mineralized zone, as well as in the waste rock and concentrator tailings. The chlorite is associated with greenschist facies regional metamorphism that altered the primary pyroxenes to secondary chlorite. In the concentrator tailings, this mineral is preferentially concentrated in the fine fractions. It reaches an abundance of 73.9 to 82.5% in the minus 6 µm tailings fraction. The lamellar morphology of chlorites and their surface charges are factors that contribute to their stability in suspension.

Other secondary minerals were detected that are greenish in color like the chlorite. These are epidote and actinolite, which contribute to the formation of the greenish suspension in the process water. Analysis of the virtual modal abundance appears to undervalue ilmenite in favour of rutile. In this regard, Corem’s report dated July 2010 states that the amorphous minerals can correspond to various compositions of iron-titanium oxides. Thus, ilmenite was identified as a major element in four of the five mineralized samples analyzed by Corem. In the same progress report, rutile is considered to be present in trace amounts. This is particularly important because BlackRock is looking into the possibility of recovering the titanium from the ilmenite in the coarse tailings in the medium-term. In the same vein, it should be noted that the size fraction greater than 150 µm was not evaluated by diffraction in the context of environmental work. Most of the ilmenite would therefore be contained in the coarser residues. This would also explain the difference in the diffraction results for ilmenite in the minus 150 µm size fraction of the tailings and the ore.

Actinolite can have an impact in terms of occupational health and safety. This secondary mineral is an amphibole that also results from pyroxene alteration. There is a fibrous, asbestiform-type variety of amphibole. If this fibrous variety is present, the ore should be handled in accordance with health and safety standards for asbestos. In light of this potential impact, the ore was checked for the presence of fibrous amphiboles using a scanning electron microscope (SEM). This was done using the fine fractions collected on a 0.45-µm filter during the settling of water from the coarse and fine slurries. The results confirmed the absence of fibers with asbestiform morphology. The minerals are in the form of plates and rods (Photo 9.1). Amphiboles generally have a lamellar morphology and chlorites have a platey structure.

Figure 9.1 Diffractograms for the Ore, Waste Rock and One Coarse Tailings Sample – 2010 Testing

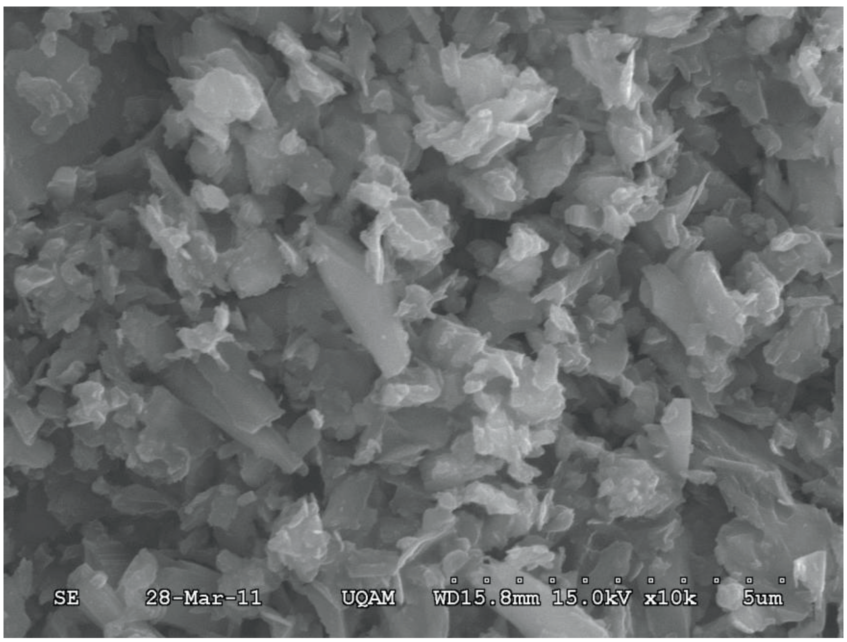


Note: In the interest of clarity, the diffractograms for samples ENBR-8A, 9, 10, 11 and 14 are not shown in Figure 9.1. Individual diffractograms for each sample are provided in Appendix 9.2.

Table 9.4 Modal Mineralogical Composition by X-Ray Diffraction for the Waste Rock and Tailings Size Fractions – 2010 Testing

	Ore				Waste Rock	Primary Separator					Secondary Separator
	Anorthosite ENBR-1	Gabbro ENBR-2	Pyroxenite ENBR-3	Diabase ENBR-4	Composite ENBR-5	ENBR-7	ENBR-8A	ENBR-9	ENBR-10	ENBR-11	ENBR-14
						38-75 µm	75-150 µm	20-38 µm	6-20 µm	<6 µm	<6 µm
	%	%	%	%	%	%	%	%	%	%	%
Mineral											
Chlorite	39.56	50.30	37.30	34.81	42.37	60.67	50.97	62.25	61.03	73.88	82.54
Epidote	24.54	22.84	20.68	2.66	6.77	6.32	8.23	8.68	4.03	2.16	2.15
Clinozoisite	-	1.52	-	-	-	-	-	-	-	-	-
Albite (Plagioclase)	35.14	14.96	3.70	13.74	32.06	8.15	16.66	4.44	8.83	4.01	2.40
Mica	0.76	-	-	0.70	2.61	1.15	1.37	1.41	0.65	0.96	0.78
Actinolite and/or Hornblende	-	-	33.37	48.09	13.16	19.12	15.69	17.74	20.06	13.81	7.15
Rutile	-	-	3.93	1.50	1.09	2.62	3.96	1.68	1.74	2.50	2.32
Ilmenite	-	-	-	1.13	-	-	-	-	-	-	-
Magnetite	-	-	1.02	8.59	1.94	1.96	0.48	0.99	0.85	1.14	2.48
Quartz	-	10.38	-	0.50	-	-	2.64	2.81	2.80	1.54	0.18

Photo 9.1 Morphology of the Tailings under the Scanning Electron Microscope (SEM)



9.4 ENVIRONMENTAL CHARACTERIZATION OF THE TAILINGS AND *DIRECTIVE 019* COMPLIANCE

9.4.1 Context and Methodology

In accordance with the requirements of *Directive 019*, characterization work included the following:

- selection of representative samples (composite of five samples in 2010: Corem, SGS and financial partners);
- analysis of solid wastes in order to compare target parameter concentrations with regional background levels (Superior geological province);

- leaching test, leachate analysis and comparison of metal concentrations with the groundwater contamination criteria for parameters whose concentration is higher than the background level in the solid wastes.

Table 9.5 gives a list of parameters analysed, analysis methods and assessment criteria. In accordance with *Directive 019* and the *Soil Protection and Contaminated Sites Rehabilitation Policy*, the background levels for the Superior geological province, in which the project is located, were used as the assessment criteria for metal concentrations in the solid wastes. For the solid waste leachate, the groundwater contamination criteria in the *Soil Protection and Contaminated Sites Rehabilitation Policy* were used, ie, the criteria for "seepage into surface water or infiltration into sewers".

Table 9.5 Characterization of Mine Tailings: Parameters Analysed and Analysis Methods

Nature of Waste and Analysis	Parameters	Analysis Method and Primary Reference	Criteria
Solid Wastes: • Waste rock • Coarse tailings • Fine tailings ICP metals analysis	Mercury, silver, arsenic, barium, cadmium, cobalt, chromium, cuivre, tin, manganese, molybdenum, nickel, lead, selenium, zinc	STL SOP 00006/12 MA.200 – Met.1.2 (1)	Background levels, Superieur province (2)
Solid waste leachate: Analysis of leached metals	Depending on the results of solid waste analysis	MA.100 – Lix.com.1.1 (1) STL SOP 00006/12 MA.200 – Met.1.2	Criteria of seepage into surface water or infiltration into sewers (2)

(1) Centre d'expertise en analyse environnementale du Québec (CEAEQ)
(2) Soil Protection and Contaminated Sites Rehabilitation Policy

9.4.2 Description of Samples Used

BlackRock conducted several tests in connection with the mining project to assess the economic and technical feasibility of mining the deposit. The samples used were pirmarily from two sources:

- samples taken during drilling to assess the project feasibility;
- tailings samples from pilot testing of the ore treatment process.

Some results of the analyses performed for the feasibility study and project design were used for the environmental aspects. The following three other samples, provided by BlackRock and Corem in the fall of 2010, were also analyzed specifically for environmental assessment purposes:

- ENBRA-67: representative waste rock sample from the deposit to be mined; composed of 33 sub-samples collected by BlackRock geologists in 2010;
- ENBRA-66: sample of the coarse fraction (± 550 µm) from pilot testing done by Corem in November 2010;
- ENBRA-74: sample of the fine fraction (D_{80} of 75 µm) from the same pilot testing.

9.4.3 Results of Waste Rock and Tailings Analysis

Results of waste rock and tailings characterization analyses are given in Tables 9.6 and 9.7. In accordance with *Directive 019*, the tests were initially performed to determine metal concentrations in the solid wastes. The results indicate that Superior province background levels were exceeded for the following parameters (Table 9.3):

- ENBRA-67 (waste rock): cobalt;
- ENBRA-66 (coarse fraction, pilot test): cobalt, total chromium, copper and nickel;
- ENBRA-74: cobalt and nickel.

The three samples subsequently underwent leach tests, and the leachate was analyzed for the parameters whose concentrations exceeded background levels. All the results (see Table 9.7) were below the groundwater contamination criteria. The samples were also analyzed for the following parameters (anions and metalloid), for which criteria are specified in *Directive 019* (Annex II, Table 1):

- total flourides;
- nitrates and nitrites;
- nitrites;
- boron.

All concentrations were below detection limits or trace and thus well below the *Directive 019* criteria. The results for the samples analyzed therefore indicate that the waste rock and process tailings are low-risk. The certificates of analysis are contained in Appendix 9.3.

Table 9.6 Tailings Analysis Results: Concentrations in the Solid Wastes (mg/kg)

Metals (or Metalloïds) and Other Inorganic Components	CRITERIA	ENBRA-67 November 2010	ENBRA-66 November 2010	ENBR-74 November 2010
	Bakground Levels mg/kg Superior Province	Waste Rock, Composite Sample (33 Sub-samples)	Coarse Fraction, Pilot Test	Fine Fraction, Pilot Test
Silver (Ag)	**0.5**	<0.8	<0.8	<0.8
Arsenic (As)	**5**	<5	5	<5
Barium (Ba)	**200**	<5	<5	<5
Cadmium (Cd)	**0.9**	<0.5	<0.5	<0.5
Cobalt (Co)	**20**	27	54	51
Total chromium (Cr)	**85**	150	22	51
Copper (Cu)	**50**	75	25	43
Tin (Sn)	**5**	<4	<4	<4
Manganese (Mn)	**1,000**	250	230	180
Mercury (Hg)	**0.3**	<0.02	<0.02	<0.02
Molybdenum (Mo)	**6**	1	<1	<1
Nickel (Ni)	**50**	76	46	62
Lead (Pb)	**40**	<5	<5	<5
Selenium (Se)	**3**	<1	<1	<1
Zinc (Zn)	**120**	34	91	94
Total sulphur (S) (%)		0.15	0.17	0.18

> Regional background levels (Superior Province). The sample must undergo a leach test and the leachate must be analyzed for parameters that exceed regional background levels (see Table 9.7).

Note: In terms of the tailings sulphur content, it should be noted that the five samples used to make the ore composite contained 0.06, 0.11, 0.15, 0.03 and 0.03% sulphur respectively, for an average of 0.08%. The 0.17% and 0.18% sulphur contents of samples ENBR-66 and ENBRA-74 show that this element becomes concentrated in the non-magnetic tailings. However, the sulphur content does not exceed the regulatory criterion of 0.3%.

Table 9.7 Tailings Analysis Results: Concentrations in the Sold Waste Leachate (µg/L)

Metals (or Metalloïds) and Other Inorganic Components	CRITERIA	CRITERIA	ENBRA-67 November 2010	ENBRA-66 November 2010	ENBR-74 November 2010
	Groundwater Contamination µG/L	ANNEX II *DIRECTIVE 019* µg/L	Waste Rock, Composite Sample (33 Sub-samples)	Coarse Fraction, Pilot Test	Fine Fraction, Pilot Test
Boron		**500,000**	<100	<100	<100
Cobalt (Co)	**500**		<10	30	20
Total chromium (Cr)	**50** (1)	**5,000**	7		
Copper (Cu) (2)	**7,3**		<20		
Nickel (Ni)	**260**		<6		15
Total flourides		**150,000**	<1,000	<1,000	<1,000
Nitrates + nitrites		**1,000,000**	<200	<200	300
Nitrites		**100,000**	<200	<200	<200

(1) Drinking water criteria
(2) The copper detection limit in the MA.200 – Mét.1.2 (CEAEQ, 2010) method is 30 µg/L.

9.5 PROCESS WATER

9.5.1 Metals in the Process Water – 2011 Pilot Tests

Table 9.8 presents two metal analyses for pilot process water used in primary separation (ENBR-15) and secondary separation (ENBR-16). The two sets of analyses are almost identical and represent water in equilibrium with the process solids. The third set of analyses is for process water generated in the laboratory (ENBR-40) from 19 hours of solid waste attrition. The parameters for this third set of analyses show similar results to the first two. This process water is also in equilibrium with the solids and represents the maximum level of soluble metals for water with a pH slightly above neutral. These results reflect the insoluble nature of the silicate minerals that constitute the waste from the deposit. With the exception of silicon, sodium, potassium, sulphur and zinc, the metals are below the detection threshold and do not constitute a risk to groundwater and surface water in the event of a spill of liquid tailings. Metal concentrations in the three samples were below the detection limit or significantly under the criteria specified in *Directive 019* for an instantaneous final effluent. Certificates of analysis are shown in Appendix 9.4.

Table 9.8 Process Water Analysis for the Primary and Secondary Separators. Pilot Tests, February 2011

Element	Units	RDL	ENBR-15 Primary	ENBR-16 Secondary	ENBR-40 Secondary (lab)	Instaneous Final Effluent *Directive 019*
Si	mg/L	2	3	4	2	-
Al	mg/L	5	<5.0	<5.0	<5	
Fe	mg/L	5	<5	<5	<5	6.0
Ca	mg/L	100	<100	<100	<100	-
Na	mg/L	5	17	18	22	-
K	mg/L	1	2	1	3	-
Mg	mg/L	10	<10	<10	<10	-
Mn	mg/L	0.5	<0.5	<0.5	<0.5	-
Ti	mg/L	0.1	<0.1	<0.1	<0.1	-
V	mg/L	0.5	<0.5	<0.5	<0.5	-
S	mg/L	-	6	5	-	-
As	mg/L	0.02	<0.02	<0.02	<0.02	0.4
Cd	mg/L	0.01	<0.01	<0.01	<0.01	-
Co	mg/L	1	<1	<1	<1	-
Cr	mg/L	0.01	<0.01	<0.01	<0.01	-
Cu	mg/L	0.1	<0.1	<0.1	<0.1	0.6
Ni	mg/L	0.01	<0.01	<0.01	<0.01	1.0
Pb	mg/L	0.05	<0.05	<0.05	<0.05	0.4
Zn	mg/L	0.1	0.5	<0.1	0.2	1.0
Th	mg/L	0.01	<0.01	<0.01	-	-
U	mg/L	0.5	<0.5	<0.5	<0.5	-
Mo	mg/L	0.5	<0.5	<0.5	<0.5	-
Se	mg/L	0.01	<0.01	<0.01	<0.01	-

As mentioned previously, the particle size of the slurry tailings is significantly finer than in the design criteria. This may have led to more dissolved metals and suspended solids in trials that during operations.

9.5.2 Settling of Process Water

Process water settling tests were carried out in 2011 (see Photo 9.2). The process water from a pre-settling sample from the primary separator was greenish in colour. The suspended load after 22 hours of settling was 75 mg/L. The residual water from the secondary separator initially had a blacker suspension, and the suspended load after 22 hours was 58.3 mg/L. Filtration was done using 0.45 µm filter paper.

The solids collected are also more greenish at the first stage of magnetic separation. This colour is typical of chlorites, epidote and actinolite. The blacker solids generated by the secondary separator are associated with fine particles of magnetite and other ferromagnesians. Photo 9.2 shows qualitatively the turbidity of the water from the primary and secondary separators after 22 hours of settling.

Photo 9.2 Process Water from the Primary (A) and Secondary (B) Separators after 22 Hours of Settling

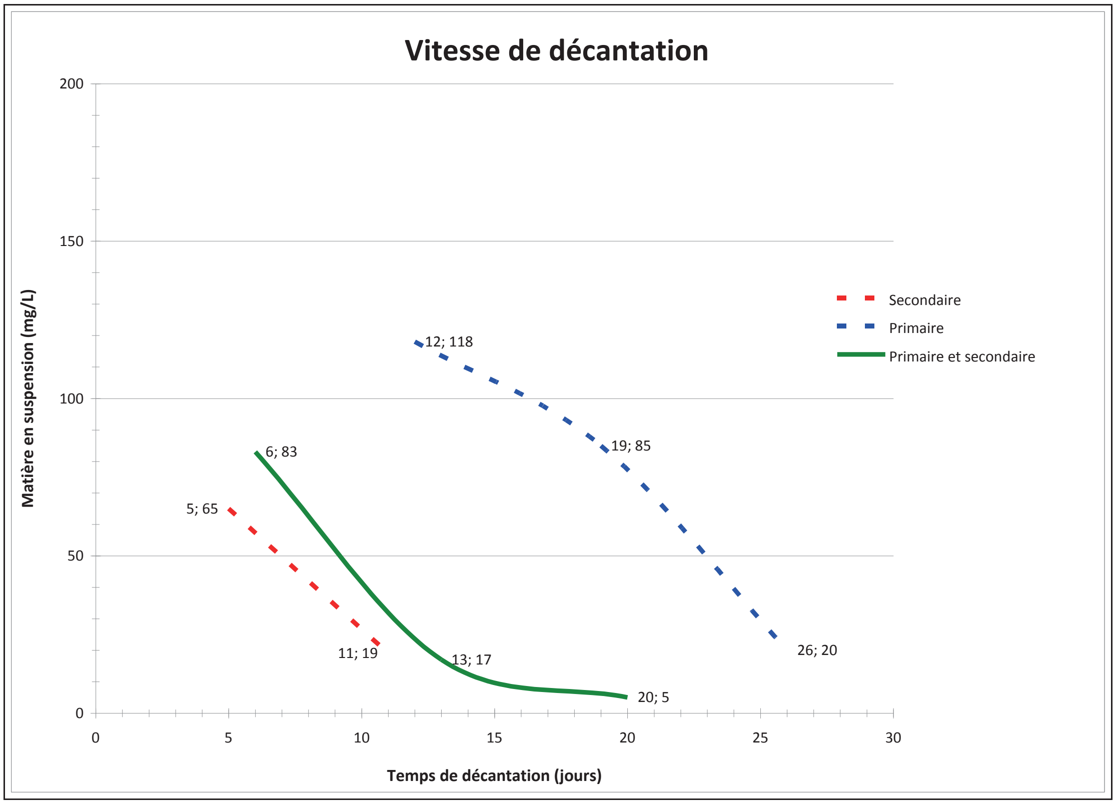
A

B

Because of the limited amounts of slurry from pilot testing in 2011, especially for secondary magnetic separation, full settling tests with fresh material could not be performed. To address this issue, the dried slurry was ground by attrition for 16 hours to increase the specific surface area of the particles in contact with water. This procedure reproduces extreme suspension conditions. The results for the primary and secondary separators and a 60% primary and 40% secondary blend are shown in Figure 9.2.

The results indicate that the water from secondary separation settles faster. After 11 days, the suspended load was 19 mg/L. The water from the primary separator settles much more slowly, and after 26 days, the suspended solids amounted to 20 mg/L. This is also reflected in the filtration rate, which is fast for water from the secondary separator and slow for primary separator water. The presence of a larger quantity of chlorite plates at the primary separation stage leads to faster clogging of the 0.45 µm filter pores. Settling occurs faster if water from both stages is mixed together; after 13 days, the load is only 17 mg/L. The electric charges present in the mixture appear to neutralize each other and facilitate settling. The results are all below the planned 30-day maximum residence time for the polishing pond. In the laboratory, the tailings are within the instantaneous maximum limit of 30 mg/L provided for in *Directive 019* for suspended load in the final effluent. The graphs in Figure 9.2 illustrate the settling rates for the three samples.

Figure 9.2 Settling Rates for Water from the Primary and Secondary Separators and a Composite of the Two



To accelerate settling, process water from the primary and secondary magnetic separators will be mixed before being sent to the fine tailings pond. However, in an operating setting, the effect of the wind combined with the steady flow of water into the settling ponds could obviously cause the fine particles to remain in suspension longer than in the laboratory.

9.5.3 Process Water and Toxicity to Daphnia

In order to obtain a sufficient quantity of process water, the dried solid tailings were rehydrated and ground to generate fresh surfaces in equilibrium with the process water. The water collected this way in the laboratory was diluted to suspended solids concentrations ranging from 400 to 20 mg/L.

Although not representative of the final effluent, these samples were used as guidelines to determine the toxicity of the liquid tailings to *Daphnia magna*. None of the seven samples proved to be lethal to Daphnia.

Table 9.9 provides a summary the conditions of suspended load, pH and conductivity for the water samples tested for toxicity. Test certification and details are given in Appendix 9.5.

Table 9.9 Toxicity of Water from the Primary and Secondary Separators to Daphnia Magna

Sample	Type of Discharge	Appearence	Suspended Solids (mg/L)	pH	Conductivity µmhos/cm	Conclusion
ENBR-17	Primary	Cloudy brown	400	8.3	284	Not lethal
ENBR-19	Primary	Cloudy brown	80	8.9	300	Not lethal
ENBR-18	Primary	Clear	20	8.9	333	Not lethal
ENBR-36	Secondary	Cloudy grey	390	7.3	255	Not lethal
ENBR-37	Secondary	Cloudy grey	195	7.3	250	Not lethal
ENBR-38	Secondary	Cloudy grey	097	7.4	248	Not lethal
ENBR-39	Secondary	Cloudy grey	48	7.3	247	Not lethal

REFERENCES

Québec, Ministère de l'Environnement, du Développement durable, de l'Environnement et des Parcs (MDDEP), April 2005. Directive 019 sur l'industrie minière. Direction des politiques de l'eau, services des eaux industrielles, 66 pages and annexes.

Centre d'expertise en analyse environnementale du Québec (CEAEQ). Liste des méthodes pour réaliser des analyses de laboratoire-Directive 019 sur l'industrie minière. http://www.ceaeq.gouv.qc.ca/methodes/list_mines.htm

10. HYDROGEOLOGICAL SETTING OF THE MINE AND RAIL TRANSFER SITES

10.1 PHYSIOGRAPHY, DRAINAGE AND CLIMATOLOGY

The BlackRock mining project is located in the Canadian Shield physiographic region, characterized by rolling hills and the omnipresence of bedrock. Within the study area, the land forms are elongated along a northeast-southwest axis, in the direction of ice flow. The terrain is fairly rugged, especially in the center of the territory, where there is a ridge that peaks at 560 metres, while the surrounding land lies at an average elevation of 400 m.

The ridge on which the deposit is located is the regional divide between St. Lawrence River watershed (to the east) and the James Bay watershed (to the west). The area is drained to the northwest by Rivière Armitage and Ruisseau Villefagnan and to the southeast by Ruisseau Boisvert. Many lakes and small streams drain the area toward the main watercourses. The hydrometric station nearest to the study area is the Ashapmushuan station (station 061906), whose catchment covers an area of 4,330 km^2. Figures 10.1 and 10.2 show the topography and catchments in the area of the mining project.

Climatology

The nearest available source of monthly weather data is the Chapais station, located about 60 kilometres west of the study site. The data is compiled by Environment Canada and covers the period from 1971 to 2000. Total annual precipitation at the Chapais station is 961.3 mm per unit area. Precipitation in the form of rain totals 659.7 mm of water, while snowfall totals the equivalent of 301.7 mm of water. The average annual temperature is 0°C, with an average maximum of 16.3°C in July and an average minimum of -18.6°C in January. Table 10.1 shows the detailed calculation of the forecast annual unit recharge rate in the study area.

10.2 GEOLOGY AND HYDROGEOLOGY

Bedrock

The deposit, which is fully described in the property development reports, is in the Lac Doré Complex, a Precambrian-age anorthosite and gabbro intrusion. The complex is folded into an anticline with a northeast-southwest axis.

The rocks of the Lac Doré Complex are composed of anorthosite, gabbros, magnetite ferrogabbros, granophyre, rhyolite, andesite and basalt. The geological contacts strike northeast-southwest and dips are 70-80° from horizontal, while the regional shear system that transects the units strikes north-northeast–south-southwest. Figure 10.3 shows an excerpt from SIGEOM geological map 32GC059 (MRNF, 2010).

Table 10.1 Estimated Annual Potential Recharge and Evapotranspiration

Month	*P*	*R*	*I*	*PET*	*AET*	*DRAS*	*RAS*	*DS*
January	54.30	16.29	38.01	0.00	0.00	0.00	40.00	38.01
February	40.30	12.09	28.21	0.00	0.00	0.00	40.00	28.21
March	42.90	12.87	30.03	0.00	0.00	0.00	40.00	30.03
April	44.20	13.26	30.94	0.00	0.00	0.00	40.00	30.94
May	71.90	21.57	50.33	61.39	61.39	-11.06	28.94	0.00
June	16.00	4.80	11.20	103.19	40.14	-28.94	0.00	0.00
July	115.40	34.62	80.78	119.57	80.78	0.00	0.00	0.00
August	112.20	33.66	78.54	100.64	78.54	0.00	0.00	0.00
September	119.40	35.82	83.58	58.93	58.93	24.65	24.65	0.00
October	83.10	24.93	58.17	20.63	20.63	15.35	40.00	22.19
November	74.70	22.41	52.29	0.00	0.00	0.00	40.00	52.29
December	60.30	18.09	42.21	0.00	0.00	0.00	40.00	42.21
Totals	**834.70**	**250.41**	**584.29**	**464.35**	**340.41**			**243.88**

Legend:

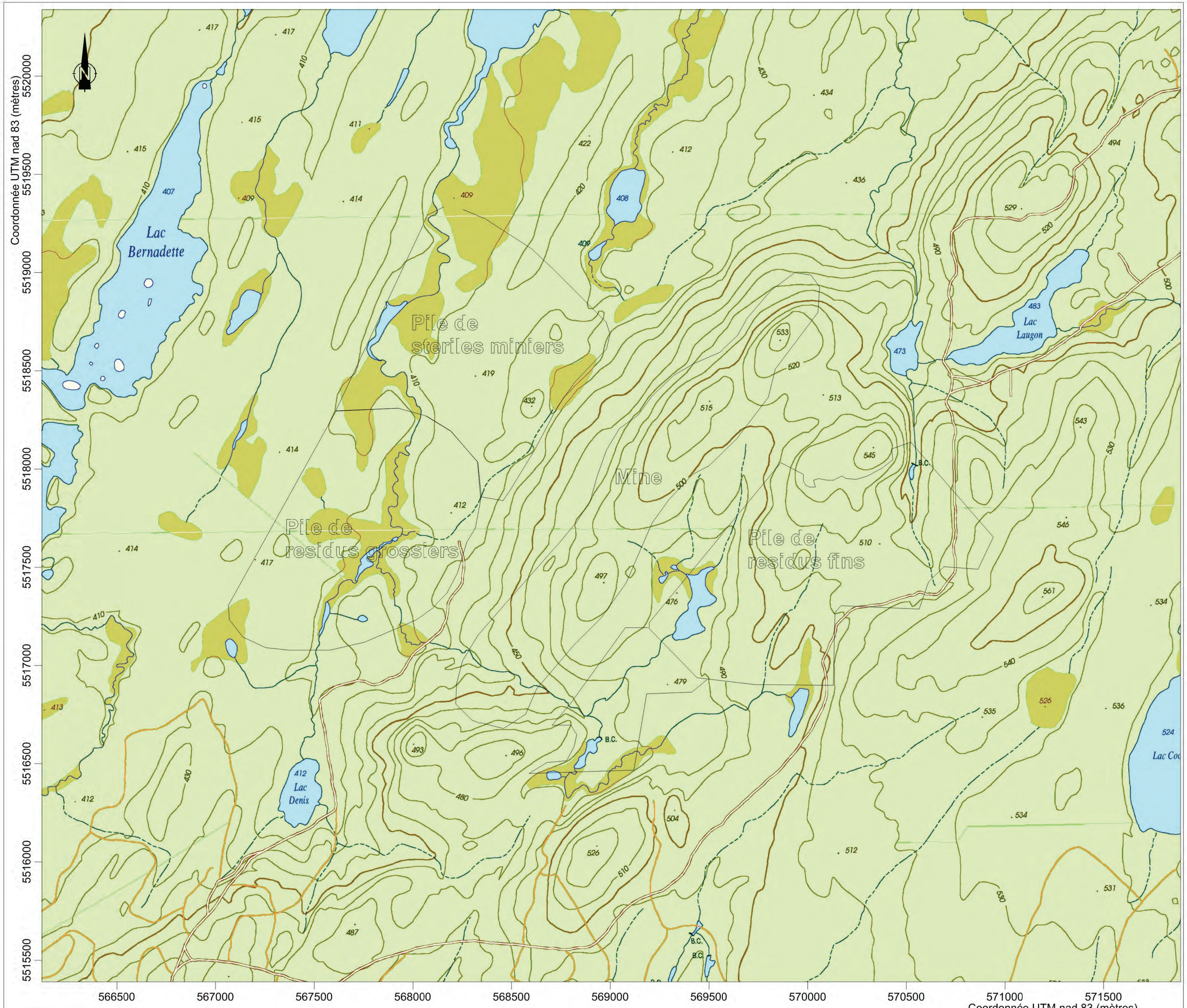
P	Precipitation
R	Runoff
I	Infiltration
PET	Potential evapotranspiration
AET	Actual evapotranspiration
DRAS	Change in available water
RAS	Plant available water
DS	Unit recharge

Surficial Deposits

Surficial deposits consist mainly of till ranging in thickness from less than a metre on ridges to more than a metre in low spots. The till has the geomorphology of ground moraine over most of the territory, with the exception of a few northeast-southwest aligned drumlins. The typical glacial deposits of the shield are generally coarse, composed mostly of boulders and gravel mixed with sand, with a small proportion of fine particles (silt, clay). Glacial deposits are usually compact and often poorly drained.

A few glaciofluvial deposits have also been mapped in the study area. These consist primarily of sand and gravel mixed with cobbles and boulders, and their structure is loose and homogeneous, hence their high porosity. One such deposit is an esker alongside Ruisseau Villefagnan, about three kilometres northeast of the deposit.

A lacustrine deposit has also been identified alongside Ruisseau Villefagnan, in the north-central part of the study area. Finally, several organic deposits have been mapped in the flat areas or depressions alongside streams and lakes. Figure 10.4 shows the location of surficial deposits in the vicinity of the mine site.



Légende

0 500 1000 1500 2000 (m)

Fond cartographique du MRN Québec
carte 32G16-102

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.1: TOPOGRAPHIE DU SITE DE LA MINE

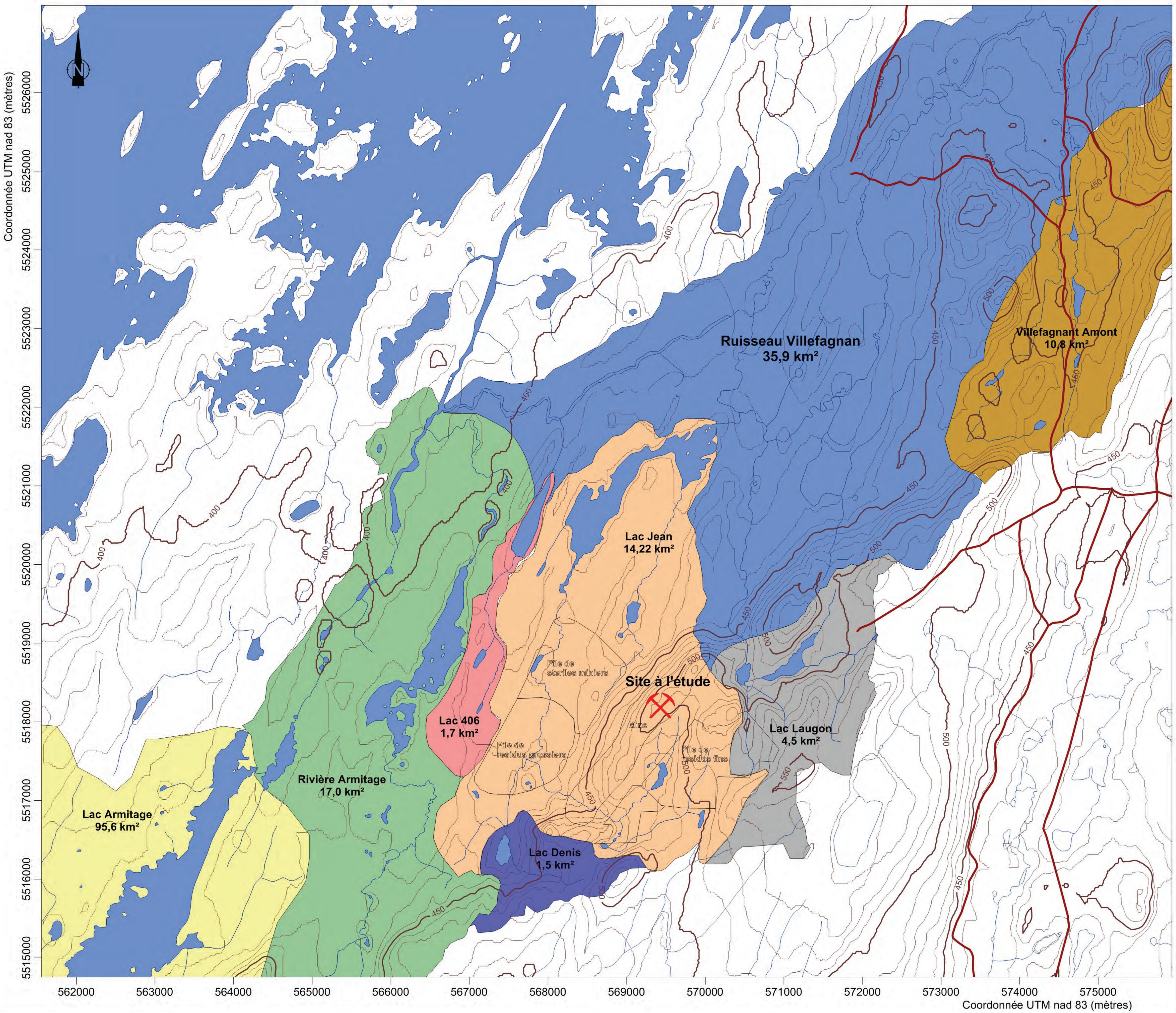
Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 50 000



Légende

Nom	Bassin versant (km²)	Débit d'étiage $Q_{2,7}$ (L/s)
Rivière Armitage	**112,6**	**555,1**
Lac Armitage	**95,6**	**471,3**
Ruisseau Villefagnan	**51,2**	**252,4**
Lac Jean	**14,2**	**70,1**
Villefagnan amont	**10,8**	**53,2**
Lac Laugon	**4,5**	**22,2**
Lac Yvette	**2,5**	**12,4**
Lac 406	**1,7**	**8,4**
Lac Denis	**1,5**	**7,4**

0 1000 2000 3000 4000 (m)

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.2: LOCALISATION DES BASSINS VERSANTS LOCAUX

Projet

PROJET MINIER BLACKROCK CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo. M.Sc. Hydrogéologue

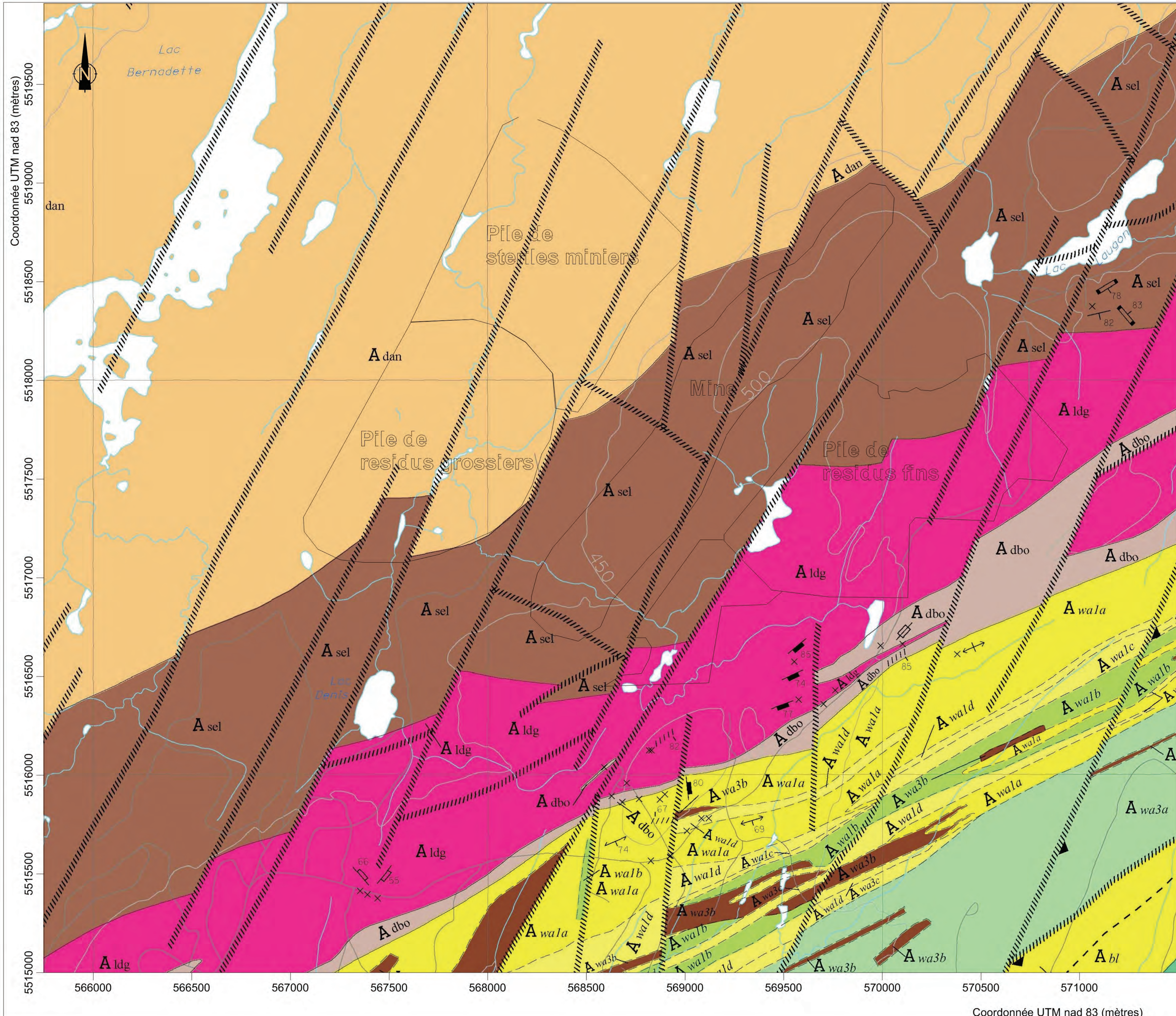
Thomas Rousseau-Beaumier B.Sc. Géographe

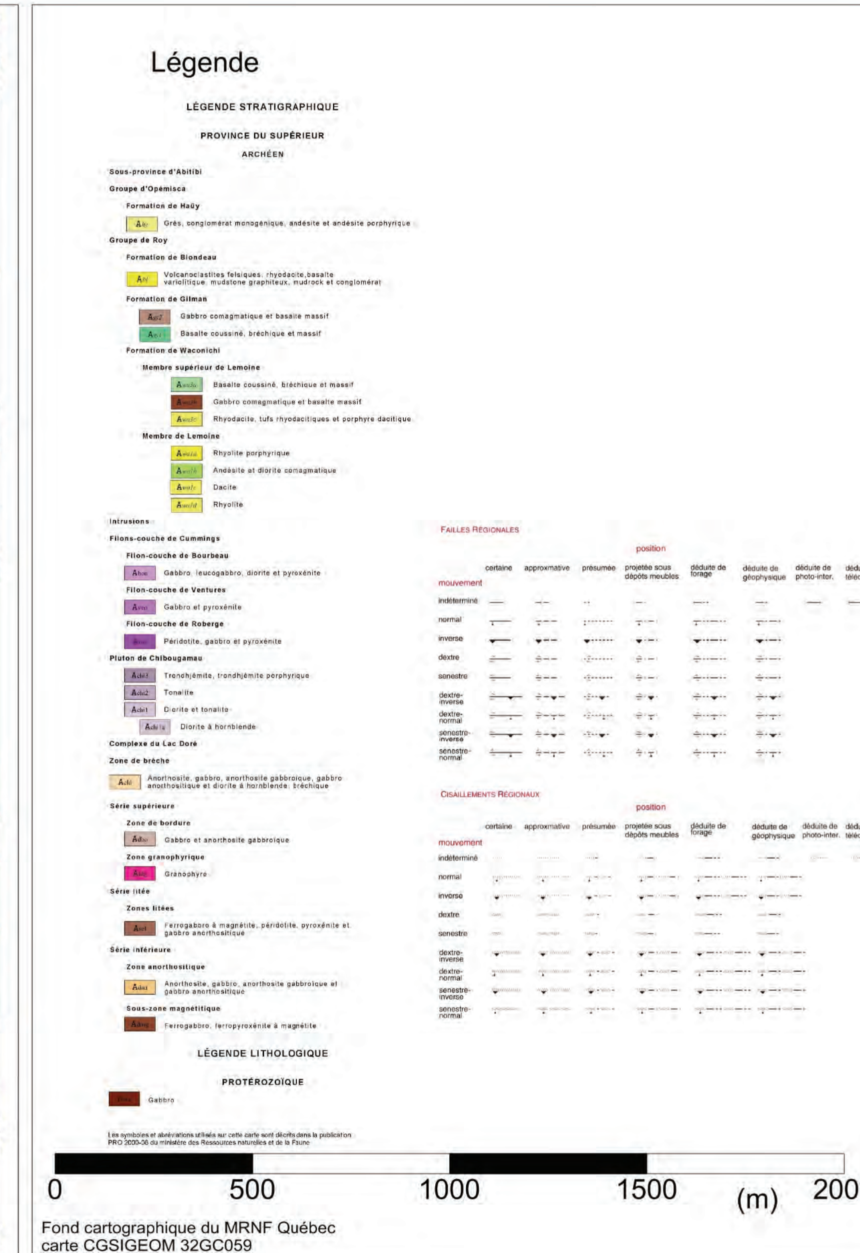
Date

Le 31 octobre 2011

Échelle

1 : 50 000





ENTRACO
Conseillers en environnement

Titre

FIGURE 10.3: EXTRAIT DE LA CARTE GÉOLOGIQUE

Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

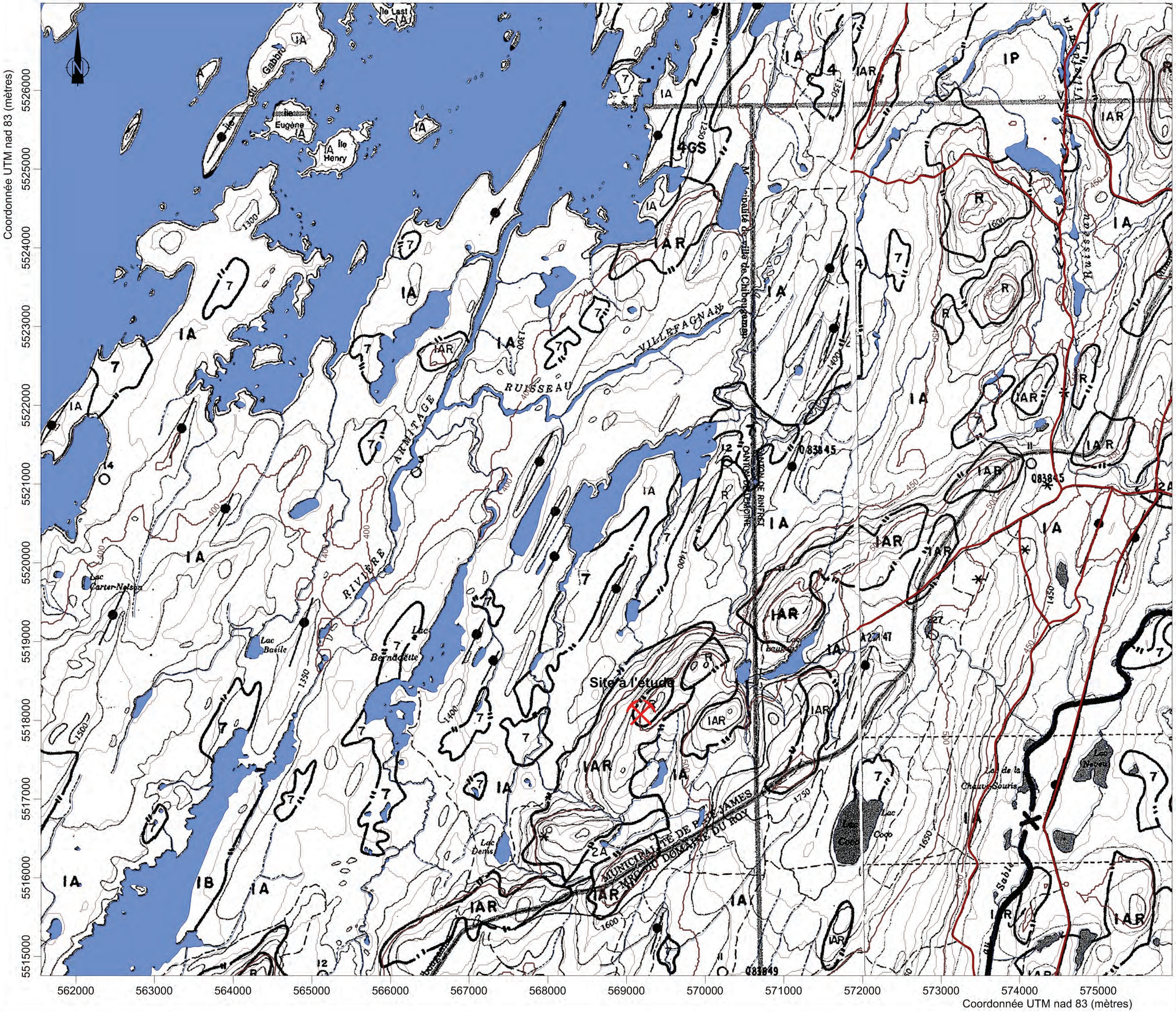
Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date

Le 31 octobre 2011

Échelle

1 : 20 000



Légende

TYPE DE DÉPÔT	CODE CARTOGRAPHIQUE	DESCRIPTION GÉNÉRALE
1 - DÉPÔTS GLACIAIRES		Dépôts lâches ou compacts sans triage constitués d'une farine de roches et d'éléments de toutes tailles généralement anguleux à sub-anguleux. La granulométrie des matériaux peut varier de l'argile au bloc selon les régions.
1.1 Dépôts glaciaires sans morphologie particulière		Idem.
- Till indifférencié	1 A	Idem. L'épaisseur moyenne est supérieure à 1 m.
- Till indifférencié mince	1 AR	Idem. L'épaisseur moyenne se situe entre 25 cm et 1 m.
1.2 Dépôts glaciaires caractérisés par leur morphologie	1 B	Les formes glaciaires retenues sont généralement composées de till.
- Drumlins et drumlinoides	1 BD	Les crêtes sont composées de till.
- Moraine côtelée (de Rogen)	1 BC	Les crêtes qui forment la moraine côtelée se composent de till riche en blocs qui peut contenir des couches de sédiments triés par l'eau.
- Moraine frontale	1 BF	Les moraines frontales présentent une accumulation importante de matériaux fluvio-glaciaires ou glaciaires : sable, gravier, blocs. Dépôts stratifiés par endroits, massifs à d'autres endroits.
- Moraine de décrépitude	1 BP	Dépôt constitué de till délavé et de matériaux fluvio-glaciaires grossiers. Présente une topographie en creux et en bosses sans orientation précise.
2 - DÉPÔTS FLUVIO-GLACIAIRES		Les dépôts fluvio-glaciaires sont composés de sédiments hétérométriques de forme sub-arrondie à arrondie. Ils sont stratifiés et peuvent contenir des poches de till (till flué).
2.1 Dépôts juxta-glaciaires	2 A	Dépôts constitués de sable, de gravier, de cailloux, de pierres, et parfois de blocs arrondis à sub-arrondis. Ils ont souvent une stratification déformée et faillée et contiennent fréquemment des poches de till.
- Esker	2 AE	Idem.
- Kame, Terrasse de Kame	2 AK	Idem.
2.2 Dépôts pro-glaciaires	2 B	Les dépôts pro-glaciaires sont surtout composés de sable, de gravier et de cailloux émoussés. Ils sont triés et disposés en couches bien distinctes. Le long d'un complexe, on note généralement un grano-classement des particules de l'amont vers l'aval.
- Delta fluvio-glaciaire	2 BD	Idem.
- Épandage	2 BE	Idem.
3 - DÉPÔTS FLUVIATILES	3	Les dépôts fluviatiles sont bien stratifiés. Ils se composent généralement de gravier et de sable avec une proportion variable mais faible de limon et d'argile. Ils peuvent contenir de la matière organique.
4 - DÉPÔTS LACUSTRES		Dépôts constitués de sable fin, de limon et d'argile stratifiés ou de matériaux plus grossiers (sable et gravier).
4.1 Plaine lacustre	4	Dépôt constitué de sable fin, de limon et d'argile. Il peut contenir une certaine quantité de matière organique.
4.2 Glacio-lacustre		
- Faciès d'eau profonde	4 GA	Dépôt constitué de limon, d'argile et de sable fin rythmés (varves).
- Faciès d'eau peu profonde	4 GS	Dépôt constitué de sable et parfois de gravier.
5 - DÉPÔTS MARINS		Dépôts fins composés d'argile mais pouvant contenir du limon et du sable fin.
- Faciès d'eau profonde	5 A	Dépôt constitué d'argile contenant parfois des pierres et des blocs glaciels.
- Faciès d'eau peu profonde	5 S	Dépôt constitué de sable et parfois de gravier.
6 - DÉPÔTS LITTORAUX MARINS	6	Dépôts constitués d'argile, de sable, de gravier, de cailloux, de pierres ou de blocs généralement émoussés.
7 - DÉPÔTS ORGANIQUES	7	Dépôts constitués d'une accumulation de matière organique plus ou moins décomposée et dérivée de sphaignes, mousses, litière forestière, etc.
8 - DÉPÔTS DE PENTES ET D'ALTÉRATIONS	8	Dépôts constitués de matériaux fins (limon, sable, gravier) ou grossiers (cailloux, pierres, blocs). Matériaux généralement anguleux.
9 - DÉPÔTS ÉOLIENS	9	Dépôts composés généralement de sable fin à moyen lités.
10 - SUBSTRATUM ROCHEUX	R	Affleurement rocheux pouvant être recouvert de matériel meuble d'une épaisseur moyenne inférieure à 25 cm.

