

## **APPENDIX E**

### **Hydrogeological Report DSO2 and DSO3 Sectors Schefferville (Québec) and Elross Lake (Newfoundland and Labrador)**

**Unofficial Translation of Sections Dealing with DSO3**



**NEW MILLENNIUM  
CAPITAL CORP.**

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## **DIRECT-SHIPPING ORE PROJECT**



### **Hydrogeological Report DSO2 and DSO3 Sectors**

**Schefferville (Québec) and Elross Lake (Newfoundland and Labrador)**

**UNOFFICIAL TRANSLATION OF SECTIONS DEALING  
WITH DSO3**

**BY: Envir-Eau**

**March 2009**



**UNOFFICIAL TRANSLATION OF SECTIONS DEALING WITH DSO3**

**HYDROGEOLOGICAL REPORT  
DSO2 AND DSO3 SECTORS**

**SCHEFFERVILLE (QUEBEC) AND  
ELROSS LAKE (NEWFOUNDLAND AND LABRADOR)**

Report prepared for:

Groupe Hémisphères

By:

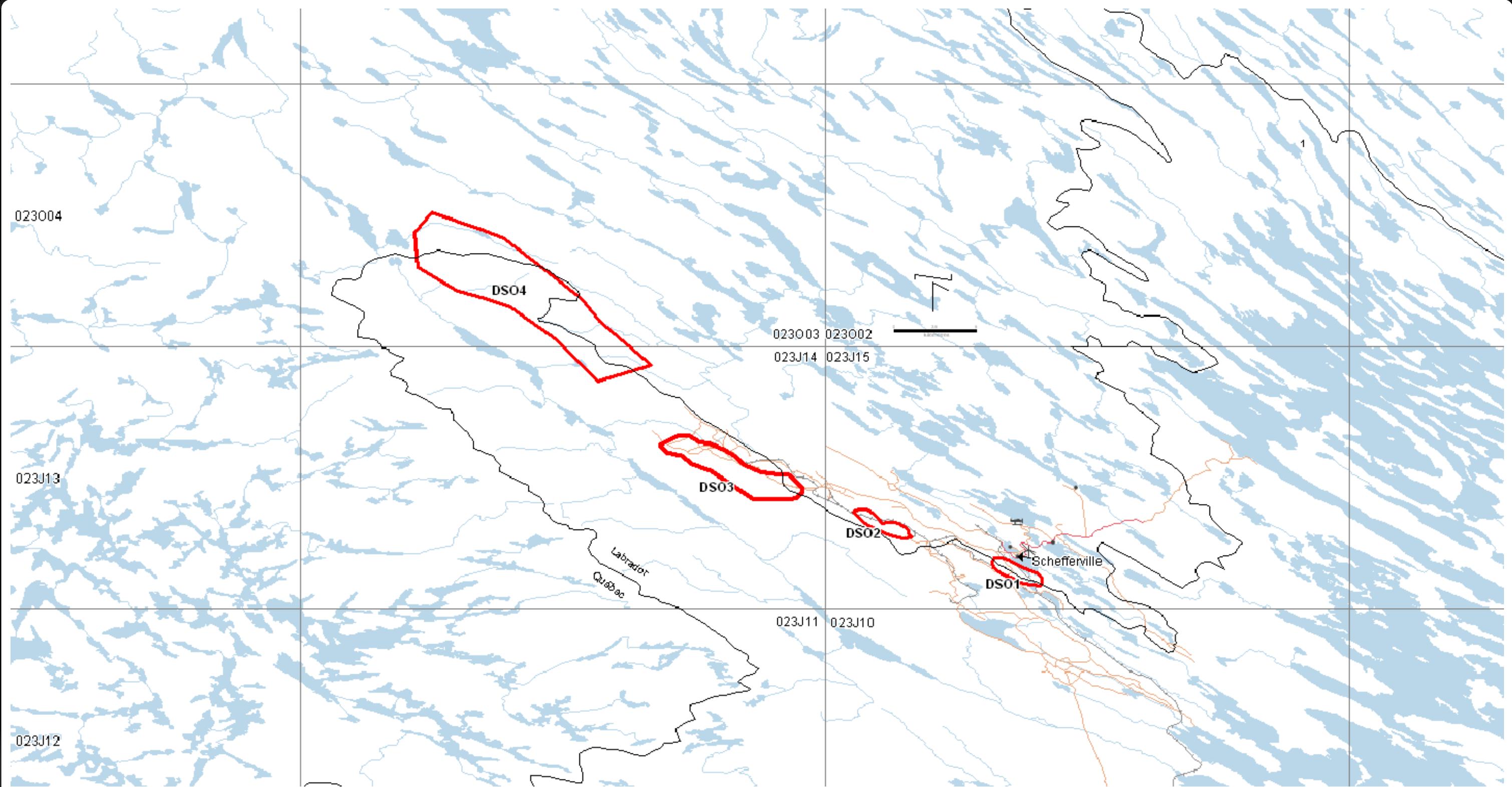


**160, BOUL. DE L'HÔPITAL  
GATINEAU (QUÉBEC)**

HB7103-00-00

March 2009





LEGEND/LÉGENDER

SOURCE:

GROUPE HÉMISPÈRES, UPDATED HYDROLOGY, 2008  
GROUPE HÉMISPÈRES, HYDROLOGIE MISE À JOUR, 2008

NUMÉRO PROJET: HB 7103      DESSINÉ PAR: K.T.      CONÇU PAR: GF

DATE: 3 MARS 2009      VÉRIFIÉ PAR: AB

ÉCHELLE: 1:2000      FICHIER AUTOCAD #: HB7103-FIG.1

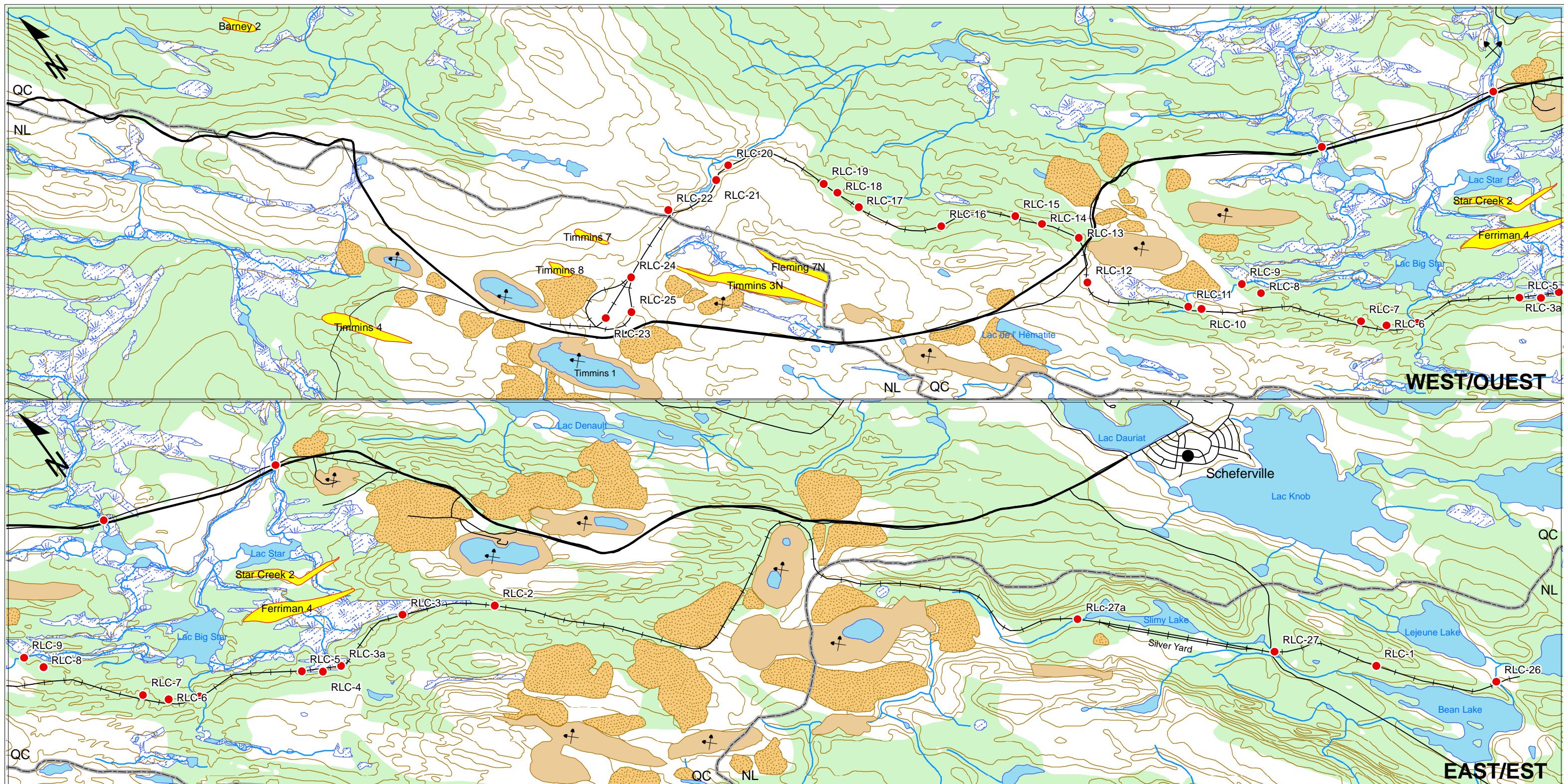


**ENVIR-EAU**  
L'environnement, un choix d'affaires

FIGURE: 1

LOCATION OF DSO DEPOSITS  
SCHEFFERVILLE  
LOCALISATION DES GISEMENTS DSO  
SCHEFFERVILLE

NEW MILLENIUM CORP.  
MONTREAL



## Legend/Légende

	Reconnaissance Station/ Station de reconnaissance		Deposit/ Gisement		Wetland/ Milieu humide
	Provincial Border/ Frontière provinciale		Existing mined-out Pit/ Fosse existante épuisée		
	Main Access Road/ Route d'accès principale		Existing Waste Dump/ Halde de stériles existante		
	Secondary road/ Chemin secondaire		Waterbody/ Plan d'eau		
	Railway/ Chemin de fer		Watercourse/ Cours d'eau		