0 1000 2000 3000 4000 (m)

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

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FIGURE 10.4: EXTRAIT DE LA CARTE DES DÉPÔTS MEUBLES

Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 50 000

Hydrogeology

Groundwater flow in the study area is generally consistent with the surface topography. Due to the small thickness of surficial deposits (except locally), the regional aquifer consists of the network of fractures in the Precambrian basement rock.

Regionally, the groundwater flows radially around a northeast-southwest striking topographic ridge in the Boisvert and Armitage river basins. The configuration of the piezometric levels correlates relatively well with the topography, according to observations made during field surveys conducted for previous studies (Entraco, 2001). Unit recharge occurs primarily by infiltration from precipitation and from a few headwater lakes such as Lac Coco and Lac Laugon. Groundwater flow velocity is controlled by the geological structures and the size of fine particles in the surficial deposits (regional and local faults, geological contacts and, locally, permeable surficial deposits). Finally, groundwater in the Chibougamau region is characterized by an alkaline pH, a low total dissolved solids content and a generally low metal content.

10.3 WORK DESCRIPTION AND SCHEDULE

The hydrogeological study is based on boreholes, monitoring wells, water level surveys and variable-head permeability tests in the monitoring wells. A groundwater sampling and analysis program was also carried out. Table 10.2 shows the work schedule.

Table 10.2 Work Schedule

Date	Activity
3 August 2011	Site visit by the hydrogeologist
17 August to 27 Sept. 2011	Monitoring well drilling and installation (PO-01 to PO-26)
26 Sept. to 3 Oct. 2011	Piezometric survey, permeability testing, *in situ* water analyses and sampling for laboratory analysis purposes
2-3 October 2011	Location and elevation survey by Paul Roy, land surveyor

The locations of the monitoring wells at the mine site and rail transfer site are shown in Figures 10.5 and 10.6. The photos in Appendix 10.1 show the monitoring wells and some details of the work.

10.3.1 Monitoring Well Drilling and Installation

Drilling and installation of monitoring wells was done between August 17 and September 27, 2011, by *Forages S.L.*, monitored by *LVM* field technicians and supervised by *Entraco* personnel.

The boreholes were drilled with a track-type geotechnical drill, using sections of HW-size casing equipped with a diamond bit that cuts by rotation. Soil samples were collected using a split-spoon sampler, while the rock samples were collected using a core sampler. The standard penetration index (N-value) was noted for the soil and rock samples, and the RQD was recorded in the recovered core. Soil and rock samples were logged by the field technician. Boreholes PO-01 to PO-20 were drilled to a depth of 15 m, while holes PO-21 to PO-26 were drilled to 4.5 m deep.

Monitoring wells PO-01 to PO-20 consist of a 3-m long casing with a PVC strainer 50 mm in diameter by 12.2 m long, while monitoring wells PO-21 to PO-26 consist of a 3-m long casing with a PVC strainer 50 mm in diameter by 1.5 m long. The screen of each well is surrounded by a calibrated silica sand pack, topped by a cement-bentonite seal to the surface. The wells are protected on surface with a protective casing and locked cover.

Geological cross-sections and monitoring well techniques are provided in Appendix 10.2.

10.3.2 Piezometer Surveys, Permeability Tests and Water Sampling

Surveys of water levels in the monitoring wells, variable-head permeability tests and groundwater sampling were carried out between September 26 and October 3, 2011. Water levels were measured from the top of the protective casing using a Solinst-brand manual electric probe. The results are presented in Section 10.4.3.

Variable-head permeability tests were done in the 26 monitoring wells installed for the purposes of the project. Rising-head tests were conducted following rapid pumping of about 2.0 litres of water, by measuring the water level until the static level was reached. Water levels were measured using a pressuremeter probe pre-programmed to capture and record data every two seconds.The tests were interpreted using Aquifer Test Pro 2011 software, based on the Bouwer-Rice analysis method. The results are presented in Section 10.4.2, and the test data and interpretation curves are presented in Appendix 10.3.

Groundwater sampling was conducted in monitoring wells PO-01 to PO-20. Water samples were collected using a *Proactive* submersible pump connected to a 9.5-mm diameter HDPE pipe. Prior to sampling, the in situ physicochemical quality of the water collected was measured using a *Hanna* HI 9828 multiparameter probe. The sample was taken once the collected water was clear and free of solids and the physicochemical parameters measured in situ were stable. Metal sampling was achieved by filtering the samples through a 0.45 μm filter.

Water analyses were carried out for the following parameters identified in Section 2.3.2.2 of the MDDEP's *Directive 019*:

- petroleum hydrocarbon C_{10}-$C_{50;}$
- pH;
- sulphates;
- total cyanide;
- conductivity;
- bicarbonates;
- arsenic;
- copper;
- calcium;
- iron;
- magnesium;
- nickel;
- lead;
- potassium;
- sodium;
- zinc.

The samples were shipped in a cooler to the Maxxam Analytics certified laboratory in Montreal. The test results are presented in Section 10.4.4 of this document. Certificates of laboratory analysis are provided in Appendix 10.4.

The location and elevation of the monitoring wells were surveyed on 2-3 October 2011 by Paul Roy, land surveyor. GPS measurements were taken using Leica GS15 GNSS receivers (centimetre accuracy) from control points BR-1, BR-5 and BR-9.

Table 10.3 presents the location and elevation data of the monitoring well built for the purposes of the project. The land surveyor's certificate of location is provided in Appendix 10.5.

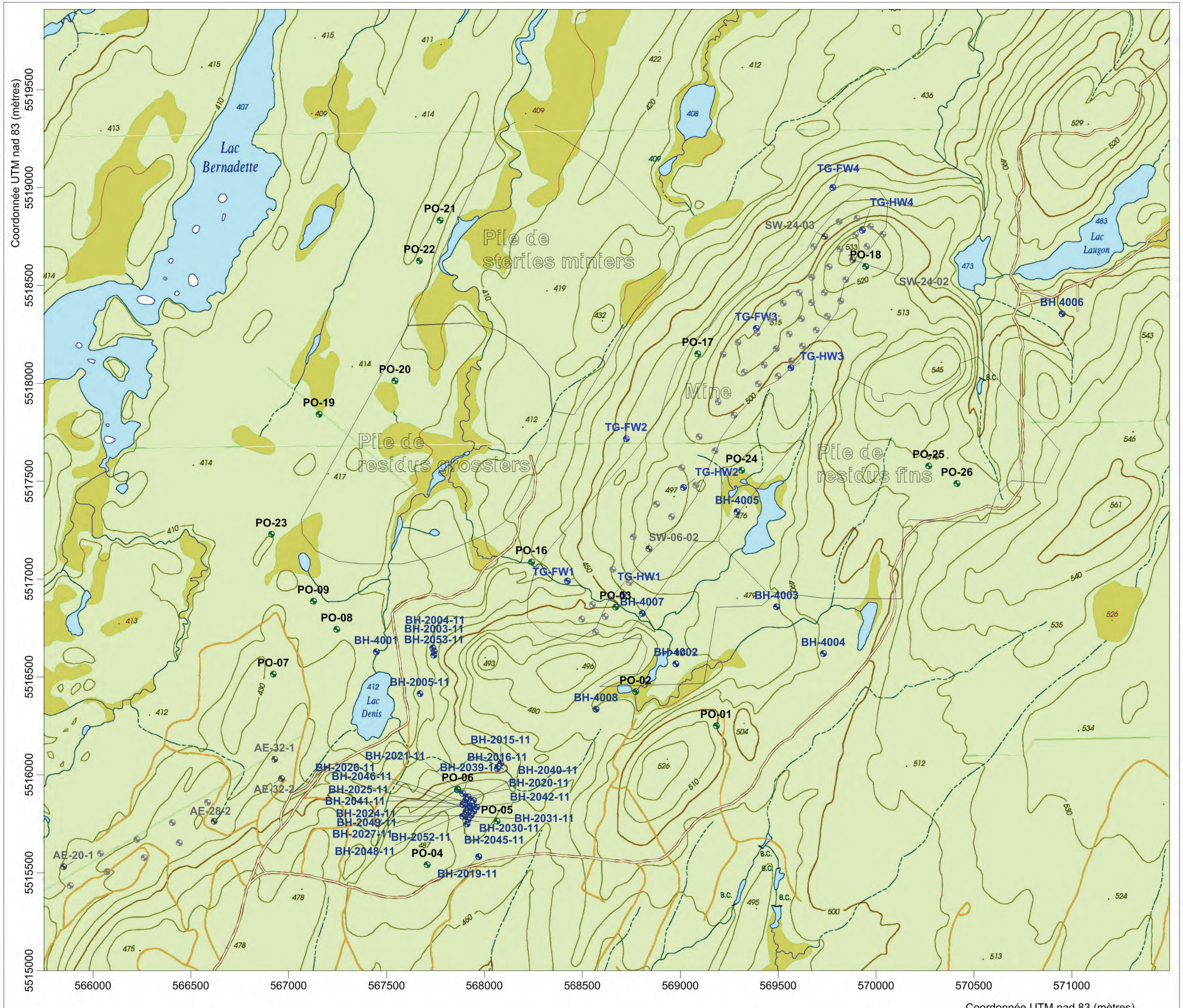
10.4 RESULTS

10.4.1 Hydrostratigraphic Units

The hydrostratigraphic units of the study area were identified through drilling. Just two units were identified at the sites investigated: a sandy till, considered an aquitard due to its small thickness, and the bedrock, which is a potential aquifer due to its network of cracks. Borehole location is shown in Figures 10.5 and 10.6, and stratigraphic sections are provided in Appendix 10.2. Till thickness in the vicinity of the various facilities is as follows:

- Fine tailings pond: 0.3 to 5.8 metres
- Processing plant: 0.8 to 3.0 metres;
- Garage: 2.7 to 3.7 metres;
- Rail transfer site: 9.9 to over 15 metres;
- Pit: 0 to 0.3 metres;
- Coarse tailings pile: 2.4 to over 5.2 metres.

In general, the surficial deposits can be said to be thin on the ridges and thicker in the valleys. The till is generally described as a grey, fine, silty sand with medium to coarse sand and gravel. It is sometimes covered by a thin layer of peat and/or organic matter. Only the rail transfer site area has thicker layers of till.



Légende

- Puits d'observation
- Forages géotechnique
- Forages d'exploration minière

0 500 1000 1500 2000 (m)

Fond cartographique du MRNF Québec
carte CGSIGEOM 32GC059

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FIGURE 10.5: LOCALISATION DES PUITS D'OBSERVATION
SECTEUR DE LA MINE

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PROJET MINIER BLACKROCK
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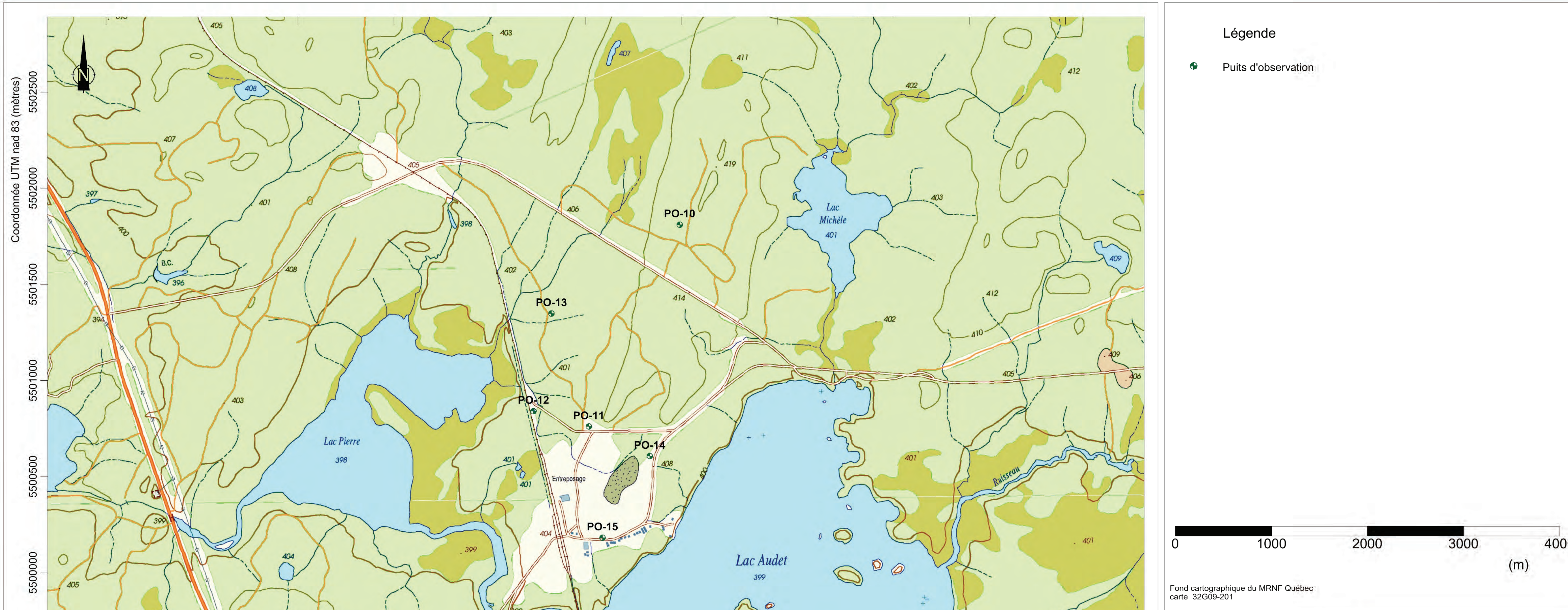

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FIGURE 10.6: LOCALISATION DES PUITS D'OBSERVATION SECTEUR SITE DE TRANSBORDEMENT

Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

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Date	Échelle
Le 31 octobre 2011	1 : 20 000

Table 10.3 Monitoring Well Locations and Elevations

Well	UTM East (m)	UTM North (m)	Well Elev. (m)	Ground Elev. (m)	Note
PO-01	569183.41	5516251.04	503.34	502.5	Polishing pond
PO-02	568771.67	5516424.29	473.43	472.5	Polishing pond
PO-03	568669.74	5516857.04	454.92	454.0	Polishing pond
PO-04	567708.32	5515541.23	486.50	485.2	Processing plant
PO-05	568064.07	5515762.47	473.67	472.8	Processing plant
PO-06	567863.54	5515927.67	468.98	468.1	Processing plant
PO-07	566921.61	5516514.12	426.29	425.3	Garage
PO-08	567245.65	5516743.96	415.98	415.1	Garage
PO-09	567126.71	5516887.00	417.94	417.0	Garage
PO-10	550989.35	5501811.02	414.86	414.0	Rail transfer site
PO-11	550516.65	5500760.68	404.61	403.7	Rail transfer site
PO-12	550228.61	5500840.81	400.88	400.0	Rail transfer site
PO-13	550321.70	5501348.54	401.52	400.7	Rail transfer site
PO-14	550833.32	5500606.38	407.06	406.1	Rail transfer site
PO-15	550587.79	5500182.82	403.80	402.9	Rail transfer site
PO-16	568239.33	5517087.62	432.07	431.1	Pit
PO-17	569089.23	5518151.22	481.86	481.0	Pit
PO-18	569946.18	5518598.28	528.13	527.2	Pit
PO-19	567155.03	5517842.87	416.00	415.0	Coarse tailings pile
PO-20	567542.48	5518012.84	413.15	412.2	Coarse tailings pile
PO-21	567773.68	5518833.78	417.61	416.7	Coarse tailings pile
PO-22	567668.02	5518626.20	418.63	417.7	Coarse tailings pile
PO-23	566911.81	5517228.61	421.02	420.1	Coarse tailings pile
PO-24	569313.99	5517556.14	477.00	476.0	Fine tailings pond
PO-25	570268.69	5517578.97	512.55	511.6	Fine tailings pond
PO-26	570413.71	5517487.82	512.12	511.1	Fine tailings pond

10.4.2 Hydrogeological Properties

Table 10.4 presents the interpretation results for variable-head permeability tests using Aquifer Test software based on the Bouwer-Rice method. The results are shown by hydrostratigraphic unit. Table 10.5 shows the results of permeability tests performed as part of the geotechnical study in deep inclined boreholes done by LVM on behalf of *Journeaux Associés* and *BBA*. Finally, Table 10.6 shows the other results obtained during the geotechnical study, for Lugeon-type tests at various depths in the same boreholes. This data leads to the following observations:

- The average hydraulic conductivity of the till is 1.29×10^{-4} cm/s; the till is less permeable in the area of the rail transfer site, where it has a hydraulic conductivity of 8.6×10^{-6} cm/s;
- The average hydraulic conductivity of the bedrock is 1.93×10^{-4} cm/s in the monitoring wells installed for the purposes of the hydrogeological study; the results range from 4.2×10^{-5} to 7.12×10^{-4} cm/s; the permeability of the bedrock is therefore relatively uniform, regardless of the geologic unit mapped; it should also be noted that the distribution of hydraulic conductivity does not necessarily correspond to the location of the shear zones mapped;

- average hydraulic conductivity of all measurement points, including wells with strainers in till and rock, is 1.56 x 10^{-4} cm/s;
- the inclined boreholes, which are deeper than the monitoring wells, generally yield lower hydraulic conductivities;
- Lugeon tests show a tendancy for hydraulic conductivity to decrease with depth.

Table 10.4 Permeability Test Results

High-Risk Facilities	Well	UTM East	UTM North	Hydraulic Conductivity	Stratigraphic Unit
		(m)	(m)	(cm/s)	
Polishing pond	PO-01	569183.41	5516251.04	1.64E-04	Bedrock
	PO-02	568771.67	5516424.29	2.10E-04	Till and Bedrock
	PO-03	568669.74	5516857.04	4.20E-05	Bedrock
Processing plant	PO-04	567708.32	5515541.23	7.12E-04	Bedrock
	PO-05	568064.07	5515762.47	6.64E-04	Bedrock
	PO-06	567863.54	5515927.67	5.01E-04	Bedrock
Garage	PO-07	566921.61	5516514.12	5.60E-04	Bedrock
	PO-08	567245.65	5516743.96	1.77E-03	Bedrock
	PO-09	567126.71	5516887.00	2.33E-04	Bedrock
Rail transfer site	PO-10	550989.35	5501811.02	8.64E-06	Till
	PO-11	550516.65	5500760.68	1.48E-05	Till and Bedrock
	PO-12	550228.61	5500840.81	2.22E-04	Till and Bedrock
	PO-13	550321.70	5501348.54	7.45E-05	Bedrock
	PO-14	550833.32	5500606.38	9.93E-05	Till and Bedrock
	PO-15	550587.79	5500182.82	7.73E-05	Till and Bedrock
Pit	PO-16	568239.33	5517087.62	4.38E-05	Bedrock
	PO-17	569089.23	5518151.22	5.25E-05	Bedrock
	PO-18	569946.18	5518598.28	4.77E-05	Bedrock
Coarse tailings pile	PO-19	567155.03	5517842.87	2.12E-04	Bedrock
	PO-20	567542.48	5518012.84	1.12E-04	Bedrock
	PO-21	567773.68	5518833.78	1.36E-04	Till
	PO-22	567668.02	5518626.20	2.01E-03	Till
	PO-23	566911.81	5517228.61	1.16E-04	Till
Fine tailings pond	PO-24	569313.99	5517556.14	1.29E-04	Bedrock
	PO-25	570268.69	5517578.97	5.18E-04	Bedrock
	PO-26	570413.71	5517487.82	1.43E-04	Bedrock

Table 10.5 Results of Permeability Tests in Inclined Geotechnical Boreholes (Source: LVM)

Well	UTM East	UTM North	Hydraulic Conductivity	Stratigraphic Unit
	(m)	(m)	(cm/s)	
TG-FW1	568422.65	5516990.95	1.22E-05	Bedrock
TG-FW4	569778.00	5519000.00	1.07E-06	Bedrock
TG-HW2	569015.40	5517468.50	1.09E-04	Bedrock
TG-HW3	569564.00	5518079.50	3.64E-05	Bedrock

Table 10.6 Results of Lugeon Tests in Geotechnical Boreholes (Source: LVM)

Well	UTM East	UTM North	Hydraulic Conductivity	Depth Interval
	(m)	(m)	(cm/s)	(m)
BH 4001	567447.00	5516628.90	1.09E-04	6.53 - 9.28
BH 4001	567447.00	5516628.90	2.99E-05	9.28 - 12.03
BH 4001	567447.00	5516628.90	7.72E-06	12.03 - 14.78
BH 4002	568977.00	5516568.00	2.09E-04	1.5 - 4.25
BH 4002	568977.00	5516568.00	2.43E-04	4.25 - 7
BH 4002	568977.00	5516568.00	1.94E-04	7 - 9.75
BH 4003	569492.00	5516858.00	2.57E-04	3.35 - 6.1
BH 4003	569492.00	5516858.00	1.03E-04	6.1 - 8.85
BH 4003	569492.00	5516858.00	1.24E-04	8.85 - 11.6
BH 4004	569730.00	5516619.00	1.30E-04	7.1 - 9.85
BH 4005	569290.00	5517344.00	1.86E-04	1.42 - 4.17
BH 4005	569290.00	5517344.00	1.88E-04	4.17 - 6.92
BH 4005	569290.00	5517344.00	1.50E-04	6.92 - 9.67
BH 4005	569290.00	5517344.00	6.96E-05	9.67 - 12.42
BH 4006	570950.00	5518355.90	2.18E-04	1.25 - 4
BH 4006	570950.00	5518355.90	2.23E-04	4 - 6.75
BH 4006	570950.00	5518355.90	1.90E-04	6.75 - 11.22
BH 4007	568805.00	5516825.00	1.85E-04	3.75 - 6.5
BH 4007	568805.00	5516825.00	1.66E-05	6.5 - 9.25
BH 4007	568805.00	5516825.00	1.30E-06	9.25 - 12
BH 4008	568570.00	5516336.00	2.92E-04	3.55 - 6.3
BH 4008	568570.00	5516336.00	5.87E-05	6.3 - 9.05
BH 4008	568570.00	5516336.00	2.23E-04	9.05 - 11.8

10.4.3 Piezometry

Table 10.7 shows the piezometer levels measured during the surveys. This data leads to the following observations:

- the water level measured is usually within 1.5 m of the ground level;
- the flow pattern conforms to the local topography;
- hydraulic loads range from 400 to 520 m above mean sea level.

Table 10.7 Piezometer Levels Measured

High-Risk Facilities	Well	UTM East	UTM North	Ground Elev.	Date	Water Level	Piezometer Level
		(m)	(m)	(m)		(m)	(m/nmm)
Polishing pond	PO-01	569183.41	5516251.04	502.5	2011-10-02	4.05	498.45
	PO-02	568771.67	5516424.29	472.5	2011-10-02	0.03	472.47
	PO-03	568669.74	5516857.04	454.0	2011-10-02	-0.80	454.80
Processing plant	PO-04	567708.32	5515541.23	485.2	2011-10-02	7.29	477.91
	PO-05	568064.07	5515762.47	472.8	2011-10-02	1.41	471.39
	PO-06	567863.54	5515927.67	468.1	2011-10-02	11.46	456.64
Garage	PO-07	566921.61	5516514.12	425.3	2011-10-02	4.95	420.35
	PO-08	567245.65	5516743.96	415.1	2011-10-02	0.34	414.76
	PO-09	567126.71	5516887.00	417.0	2011-10-02	0.27	416.73
Transfer point	PO-10	550989.35	5501811.02	414.0	2011-10-03	0.45	413.55
	PO-11	550516.65	5500760.68	403.7	2011-10-03	0.26	403.44
	PO-12	550228.61	5500840.81	400.0	2011-10-03	0.91	399.09
	PO-13	550321.70	5501348.54	400.7	2011-10-03	0.21	400.49
	PO-14	550833.32	5500606.38	406.1	2011-10-03	0.70	405.40
	PO-15	550587.79	5500182.82	402.9	2011-10-03	0.45	402.45
Pit	PO-16	568239.33	5517087.62	431.1	2011-10-02	2.47	428.63
	PO-17	569089.23	5518151.22	481.0	2011-10-02	3.83	477.17
	PO-18	569946.18	5518598.28	527.2	2011-10-02	9.96	517.24
Coarse tailings pile	PO-19	567155.03	5517842.87	415.0	2011-10-02	0.30	414.70
	PO-20	567542.48	5518012.84	412.2	2011-10-02	0.23	411.97
	PO-21	567773.68	5518833.78	416.7	2011-10-02	2.58	414.12
	PO-22	567668.02	5518626.20	417.7	2011-10-02	2.49	415.21
	PO-23	566911.81	5517228.61	420.1	2011-10-02	2.46	417.64
Fine tailings pond	PO-24	569313.99	5517556.14	476.0	2011-10-02	0.28	475.72
	PO-25	570268.69	5517578.97	511.6	2011-10-02	1.34	510.26
	PO-26	570413.71	5517487.82	511.1	2011-10-02	1.03	510.07

10.4.4 Water Quality

Tables 10.8 and 10.9 present the results of in situ physicochemical measurements and analysis results for groundwater samples collected from September 26 to October 3, 2011, in monitoring wells PO-01 to PO-20. The following observations can be made:

- groundwater condition varies from aerobic to anaerobic, with dissolved oxygen concentrations of 0 to 12.27 mg/L; in general, it can be said that the groundwater is more oxygenated in the vicinity of recharge zones, whereas it is poorly oxygenated near wetlands;
- groundwater pH is generally acidic in recharge zones, i.e., on ridges; wells in discharge zones are characterized by alkaline water; the pH of wells in the rail transfer site area, where till thicknesses are greater, is fairly alkaline;

- changes in pH as the water flows from the recharge to the discharge areas shows that the bedrock has a significant capacity to neutralize acid rain;
- the bedrock has a significant capacity to neutralize acid rain;
- the low electrical conductivity indicates that the groundwater is generally relatively unmineralized, except for the wells in the area of the rail transfer site and well PO-23, which is located in the plain between Lac Denis and Lac Bernadette
- concentrations of hydrocarbons C_{10}-C_{50} are all below the detection limit;
- iron was only detected in the rail transfer site area, in concentrations ranging from 0.1 to 26 mg/L (well PO-15); it should be noted that this area was previously the site of a sawmill operation;
- of the other metals analyzed, only arsenic, copper and zinc were detected in a few wells, at concentrations just above the detection limit and well below the applicable criteria.

A second groundwater sampling program should be conducted to validate the results obtained and determine threshold values. Certificates of analysis from the laboratory are provided in Appendix 10.4.

10.4.5 Groundwater Classification

According to the classification grid in *Directive 019*, bedrock groundwater would be Class II, as it could adequately meet domestic flow requirements of less than 75 m^3/day, and common treatment methods could be used to meet drinking water criteria if required. The groundwater in the till unit is Class III because this unit is incapable of collecting a sufficient quantity and quality of water.

10.5 MODELLING OF GROUNDWATER IMPACT

10.5.1 Methodology

The mathematical modeling calculation method was selected to assess the impact of the open pit, tailings disposal and other mining activities on groundwater. A numerical flow model was therefore developed using *Visual MODFLOW* software, integrating the hydrogeological properties derived from the field work described above. The model was then calibrated using the October 2011 water level measurements, adjusting the boundary conditions and hydrogeological parameters to achieve the best possible representation of the flow. This allows predictions to be made based on the expected flow constraints.

Table 10.8 *In Situ* Groundwater Quality Measurements

Paramètres	Unités	PO-01	PO-02	PO-03	PO-04	PO-05	PO-06	PO-07	PO-08	PO-09	PO-10	PO-11	PO-12	PO-13
Échantillon		PO-01	PO-02	PO-03	PO-04	PO-05	PO-06	PO-07	PO-08	PO-09	PO-10	PO-11	PO-12	PO-13
Date de mesure		2011-09-25	2011-09-26	2011-09-29	2011-09-23	2011-09-23	2011-09-23	2011-09-27	2011-09-26	2011-09-27	2011-09-22	2011-09-21	2011-09-22	2011-09-23
MESURES *IN SITU*														
Température	(°C)	6.52	7.78	5.62	8.28	7.01	5.73	4.97	8.89	4.78	7.24	7.17	7.75	5.77
pH	(-)	6.66	7.4	7.05	5.04	5.38	6.69	7.42	7.93	7.5	8.18	8.02	7.73	7.19
Rédox	(mV)	-98.5	-167.6	-153.6	-43.4	-30.6	-51.7	-64.3	-120	-173.5	-168.1	-128.6	-132.5	-213.5
Oxygène dissous	(ppm)	4.36	0	0	10.46	10.24	12.27	13.71	4.55	0	4	5.2	5.87	0
Conductivité	(µS/cm)	107	138	145	18	34	83	70	87	197	199	201	130	241
Solides totaux dissous	(ppm)	53	69	72	9	17	41	35	43	98	99	101	65	120

Paramètres	Unités	PO-14	PO-15	PO-16	PO-17	PO-18	PO-19	PO-20	PO-21	PO-22	PO-23	PO-24	PO-25	PO-26
Échantillon		PO-14	PO-15	PO-16	PO-17	PO-18	PO-19	PO-20	PO-21	PO-22	PO-23	PO-24	PO-25	PO-26
Date de mesure		2011-09-21	2011-09-21	2011-09-28	2011-09-28	2011-09-30	2011-10-02	2011-10-02	-	-	2011-10-01	2011-09-30	2011-10-01	2011-10-01
MESURES *IN SITU*														
Température	(°C)	5.77	6.89	7.2	7.83	5.97	4.21	5.93	-	-	6.88	6.46	5.67	6.49
pH	(-)	8.71	7.05	6.48	5.46	6.04	7.45	8.52	-	-	12.58	8.47	6.69	5.64
Rédox	(mV)	-152.2	-247.9	-105.9	-95.6	-31	-119.9	-189.8	-	-	-149.1	-100.5	-115.5	-103
Oxygène dissous	(ppm)	0.58	0	2.47	0	8.54	1.52	0	-	-	3.54	6.69	0.67	0
Conductivité	(µS/cm)	408	1442	108	52	35	165	175	-	-	1293	158	116	35
Solides totaux dissous	(ppm)	204	721	54	26	18	82	87	-	-	647	79	58	17

Table 10.9 Results of Groundwater Laboratory Analysis

Paramètres	Unités	Politique [1] Consommation [2]	Politique [1] Résurgence [3]	CMM [4] Égout pluvial [5]	PO-01	PO-02	PO-03	PO-04	PO-05	PO-06	PO-07	PO-08	PO-09	PO-10
Échantillon					PO-01	PO-02	PO-03	PO-04	PO-05	PO-06	PO-07	PO-08	PO-09	PO-10
Date d'échantillonnage (mm/jj/aaaa)					2011-09-25	2011-09-26	2011-09-29	2011-09-23	2011-09-23	2011-09-23	2011-09-27	2011-09-26	2011-09-27	2011-09-22
HYDRO. PÉTROLIERS TOTAUX														
Hydrocarbures Pétroliers (C10-C50)	ug/L	AC	3500	AC	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
MÉTAUX														
Arsenic (As) [c]	mg/L	0.025	0.34	1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (Cd)	mg/L	0.005	0.0021 (6)	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chrome (Cr)	mg/L	0.05	AC	1	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cobalt (Co)	mg/L	AC	0.5	AC	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cuivre (Cu)	mg/L	1	0.0073 (6)	1	<0.003	<0.003	<0.003	0.006	0.004	<0.003	<0.003	<0.003	<0.003	<0.003
Plomb (Pb)	mg/L	0.01	0.034 (6)	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)	mg/L	0.02	0.26 (6)	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (Na)	mg/L	200	AC	AC	0.9	4	1.9	1	1	0.8	1.1	1.6	2.9	12
Zinc (Zn)	mg/L	5	0.067 (6)	1	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fer (Fe)	mg/L	AC	AC	17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.9
Magnésium (Mg)	mg/L	AC	AC	AC	1.2	3.4	2.2	0.4	0.5	0.6	5.5	5.9	13	12
Potassium (K)	mg/L	AC	AC	AC	1.5	1.8	0.5	0.3	0.3	0.3	0.3	0.6	0.9	5.3
Calcium (Ca)	mg/L	AC	AC	AC	25	31	35	2.6	7.4	23	11	14	37	26
CONVENTIONNELS														
Conductivité	mS/cm	AC	AC	AC	0.15	0.19	0.145	0.025	0.049	0.12	0.1	0.12	0.28	0.27
Cyanures Totaux	mg/L	0.2	AC	0.1	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
pH	pH	AC	AC	AC	7.02	7.83	7.05	5.94	6.47	7.3	7.78	7.89	7.75	7.74
Bicarbonates (HCO3 comme CaCO3)	mg/L	AC	AC	AC	65	95	98	8	22	55	62	59	150	120
Sulfates (SO4)	mg/L	AC	AC	1500	8.2	3.9	5.3	2.2	2.4	3.1	3.1	5.7	1	24

Paramètres	PO-11	PO-12	PO-13	PO-14	PO-15	PO-16	PO-17	PO-18	PO-19	PO-20	LDR
Échantillon	PO-11	PO-12	PO-13	PO-14	PO-15	PO-16	PO-17	PO-18	PO-19	PO-20	LDR
Date d'échantillonnage (mm/jj/aaaa)	2011-09-21	2011-09-21	2011-09-22	2011-09-21	2011-09-21	2011-09-29	2011-09-28	2011-09-28	2011-09-30	2011-10-02	
HYDRO. PÉTROLIERS TOTAUX											
Hydrocarbures Pétroliers (C10-C50)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	100
MÉTAUX											
Arsenic (As) [c]	<0.002	<0.002	0.011	<0.002	0.01	<0.002	0.062	<0.002	<0.002	<0.002	0.002
Cadmium (Cd)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Chrome (Cr)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03
Cobalt (Co)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03
Cuivre (Cu)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.009	<0.003	<0.003	<0.003	0.003
Plomb (Pb)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Nickel (Ni)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Sodium (Na)	6.9	2.4	2.5	15	7.2	1.3	1.9	0.7	2.1	4.0	0.2
Zinc (Zn)	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.017	0.010	0.005
Fer (Fe)	0.2	0.1	4.2	<0.1	26	<0.1	0.6	<0.1	<0.1	<0.1	0.1
Magnésium (Mg)	10	8.7	13	23	79	3.2	0.5	0.3	7.8	6.5	0.2
Potassium (K)	2.1	1	0.9	5.4	3.9	0.3	<0.2	<0.2	0.4	0.7	0.2
Calcium (Ca)	22	21	46	48	180	23	11	5.9	23	26	0.5
CONVENTIONNELS											
Conductivité	0.21	0.18	0.32	0.52	1.4	0.108	0.052	0.035	0.165	0.175	0.001
Cyanures Totaux	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003
pH	7.85	7.83	7.48	8.14	6.98	6.48	5.46	6.04	7.45	8.52	N/A
Bicarbonates (HCO3 comme CaCO3)	92	84	180	240	830	71	31	16	90	99	1
Sulfates (SO4)	12	8.1	<0.5	42	1.1	5.5	2	3.2	7.8	4.5	0.5

Notes:

(1)	: Politique de protection des sols et de réhabilitation des terrains contaminés, MDDEP, 1999, rev. novembre 2001.
(2)	: Critère d'eau souterraine pour fin de consommation
(3)	: Critère d'eau souterraine pour la résurgence dans les eaux de surface ou infiltration dans les égouts
(4)	: Communauté métropolitaine de Montréal
(5)	: Rejets dans un réseau d'égout pluvial ou dans un cours d'eau, règlements 87, 87-1, 87-2 et 87-3, article 11, CMM, 1999.
(6)	: Le critère augmente avec la dureté. La valeur inscrite au tableau correspond à une dureté de 50 mg/L (CaCO3). Voir « Critères de qualité de l'eau de surface au Québec ».
LDR	: Limite de détection rapportée par le laboratoire
AC	: Aucun critère disponible
-	: Non analysé
c	: Substance classée cancérigène, cancérigène probable, cancérigène possible ou peut-être cancérigène selon Santé Canada, l'OMS ou l'EPA
0.7	: Concentration supérieure au critère d'eau souterraine pour fin de consommation
5.9	: Concentration supérieure au critère d'eau souterraine pour la résurgence dans les eaux de surface ou infiltration dans les égouts
300	: Concentration supérieure au critère d'eau souterraine pour fin de consommation et supérieure au critère d'eau souterraine pour la résurgence dans les eaux de surface ou infiltration dans les égouts

Note: pH and conductivity at monitoring well PO-23 were anomalous due to probe malfunction or a localized anomaly

Subsequently, keeping the same overall properties of the model, drain-type specified head boundary conditions were added to represent the planned pit. This simulation, carried out for a steady flow state, allowed piezometer levels and drawdowns around the open pit mine to be predicted, as well as the infiltration flow that will have to be pumped to surface. To assess the impact of tailings disposal on groundwater, specified heads (ref. *Directive 019*) of a height of about 10 metres above the ground surface were added to the initial model, and virtual water particles were then tracked from the sites using the model.

10.5.2 Description of the Numeric Flow Model

Software

Visual MODFLOW 2010 software was selected to model groundwater flow for the purposes of the study. This software uses the *MODFLOW 2005* code to represent groundwater flow in simplified form. It was developed by the Geological Survey of the United States (USGS) and is commonly used in Canada and the United States. It is also recognized by government authorities. The equations that govern the model can be found in the model Reference Manual (Harbaugh and McDonald, 1998).

Assumptions

In light of the available hydrogeological information and the fact that this is a conceptual model, the following assumptions were made:

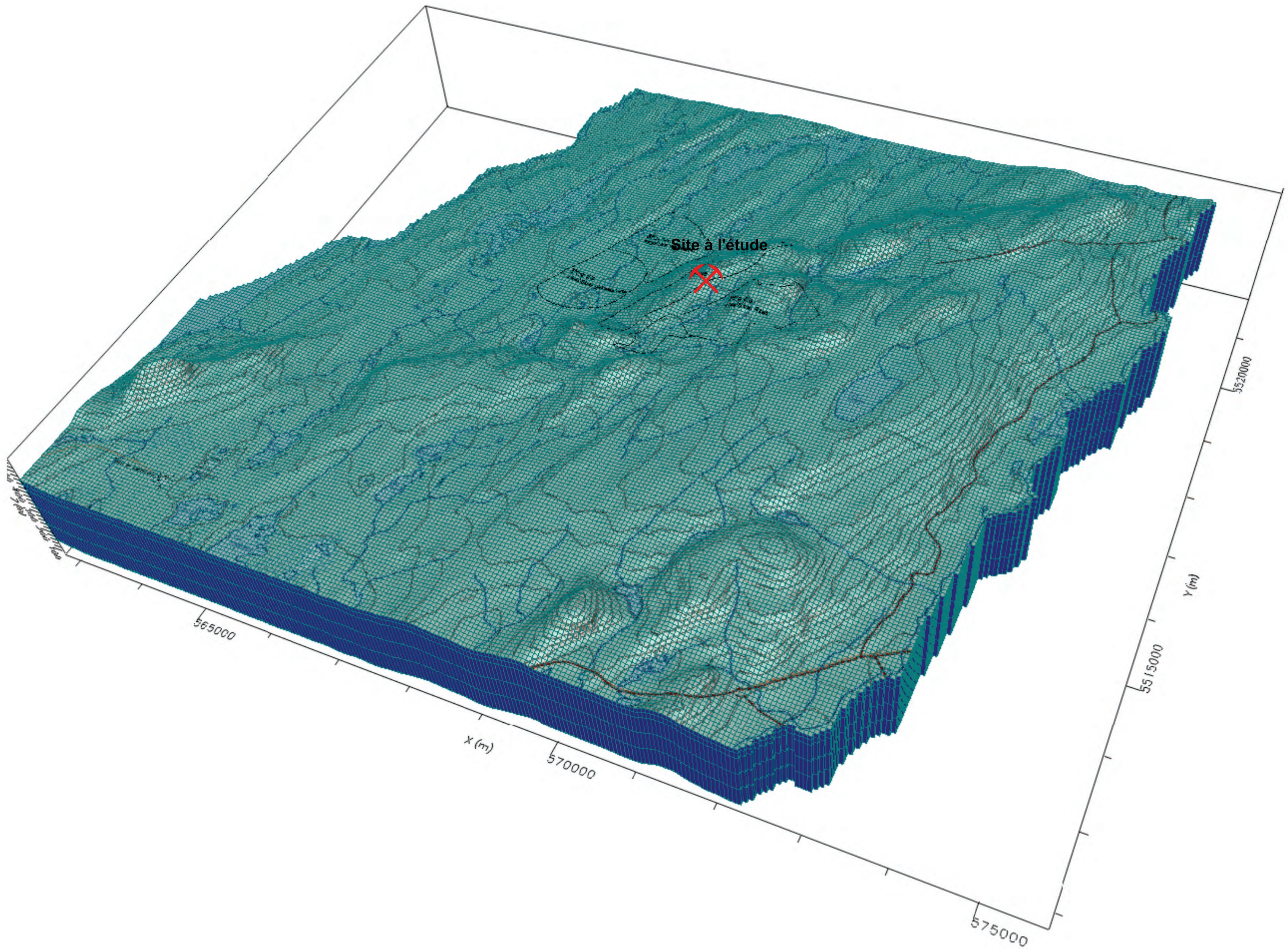
- within the study area, the surficial deposits are thin and similar in permeability to the bedrock: the flow in the surficial deposits is therefore assumed to be vertical, so the conceptual model does not directly consider the surficial deposits as a hydrogeological unit;
- overall, the bedrock is assumed to behave like an equivalent porous medium under free water table conditions;
- it is assumed that potential contaminants will flow at the same speed as the groundwater.

Grid, Boundary Conditions and Hydrogeological Properties

The model domain size is 13,000 m by 10,000 m. The grid is aligned with UTM NAD 83 coordinates. The origin of the grid system is located at coordinates 562,750.00 East, 5,511,800.00 North. The model domain is divided into 260,000 cells (260 columns, 200 rows and 5 layers). The cells are square in shape with 50 m sides, while cell height varies from 18.75 m near the surface to 84.6 m at depth. The surface defining the top layer of the model was obtained from National Topographic Data Base of Canada (NTDB) digital files. The surface defining the lower layer of the model is located at a depth of 300 metres from ground level, and the bedrock is assumed to be impermeable at greater depths. Figure 10.7 shows the model grid configuration.

The cells representing the open pit are represented by drain-type specified head boundary conditions, as were most of the streams that drain the area. These boundary conditions are unique in that they specify a head that allows the head of adjacent cells to be lowered, but do not allow the head of adjacent cells to be raised when it is lower than the specified head in the drain-type boundary condition. The main lakes of the model domain are represented by river-type specified head boundary conditions. These allow specified heads of adjacent cells to be connected, with a corresponding loss of head in the sediments that line these streams. The perimeter of the model, meanwhile, was represented by constant head boundary conditions where the specified heads lie two metres below ground level. Finally, the potential recharge is represented by a recharge-type constant flow boundary condition applied uniformly to all the cells in the first layer of the model, and values of 244 mm/year were assigned to these cells. Evapotranspiration-type specified head boundary conditions were specified for the entire surface of the model to prevent water levels from rising above ground level. Figure 10.8 shows the boundary conditions assigned to the model.

The hydraulic conductivity of the first layer of the model corresponds to a matrix of hydraulic conductivity values interpolated from the results of permeability tests conducted for the purposes of this study. To represent the gradual decrease in hydraulic conductivity with depth, the second layer of the model was set as uniform at 1×10^{-5} cm/sec, while the hydraulic conductivity of layers 3 to 5 of the model was set at 1×10^{-6} cm/sec. Storage parameters were determined using data from the literature. Thus, the effective porosity of layer 1 was set at 0.05, layer 2 at 0.02 and layers 3 to 5 at 0.01. All properties were simulated isotropic. Figure 10.9 shows the distribution of the hydrogeologic units in the model.



Légende

Maillage:

Coordonnée à l'origine: 562 750 mE 5 511 800 mN (UTM)

Dimensions: 13 000 m par 10 000 m

Taille des mailles: 50 m x 50 m

Hauteur des mailles:
1ere couche = 18,75 m
2eme couche = 27,40 m
3eme couche = 84,60 m
4eme couche = 84,60 m
5eme couche = 84,60 m

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FIGURE 10.7: MAILLAGE DU MODÈLE

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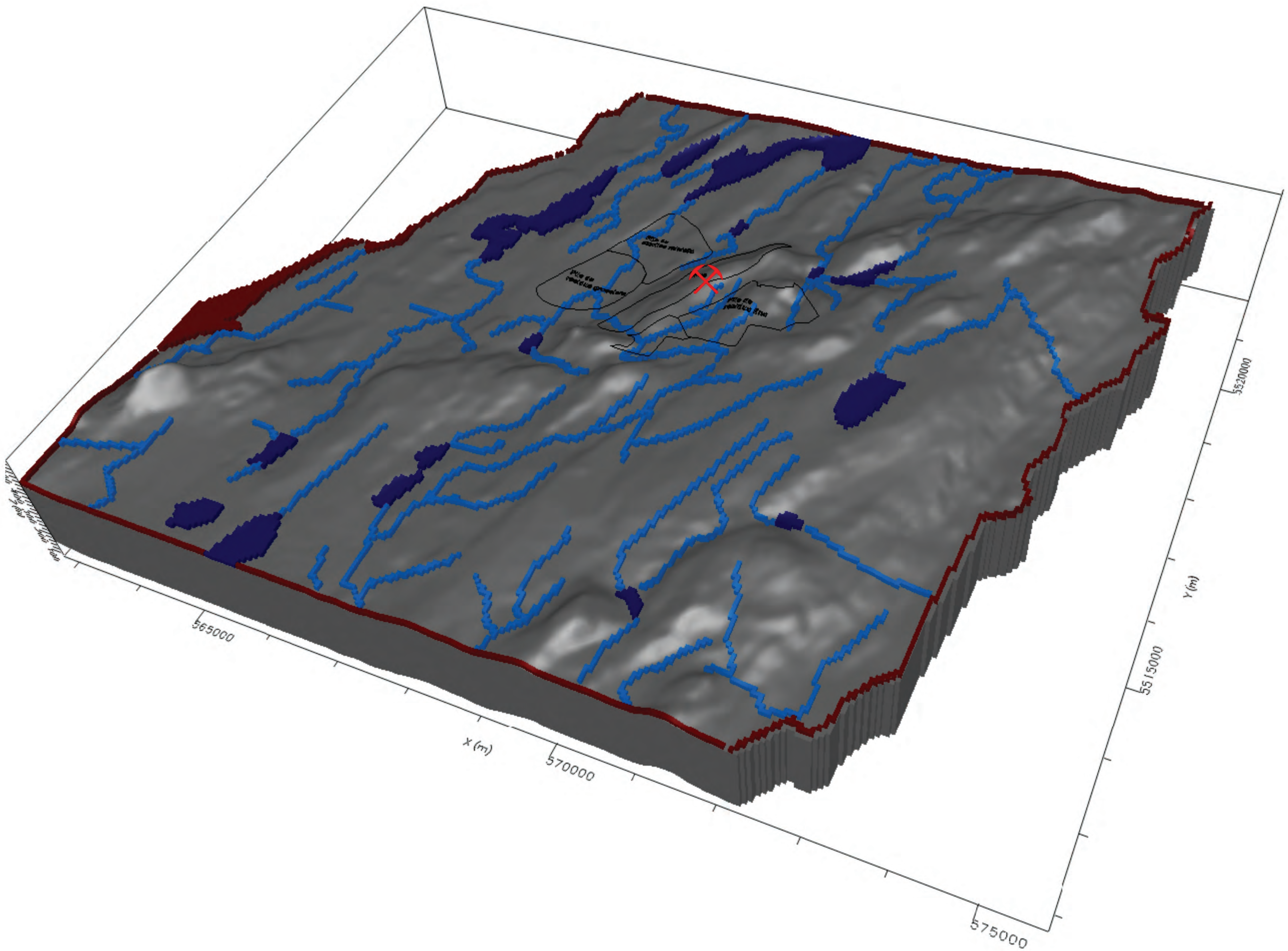
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 50 000



Légende

Conditions limites:

- Charges imposées de type "charge constante"
- Charges imposées de type "rivière"
- Charges imposées de ype "drain"

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FIGURE 10.8: CONDITIONS LIMITES DU MODÈLE

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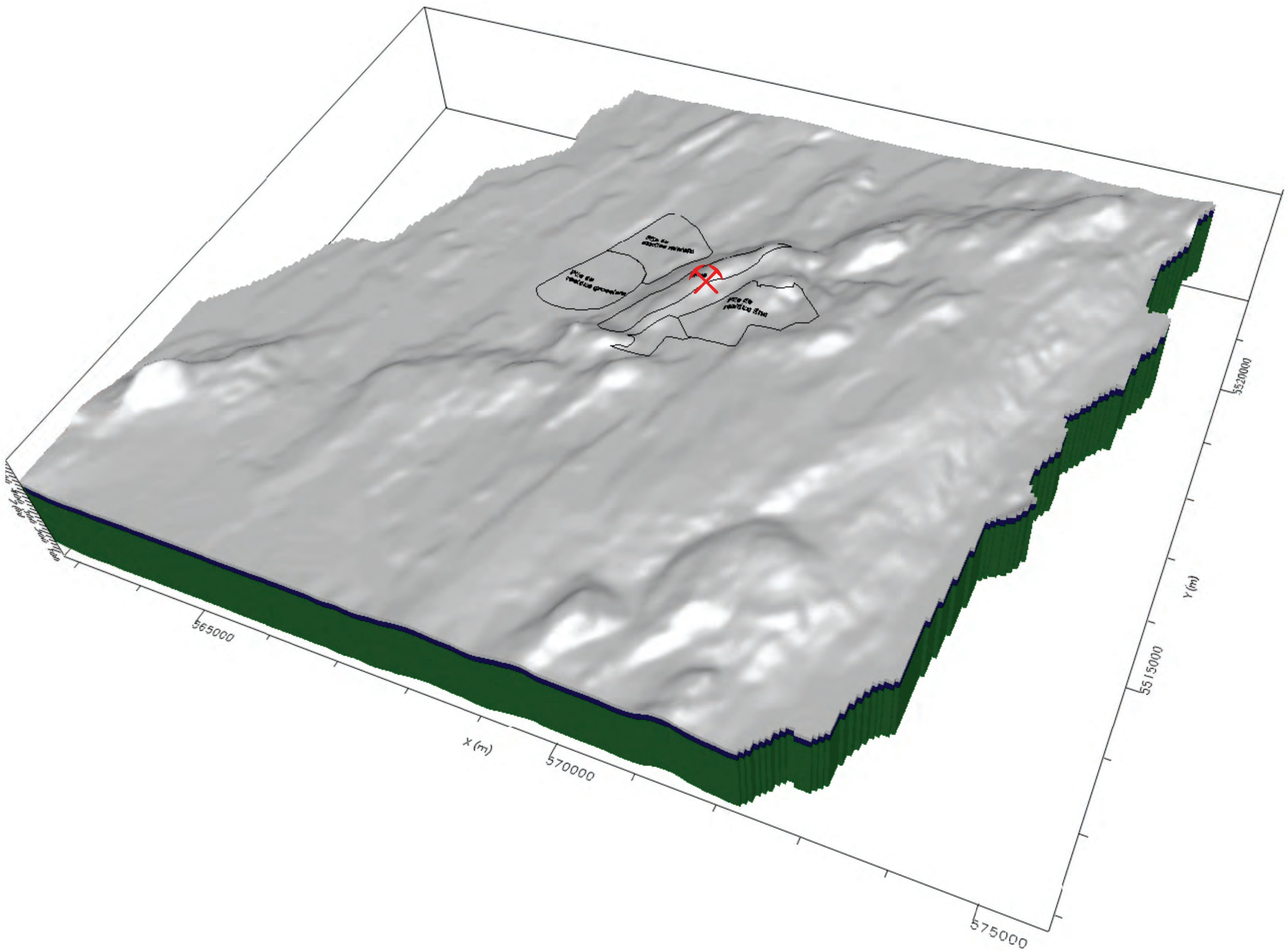

Légende

Propriétés hydrogéologiques

- De 0,00 à 18,75 m: Kmoy = 1,56E-4 cm/s Sy = 0,05
- De 18,75 à 46,15 m: K = 1,00E-5 cm/s Sy = 0,02
- De 46,15 à 300 m: K = 1,00E-6 cm/s Sy = 0,01

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FIGURE 10.9: PROPRIÉTÉS HYDROGÉOLOGIQUES

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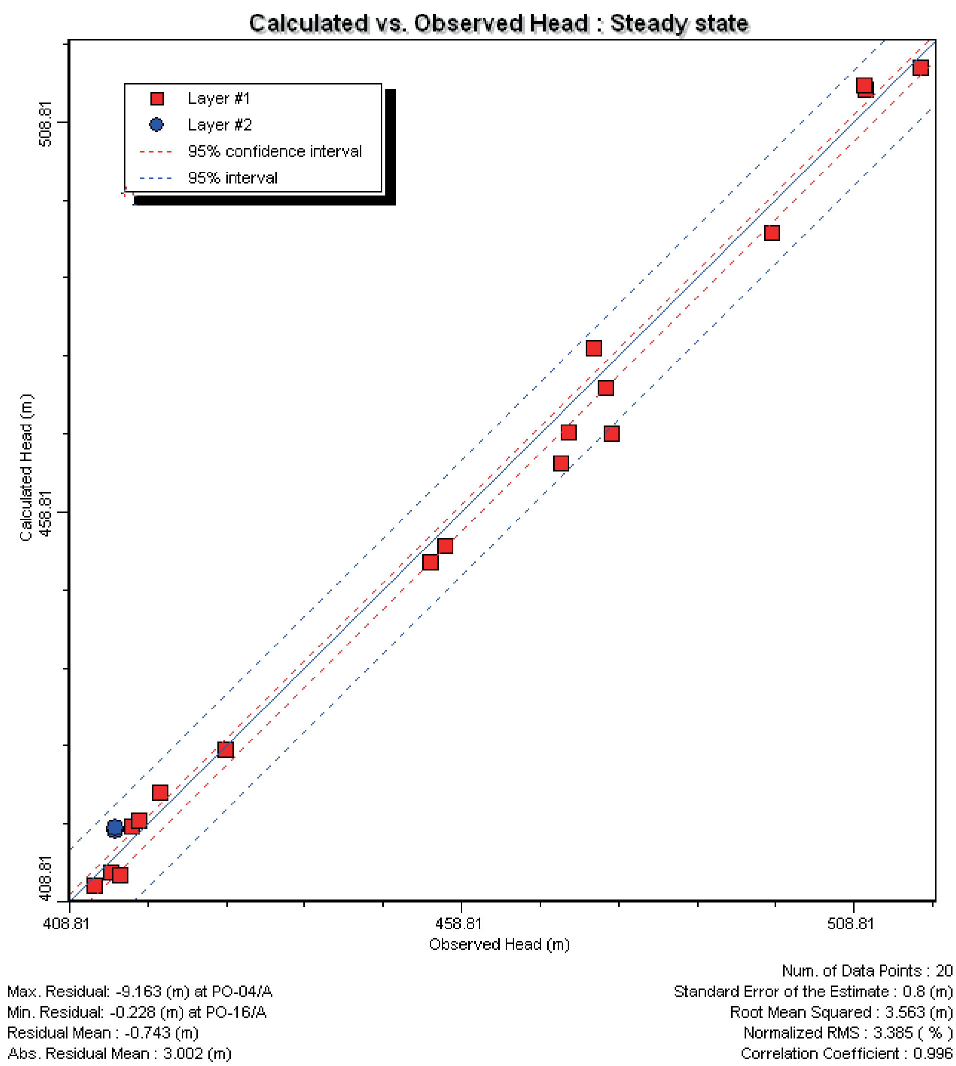
Model Calibration

The model was calibrated by adjusting hydraulic conductivity and recharge to reproduce the September 2011 piezometer readings. The calibration was considered satisfactory once it was no longer possible to reduce the differences between observed and calculated data without using boundary conditions that were not identifiable physically or by interpretation. Discrepancies between the heads calculated by the model and observed heads are considered normal because the latter occur under different conditions than those modelled.

Figure 10.10 shows the correlation between observed heads and the heads calculated by the model for all control points. The points can be seen to be fairly well distributed on both sides of the perfect correlation line (calculated = observed), and the model can therefore be considered to be calibrated.

Figure 10.10 Variance Distribution Graph



Model ParameterSensitivity

Assessment of the sensitivity of the parameters used for the design of the numerical model was carried out during the calibration process by noting the effect of changes in the parameters on the result obtained by predictive simulation.

ASTM (American Society for Testing and Materials) standard D 5611 - Sensitivity Analysis describes the four types of parameter sensitivity:

- Type 1 sensitivity: changing a parameter has no effect on calibration or the result;
- Type 2 sensitivity: changing a parameter changes the calibration, but not the result;
- Type 3 sensitivity: changing a parameter changes the calibration and the result;
- Type 4 sensitivity: changing a parameter has no effect on calibration, but changes the result.

The four types of sensitivity described above refer to the model calibrated in steady state to average actual flow conditions and to the results obtained in forecast flow conditinos. Under this standard, the model parameters show type 3 sensitivity. Changing a parameter changes the calibration and results of the predictive simulation. If the model is properly calibrated, the results are deemed to be reliable.

Given this, the most significant points are as follows:

- hydraulic conductivity of layer 1 of the model is the most sensitive parameter of the model; it is not possible to calibrate the model without combinations of hydraulic conductivity and recharge; in view of the probable range of values for this parameter obtained from many trials, the few possible combinations that would allow the model to be calibrated would all generate similar results; the hydraulic conductivity of the other layers is also sensitive in the model, but less so;
- recharge and evapotranspiration type boundary conditions are also sensitive, as they create the flow field in which the study site is located; as mentioned above, they are related to the hydraulic conductivity parameter.

While other combinations of parameters might lead to a similar calibration, the hydraulic conductivity used, as well as the specified head boundary conditions, could be considered to be those most representative of the actual flow conditions. The geometric mean of the on-site test results is also similar to the hydraulic conductivity used.

10.6 SIMULATIONS AND RESULTS

Once the model was calibrated, the first steady state simulation performed was designed to reproduce the initial flow conditions, namely those existing prior to pit development. Figures 10.11 and 10.12 show representative piezometric maps of initial groundwater flow conditions; they can be seen to fit very well with the site topography, as observed in the monitoring wells.

For the second simulation, only the drain boundary conditions representing the pit were added. The heads were set at the base of each unit intersected, to a depth of 250 m, being an elevation of approximately 200 m. This was also a steady state flow simulation. Figures 10.13, 10.14 and 10.15 present the piezometric results, while Figure 10.16 shows the distribution of the resulting drawdowns. The maximum distance from the pit at which drawdown would fall below 0.5 m range from 500 to 1,000 metres, depending on the model. Drawdown intensity would be nearly 200 m in the immediate vicinity of the mine.

Finally, examination of the ZONE BUDGET module of the Visual *MODFLOW* software allows the rate of long-term infiltration into the mine to be estimated (once steady state flow is reached). Based on possible parameter combinations that accurately reflect actual piezometer levels, the infiltration rate into the pit could range from 1,400 to 2,800 m^3/day. Figures 10.12 to 10.16 indicate that drawdowns are relatively low due to the rugged relief on the site and the low hydraulic conductivity of the bedrock at depth. Within this zone, there are no sensitive environments that would be threatened by the lowering of the groundwater level.

In terms of groundwater users, no catchment facilities have been identified within the boundaries of the area of influence of the mine, and no impact is therefore expected. However, drawdown should be taken into account when selecting the site for the drinking water well to supply the mine site buildings.

10.7 PROJECT IMPACT ON WATER QUALITY

Water quality is expected to be affected by two things: the mixing of water from the pit with the surface water into which it will be discharged, and the injection of potentially contaminated water into the groundwater via the tailings, and via the pit once it fills at the end of the project.

In relation to the discharge of reclaim water from the pit, groundwater meets all the *Directive 019* discharge criteria, even if it were to be released untreated. In practice, however, the water pumped from the pit may contain hydrocarbons and nitrogen residue from explosives, and it will therefore be sent to the fine tailings pond before being transferred to the polishing pond. It will not be released into Lac Denis until it meets all the discharge criteria.

In terms of flow, the volume of water collected daily will by and large be recycled in the mineral processing circuit. It is therefore highly unlikely that the water collected will have any impact on the local water network.

In terms of groundwater quality, piezometric maps show that the pit will be the aquifer outlet during the life of the operation, and can therefore not emit contaminants. Moreover, in relation to the tailings and polishing pond, virtual particle tracking (see Figure 10.14) shows that any potentially-contaminated water that reaches the bedrock would flow downward and towards the pit, where it would eventually be collected. For the coarse tailings and waste rock piles, virtual particle tracking (see Figure 10.17) shows that any potentially-contaminated water would flow northwest. As the groundwater level is very close to surface in this area, which is at the foot of a hill, the infiltration potential is very low and the leached water would very quickly discharge into ditches built for this purpose.

It will therefore be impossible to contaminate the groundwater as long as pumping takes place. Once mining activities cease, however, the pit will gradually fill up until a lake forms, in equilibrium with the surrounding topography. If contaminants (metals, hydrocarbons and others) are present, they may migrate through the more permeable units. It is therefore important that groundwater quality be monitored in observation wells. If any contamination is detected, the pit could be maintained as a hydraulic trap, with the water continuing to be treated until it meets the quality criteria.

10.8 CONCLUSION

The hydrogeological conditions of the mine site located southeast of Lac Chibougamau were determined on the basis of the work, tests and analyses done for the BlackRock project. The conclusions are as follows:

- The hydrostratigraphic units identified consist of glacial till and bedrock. The thickness of the surficial deposits ranges from nil to 5 metres in the area of the mine, while it is over 15 m in the area of the rail transfer site.
- Variable-head permeability tests show that till permeability is in the order of 10^{-4} cm/s in the area of the mine site. The hydraulic conductivity is of the same order of magnitude in the first 15 m of bedrock, but decreases with depth. The bedrock does not appear to be linked to the major tectonic structures mapped in the area.
- The piezometric surveys performed indicate a flow direction that conforms closely to the topography. Recharge zones are located in topographic peaks, while the aquifer discharges through seeps at the base of the mineralized hill and by surface runoff.
- Groundwater condition ranges from aerobic to anaerobic. The groundwater has a slightly alkaline pH, is poorly mineralized and meets the *Directive 019* discharge criteria.
- Drawdown is not expected to have a significant impact as the environment affected by drawdown has been greatly altered by mining activities (tailings and waste rock piles, roads, infrastructure, etc.).
- No significant impact on water quality is anticipated. Despite the fact that the till does not constitute an impervious barrier to water flow from the tailings, groundwater that infiltrates from the fine tailings and polishing pond will flow to the pit. Very little infiltration is expected under the waste rock and coarse tailings piles. Water levels in this area are in fact close to surface, as these piles are in the groundwater discharge zone. Such exfiltration would therefore surface quickly and could be collected in drainage ditches. Any impact on groundwater quality would only occur once the pit fills up.

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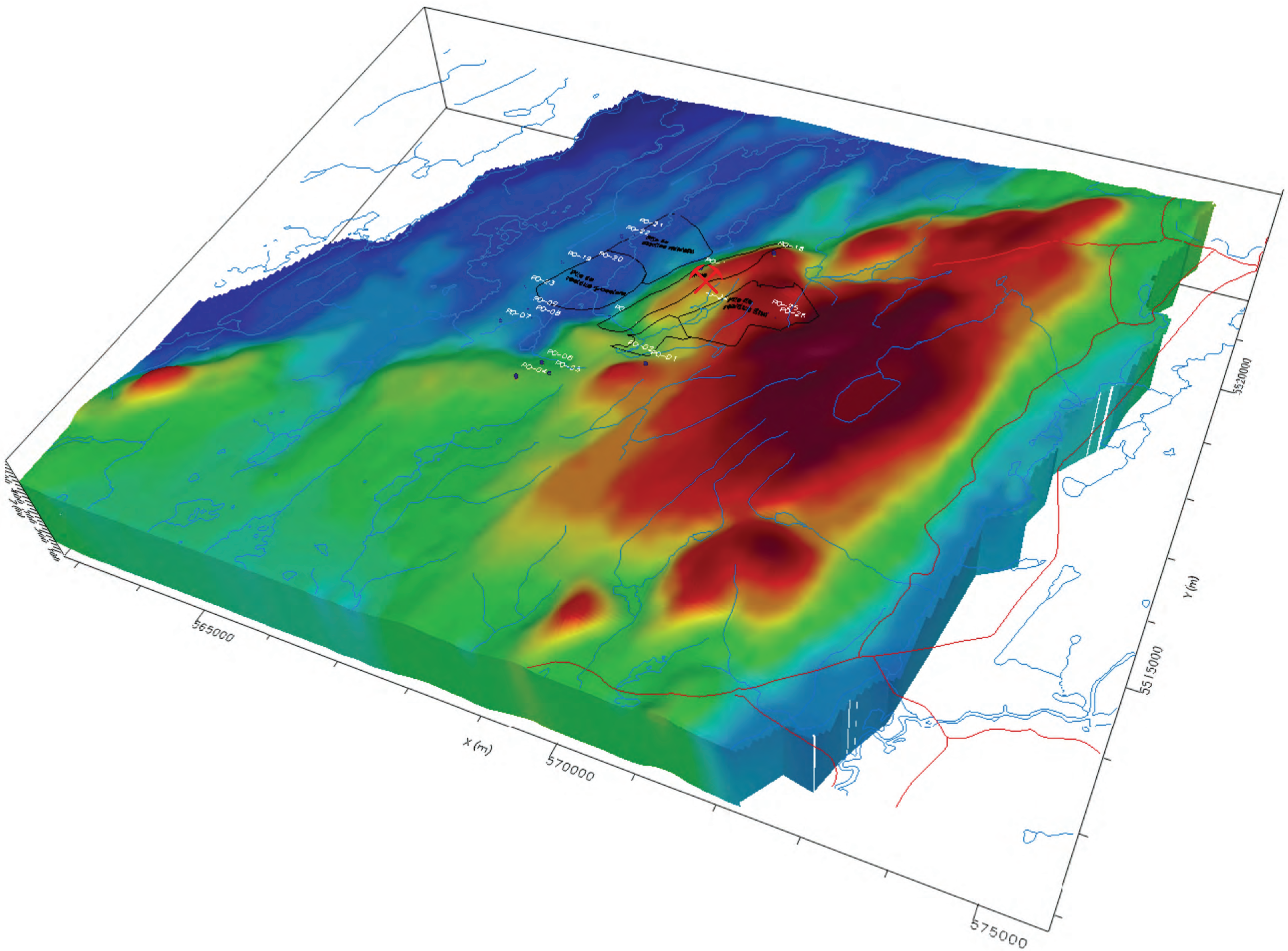

Légende

Piézométrie

380	
405	
430	
455	
480	
505	
530	

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FIGURE 10.11: PIÉZOMÉTRIE INITIALE MODÉLISÉE
- VUE EN BLOC-DIAGRAMME -

Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

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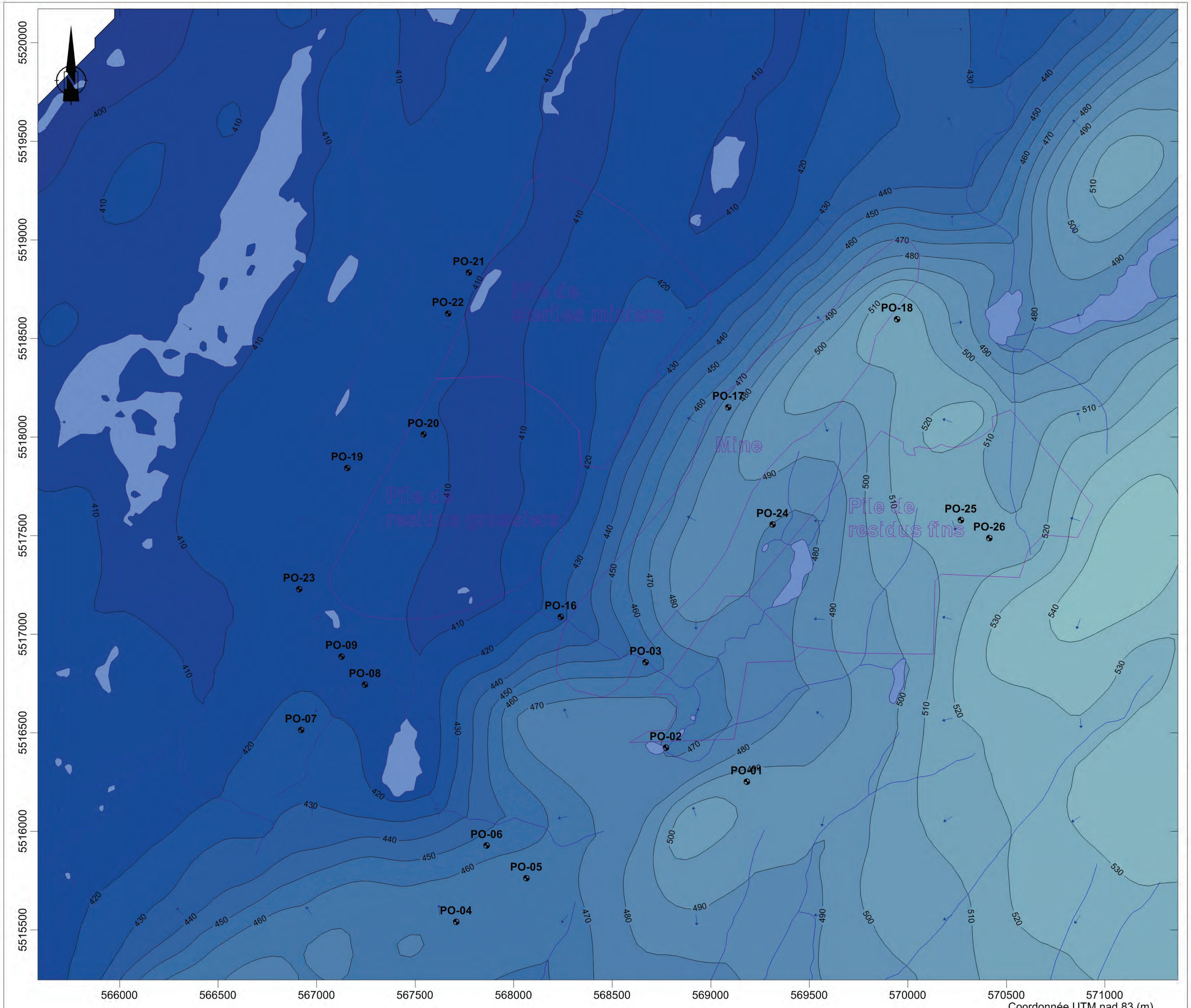
Date

Le 31 octobre 2011

Échelle

1 : 50 000



Légende

Puits d'observation

Piézométrie (mètres au dessus du niveau de la mer)

550
540
530
520
510
500
490
480
470
460
450
440
430
420
410
400
390
380

0 500 1000 1500 2000

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.12: PIÉZOMÉTRIE INITIALE MODÉLISÉE
- VUE EN PLAN -

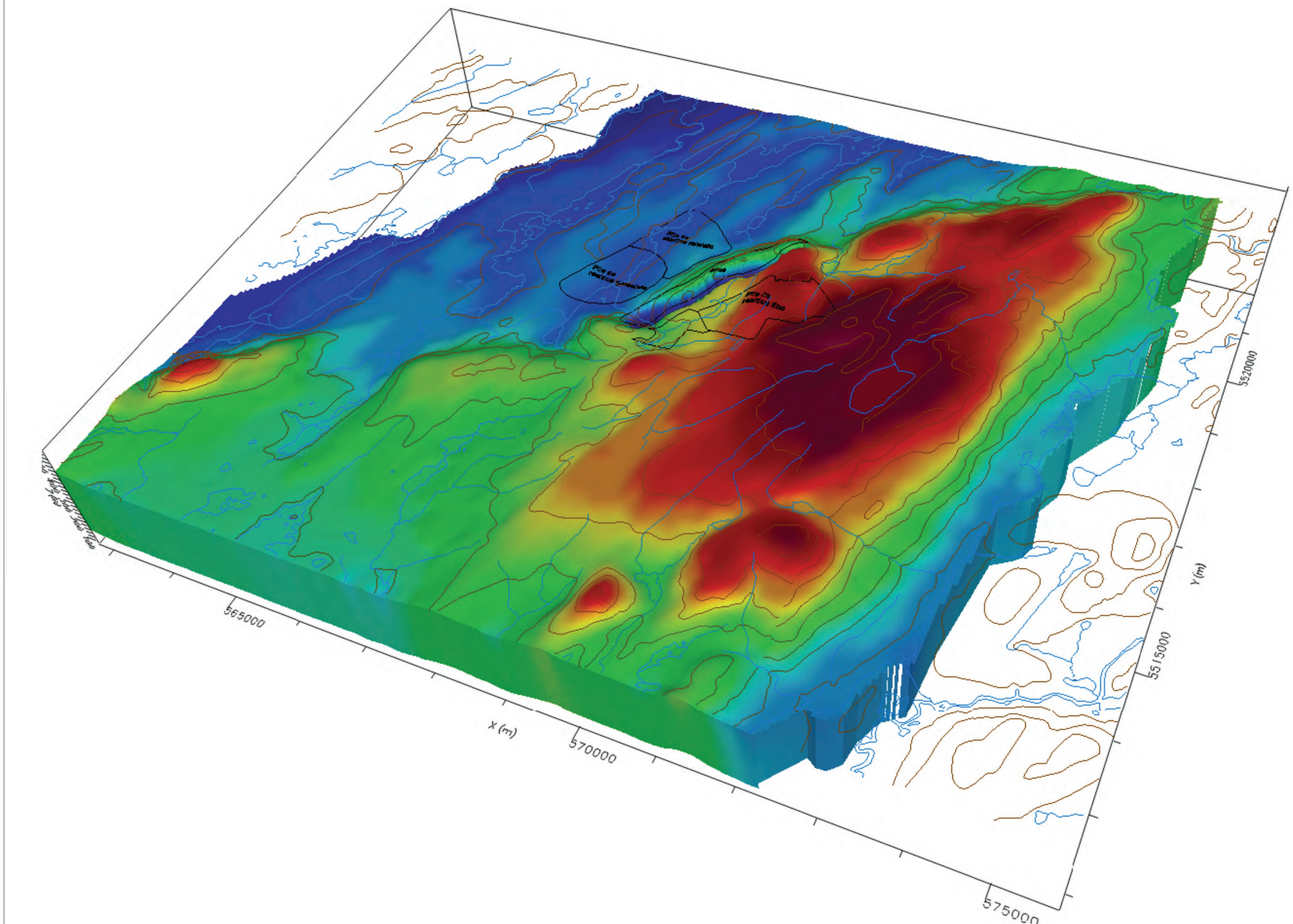
Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 20 000



Légende

Piézométrie

- 380
- 405
- 430
- 455
- 480
- 505
- 530

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.13: PIÉZOMÉTRIE FINALE MODÉLISÉE
- VUE EN BLOC-DIAGRAMME -

Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
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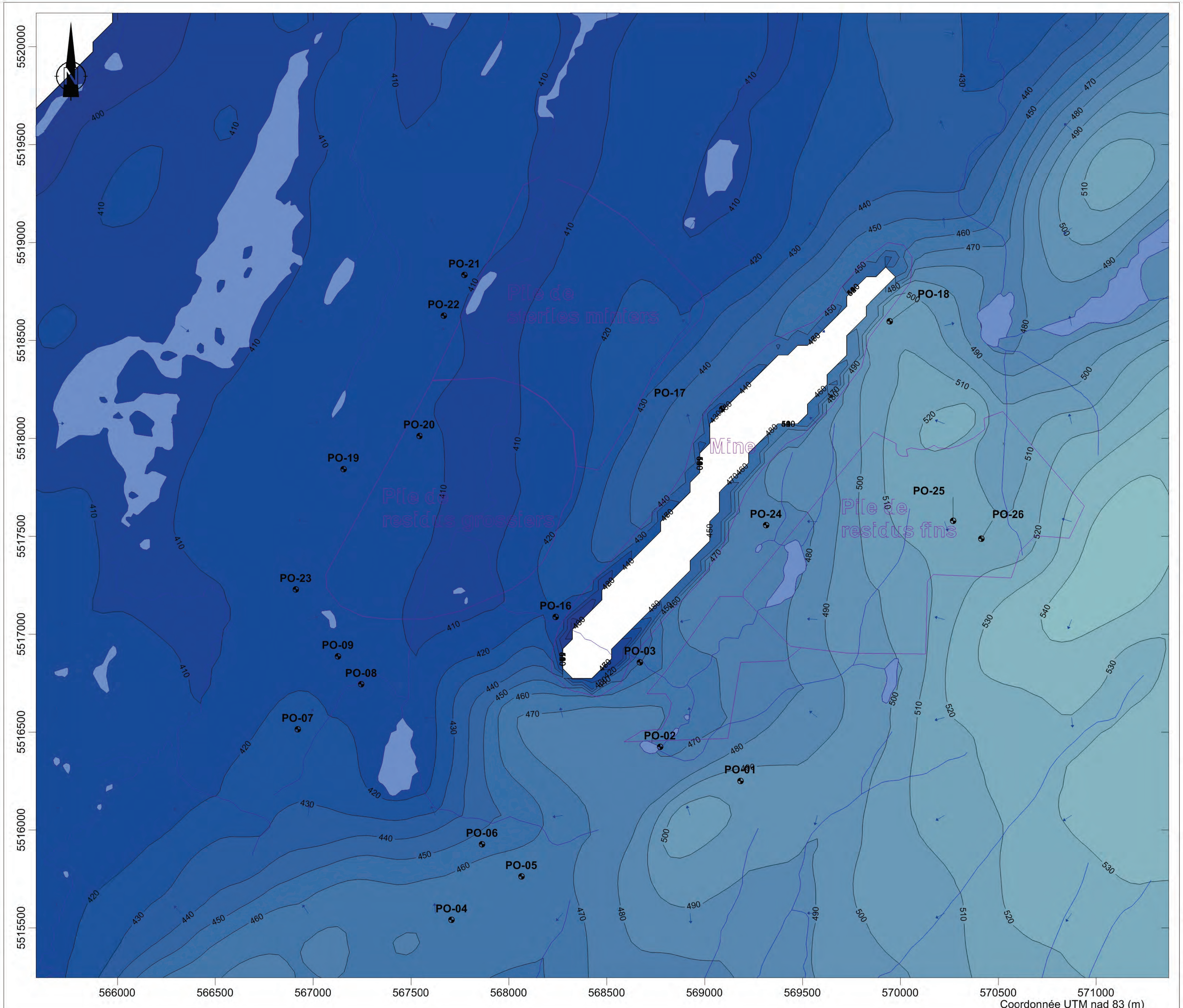
Date	Échelle
Le 31 octobre 2011	1 : 50 000



Légende

Puits d'observation

Piézométrie (mètres au dessus du niveau de la mer)

550
540
530
520
510
500
490
480
470
460
450
440
430
420
410
400
390
380

0 500 1000 1500 2000

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.14: PIÉZOMÉTRIE FINALE MODÉLISÉE
- VUE EN PLAN -

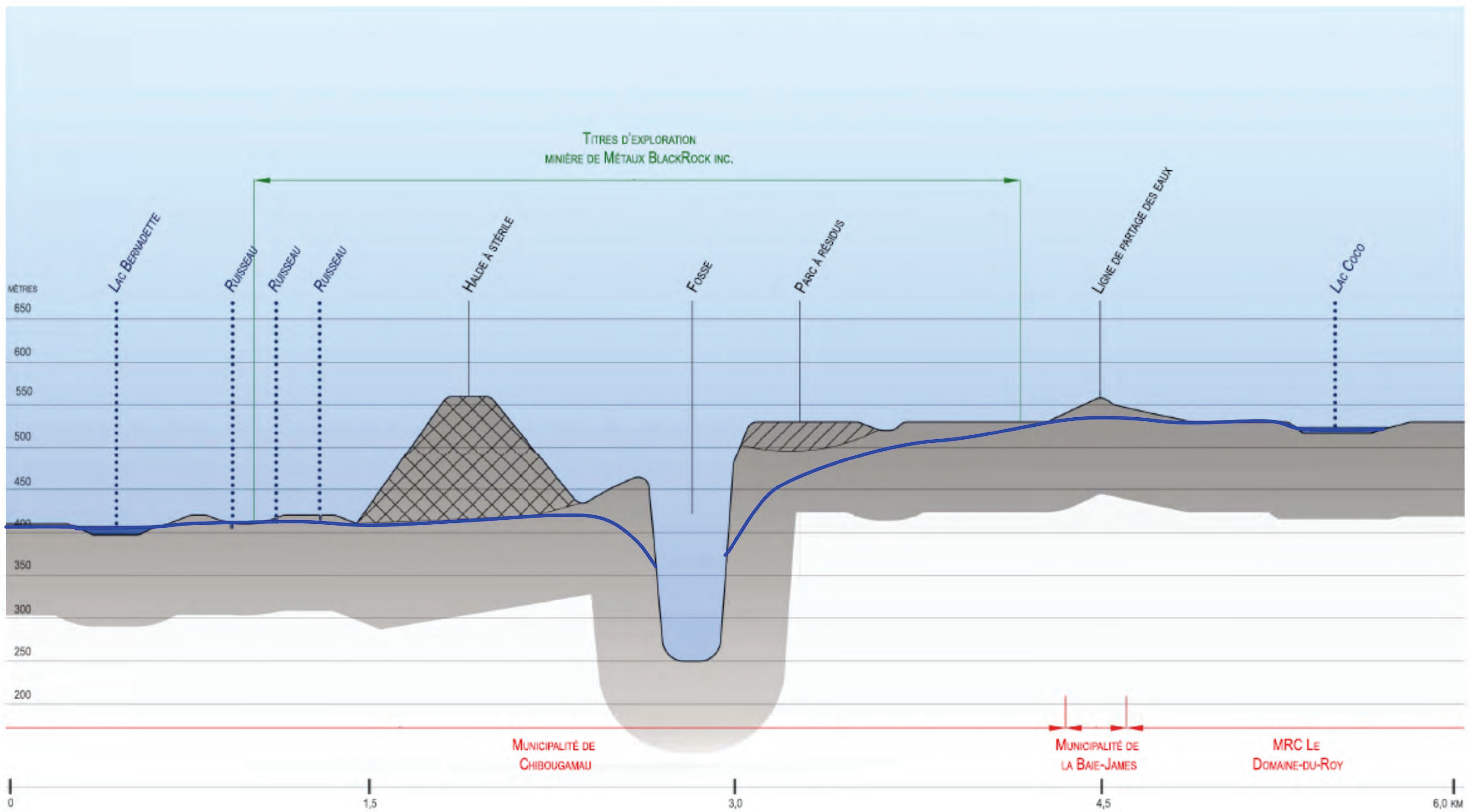
Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 20 000



Échelle verticale 1: 5 000
Échelle horizontale 1: 20 000
Exagération verticale de 4x

Légende

Piézométrie (mètres au dessus du niveau de la mer)