# Location of DSO2 and DSO3 Deposits

## Localisation des gisements de DSO2 et DSO3

Kilometers/Kilomètres

0 0,5 1 2 3 4

Scale/Échelle: 1:40 000 UTM Nad 83 Zone 19N

Sources: Government of Canada, NTDB, 1:50 000, 1979  
Government of Newfoundland and Labrador and Gouvernement of Quebec, Boundary used for claims  
New Millennium Capital Corp., Mining sites and roads  
Groupe Hémisphères, Hydrology update, 2008

Gouvernement du Canada, BNDT, 1/50 000, 1979  
Gouvernement de Terre-Neuve-et-Labrador et Gouvernement du Québec, frontière utilisée pour les titres  
New Millennium Capital Corp., gisements et routes  
Groupe Hémisphères, mise-à-jour de l'hydrologie, 2008

FILE, VERSION, DATE, AUTHOR  
FICHIER, VERSION, DATE, AUTEUR:  
GH-0022-00, 09-04-02, J.T.  
Groupe Hémisphères Inc.

## **1.2 NATURE OF THE STUDY**

The goal of the present hydrogeological study is to collect baseline data in order to answer questions that may be raised by Quebec, Newfoundland and Labrador or Fisheries and Oceans Canada, principally with regard to the following components:

- the classification of the groundwater (class I, II or III);
- the physical and chemical quality of the groundwater;
- the identification of aquifers;
- the vulnerability of the groundwater to pollution;
- the direction of the flow of the groundwater;
- the impact on the groundwater of dewatering the deposits by identifying:
  - measures to limit pumping for purposes of dewatering;
  - the identification of the main contaminants likely to be found in the dewatering water and its physical and chemical characteristics;
  - the anticipated volume and average daily flow of the dewatering water;
  - the method for managing the dewatering water;
  - the components of the dewatering system;
  - the site of discharge of the dewatering water.

## **2. CHRONOLOGY AND GENERAL METHODOLOGY**

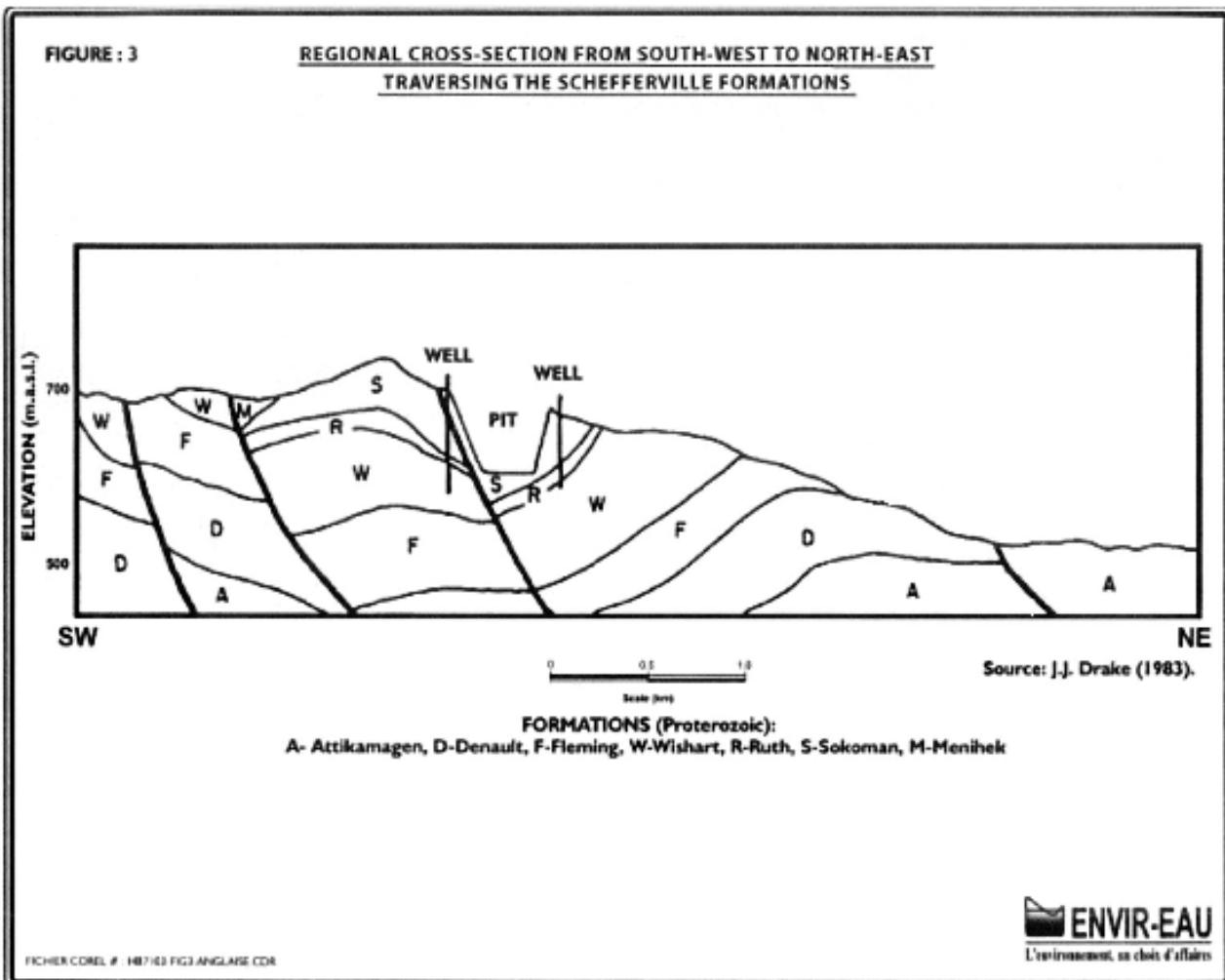
A first field visit was carried out from October 15 to 17, 2008 by Mr. Gilles Fortin, Project Manager for WEE. This visit produced an understanding of the geological and hydrogeological environment of the two sectors and permitted the identification of the elements that could have an impact on the environment during the mining of the deposits. More specifically, the site visits yielded an understanding of the topography of the sites, the position of the various geological formations, the presence of groundwater resurgence zones, the probable direction of groundwater flow and the most appropriate sites for the installation of piezometers, pumping wells, etc. The visit by the Project Manager also made it possible to select the location and configuration of a pumping test in DSO2.