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.15: PIÉZOMÉTRIE FINALE MODÉLISÉE
- VUE EN COUPE -

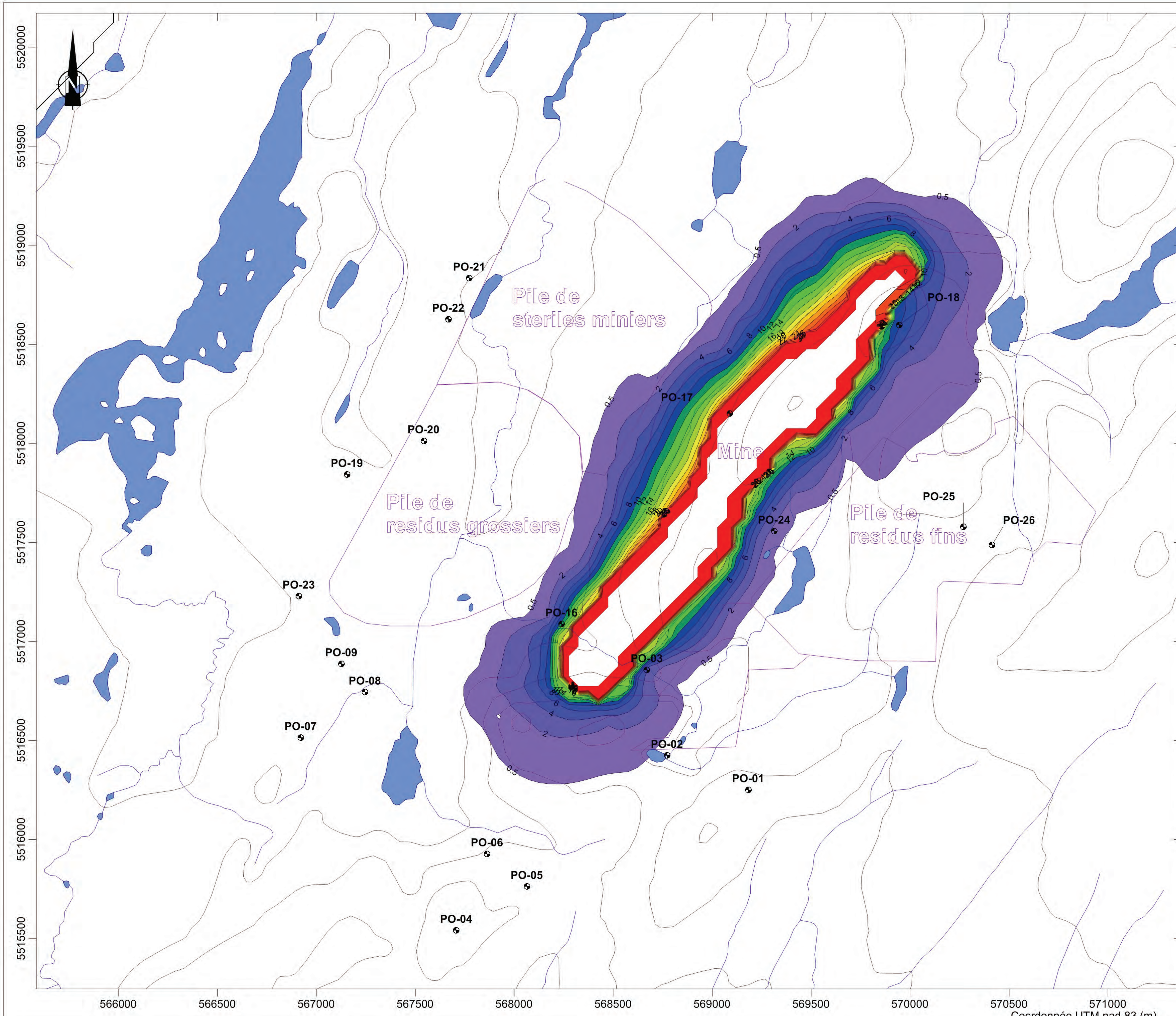
Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 40 000



Légende

Puits d'observation

Rabattement (mètres)

30, 28, 26, 24, 22, 20, 18, 16, 14, 12, 10, 8, 6, 4, 2, 0.5

0 500 1000 1500 2000

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.16: RABATTEMENT FINAL MODÉLISÉ
- VUE EN PLAN -

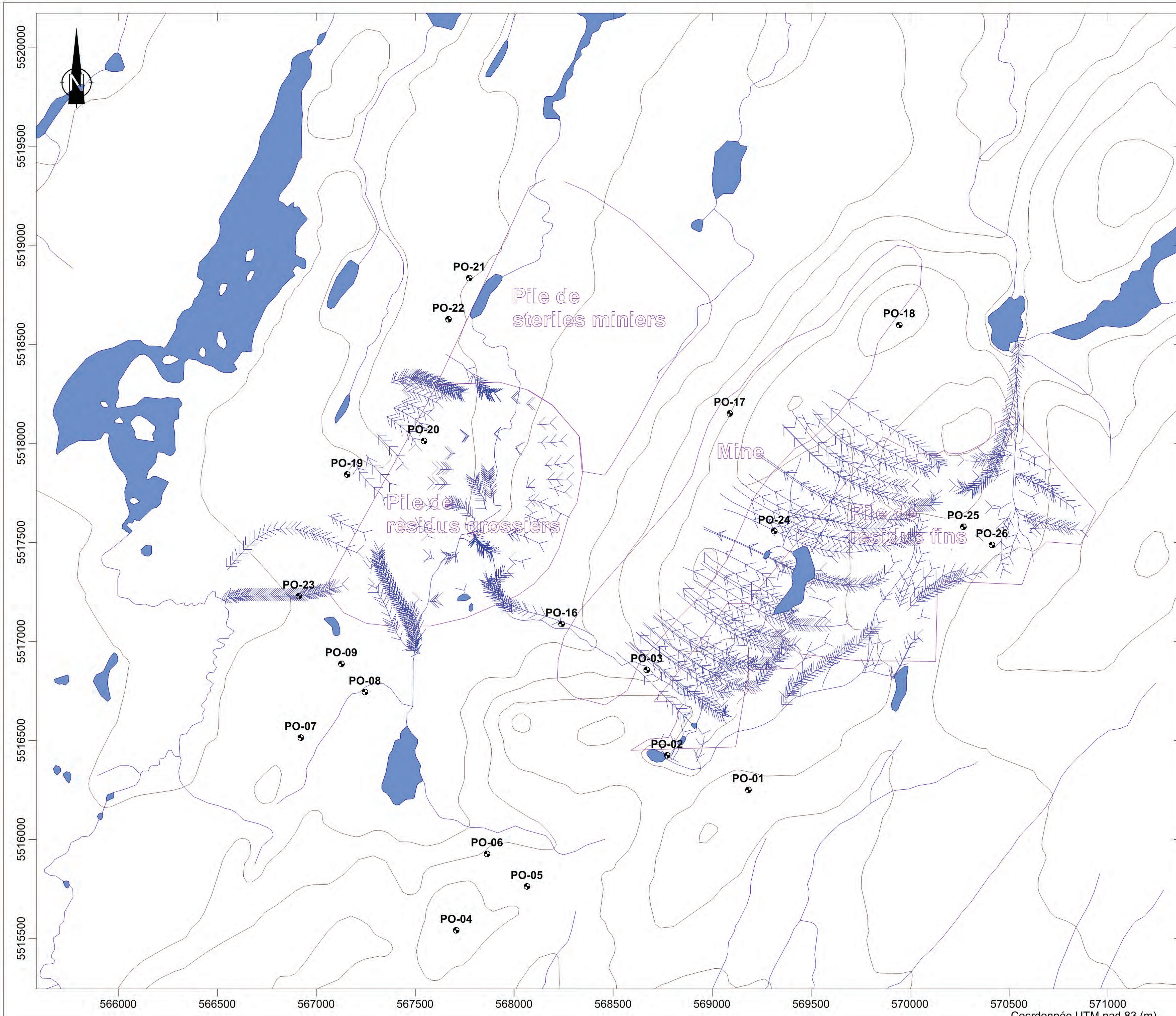
Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 20 000



Légende

- Puits d'observation
- Lignes d'écoulement à partir des parcs à résidus miniers

0 500 1000 1500 2000

Fond cartographique du MRN Canada
carteS 32G16 ET 32h13

ENTRACO
Conseillers en environnement

Titre

FIGURE 10.17: TRAJECTOIRE MODÉLISÉE
À PARTIR DES AIRES D'ACCUMULATION DE RÉSIDUS MINIERS
- VUE EN PLAN -

Projet

PROJET MINIER BLACKROCK
CHIBOUGAMAU

Interprétation et dessin

Yves Leblanc, ing. géo.
M.Sc. Hydrogéologue

Date	Échelle
Le 31 octobre 2011	1 : 20 000

11. RISK MANAGEMENT, HEALTH AND SAFETY

11.1 BLACKROCK CORPORATE POLICY

Health and safety and environmental management are a priority for BlackRock. This is clearly reflected in the company's corporate policy:

BlackRock makes every effort to ensure that management of quality, health & safety and the environment is an integral part of its corporate culture and operations. BlackRock considers that the best route to full compliance is enhanced response to growing demands from the markets and government authorities for risk management in the areas of worker safety and environmental impact.

Accordingly, BlackRock maintains that its operations and local communities depend on a healthy environment, which is essential for everyone. BlackRock aims for excellence, leadership and sustainable operations, and instills an employee work ethic that emphasizes social integrity and continuous improvement of environmental performance.

To do this, BlackRock incorporates health & safety and environmental prevention into its corporate decisions and requires that its employees show respect for health & safety and the environment through optimal resource management, minimization of environmental impact, sound risk management, implementation of health & safety and environmental management systems, support of accident and incident prevention efforts, health & safety and environmental performance assessments, constructive collaboration with regulatory authorities, unscheduled health & safety and environmental audits, and reporting of results to the board of directors, shareholders, employees and communities concerned.

BlackRock is committed to providing a safe workplace and the material and training required for employees to carry out their work safely. BlackRock has permanent and effective programs and methods in place to achieve regulatory compliance and set high-quality standards, as well as a broad system of health & safety and environmental management that applies to all its facilities and areas of activity.

To ensure optimal project management and compliance with BlackRock's corporate policy, an inventory of risks related to health and safety and the environment was drawn up, which then allowed the identification of potential technological accidents. A strategy was then devised to limit the occurrence of accidents and minimize the consequences of accidents that cannot be avoided.

All employees will receive information on the risk management plan during training sessions, and those with an active role to play in environmental emergency response will receive full training. The plan will include environmental emergency responses for the construction and operation phases. Responses to any environmental emergencies that occur during or after mine closure will be included in the closure plan required by the *Mining Act* (c M-13.1).

11.2 IDENTIFICATION OF POTENTIAL ACCIDENTS

Mining drove the regional economy up until very recently. Since the early 1950s, there have been 24 mines in the Chibougamau-Chapais area that have produced 74 million tonnes of ore.

To help weight the risks related to the BlackRock mining project, a review was carried out of all the technological accidents identified by the MDDEP from 1990 to 2006 in the area of Chibougamau and Chapais. This indicated that, of the 134 technological accidents identified, only 14 of the reported incidents, or 10%, were attributable to mining activities.

These 14 technological accidents comprised 10 hydrocarbon spills, 2 contaminated water spills, 1 paste-backfill spill and 1 chemical spill. Some 71% of technological incidents reported by mining companies are related to hydrocarbon spills. All spills occurred directly on or in very close proximity to mine sites.

Trucks carrying raw materials or concentrate were responsible for two of the hydrocarbon spills. Only one spill involved an oil supplier. Transport and supply were therefore responsible for 30% of incidents related to petroleum products, and the remaining 70% were directly caused by mine operators.

Two of the 14 incidents reported involved spills of contaminated water from tailings facilities, corresponding to 14% of technological incidents reported by mining companies. These two incidents were related to tailings site management.

From a broader perspective, it appears that the vast majority of the 134 technological accidents reported between 1990 and 2006 (for all industries) were also hydrocarbon spills (Table 11.1).

To identify the risks of accidents specific to the BlackRock project, planned mine site activities were examined, along with their interaction with other project components or outside receivers. The causes and environmental effects of potential break-downs and failures were examined for each component. The significance of technological risk was assessed using the methodology presented in Table 11.2, and the significance of consequences depending on the type of incident is presented in Table 11.3. This assessment is limited to the environmental impact of failures and accidents. The impact of such events on employee health and safety is addressed in Section 11.4.

The grid in Table 11.2 shows the methodology commonly used to assess environmental risks for mining operations. Weighting factors were determined from the above-mentioned local statistics and as a function of the experience acquired during mine construction and operation. The weighting factors also reflect project specifics, such as its remoteness from communities, its location in an area where the mining industry is already established and accepted, and the intensity of road traffic it will generate.

Table 11.1 List of Technological Accidents for Chibougamau and Chapais (1990 to 2006)

Category	Product Name	Litres	Company Involved	Date	Location	City
Fuel, heating oil and lubricants	Diesel	20	Pétroles M.J. (Esso)	2000-10-25	551 Route 167 South, at the company garage	Chibougamau
	Diesel	50	Pétroles M.J. (Esso)	2001-06-05	Loading yard	Chibougamau
	Fuel oil No.2	20	Pétroles M.J. (Esso)	2000-12-14	Esso loading area	Chibougamau
	Diesel	1,118	Pétroles M.J. (Esso)	2003-12-11	Route du Nord - Km 118	Chibougamau
	Diesel	125	Pétroles M.J. (Esso)	2004-10-20	Pétroles M.J. inc	Chibougamau
	Diesel	10,000	Pétroles M.J. (Esso)	1997-02-24	Km 7 of the Route du Nord in Chibougamau L-28, Chemin des chantiers (du moulin)	Chibougamau
	Diesel	1,000	Pétroles M.J. (Esso)	2004-11-09	Esso depot	Chibougamau
	Diesel	60	Pétroles M.J. (Esso)	2005-05-04	551 Route 167 South, Truck loading and unloading zone	Chibougamau
	Heating oil	400	Pétroles M.J. (Esso) depot	1995-12-22	Cottage on the shore of Lac Caché	Chibougamau
	Diesel	20	Pétroles M.J. (Esso)	1996-05-23	Esso area	Chibougamau
	Heating oil	44	Pétroles M.J. (Esso)	1998-10-26	Route 113	Chibougamau
	Gasoline	6,500	Pétroles M.J. (Esso)	2003-09-05	Barrette-Chapais fuel depot, ditch off Route 113, Km 546	Chapais
	Heating oil	50	Pétroles M.J. (Esso)	1995-03-16	Residence	Chapais
	Heavy fuel oil (6-C) Bunker	50	Pétroles M.J. (Esso)	2004-12-22	At the loading pump	Chibougamau
	Unleaded gasoline	200	Esso Pétroles M.J.	1995-10-30	Esso depot, 551 Route 167 South	Chibougamau
	Diesel	278	Shell Canada Ltd.	1992-09-14	Chibougamau depot 919, 3e rue CP 277	Chibougamau
	Diesel	250	Shell Canada Ltd.	1993-03-17	MSV Resources Inc.	Chibougamau
	Gasoline		Les Pétroles Belzile	1995-11-29	Residences adjacent to the service station	Chibougamau
	Dyed diesel	2	Transport Forestville	2003-03-27	Chibougamau Shell depot	Chibougamau
	Diesel	200	Transport Malo	2004-10-14	Property next to the Pétrole Belzile depot	Chibougamau
	Diesel	50	Transport GMGL inc.	2006-07-18	Traces of diesel on Rue St-Luc	Chibougamau

Category	Product Name	Litres	Company Involved	Date	Location	City
Fuel, heating oil and lubricants	Diesel	220	Transport Fidèle inc.	1999-01-20	Motel du Lac Caché	Chibougamau
	Dyed diesel	50	Transport RBR inc.	2002-11-28	Chapais community centre parking lot, 188 Bd. Springer	Chapais
	Diesel	500	R.S.T Industrie	2003-07-03	Chapais Énergie	Chapais
	Diesel	200	Équipement CRD inc.	2006-01-16	Route 113, Km 308	Chapais
	Diesel	1	Transport Doucet&fils	2006-03-29	Route 113, Km 314	Chapais
	Diesel and motor oil		Entreprise D.Morin and Transport P.B.J.	2002-10-17	Route 167, Km 217	Chibougamau
	Diesel	15	H-Q TransÉnergie	2006-09-13	Service Centre H-Q, 511 Route 167 South	Chibougamau
	Diesel	45	Hydro-Québec	1994-07-13	83 km north of Chibougamau, Route 167	Chibougamau
	Diesel	800	Hydro-Québec	1993-07-13	Abitibi Substation	Chapais
	Diesel	1	Hydro-Québec	1995-09-25	Abitibi Substation	Chapais
	Diesel	5	Hydro-Québec	1997-07-11	Lac Abitibi, Route 113, Km 284	Chapais
	Diesel		Canadian National (CN)	1990-05-17	1,000 feet from the Chibougamau train station	Chibougamau
	Diesel	4	3340147 Canada inc.	2007-08-07	Km 166, Chibougamau park	Chibougamau
	Diesel	600	9162-9717 Québec inc.	2006-05-15	Route 167, Km 226	Chibougamau
	Heating oil and various hydrocarbons	800	9088-0576 Québec inc.	2005-07-13	948 and 948-A, 3e Rue	Chibougamau
	Fuel oil No.2	1,000	9041-7320 Québec inc.	2001-12-09	Outside, in the garage	Chapais
	Heating oil	28,350	Camchib Mine Inc.	1991-02-23	Camchib mine	Chibougamau
	Diesel	17.5	Meston Resources	1993-11-05	Joe Mann mine	Chibougamau
	Heating oil	2,250	Meston Resources	1994-09-27	Main mine site boiler room	Chibougamau
	Diesel	13,700	MSV Resources + Chibou-vrac inc.	1995-03-02	Ore stockpile, about 5 km before the Témiscamie River bridge, Km 400, Route 167	Chibougamau
	Diesel	50	Transport Saguelac Meston Resources	1997-07-09	Main site	Chibougamau
	Diesel		Forage Pelletier	1991-06-01	Near Lac Caché	Chibougamau
	Diesel		Chantier Chibougamau	2007-02-20	Km 386 Route 167, Chibougamau	Chibougamau

Category	Product Name	Litres	Company Involved	Date	Location	City
Fuel, heating oil and lubricants	Heating oil	3,200	Domaine Alpha (1993) enr.	2004-11-22	100 5e Avenue Nord	Chibougamau
	Diesel	85	M. Claude Asselin	2000-05-14	M. Asselin's garage, Lac Caché, Route 167	Chibougamau
	Diesel	200	Les litières du Lac St-Jean inc.	1997-12-04	Route 113, Km 354.6	Chibougamau
	Hydraulic oil	50	Hydro-Québec	2000-03-29	Abitibi Substation	Chapais
	Hydraulic oil	25	Hydro-Québec	2002-06-03	Abitibi Substation, east of breaker 700-62 Phase C	Chapais
	Hydraulic oil	25	Hydro-Québec	2002-06-05	Abitibi Substation	Chapais
	Hydraulic oil	40	Hydro-Québec	1994-06-20	Abitibi Substation	Chapais
	Hydraulic oil	30	Hydro-Québec	1995-06-20	Abitibi Substation	Chapais
	Hydraulic oil	10	Hydro-Québec	1996-07-03	Abitibi Substation	Chapais
	Hydraulic oil	150	Hydro-Québec	1998-07-08	Abitibi Substation, Route 113, Km 289	Chapais
	Hydraulic oil	12	H-Q TransÉnergie	2006-10-06	Abitibi Substation, circuit-breaker 700-09 phase A, head 4	Chapais
	Hydraulic oil	4	H-Q TransÉnergie	2006-10-06	Abitibi Substation, Km 290 Route 167 North	Chapais
	Hydraulic oil		H-Q TransÉnergie	2006-11-04	Abitibi Substation	Chapais
	Hydraulic oil	60	H-Q TransÉnergie Transport Nord	2001-10-19	Abitibi Substation	Chapais
	Hydraulic oil	5	H-Q TransÉnergie Transport Nord	2006-07-26	Abitibi Substation Km 290 Route 113	Chapais
	Hydraulic oil	30	H-Q Territoire Nord-Est	2005-08-01	123, 2ème avenue	Chibougamau
	Hydraulic oil	50	Meston Resources Inc.	1998-02-11	Meston concentrator - Île Merril, Lac Doré (main site)	Chibougamau
	Hydraulic oil	130	Meston Resources Inc.	1998-05-22	Meston concentrator	Chibougamau
	Hydraulic oil	60	Barrette-Chapais Ltd. - sawmill	2003-06-16	Barrette-Chapais sawmill (Yard)	Chapais
	Esso gear oil	20	Hydro-Québec	1992-08-18	Parking lot for Hydro vehicles	Chibougamau
	Motor oil	20	Hydro-Québec	1996-10-02	Abitibi Substation	Chapais
	Transmission fluid	20	Polaire CCm inc.	2003-04-16	117, rue Joe-Mann (in the street)	Chibougamau

Category	Product Name	Litres	Company Involved	Date	Location	City
Used oils	Used oil		MSV Resources, Copper Rand Mine	1995-05-25	Shore of Lac Doré across from the mine site	Chibougamau
	Used oils	400	MSV Resources	1996-05-20	Copper Rand site, Lac Doré	Chibougamau
	Used oils, motor oil		Construction Ex-Terre inc.	1995-05-26	Ruisseau David between 3e Rue and the railway	Chibougamau
	Used oils, motor oil	10	Plomberie Chibougamau	2000-08-06	320 2e rue, backyard	Chibougamau
	Used oils		Automobiles Ford Mercury Chibougamau inc.	1993-05-26	Garage, 973 A 3e rue	Chibougamau
Chemical Products	Hydrochloric acid	200	Meston Resources – Camchib Mine	1995-09-27	Main site (mill)	Chibougamau
	Ethylene glycol	180	Hydro-Québec	2003-02-11	Chibougamau Substation, 30-35 km south of Chibougamau on Route 113	Chibougamau
	Ethylene glycol	60	Hydro-Québec	1995-10-12	Abitibi Substation	Chapais
	Glycol	160	H-Q TransÉnergie-Direction Transport Nord	2006-02-19	Chibougamau Substation, cooler CLC 12	Chibougamau
	Solvent		Ville de Chibougamau	2005-01-20	Downtown Chibougamau	Chibougamau
Gas	Propane	300	Les Pétroles M.J.inc	2004-07-02	Chez Raymonde restaurant	Chibougamau
	Propane	227	Propane M&M, Nutrinor Division	2002-11-12	Chantier Chibougamau (yard)	Chibougamau
	Propane		M&M Propane	1995-01-24	Propane tank, Motel Lac Caché	Chibougamau
Ore	Non acid-generating ore + hydraulic oil	40,000	Chibou-vrac inc.	1996-04-18	Km 353.5, Route 167 between Chibougamau and the mine road	Chibougamau
Water	Contaminated water		Campbell Resources Inc.	2003-04-22	Old tailings site point #24 and final effluent point #20 Main site	Chibougamau
	Water (tailings pond)	445	Campbell Resources Inc.	2004-03-03	Main mine	Chibougamau
	Drinking water (E-Coli and total coliforms		Municipality of Chapais	2004-04-29	169 9e Avenue	Chapais
	Wastewater		Municipality of Chapais	2001-11-06	Chapais landfill	Chapais

Source: Alliance Environnement – February 2008

Table 11.2 Methodology for Assessment of Technological Risk and Potential Consequences

Criteria	Scope	Reversibility	Importance for the public	Probability of occurrence
Definition	Extent of the physical area affected.	Speed at which the biophysical environment can recover with or without human assistance	Local and regional public perception of the incident.	Assessment of event frequency
Weighting (100%)	30%	10%	30%	30%
Significance of potential impact by criteria				
1	Isolated	Effects from the incident can be rectified within a month.	Event that can easily be managed by local resources.	Highly unlikely
2	Local	Can be restored within a year.	Event that will require the intervention of outside specialists.	Likely to occur once during the life of the mine and processing plant.
3	Regional	Will take more than one year to restore.	Event that should result in site closure.	Likely to occur more than once during the mine life.
Significance of potential impact				
Low	Weighted total between 0 and 1.5			
Medium	Weighted total between 1.6 and 1.9			
High	Weighted total between 2.0 and 3			

Table 11.3 Significance of Consequences of Potential Technological Accidents

Criteria	Scope	Reversibility	Importance for the public	Probability of occurrence	Impact significance*
Weighting	0.3	0.1	0.3	0.3	1 to 3
Accident					
Petroleum Products					
Oil spill during road construction	2	2	2	2	2.0
Spill during transport of petroleum products	2	2	2	2	2.0
Oil spill during the use of roads (transport trucks)	1	2	2	3	2.0
Major oil tank spill	2	2	2	1	1.7
Leak from oil tanks and ancillary equipment	1	1	2	3	1.9
Oil spill in garage or other workshop	1	1	1	3	1.6
Oil spill in the pit, or on haulage roads or stockpiles	1	1	1	3	1.6
Uncontrolled leachate during contaminated soil storage	1	1	2	2	1.6
Reagents					
Spill during reagent transport	2	2	2	2	2.0
Spill at the plant during reagent handling	1	1	1	3	1.6
Emission of uncontrolled explosive dust at the plant	1	1	2	3	1.9
Fire or explosion inside the plant or reagent warehouse	1	2	2	2	1.7
Reagent tank leak	1	2	2	2	1.7
Hazardous Waste					
Hazardous waste storage site spill	1	1	1	3	1.6
Hazardous waste storage site fire or explosion	1	1	2	2	1.6
Explosives					
Unexploded or partially exploded explosives left in the pit	1	1	1	3	1.6
Spill of raw materials used to manufacture explosives	1	1	1	3	1.6
Geotechnical Stability					
Discharge of liquids due to dam failure	3	2	2	2	2.3

Criteria	Scope	Reversibility	Importance for the public	Probability of occurrence	Impact significance*
Weighting	0.3	0.1	0.3	0.3	1 to 3
Accident					
Discharge of solids due to dam failure	2	2	2	1	1.7
Bench collapse: pit, waste rock or coarse tailings pile	1	2	2	1	1.4
Waste rock slide	1	1	2	2	1.6
Other					
Major fire or explosion at the plant	2	3	3	1	2.1
Spill of secondary chemical products: workshop and garage	1	1	1	3	1.6
Spill due to break in process water pipeline or ancillary equipment	1	1	1	3	1.6
Process water reservoir leak	1	1	1	1	1
Sewage spill	1	1	1	2	1.3
Spill due to break in fine tailings pipeline	1	1	1	3	1.6

***** Impact significance is the product of 'score per criterion' x 'weighting factor' (eg: accident: spill during road construction: (3 x 0.3) + (2 x 0.1) + (2 x 0.3) + (3 x 0.3) = 2.6

The information in Table 11.3 allows technological accidents to be grouped according to their potential effects described below.

Major potential impact

Project activities for which there is a risk of technological accidents with a severe environmental impact are:

- road construction **(hydrocarbons)**;
- transport of petroleum products **(hydrocarbons)**;
- transport of raw materials and ore concentrate **(hydrocarbons);**
- reagent transport **(uncontrolled chemical emissions)**;
- tailings and polishing pond management **(liquid spill of metals and suspended solids)**;
- process management **(fugitive chemical emissions, fire or explosion)**.

Moderate potential impact

Project activities for which there is a risk of technological accidents with a moderate impact on the environment are:

- on-site management of petroleum products **(major hydrocarbon spill)**;
- on-site storage of petroleum products **(hydrocarbon leaks)**;

- oil spill in workshops or the garage **(hydrocarbon leaks)**;
- oil spill in the pit or on haulage roads or stockpiles **(hydrocarbon leaks)**;
- contaminated soil management **(fugitive hydrocarbon emissions)**;
- reagent storage **(uncontrolled chemical emissions)**;
- reagent handling **(chemical leaks)**;
- reagent handling **(emissions of explosive chemical dust)**;
- reagent handling **(fire or explosion)**;
- hazardous waste **(hydrocarbon or chemical spill)**;
- hazardous waste **(hydrocarbon or chemical fire or explosion)**;
- explosives handling **(fugitive emulsion emissions)**;
- explosives handling **(spill of raw chemical materials)**;
- geotechnical stability **(waste rock slide)**;
- tailings pond management **(spill of solid tailings, metals and suspended solids)**;
- process water management **(water spill)**;
- tailings management **(tailings pipeline break, spill of metals or suspended solids outside the pond)**;
- management of secondary chemicals **(chemical spill)**.

Minor potential impact

Project activities for which there is a risk of technological accidents with a minor impact on the environment are:

- geotechnical stability **(pit walls, waste rock and coarse tailings piles)**;
- process water storage **(process water reservoir leak)**;
- sewage water management **(wastewater spill)**.

11.3 ACTIVITIES WITH ASSOCIATED ENVIRONMENTAL RISK

Activities where a technological accident or failure could have a major or moderate impact on the environment will be monitored more closely and on a more regular basis. Compliance with applicable environmental laws and regulations is the first step in prevention. An environmental compliance auditing program will be implemented to ensure that such laws and regulations are respected. Furthermore, the incident risk for all phases of the project will be reduced through high engineering standards, high-performance equipment, warning systems and management procedures.

11.3.1 Road Construction

Access and mine (haulage) road construction involves stream crossings and the risk of hydrocarbon spills. To reduce its potential impact, construction work will be carried out in compliance with forest management regulations enacted by the *Ministère des Ressources naturelles et de la Faune* (MRNF, 2000).

In an ongoing effort to reduce the risk of technological accidents, particularly hydrocarbon spills, the following measures will be applied:

- to bid on an offer, contractors must demonstrate that they have pollution liability insurance;
- environmental contractual clauses pertaining to hydrocarbon management will be included in project plans and specifications;
- all construction equipment will be fully inspected for leaks and to make sure they are in proper working order before work begins;
- vehicles in questionable state will not be granted access to the site;
- contractors will be required to keep complete spill kits on site; BlackRock will determine the number of kits required based on equipment type and numbers;
- contractors will be required to have basic safety and response kits in each vehicle in case of spills;
- vehicle refuelling will always take place at least 100 m away from streams;
- environmental considerations will be discussed during pre-construction meetings;
- information regarding adopted measures will be communicated to contractor supervisors and workers;
- current practices and possible improvements will be discussed regularly during weekly toolbox meetings;
- construction work will be subjected to environmental monitoring;
- weekly inspections will be carried out to ensure the equipment is safe for the environment.

11.3.2 Petroleum Product Transport, Handling and Storage

The environmental risks most likely to materialize are those associated with the transport, handling and storage of petroleum products. These risks are strictly controlled by provincial and federal laws and their applicable regulations. Laws and regulations pertaining to petroleum products will be strictly enforced and communicated to personnel in a clear manner.

In keeping with the spirit of current legislation, the risk management program will include the following elements at the design stage:

- plans and specifications for petroleum storage facilities will be signed and sealed by an engineer and installation will be done by an accredited installer;
- plans and specifications will allow for the installation of hydrocarbon separation systems to recover minor leaks in all work areas;
- tanks will be equipped with automatic gauge systems as well as leak detection systems.

An emergency response plan will be prepared prior to the first transfer of petroleum products. This plan will cover transport, supply, handling and distribution activities, and will apply to all reservoirs. It will include:

- a list of personnel in charge, and their roles and responsibilities;

- personnel training criteria;
- a list of emergency equipment and location;
- places where the emergency response plan will be available for consultation at all times;
- how and when personnel are to be alerted;
- response and clean-up measures;
- procedures for communication with public authorities and the general public.

During mining operations, the risk management plan will ensure, among other things, that:

- suppliers are equipped with the same radio communication devices as the ones used by the concentrate transport vehicles;
- suppliers have an obligation to signal their presence to other carriers as soon as they reach road 210 and at specified kilometre posts thereafter;
- handling procedures are implemented for each product;
- access to petroleum products is limited to designated, trained employees;
- suppliers are bound by contract to immediately report all spills resulting from the transfer of petroleum products and any sign of leaks;
- a monthly record of petroleum products is produced;
- storage and distribution equipment is tested annually for leaks.

11.3.3 Tailings and Polishing Pond Management

Tailings pond operation is the mining industry activity most likely to have a severe impact on the environment. The project's three types of solid waste (waste rock, coarse tailings and fine tailings) have a higher neutralizing than acid-generating potential. The most significant environmental risk is dam failure, which would lead to the discharge of metals and suspended solids in the receiving environment. To minimize this risk, the pond is located in the upstream portion of the catchment. It was also designed based on the most pessimistic bearing capacity, precipitation and seismicity scenarios for the region. This aspect of environmental risk is further discussed in Chapter 4. The pond will be managed in accordance with the Mining Association of Canada's *Guide to the Management of Tailings Facilities* (2002). This guide provides for the implementation of operating, maintenance and inspection procedures, as well as documented procedure monitoring.

The risk management plan will ensure that construction and operation are in line with engineering specifications and environmental mitigation measures.

Construction Phase

- Construction of dams for the water supply reservoir (Lac Denis) and the tailings and polishing ponds will be subject to inspections in accordance with design recommendations to ensure compliance with plans and specifications.
- Any departure from the specifications will require regulatory approval.
- Weekly qualitative work progress reports will be submitted to corporate authorities.

- As-built plans will be produced and distributed to all managers responsible for the operation, safety, maintenance and environmental monitoring of the structures.

Operation Phase

A charter of responsibilities will be drafted to define the role and tasks assigned to each person involved in tailings management. The sequence and frequency of the required activities will be established ahead of time. An emergency response plan will be implemented to define the nature of potential accidents, and related actions and responsibilities. The tailings pond management system will include measures to preserve its integrity in the event of personnel changes.

During the life of the operation, procedures will be applied to ensure that structures function perfectly and the host environment is protected. To achieve this, standardized monitoring checklists will be prepared and colligated data from all available sources will be recorded on a regular basis, including:

- compliance of sequential dam construction;
- compliance with tailings disposal procedures;
- water balance and quality;
- tailings characterization;
- nature and frequency of maintenance work;
- compliance with government standards;
- monitoring of structure stability and instrumentation;
- departures from objectives and corrective measures;
- ongoing rehabilitation work.

The tailings pond management system will also cover the tailings and process water pipelines. These components are vulnerable to weather extremes. To minimize the risk of spills, pipelines will be installed in such a way as to allow for contraction and expansion caused by outdoor temperatures, the route will be accessible to facilitate repairs, and the entire length of the pipeline will be inspected daily.

Colligated data will be made available, in real time, to all parties involved in tailings pond management. Furthermore, a third party will perform an annual audit of the management of the tailings pond and its constituents and compliance with disposal standards. The audit report will be submitted to BlackRock executives for assessment and feedback.

11.3.4 Management of Reagents, Chemicals and Hazardous Waste

Management of hazardous materials requires a specific approach for transportation, handling, storage, use and disposal. It generally entails meticulous planning at the engineering stage and ongoing monitoring during operations.

Engineering Phase

Storage procedures for hazardous materials will be based on the National Fire Code of Canada 2010 (NRC, 2010). Special attention will be paid to proper ventilation of sites containing sources of air pollution.

- All work areas where reagents are handled, stored or used will have automated ventilation systems.
- Ventilation systems will be equipped with alarms that will sound if the threshold limit value (TLV) is exceeded. This value is determined for each reagent.
- Hazardous materials will be monitored and confined to the smallest possible areas.

Operation Phase

During the operation phase, the person in charge of risk management will be tasked with monitoring the quality of transport, handling, storing, use and disposal of hazardous materials. More specifically, this person will have to:

- supervise risk assessments for specific work areas where reagents are handled, stored or used;
- designate the personal protective equipment and tools to use when working in areas where reagents are handled, stored or used;
- designate personal safety and emergency equipment to use in case of a technological accident in a work area where reagents are handled, stored or used;
- confirm, upon each delivery, that material safety data sheets (MSDS) are provided and posted as per regulations;
- during operations, ensure that MSDS (in English and French) are placed on containers in which regulated products are stored, and are accessible on all computer terminals;
- monitor the inventory as well as entry and exit of hazardous materials and hazardous waste;
- update and circulate the MSDS;
- prepare and update training sessions;
- supervise emergency responses.

Reagents will be delivered by suppliers whose contracts include environmental liability clauses. It is normal practice in the mining industry to purchase these products under contracts that exclude the client from all liability until the product is on site. Nonetheless, regardless of contract type, BlackRock will make sure that the carrier has an emergency response plan and that drivers have been appropriately trained. In case of a spill during transport, BlackRock will have emergency service agreements with Chibougamau and Chapais firefighters. A trained employee certified for the transport of hazardous materials will supervise unloading operations of new chemical products, as well as loading of hazardous wastes to be eliminated off site. Chemicals whose use or storage is hindered by damaged packaging will be returned to the supplier.

Personnel required to handle and use hazardous materials at the processing facilities will be appropriately trained. Special attention will be paid to toxicity, incompatibility and reactivity of hazardous materials. An external audit of the management plan for hazardous materials and hazardous waste will be performed annually, and the results will be reported to company executives.

All hazardous materials entering or exiting the site or used on site will be classified in accordance with the *Transport Canada* categories:

Class 1: Explosives
Class 2: Gases
Class 3: Flammable liquids
Class 4: Flammable solids
Class 5: Oxidizing agents
Class 6: Toxic and infectious substances
Class 7: Radioactive materials
Class 8: Corrosives
Class 9: Miscellaneous dangerous goods

All incompatible hazardous waste will be stored separately and removed from site on a regular basis by an authorized carrier. Designated warehouses will be ventilated and clearly marked. These warehouses will be kept locked, and only authorized personnel will have access. Storage sites will be protected against potential vehicle impact, and the reservoirs containing the liquids will be surrounded by a double wall or a containment dike, which will be regularly drained and cleaned. All containment areas and reservoirs will be regularly inspected and cleaned.

If a hazardous material spill occurs, the department in charge will act as first responder and will trigger measures to contain and recover the spill and clean the contaminated site. Personal protection equipment and spill kits will be available to personnel in all hazardous material handling, use and disposal areas.

Hazardous material storage areas and supply and distribution systems will inspected on a weekly basis.

11.3.5 Low-Risk Activities

Activities with a low environmental risk will also be monitored on a regular basis. Any irregularities noted during inspections will be addressed promptly.

Chemical products in small containers will be stored inside buildings. Special attention will be paid to product compatibility to avoid storing incompatible products next to each other; for example, bases will be stored separately from acids. Class 2 gas cylinders and tanks will be sheltered from physical damage. Allowing combustible liquids or solids to accumulate inside and around buildings will be prohibited. Inventory will be managed so as to use products in the order in which they are received to reduce the risk of using expired products.

11.3.6 Environmental Emergencies

Despite all the planned precautions to minimize risk, some incidents will likely still occur, and the company must be prepared to respond. This involves putting in place incident detection mechanisms (alarm and notification) and response procedures, and having emergency equipment on hand. Response criteria, response procedures and the location of emergency equipment at high, moderate or low-risk site will be specified in the emergency response plan.

The emergency response plan will be kept up to date in accordance with the *Metal Mining Effluent Regulations*, and will be given to all employees. All employees will attend at least one information session per year on the emergency response plan. Those playing a key role in emergency response procedures will receive more comprehensive training, including practical exercises.

The list and location of emergency equipment will be kept up to date as an integral part of the emergency response plan. Equipment should include absorbent material, shovels and containers to clean-up spills on the ground, booms to contain chemicals spills in water, masks and other protective gear, as well as reserves of building materials for emergency constructions. As mentioned previously, most environmental incidents involve spills, and spill control and clean-up are therefore the main corrective measures to be mastered. Such operations will be conducted in accordance with industry best practice. Table 11.4 gives an overview of such practices.

Table 11.4 Spill Control

LIQUIDS ON THE GROUND	LIQUIDS AND SOLIDS IN WATER	SOLIDS ON THE GROUND
MINOR SPILL • ABSORB The absorbent used must be compatible with the spilt liquid; for example: • Inorganic liquids: sand, ashes, vermiculite, etc. • Organic liquids: wood chips and sawdust, straw, cotton, compost, etc. • Synthetic liquids: polyurethane foam, polyester granules, etc. ***MODERATE SPILL*** • CONTAIN (erect a barrier) using absorbents. ***MAJOR SPILL*** • DIVERT TOWARDS A POND OR IMPERMEABLE TRENCH OR • CONTAIN (ERECT A BARRIER).	***SOLUBLE*** • CONTAIN with an impermeable barrier. or • CONTAIN AND DIVERT the liquid towards an impermeable pond. ***INSOLUBLE - Light contaminant*** • CONFINE with a floating boom (water-repellent absorbents, i.e., that will not absorb water). • CHEMICAL DISPERSAL with a surfactant (soap). or • BIOLOGICAL DISPERSAL with bacterial cultures. • CONTAIN with an impermeable barrier that drains from the bottom (pipe or siphon). ***INSOLUBLE - Heavy contaminant*** • CONTAIN behind an impermeable barrier and drain water off the top (once the contaminant has settled).	• COLLECT and clean the site. • COVER the contaminant and contaminated ground with a (plastic) tarp to prevent dispersal, dissolution or leaching. • ELIMINATE in an appropriate manner (see waste management).

Outside the walls of the processing plant, spills generally lead to soil contamination. Contaminated soils will be collected immediately after the incident. Subsequent characterization will assess the effectiveness of clean-up operations and define the scope of any additional work to be done. Areas most subjected to soil contamination, such as areas in the vicinity of garages and compressors, will be inspected on a weekly basis.

11.3.7 Incident Report

Despite all the measures taken to reduce the risk and scope of the effects, environmental incidents will likely still occur. If such an event arises, it will be immediately reported to *Urgence-Environnement* at the *ministère du Développement durable, de l'Environnement et des Parcs* (MDDEP). If the incident affects fish habitat, it will also be reported to *Environment Canada*. Subsequently, an incident report will be produced and submitted to the appropriate government departments. The incident report will allow causes of the incident to be identified and communicated, and any required corrective measures to be taken.

11.4 STORAGE OF CHEMICALS AND COMBUSTIBLES

Table 11.5 gives information on chemical products and hydrocarbons to be used, including:

- annual consumption/production;
- number of truck trips (per year, per week, etc.);
- indoor and outdoor storage sites;

- type of storage (tanks, silos, bags, etc.);
- maximum quantity stored.

The processing plant is expected tol produce 2.5 M tonnes/year of concentrate. This production capacity is based on continuous production, 24 hours per day, 365 days per year. However, production equipment availability is estimated at 90%. All calculations were based on 7,884 hours of production per year.

A rail transfer point is planned to facilitate the transport of raw materials and finished product between suppliers, the processing plant and customers. Thus, raw materials could be transported by truck or train to the rail transfer point. They will be brought to the processing plant by truck. The concentrate will be transported by truck from the processing plant to the rail transfer point, then shipped by train to the Québec City or Saguenay port. In all, 240 trips will be made in each direction each day by trucks transporting the concentrate from the processing plant to the rail transfer point. Eight 38-tonne semi-trailers will be assigned to these operrations 24 hours per day.

Storage of chemicals on the site of the processing facilities will be designed to facilitate supply and take chemical incompatibility of reagents into account. All designated storage sites will be built and managed in compliance with occupational health and safety regulations as well as building codes and fire safety regulations. Accordingly, indoor warehouses will be heated, ventilated, protected from fires and explosions and equipped with emergency showers and eye wash stations. These spaces will be thermally insulated and kept at a temperature of 15°C. Outdoor storage areas will be properly surrounded by containment dikes or fencing and marked with appropriate warning signs. Only designated, trained personnel will handle chemicals and have access to storage areas. Certain products will be stored in tanks, which will have holding ponds with a capacity equal to 115% of the tank capacity.

Table 11.5 Chemical Product Data

Product	Consumption/ Production		Truck transport	Storage		Type of storage/ Maximum stored quantities		
	tonnes / year	litres/ year	Estimated number of trips per year	Indoor	Outdoor	Reservoir (litres)	Bag (kg)	Container (tonnes)
Fuel oil No.2		18,315,893 (1)	915		√	400,000 (3)		
Gasoline		1,894,000 (2)	95		√	20,000		
Propane C_3H_8					√			
MAGNAFLOC 351 Non-ionic polyacrilamide	100.7		8	√	√		500-750	
FLOTTEC PAX COLLECTOR - potassium sulphide - carbonodithioic acid, O-(3-Methylbutyl) ester, potassium salt - potassium hydroxide	444.8		28	√	√		900	
UNIFROTH 250 CM Polyglycol	59		3	√	√			1
TITAN XL 1000 (4) (or equivalent) - ammonium nitrate - calcium nitrate - fuel - mineral oil	9,068 13.6 13.6	224,033 416,061	2 2 12 22		√ √ √ √	50,000 10,000		20 20 3

(1) Fuel oil No.2 consumption for primary and secondary mining equipment increases over time due to deepening of the pit. Maximum consumption is 18,315,893 litres (tenth year estimate, 2022).

(2) Consumption for ancillary equipment is calculated as gasoline. Consumption is stable over the life of the operation.

(3) The maximum storage capacity for fuel oil No.2 at the fuel depot is 400,000 litres (5 x 80,000 litres). Three other supply reservoirs for heavy vehicles will be located in various strategic locations around the mine site.

(4) The emulsion explosive tonnage was based on the amount of explosives used per tonne of ore and waste rock, representing 0.23 and 0.20 kg/t respectively for the 15 years of the project.

11.4.1 Outdoor Storage

The following chemicals will be stored in sites or warehouses outside the processing plant:

- reagents for mixing of TITAN XL 1000 explosives (or equivalent);
- fuel oil No.2;
- gasoline;
- propane.

Products that will be stored inside the processing plant are:

- MAGNAFOC 351 (flocculant);
- FLOTTEC PAX (collector);
- UNIFROTH 250 CM (frother).

Flocculants (if required), collectors and frothers will be delivered as granules in reinforced plastic bags or plastic containers. They will be stored in areas designed specifically for this purpose (see Table 11.5).

Chemicals stored inside the warehouse will not be in contact with one another in case of fugitive emissions.

11.5 OCCUPATIONAL HEALTH AND SAFETY

Occupational health and safety concerns go well beyond the risk analysis of an environmental assessment. Worker safety is strictly controlled by the applicable provincial and federal laws and regulations, most notably the *Act respecting Occupation health and safety* (RSQ, c S-2.1) and the *Act respecting industrial accidents and occupational diseases* (RSQ, c A-3.001). Canadian legislation also addresses the issue of corporate liability in relation to occupational health and safety in *Bill C-45*. Within the smaller scope of this environmental study, human health risks associated with the project are addressed in this section. Chemicals used during construction and operation are described and categorized according to the associated potential risk.

11.5.1 Classification of Chemicals

The *Service du répertoire toxicologique* of the *Commision de la santé et de la sécurité du travail* (CSST) was consulted with regard to the main chemicals to be used in mining activities, for iInformation on product toxicity, chemical reactivity and personal protective equipment to be used. Such information was also gleaned from the databases of the Occupational Safety & Health Administration (OSHA), the National Institute for Occupational Safety & Health (NIOSH) and the EPA *Acute Exposure Guide-lines levels* (AEGL) website. Specific data on hazardous materials was also obtained from the WHMIS system administered by the CSST.

WHMIS divides hazardous materials into six classes based on their specific hazard. If a product corresponds to one or more of these classes, it becomes a controlled product. If a chemical does not correspond to any of the classes, it is then classified as an “uncontrolled product.” The WHMIS classification for chemicals used in processing is presented in Table 11.6. To facilitate consultation, products have been divided into three categories: combustibles, compressed gases and organic materials.

It can be seen that, under Canadian regulations, most of these chemicals are uncontrolled. Some of the controlled chemicals, however, fall into more than one WHMIS category.

Chemicals considered uncontrolled based on WHMIS criteria, or which have not yet been listed, are:

- fuel oil No.2
- non-ionic polyacrilamide (Magnafloc 351);
- potassium sulphide (component of Flottec Pax collector);
- carbonodithioic acid, O-(3-Methylbutyl) ester, potassium salt (component of Flottec Pax collector);
- calcium nitrate (component of emulsion explosives);
- fuel oil (component of emulsion explosives);
- mineral oil (component of emulsion explosives).

Many of the chemicals listed in Table 11.5 are used in mixtures and some of them in very small amounts. Because of this, health risks cannot be directly determined for Flottec Pax collector and Unifroth 250 CM. However, the toxicity level of the chemical components of these products can be used as a guide for safe use.

Table 11.6 WHMIS Classification for Chemicals Used in Magnetite Processing

Chemical CAS Number	Controlled Chemical					Uncontrolled chemical in WHMIS	Transport (risk category) / packaging
	Compressed gases	Flammable and combustible materials	Materials causing immediate and serious toxic effects	Materials causing other toxic effects	Corrosive materials		
Combustible organic products							
- Fuel oil no.2 / 68476-30-2		√		√		√	3 / III
- Gasoline / 8006-61-9		√		√			3 / II
- Propane (C_3H_8) / 74-986	√	√		√			2.1/ -
Other organic products							
Magnafloc 351 - Non-ionic polyacrilamide						√	Transport not regulated
FLOTTEC PAX COLLECTOR (mixture)							4.2 / II
- Potassium sulphide (K_2S) / 1312-73-8		√		√		√	s.o.
- Carbonodithioic acid, O-(3-methylbutyl) ester, potassium salt ($C_6H_{11}KOS_2$) / 928-70-1						√	s.o.
- Potassium hydroxide (HKO) / 1310-58-3							s.o.
UNIFROTH 250 CM (mixture)							Transport not regulated
- Polyropylene glycol monomethyl ether / 37286-64-9		√					s.o.
- Dipropylene glycol monomethyl ether / 34590-94-8		√					s.o.
- 2-Ethylhexanoic acid / 149-57-5				√			s.o.
Explosive emulsion Titan XL 1000 (mixture)							
- Ammonium nitrate / 6484-52-2		√					5.1 / III
- Sodium nitrate / 7631-99-4		√					5.1 / III
- Calcium nitrate / 10124-37-5		√				√	5.1 / III
- Fuel oil / 68476-34-6		√				√	3 / III
- Mineral oil / 64742-35-4		√				√	Transport not regulated

A Compressed gas: products held under pressure
B Flammable and combustible materials: products that will easily burn or catch on fire
D1 Materials causing immediate and serious toxic effects: products that can rapidly cause harmful health effects, including death
D2 Materials causing other toxic effects: products whose health effects generally appear over time following one or several exposures
E Corrosive materials: products that can be health or safety hazards under certain conditions (pressure, temperature, impact, violent reaction with water or air.

11.5.2 Toxicity of Chemicals

Information obtained from Canadian and American chemical safety agencies about products used in the magnetite concentrate process is given in Tables 11.6 and 11.7. Table 11.6 gives characteristics such as appearance, flammability, explosiveness, toxicity and first aid measures. First aid measures are classified according to the nature of the contact with the chemical (inhalation, ingestion, etc.). For most chemicals in their pure state, Canadian standards for time-weighted average exposure values (TWAEV), short-term exposure values (STEV) and 'immediately dangerous to life or health' (IDLH) levels are listed. Certain chemicals, such as fuel oil No.2, have not yet been assessed for exposure limits by appropriate North American agencies.

Occupational health and safety management measures (incompatibility, handling and storage) are presented in Table 11.7. Chemical handling measures involve in particular the wearing gloves, goggles, respirators, protective clothing, etc. When handling chemicals in closed premises, appropriate respiratory devices should be worn and the room adequately ventilated. First aid measures for each chemical in case of an accident are listed in Table 11.6. All chemicals listed are commonly used in the industry and should be handled in accordance with recognized industrial safe practices.

11.5.3 Handling Procedures and Chemical Incompatibility

Chemicals will generally be handled in accordance with Quebec occupational health and safety regulations, manufacturer safety instructions and industrial health and safety procedures. The following general rules will be applied:

- do not mix bases and acids;
- never add water to a base or acid;
- never place a flammable chemical close to an ignition source;
- always handle solid chemicals with care to avoid formation of fine dust;
- never place incompatible chemicals close to each other;
- always avoid exposing hygroscopic chemicals to humidity;
- always wear the required personal protective equipment;

Table 11.7 Chemical Product Toxicity and First Aid Measures

Name of chemical CAS number	RROHS regulation	Appearance / Flammable and explosive nature	Toxicological properties	First aid measures
Combustibles				
Fuel oil no.2 68476-30-2	Not regulated Threshold limit value (TLV) 100 mg/m^3	- Translucent liquid, amber, hydrocarbon smell - Flammable if exposed to an ignition source.	- Absorbed through the skin, respiratory tract and digestive tract	- Skin contact: remove contaminated clothing. Wash contaminated areas with soap and water. - Eye contact: flush eyes with clean water and seek medical attention. - Inhalation of vapours or dust: remove person to fresh air. If person is not breathing, provide artificial respiration. Seek medical attention. - Ingestion: do not induce vomiting. Seek medical attention.
Gasoline	TWAEV 300 ppm or 890 mg/m^3 STEV 500 ppm or 1480 mg/m^3	- Volatile liquid, colourless or amber, gasoline smell. - Flammable: flash point -43^{o}C (closed cup).	- Irritating to skin and eyes, may cause damage to eyes. - Inhalation may irritate respiratory tract and cause respiratory problems. - Severe exposure may provoke nausea.	- Skin contact: immediately remove contaminated clothing. Wash skin thoroughly with soap and water, remove person from area of exposure. - Eye contact: immediately flush eyes with plenty of water for 15 minutes, lifting eye lids. Remove any contact lenses. - Inhalation: provide artificial respiration if required and cardiac massage if the heart has stopped. Seek medical attention. Prolonged exposure may cause cancer.
Propane (74-98-6)	TWAEV 1000 ppm or 1500 mg/m^3	- Colourless and odourless gas: mercaptan added to give it an odour - Flammable gas with a flammable lower limit of 2.1%. - May cause an explosion.	- Absorbed through the respiratory tract. - Not toxic in low concentrations: 1,000 ppm in 8 hours - Central nervous system depression at a concentration of 4.7%. - Risk of asphyxia, nausea, headaches, dizziness, lack of coordination, unconsciousness and death from anoxia	- Skin contact: submerge the affected area in water (in case of cold burn), seek medical attention. - Eye contact: flush with plenty of water for 15 minutes, lifting eyelids, remove contact lenses, seek medical attention. - Inhalation: remove person from zone of exposure, provide artificial respiration and cardiac massage if heart has stopped. Seek medical attention.

Name of chemical CAS number	RROHS regulation	Appearance / Flammable and explosive nature	Toxicological properties	First aid measures
MAGNAFLOC-351 Non-ionic polyacrilamide (polymer flocculant)	Not regulated TWAEV: 10 mg/m^3	- white granular powder, odourless - not flammable under normal conditions - may burn if exposed to fire	- Routes of exposure are through the skin, eyes and inhalation. - May be absorbed through the digestive tract. - Does not contain hazardous ingredients.	- Skin contact: wash affected areas with plenty of soap and water. Seek medical attention if irritation occurs. Launder clothing before re-use. - Eye contact: flush eyes with water for 15 minutes. Seek medical attention. - Inhalation: Remove patient to fresh air. Seek medical attention if respiratory irritation develops, or breathing becomes difficult. - Ingestion: do not induce vomiting. If patient is conscious, give 2 to 4 glasses of water to drink. Seek medical attention. Do not give anything by mouth if patient is unconscious.
FLOTTEC PAX COLLECTOR Potassium isoamyl xanthate ($C_6H_{12}OS_2K$) **Mixture of :** - Potassium sulphide CAS No: 1312-73-8 ± 1% - Carbonodithioic acid, O-(3-methylbutyl) ester, potassium salt CAS No: 1928-70-1 >90 % - Potassium hydroxide CAS No: 1310-58-30 up to 1 %	Not regulated Not regulated Regulated D1B (toxic material that causes serious and immediate effects) E (corrosive materials) Threshold value limit (TVL) 2 mg/m^3	- yellow-green colour - pellets, flakes or powder - disagreeable odour - self-heating material; may form explosive dust-air mixtures	- Toxic to aquatic organisms. Not readily biodegradable. - Potassium sulphide (K_2S) is absorbed through the respiratory and digestive tracts. Acute effects are eye irritation (redness, pain), possible corrosion of eyes, skin and respiratory tract, blurred vision. - Inhalation of dust: coughing, shortness of breath. - Ingestion: abdominal pains, vomiting and diarrhoea.	- Skin contact: Remove contaminated clothing and shoes. Wash affected area with plenty of water. Wash contaminated clothing. Seek medical attention if pain or irritation persists. - Eye contact: Rinse immediately with plenty of water for 15 minutes. Seek medical attention. - Inhalation: Remove person to fresh air. If breathing is difficult, give oxygen. Seek medical attention. - Ingestion: do not induce vomiting. If the patient is conscious, give 2 to 4 glasses of water. Seek medical attention. Do not give anything by mouth if the patient is unconscious.

Name of chemical CAS number	RROHS regulation	Appearance / Flammable and explosive nature	Toxicological properties	First aid measures
UNIFROTH 250 CM **Mixture of:** - Polypropylene glycol monomethyl ether CAS No: 37286-64-9 60 to 90 % (w) - Dipropylene glycol monomethyl ether CAS No: 34590-94-8 10 to 30 % (w) - 2-Ethylhexanoic acid CAS No: 149-57-5 1 to 5 % (w)	Regulated Classes D-2A et D-2B TVL: 150 ppm - Not regulated - Regulated: B3 (combustible liquids) - Regulated: E (corrosive materials)	- resembles alcohol, colourless to pale yellow - not flammable - no information on explosive nature	- routes of exposure are eyes, inhalation and ingestion. - Danger in case of contact with eyes (irritation), ingestion or inhalation - Slight danger in case of contact with skin - Prolonged contact can cause damage to internal organs.	- Skin contact: wash immediately with plenty of water. If irritation persists, consult a doctor. Wash contaminated clothing before re-use. - Eye contact: immediately flush with water for 15 minutes, keeping eyes open. Seek medical attention. - Inhalation: remove patient to a well-ventilated area. Immediately seek medical attention. - Ingestion: give patient several glasses of water or milk. Do not induce vomiting. Immediately seek medical attention.

Name of chemical CAS number	RROHS regulation	Appearance / Flammable and explosive nature	Toxicological properties	First aid measures
Titan XL 1000 **(or equivalent)** Explosive emulsion	Not regulated	- Translucent or opaque viscous liquid, may be silver-coloured, fuel oil smell - may explode or detonate in case of fire	- Skin contact: prolonged contact can cause irritation - Eye contact: irritation, pain and tearing - Inhalation: can cause dizziness, nausea, and abdominal discomfort. - Ingestion: harmful in large quantities.	- Skin contact: remove contaminated clothing, wash with soap and water. - Eye contact: flush with water for 15 minutes. Consult a doctor if irritation persists. - Inhalation: remove person to fresh air. Consult a doctor if irritation persists. - Ingestion: Consult a doctor.
Mixture of:				
- Ammonium nitrate CAS No: 6484-52-2 60 to 80%	Regulated: C (oxidizing materials)	- White deliquescent solid, odourless - Flammable when in contact with organic substances	- absorbed through respiratory and digestive tracts. - formation of clots on skin, eye irritation. - ingestion or inhalation: frequent urination, acidification of urine - ingestion of large quantities can lead to death.	- Skin contact: remove contaminated clothing. Wash skin. - Eye contact: flush with plenty of water and consult a doctor. - Inhalation: move the person to a well-ventilated area. Provide artificial respiration if required. Seek medical attention. - Ingestion: give person large quantities of water to drink, induce vomiting, seek medical attention.
- Sodium nitrate CAS No: 7631-99-4 10 to 18%	Regulated: C (oxidizing materials)	- White deliquescent solid, odourless - Flammable if strongly heated	- eye and skin irritation. - irritation of mucous membrane if inhaled. - if ingested in large quantities, dizziness, cramps, bloody diarrhoea, weakness, convulsions, death.	- Skin contact: immediately remove contaminated clothing. Wash affected skin with soap and water. - Eye contact: flush with plenty of water and seek medical attention. - Inhalation: move person to a well-ventilated area. Seek medical attention. - Ingestion: Seek medical attention.
- Calcium nitrate CAS No: 10124-37-5 0 to 35%	Not regulated	- Information not available in WHMIS	Information not available in WHMIS	Information not available in WHMIS
- Fuel oil CAS No: 68476-34-6 0 to 10%	Not included in WHMIS	- Information not available in WHMIS	Information not available in WHMIS	Information not available in WHMIS
- Mineral oil CAS No: 64742-35-4 0 to 3%	Not regulated	- Information not available in WHMIS	Information not available in WHMIS	Information not available in WHMIS

CAS: Number assigned by the *Chemical Abstracts Service,* a division of the *American Chemical Society,* for designating chemical substances. It is characterized by two hyphens that are always placed in the same location.
IDLH (immediately dangerous to life or health): this value represents the maximum concentration of exposure to a product to which a person can be subjected for 30 minutes without suffering irreversible health effects or impeding the ability to escape. This concentration was defined for to select appropriate respirators.
ppm: Measure of concentration volume. Concentration is expressed as parts per million, for example, one cm^3 of a substance per million cm^3 of air.
WHMIS: Workplace Hazardous Materials Information System.
TWAEV (time-weighted average exposure value): the time-weighted average concentration for an 8-hour workday and a 40-hour workweek of a chemical substance present in the air in a worker's respiratory zone.
STEV (short-term exposure value): the 15-minute time-weighted average concentration for exposure to a chemical substance, present in the air in a worker's respiratory zone which should not be exceeded at any time during a workday, even if the time-weighted average exposure value is not exceeded. The average exposure for a 15-minute consecutive period may be included between the TWAEV and the STEV, insofar as such exposures are not repeated more than four times a day and have intervals between them of periods of at least 60 minutes.
Ceiling value: the concentration never to be exceeded during any length of time whatsoever.
TLV: 'threshold limit value' is the value at which workers can be regularly exposed, day after day, without affecting their health being.

NOTES:
FLOTTEC PAX COLLECTOR:
Information provided relating to appearance, flammability, explosiveness, toxicological properties and first aid measure apply to the product as it is sold.
The product is pre-mixed upon delivery.

UNIFROTH 250 CM:
Information provided relating to appearance, flammability, explosiveness, toxicological properties and first aid measure apply to the product as it is sold and not to its ingredients.
The product is pre-mixed upon delivery.

TITAN XL 1000 (or equivalent):
Information is provided for each ingredient composing the explosive emulsion mixture, as well as for the mixture. The ingredients for the explosive emulsion are delivered and stored separately.

Chemical incompatibility between products was identified and is shown in Table 11.8. If the following chemicals come into contact with each other, a violent reaction will ensue that will release heat and/or cause an explosion.

- **fuel oil No.2** and oxidizing agents such as perchlorates, chlorine, chromium and fluorine;
- **gasoline** and oxidizing agents such as perchlorates, peroxides, permanganates, chlorates, nitrates, chlorine, chromium and fluorine;
- **propane gas** and oxidizing agents such as perchlorates, peroxides, permanganates, chlorates, nitrates, chlorine, chromium and fluorine;
- **Magnafloc 351** (non-ionic polyacrilamide) and ambient air in the presence of high particulate concentrations and static electricity;
- **Flottec Pax Collector** (potassium isoamyl xanthate) and ambient air in the presence of high particulate concentrations and static electricity, flames and sparks;
- **Ammonium nitrate** and acids, reducing agents, organic substances, powdered metals, sulphur, phosphorus and sodium perchlorate.

It should be noted that with the exception of nitrates, the oxidizing agents listed above are not used in the ore treatment processes. However, it is plausible that small amounts of certain oxidizing agents might be present in the various workshops or the garage.

A specialized company will take care of transportation, raw material handling and manufacturing of mining explosives. This company will use its own equipment and facilities. Blasting activities will be directly carried out by BlackRock employees or sub-contractors. Chemicals used in the manufacturing of explosives will not come into contact with chemicals used in ore processing. The emulsion explosive will be mixed each day as needed, away from mining facilities. The specialized explosives company will deliver all the ingredients on a regular basis. Ammonium, sodium and calcium nitrates will be stored in separate buildings, in 900 to 1,000-kg plastic containers. Fuel oil No.2 will be stored in a protected above-ground reservoir, located near the emulsion mixing plant. The site, as well as the emulsion plant, will comply with federal explosives legislation.

Handling of the raw materials and emulsion will be subject to regular audits, and performance reports will be submitted to management. Any spill of controlled products used to manufacture the emulsion will be reported and responded to immediately in accordance with the emergency response plan.

Table 11.8 Occupational Health and Safety Measures

Name of chemical CAS number	Reactivity (Stability/ Incompatibility)	Handling	Storage
Fuel oil no. 2 68476-30-2	- Unstable if heated to its burning point (release of the toxic gases carbon monoxide and carbon dioxide). - Incompatible with strong oxidizing agents	- Avoid all contact with skin. - Wear eye protection and in case of inadequate ventilation, a respirator. - Equipment must be grounded.	- Keep containers in a separate area, safe from fires. - Ground containers and keep in a cool and ventilated area. - Keep away from oxidizing substances and from all sources of ignition.
Gasoline 8006-61-9	- Unstable if heated and risk of explosion - Releases toxic gases - Incompatible with strong oxidizing agents	- Avoid all contact with skin and wear gloves. - Wear eye protection and in case of inadequate ventilation, a respirator. - Do not smoke when using - Handle away from any source of ignition.	- Indoors, keep in a cool, dark and ventilated place and ground. - Store in air-tight containers away from all sources of heat or ignition, do not smoke. - Store away from oxidizing substances
Propane	- Risk of explosion. - Incompatible with strong oxidizing agents	- Handle away from any source of ignition. - Do not smoke. - Do not use metal tools.	- Ground equipment and keep away from oxidizing substances. - Use explosion-proof electrical equipment. - Protect from impact, do not smoke. - Respect the CSA B149.2-05 code. - Keep away from all sources of heat and ignition. - Use devices that detect concentrations exceeding appropriate levels.
MAGNAFLOC 351 (non-ionic polyacrilamide)	- Unstable if heated (release of carbon oxides, nitrogen oxides and various hydrocarbons, and/or ammonium hydroxide, which can be irritating or harmful). - Incompatible with strong oxidizing agents such as liquid chlorine, liquid oxygen, and sodium or calcium hypochlorites. - Dust generated from handling may be explosive if sufficient amounts are mixed in the air.	- Avoid all contact with skin. Wear gloves. - Wear goggles. - Use an approved dust-proof respirator and wear protective clothing (resistant to chemicals). - Handle away from all sources of ignition. - Do not handle with wet hands.	- Store in tightly-shut, original container and keep in a cool and dry place. - Avoid extreme temperatures and ignition sources. - Ensure adequate ventilation to avoid dust accumulation in the ambient air. - Keep containers air-tight and away from incompatible chemicals.

Name of chemical CAS number	Reactivity (Stability/ Incompatibility)	Handling	Storage
FLOTTEC PAX COLLECTOR Potassium isoamyl xanthate	- Substance that can provoke spontaneous combustion. - May form an explosive dust in the air. - Products of decomposition in a fire are toxic	- Avoid all contact with eyes, skin and clothing. - Avoid breathing in dust, wear an approved respirator and goggles. - Wash after handling the chemical and also wash clothing. - Only use tools that will not cause sparks.	- Avoid humidity and excessive heat. - Maintain containers air-tight. - Ensure constant ventilation. - Electrical equipment must be explosion-proof. - Emergency showers and eye wash stations should be located in areas of exposure.
UNIFROTH 250 CM (Mixture) - Polypropylene glycol monomethyl ether 60-100 % (w) CAS 37286-64-9 - Dipropylene glycol monomethyl ether 10-30 % (w) CAS 34590-94-8 - 2-Ethylhexanoic acid 1-5 % (w) CAS 149-57-5	Not flamable, easily dissolved in water	- Wear waterproof gloves that are resistant to chemicals. - Wear goggles. - Avoid contact with skin and eyes. - Wash hands with soap and water after handling the chemical.	- Have emergency showers and eye wash stations near workstations. - Ensure good ventilation to maintain air concentrations within acceptable levels.

11.5.4 Occupational Health and Safety Committee

Collaboration between management and workers is essential to the implementation of occupational health and safety measures. An occupational health and safety committee will be composed of management representatives and an equal or greater number of workers. This committee should:

- receive sufficient information regarding occupational health and safety issues;
- examine factors that affect worker health and safety;
- suggest relevant measures;
- be consulted when significant new occupational health and safety measures are planned, before they are implemented;
- promote the soundness of these measures to employees;
- be consulted on any planned changes to work methods, nature of work and work organization that might have an impact on worker health and safety;
- contribute to the corporate decision-making process in relation to health and safety matters;
- have a reasonable amount of paid time to carry out its health and safety duties and receive related training in how to do so;
- have access to experts for advice on specific health and safety issues.

The occupational health and safety committee should meet regularly to examine all occupational health and safety aspects that have caused problems at the site of the processing plant and propose measures to address them. BlackRock Metals Inc. will actively assist the occupational health and safety committee so as to foster its effectiveness and maintain high occupational health and safety standards.

BlackRock Metals Inc. will keep a register of accidents and of all cases of acute exposure to hazardous materials that occur at the mine or processing plant. This information will be reported to the regulatory authorities and the occupational health and safety committee.

11.5.5 Health and Safety Program

"Health and safety is of prime importance for BlackRock, and the company wants all its employees and partners to also consider it as such. Consequently, the company calls on personnel to behave responsibly toward themselves and others. It encourages employees to share of a common way of thinking whereby health and safety are automatically given priority." (ref. Section 51 of An Act respecting Occupational health and safety).

Mine management will develop an occupational health and safety program containing the following information:

- general instructions;
- relevant health and safety regulations;
- procedures related to accident prevention (Regulation respecting prevention programmes, Section 1.4);
- a list of hazardous materials, handling procedures and antidotes (Act respecting Occupational health and safety);
- schedule of health and safety meetings (Act respecting Occupational health and safety);
- accident and incident investigation procedures (Act respecting industrial accidents and occupation diseases);
- health and safety inspection procedures (*Commission de la santé et de la sécurité du travail*)

The occupational health and safety committee will review and comment on the health and safety program proposed by company executives (Act respecting Occupational health and safety).

BlackRock Metals Inc. will set up and maintain training programs and ensure that all employees receive the training required to carry out their duties in a skilled, safe manner. This requirement applies to all levels and categories of employee (Act respecting Occupational health and safety, Act respecting industrial accidents and occupation diseases, *Commission de la santé et de la sécurité du travail*, Bill C-45).

11.5.6 Medical Monitoring Program

BlackRock Metals Inc. will set up a medical monitoring program for those exposed to excessive noise and to physical and chemical agents. All those involved will be advised of the health risks, and of the existence of the program and how to register.

11.5.7 Training of First-aid Attendants and Nursing Teams

The *First-aid Minimum Standards Regulation*[(1)] stipulates that all employers of an establishment or principle contractors of a construction site, except for institutions of the Social Affairs network, must make sure that a minimum number of first-aiders are present at all times during working hours.

A first aid certificate is awarded to anyone who has taken the *First Aid in the Workplace* training course and passed the theoretical and practical exam. This course must take place during normal work hours. The first aid certificate is valid for a three-year period from the date it is issued.

(1) *First-aid Minimum Standards Regulation (O.C. 1922-84, 1084 G.O. 2, 3383 modified by O.C. 1798-87, 1987 G.O. 2, 4143).*

The minimum number of first aid attendants is determined for each shift by applying the following rule:

- 50 employees or less: 1 first aid attendant
- 51 to 150 employees: 2 first aid attendants
- 151 employees or more, add one first aid attendant per 100 employees

For the proponent, the following first aid obligations apply:

- designate the required number of people as first aid attendants and make sure they are registered with an organization recognized by the CSST to issue a first aid certificate;
- make sure the required number of first aid attendants are present during working hours;
- when designating first aid attendants, make sure that the nature of their work does not compromise response speed and effectiveness;
- recognize that the person designated as a first aid attendant is considered to be at work during training and each time he or she must act as a first aid attendant during working hours;
- ensure that a sufficient number of first aid kits containing the required material are available at all times in the establishment or at the construction site.

In terms of health professionals available on site, BlackRock will have nursing professionals on site for each shift. These professionals will work in an infirmary consisting of an examination room, equipment and a pharmacy that meet current standards. Nursing staff will have full time access to medical consulting services.

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12. IMPACT ASSESSMENT AND MITIGATION MEASURES

The impact assessment method applied in this study is based on those developed by the Federal Environmental Assessment Review Office (1978, 1986), the *Ministère de l'Environnement* (1981, 1984) and Hydro-Québec (1985, 1986b, 1991a, May 2000, June 2000).

This method consists of relating the project's components to components in the receiving environment that are likely to undergo an impact as a means of determining their significance. To assess impact significance, it is necessary to have an idea of the project's scope and of the biophysical and human environments that will be affected. These aspects have been covered in previous chapters. This chapter presents the nature and intensity of impacts on all the environmental components. It includes the project's impacts on air quality, noise, surface water quality and groundwater quality as examined in specific technical studies.

Impact assessment and determination is based on criteria of resistance to the project. These intensity and scale criteria are defined according to the characteristics of the natural and human environment, as well as the value assigned to them by the public and by various specialists. The significance of the impact determines the mitigation measures for reducing or eliminating the project's negative effects on the environment and planning of a monitoring and follow-up program. Impact significance is determined before mitigation measures are applied; the residual impact is the effect that persists after these measures are instituted.

12.1 ENVIRONMENTAL COMPONENTS

The environmental components affected by the project are summarized in the following paragraphs; the affected spaces are indicated in Table 12.1. The project footprint covers a total of nearly 600 hectares (6 km^2). The project's characteristics are specified in Chapter 4 and summarized in this chapter as sources of impact. Together, this information allows the significance of the impacts to be determined.

The setting contains sensitive components requiring special attention before, during and after construction work and operation. Sensitive components encompass lakes and streams, wetlands, traditional land use, wildlife habitats, groundwater, vulnerable species, the built environment and any other areas identified as such in this study.

In biological terms, the habitats affected by mining activities are generally not highly diversified and tend to be of low productivity. Wetlands and aquatic habitats will nevertheless be lost. From a geochemical standpoint, the receiving environment in the area of the mine site has a greater ability to neutralize contaminants than any other region in Quebec. In human terms, traditional land use and employment are the components of greatest importance.

The project's entire local zone of influence has been reviewed from an archaeological standpoint; some 15 potential archaeological sites have been identified, but a survey of these did not revealed any property of historical or prehistoric interest.

12.1.1 Ground

The project will affect nearly 600 hectares of ground, with the pit and tailings facilities covering 52% of the surfaces that will be irrevocably transformed. The mining area has a rolling topography broken by small rocky ridges in a northeast-southwest alignment, in particular the deposit hill, where inclines can reach 10%. Elsewhere, slopes are gentle, and the land has very low susceptibility to erosion.

Apart from the pit and its perimeter formed of rock and a thin layer of glacial till resting on bedrock, most of the surface area affected by the project consists of moraine. This deposit of glacial origin is coarse (with many boulders), generally compact and of low permeability. Particle size analysis of the soil showed a high proportion of sand and fine particles, which, added to the soil's compactness and the land's generally low inclines, raises the soil's buffering capacity in case of an accidental oil or chemical spill or a tailings dam leak.

A number of borrow pits have been identified along Route 167, along the route of the access road and in the Lac Jean sector (drumlins). Many gravel pits opened for the building of logging roads can be used for the project's needs. A high proportion (80%) of the aggregate will come from blasting during development of the pit and other infrastructure. The preferred borrow pits are those that have already been operated or that are located directly on the mine site. No significant impact is expected from the use of granular deposits.

Organic deposits and wetlands cover nearly one-quarter of the study area and 16% of the project's surface area. Wetlands are two to three times more abundant in the project area than in the Rivière Nottaway watershed as a whole. Infrastructure sites have been selected in such a way that these environments are only really affected by the waste rock and coarse tailings piles. Wetlands are concentrated in low points of the landscape and around water bodies; their bearing capacity is very low, but their water and metal retention potential is high. Consequently, wetlands help regulate and maintain the physicochemical quality of the water and protect aquatic fauna.

The 161-kV power line that will feed the mining project falls under the responsibility of Hydro-Québec; regardless of the route chosen, it will be about 30 km long and cover about 105 hectares (with a 35-metre right of way). The ground will mainly be disturbed in places where towers are installed, which represent an area of less than one hectare, in bedrock or glacial deposits. For the power line, the loss of land is more an issue of land use than land disturbance.

12.1.2 Hydrography and Hydrogeology

Hydrography

The mining project is located at the head of the James Bay watershed, which receives water from Ruisseau Villefagnan, a tributary of Rivière Armitage and Lac Chibougamau; most of the facilities are less than one kilometre from the drainage divide between this watershed and the St. Lawrence River watershed (subsystem of the Boisvert and Ashuapmushuan rivers and Lac Saint-Jean).

The processing plant, pit and waste rock piles pose little risk of contaminating the aquatic environment. The average pH level found for surface water is 7.85; its bicarbonate and organic matter content is high. These properties give the receiving environment a high capacity for neutralizing acid inflows and complexing metallic ions.

Apart from the rail transfer point located near Route 167 in the Ruisseau Audet and Lac Chevrier subsystem (in the Rivière Nottaway watershed flowing to James Bay), all mine facilities are in the Lac Denis and Lac Jean subsystem, and the explosives magasines are in the Lac Bernadette subsystem. The biggest lake indirectly affected by the project, Lac Jean, is about 45 hectares in area, with an average depth of one metre. Most water bodies affected by the project are small ponds undergoing eutrophication or slow-flowing creeks.

Lakes B-14 and B-12 and their outlet (see Chapter 8) will be eliminated by fine tailings pond dam construction and pit development. This system, ending at lake B-6, is exceptional in terms of habitat quality. It is well oxygenated and hosts a brook trout population. Lac Denis will be raised to serve as a reservoir. The water to be sent there will comply with discharge standards. Its outlet will be diverted to the west side of the coarse tailings facility and channelled over a distance of 1.4 km to join the lake B-1 tributary.

Table 12.1 Environmental Components affected by the Project

Environment / Project	Access road (1)	Pit (2)	Plant and crusher (3)	Garage (4)	Fine tailings pond (5)	Coarse tailings pile	Waste rock piles	Mine road (6)	Transfer point	Work camp	Totals
Total area (ha)	3.5	112	38	20	96	85	110	21	100	7.5	593
Mature community (ha)	0.5	26	0	3	17	18	24	4	55	0	147.5
Immature community (ha)	1	0	34	1	3	0	0	3	26	4.5	72.5
Regeneration (ha)	0.5	15	4	0	12	1	7	3	1	0	43.5
Planted areas (ha)	0	0	0	0	0	0	0	0	0	0	0
Logged areas (ha)	1	71	0	5.5	57	38	48	7	0	0	227.5
Wetlands (ha)	0.5	0	0	10	4	27	30	4	18	3	96.5
Lakes (ha)	0	0	0	0.5	3	1	1	0	0	0	5.5
Number of streams	0	1	0	0	3	1	2	5	1	0	13
Fish spawning grounds	2	0	0	0	1	0	0	0	1	0	4
Hunting camp along road 210	1 camp at Lac André / 5 units - Camp Wapachee	0	0	0	0	0	0	0	0	0	1 camp at Lac André / 5 units - Camp Wapachee

(1) The access road exists and is in good condition over 90% of its length. The Lac France portion to be built is 3.5 km long with a road surface 10 metres wide.

(2) The pit surface is the length of the deposit mineable from now until 2028 (Phase 1 pit), or 2.8 km, by an average width estimated at 400 metres.

(3) The area of the plant and the crusher includes the space affected by the conveyer, the concentrator, the ore stockpile and the electrical substation, or the space on the east, south and southeast sides of Lac Denis, as well as the work space around the facilities.

(4) The area of the garage includes the road surface on the garage's periphery.

(5) The area of the fine tailings pond includes the polishing pond.

(6) The mine roads run from the pit to the crusher, the tailings facilities and the garage; they are about 6 km long and up to 30 metres wide.

In June 2011, the creeks directly affected by the project had flows of less than 0.16 m^3/s, except for the common emissary of Lac Denis and lakes B-6, B-7, B-8, B-11, B-12, B-13 and B-14, which had a flow of 1.32 m^3/s in its central part, which will be affected by the waste rock pile near where it reaches Lac Jean. At its outlet, Lac Denis had a flow of 0.064m^3/s. Ruisseau Wynne, which flows under road 210 at Lac Stella and Lac Pillow, had a flow of 165 m^3/s; it is by far the largest waterway studied. It is not affected by the project but could play a role in terms of compensation measures.

From the standpoint of river dynamics (erosion and sedimentation), the study area is in balance; in other words, there are no major areas of soil erosion due to stream action or run-off, nor are there any areas with significant accumulation of granular sediments (beaches, deltas). It is also worth noting that there is a major accumulation of organic matter in most water bodies undergoing eutrophication.

Hydrogeology

The groundwater flows radially around the rocky ridge of the deposit. The configuration of piezometer levels fits well with the topography. The hydrogeological data and models were used largely to determine the best sites for tailings disposal. According to the hydrogeological study, the local aquifer is made up of faults and sheer zones crisscrossing the area. Average till conductivity is 1.29 x 10^{-4} at the mine site and 8.6 x 10^{-4} cm/s at the rail transfer site. The average conductivity of the bedrock is 1.93 x 10^{4}cm/s.

The piezometric level is generally near the surface. In glacial deposits, the precipitated water curtain is distributed as follows:

- 7% to infiltration;
- 51% to run-off;
- 42% to evaporation.

In organic deposits (peatlands), the precipitated water curtain is distributed as follows:

- 17% to infiltration;
- 36% to run-off;
- 47% to evaporation.

The groundwater is characterized by a slightly alkaline pH and low levels of dissolved solids and, for the most part, of metals. During operations, the project's impact on groundwater quality is nil for all practical purposes as the pit will be the outlet of the aquifer and of infiltration water from the fine tailings and polishing ponds. Any infiltration from the fine tailings and polishing ponds will be looped back to the fine tailings pond. Finally, bedrock permeability drops considerably with depth.

12.1.3 Vegetation

Prior to large-scale logging, vegetation in the mining area was dominated by black spruce. This species represents the mature communities (80 years or older) concentrated between Lac Audet and Lac Armitage. Most surfaces in the study area have been disturbed by cuts in recent decades and are colonized now by communities of young hardwoods (more than 20 years old) or hardwoods under regeneration (0 to 20 years old). Pine plantations are found south of Lac France (access road) and at the rail transfer point (0 to 20 years old).

There are no communities of phytosociological interest, and no threatened or vulnerable plant species have been identified in the mine site area. However, some species associated with wetlands can be found in the area. According to the *Centre de données sur le patrimoine naturel du Québec* (CPDNQ), many plant species likely to be designated as threatened or vulnerable can be found in the James Bay region and in the Domaine-du-Roy RCM. Most of these species are associated with wetland habitats. However, none of these species is present in the area of the mine site. The survey conducted in the area shows low potential for the presence of plant species at risk or even of threatened species as defined by the *Species at Risk Act*.

Clearing required for the facilities mostly affects logged areas; mature communities are affected next, followed by wetlands and a smaller proportion of immature or regenerating communities.

12.1.4 Wildlife

Lac Chibougamau is of great importance to local people and tourists for fishing, mainly for walleye. Baie Girard and the mouth of Rivière Armitage are eight kilometres north of the pit and are frequented mainly during the summer season.

In the current state of environmental knowledge, the mine site includes small brook trout spawning grounds in the system formed by lakes B-14 and B-12 and their common emissary, as well as a spawning ground for walleye in Rivière Armitage, one for white sucker in Ruisseau Villefagnan, one for walleye at the outlet of Lac Audet (near the rail transfer point) and two (for whitefish and walleye) in Ruisseau Wynne, on either side of the access road. Only the brook trout spawning grounds are directly affected by the work.

Apart from Lac Chibougamau, the lakes in the area are not used much for fishing. The main species harvested in experimental fishing belong to the chub family; walleye, northern pike, brook trout and sucker were also captured but in much smaller quantities. There are no habitats in the area of the project site that provide for walleye survival. Northern pike is present in several lakes in the mine site area. Brook trout are also present but only at one spot.

Winter moose habitats have been identified in the Lac Armitage area and in the vicinity of the deposit. Those near the deposit will be directly affected by the project. Moose are also present on the mine site in summer. The Lac Armitage basin, west of the project, is a zone of major biological diversity that merits conservation.

No wildlife habitats as defined by the *Act respecting the conservation and development of wildlife* (R.S.Q., chapter C-61.1) have been identified on the territory of the study area. A dozen wildlife species likely to be designated as threatened or vulnerable (in particular the rock vole, tree frog, golden eagle, white-tailed eagle, great grey owl and lynx) could be found in the mining sector but, apart from the lynx, none of these species has been observed to date. The study area corresponds to a woodland caribou habitat, but there is little chance it will be affected due to its low density and great mobility, and the large number of similar habitats at the regional level.

The number of bird species observed at the mine site and the rail transfer point is relatively limited. It is worth noting, however, the presence of an osprey pair nesting near Lac Coil, in the northern part of the future waste rock pile. As regards migratory birds, the project is not situated in a protected area or an area of ecological importance.

12.1.5 Land Use and Built Environment

The mine site is located about 60 km from the town of Chibougamau along Route 167 (about 32 km), logging road 210 and the deposit access road (an additional 30 km). In the project’s local study area, the built environment amounts to the hunting camps of the Wapachee family (tallyman, trapline O-59) along logging road 210. These seasonal hunting camps (Rabbit Camp) will be directly affected by ongoing concentrate transport activities. These camps should be moved to a spot chosen by the tallyman and his family. In the Lac Vimont sector (Domaine-du-Roy RCM), about 12 km southeast of the deposit, there are also secondary residences occupied on a seasonal basis. All told, land use is primarily associated with the hunting and fishing seasons.

The mining project extends to the Municipality of James Bay (rail transfer point and 20 km of access road) and the town of Chibougamau (pit and production facilities). The processing plant, fine tailings pond, polishing pond and part of the access road starting at Lac Yvette are contiguous with the Domaine-du-Roy RCM. Land allocation and use permitted in the municipalities affected are compatible with mine development. Certificates of compliance have been issued in this regard by the appropriate authorities in the Municipality of James Bay and the town of Chibougamau.

The major activities in the project’s zone of influence are related to logging, mining and extensive tourism (hunting and fishing). Large-scale logging ended in the 1990s; the planting of pine and spruce and pruning of cut sites are the main logging activities. Mining activity consists of exploration. Such work around the Lac Doré Geological Complex led to a feasibility study in August 2011, and BlackRock Metals now intends to mine the iron ore there.

As regards traditional activities, the Cree and Innu tallymen share the Mistissini beaver reserve (traplines O-59 and O/M-57) and the Roberval beaver reserve (trapline 24). Management of trapline O/M-57, immediately north of trapline O-59, is the subject of discussion between the Cree communities of Mistissini and Oujé-Bougoumou. There also seems to be a lack of consensus between the tallymen on the boundaries of traplines O-59 and O/M-57. According to information obtained by the Grand Council of the Crees and the community of Oujé-Bougoumou, the mining project is located entirely within the boundaries of trapline O-59.

Hunting, fishing and trapping are practised extensively, while berry-picking is less prevalent. Matthew and Philip Wapachee, the main Cree users, say they hunt moose and goose in the Lac Armitage area, as well as around the mine site. They trap various fur-bearing animals over the entire area of their trapline (O-59). Fishing is done mostly in Lac Chibougamau and Lac Armitage, “in winter and summer alike”.

12.2 DETERMINATION OF IMPACT SIGNIFICANCE

The significance of impacts depends first on two indicators of their intensity and scope. A third indicator covers the resistance of the impacted component to project development. Duration is a criterion to be considered in terms of impact significance, but is not part of the determination process. The environmental components analyzed have all been dealt with in specific chapters: fauna, flora, wetlands, noise, air quality, hydrogeology, geochemistry and risks. Their impacts, whether or not they can be spatialized, have been defined and weighted.

12.2.1 Intensity and Scope

<u>Impact Intensity</u>

Intensity refers to the level of disturbance of the environmental components affected by the project. Three levels of intensity, set out below, have been established.

High intensity

Natural and human environment

- The intensity of disturbance is high when it destroys or significantly alters the integrity of a component of the natural environment, in a manner likely to cause its decline or a major change in its general occurrence in the environment.
- The intensity of disturbance is high when it compromises or substantially limits the use of a component in the human environment by a community or local population.

Medium intensity

Natural and human environment

- The intensity of disturbance is medium when it destroys or alters a component in the natural environment to a lesser degree, without threatening its integrity but causing limited changes to its general occurrence in the environment.
- The intensity of disturbance is medium when its affects an environmental aspect or compromises the use of a component of the human environment by part of the local population, without threatening its integrity or use.

Low intensity

Natural and human environment

- The intensity of disturbance is low when it alters a component in the natural environment only slightly, without threatening its integrity or causing a reduction or significant change in its general occurrence in the environment.
- The intensity of disturbance is low when it has little effect on an environmental aspect or the use of a component of the human environment and does not threaten its integrity or use.

Impact Scope

Scope relates to the number of users or relative area of the environmental component undergoing an impact following completion of the project. The area of influence extends several hundred metres on either side of the access road and over a radius of several kilometres around the pit. Three levels of scope have been established.

Regional or national scope

- For a component in the natural environment, the impact affects a large area extending beyond the limits of the project's zone of influence (regional receiving environment).
- For a component in the human environment, the impact affects a component used or perceived by a regional community or by a large proportion of the Quebec or Canadian population.