### 3. GEOSCIENTIFIC AND CLIMATIC CONSIDERATIONS

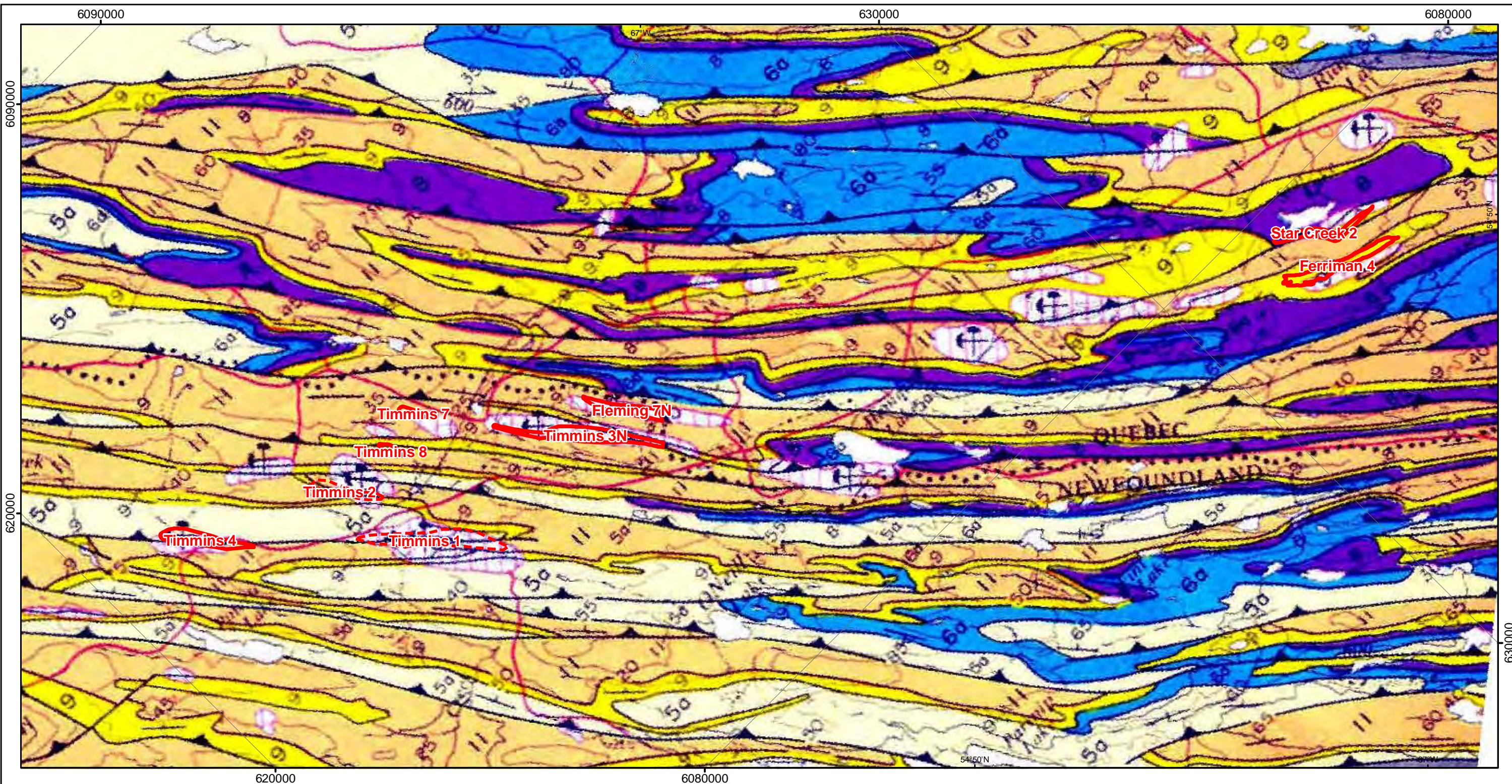
#### 3.1 GEOLOGY AND GEOMORPHOLOGY

The geology and geomorphology have been described in detail by others.

J.J. Drake (1983) gives a succinct description of the geomorphology of the region of Schefferville as a series of ridges and valleys oriented NW-SE, which are the surficial expression of repeated folding and thrusting of the Lake Knob Proterozoic deposits in the Labrador Trough. The presence of ridges and valleys results from the differential resistance of the various formations to glaciofluvial erosion. **Figure 3** shows a typical cross-section of the geology of the Schefferville region.



**Figure 4** shows the regional geology according to R.J. Wardle (1982). All iron ore deposits are found in synclinal folds, either in the shale of the Ruth Formation or in the chert of the Sokoman Formation.



**LEGEND/LÉGENDE**

Deposit/gisement

Pit/Fosse

9 ORTHOQUARTZITE, QUARTZITE AND SILTSTONE  
ORTHOQUARTZITE, QUARTZITE ET MICROGRÈS

5a GREY SHALE, SILTSTONE AND GRAYWACKE  
SCHISTE GRIS, MICROGRÈS ET GRAUWACKE

6a DOLOMITE  
DOLOMITE

8 BRECCIATED CHERT  
CHERT BRÉCHIQUE

**Regional Surface Geology  
Géologie régionale de surface  
DSO - Phase 1**

0 0.45 0.9 1.8 2.7 3.6

KILOMÈTRES/KILOMÈTRES

SCALE/ÉCHELLE:  
1:40,000

UTM 19N NAD 83

FILE, VERSION, DATE, AUTHOR/  
FICHIER, VERSION, DATE, AUTEUR:

GIS-0078-00 , 2009-02-23 , S.D.

SOURCES:  
Wardle, RJ. 1982. Geology of the  
South-central Labrador Trough.  
Gov. of Canada.

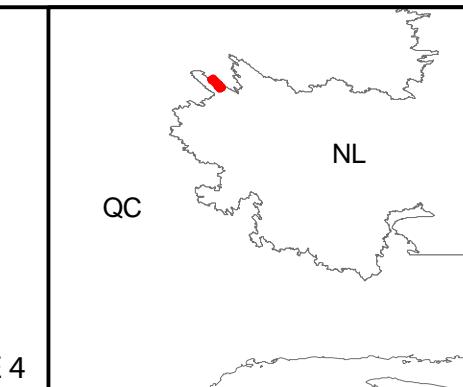
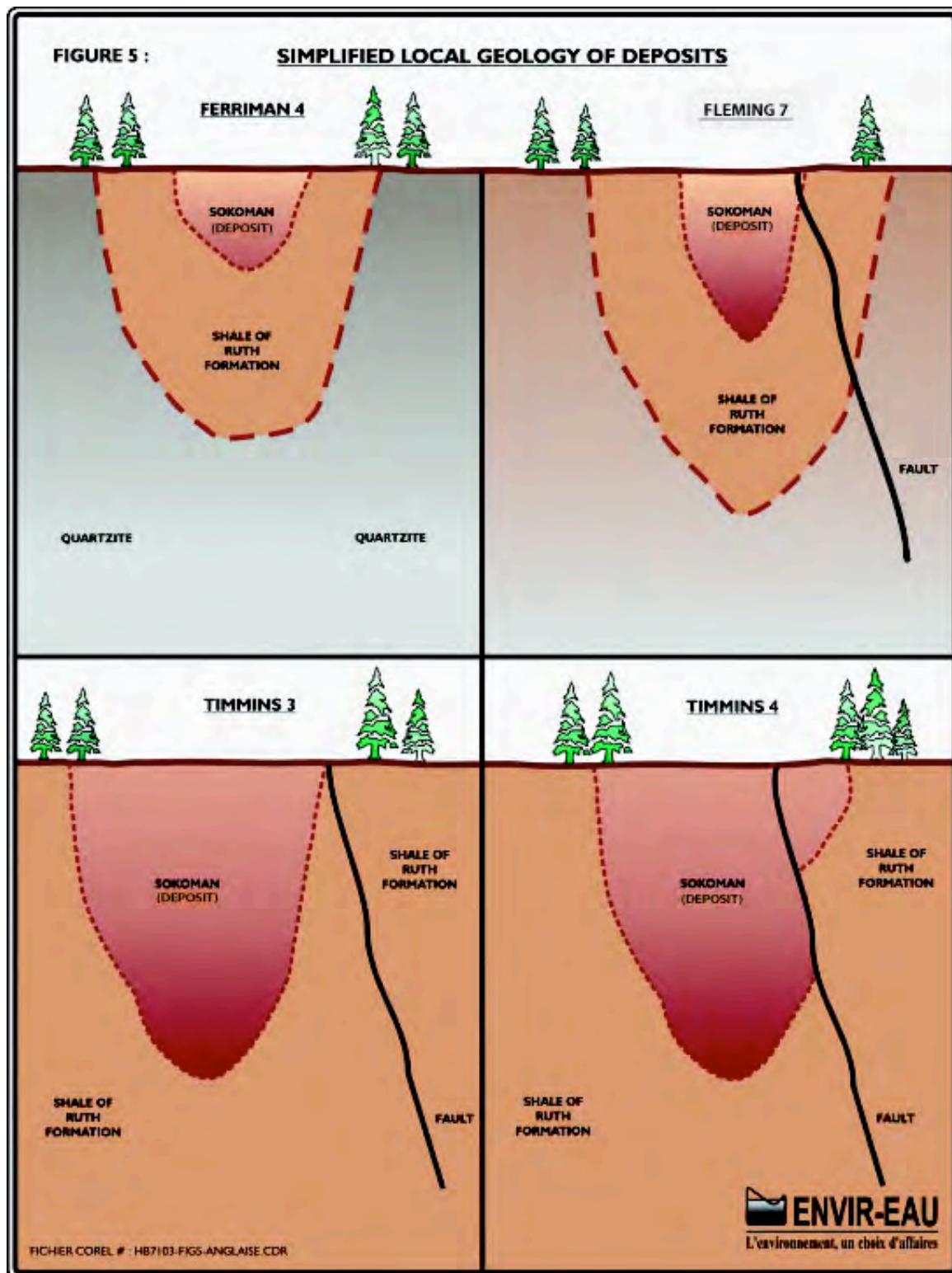


FIGURE 4

Figure 5 shows the conformation of the deposits.



### **3.2 CLIMATE**

An understanding of the climate is a prerequisite for hydrogeological analysis, since the recharging of aquifers is linked to the water cycle, which itself depends on the climate. Information on climate was obtained from the Schefferville meteorological station climate data for the period 1971 to 2000 and from communications with Groupe Hémisphères.

Long-term data recorded in Schefferville indicate an average annual temperature of  $-5.3^{\circ}\text{C}$ . The seasonal profile of air temperature is characterized by dramatic extremes between annual minima and maxima, which can respectively be as low as  $-51^{\circ}\text{C}$  in winter and as high as  $34^{\circ}\text{C}$  in summer. The average frost-free period lasts approximately three months, from mid-June to mid-September (Cournoyer *et al.* 2007).

Based on long-term data, the annual precipitation is on average 833 mm, and is roughly skewed with a peak in July.

The study area is among the driest in Labrador. A little over half of the precipitation falls as snow, which accumulates on average to a depth of 710 mm by March. Statistics show 216 days of liquid or solid precipitation annually.

### **3.3 CALCULATION OF AQUIFER RECHARGE IN DSO3 AND DSO2**

As a general rule, an aquifer that is being pumped recharges in three ways:

- by infiltration through the beds of watercourses and lakes (Q1) (negligible in the case of Timmins 1 and 2 and presently undefined for Ferriman 4 because of a lack of data);
- by infiltration through recharge areas and areas influenced by pumping (Q2);
- by groundwater captured by the cone of depression (Q3).

**Table 1** shows the results of the calculation of groundwater recharge for the Ferriman 4 deposit in DSO2 and in the former pit of Timmins 1 in DSO3. The Q2 and Q3 values were obtained respectively by applying the following formulae:

Q2 = Recharge area x Infiltration from precipitation

Q3 = KiA

Where:      K =      Hydraulic conductivity of the aquifer (value obtained at Ferriman 4)  
                  i =      hydraulic gradient  
                  A =      vertical recharge area

**Table 1 : Recharge of Ferriman 4 (DSO2) and Timmins 1 (DSO3)**

Site	Direct recharge through infiltration			Contribution of groundwater to recharge			<b>Q2+Q3 (m<sup>3</sup>/d)</b>
	Recharge area (km <sup>2</sup> )	Infiltration (30%P) (mm/y)	<b>Q2 (m<sup>3</sup>/d)</b>	K (m/d)	i	A (m <sup>2</sup> )	
<b>Ferriman 4</b>	8.75	250	<b>5,993</b>	1.09	0.05	1,318m x 100m	<b>7,183</b> <b>13,176</b>
<b>Timmins 1</b>	12.4	250	<b>8,479</b>	1.09	0.05	1,100m x 30m	<b>1,799</b> <b>10,278</b>

P = precipitation

## 4. HYDROGEOLOGY OF DSO3

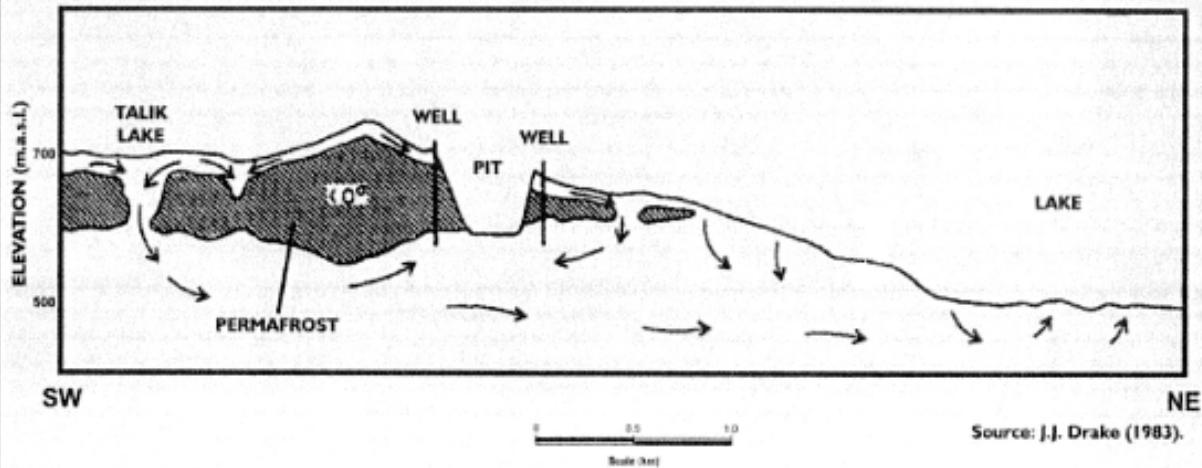
The literature review and field observations made it possible to establish a preliminary basic conceptualization of groundwater flow in DSO3. The presence of permafrost in DSO3, which was already documented in the literature, was confirmed during the drilling program conducted by NML. Permafrost is an essential element to consider in the hydrogeological analysis and the conceptualization of groundwater flow in DSO3, since it can control and substantially modify the movement of groundwater.

### 4.1 GROUNDWATER FLOW IN PERMAFROST AREAS

The conceptual model of groundwater flow in an area of discontinuous permafrost shown in **Figure 6** is taken from J.J. Drake (1983). Totally and permanently frost-free areas occur within a permafrost zone. Those areas, called taliks, are found principally under some lakes and components of the drainage system of ridges at higher elevations. In permafrost areas, groundwater flows on the roof of the permafrost along underground ice-free drainage features, mostly small valleys filled with granular material. The groundwater flowing above the permafrost feeds the taliks that recharge the water table beneath the permafrost.

Flowing groundwater carries some heat and can therefore infiltrate frozen soils that are sufficiently porous. As a result, the roof of the permafrost thaws rapidly in active areas (Nicholson and Lewis, 1976). Thus, the distribution and configuration of permafrost are parameters that change with time with a general tendency towards regressing.

FIGURE : 6

PATTERN OF GROUNDWATER FLOW IN AREA  
OF DISCONTINUOUS PERMAFROST

Source: J.J. Drake (1983).

FICHER COREL # : H87103 PIGE ANGLAISE CDR



#### 4.2 STATE OF KNOWLEDGE ON PERMAFROST AND AQUIFERS IN DSO3

DSO3 is located in an area of discontinuous permafrost. In that region, characterized by series of elongated ridges flanking parallel valleys, the permafrost, which can attain a depth of 100 m in places, is found at the highest elevations on tundra sites poorly protected against the wind (Services techniques, IOCC, 1974). Permafrost does not occur at lower elevations in wooded valleys that are less exposed to wind (Nicholson, 1978).

**Table 2** shows the status of each deposit scheduled for mining by NML with respect to permafrost and the estimated depth of mining. The permafrost thickness values were taken from the literature and have not been verified. It should be noted that, unlike the other deposits, Timmins 3 has been partially mined.

**Table 2 : Permafrost in Deposits**

Deposit	Proposed final pit depth (m)	Permafrost (NML)	Thickness (m) (literature)
Ferriman 4	110	absent	n/a
Timmins 3N	80	absent	n/a
Timmins 4	100	present	60 to 100
Timmins 7	50	present	3 to 20
Timmins 8	50	absent	n/a
Fleming 7 N	110	discontinuous	60 to 100

The first permafrost studies on IOC's properties were carried out jointly by McGill University and the National Research Council of Canada between 1955 and 1961 in the vicinity of the Ferriman deposit. Areas of permafrost were intercepted from the surface to a depth of 75 m. With the opening of the Timmins 1 deposit in 1967, and given the importance of permafrost in that region, the research shifted to the Timmins area. The Timmins 4 deposit in DSO3 was selected as an experimental site to identify the factors affecting permafrost and to refine techniques of delineating areas of permafrost. Concurrently, the Geotechnical Department of IOC developed, between 1970 and 1973, a structured program to delineate permafrost during the mining of deposits and to determine the physical properties of the frozen rock.

Between 1973 and 1975, Nicholson (February 1978) conducted research on the distribution of permafrost at several sites in the Schefferville region, including Timmins 4 and Fleming 7. In his opinion, the permafrost thickness varied at that time from 60 to 100 m, although frost-free areas were found in the valleys bordering those sites.

According to an IOC internal report (G. Mihalovic March 14, 1980), a layer of permafrost averaging 4 m in thickness is present at Timmins 7. Permafrost was recorded to a depth of 20 m in the northernmost part of that sector, while it was found to a depth of as little as 3 m in the southernmost part. In addition, there were signs that a second ice lens is present underneath the first at the south end. A perched water table was reportedly observed. The main aquifer may underlie the permafrost, and the depth of its roof could perhaps be estimated from the position of the water table observed nearby at Timmins 2.

In another letter dated March 14, 1980, Mihalovic indicated that the Fleming 7 deposit is frozen starting at a depth of 2 m from the surface to more than 43 m. A perched water table was also observed.

Mihalovic (April 8, 1980) noted that matching reports compiled over several years by the McGill Research Station and the IOC Technical Department demonstrated that the Timmins 4 deposit is frozen from the surface to a depth of more than 100 m. He also noted that it is difficult to establish the depth of the water table in a permafrost area. He was probably referring to the presence of perched water tables.