Local scope

- For a component in the natural environment, the impact affects an area corresponding to the limits of the project's area of direct influence (local study zone).
- For a component in the human environment, the impact affects a component used or perceived by all or part of a community.

Isolated scope

- For a component in the natural environment, the impact affects a relatively small area within the limits of the project's area of influence.
- For a component in the human environment, the impact affects an environmental component used or perceived by a small group of individuals.

12.2.2 Resistance of Environmental Components

The level of resistance of an environmental component is based on the anticipated impact the project will have on it and the component's assigned value. Both environmental and technical resistance are recognized. In addition to a constrained level, five categories of resistance are recognized: very high, high, medium, low and very low.

Anticipated impact and assigned value

Anticipated impact refers to the likelihood of a component in the natural and human environments being affected by infrastructure construction or being a source of technical difficulties during infrastructure development.

Assessing the level of anticipated impact consists of specifying the use or function of the environmental component in terms of preserving its integrity. The three levels of anticipated impact are defined as follows:

- an anticipated impact is high when a component is destroyed or heavily altered by project development, or if it creates major technical difficulties that significantly raise development costs or lower facility effectiveness and reliability;
- an anticipated impact is medium when is component is altered by project development or causes significant difficulties without compromising economic or technical feasibility;
- an anticipated impact is low when a component is only slightly altered by project development or causes minor technical difficulties.

The value of a component depends on an overall judgment that takes into account the component's intrinsic value, i.e., its rarity, size or position in the environment, and the applicable laws. It also takes into account the value assigned to the component by specialists and the public. Unlike anticipated impact, assigned value takes the component's regional dimension into consideration. The five levels of value are defined as follows:

- the component's value is said to be legal when it is, or is about to be, protected by a law that prohibits or strictly controls project development or when it is very difficult to obtain government authorizations to develop the project;
- the component's value is high when it has exceptional characteristics whose conservation or protection is the subject of consensus;

- the component's value is medium when it has characteristics whose conservation or protection is a subject of considerable concern but not general consensus;
- the component's value is low when conserving or protecting it is not of major concern;
- the component's value is very low when conserving or protecting it is not of concern for the public or specialists.

Definition of resistance

Combining levels of anticipated impact and component value produces six levels of resistance, as illustrated in Figure 12.1:

- constrained refers to a component protected by a law governing facility development to the extent that this component must absolutely be avoided; it also characterizes a component that creates nearly insurmountable technical difficulties requiring excessive investment to overcome;
- very high resistance refers to a component that should only be affected in cases of extreme necessity; in technical terms, very high resistance represents a space that should only be occupied in cases of absolute necessity, due to major technical and economic difficulties to which facility development in these spaces would be exposed;
- high resistance refers to a component to be avoided to the greatest extent possible because of the importance conferred by its intrinsic value or fragility or because of the risk of technical difficulties that would generate substantial additional costs;
- medium resistance refers to a component that may, with some environmental or technical reservations, be selected for infrastructure development; however, a medium resistance component requires the application of specific mitigation measures or involves additional investment;
- low resistance refers to a component that can be affected with minimal environmental or technical restrictions;
- very low resistance refers to a component that can be affected without restriction or that will create no technical drawbacks.

12.2.3 Classification of Components Based on Resistance

Classification of the project's components based on their degree of resistance is presented in Table 12.2. The text that follows is subdivided, with environmental resistance shown first and, when relevant, the technical aspect presented afterwards.

Figure 12.1 Resistance Matrix

ANTICIPATED IMPACT	VALUE OF THE ENVIRONMENTAL COMPONENT				
	Legal	High	Medium	Low	Very low
High	**Constrained**	**Very high resistance**	**High resistance**	**Medium resistance**	Low resistance
Medium	**Constrained**	**High resistance**	**Medium resistance**	Low resistance	Very low resistance
Low	**Constrained**	**Medium resistance**	Low resistance	Very low resistance	Very low resistance

Table 12.2 Resistance of Project Components

ENVIRONMENTAL COMPONENT	ANTICIPATED IMPACT	ASSIGNED VALUE	ENVIRONMENTAL RESISTANCE
Lakes and streams – fish habitat	High	High	Very high
Wetlands	High	High	Very high
Vulnerable plant and wildlife species	Medium	High	High
Traditional land use	Medium	High	High
Spawning grounds – project area of influence	Low	High	Medium
Groundwater	Medium	Medium	Medium
Forestry and primary resources	Medium	Medium	Medium
Mature forest	Fort	Low	Medium
Tourism activities	Medium	Medium	Medium
Resorts	Low	High	Medium
Planted areas	Fort	Very low	Low
Young and regenerating communities	Medium	Low	Low
Logging	Low	Low	Very low
Surficial materials	Medium	Very low	Very low

12.2.4 Resistance of Components of the Natural and Human Environments

Constrained

None of the components of the proposed mine site constitutes an environmental or technical constraint.

Very high resistance

Lakes and streams – very high resistance

From an environmental standpoint, the anticipated impact on lakes and streams is considered high as many of them will be destroyed. This judgment takes into account the brook trout spawning grounds located in the system formed by lakes B-14 and B-12 and their common emissary. The resistance of aquatic environments also arises from the fact that they are regulated at the federal and provincial levels and subject to special attention inasmuch as they constitute fish habitats. In the BlackRock project sector, given their size and features, the lakes and streams are of low value for traditional, recreational or tourism activities. The scope of the impact does not extend outside the project's areas of influence. Nevertheless, with a few exceptions, fish habitats are involved; resistance with respect to the project is therefore considered very high.

Wetlands – very high resistance

From an environmental standpoint, wetlands are fragile and are also likely to host vulnerable or threatened biological species. Wetlands constitute, or are part of, the home range of various mammal and amphibian species, and are closely associated with the integrity of fish habitats. They regulate the surface water flow and feed the drainage system. They may play a role in complexing certain pollutants, thus helping enhance water quality. The anticipated impact of the project elements on these environments is high, and their value is high; resistance is therefore very high.

High resistance

Vulnerable plant and wildlife species – high resistance

According to research and the environmental surveys presented in Chapter 7, some vulnerable or threatened plant and wildlife species are likely to be found in the region, but no wildlife habitats under the meaning of the *Act respecting the conservation and development of wildlife* have been identified in the area of the mine site (Chapter 8). These species mainly occupy wetlands.

Overall, it is believed that the infrastructure will have a medium impact on vulnerable species because their presence in the study area remains theoretical. Only the rock vole has a high likelihood of being present in the area of the mine site. The value assigned to vulnerable or threatened species is considered high because their conservation and protection are regulated and because they are the subject of consensus. Their environmental resistance is therefore considered high.

Traditional land use – high resistance

Traditional activities (hunting, fishing and gathering) have a high value because of their cultural significance for aboriginal communities. These activities, moreover, are governed by the

JBNQA. They are practised over vast expanses on a seasonal basis by a limited number of individuals. Wildlife and plant components that may be affected by the infrastructure are common in the region. It should, however, be noted that the moose habitats used for hunting by the tallyman and his family will be lost. As regards the O-59 hunting and trapping grounds, the presence of infrastructure covering an area of about 6 km^2 will alter its use, even though the grounds cover a vast territory of more than 1,000 km^2. The presence of infrastructure and intense traffic will have an impact on the safety and accessibility of certain hunting, fishing and gathering areas.

This is especially true of the Wapachee family's hunting camps located along road 210. Traffic there will be heavy and intense, and will represent a risk to the safety of users, in addition to generating particulate matter near the camps and the drinking water source adjacent to the Wapachee family's camp. It is reasonable to believe that the anticipated impacts are medium. Traditional activities present high resistance.

<u>Medium resistance</u>

Spawning grounds in the project's area of influence – medium resistance

Spawning grounds have been identified in Ruisseau Audet and Ruisseau Wynne near road 210. The walleye spawning ground located in Rivière Armitage and the white sucker spawning ground in Ruisseau Villefagnan are unlikely to be affected, given their position at the edge of the area of influence of mining activities. The brook trout spawning ground near the mine site was covered earlier, with very high resistance attributed to it. The anticipated impact on the spawning grounds is low because they are located along existing roads or at the edge of the project's area of influence. Their value is high, however, meaning that the associated resistance is medium.

Groundwater – medium resistance

Hydrogeological studies (Chapter 10) show that the geological formations tend to allow groundwater to flow in large fractures. However, in the mining sector, the northeast-southwest trending areas of weakness do not extend directly into Lac Chibougamau or toward inhabited environments. In addition, the waste accumulation areas are covered by glacial deposits of low permeability, which naturally helps slow the movement of particles. Hydrogeological studies also show that the open-pit mine will be an aquifer outlet. Water containing possible contaminants from the fine tailings pond or the polishing basin will be pumped back into the fine tailings pond. Water re-emerging at the western edge of the waste rock and coarse tailings piles will be processed at the treatment and monitoring pond created downstream. Finally, the results of laboratory analyses indicate that the mine tailings are neither acid-generating nor leachable.

Accordingly, the project's anticipated impact on groundwater quality is considered medium. The value attached to this component is also considered medium. Its environmental resistance is therefore medium.

Logging and primary resources – medium resistance

As regards the exploitation of forestry resources, although little activity is planned in the project area, it is obvious that the scope of mining traffic will create problems with the sharing of road 210 by the two types of primary industry. This will have a significant impact on user safety. The size of wood haulage trucks and the traffic intensity of the semi-trailers carrying the concentrate are areas of concern. Meticulous, sustained co-operation between operators must be provided for. The anticipated impact in terms of logging activities is considered medium. The value attached to logging activities in the mining project's area of influence is also deemed to be medium. No other mining projects are planned in the project's area of influence at present or foreseeable in the mid-term. Resistance to primary resource operating activities by third parties is medium.

Mature forest – medium resistance

The anticipated impact on mature forest is high because it is destroyed on the infrastructure development sites. In ecological terms, forest protection is important. However, in a region recognized for commercial logging, the value of this resource is considered low as it is part of the logging companies' cutting plans. Protecting mature forest at the mining project's implementation sites is not an area of major concern. For these reasons, the environmental resistance of the mature forest is considered medium.

Tourism activities – medium resistance

Tourism activities in the project area are marginal because the water bodies affected are not of interest to fishermen. The hunting picture is less clear, as the area supports a moose population and small game hunting is practised along the roads. It should be recalled, however, that the presence of hunters or fishermen unrelated to traplines is systematically regarded by the tallymen as being in conflict with traditional activities and the rights granted to them under the JBNQA. In light of intensified mining activity along the road between the rail transfer point and the mine site, the anticipated impact on tourism is judged as medium. The value of the component is medium and takes into account the abundance of similar environments in the region. The resistance of this component is therefore medium.

Resorts – medium resistance

The impact on resort areas at the edge of Lac Chibougamau (north, west and south shores) and Lac Vimont (Domaine-du-Roy RCM) is low because they are far from the project and there is no conflict over use of the access road; nevertheless, resorts are assigned a high value. Environmental resistance is therefore medium.

<u>Low resistance</u>

Planted areas – low resistance

The project's anticipated impact on planted areas is high because they will be destroyed. The areas affected are very small, however. Their value is very low because their disappearance from the project development sites will not be challenged by specialists or the general public. Resistance to project development is low.

Young and regenerating communities – low resistance

The impact on young and regenerating communities is high during the construction phase because they will be destroyed locally, but their value is very low because they are not part of the commercial forest, and protecting them is not a subject of concern in the short or medium term. The environmental resistance of these communities is considered low.

Very low resistance

Logging – very low resistance

The project's impact on logging areas is low, and their value is very low. With some exceptions, logging will not return to these areas for several decades – 50 years at the earliest. Environmental resistance is therefore very low.

Surficial materials – very low resistance

Sand and gravel deposits cover small areas. Use of these deposits may cause gullying, alter surface water flow and affect groundwater quality, and the anticipated impact is therefore medium. The value attached to surficial materials is very low. Environmental resistance is therefore very low.

12.3 STATEMENT OF IMPACTS AND MITIGATION MEASURES

Based on the grid presented in Figure 12.2, the correlation between indicators of intensity, scope and resistance can establish the significance of impacts on the natural and human environments, indicating whether the significance is major, intermediate or minor. Duration was not used as a criterion for determining the impact but rather as an item of information that can help in selecting appropriate mitigation measures.

The components of the host environment affected by the project are soil, air, plants, wildlife, the built environment, land use, the economy and landscapes. Figure 12.3 (Impact Matrix) shows the existing relationship between sources of impact and environmental components, as well as the impact significance. Table 12.3 below summarizes impact significance based on activities inherent in project development. It also indicates the mitigation measures to be applied and an appreciation of the residual impact. Only direct effects have been listed in the matrix. It should be noted that the "archeology", or "heritage", component does not appear in the impact matrix (Figure 12.3) or in the table summarizing environmental impacts (Table 12.3) this is because research on archeological and heritage remains turned up nothing. The impacts on the natural and human environments and the landscape are shown in Figure 12.4. Current mitigation measures and descriptive sketches are presented in Appendices 12.1 and 12.2; special mitigation measures are indicated in the text and repeated in Appendix 12.3.

Considering the alteration and change of vocation of the host environment, most of the impacts on the natural environment are negative. They may, however, be mitigated in the short, medium or long term. The positive impacts are related to the human environment, and more specifically to the economy and employment.

Mining operations cause impacts involving the atmospheric dispersion of contaminants (Chapter 5), noise (Chapter 6) and the generation of solid and liquid wastes (Chapters 9 and 10). These topics were covered in specific studies because of their particular technical aspects and applicable regulations. The related impacts are also identified in the matrix in Figure 12.3.

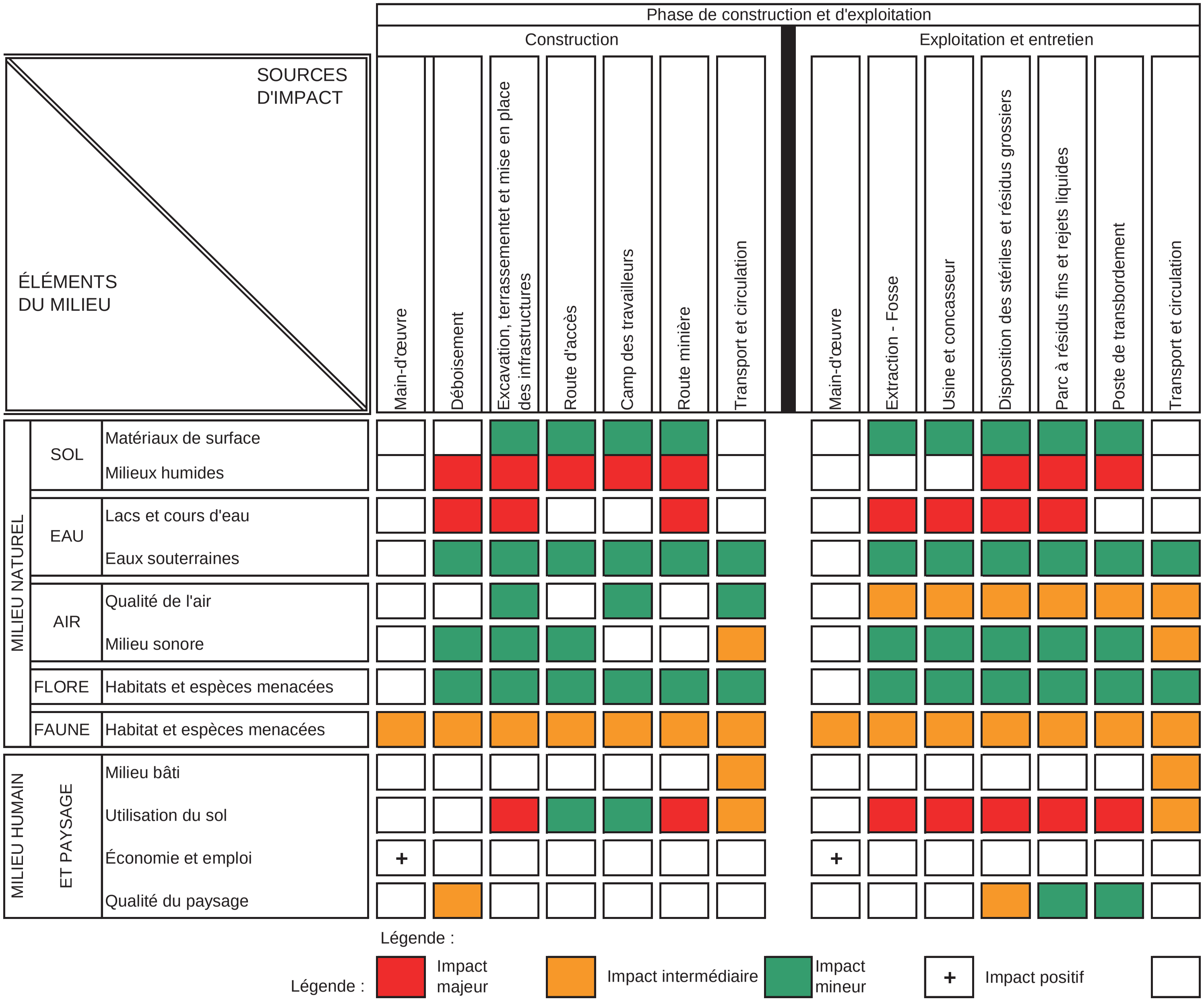
It is important to recall that the significance of impacts is determined before mitigation measures are applied, as these measures are intended to mitigate or eliminate the impacts. Residual impacts on environmental components are those that persist despite the application of mitigation measures. Residual impacts are generally from minor to nil. In this regard, compliance with laws and regulations, along with the application of the development standards and criteria set out in the various planning guides, constitutes a mitigation measures in itself (see references at the end of this chapter).

In addition, establishing a risk management system for technological accidents and emergency response plans for workers' health and the environment (Chapter 11) also helps prevent and contain certain potential accidents inherent to the project. Finally, environmental monitoring and follow-up programs (Chapter 14) and a rehabilitation plan (Chapter 13) are other measures that help reduce or eliminate the project's negative impact on the environment.

Figure 12.2 Impact Significance Determination Grid

COMPONENT RESISTANCE	IMPACT INTENSITY	IMPACT SCOPE	IMPACT SIGNIFICANCE
CONSTRAINED OR VERY HIGH	HIGH	REGIONAL LOCAL ISOLATED	MAJOR
	MEDIUM	REGIONAL LOCAL ISOLATED	MAJOR INTERMEDIATE INTERMEDIATE
	LOW	REGIONAL LOCAL ISOLATED	INTERMEDIATE MINOR
HIGH	HIGH	REGIONAL LOCAL ISOLATED	MAJOR MAJOR INTERMEDIATE
	MEDIUM	REGIONAL LOCAL ISOLATED	MAJOR INTERMEDIATE INTERMEDIATE
	LOW	REGIONAL LOCAL ISOLATED	INTERMEDIATE MINOR MINOR
MEDIUM	HIGH	REGIONAL LOCAL ISOLATED	MAJOR INTERMEDIATE INTERMEDIATE
	MEDIUM	REGIONAL LOCAL ISOLATED	INTERMEDIATE INTERMEDIATE MINOR
	LOW	REGIONAL LOCAL ISOLATED	MINOR
LOW	HIGH	REGIONAL LOCAL ISOLATED	INTERMEDIATE MINOR MINOR
	MEDIUM LOW	REGIONAL LOCAL ISOLATED	MINOR
VERY LOW	HIGH	REGIONAL LOCAL ISOLATED	MINOR
	MEDIUM LOW	REGIONAL LOCAL ISOLATED	MINOR TO NIL

Figure 12.3 Impact Matrix



Traduction du "Figure 12.3 Impact Matrix"

Construction and operating phase
Construction *Operation and maintenance*

SOURCES OF IMPACT
ENVIRONMENTAL COMPONENTS

Labour
Deforestation
Excavation, levelling and installation of infrastructure
Access road
Workers' camp
Mine road
Transportation and traffic

Labour
Extraction – Pit
Plant and crusher
Disposal of waste rock and coarse tailings
Fine tailings and liquid waste pond
Transfer point
Transportation and traffic

NATURAL ENVIRONMENT

SOIL	*Surface materials*	*Wetlands*
WATER	*Lakes and streams*	*Groundwater*
AIR	*Air quality*	*Sound environment*
FLORA	*Habitats and threatened species*	
FAUNA	*Habitats and threatened species*	

HUMAN ENVIRONMENT AND LANDSCAPE
Built environment *Land use* *Economy and employment* *Landscape quality*

Legend:
Legend *Major impact* *Intermediate impact* *Minor impact* *Positive impact*
Not applicable

Table 12.3 Summary of Environmental Impact by Project Activity

Environ-ment Affected	Component Affected	Description of Impact	Phase	Activity	Component Resistance	Impact Intensity	Impact Scope	Impact Significance	Current Mitigation Measures	Specific Mitigation Measures	Residual Impact
SOIL	Surface materials	• Alteration of the soil profile, erosion • Loss of original soil at the location of the tailings management facilities • Soil compaction caused by the passing of heavy machinery and trucks • Risk of contamination by accidental spills	Construction Operation	• Clearing • Borrow pits • Excavation and levelling • Access and mine roads • Transportation and traffic • Extraction – pit • Tailings disposal • Rail transfer point	Very low (rock, moraine and gravel)	Medium	Isolated	Minor	Appendices 12.1, 12.2 Measures 1-8, 34, 36-40, 42-45	Section 12.3.1.1 Measures S1, S 2	Minor to nil
	Wetlands	• Loss of wetlands through encroachment of tailings management facilities • Risk of accidental spills of contaminants	Construction and Operation	• Clearing • Excavation and levelling, disposal sites and dikes • Water flow management	Very high	High	Isolated	Major	Appendices 12.1, 12.2 Measures 1-41, 43-56, 61-64	Section 12.3.1.2 Measures MH1, MH2	Minor
WATER	Lakes and streams	• Alteration of run-off, infiltration and the flow system • Increased sediment flow in streams and wetlands • Loss of small waterways and creeks • Loss of fish habitats • Risk of accidental spills of contaminants	Construction Operation	• Clearing and site preparation • Dynamiting, excavation and levelling • Access and mine roads • Extraction – pit • Water management • Tailings disposal • Transportation and traffic	Very high	High	Local	Major	Appendices 12.1, 12.2 Measures 1-41, 46-56	Section 12.3.2 Measures E1-E3	Minor
	Groundwater	• Contamination by oil products (accidental spills) • Contamination by leachates, wastewater or accidental spills	Construction Operation	• Transportation and traffic • Excavation and levelling • Management of wastewater and contaminants • Extraction – pit • Tailings disposal • Management of wastewater and contaminants • Transportation and traffic	Medium	Medium	Isolated	Minor	Appendix 12.1 Measures 3, 9-18, 35, 55, 56	Section 12.3.3 Measures ES1-ES2	Minor
AIR	Air quality	• Deterioration of air quality by suspended dust and greenhouse gas emissions	Construction Operation	• Excavation and levelling • Transportation and traffic • Ore extraction • Plant and crusher • Transportation and traffic	High	Low	Local	Intermediate	Appendix 12.1 Measures 3, 8, 19, 20, 57, 58	Section 12.3.4 Measures A1-A6	Minor
	Sound environment	• Increase in the noise level and deterioration in the sound environment in the area of the mine site and transfer point and on the access road	Construction Operation and maintenance	• Transportation and traffic • Dynamiting, excavation and levelling • Extraction – pit (dynamiting) • Plant and crusher • Transportation and traffic	High	Medium	Isolated	Intermediate	Appendix 12.1 Measures 59, 60	Section 12.3.5 Measures MS1-MS10	Minor: sound level below the limit of 40 dB(A) 250 m from the access road and 2 km from mine site activities

Table 12.3 Summary of Environmental Impacts by Project Activity (cont'd)

Environment Affected	Component Affected	Description of Impact	Phase	Activity	Component Resistance	Impact Intensity	Impact Scope	Impact Significance	Current Mitigation Measures	Specific Mitigation Measures	Residual Impact
FLORA	Habitats and species	• Elimination of vegetation on 587 ha of land • Loss of space for commercial forest • Theoretical loss of threatened species or of species likely to be found in the mine sector	Construction Operation and maintenance	• Clearing • Excavation and levelling • Access and mine roads • Pit • Tailings disposal • Presence of production and support equipment	High (mature forest) Low (young forest, regenerating forest, planting) Very low (logging)	Low	Isolated	Minor	Appendices 12.1, 12.2 Measures 1-8, 34, 36-40, 42-45	Section 12.3.6 Measures Fl1, Fl2	Minor
FAUNA	Habitats and species	• Loss of habitats for certain mammal, fish and bird species through the encroachment of disposal sites and of production and support infrastructure • Higher accident risk in contact with animals • Fishing by workers in the study zone	Construction Operation and maintenance	• Labour • Clearing • Excavation and levelling • Access and mine roads • Transportation and traffic • Labour • Extraction – pit • Tailings disposal • Transportation and traffic	High	Medium	Local	Intermediate	Appendices 12.1, 12.2 Measures 1-8, 65-67	Section 12.3.7 Measures Fa1-Fa6	Minor
HUMAN ENVIRONMENT	Built environment	• Heavy and intense regular traffic, day and night, for at least 14 years • Higher accident risk on road 210 and the access road • Noise, dust and carbon monoxide on road 210 and the access road	Construction and operation	• Transportation and traffic	High	High	Isolated	Intermediate	Appendix 12.1 Measures 57, 59, 60	Section 12.3.8 Measure MB1	Nil
	Land use	• Heavy and intense traffic, day and night, for at least 14 years • Restricted access to certain areas (rail transfer point, mine site) • Mining vocation confirmed between the deposit and the rail transfer point • Land use conflict between traditional, logging and primary resource activities • Higher risk of accidents with other users. • Noise, dust and atmospheric contaminants	Construction Operation and maintenance	• Transportation and traffic • Clearing • Excavation and levelling • Workers' camp • Access and mine roads • Extraction – pit • Plant and crusher • Tailings disposal • Rail transfer point • Transportation and traffic	High (traditional use) Medium (logging, primary resources, tourism)	High	Local	Major	Appendix 12.1 Measures 1-57, 59-67	Section 12.3.9 Measures US1-US4	Minor

Table 12.3 Summary of Environmental Impacts by Project Activity (cont'd)

Environ-ment Affected	Component Affected	Description of Impact	Phase	Activity	Component Resistance	Impact Intensity	Impact Scope	Impact Significance	Current Mitigation Measures	Specific Mitigation Measures	Residual Impact
HUMAN ENVIRONMENT	Economy and employment	• Investment of about $600 million in the region • Increased activity in the region • Job creation for local and regional manpower and businesses • Purchases of goods and services	Construction and operation	• All activities	N/A	N/A	Regional	Positive impact		Mitigation measure E1E1 Optimization measures Section 12.3.10	Positive
	Quality of landscape	• Introduction of anthropogenic components perceptible from Lake Chibougamau	Construction and operation	• Tailings management facilities	Medium to high	Minor to nil	Low	Intermediate to minor (rocky ridge visual unit) Minor to nil (lakes and forest visual unit)	N/A	Mitigation measures V1, V2	Minor

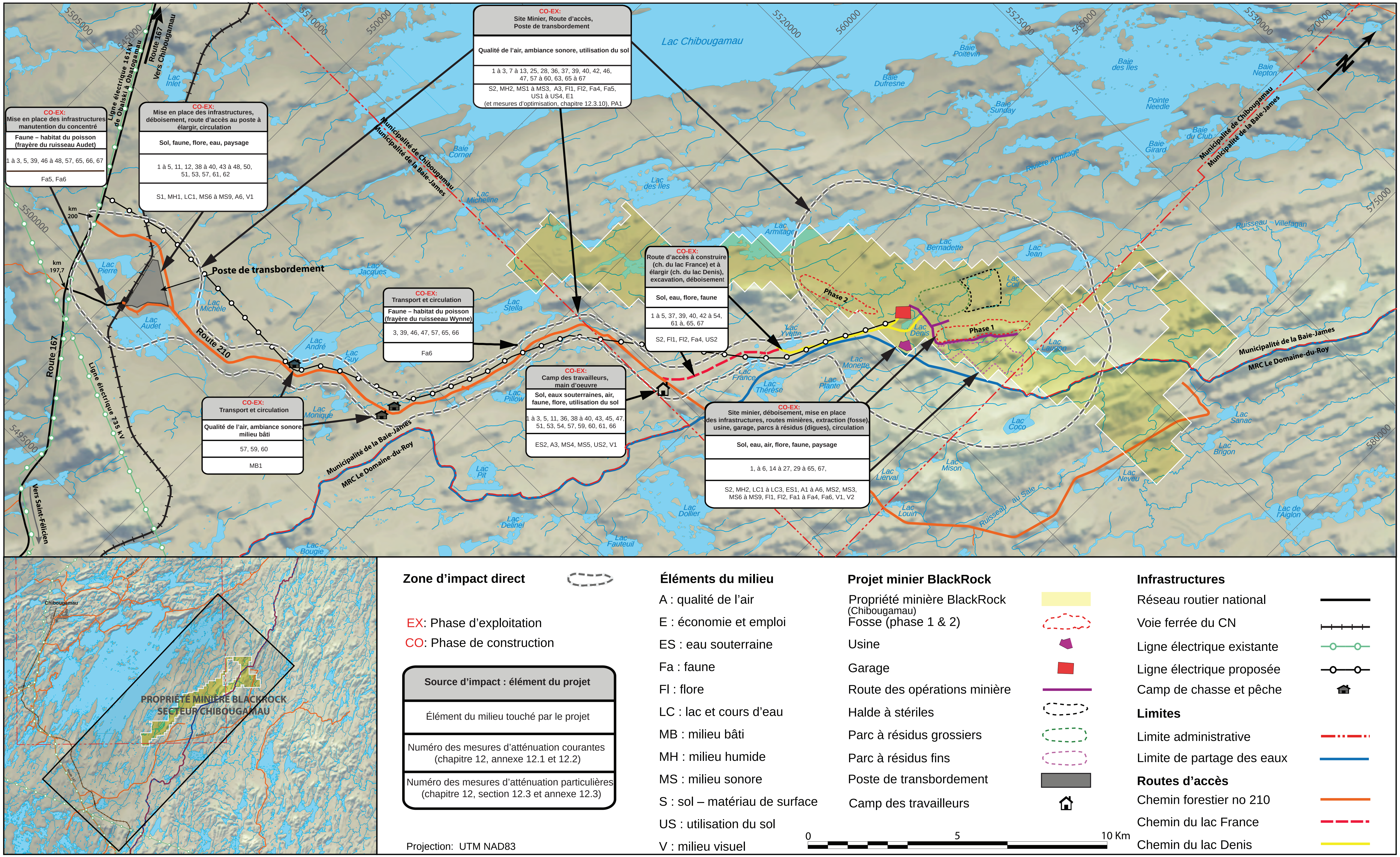


Figure 12.4 Location of Impact and Mitigation Measures

12.3.1 Impact on the Natural Environment – Ground

The ground includes surficial materials as well as wetlands: the impact affects their structure or function in the environmental balance. The impact will be the greatest during the construction phase, but will extend into the mine's operation and beyond closure.

12.3.1.1 Ground – Surficial Materials

Sources of direct impact

Nearly 600 hectares of soil will be disturbed during construction and operation, including 482 hectares at the mine site when the tailings management facilities have reached their full size. The ground will be stripped, excavated, filled and levelled for the development of roads, platform bases for infrastructure, dams, the pit, piles and tailings facilities.

The raising of Lac Denis for its use as a process water supply reservoir will encroach on nearly 8.5 hectares of ground. The footprint of the project's other components is as follows: the access road (3.5 ha), the workers' camp (7.5 ha) and the rail transfer point (100 ha). Since the rail transfer point has already been used by the forestry industry, the impact there will not be great. In this regard, the Phase 1 environmental assessment conducted in May 2011 on the rail transfer point provided no clear indication that the soil is free of contamination. Since use of the site for ore shipment and storage purposes creates risks of soil contamination, learning more about the property's environmental condition is of primary importance. For the project as a whole, soil contamination risks arise from the handling of hydrocarbons and chemical products, as well as from the presence of tailings facilities.

Use of the existing borrow pits should not disturb the ground significantly. The setting is already altered, and the existing logging roads provide access to these sites. Specific certificates of authorization will be requested for each borrow site. In addition, a very large portion of the granular material will come from waste rock excavated from the pit and the mine infrastructure sites. At the pit, mineral and organic soil will be stripped gradually and set aside for rehabilitation needs.

Sources of indirect impact

Tree clearing, creation of ruts by construction machinery, creation of a drainage system and general traffic will cause the movement of fine particles to the water network. These ground disturbances will have a minor impact on run-off and infiltration.

Impact significance

Rock, till and gravel can be used with a minimum of restrictions without major risk of erosion (very low resistance). The work will disturb the ground surface without, however, causing any major change (medium intensity), considering the small areas affected (isolated scope). For mineral soil, the impact is therefore of minor significance. The impact extends beyond the mine life; the original ground will forever be altered in the areas of the pit and the tailings facilities.

Current mitigation measures

Appendix 12.1: measures 1 to 8, 34, 36 to 40 and 42 to 45.

Appendix 12.2: descriptive sketches.

Specific mitigation measures

S1 Conduct a Phase 2 environmental assessment of the rail transfer point before starting construction work.

S2 Depending on material quality, which is still to be confirmed, give priority to operation of borrow pit No. 13 (drumlin, permeable material), the glacial till (impermeable material) below borrow pit No. 13 and the borrow pits already open and listed in GESTIM, so as to reduce the project's footprint and visual impact.

Residual impact

Despite the application of mitigation measures, there will be permanent and irreversible ground alterations at the open-pit mine, waste rock piles and tailings facilities (permanent alteration of the topography and the ground layers).

12.3.1.2 Ground - Wetlands

The importance of wetlands in the balance of the water system and their fauna and flora support capacity are demonstrated in Chapters 7 and 8. Some plant and animal species that are fragile or likely to be threatened can be found in the wetlands. From a technical standpoint, wetlands are sensitive and very poorly drained environments with a low load-bearing capacity, and should ideally be avoided.

Wetlands account for 13.9% of the area of the Rivière Nottaway watershed. In the project's area of influence, they cover about 28% of the ground surface. The rail transfer point and mine site encompass 16.3% of the wetlands. Therefore, 75 hectares of wetlands are lost at the mine site, as are 0.5 and 3 hectares respectively at the access road and camp. At the rail transfer point, BlackRock Metals plans to use the areas that have already been developed for industrial purposes. Only a small part of the 18 hectares of wetlands at the rail transfer point will be affected.

Sources of direct impact

In the construction and operation phases, deforestation, levelling, ore extraction, tailings storage, water management, stream crossings, use of road salt or dust control agents and spills are all sources of direct impact.

Project development will also cause changes in the wetlands located downstream from the mining infrastructure, altering surface and groundwater dynamics. The diversion of the Lac Denis outlet to lake B-1 will accentuate this phenomenon at Lac Jean.

On the other hand, there should be some offset in terms of water in the wetlands bordering Lac Jean, as the run-off coefficient for developed areas is much higher than under natural conditions.

With respect to soil erosion, there will be an increase in run-off rates, erosion risks and the movement of fine sediments to wetlands downstream from the project as a result of tree clearing, soil exposure, construction of impermeable surfaces (infrastructure) and the installation of stream crossings. The migration of contaminants to these wetlands could also alter biophysical conditions and habitat quality.

The wetlands affected directly by the project account for 0.05% of the wetlands in the Rivière Nottaway watershed and 3.7% of the wetlands in the study area. The integrity of wetlands at the local or regional level is therefore not threatened. The wetlands have a very high resistance to the project, and the impact intensity is high. The areas affected have an isolated scope. The significance of the impact on wetlands is major.

Sources of indirect impact

The change in the water system and the sedimentary balance in the wetlands downstream from worksites could cause a deterioration or loss of habitats valued by some wildlife and plant species. The rearrangement of surface drainage will have an effect on the ecological dynamics of the wetlands at the project's periphery.

Current mitigation measures

Appendix 12.1: measures 1 to 41, 43 to 56 and 61 to 64.

Appendix 12.2: descriptive sketches.

Specific mitigation measures

MH1 At the rail transfer site, prioritize the use of areas already developed for industrial purposes. Use areas characterized by wetlands or mature forest only as a last resort.

MH2 With the trapline O-59 tallyman, identify wetlands that could be part of a rehabilitation plan and those that could be used for wildlife compensation measures. Priorities identified in this way will be submitted to the federal and provincial authorities before measures are instittuted.

Residual impact

Wetlands located at the site of the waste rock and coarse tailings piles are irrevocably lost and will have to be offset. The original conditions of wetlands located downstream from the mining infrastructure, around Lac Jean and lake B-1 (Chapter 8), could be restored or improved at the end of mining operations. Lake B-1 may then handle the same quantities of water that characterized it before the work. As regards Lac Jean, it is even plausible that habitat quality could be significantly enhanced. All the water used in the mining process will be returned to it directly. The disappearance of water bodies and in particular of wetlands upstream from Lac

Jean will reduce the water loss through evaporation and infiltration that characterized the original environment. The downstream flow of Ruisseau Villefagnan will rise accordingly.

12.3.2 Impact on the Natural Environment – Lakes and Streams

Surface water quality is linked to flow coefficient and physicochemical parameters, in particular the presence of suspended particles and dissolved solids, pH, dissolved oxygen, conductivity, reduction oxidation potential, etc. Surface water quality may be affected by water system changes, chemical products, run-off, oil spills and mine tailings. The impact on surface water will be felt at every stage of the project.

Sources of direct impact

During construction, the ground structure is broken by site preparation, drainage system development, water diversion, stream crossings and culvert installation, leading to sediment in streams and altering the natural flow. Traffic on gravel roads generates a significant quantity of dust in the air, some of which may end up in waterways. In the area of the mine site, the most heavily altered subsystem will be that of Lac Jean. The reduced flow from Lac Jean will also affect its main collector, Ruisseau Villefagnan. The rearrangement of the water system will reduce the low flow in Ruisseau Villefagnan by about 9%. The lakes B-1, B-2 and A-1 subsystem will be altered to a minor extent by occasional discharges from Lac Denis.

The building of the access road to the processing plant should improve surface drainage. The existing culverts on the logging road at Lac Yvette and Lac Denis are clearly undersized. No significant impact on surface water is anticipated at the rail transfer point, as the area was developed in the past for the Gagnon-Frères sawmill operation, and drainage is adequate.

During mine operation, mine water management and tailings disposal are the main sources of direct impact on surface water. At the pit, stripping, blasting and ore extraction will generate fine particles and nitrogenous waste, as well as causing possible hydrocarbon spills. These contaminants will largely be carried away by the mine water. Mine reclaim water and any such contaminants will be sent to the fine tailings pond for treatment.

The tailings pond is located at the top of the watersheds but encroach on ponds and creeks that will be lost. These are small, shallow ponds covering 5.5 hectares; they are mostly undergoing eutrophication, and their discharge is very low. Once again, it should be recalled that the only exception in terms of habitat quality is the system formed by lakes B-14 and B-12 and their emissary, which cascades down from the deposit hill.

Water from the fine tailings pond will be recovered in a polishing pond and sent to Lac Denis for reuse as process water. Lac Denis will in effect serve as a process water reservoir and will be maintained as such throughout the operation phase. Water entering Lac Denis will meet discharge standards. Water released into the environment will be sent from Lac Denis to lake B-1. Run-off from the mine site will be collected by drainage ditches and redirected to the west side of the coarse tailings pile, where a treatment and monitoring pond will be created to ensure that the water returning to Lac Jean is of a physicochemical quality that meets regulatory standards.

Sources of indirect impact

The higher run-off rates in the developed areas will have an indirect and variable effect on surface water quality, as it will contain particles and contaminants. Management of mine tailings and reclaimed water and refuelling are activities that can have a significant impact on surface water quality.

Impact significance

The environmental resistance of lakes and streams to project development is very high, and impact intensity is high. Sources of impact will cause major local alterations. The impact is considered major.

Current mitigation measures

Appendix 12.1: measures 1 to 41 and 46 to 56.

Appendix 12.2: descriptive sketches.

Compensation measures

The project's impact on surface water is offset by the raising of Lac Denis from an elevation of 412 metres to 424 metres, as well as by fish management measures to be put in place. The lake will be expanded to about 2.6 times its current area, from 5.4 to 13.8 hectares, for a gain of 8.4 hectares. The volume of Lac Denis will rise from 50,000 m^3 to 1.3 million m^3, a 26-fold increase compared to its original volume. This reserve of clean water will therefore become a good environment for aquatic fauna, especially northern pike. This species is found in the lake under natural conditions that are far from optimal (see Chapter 8). The dam raising the level of Lac Denis can be left in place after the mine closes if safety conditions are met and the tallyman considers it an advantage.

The total area of shallow ponds lost to project development (5.5 hectares) is largely offset by the gain at Lac Denis (8.4 hectares), for a net gain of 2.9 hectares. Obviously, this all depends on rigorous compliance with discharge standards for the polishing and sedimentation pond water sent to Lac Denis. In addition to Lac Denis, other water bodies may be the subject of compensation measures; this is covered in Section 12.5.

Specific mitigation measures

The specific mitigation measures listed below are applied as of the construction and mining facility installation phase.

LC1 The local, partial diversion of waterways and the alteration of surface drainage in the areas of the waste rock pile and tailing pond should be done during low-water periods.

LC2 A sill 1.5 metres high will be built at the outlet of Lac Jean to maintain a water level that allows fish to survive during low-water periods.

LC3 A stilling pond will be built where the channelled water leaves Lac Denis. From here, at least two sills will be built along the route along which the water flows before entering lake B-1.

Residual impact

The application of mitigation measures should significantly reduce the impact on surface water quality. The original flow will be altered permanently by the presence of mine tailings. However, the entire volume of water taken from the environment for processing purposes can be returned to its original watershed (Lac Jean) at the end of operations. The residual impact should be minor.

12.3.3 Impact on the Natural Environment – Groundwater

The impact assessment for groundwater takes into account the presence of two hydrostratigraphic units, namely an aquitard of sandy till and a fractured rock aquifer. The average hydraulic conductivity of the till is 1.29 x 10^{-4} cm/s at the mine site and 8.6 x 10^{-6} cm/s at the rail transfer site. The average hydraulic conductivity of the bedrock is 1.93 x 10^{-4} cm/s. The water table is near the surface, and the flow pattern closely follows the local topography. The water is more oxygenated in recharge zones and less oxygenated near the wetlands. It is important to note that in recharge zones, precipitation brings in slightly acidic water that is buffered along its route. The wells in discharge areas in fact have alkaline water. This observation confirms that the bedrock has a significant capacity for neutralizing acid rain. Metals found in the groundwater are below or very close to the detection threshold.

The effects of the open-pit mine and the tailings facilities on groundwater were established by modelling using *Visual MODFLOW* 2010 software. The results indicate that drawdowns are low because of the high relief and the low hydraulic conductivity of the bedrock at depth. Infiltration into the pit could range from 1,400 to 2,800 m^3/day. Finally, there are no sensitive hydrogeological environments in the project area.

Sources of direct impact

Two types of impact can be expected in relation to groundwater quality: the impact from mixing water from the pit with the surface water toward which it will later be discharged, and the impact of injecting potentially contaminated water into the groundwater from the tailings facilities and the pit, once it fills up at the end of the project.

Groundwater that seeps into the pit should meet all the *Directive 019* discharge criteria, and could theoretically be returned to the environment without treatment. In practice, water pumped from the pit could contain hydrocarbons and nitrogenous waste from explosives. This water will be sent to the fine tailings pond before being transferred to the polishing basin. It will meet all discharge parameters before being released into Lac Denis.

Piezometric modelling also shows that the pit will be an aquifer outlet during the life of the operation. Any contaminants that might infiltrate will be looped back to the fine tailings pond. For the waste rock and coarse tailings piles, virtual water particle tracking shows that potentially contaminated water would flow northwest. Since the water table at this spot is very near the surface and the site is at the foot of a hill, the likelihood of infiltration is very low, and leached water would quickly re-emerge in the ditches or the treatment and monitoring pond set up south of Lac Jean.

It will therefore be impossible to contaminate the groundwater as long as pit dewatering activities are ongoing. However, once mining activities end, the pit will gradually fill up until a lake forms in equilibrium with the surrounding topography. If any contaminants (such as metals or hydrocarbons) are present, they could migrate through the most permeable units.

On a different matter, the drinking water supply for the construction camp will come from a drilled well. Hydrocarbon or chemical product spills and wastewater treatment may constitute sources of direct impact on groundwater quality.

Indirect sources of impact

Run-off and seepage of dangerous substances or fuel are potential indirect sources of groundwater contamination.

Impact significance

Mine tailings are not acid-generating, and the results of analyses show that concentrations of leachable metals are well below the standards. As such, groundwater resistance to the project is medium. The same applies to the impact intensity. The sources of impact will cause a limited alteration of groundwater quality and flow due to the presence of the pit. Possible groundwater contamination would affect a limited area within the site boundaries. For these reasons, the significance of the impact is considered minor.