#### 4.3 GROUNDWATER FLOW AT DSO3

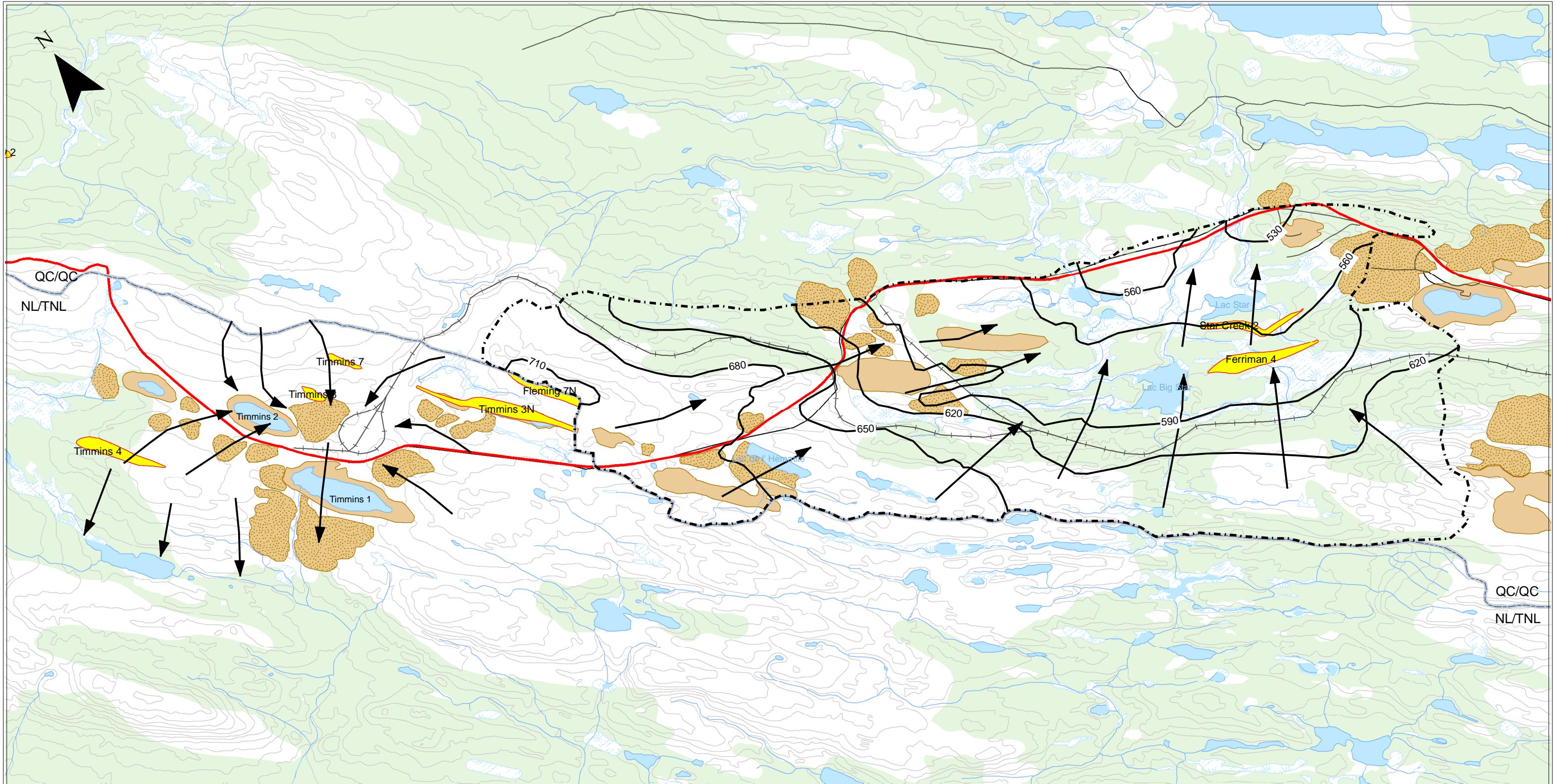
The main aquifers in this sector are found mostly in the bedrock. The presence of discontinuous permafrost in that sector promotes the formation of local perched water tables. The landform maps indicate that the bedrock is exposed practically everywhere throughout the deposits (Groupe Hémisphères, Mars 2009), which is in keeping with the fact that several deposits were stripped down to the bedrock by the IOC with a view to eventually mining them. The soil that is still present in the sector is said to be composed almost entirely of moraine. According to the geologists of NML, the maximum thickness of natural overburden is in the Fleming 7 sector, where thicknesses of up to 5 m were found. The overburden in the DSO3 sector is not thick enough to contain important aquifers.

The regional groundwater flow is illustrated in **Figure 7**. The DSO3 sector is entirely located in Labrador, a short distance from the Quebec border and, hence, from the drainage divide. The recharging of the aquifers will mostly occur on the higher ridges where the surface water divides. All of the deposits in DSO3 are located close to the principal recharge area, thus benefiting from a limited recharge area. The regional groundwater flow in that sector roughly follows the surface flow. Some of the water that infiltrates in the recharge area flows towards Labrador, namely towards the DSO3 sector.

The groundwater will also be recharged through direct infiltration in the area downstream from the flow. The DSO3 sector was greatly disturbed by previous mining operations. Several abandoned pits and waste rock piles were observed. There is practically no vegetation in areas that were mined. According to Groupe Hémisphères (Décembre 2008), which compared old maps with recent field observations, the drainage network was somewhat reduced by the former mining operations. All those changes at the biophysical level have an impact on the recharging of the aquifer in the disturbed areas.

It should be noted that permafrost areas have been identified at Fleming 7 and Timmins 4 and 7. Permafrost can significantly limit the infiltration of water into the soil and thus the

recharging of the aquifer in the permafrost area. The surface water would then tend to travel over the frozen soils or in the ice-free superficial layer of the recharge area and to infiltrate in unfrozen areas at lower elevations and in zones of taliks.



Limit of Fleming Hydrogeological Basin/  
Limite du bassin hydrogéologique Fleming  
 Piezometric Isocontour (m)/  
Isocontour piézométrique (m)  
 Border/  
Frontière  
 Railway to be reconstructed/  
Voie ferrée à reconstruire  
 Main Access Road/  
Route d'accès principale  
 Road/route  
 Deposit/gisement

Watercourse/  
Cours d'eau  
 Wetland/  
Milieu humide  
 Waterbody/  
Plan d'eau  
 Existing mined-out Pit/  
Fosse existante épuisée  
 Existing Waste Dump/  
Halde de stériles existante  
 Contour Interval/  
courbe de niveau  
 Source and direction of Groundwater Flow/  
Sens d'écoulement de l'eau souterraine

## Regional Groundwater Flow Hydrogeological Basin

Fleming and Timmins Area

0 1 2 3  
KILOMETERS/KILOMÈTRES

## Écoulement souterrain régional Bassin hydrogéologique

SCALE/ÉCHELLE:  
1:40 000

UTM NAD 83 Zone 19

SOURCES: Government of Canada, NTDB, 1:50 000, 1979  
Government of Newfoundland and Labrador and Gouvernement du Québec,  
Boundary used for claims  
New Millennium Capital Corp., Mining sites and roads  
Groupe Hémisphères, Hydrology update, 2008  
Hydrogeological Basin "Fleming", adapted from L. Nichols, 1966

Gouvernement du Canada, BNDT, 1/50 000, 1979  
Gouvernement de Terre-Neuve-et-Labrador et Gouvernement du Québec,  
frontière utilisée pour les titres  
New Millennium Capital Corp., gisements et routes  
Groupe Hémisphères, mise-à-jour de l'hydrologie, 2008  
Bassin hydrogéologique "Fleming", adapté de L. Nichols, 1966

FILE, VERSION, DATE, AUTHOR/  
FICHIER, VERSION, DATE, AUTEUR: GH-0010-02, 2009-04-02, J.T.  
Groupe Hémisphères Inc.

The pits excavated during the former mining operations, namely Timmins 1, 2, 3 and 6, all appear as bodies of water, possibly corresponding to the roof of the water table. **Table 3** indicates the approximate position of the water level in the pits in relation to the surface. On that basis, the main water table is located at a good depth from the surface.

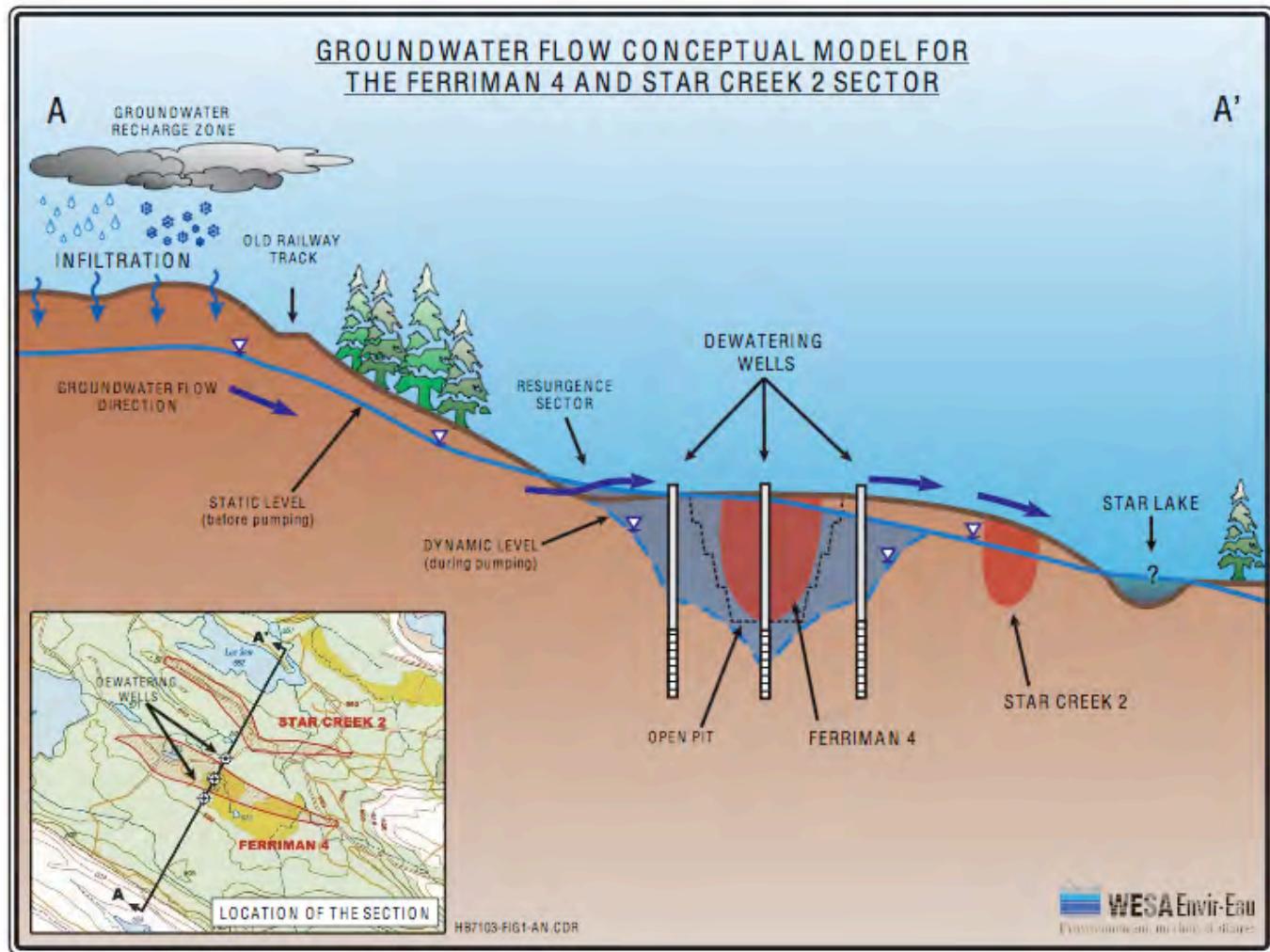
The IOC extracted ore in three sectors of the Timmins 3 deposit. Those sectors are respectively identified, from north-west to south-east, as Sectors A, B and C. Sectors B and C are filled with water throughout the year, while Sector A is filled only periodically, mostly at snowmelt and following heavy rain. Given the absence of permafrost at Timmins 3, it can be inferred that the water level in the pits represents the level of the roof of the water table at that location.

**Table 3 : Depth of Water in Pits**

Deposit	Water level (m below the surface)
Timmins 1	35
Timmins 2	50
Timmins 3	10
Timmins 6	55

**Figure 7** indicates that the Timmins 1 pit corresponds to the endpoint of all the groundwater flowing through the Fleming 7 and Timmins 2, 3, 7 and 8 deposits. Being the source of the watercourse called Elross Creek, Timmins 1 constitutes a topographical low point in relation to the other deposits. Analysis of the topography supports the assumption that the water flowing through Timmins 4 and Timmins 6 belongs to another drainage basin, namely that of Goodream Creek. The water levels in Timmins 1 and 2 correspond to the roof of the water table. According to the configuration of the topography, the water transiting through Timmins 2 should flow towards Timmins 1. Elross Creek serves as the outfall for a part of the groundwater of Timmins 1. According to AMEC (Janvier 2009), the downstream portion of Elross Creek, close to the pit, is permeable, which would also allow the resurgence of groundwater into the creek. The submerged part of Timmins 1 has an average depth of 30 m and a maximum of 70 m. The groundwater beneath the surface should therefore flow through the rock formations towards the lower ground and then come to the surface in the valleys and depressions downstream.

**Figure 9: Groundwater Flow Conceptual Model for the Ferriman 4 and Star Creek 2 Sector**



**Note :** This is a slightly revised version of the figure that appeared in the French version.

## 7. DEWATERING OF DEPOSITS

The dewatering of a deposit in production involves extracting a volume of groundwater over a period commencing several months prior to the beginning of the mining operations and extending until the closing of the mine. A deposit is mined in successively deeper layers (lifts). Thus, dewatering is done progressively during mining operations so as to extract water only from that part of the aquifer above the floor of the layer that is intended to be mined. Once the desired level is reached, the pumping rate is adjusted and is maintained until all the layer in question has been mined. The next layer is then dewatered following the same principle, which means that the maximum pumping rate will be attained at the very end of the mining operations.

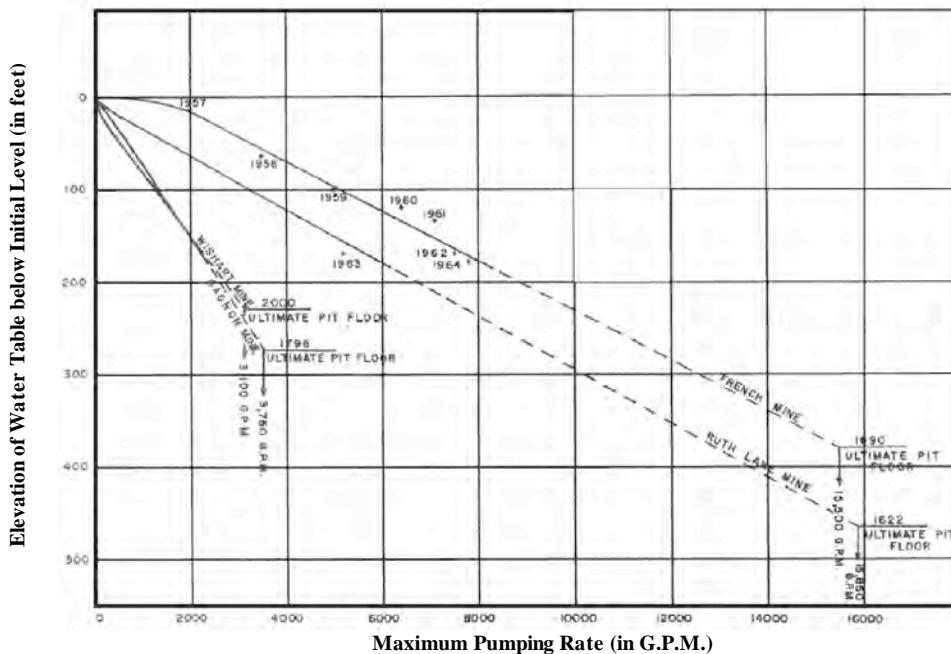
As a general rule, once the desired drawdown is attained, the pumping rate required to maintain the desired level of the water table is between 33 and 50% of the initial pumping rate (Tomlinson, 1963). What is involved is pumping the volume of water coming from the aquifer recharge.

### 7.1 OVERVIEW OF EQUIVALENT DEWATERING ACTIVITIES IN THE SCHEFFERVILLE REGION

**Figure 13** illustrates the relationship between the drawdown and the required pumping rate for various direct shipping iron ore deposits that have been mined in the immediate vicinity of Schefferville. The graph shows that in order to achieve an equal drawdown, the French and Ruth Lake mines required a pumping effort three times greater than did the Gagnon and Wishart mines.

The anticipated drawdown of the water table for the DSOP is not expected to exceed about 100 m. Based on historical data, the maximum pumping rate should be between 15 and 50 m<sup>3</sup>/min depending on the hydrogeological characteristics of the deposits. Field observations, the literature review on recharge areas and other relevant features suggest that the required pumping effort will be greater for DSO2 than for DSO3, where the recharge area and the storage structures of surface water are clearly smaller. The pumping test carried out at Ferriman 4 in the DSO2 sector indicates that the pumping rate required to draw down the water table by 100 m should be similar to that of about 50 m<sup>3</sup>/min applied at the French and Ruth Lake mines. The pumping rate for the deposits in the DSO3 sector should be similar to the 15 m<sup>3</sup>/min that was required at the Gagnon and Wishart mines.

**Figure 13: Relationship between Pumping Rate and Level of Water Table in four Mines in the Schefferville Region (Taken from Stubbins and Munro, 1965)**



#### 7.2.4 Impacts of Dewatering

##### DSO3 Sector

The drainage network of this sector was greatly reduced by former mining activities. A stream rising close to the north-west end of Fleming 7 flows to the north-west end of Timmins 3 only to disappear a few hundred metres farther along. This stream would most likely be affected by the mining of Timmins 3 and Fleming 7N.

The aquifer at Timmins 1 is at the point of convergence for the drainage network located downstream from it. Dewatering the deposits in the same drainage basin as Timmins 1 (Fleming 7 and Timmins 2, 3, 7 and 8) will have a negligible influence on the water balance in Timmins 1. The impact will be practically zero if the pumped water is discharged in the same drainage basin.