The duration of the impact is long, as there is a risk of groundwater contamination throughout the life of the project. Based on the available information, groundwater contamination is unlikely once the mine closes.

Current mitigation measures

Appendix 12.1: measures 3, 9 to 18, 35, 55 and 56.

Specific mitigation measures

The specific mitigation measures listed below are applied starting as of construction and mine facility installation.

ES1 If any contamination is detected, maintain the pit as a hydraulic trap, with the water continuing to be treated until it meets the quality criteria.

ES2 During construction, ensure that the wastewater treatment and purification system at the workers' camp is functioning properly, and that hydrocarbon, chemical product and waste management principles set out in Chapter 11 are being complied with.

Residual impact

Despite the application of mitigation measures, groundwater quality may be affected in a minor way as long as mining operations are ongoing.

12.3.4 Impact on the Natural Environment – Air Quality

Air quality relates to the presence of particulate matter and greenhouse gases. This aspect, involving a specific assessment methodology, is covered in Chapter 5. A study was conducted for all regulated sources of emissions: total particulate matter (TPM) in the air, fine particles, carbon monoxide, sulphur dioxide, nitrogen dioxide and heavy metals.

Sources of direct impact

Air quality will be affected from the start of construction work, mainly by generator use, vehicular traffic on gravel roads, soil disturbance and borrow pit operation.

During operation, ore extraction and processing and traffic are the primary causes of impact on air quality. Given that all the facilities are grouped around the pit, gases and suspended particulates could affect the workers. In addition to greenhouse gases, emissions can contain particulate matter and metals, especially chromium. The ambient air quality study shows that TPM and identified gaseous pollutants fall within regulatory levels during the construction phase. During operation, the level of atmospheric contaminant emissions depends on the application of mitigation measures. Without these measures, only TPM and chromium levels in the air can be seen to exceed the criteria in the summer months. This occurs at a number of sites at the southern edge of the mine site (plant and crusher area).

Air quality will also be affected by the handling of concentrate at the rail transfer point.

Sources of indirect impact

The coming and going of concentrate transport trucks along a gravel road to the rail transfer site is a source of impact on air quality due to dust and fine particle emissions.

Impact significance

During the construction phase, air quality will be altered essentially by the emission of the above-mentioned dust and air pollutants. Despite the high resistance of this component vital to life and the regulations governing it, the intensity of the impact remains low on the basis of the modelling results; the overall impact is therefore minor.

The operation phase is when the intensity of the impact will be highest. Most of the pollutants will be below regulatory limits, but some (chrome and TPM) could exceed Quebec’s applicable criteria during summer months. These contaminants could be dispersed by the wind around the mine site or the rail transfer point. For these reasons, there is an impact of intermediate significance that lasts throughout the operation phase.

Current mitigation measures

Appendix 12.1: measures 3, 8, 19, 20, 57 and 58.

Specific mitigation measures

During the construction period, maximum contaminant concentrations meet regulatory criteria. During operation, the application of mitigation measures to maintain air quality on the mine site may help reduce particulate emissions, including TPM and chromium, by 80%. These measures will also help protect the environment located in downwind areas based on the prevailing winds, especially areas not covered by the JBNQA and the Nitassinan of the Pakuakamiulmatsh.

A1 Limit traffic on haulage roads to authorized vehicles.

A2 Coat haulage roads with low-silt materials.

A3 During the summer season, spray roads regularly based on the following equation provided in the *Air Pollution Engineering Manual* (Cowherd, 1992):

$$C = 100 - (0.8*P*D*T/I)$$

Where:

C: is the average emission control efficiency (%)
P: is the average hourly daytime evaporation rate (mm/hour)
D: is the average hourly daytime traffic rate on the unpaved mine site roads (h^{-1})
T: is the time between applications (hours)
I: is the application intensity ($litres/m^2$)

A4 To ensure compliance with applicable standards and monitor particulate matter emissions, install, as of the start of mine construction:

- an air quality sampling and measurement station; based on prevailing winds, this station should be placed in the south-southeastern part of the mine site for continuous measurement and analysis of TPM, $PM_{2.5}$ and PM_{10} concentrations;
- an automated weather station on the mine site to measure the main climate parameters, such as air temperature and humidity, horizontal visibility, wind speed and direction, and precipitation.

A5 Cover the fine tailings subject to wind action with a layer of water and implement an ongoing rehabilitation program. In the winter, cover these tailings with snow. As much as possible, maintain a band of forest cover around the tailings pond to reduce the spread of dust.

A6 Using dust masks at work locations where emission levels are likely to exceed occupational health and safety standards.

Residual impact

Applying current and specific mitigation measures and at-source reduction techniques will help lower pollutant emissions to below regulatory limits. In this context, mine activities can be considered to have a negligible residual impact on ambient air quality.

12.3.5 Impact on the Natural Environment – Noise

The noise associated with mine construction and operation and processing plant operation was covered in a study presented in Chapter 6; the main effects are described below. The noise standards that apply to the project are taken from *Directive 019* (April 2005).

Sources of direct impact

During construction, the noise environment will be altered by infrastructure and mining facility installation activities. Heavy vehicle traffic and the use of specialized machinery generate noise at a level of about 85 dB(A) at 15 metres, disturbing the ambient noise and worker comfort. Workers at the camp located along the access road will not be affected by the noise from worksite machinery, but they will be affected by the traffic in general. The operation of borrow pits should not generate noise disturbance as they are located at distances greater than the standards set out in regulations for those at the receiving end.

During operation, some work locations are likely to have noise levels above 90 dB(A), notably for operators of hydraulic shovels and drills. Overall, industrial noise generated by mining activities is above 40 dB(A) up to a distance of two kilometres away from the pit and the plant. Noise from open-pit mine activities meets the *Regulation respecting pits and quarries* (Q-2, r.2) due to the absence of residential, commercial or mixed zones and housing.

Noise from the trucks carrying iron ore concentrate between the plant and the rail transfer point is below 40 dB(A) outside a 250-metre distance on either side of the access road. It was decided to use conventional semi-trailer dump trucks for this operation. To move the thousands of tonnes of concentrate produced each day, preliminary estimates indicate that a load will leave the processing centre every six minutes. This represents a total of about 20 trips per hour on the access road, or nearly 500 heavy vehicle trips a day, constituting a potentially significant noise source as the route is very long and difficult.

Operations at the rail transfer point beside the CN line are conducted largely in a heated garage, partly attentuating the noise produced. In addition to a motor, the facility is equipped with two blowers and an unloading station for trucks coming from the mine. Again, these noise sources involve operations that should remain sporadic and of low intensity compared to the CN trains passing nearby. At this stage of the project, development of the rail transfer point does not seem to present any particular risk of noise impact. Nevertheless, a zone two kilometres in radius has been drawn around the facility to indicate the limit beyond which the sound level will be below 40 dB(A).

The mining project's potential noise impact on wildlife cannot be commented on. It is evident, however, that creating new sources of noise, along with blasting, will affect some species and will certainly affect moose, but this aspect is not well enough documented to be analyzed in greater detail.

Sources of indirect impact

There is no noteworthy indirect impact on the noise environment. Noise could nevertheless spread over varying distances carried by the wind.

Impact significance

Activities related to use of heavy construction equipment will generate a noise level that falls within the limits set by *Directive 019*. The noise environment at the work site will be controlled. A small number of workers could be subjected to a noise level exceeding occupational health and safety standards. During operation, industrial noise will exceed the 90 dB(A) limit in certain work locations, and workers will have to use personal protection equipment.

Pursuant to *Directive 019*, the anticipated impact on the noise environment is low, as is its intensity. In a natural setting, the noise environment has a high value. The scope of the impact is local. Its significance is therefore minor. There are two exceptions, however: at the workers' camp and at the Wapachee family's hunting camps. These facilities are close to the road and will be subject to noise levels above 50 dB(A) (Chapter 6) and likely above 70 dB(A). Under these conditions, noise exposure caused by transportation and by traffic in general would not be compatible with the vocation of these facilities. The anticipated impact at these facilities is high, the value of the components is high, and resistance is therefore high. The intensity of the impact is medium, and its scope is isolated. The anticipated impact at the workers' camp and at the Wapachee family's hunting camps is intermediate.

Apart from the cases mentioned above, the noise study (Chapter 6) showed that the noise does not spread to the built environment, located more than 10 kilometres from the mining operation. Under these conditions, the significance of the project's impact on the noise environment outside the operation's area of influence is negligible.

During construction, the duration of the impact on the noise environment is short and intermittent, with activities taking place over a period of no more than two years. However, during operation, the duration of the impact is intermediate, since it will be felt for nearly 15 years.

Current mitigation measures

Appendix 12.1: measures 59 and 60.

Specific mitigation measures

MS1 Check the noise environment at the mine site, along road 210 and at the rail transfer point once a year for the first three years, from 2012 to 2014. Later, conduct a new noise survey every four years or when significant equipment is added. Plan for a compilation of noise levels at the boundaries of the BlackRock property.

MS2 Include sound pressure as a selection criterion for the project's noisiest equipment.

MS3 Where applicable, for various types of trucks, select boxes with flexible liners.

MS4 Design camp modules to meet recognized acoustic comfort criteria. Plan the camp layout such that the most sensitive facilities (bedrooms, dining rooms and recreational areas) are furthest from local noise sources and road 210. Build a protective berm between the camp and the road to reduce the influence of heavy vehicular traffic.

MS5 Noise monitoring should be done at the camp immediately after it is set up and during a representative period of activity. Daytime and night sound levels should not exceed 45 dB(A) in the vicinity of the dormitories. Noise level measurements at the camp should be taken on an annual basis.

MS6 Dosimetric measurements should be taken at each work location at least once a year. Daily noise doses for workers are measured using integrating dosemeters. These are portable devices installed on workers' belts. The microphone connected to an integrating dosimeter is placed on the worker's shoulder. Noise levels are integrated to get the daily noise dose of a worker wearing the device. Dosimetric measurements should be taken starting in the first year of operation.

MS7 Employees at work locations where daily noise exposure is above 90 dB(A) must wear hearing protectors meeting the CSA Z94.2-1974 standard. If applicable, corrective measures to bring noise below the permissible limit should be instituted, in particular the installation of sound barriers and sound suppressors. Absorbent materials will be used on vibrating surfaces and, when required, work areas will also be soundproofed. Jobs for which the calculated daily noise exposure is above the limit are those of loader, bulldozer and grader operators, as well as concentrator operators.

MS8 Signs regarding the wearing of hearing protection will be placed systematically wherever the sound level exceeds 90 dB(A) to protect workers without fixed jobs, such as mechanics and electricians who may be working in a noisy area throughout their shift.

MS9 Other noise reduction measures will include the use of sound barriers or cabins at work locations, the wearing of hearing protectors and alternation of jobs.

Residual impact

The application of mitigation measures and compliance with regulations will bring the noise environment into accordance with occupational health and safety standards. Industrial noise will nevertheless disturb the local noise environment around equipment (mine site and rail transfer point).

12.3.6 Impact on the Natural Environment – Flora

Sources of direct impact

The construction phase is when the forest cover will most feel the project's impact. The tree clearing required to develop the sites and build the access road is the main source of direct impact on the tree stratum. The plant cover, including wetlands, affected by mining equipment totals 588 hectares, and 39% of this area has already been subjected to commercial logging. Regeneration covers an area of 43.5 hectares, young communities 72.5 hectares and mature communities 147.5 hectares. At the mine site, mature groups of black spruce are dispersed in small parcels that have been spared by logging. At the deposit, the surface has been stripped many times for exploration activities.

Wetland flora will be affected gradually during construction and operation. Areas of 0.5 and 3.0 hectares respectively will be lost at the access road and the workers' camp. By the end of operations, 75 hectares of wetlands will also have been lost at the mine site.

The building of the access road between road 210 and Lac Yvette will also affect dry cleared or semi-cleared spaces, several red pine plantings, two hectares of young or regenerating communities and 0.5 hectare of mature communities.

At the transfer point, young or regenerating communities, as well as a few red pine plantings, will be lost to make way for the railway siding and ore storage facilities. Mature communities at this spot (55 hectares) are located at the eastern edge of the rail transfer site and are not likely to be affected. This is also true of the 18 hectares of wetlands located largely in the same area. The plant cover will be affected throughout the life of the project.

Sources of indirect impact

In terms of indirect impacts, the analysis of threatened or vulnerable species presented in Chapter 7 shows that a number of species covered by the *Species at Risk Act* are likely to be found in the study area; their presence remains theoretical, however, as none of them has been formally observed.

Transportation and intense traffic between the mine site and the rail transfer point will generate dust that will land on vegetation adjacent to the road. This particulate matter can interfere with photosynthesis, alter the soil structure and degrade the habitat. Another source of indirect impact is the increase in run-off and infiltration. This may cause an additional flow of fine particles into waterways.

Impact significance

The vegetation found in the wetlands has been covered separately in Section 12.3.1. As regards the various forest stands (mature forest, plantings, young communities, regeneration and logged areas), they present a range of environmental resistance to the project. All of them will undergo an impact of minor significance given the low intensity of the impact (the integrity of the component is not called into question). The impact will be felt on small areas (isolated scope). For these reasons, the project's impact on vegetation, including threatened plant species likely to be found on the project site, is considered minor.

The project's impact on vegetation will be long-lasting since revegetation will take place over many years after the infrastructure is dismantled and the site is rehabilitated. At that stage, it is plausible that indigenous tree species may not be able to recolonize certain areas, such as the tailings facilities.

Current mitigation measures

Appendix 12.1: measures 1 to 8 and 61 to 64.

Appendix 12.2: descriptive sketches.

Specific mitigation measures

Fl1 The gradual clearing of work areas and the equally gradual rehabilitation of the tailings sites will help minimize erosion and favour the return of plant cover.

Fl2 Organic overburden will be stripped gradually and kept for rehabilitation purposes. At the tailings facilities, it is recommended that the organic layer be maintained as a buffer between the tailings and the underlying soil.

Residual impacts

Despite the application of mitigation measures and the rehabilitation plan, the vegetation's seral stage (spruce stands) in the pit and tailings area may never come back because of the new soil type (profile: soil horizon, physicochemical composition). For the other affected areas (access roads, plant, garage, rail transfer point), the progress of species toward the seral stage will be delayed by about 20 years.

12.3.7 Impact on the Natural Environment - Fauna

Creeks with a permanent flow along sloping gravel beds, such as Ruisseau Villefagnan, are habitats that favour the development and maintenance of aquatic fauna in general. Intermittent streams and poorly drained environments are low-productivity habitats for aquatic fauna. All environments, however, may contain many organisms at the bottom of the food chain.

Despite their low productivity, lentic environments in the mining area are good beaver habitats. The land's gentle gradient easily allows for dams to be built and kept functional regardless of the weather. This leads to a proliferation of forage fish, in particular cyprinids, and enables predators such as otters to move into this ecological niche. Again in terms of predators, the aquatic environment, although not highly diversified, supports the presence of an osprey pair. Moose also make intensive use of the lakes and bordering wetlands for their food and use the adjacent mature forests as winter habitat. To this portrait must be added a small number of bird species, as well as various small mammals. To sum up, although this environment has low productivity, it maintains an ecological balance that serves a small number of birds, mammals and aquatic species. The project's impact on fauna will be felt during construction and operation.

Sources of direct impact

During construction, clearing and site preparation will eliminate habitats and cause repercussions on fauna. Most species are flexible enough to be able to move away. Species with a very small home range, such as the red-pointed Eastern newt, small mammals such as the Southern bog lemming and a large number of fish risk being eliminated as work advances.

Winter moose habitats at the periphery of the mine site, along with summer feeding sites, will be affected by the project. This is also the case with the nesting area of an osprey pair. Elimination of lakes B-14 and B-12 and their common emissary (Chapter 8) will eliminate a local population of brook trout. The lower flow in Lac Jean will have a direct impact on the fauna living or spending time there. The occasional release of water from Lac Denis into the basin of lakes B-1, B-2 and A-1 is also likely to affect the balance of this small system.

As regards the access road, much of it already exists, and the new portion will pass through places that are cleared, dry and open. The road's impact on fauna, especially on known spawning areas, should not be felt significantly.

Sources of indirect impact

The encroachment of waste rock piles and tailings ponds on water, stream diversion and creation of a drainage network will bring fine particles into the water system and could disturb aquatic life. A reduction in the flow of Ruisseau Villefagnan downstream from Lac Jean could have indirect effects on habitats and aquatic species.

The displacement of various wildlife species outside the work zone could lead to higher density of individuals on the periphery and greater predation. The presence of workers during construction and operation is likely to entail more hunting and fishing activities.

Intensive use of the access road will have the effect of forming a barrier limiting the passage of some wildlife species or increasing the risk of collision. Traffic will raise dust that will fall on nearby vegetation and bodies of water. Dust accumulation may alter land habitat quality locally and disturb fish habitats, especially the spawning grounds along road 210 (Ruisseau Wynne, Ruisseau Audet).

Impact significance

Although wildlife resistance to the project is high, the intensity of the impact is medium. The aquatic habitats have low productivity, and the land habitats that are affected do not stand out as unique; they are common in the territory. The project will destroy environments that are well suited to certain species but will not threaten their integrity. Rather, the project will cause limited changes to their distribution in the environment; many species will easily be able to move to find similar subsistence environments. The impact has a local scope, reaching to the edge of the project's area of influence. In this context, an impact of intermediate significance is obtained.

The duration of the impact is medium since it will start at the construction phase and end a few years after the mine closes, in more than 15 years, once the sites are rehabilitated and the area finds a new environmental equilibrium.

Current mitigation measures

Appendix 12.1: measures 1 to 8 and 65 to 67.

Appendix 12.2: descriptive sketches.

Current measure 67 is especially important because it relates to the work schedule that must be followed to avoid harming the reproduction of certain species.

Specific mitigation measures

Fa1 In collaboration with the tallyman, monitor the quality of replacement winter habitat for moose along trapline O-59. Compensation measures should either allow for the enhanced potential of the wildlife resources on trapline O-59 or at least facilitate its general management.

Fa2 During the first year of construction, no work will be done within one kilometre of Lac Coil between mid-April and late August, which are the nesting, incubation and dependency periods for young ospreys.

Fa3 Conduct a study to identify replacement nesting sites for the osprey and erect nesting platforms. This measure could also be beneficial to the bald eagle that is present in the Lac Chibougamau area.

Fa4 Use the Cree tallyman’s services to catch fur-bearing animals in the sectors to be affected by the facilities before work starts. This measure also applies to catching beaver (November to March) and relocating them (April to October). This measure for beavers also applies during operation, as beavers see culverts as a prime opportunity to build a dam.

Fa5 BlackRock will prohibit access to the industrial site for purposes other than work. Fishing within the boundaries of the property will thus be excluded.

Fa6 Detailed compensation measures to offset fish habitat loss must be developed. The sites that should be the addressed by the most in-depth studies are Rivière Armitage, Lac Denis, Lac A-2 and all of Ruisseau Villefagnan, including its two main branches, as well as Ruisseau Wynne and Ruisseau Audet. The studies and implementation of work will be conducted in collaboration with the trapline O-59 tallyman. Progress reports will be submitted to Fisheries and Oceans Canada, as well as to the *Ministère des Ressources Naturelles*, for comment and approval.

Residual impact

Despite the application of current and specific mitigation measures and the mine site rehabilitation plan, some habitats will never be restored to their original condition, particularly in the tailings area and the pit. The dynamics of wildlife populations in these sectors will therefore be altered permanently.

Compensation measures

The development of sills could make the upper reaches of Rivière Armitage and Ruisseau Villefagnan accessible to walleye. There is also potential for compensation measures on Ruisseau Villefagnan and Lac A-2 for brook trout. Habitat productivity could also be enhanced by the creation of the reservoir at Lac Denis and the implementation of compensation measures on Ruisseau Wynne. Some of these measures can be harmonized with the integrated fisheries resources management program to increase production of the sought-after species and support sport fishing in Lac Chibougamau. Such studies and work will be conducted in collaboration with the trapline O-59 tallyman. Section 12.5 provides an overview of the possibilities mentioned above.

12.3.8 Impact on the Human Environment – Built Environment

There is no permanent dwelling in the project's zone of direct influence; a few hunting and fishing camps belonging to the trapline O-59 tallyman (Philip Wapachee) have been identified in the Lac André sector, along the access road (logging road 210). In the regional zone of influence, the town of Chibougamau is about 30 kilometres as the crow flies northwest of the pit, on the other side of Lac Chibougamau, or more than 60 kilometres away via road 210 and Route 167. In the Domaine-du-Roy RCM, the hunting and fishing camps are located around Lac Vimont, about 12 kilometres southeast of the ore body.

Sources of direct impact

The project's direct impact on the built environment (Camp Wapachee) is caused essentially by traffic on road 210. Traffic volume will be heavy with the start of the construction phase and will grow in the operaton phase.

During operation, the regular passing of trucks carrying iron ore concentrate to the rail transfer point on a daily basis, along with movements of workers and suppliers, will have a significant impact. Noise, dust and the emission of atmospheric contaminants will compromise environmental quality and the safety of road and hunting camp users.

Sources of indirect impact

There is no indirect impact on the built environment.

Impact significance

Built environment resistance is high. The intensity of the impact is high, although its scope is isolated. The project has on intermediate impact on the built environment.

The duration of the impact is medium because it will be felt during construction and throughout the life of the project. The impact will continue for several years after the end of operations, taking into account the time required to dismantle the equipment and rehabilitate the area.

Current mitigation measures

Appendix 12.1: measures 57, 59 and 60.

Specific mitigation measures

MB1 Relocate the Wapachee family's camp to an area unaffected by traffic. Discussions between BlackRock and the trapline O-59 tallyman on this subject are progressing well. The spot preferred by the Wapachee family is located along Ruisseau Wynne, near Lac Stella. Ruisseau Wynne provides access to Lac Pillow, Lac Stella, Lac Armitage, Lac Chibougamau and Rivière Armitage. This measure should be implemented before the start of construction.

12.3.9 Impact on the Human Environment – Land Use

This component encompasses human activities related to forestry, including exploitation of primary resources, as well as recreation, tourism and traditional activities. Large-scale logging activities in the vicinity of the mining project have ended, and no other mining projects have started in the area. Other types of use occur on a seasonal and extensive basis.

Sources of direct impact

From the start of construction, land use will be affected by the traffic generated by work at the workers' camp, the rail transfer point and the mine site and for construction of the access road. On construction sites, land use will be affected on an isolated basis, but intensive use of road 210 by workers will make it difficult for others to use the road. Some 600 hectares of land will gradually change vocation.

The impact will extend into the operation phase because of mining activities, the presence of equipment (tailings facilities and processing plant) and the heavy traffic on road 210. Hunting and fishing activities will be compromised in the vicinity of the mining facilities and the road linking the rail transfer point with the mine site. Third parties exploiting primary resources will also have to deal with this new reality. It should be specified, however, that the harvesting of the wildlife resources near the facilities is, in any case, incompatible with safety criteria associated with mine operation.

Sources of indirect impact

Mining activities will have indirect effects on other potential types of land use, such as extensive recreation and tourism. This is a large project that will confirm the mining vocation of the entire area around road 210 east of Lac Chibougamau. The project has little effect on logging, which has practically ended in the area of the project site and is unlikely to resume before 2030 or 2050, depending on the area.

Impact significance

Resistance of the land use component is considered high because the project heavily compromises other valued non-industrial activities around road 210 and the mine site, although it complies with municipal zoning. The intensity of the project's impact on the environment is high because it heavily compromises or limits use of this component for the population and traditional users of the territory. The latter have rights enshrined in the JBNQA. The extent or scope of the impact is local because it extends over a linear band about 30 kilometres long.

Apart from the access road that is already in place (road 210), the road to be built (along the route of an old logging road) and the workers' camp (a temporary facility for construction), the project's impact on land use is considered major.

The duration of the impact is medium and will be felt continuously during construction and throughout the life of the project. The impact will produce lesser effects for a few years after operations end, taking account of the time required to dismantle the facilities and rehabilitate the site.

Current mitigation measures

Appendix 12.1: measures 1 to 57 and 59 to 67.

Appendix 12.2: descriptive sketches.

Specific mitigation measures

US1 Advise the tallyman, municipal authorities, other users and general public of the work period, impact on land use and effect on their safety.

US2 Install signage at dangerous spots on the access road, e.g., at Km 200 on Route 167, at the junction of the road leading to the rail transfer point and at intersections with other logging roads, at the workers' camp, at the plant and on the mine site.

US3 In collaboration with the *Association Touristique Régionale* and with hotelkeepers, produce and disseminate documentation for hunters and fisherman who use the territory for walleye fishing and bear hunting. Promote alternate access routes to the territory and specify the dangers involved in tourism activities along road 210 between the rail transfer point and the mine site.

US4 Suppliers, the tallyman and the other resource companies who use road 210 should be equipped with the same radio communications equipment used by the concentrate transportation vehicles. All road 210 users associated directly or indirectly with the mining project, including other resource companies, should indicate their presence to the other carriers from the time they access road 210 and again at the prescribed kilometre posts.

Residual impact

Despite the application of mitigation measures, the entire area between the rail transfer point and the mine site will be under the influence of intensive mining activities. This may reduce or eliminate other land use possibilities.

12.3.10 Impact on the Human Environment – Economy and Employment

Basic investment (direct and indirect costs) for product construction and start-up amount to $609 million. Direct costs are in the order of $400 million and mainly include electrical equipment, infrastructure and production equipment. Indirect costs of about $153 million include engineering studies, work management, construction, commissioning and contingencies. Chapter 4 of this study provides details of the project costs and staffing requirements.

Sources of direct impact

The project will have positive direct effects on employment and will create local and regional economic benefits at every stage of development. Priority in the purchase of goods and services for the mine's construction and operation, as well as in the hiring of employees, will be given to the municipalities of Chibougamau and Chapais as well as to the communities of Oujé-Bougoumou and Mistissini.

During construction, BlackRock plans to hire workers for clearing, access road construction, site preparation, and building construction and mining infrastructure development. Plans call for an average of 200 workers spread over two years (2012-2014), with up to 500 workers at peak periods for construction. BlackRock can rely on local and regional expertise that is well structured and diversified to meet a significant portion of its needs (see Chapter 2, Section 2.3.7.2). In the event that demand for manpower exceeds regional supply, representatives of training and economic development bodies are in a position to set up programs to support BlackRock.

The company expects to make year-round use of the services of 80 to 160 workers during operation (2014-2028). Given an average salary of $100,000 and the average number of workers, this amounts to an annual payroll of about $12 million. Assuming a combined provincial and federal income tax rate of 30%, the two levels of government will receive $3.6 million annually and an undiscounted $54 million over 15 years.

Mine operation will require outlays of many millions of dollars for the purchase of heavy trucks, vans, tractors and drilling equipment. For example, more than $55 million in basic mining equipment will be purchased starting in the first year of operation. The purchase of fuel alone represents an annual amount of about $14 million.

At the municipal level, the annual industrial taxation rate is $3.21 per $100 of valuation, applicable to large-sized buildings (the plant or garage). The size of the buildings assures the town of Chibougamau of substantial tax revenues.

Sources of indirect impact

The indirect impacts on the economy and employment involve equipment maintenance and services: road maintenance, snow clearing, building maintenance, heavy machinery and equipment maintenance, and cleaning services. Purchases of goods and services also encompass food and lodging, clothing, car and truck rental, and tool and machinery purchase or rental, as well as air and road transportation, gasoline, hardware and leisure activities. BlackRock will also incur management expenses such as office maintenance, office supplies, cafeteria services, staff training, environment, communications, etc. All these requirements entail major spending in the region.

In addition to benefits for companies in the region and indirect job creation, the potential for creating new businesses is also substantial. The sustained injection of new money into the regional economy for 15 years will have indirect effects on citizens' quality of life. This will result in improved living standards for many families and will enhance job security and economic and social stability at the local and regional level.

BlackRock must also depend on the expertise of a certain number of workers from outside the region. This could produce a slight population increase and greater demand for services, especially in health care and education. Workers from outside required on more sporadic basis will have an impact on the supply of food and lodging.

The municipalities of Chapais and Chibougamau and the communities of Oujé-Bougoumou and Mistissini are looking forward to the positive impact on jobs and contracts.

Specific mitigation measure

E1 Preferential employment of the tallyman's immediate family, especially in relation to the environmental future of their territory. This includes biological and monitoring studies, the implementation of compensation measures for wildlife and wetlands, and the general enhancement of the wildlife potential of trapline O-59.

Optimization measures

- Creation by the company and the community of staff training programs to meet the project's requirements.
- Establishment of interaction mechanisms between employment centres in the region's various communities and the company.
- Preferential hiring of workers and contractors from Chibougamau, Chapais, Oujé-Bougoumou and Mistissini, followed by the nearby regions of Saguenay–Lac-St-Jean and Abitibi.
- Creation by BlackRock of a team of Cree trainers who have acquired similar mining project experience, especially at the Troilus mine.
- Setting up of a steering committee to develop and monitor the strategy for optimizing economic benefits.

12.3.11 Impact on the Human Environment - Archaeology

The archeology or heritage component is not listed in the impact matrix (Figure 12.3) nor in the table summarizing the impacts on the environment (Table 12.3) because the search for archeological or heritage vestiges has been fruitless. About 15 potential archaeological zones were identified between Route 167 and Lac Chibougamau, north of the deposit, including the rail transfer point, the access road corridor and the mine site (pit, tailings facilities, plant).

More than 500 surveys in the zones of archeological potential have confirmed the absence of artefacts or objects of historical or prehistoric value. In all likelihood, the project's impact on archeology and historic heritage is nil. The archaeological study's conclusion is summed up as follows: "*Mining work can thus be undertaken by BlackRock Metals in the surveyed areas without risk to archaeological resources*."

Nevertheless, to comply with the *Cultural Property Act* (R.S.Q., Chapter B-4), construction contractors and the developer will be required to cease work and advise the regional branch of the *Direction régionale du ministère de la Culture, des Communications et de la Condition féminine* (MCCCF) if they find archeological indicators. BlackRock would then be required to do a survey of these. The following preventive measure applies.

PA1 In the event that vestiges of archeological or heritage interest are discovered, work must cease immediately, and the MCCCF must be advised (*Cultural Property Act*, Section 41); it is forbidden to remove anything or to move objects and vestiges.

12.4 IMPACT ON THE LANDSCAPE

The visual analysis covers the territory within a radius of about 20 km of the deposit and focuses on "sensitive" vantage points such as roads, in particular public road 210 starting at Route 167, resort areas or observation points from which the mining facilities might be visible. The area of study is characterized by undulating topography and low relief.

Landscape is a natural or developed component that presents itself to the observer. The territory under study generally reflects a strong presence of past and present human activity (mining and logging) resulting in a notable fragmentation of the natural environment.

Landscape has a relative value based on its unique character, its geographic location (perception) and its use. There is a specific methodology for determining visual impact.

12.4.1 Methodology

The visual impact evaluation method used in this study is the one suggested by Hydro-Québec, *Méthode d'étude du paysage pour les projets de lignes et de postes de transport et de répartition* (1992), adapted to the needs of the project.

The first stage in the process consists of assessing the level of resistance of these units to the mining facilities once the landscape has been divided into specific landscape units based on their unique nature and characteristics. To this is added an assessment of the observer's degree of perception and the extent of the impact in the environment; these three parameters are used to establish the magnitude of the impact of new infrastructure on the landscape.

Determining the landscape's level of resistance

The landscape's resistance level is determined on the basis of two criteria, namely its concealment capacity and assigned value (see Table 12.4). Concealment capacity is determined by taking into account the landscape's absorption and insertion capacity in relation to infrastructure development. Insertion capacity refers to the physical compatibility of landscape components with new structures to be erected in the surroundings (scale, nature of the object). Absorption capacity refers to the landscape's capacity to conceal or integrate new components without transforming its unique character. Absorption is related to ease of visual access, stemming from the area's configuration and the type of facility planned.

Assigned value is determined by the landscape's intrinsic quality and the interest shown toward it in light of the area's vocation.

Assessing the observer's level of perception

The degree to which facilities are perceived is based on the observer's degree of visual exposure to them, and takes into account the observer's sensitivity to the perceived landscape (see Table 12.5). The degree of exposure is related to the portion of the visual field altered by the facilities, the relative distance and the observer's position vis-à-vis the planned installations, while the observer's sensitivity is defined by his interest in the landscape, based on the observer's activity and mobility.

Assessing impact scope

Impact scope takes into account the impact's reach, i.e., its physical scope, its duration and the number of users affected (see Table 12.6).

Table 12.4 Landscape Resistance Determination gGrid

Value accorded	Concealment capacity		
	LOW	**MEDIUM**	**HIGH**
HIGH	High	Medium	Low
MEDIUM	Medium	Medium	Low
LOW	Low	Low	Low

Table 12.5 Observer Perception Assessment Grid

Observer's Sensitivity	Level of Exposure		
	HIGH	MEDIUM	LOW
HIGH	High	Medium	Low
MEDIUM	Medium	Medium	Low
LOW	Low	Low	Low

Table 12.6 Impact Scope Assessment Grid

Duration	Level of Exposure		
	REGIONAL	LOCAL	ISOLATED
PERMANENT	Long	Medium	Short
TEMPORARARY	Medium	Short	Short

12.4.2 Resistance and Impact Signficance Based on Visual Units

Mining infrastructure is regarded as a single entity in this landscape impact assessment. Considering the distance of visual access to the site, a precise description of the structures perceived based on particular vantage points would not be pertinent. The telecommunication antenna installed at a high point on the site will probably be the most obvious component overall, as it will stand out from the ridge's profile on the horizon.

Resistance, degree of perception and impact scope are determined for each unit based on the the above grids, to produce an overall portrait of the impact of the projected site on the visual unit in question (see Table 12.7).

Table 12.7 Grid for Determining the Significance of the Project's Effect on the Landscape

At the Landscape Unit Level	At the Visual Field Level		Impact Significance
Resistance Level	Impact Scope	Observer's Degree of Perception	
High	High	High Medium Low	Major Major Medium
	Medium	High Medium Low	Major Medium Medium
	Low	High Medium Low	Medium Medium Minor
Medium	High	High Medium Low	Major Medium Medium
	Medium	High Medium Low	Medium Medium Minor
	Low	High Medium Low	Minor Minor Nil
Low	High	High Medium Low	Medium Minor Minor
	Medium	High Medium Low	Minor Minor Nil
	Low	High Medium Low	Minor Nil Nil

Visual Unit 1: The central rocky ridge

Despite previous alteration of this unit's natural landscape by logging and mining, its large visual access, dominating the landscape, creates high resistance to infrastructure implementation. The line of hills forms a backdrop from many vantage points in the area (see Photo 12.1). Furthermore, panoramic views from the peaks look out on spectacular landscapes. It should be noted that public road 210 cannot be seen from the peaks where the mining facilities will be located, as the landscape is entirely closed south of the ridges, but opens out to a view of various lakes to the north.

The observers' level of exposure to the planned installations is obviously greater in this unit; however, no formal look-outs have been identified. The vegetation along road 210 serves as a screen over the entire route.

Low to medium absorption / low to medium insertion = low to medium concealment

Assigned value: medium

Resistance to implementation: medium to high

Degree of perception = low

Impact scope = low to medium

Impact significance: minor to medium

Photo 12.1: Panoramic view from the rocky ridge, northeast of the planned mining installations

Visual Unit 2: Lac Chibougamau and Lac Vimont

The resistance of this unit is also high. By their very nature, lakes have a very low absorption and insertion capacity. They offer a large visual opening, a unique character and major symbolic value. The value assigned to this unit is also high, all the more so as both these lakes are considered important resort and recreational sites in the area.

The degree of perception was established taking into account the unit's large visual opening and the backdrop of the rocky ridge, which is the site of the planned mining operation. However, due to the distance of the lakes from the mine site (10 to 20 km) and the project's location at the horizon line, the perception of the project is of little significance to the observer.

The scope of the impact at this level is low, all the more so as the projected site is perceptible only from certain vantage points and there are no permanent dwellings in this area. Also, the dynamics and diversity of the landscapes in the area of the lake, with Mont du Sorcier and the various islands, reduces the importance of the ridge line in the landscape composition. Photo 12.2, taken from the rocky ridge, provides a sense of the distance separating the ridge unit from the lake unit and explains the low signficance of the impact on this unit.

Low absorption / low insertion = low concealment capacity

Assigned value = high

Resistance = high

Impact scope = low

Degree of perception = low

Impact significance: minor

Photo 12.2: Panoramic view from the rocky ridge, with Lac Chibougamau on the horizon

Visual Unit 3: The forest

This unit's resistance to project development is low. The unit's high absorption and insertion capacity is related to the fact that the environment has been altered by human activity (former Lemoyne mine, borrow pits, logging roads, hunting camps) and the access roads are generally line by forest vegetation on either side, creating a corridor effect and closing off views toward the mine site. The value assigned to this unit is also diminished by the fact that it is a common landscape in the region.

The observer's degree of perception of this unit is considered low. Factors such as distance, a generally closed view and relatively flat topography mean that an observer's level of exposure to the infrastructure is almost nil. The observer's sensitivity to the unit is also considered low to medium as this is an already-altered environment and most observers are mobile, with the landscape seen mainly from vehicular roads.

High absorption / high insertion = high concealment capacity

Assigned value: medium

Resistance to implementation: low

Degree of perception = low

Impact scope = low

Impact significance: minor to nil

12.4.3 Global Impact

Overall, the significance of the mining installations' impact on the landscape is minor (medium for the view of the rocky ridge). There are quite a few vantage points with views of the project site due to the elevation of the installations, but they remain distant, with minimal perception for an observer. Also, this landscape, like many others in the area, has already been marked by mining and logging. It is fairly characteristic of this region, which depends on these industries. The landscape's function in this case and its logic in the regional economy will clearly reduce sensitivity to new infrastructure for some observers.

Current mitigation measures

The position of the mining installations at the top of the ridge does not allow for any current mitigation measure near the site.

Specific mitigation measures

V1 Clad buildings in a colour that blends with the environment.

V2 Ensure that the height of waste rock and coarse tailings piles blends with the surrounding peaks.

Residual impact

Despite the proposed mitigation measures, the pit and tailings facilities will remain visible around the mine site and from vantage points on Lac Chibougamau during and after mine operation, but the residual impact is considered minor.

12.5 CUMULATIVE IMPACT

Assessment of the cumulative impact helps relate the project to the other anthropogenic alterations that characterize the host environment and have an impact on the people living there. This makes it possible to gain a better appreciation of the project's potential to fit in with a minimal risk of impact in a changing environmental and social context.

Initially, this exercise must take into consideration the valued environmental components and must set space and time limits on the analysis. Anthropogenic alterations to the environment must also be identified on the basis of these same space and time limits. The reference condition of and changes in valued components must known. Finally, there should be broad consensus regarding the valued components, which must be affected by the project.

The environmental components affected by the project that meet these criteria are:

- lakes and streams;
- traditional land use;
- use of the surroundings for exploitation of other resources;
- economy and employment.

12.5.1 Lakes and Streams

Lakes and streams are highly valued by the public primarily because of the wildlife resources they contain. The project clearly has an impact on this environmental component that structures the landscape in the Chibougamau region, as well as giving it a reputation as a high-quality fishing area. The project's influence on lakes and streams mainly involves the brook trout habitat and spawning grounds in the network formed by lakes B-14 and B-12 and their common emissary. These environments, though limited in space, will be affected. In addition, the quality of water as a habitat is linked to the flow coefficient and to maintenance of its physicochemical balance. Water quality will be affected to some degree by changes in the area's water system.

In the area of the mine site, the subsystem that will be altered substantially is that of Lac Jean. The reduction of its flow will also have effects on its main collector, Ruisseau Villefagnan. Rearrangement of the hydrographic system will cause the low-water flow of Ruisseau Villefagnan to drop by about 9%. The subsystem of lakes B-1, B-2 and A-1 will be altered slightly by the inflow of occasional releases from Lac Denis. During operation, the management of mine runoff and tailings disposal are the main sources of direct impact on surface water.

The tailings facilities are at the head of the watersheds but encroach on bodies of water and creeks that will be lost. These water bodies, totalling 5.5 hectares, are small, shallow and generally undergoing eutrophication, and their flow is very limited. The only exception in terms of quality of habitat is the system formed by lakes B-14 and B-12 and their common emissary, which cascades down from the deposit hill.

12.5.2 Traditional Land Use

Traditional activities (hunting, fishing and gathering) are of major cultural significance for the Native communities. These activities are also controlled under the JBNQA. They are practised over vast territories on a seasonal basis by a small number of individuals. Although the fauna and flora components affected by the infrastructure are common in the region, the moose habitats used for hunting by the tallyman and his family will be lost. The presence of infrastructure covering an area of about 6 km^2 alters the use of trapline O-59, even though it covers a sprawling territory of more than 1,000 km^2. The presence of infrastructure and intense traffic will have an impact on safety and on access to certain hunting, fishing and gathering areas.

This applies in particular to the Wapachee family's hunting camps located along road 210. Heavy traffic there will be intense and will create a risk for the safety of users, as well as generating particulate matter around the camps and the adjacent drinking water source. To minimize this impact, the tallyman has agreed to relocate his camp. From the standpoint of cumulative impacts, the project is one of many successive anthropocentric alterations in the region since the early 1950s.

12.5.3 Exploitation of Primary Resources and Wildlife

In terms of the exploitation of forestry resources, although little activity is planned in the project area, it is obvious that the scope of mining traffic will lead to logistical complexity in the sharing of road 210 by the two types of primary industry. This has a significant effect on the safety of users. In the current context and the foreseeable mid-term, no other mining project is expected in the BlackRock project zone of influence. The cumulative impact of land use along the route of logging road 210 is thus significant. This road's carrying capacity is currently at the limit of its potential. The addition of other projects on top of the BlackRock project cannot be envisaged in this corridor without substantial added measures.

12.5.4 Land Use for Fishing and Wild Game Activities

Fishing activities in the project area are marginal because the lakes affected offer little interest in terms of sport fishing species. The hunting picture is less clear, as the area supports a moose population, and small game is hunted along the roads.

With the start of construction, land use will be affected by the traffic generated by work at the workers' camp, the rail transfer point and the mine site, and by access road construction. Intensive use of road 210 during the operation phase will make it even more difficult for third parties to use the road.

Hunting activities will therefore be affected in the vicinity of the mining installations and the road linking the rail transfer point to the mine site. Hunters and fishermen will have to take this new reality into account.

12.5.5 Economy and Employment

The project will have positive direct effects on employment and will generate local and regional economic benefits. Preference in the purchase of goods and services for the mine's construction and operation, as well as in the hiring of employees, will go to the municipalities of Chibougamau and Chapais and the communities of Oujé-Bougoumou and Mistissini.

During construction, BlackRock intends to hire an average of 200 workers a year for two years (2012-2014). BlackRock can depend on well-structured, diversified local and regional expertise to meet a significant portion of its needs. During the operation phase, the company expects to make year-round use of the services of 80 to 160 workers. The project's influence on the economy and employment also extends to the purchase of goods and services, resulting in substantial spending in the region.

The sustained injection of new money in the regional economy for 15 years will also have an impact on citizens' quality of life, resulting in a higher standard of living for many families, strengthening job security and leading to economic and social stability at the local and regional level.

The municipalities of Chapais and Chibougamau and the communities of Oujé-Bougoumou and Mistissini are looking forward to the project's impact on jobs and contracts.

12.5.6 Key Anthropogenic Environmental Changes

Spatial limits to the analysis of the cumulative impact cover the greater Chibougamau area, including the traditional territory of the community of Oujé-Bougoumou. In terms of timeframe, the second half of the 20^{th} century marks a turning point in the development and future of the surroundings and the region.

It should first be noted that a number of historical documents confirm that Crees occupied the territory continuously between the 17^{th} and 20^{th} centuries. Toward the end of that period, the region would be greatly influenced by its outstanding mineral potential.

Early in the 20^{th} century, the territory structured by Lac Chibougamau was exploited traditionally by Crees, then known as the "*Chibougamau Crees*" or "*Lac Doré Crees*." There was ongoing frequent trading between the *Chibougamau Crees*, those further north, and the Mashteuiatsh Innus. The Geological Survey of Canada first showed interest in the Chibougamau area in 1870. The report published by this body revealed the presence of mineral occurrences. In the first decade of the 20^{th} century, prospectors explored the area with federal government support. In 1910, the provincial government built a winter road linking St. Félicien to Chibougamau. The present-day Route 167 is built along the route of the old winter road. New exploration-related activities would result in the establishment of a Hudson's Bay Company post at Lac Chibougamau. This marked the beginning of the settling of non-Natives in the region.

The First World War, the economic crisis of 1929 and the Second World War were pauses followed by economic renewal for the region. Following this sequence of events, the provincial government built a permanent road between St. Félicien and Chibougamau in 1950. This highway marked the decline of the fur trade and a boom in mining activity. In the early 1950s, the Chibougamau Crees began to become involved in mining. This was also when the Chibougamau area started to become known for its outstanding wildlife potential.

The Parish of Chibougamau was established in 1952, and the municipality was formed in 1954. In 1958, a railway line was built from Lac St. Jean to Chibougamau. The Campbell and Opemiska mines were the first to enter operation, in 1955 and 1956 respectively. Alongside mining activity, logging also grew so quickly that in 1952, more than 20 sawmills were operating in the Chibougamau area. In 1952, just over 100 people were living in Chibougamau. In 1955, the town's population grew to more than 1,000, reaching 4,000 in the early 1960s and more than 9,000 in 1970.

Rapid population growth in Chibougamau in the 1950s in connection with growing mining and forestry would force the Crees to move their Lac Chibougamau and Lac aux Dorés camps several times and to disperse. On the other hand, a growing number of Cree workers became involved in mining, particularly in exploration work.

The start-up of the Troilus mine in 1995 marked a turning point in Cree involvement in mining. For nearly 15 years, a large number of Cree workers played an active role in this mine. Today, the Grand Council of the Crees and the Cree communities regard mining as a major economic means of moving the population up the economic ladder.

In 60 years, attitudes of Native and non-Native communities alike have changed enormously. Regardless of cultural differences, citizens of all origins in the area are prepared to work together to advance the region's economic development. Traditional activities nevertheless remain a key value in the cultural identity of the Crees. The establishment and operation of a mining project must take this cultural specificity into account.

This historical outline provides a perspective on the major changes that have marked the contemporary history of Chibougamau and the evolution of the biophysical environment.

12.5.7 Anthropogenic Changes in the Chibougamau Region

Mining industry

As seen above, the mining industry has played a central role in the development of the Chibougamau region. Some 30 mines have been operated there over the last 60 years. Historically, the Lac aux Dorés and Lac Chibougamau mines have supplied total production of about 50 million tons of copper and gold ore.

Generally speaking, the mining of mineral deposits is likely to cause environmental contamination. Mine effluents and drainage water may contain organic contaminants and heavy metals. When acid-generating minerals are present, heavy metals are likely to be found in the receiving environment. Many types of mines have been put into production in the Chibougamau area, some of which had these characteristics to a greater or lesser degree. Moreover, mine site rehabilitation was not an obligation or even a concern for the mining industry prior to the late 1970s. This situation has changed enormously. Since 1989, mining has been subject to *Directive 019*. The enactment of the *Metal Mining Effluent Regulations* in 2002 also led to new environmental responsibilities that gave rise to very different practices.

The oldest mining operations in the region date back to 1955. They left considerable waste resulting from obsolete practices. Huge tailings ponds have encroached on Lac Chibougamau without appropriate impoundment measures being applied. Despite this, regular follow-up by the MDDEP and the MRNF have not found contamination of living organisms in the lake, except in the immediate vicinity of these facilities. At present, all mines in the Chibougamau area are closed. The Troilus mine was the last to cease operations. It was in operation for 15 years and stood out from an environmental angle because of its progressive standards. The mine is an eloquent example of the effectiveness of the environmental regulatory framework governing mining activities.

Five old tailings ponds have been identified in the Chibougamau area: Copper Rand, Eaton Bay, Lemoine, Norbeau and Principal.

Power infrastructure

Since Phase 1 of the La Grande complex went into service in the early 1980s, three Hydro-Québec substations have been built in the region: Chibougamau, Obalski and Obatogamau. The presence of these facilities leads to the risk of soil contamination by hydrocarbons and other hazardous products. Chapter 11, which deals with this risk, illustrates this reality quite clearly. The region also hosts more than 10 735-kV transmission lines, one 450-kV line, one 350-kV line and numerous 161-kV lines. These power transmission and distribution lines, while essential for the Quebec economy, contributed to territorial fragmentation.

Forestry activities

Since the early 1950s, forestry activities have played a role in altering the Chibougamau area's biophysical environment as a whole. Chantiers Chibougamau Inc. currently exploits the forestry resource north of Lac Chibougamau. To the east and south, large-scale logging has almost ended. Like mining, logging can lead to an increase in nutrients and particulate matter in lakes and streams. Disturbances of the forest cover are likely to cause higher levels of mercury methylation in bodies of water. The dissolved organic carbon load disturbs the natural mercury cycle and leads to higher mercury levels in fish at the bottom of the food chain.

Landfills and contaminated sites

The region has two authorized landfill sites in operation, namely those of the towns of Chibougamau and Chapais. The former is located northeast of the town, on Chemin Merrill. The Chapais landfill site is beside the old Opémiska mine. The MDDEP's list of contaminated sites shows 17 sites in the Chibougamau area, primarily containing hydrocarbon-contaminated soils.

Industrial risks

Chapter 11 portrays the industrial risks inherent to the region. It shows clearly that these are linked mainly to hydrocarbon management but very little to mine tailings.

12.5.8 Environmental Components Subject to Cumulative Impact from the Project

Historically, lakes and streams have been broadly used in connection with mining operations. The main lake affected is Lac Chibougamau. The BlackRock project does not involve any activities that might increase pressure on this lake. However, it will affect some small lakes that contribute to the regional ecological balance.

The BlackRock project also has effects in terms of cumulative impact on traditional land use.

The intensive transportation linked to the mining project is also very significant for other users of the area. Users of primary resources and wildlife along road 210 will experience major pressure on this road corridor; the carrying capacity of this logging road is close to its limit.

In spite of everything, the BlackRock project cannot be viewed as an anthropogenic alteration of the environment as significant as those that characterized mining operations from the 1950s to the 1990s. Government regulations and BlackRock's own environmental management practices, including the rehabilitation plan, should allow the project to fit harmoniously into the environment.

In terms of economy and employment, the cumulative impact is overwhelmingly positive, especially since the region has seen a decline in economic activity over the last few years. It is also important to note that the Cree Nation's new approach to economic development supports the participation of all regional stakeholders, at every stage of new project development.

12.6 COMPENSATION MEASURES

12.6.1 Fish Habitat

A total area of some 5.5 hectares of shallow ponds and creeks will be lost as a direct result of project development. The planned compensation measures in the vicinity of the project affect five sites, namely Rivière Armitage, Ruisseau Villefagnan, lake A-2, Ruisseau Wynne and Lac Denis. Potential compensation measures for each of these sites are briefly described below.

Rivière Armitage
Rivière Armitage plays a major role in Lac Chibougamau's ecology because it hosts large walleye spawning grounds. At this spot, compensation measures would be aimed at creating a passageway to potential spawning grounds upstream from impassable barriers on Rivière Armitage. Potential measures would be on the east bank. Any such measures are closely linked to the dynamics of Lac Chibougamau's walleye populations, especially the need for increased recruitment. The MNRF's advice is required for this.

Ruisseau Villefagnan
Ruisseau Villefagnan drains the water of lake A-1, Lac Jean, lake A-2 and Lac Laugon. It is formed by a succession of whitewater areas, pools, meanders and channels with fairly coarse grain size dominating in its downstream reach.

The downstream section of Ruisseau Villefagnan, very near the mouth of Rivière Armitage, has a bed consisting of boulders and rubble. This area is well suited to walleye reproduction.

Further upstream, up to the mouth of the lake A-1 emissary, the creek is characterized by long basins with beds of organic sediments and stones. These basins are good for northern pike but are also viable for lake trout. The basins are interspersed by rapids that are suitable for brook trout.

The section of the river starting at the lake A-1 emissary is a lentic, meandering stretch that continues two kilometres upstream. This section is well suited to northern pike.

The upstream part of the lentic sector splits into two branches flowing in hilly terrain. One drains the waters of Lac Laugon and lake A-2. Both sections are well suited to brook trout.

Lake A-2
Lake A-2 is about 300 metres long. It receives the waters of two tributaries, the main one being the Lac Laugon emissary. The lake's bathymetry indicates that lake is generally less than 1.1 metre deep. A 3.25-metre trough is found in the northern part of the lake. An abundance of stones confirms the lake's minerotrophic nature. The emissary flows on a bed of stones and gravel. Downstream, the flow becomes fast and uneven. Rapids and waterfalls prevent brook trout from swimming up to the lake from Ruisseau Villefagnan.

The lake A-2 fish populations seem lower than the lake's carrying capacity. The lake could probably host brook trout; dissolved oxygen is adequate, as is the food provided by an abundance of forage fish. The presence of longnose dace in the tributary of the lake A-2 emissary is also a favourable indicator. Moreover, the downstream part of the Lac Laugon emissary constitutes a potential brook trout spawning ground.

Ruisseau Wynne

Ruisseau Wynne is the biggest stream in the Rivière Armitage catchment. It drains water from Lac Pillow toward Lac Stella, which in turn empties into Lac Armitage. Ruisseau Wynne crosses logging road 210 very near the southwest boundary of the BlackRock claims block.

A whitefish spawning area is found upstream from the road. Near Lac Stella, the creek is also a springtime breeding area for yellow walleye and chub sp. Electrofishing was carried out both downstream and upstream from the road 210 culvert. The species harvested were pike, burbot, pearl dace, mottled sculpin, white sucker and longnose dace. In the context of compensation measures, electrofishing highlights certain aspects of the quality of the environment and the local aquatic fauna; the species of fish captured reveal a rich habitat and excellent biodiversity. Forage fish are well represented, as are sports fishing species.

Lac Denis

Lac Denis will serve as a reservoir for process water. This requires building a dam at its outlet to bring its elevation from the original 412 metres to 424 metres. The lake's area will increase from 5.4 to 13.8 hectares, and its volume will rise from 50,000 m^3 to 1.3 million m^3 of water. In the process, this reservoir of clean water will become a good environment for aquatic fauna, especially northern pike. Fish compensation measures are planned to optimize its productivity. If safety measures allow for this, and if the tallyman so desires, the dam will be left in place at the end of mining operations.

12.6.2 Wetlands

The project will cause a net loss of 96.5 hectares of wetlands, not including streams. This is mostly swampland and poor resinous marshes. Most of the areas affected are riparian wetlands that play a role in maintaining water quality, regulating flow and controlling erosion. Compensation measures should be aimed at restoring these functions, and should take into account the reduced integrity of wetlands located downstream from the project.

Creation of new wetlands

Creation of a reservoir at Lac Denis involves putting excess clean water into the lake B-1 tributary. The energy of the water to be released from Lac Denis (elevation 424 metres) into the environment (elevation 414 metres) must be dissipated in such a way as not to disturb the equilibrium of lake B-1 or the surrounding wetland.

Upstream from lake B-1

The stilling pond to be created at the outlet of the water channelled from Lac Denis could serve as a starting point for the creation of wetlands upstream from lake B-1. The additional of at least two sills at its tributary will increase wetland areas upstream from the lake, in addition to helping buffer the energy of the water from Lac Denis.

Downstream from lake B-1

The topography around lakes B-1, B-2 and A-1, as well as the characteristics of their common emissary, allows for new wetlands to be created downstream from lake B-1, in the stretch of more than two kilometres leading to lake A-1. To achieve this, sills one to two metres high could be built at the outlet of lakes B-1 and B-2, as well as along the course of their emissary.

Lac Jean

The project will reduce the amount of water draining into Lac Jean, leading to a significant reduction in the flow and volume of water in this lake. This problem will be heightened during low-water periods. To support the viability of the environment, especially in winter, a sill will be built at the outlet of Lac Jean. This raising of the Lac Jean creek will affect the surrounding environment and its tributaries (Lac Coil and the wetland downstream from lake B-3).

Design criteria

The proposed compensation measures downstream from the mining installations will be influenced by the physical properties of the original streams (channel width, width of stream bed, bank height, water depth, substrate, etc). Measures should allow water flow to be managed so as to maintain a phased water system. The sills would in effect regulate natural flood cycles and storm and low-water flows. A low-water channel will also be maintained throughout the system to enable fish to survive.

Enhancement of the flow coefficient of Ruisseau Villefagnan

The above-mentioned measures will create new wetlands and, despite lower flow, the water phasing will simulate the original conditions for water directed toward Ruisseau Villefagnan. The original abundance of wetlands in the Lac Jean watershed helped buffer peak water flows and allowed for a very steady flow of water into Ruisseau Villefagnan over time. All the proposed measures aim to reproduce these conditions to the greatest extent possible, and to thus support the ecological equilibrium of Ruisseau Villefagnan.

Other wetlands – trapline O-59

In addition to these compensation and corrective measures downstream from the project, the tallyman will be consulted to target other degraded or natural wetlands with development potential on the O-59 trap line.

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13. REHABILITATION PLAN

Once mining activities have permanently ceased, one of BlackRock's obligations under the regulations is to implement a site rehabilitation plan. The firm of Journeaux Associés prepared a rehabilitation plan for the purposes of this study. Because it deals with some of the aspects already covered in other sections of this report, in line with the *Guide et modalités de préparation du plan et exigences générales en matière de restauration des sites miniers au Québec*, the plan is provided in Appendix 13. It covers the following aspects:

- Site security;
- Dismantling of buildings, support infrastructure, etc.;
- Dismantling of sanitary facilities;
- Pit closure;
- Rehabilitation of the waste rock pile, tailings sites, etc.;
- Management of hazardous material, waste and hazardous waste;
- Rehabilitation of contaminated soil, if required;
- Surface water control and monitoring;
- Final site redevelopment, including revegetation.

14. ENVIRONMENTAL MONITORING AND FOLLOW-UP

14.1 ENVIRONMENTAL MONITORING

The environmental monitoring program is intended to ensure optimal integration of the project to the environment during construction and operation. The goal of the program is to monitor the implementation of the various prescribed mitigation measures and guarantee their effectiveness.

In anticipation of construction activities, BlackRock Metals has already hired a person in charge of environment issues, the environmental superintendent, who lives in Chibougamau and is therefore sensitive to local concerns. The environmental superintendent will keep BlackRock managers involved in purchases or bids informed of the company's environmental standards and values and will see to it that BlackRock's values and obligations are reflected in tendering documents and contractual plans and specifications. Before the start of any activity, the environmental superintendent will review the various environmental concerns and obligations related to the project. The contractors chosen to perform construction work will be bound by their contract to comply with mitigation measures.

The environmental superintendent will also be in charge of overseeing mine operation compliance. From an organizational standpoint, the environmental superintendent reports to the general manager. Both report to the Vice-President - Mine Development.

The environmental superintendent is also in charge of BlackRock's environmental performance and works with the corporate management team and the various departments to ensure that the environmental contribution of all resources is optimized at every stage of the project.

The main issues to be considered in the construction and operation phases are:

- management of mine wastes, including splitting of fine and coarse tailings;
- identification of any signs of possible failure of waste management equipment or infrastructure;
- drainage water control and treatment;
- process water and final effluent quality control;
- atmospheric emissions (particulate matter and greenhouse gases);
- noise levels from project activities;
- sourcing and management of borrow materials;
- construction of haulage roads with low-silt materials;
- application of dust control agents on haulage and access roads;
- management of stripped mineral and organic soil;
- ongoing and final site rehabilitation;
- watercourse, vegetation and wildlife habitat protection;
- environmental auditing of chemicals, hydrocarbons and waste management quality;
- protection against accidental spills;

- drinking water and wastewater quality control.

Many of these issues are addressed in regulations under the *Environment Quality Act*. Many of these regulations require area-specific permits pursuant to Section 22 of the Act. The environmental superintendent must apply for the necessary certificates of authorization and supervise the resulting activities. The following area-specific regulations are particularly relevant to the development and operation of the mining project:

Regulation respecting hazardous materials (MDDEP);
Règlement sur le rejet des eaux usées (MDDEP);
Groundwater Catchment Regulation (MDDEP);
Regulation respecting the quality of drinking water (MDDEP);
Regulation respecting sanitary conditions in industrial or other camps (MDDEP);
Regulation respecting pits and quarries (MDDEP);
Regulation respecting standards of forest management for forests in the domain of the State (MRNF).

The environmental superintendent must collaborate with various external bodies and stakeholders. Regular communication will be maintained between the environmental superintendent and the main bodies and stakeholders concerned, namely:

Ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEP);
Environment Canada (EC);
Department of Fisheries and Oceans Canada (DFO);
Ministère des Ressources naturelles et de la Faune (MRNF);
Town of Chibougamau;
Municipality of James Bay;
First Nations communities directly or indirectly affected by the project, namely Oujé-Bougoumou, Mistissini and Mashteuiatsh.

Ongoing communication will be maintained with the tallyman of trapline O-59, where most of the work will be carried out. The representatives of the organizations mentioned above, as well as the tallyman, will be continually updated on the status and environmental performance of project activities. They will be immediately informed of potentially environmentally deleterious incidents. Finally, at the end of each of construction and operation phases, the environmental superintendent will produce an environmental compliance report to be sent to corporate authorities and to the stakeholders mentioned above.

14.2 ENVIRONMENTAL FOLLOW-UP

The corporate environmental follow-up program covers the construction, operation and post-closure phases of the project. The goal of the program is to provide an image in space and time of the environmental impact of the project in order to assess the effectiveness of mitigation measures and the monitoring program.

Environmental surveys and analyses conducted ahead of project implementation help constrain the sensitivity of the host environment and, to a certain extent, predict changes in the environment during and after operation. Environmental follow-up provides feedback used to correct any departure from expected results, thus ensuring that BlackRock commitments and obligations are managed effectively. The environmental follow-up program is also a way to assess the operational effectiveness of the technological risk management plan, at least as far as the environmental portion of the plan is concerned.

In addition to the corporate follow-up program, a strict regulatory framework is in place relating to the environmental performance of mining companies. This includes the MDDEP *Directive 019* and the Fisheries and Oceans Canada *Metal Mining Effluent Regulations*. These very thorough regulatory documents cover every phase of a mining project, from planning to post-closure. They contain guidelines and standards pertaining to quantitative and qualitative compliance criteria for final effluent and receiving water and groundwater. Changes in plant and animal populations in the receiving environment are also addressed. The noise environment, vibrations from blasting, and particulate matter emissions are other issues regulated by government authorities.

A third relevant regulatory document is the *Regulation respecting industrial depollution attestations*, which is aimed at ensuring that actual contaminant releases conform to authorized releases. It applies to the industrial activities and provides a mechanism for estimating depollution efforts for Quebec as whole.

A description of measures taken by BlackRock to conform to the corporate and regulatory framework is provided in the following sections.

14.2.1 Types of Final Effluent and Quality Control

The performance criteria for effluents set out in *Directive 019* and the *Metal Mining Effluent Regulations* apply to, among other things, mine water, water from tailings or waste piles, runoff, wastewater from ore treatment processes, and any other industrial wastewater resulting from mining activities.

Sampling stations as well as flow and pH measuring systems will be set up and maintained immediately upstream from the discharge points of each final effluent.

A record of measuring systems inspections, verifications, adjustments and repairs will be kept up to date and available at all times. For quality control purposes, this record will include the following information:

- methods used to verify instrument precision;
- the precision of flow measurements following verification;
- any errors in flow measurement prior to verification and possible sources of such errors;
- implications of such errors for reports previously submitted to governments.

Flow measurements and system verifications will be conducted according to the most recent version of Booklet 7 of the MDDEP “Sampling Guide for Environmental Analysis”, entitled “Flow Measurement Methods in Open Channels”.

14.2.1.1 Final Effluents – *Directive 019*

Performance criteria set out in *Directive 019* for final mine effluents at discharge points are listed in Tables 14.1 and 14.2. Regular sampling frequencies for follow-up parameters are given in Table 14.3. Sampling conditions are provided after these tables.

Table 14.1 Requirements at Final Effluent Discharge Point – *Directive 019*

Parameter	Requirements to be met
pH	6.0 to 9.5
Thiosalts	Avoid causing a change in pH such that it falls outside the range from 6.0 to 9.5
Toxicity for rainbow trout and daphnia	Avoid causing acute lethality

Table 14.2 Final Effluent Discharge Point – *Directive 019*

Parameter	Column I Acceptable average concentration (monthly average)	Column II Acceptable maximum concentration in grab sample
Arsenic	0.200 mg/l	0.400 mg/l
Copper	0.300 mg/l	0.600 mg/l
Iron	3.000 mg/l	6.000 mg/l
Nickel	0.500 mg/l	1.000 mg/l
Lead	0.200 mg/l	0.400 mg/l
Zinc	0.500 mg/l	1.000 mg/l
Total cyanides	1.000 mg/l	2.000 mg/l
Hydrocarbons (C_{10}-C_{50})	-----	2.000 mg/l
Suspended solids	15.000 mg/l	30.000 mg/l

Table 14.3 Frequencies for Final Effluent Sampling, Analysis, and Regular Follow-up Measurement – *Directive 019*

	Frequencies			
	Continuous	3/week	1/week	1/month
Parameter	pH	Suspended solids	As	Acute toxicity
	Flow*	Flow	Cu	Flow
		pH	Fe	
			Ni	
			Pb	
			Zn	
			Flow	

* lorsque applicable

Details of sampling approach

- After six months of operation, metal monitoring frequency may come down to once per quarter if monthly average concentrations are below one-tenth the value shown in Column I of Table 14.2.
- The frequency of acute toxicity analyses may come down to once per quarter if acute toxicity results are negative for 12 consecutive months. However, effluent must be flowing during this 12-month period.
- Annual follow-up parameters must be measured and analyzed once a year in July or August. Because sporadic releases are inherent to the BlackRock project, annual follow-up must be conducted in the first days of flow following the summer period.
- Annual sampling and follow-up measurements must be done on the same day. The results must reach the MDDEP no later than September 30 of each year. Parameters included in the annual follow-up program for the BlackRock project are shown in Table 14.4.
- Flow measurements and verification of their precision must be carried out according to the most recent version of Booklet 7 of the “Sampling Guide for Environmental Analysis” entitled “Flow Measurement Methods in Open Channels”. For intermittent discharges from the BlackRock project, released volumes must be spread out over the longest possible periods to take into account flow in the receiving environment.

Table 14.4 Groups of Annual Follow-up Parameters and Measurements – *Directive 019*

Group 1			Group 4
Conventional parameters	**Nutrients**	**Ore or metallic elements**	**Biological parameters**
Alkalinity Chlorides Conductivity BOD_5 COD Flow Hardness Fluorides Hydrocarbons (C_{10}-C_{50}) Suspended solids pH Dissolved solids Total solids Phenolic substances Sulphates Turbidity	Ammoniacal nitrogen Total Kjeldahl nitrogen Nitrates + nitrites Total phosphorus Nickel	Aluminium Arsenic Cadmium Calcium Chromium Cobalt Copper Iron Magnesium Manganese Mercury Molybdenum Lead Potassium Silicon Sodium Zinc	Acute toxicity

14.2.1.2 Final Effluents – Metal Mining Effluent Regulations (MMER)

Pursuant to the Fisheries and Oceans Canada *Metal Mining Effluent Regulations* (MMER), final effluent pH must fall between 6.5 and 9.0. It must not cause acute lethality in biological indicators and must comply with values in Table 14.5, taken from Schedule 4 of the regulations.

Table 14.5 Authorized limits of deleterious substances - MMER

	Column 1	Column 2	Column 3	Column 4
Item	Deleterious Substance	Maximum Authorized Monthly Mean Concentration	Maximum Authorized Concentration in a Composite Sample	Maximum Authorized Concentration in a Grab Sample
1.	Arsenic	0.50 mg/l	0.75 mg/l	1.00 mg/l
2.	Copper	0.30 mg/l	0.45 mg/l	0.60 mg/l
3.	Cyanide	1.00 mg/l	1.50 mg/l	2.00 mg/l
4.	Lead	0.20 mg/l	0.30 mg/l	0.40 mg/l
5.	Nickel	0.50 mg/l	0.75 mg/l	1.00 mg/l
6.	Zinc	0.50 mg/l	0.75 mg/l	1.00 mg/l
7.	Total Suspended Solids	15.00 mg/l	22.50 mg/l	30.00 mg/l
8.	Radium 226	0.37 Bq/l	0.74 Bq/l	1.11 Bq/l

Note: All concentrations are total values.

Effluent follow-up studies required by the MMER must include analysis of the following parameters:

- pH;
- alkalinity;
- hardness;
- aluminium;
- cadmium;
- iron;
- mercury;
- molybdenum;
- ammonia;
- nitrate.

Sampling frequency is four times a year at intervals of at least one month. Sublethal toxicity testing must be conducted on rainbow trout and benthic invertebrates according to methods specified by Fisheries and Oceans Canada in Schedule 5 of the Regulations. Toxicity testing must be conducted twice a year for three years and on an annual basis subsequently.

14.2.2 Surface Water Monitoring – MMER

Surface water quality is monitored in exposed and control areas, pursuant to conditions set out in Schedule 5 of the MMER. Reports on final effluent and water quality monitoring studies must be submitted to federal authorities no later than March 31 of the following year. The annual report must include the following items:

- the dates on which samples were collected for effluent characterization, sublethal toxicity testing and water quality monitoring;

- the sites, as well as the reasons for site selection, of final discharge points for effluent characterization and toxicity testing;
- the coordinates and description of the sampling areas for water quality monitoring;
- the methodologies used, detection limits and results of effluent characterization, sublethal toxicity testing and water quality monitoring.

14.2.3 Biological Monitoring

14.2.3.1 Wildlife and Birds

The project has an impact on some moose winter habitats. In collaboration with the tallyman of trapline O-59, the follow-up program should address the quality of replacement winter habitats for moose on the trapline. Compensation efforts should lead to an increase in the wildlife resource potential of trapline O-59, or at least facilitate its general management.

The project will also directly impact an osprey pair nesting near Lac Coil. Establishment of coarse tailings and waste rock piles to the east and the operation of potential borrow pits to the west will disturb this nesting area. In addition, few alternative natural sites with an encompassing view of the territory and mature trees are available in the area. A study must be conducted to identify natural replacement sites and potentially to set up nesting platforms. This measure could also benefit the bald eagle that lives in the Lac Chibougamau area.

14.2.3.2 Wetlands

Project development will destroy 96 hectares of wetlands. Follow-up will consist of identifying, together with the tallyman of trapline O-59, wetlands that could be included in a rehabilitation plan as well as wetlands where wildlife compensation measures could be implemented. Priorities thus identified will be submitted to the relevant federal and provincial authorities prior to implementation of these measures.

14.2.3.3 Aquatic Fauna

Wildlife surveys of lakes and watercourses in the general project area provide a precise picture of the aquatic environment. From this, it is clear that most aquatic habitats affected by the project are characterized by poor ecosystems.

Be that as it may, a detailed compensation program for aquatic fauna must be defined. In-depth studies must be conducted on Rivière Armitage, Lac Denis, the full length of Ruisseau Villefagnan including its two main branches, lake A-2 and Ruisseau Wynne. These studies and implementation of the compensation program will be carried out in conjunction with the trapline O-59 tallyman. Progress reports will be submitted to Fisheries and Oceans Canada as well as to the MRNF for comments and approval.

Benthos

The aim of benthos monitoring studies is to determine whether mine effluents affect benthic communities and, by extension, piscivorous fish and their predators. This involves comparing organisms gathered in areas exposed to effluents with those gathered in control areas. To this end, univariate descriptors will have to be calculated, and the following univariate descriptors will then be compared for each sampling station: density (number of organisms per square meter), taxonomic richness (number of taxa), Simpson's evenness index, Simpson's diversity index and Bray-Curtis coefficient. Because taxa present can not be identified using univariate descriptors, a correspondence analysis (MCA) will also be performed. Potential differences in benthic communities can be linked to changes in the receiving environment, taking into account other variables that affect the spatial distribution of benthic organisms, such as grain size distribution, organic matter concentrations in sediments and flow velocity.

Fish

The goal of fish monitoring studies is to constrain the effect of mine effluents on target species of fish. This is done by comparing morphometric relationships of fish captured in exposed areas near discharge points with specimens captured in reference areas. These morphometric relationships refer more specifically to growth, weight, external state and energy reserves, as well as hepatic and reproductive activity.

Studies of fish populations and fish tissue and of benthic communities must be conducted in compliance with Schedule 5, Part 2 of the MMER:

- the first study design must be presented to federal authorities not later than 12 months after the mine becomes subject to the regulations;
- studies must start not sooner than six months after the study design is submitted;
- the first interpretative report must be submitted not later than 30 months after the mine becomes subject to the regulations;
- subsequent biological monitoring studies are submitted according to variable timelines based on effects on aquatic fauna noted in previous studies;
- prior to closing the mine, a final biological monitoring study is submitted for approval not later than six months after providing the notice of mine closure.

The benthic organisms and fish monitoring program will draw upon the "Metal Mining Environmental Effects Monitoring (EEM) Technical Guidance Document" (Environment Canada, June 2011).

14.2.4 Groundwater Monitoring – *Directive 01*

The groundwater monitoring network is set up around components of the mine site and transfer point that could affect groundwater quality. Observation wells are located upstream and downstream from the plant, garage, mine waste accumulation areas and the rail transfer point. Three wells, one upstream and two downstream, are located at each potential contamination site. Observation well locations are shown in Figures 10.5 and 10.6. Samples will be collected periodically at each well to confirm that mine operations are safe and detect any potential significant deterioration of groundwater quality. Any values over groundwater background values will trigger a response. The causes of such values will then be identified and, where appropriate, the effectiveness of measures and management practices will be reassessed.

Groundwater parameters to be analyzed are taken from *Directive 019* and shown in Table 14.2, although there is no need to measure suspended solids concentrations. In addition to parameters listed in Table 14.2, major ions (Ca^{+2}, HCO_3, K^+, Mg^{+2}, Na^+, SO_4^{-2}), conductivity and pH must also be recorded. These parameters must be measured twice a year, in spring and summer, to provide a representative picture of conditions during flood and low-water periods. Piezometric monitoring must also be done at those times.

For the rail transfer point, a Phase II environmental assessment must be done to constrain contamination levels resulting from previous industrial activities. This type of assessment is also required for soils above the water table.

14.2.5 Noise and Vibration Monitoring

As regards noise monitoring studies, the basic hypotheses used in Chapter 6 to calculate noise levels must first be checked to see if they are representative of noise coming from plant, pit and rail transfer point operations. More specifically:

- sound pressure will be one of the criteria used in selecting mining equipment;
- the sound climate will be assessed at a representative time during construction work;
- the noise environment will be assessed once a year in the first three years of operation and, subsequently, every four years or when equipment or activities are added to the project;
- a noise barrier should be erected between the construction camp and road 210;
- noise monitoring will be done at the camp immediately after it is established, during a representative period of activity; daytime and nighttime noise levels should not exceed 45 dB(A) around dormitories; noise levels at the camp will be measured annually.

According to Section 141 of the *Regulation respecting occupational health and safety* (c.S-2.1, r.13), dosimetric measurements must be taken at every work station at least once a year. Daily noise doses for workers are measured using an integrating dosimeter, a portable device attached to a worker’s belt. A microphone connected to the integrating dosimeter is fixed on the worker’s shoulder. Noise levels are integrated to obtain the daily noise dose to which the worker wearing the device is exposed. Dosimetric measurements must be taken from the first year of mine operation.

According to *Directive 019* specifications pertaining to vibrations and noise during blasting, a record of the following data must be kept and remain available for at least two years:

- vibration velocity;
- ground vibration frequencies;

- air pressure;
- blast design.

Also according to *Directive 019*, blast operations must comply with parameters shown in Table 14.6.

Table 14.6 Maximum Allowable Velocity as a Function of Ground Vibration Frequency – *Directive 019*

Ground vibration frequency (Hertz)	Maximum allowable velocity (mm/s)
Frequency ≤ 15	12.7
15 < Frequency ≤ 20	19.0
20 < Frequency ≤ 25	23.0
25 < Frequency ≤ 30	30.5
30 < Frequency ≤ 35	33.0
35 < Frequency ≤ 40	38.0
Frequency > 40	50.0

14.2.6 Air Quality Monitoring

Air quality at the mine site and transfer point will be altered. Measurements will be taken at the mine site and transfer point to check the effectiveness of atmospheric emissions mitigation measures at the source and to ascertain compliance with atmospheric quality standards pursuant to the *Regulation respecting the quality of the atmosphere*.

An air quality sampling station will be set up in 2012 southeast of the mine site, down the prevailing wind direction. Results will be compared to the expected effectiveness of the mitigation measures. Adjustments will be made as required.

Watering of haulage roads in the summer will be conducted at a frequency calculated using the equation in the *Air Pollution Engineering Manual* (Cowherd 1992 – see Chapter 5).

14.2.7 Monitoring of Containment Dam Stability

A containment structure performance monitoring program is planned to ensure that the performance of these structures conforms to expected levels. The program must allow for appropriate adjustments and guard against unwanted events. To facilitate monitoring, water pressure will be measured using piezometers placed in the dams and periodic groundwater sampling will be carried out at observation wells around the tailings pond.

Instrument inspections and verifications will be conducted on a monthly basis for the first six months, after which they will be done at least four times a year for as long as the structures are in operation. A comprehensive monitoring program also includes periodic visual inspections of the structures (Table 14.7). These routine visual inspections will be conducted by operators or safety personnel. A detailed inspection will be conducted every three months by the person in charge of the tailings pond, and an annual inspection will be performed by an engineer specializing in dam design. Results of this statutory inspection will be included in the BlackRock annual report.

Specific inspections will also be conducted as issues arise. A review of the structural stability of containment structures will be conducted every five years by an engineer specializing in dams. The BlackRock dam inspection program will therefore exceed the requirements set out in the *Dam Safety Regulation*.

Table 14.7 Typical Components of a Dam Inspection Program

Type of inspection	Goal	Frequency	Contact
Routine	Visual inspection of tailings pond and ancillary structures (waste conduits, pumps, etc.) to detect any anomaly.	Regularly	Operator, safety personnel
Detailed	Walking along dams to inspect their tops, embankments, ditches and bottoms, as well as ancillary structures.	Every three months or after exceptional weather events or seismic activity	Tailings pond operator
Statutory	Detailed visual inspection of all dams and water control structures.	Once a year (summer)	Engineer with experience in tailings pond design
Specific	Follow-up on an observation from a detailed or statutory inspection that may require specific action (e.g., fissure monitoring, measurement of seepage flow).	As required	Tailings pond operator
Review of stability	Review of inspection reports, design concepts, construction work, deposition plans, water management, etc.	Every five years (according to risk associated with the dam)	Engineer with experience in tailings pond design (expert)

Source: Demers and Poirier, 1999; from Aurbertin et al., 2002.

14.2.8 Regulation Respecting Industrial Depollution Attestations

An application for a depollution attestation must be filed with the MDDEP within a month following the date on which project operation begins. It must include, specifically:

- The daily and yearly nominal production capacity;
- a plan showing the location of, and a description of, the points of emission or deposit of mine wastes;
- the type, quantity, and characterization of contaminants emitted;
- a description of control procedures and equipment;
- emergency measures to be taken in the event of the accidental occurrence of contaminants in the environment.

The annual report to be submitted to the MDDEP must include a record of all values exceeding discharge standards, the time, location, causes and circumstances of such values and the corrective measures taken.

For the aquatic environment, the annual report must detail any discharge of suspended solids and the biological oxygen demand (BOD_5).

Reported cases of discharge into the atmosphere must provide details relating to particulate matter, SO_2, VOCs, total reduced sulphur compounds (TRS) and polycyclic aromatic hydrocarbons (PAH).

The report must be sent within 30 days of the end of each calendar month and must include the information contained in the record. The December 31 annual report must be submitted before April 1 of the following year.

14.2.9 Post-operation and Post-rehabilitation Periods – *Directive 019*

During the post-operation period, but before completion of rehabilitation work, the surface water and groundwater monitoring program must be updated and approved by the MDDEP.

Sample collection and flow measurements must be conducted according to the following minimum frequency schedule:

- months 0 to 6: bimonthly;
- months 6 and beyond: monthly;
- semi-annual groundwater monitoring must continue, at the same times of year and for the same parameters as those used during project operation;
- the post-rehabilitation surface water and groundwater monitoring program must be accepted by the MDDEP prior to being implemented; as a minimum, it must include the same parameters as those used during operation;
- the post-rehabilitation program remains in effect until waters meet final effluent discharge requirements and groundwater protection goals;
- the minimum post-rehabilitation control frequency is twice per year;
- the minimum duration of monitoring is five years.

14.2.10 Follow-up with the Community

In general, the Chibougamau area population relies on the mining project for environmentally-friendly economic recovery and employment. For the Cree tallyman, Philip Wapachee, and his family, use of the territory to pursue traditional activities is central to their concerns (see Appendix 1.2).

Monitoring committee

To ensure transparency and to keep to local population informed about the project, BlackRock intends to support the creation of a monitoring committee. Stakeholders who will be invited to join should, by definition, have diverse interests covering, in particular, training, employment, intercultural harmony within the company, regional economic benefits and resource development. Committee members will be chosen by the bodies they represent and must show openness towards the divergent values and interests of other members. Each member will be responsible for reporting on the committee's work to the organization they represent.

BlackRock representatives on the committee will be designated by the company president. Depending on the themes addressed at a given meeting, BlackRock or external experts may also attend meetings. These meetings should be open to members of the public so that they can stay abreast of the committee's work and express their concerns.

The monitoring committee meeting schedule will be set as soon as the committee is formed, based on the timelines to be met for the various project monitoring studies and work items. The committee should meet at least once a year at the mine site and tour all facilities. The committee should be in place to review the environmental impact study, comment on it, and then take part in all phases of the project, from construction to rehabilitation. To this end, the committee members should jointly:

- define the committee's mandate;
- determine topics to be addressed and related timelines;
- determine ways and means of interfacing with the general public.

By definition, this advisory committee must present recommendations to BlackRock management to ensure that actual results match expectations for every item addressed by the committee.

Community relations officer

As a policy, BlackRock will promote economic benefits for Chibougamau, Chapais, Oujé-Bougoumou and Mistissini. However, it must be noted that significant socio-economic differences persist between Native and non-Native communities in the host region of the BlackRock project, where indicators such as educational level, unemployment rate, average employment income and longevity underscore the socio-economic divide between Native and non-Native residents.

A community relations officer position will therefore be created within the human resources department. This person will act as liaison officer between the Native population and BlackRock and, in particular, will be responsible on a day-to-day basis for:

- managing the BlackRock liaison office at Oujé-Bougoumou;
- disseminating information about training programs provided by the Cree School Board and BlackRock Metals for upgrading worker skills;
- posting and promoting, within the communities of Oujé-Bougoumou and Mistissini, job openings during the construction and operation phases of the project;
- taking part in coordinating employment promotion campaigns within the Cree communities of Oujé-Bougoumou and Mistissini;
- matching contract opportunities with skills available within aboriginal businesses.

So that Native and non-Native workers can work effectively together, BlackRock will ensure that company supervisors are fluent in French and English and that Cree and non-Native employees have equal opportunities to be heard and understood. Work and vacation schedules will also take into account culturally significant periods for the Cree, namely goose and moose hunting seasons.

The human resources department will also be in charge of implementing the Cree culture awareness program, which will be provided to all BlackRock workers. All measures aimed at ensuring better integration of Cree workers and contractors will be assessed annually using performance indicators, and formal feedback mechanisms will be put into place.

Community satisfaction

A community follow-up program must include mechanisms to assess community satisfaction with respect to the project, particularly with regard to hiring during the construction and operation phases, as well as to the impact of the project on the quality of life of community members and on different land use opportunities (tourism, hunting and fishing, recreation, traditional activities, logging). The project monitoring committee will play an active role in this regard.

BlackRock Metals will aim to ensure harmonious cohabitation with the local population, maximize local economic benefits and meet its environmental commitments by being proactively involved with the community.

REFERENCES

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15. CONCLUSION

In conclusion, the environmental impact assessment makes it clear that the Lac Doré iron ore-titanium-vanadium mining project lies in an area favourable to its development, and that its characteristics make it compatible with its host environment. Mineral reserves are sufficient for 15 years of mine operation. Furthermore, exploration work on the 17 kilometres of the deposit could lead to the identification of additional resources, and have additional repercussions on BlackRock's long-term presence in the Chibougamau region.

The goal of this environmental impact assessment was to analyze all the elements of the physical and social environment likely to be affected by the project. The choices made with regard to the project facilities and environmental management were dictated by respect for the population and its values, the host environment and the applicable regulations. The assessment also included mitigation measures to reduce or eliminate much of the project's impact.

Project Location

The mine site is east of Lac Chibougamau, some 60 kilometres from the town of the same name. It straddles the territories of Chibougamau and the Municipality of James Bay. The host environment is vast and undeveloped: there are no permanent residences within a 10 kilometre radius. Air quality and noise studies show that with a proactive air quality and noise control program, the project could comply with existing standards at all times, in every respect.

Comparative studies were carried out for the entire mine and support infrastructure to identify sites that would cause the least impact. The project footprint is minimal, and the same consequently holds true for emissions of greenhouse gases and particulate matter.

Most of the access road to the mine site already exists, and the section to be upgraded is in the corridor of an old logging road. Wetlands and fish habitats will, however, be lost when the mine infrastructure is built.

A Project with International Reach

The Lac Doré geological complex offers BlackRock and its partners an opportunity to mine an iron ore deposit with high value-added due to the presence of vanadium and titanium. The unique nature of the deposit will provide BlackRock with stability in the iron ore market that is unmatched in Quebec, for many years to come. The economic and social effects are largely positive, and will have an impact on the region's activities and international influence.

A Region that Supports Project Development

The mining history of the region facilitates social acceptance of the project. The people of the Chibougamau region have a long tradition of mining, which was the economic base and primary source of jobs for the local and regional population for more than half a century. Having declined somewhat in the past few years, the mining industry in the region will be revitalized by the arrival of the BlackRock project.

The town of Chibougamau offers all the services and equipment required for project construction and worker accomodation. The regional population considers the project to be of interest, provided it is environmentally acceptable. Furthermore, the know-how of the local population, which has contributed greatly to the success of many mining projects, is a major asset for BlackRock.

The project represents an investment of in the order of $600 million. Over $400 million is required for the construction of the processing plant and related facilities. This includes 1.3 million hours of work that would mainly accrue to people in the region. During mining, some 160 workers would be directly employed by BlackRock. This also translates into indirect jobs that would stimulate local and regional activity in general.

Protecting the Environment

Industrial activity associated with resource exploitation has left its mark on the Chibougamau landscape, and Native peoples have seen their living environment change significantly in the last 60 years. Increased awareness on the part of citizens, governments and mine operators has led to the adoption of standards that reflect greater respect for the host environment. The BlackRock project planning includes those who use the land and local authorities in all phases of the project. Their concerns therefore helped form the decisions taken regarding project development.

From a human perspective, the main issues surrounding the project are traditional activities and the harmonious, safe sharing of the road corridor between Route 167 and the mine site. Many mitigation measures are therefore planned in this regard, and other measures are planned to offset the effects of the project on traditional land use.

In terms of the biophysical environment, the likelihood of rare or threatened wildlife or plant species being present in the area is to a large extent theoretical. Furthermore, fish habitat in the project area is characterized by a very low incidence of predator species and an abundance of species from other levels of the food chain, which can tolerate marginal conditions. This is indicative of the overall poor quality of the fish habitat.

It has also been shown that the very high pH in the lakes of the study area and the abundance of calcium bicarbonates, cations like calcium and organic carbon tend to decrease the toxicity of metal for fish. The physicochemical characteristics of the surface water in the study area are very distinct from those in the rest of Quebec. In general, metals are compounded before reaching the fish. As a result, metals in the sediments are not available to benthic invertebrates or to benthivorous fish and their predators.

All the indicators recorded to constrain the state of the environment prior to project development will be used to monitor physicochemical changes in the environment once the project is underway.

Strong Focus on Fitting the Project into the Host Environment

The magnetite concentration process is unmatched in terms of efficiency, economic viability and low environmental impact. The hydrogeological study allowed the environment to be characterized in order to identify the best tailings storage sites. Analysis of the tailings show that they are neither acid-generating nor leachable. Furthermore, the surface water collection system will isolate the mine site and protect the surrounding environment.

With regard to the tailings impoundment design criteria, it should be noted that the dams can contain a 1,000-year flood event. The static and dynamic safety factors of these structures are also higher than the criteria set by governments. Moreover, process water is fully recycled, and the highly-valued Rivière Armitage subsystem will remain untouched.

In the end, there are rigorous frameworks built into the overall project management for the application of environmental monitoring programs, site rehabilitation and impact monitoring. The environmental management plan will also provide an ongoing objective picture of the project's environmental performance. The mining project is designed to incorporate a full slate of measures to prevent or minimize discharge into the environment, comply with regulatory standards and prevent the occurrence of environmental problems. Feedback mechanisms will allow actual performance to be measured against BlackRock's corporate objectives.

Environmental and occupational health and safety risks have also been identified, along with their management plans.

Compensation measures for fish habitat and wetlands will be introduced on the periphery of the project or in environments that enhance the productivity of trapline O-59. Work will be planned and executed jointly with the tallyman of trapline O-59.

It is now up to the population and the authorities to assess the merits of the project and the potential for it to fit harmoniously into the host environment, in light of the work done for this assessment and the commitments made by BlackRock.