## **8.0 MANAGEMENT OF GROUNDWATER**

### DSO3 Sector

The disposal of dewatering water will be planned so as not to transfer water from one hydrogeological basin to another. Based on that principle, the dewatering water from all of the deposits in DSO3, except for that from Timmins 4, which is located in another basin, will be pumped to the abandoned Timmins 2 pit along with the process water, other water that can no longer be recycled and the sump water from the floor of the operating mines. The dewatering water and the sump water from Timmins 4 will be disposed of in the abandoned Timmins 6 pit, which is located in the same hydrogeological basin. The foregoing strategy will allow the water pumped to rejoin the groundwater without significantly affecting the water balance in either of the basins.

## **9. DISPOSAL OF WASTE ROCK**

### DSO3 Sector

Hydrogeological considerations do not impose any restrictions on the disposal of waste rock. There is no resurgence of water that would exclude certain parts of the DSO3 sector as the site of waste rock piles. The hydrographic network in this sector is somewhat atrophied, with the result that the presence of waste rock piles cannot interfere with the recharge of aquifers by surface water.

## 10. CONCLUSIONS AND RECOMMENDATIONS

### DSO3 Sector

The state of knowledge for this sector is limited to the literature review and the preliminary direct field observations. Additional work is needed to obtain complementary information on the hydrogeological parameters of the sector. A recommended first step would be to visit the sector and to make a list of the wells and drill holes that may remain from earlier activities. If dewatering wells have been preserved and are in good condition, they could perhaps be used for pumping tests.

The DSO3 sector covers two drainage basins. As in the case of the DSO2 sector, the depth of the surface of the water table and the direction of flow of the groundwater should be confirmed by field measurements of the elevations of the level of the water in the observation wells and in abandoned pits that were excavated to below the level of the water table. Those measurements should be related by means of a survey to a common reference point.

Since the abandoned Timmins 2 pit will be used to dispose of process water, it would also be important to know well the hydrogeological characteristics of the aquifer there and to establish the parameters of the movement of groundwater in this sector.

We recommend undertaking the following activities in the 2009 field season in order to obtain the missing information:

- pumping tests to ascertain the hydrogeological characteristics of the aquifer in the rock;
- converting certain exploratory drill holes into observation wells;
- surveying all the piezometers and the major water bodies in order to establish the direction of the flow of the groundwater;
- recording the water levels in the observation wells.

Signed

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Abdel Mounem Benlahcen Ph.D.  
Hydrogeologist – Project Director

Signed

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Gilles Fortin M. Sc.  
Director, Environmental Engineering

## 11. LITERATURE CITED

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## **APPENDIX G**

### **Survey of Fish Habitat along the Railway Line and Main Access Road, DSO Project**



**NEW MILLENNIUM  
CAPITAL CORP.**

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## **DIRECT-SHIPPING ORE PROJECT**



**Survey of Fish Habitat along the Railway Line and Main  
Access Road, DSO Project**

**Technical Report**

**BY: Groupe Hémisphères inc.**

**November 2008**

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New Millennium Capital Corporation

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This report can be cited as follows:

Groupe Hémisphères (2008) *Survey of Fish Habitat along the Railway Line and Main Access Road*. Technical Report prepared for New Millennium Capital Corp. 12 p. and 8 appendices

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- Appendix III Types of streams and water quality
- Appendix IV Stream hydrology
- Appendix V Substrate composition
- Appendix VI Composition of plant cover
- Appendix VII June 2008 culvert study
- Appendix VIII Description of channel patterns used to characterize the streams

## LIST OF ABBREVIATIONS AND SYMBOLS

AR	Culvert along the main access road
$^{\circ}\text{C}$	Celsius
$\mu\text{g/L}$	Microgram per litre
$\mu\text{mhos/cm}$	Micromhos per centimetre
IOC	Iron Ore Company of Canada
km	Kilometre
$\text{km}^2$	Square kilometre
L	Litre
THE NHWL	Natural high water line
m	Metre
$\text{m}^3/\text{s}$	Cubic metres per second
m/s	Metre per second
NML	New Millennium Capital Corp.
NTU	Standard unit of measure of turbidity
pH	Unit of measure of the acid or alkaline condition of a substance
RLC	Culvert along the railway line

REVISION AND PUBLICATION		
Number	Date	Modification or detail of publication
00	2008-11-11	Preliminary technical report
01	2008-11-20	Final technical report

N.B. This final technical report takes into account the changes made to Table 2 on 23 December, 2008.



## 1 INTRODUCTION

### 1.1 Background

The price of iron ore has considerably increased since 2002, making it profitable to develop the Millennium Iron Range, located in the Schefferville region. The Direct-Shipping Ore Project (DSOP) is one of three initiatives undertaken by New Millennium Capital Corp (NML). Its goal is the production of direct-shipping ore. The first phase involves the mining of two sectors (DSO 2 and DSO 3), located partly in Québec and partly in Labrador. The second phase will involve the mining of sector DSO 4, also located partly in Québec and partly in Labrador. The yearly tonnage for phase 2, however, has not been established to date. Two of these three sectors (DSO 2 and DSO 3) have been partially developed by the Iron Ore Company of Canada (IOC), which means that their biophysical environment was somewhat disturbed. For its part, the third sector, DSO 4, has remained more natural and kept its integrity. In both phases of the DSOP, the ore will be transported by train, which requires upgrading an abandoned section of the railway.

### 1.2 Mandate and Objectives

Physical modifications to the riparian habitat represent a source of pressure that contributes to the deterioration of the habitat of fish communities (Smokorowski and Pratt, 2007). Smokorowski and Pratt (2007) believe there is a direct link between the habitat and the abundance or biomass of fish. According to DFO (2008a), it is important to protect the habitat that provides fish with healthy waters, spawning and fry-rearing grounds, an adequate supply of food and unblocked migration paths. Given that brook trout (*Salvelinus fontinalis*) is very common in Labrador, according to DFO (2008b), its habitat must be characterized in this study. DFO (2008a) identifies "fish habitat" as "places that supply fish with their life cycle requirements for food, shelter, reproduction and movement." It is in this context that a characterization study of fish habitat in the streams that will be crossed by the NML project infrastructure was conducted in the sectors to be mined during phase 1 of the DSOP.

The fish habitat survey was carried out along an abandoned railway line between Timmins 1 and Mile 353 of the existing railway linking Schefferville and Sept-Îles. Excluding the twinning of tracks in the vicinity of Lake Slimy, the survey ranged over 27.83 km. The fish habitat survey was also carried out over 21 km along the main access road linking Schefferville and the DSOP Timmins 1 area.

It should be noted that the railway was used by IOC until 1982. Except for the rails and ties, most of the railroad infrastructure is already in place and in good condition. The methodology is similar to that used by AMEC in the fish habitat survey carried out in 2008 for the mine sites of the DSOP and its access roads (AMEC, 2008), as well as in the survey of stream crossings carried out in 2005 for the LabMag project (AMEC, 2005).

## 2 METHODOLOGY

### 2.1 Sampling of Streams

Federal maps at a scale of 1/50 000 indicated over 30 possible stream crossings along the abandoned railway line. The goal was to find all culverts crossing this right-of-way and to proceed with their characterization. When a stream was found, a description of the fish habitat quality was carried out both downstream and upstream of each crossing point. The upstream and downstream sampling sites jointly constituted a sampling station.

Streams were sampled as follows: a 12-channel GPS with an activated WAAS function was used to determine the locations of the sampling station and the sampling points; and the nature of the substrate and the hydrological conditions were noted (see the field sheet in Appendix II).

All the streams shown on the map were visited. This report refers, however, to the visit to all culverts, whether or not a flowing stream was found.

### 2.2 Survey Schedule

The first part of the work took place on June 18, 2008, when Roy Logan carried out a survey of the condition of the culverts (Appendix VII). At that time, the various locations where culverts could be found along the existing track right-of-way were visited and numbered RLC-1 to RLC-27 (RLC; *Railway Culvert*).

The second part of the work took place between July 17 and 20, 2008, when Daniel Néron conducted a survey of all the access roads. Two stream crossings were identified as AR1 and AR2 (AR; *Access Road*).

The third part of the work took place between September 14 and 16, 2008, when Simon Chartrand and Michel Ashini-Goupil carried out the fish habitat survey. Roy Logan toured the study area with them. The letter (a) refers to streams that were not listed by Roy Logan at the time.

### 2.3 Fish Habitat and Use Survey

It is important to note that any discussion of fish in this report refers mainly to brook trout habitat because this species can be assumed to be the most abundant in the region, particularly at higher elevations.

The fish habitat survey consisted in estimating the hydraulic radius of a stream by measuring its width and mean depth, flow velocity, substrate composition and quality, bank and shoreline vegetation (type, dominant species and cover), as well as its integrity. A Global Flow Probe FP101 water velocity meter (0.01m/s) was used randomly at three points along the hydraulic radius (1/3, 1/2 and 2/3) to assess the velocity of the stream at a given point. Distances were measured with a 30 m measuring tape, while a Suunto clinometer was used to assess the slope of the stream stretches.

Appendix VIII describes the channel patterns used for this study, which were for the most part the same as those established by Malavoi (1989). In summary, streams are divided into seven channel patterns: pool, cascade, channel with uniform bed, waterfall, step-pool, rapids and pool riffles.

Finally, some physical and chemical baseline data were recorded during this survey, namely water temperature (°C), dissolved oxygen (mg/l), conductivity (µS/cm), turbidity (NTU) and pH (unit). The meteorological conditions prevailing at the time of the survey were also noted, including air temperature and cloud cover.

### 3 RESULTS

#### 3.1 General Description of the Study Area

The study area is located north of the Town of Schefferville (Figure 1). It extends some 25 km on a north-west/south-east axis. It is located at the interfluve between the Howells River valley to the west and a lacustrine zone to the east. On this axis, it follows the watershed and consequently goes back and forth across the Québec/Labrador inter-provincial border. The elevation varies from 500 to 790 m, the northern part of the study area being generally more elevated.

In its southern part, which corresponds to the DSO 2 sector, the study area is mainly characterized by open forest vegetation, such as spruce stands with mosses or lichens. Most summits are characterized by alpine vegetation (tundra). Some small lakes and wetlands, such as ponds and fens, are found in this part of the study area. Its northern part, which corresponds to the DSO 3 sector, is more elevated, less forested and much dryer. Both parts contain old mining sites with wide, deep and steep-sided trenches, waste rock piles, stripped zones and numerous secondary roads.

#### 3.2 Description of Sampling Stations

This section presents the results and data interpretation obtained for each sampling station. Figure 1 shows the stations divided in two groups: RLC and AR.

Appendix I contains photographs of each site. Appendix II lists the physical and chemical parameters of the streams. The types of streams and water quality data are shown in Appendix III, while Appendix IV presents data on stream hydrology. Appendix V shows the substrate composition for each station, while the composition of the plant cover is described in Appendix VI. The survey of stream crossings carried out by Roy Logan is reproduced in Appendix VII. Table 1 gives an overview of the sampling stations and their geographical coordinates, while Table 2 shows the stream crossings with potential fish habitat and indicates the types of obstacles.

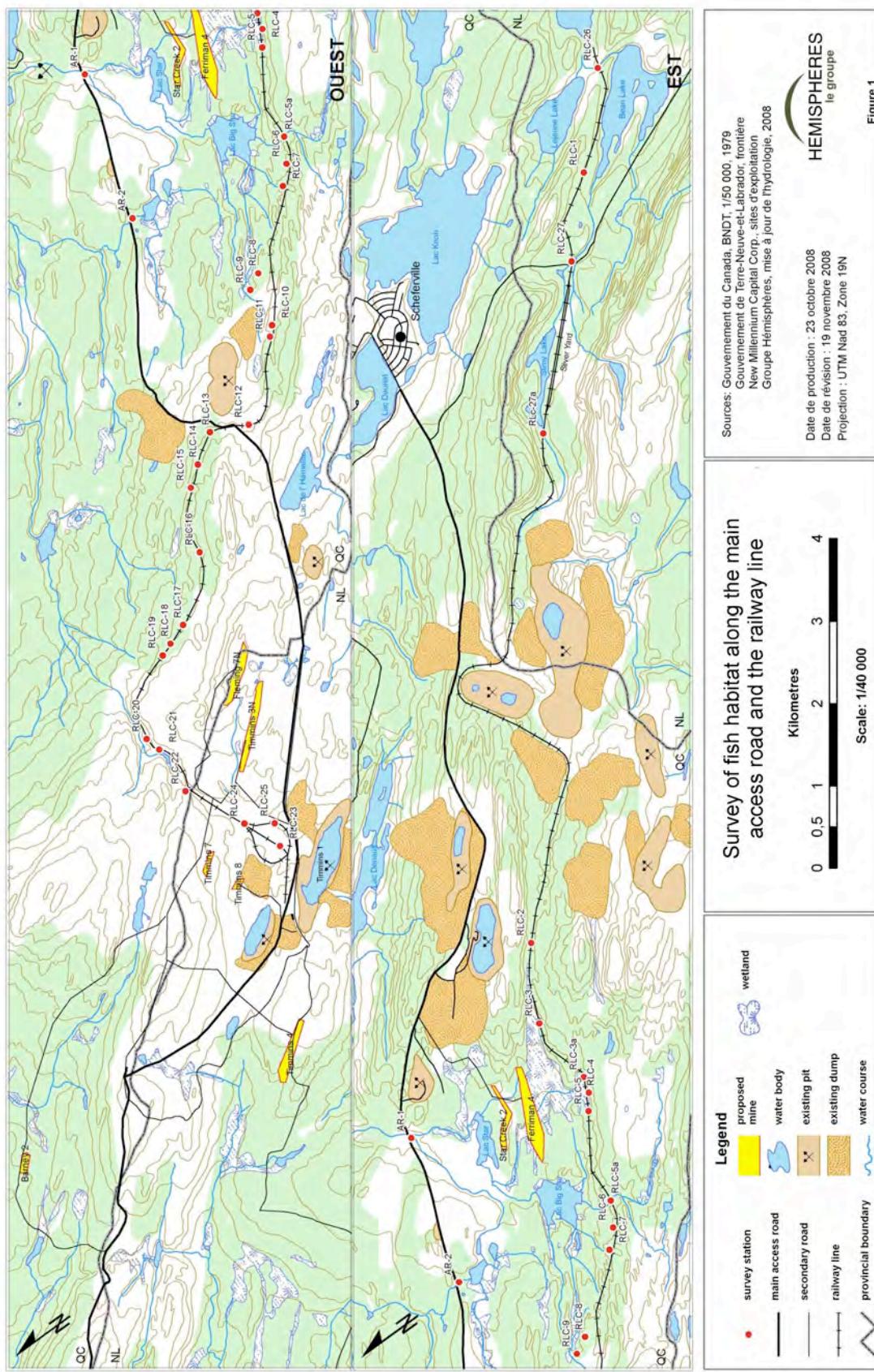


Figure 1

**Table 1. Coordinates of the sampling stations: RLC and AR**

Station	Geographic coordinates		Province	Notes
	Longitude	Latitude		
RLC-1	-66.8150	54.7737	NL	
RLC-2	-66.9240	54.8297	QC	
RLC-3	-66.9370	54.8344	QC	
RLC-3a	-66.9502	54.8341	QC	
RLC-4	-66.9532	54.8347	QC	
RLC-5	-66.9559	54.8360	QC	
RLC-5a	-66.9718	54.8401	QC	Stream
RLC-6	-66.9761	54.8417	QC	
RLC-7	-66.9791	54.8434	QC	
RLC-8*	-66.9893	54.8514	QC	
RLC-9*	-66.9909	54.8532	QC	Stream
RLC-10	-66.9987	54.8537	QC	
RLC-11	-67.0002	54.8546	QC	Stream
RLC-12	-67.0109	54.8623	QC	
RLC-13	-67.0075	54.8662	QC	
RLC-14	-67.0110	54.8694	QC	
RLC-15	-67.0137	54.8715	QC	
RLC-16	-67.0244	54.8751	QC	
RLC-17	-67.0333	54.8813	QC	
RLC-18	-67.0346	54.8837	QC	
RLC-19	-67.0355	54.8851	QC	
RLC-20	-67.0462	54.8921	QC	
RLC-21	-67.0493	54.8917	QC	
RLC-22	-67.0585	54.8922	NL	
RLC-23	-67.0777	54.8877	NL	
RLC-24	-67.0702	54.8893	NL	
RLC-25	-67.0736	54.8866	NL	
RLC-26	-66.8011	54.7655	NL	Stream
RLC-27	-66.8269	54.7807	NL	Stream
RLC-27a	-66.8493	54.7947	NL	Stream
AR-1	-66.9395	54.8529	QC	Stream
AR-2	-66.9664	54.8585	QC	Stream

\*RLC-8 and RLC-9 are not located on the planned rail line

#### *RLC-1 to RLC-3*

No stream bed was observed and no characterization was carried out.

#### *RLC-3a*

RLC-3a is a culvert found by GHI: no stream bed was observed and no characterization was carried out (Photos RLC-3A: 1-3).

#### *RLC-4, RLC-5*

No stream bed was observed and no characterization was carried out. There might be some flow during snowmelt.

#### *RLC-5a*

RLC-5a is a culvert found by GHI. The characterization of this station was carried out at two points, one in the upstream segment and the other in a segment of the channel with a uniform bed downstream from the culvert.

RLC-5a has a flow of 0.02 m<sup>3</sup>/s, a mean velocity varying from 0.01 to 0.07 m/s, and a mean depth of 0.21 m. The wet width is 1.10 m upstream and 4.50 m downstream. However, the width at the NHWL is 10.15 m, and this line is located 0.80 m above the normal water level. The substrate is made up mainly of gravel and pebbles (55%) and organic matter (20%). Blocks (or coarse substrate) cover 15% of the stream bottom, and sand (or fine substrate) covers 10%. The slope of the segment varies from 1 to 2%. The physical and chemical values of the stream are as follows: temperature of 10.4°C, pH of 6.7, conductivity of 5 µmhos/cm and turbidity of 0.83 NTU (Photos RLC-5a: 6-10). The study of the vegetation shows that this station is characterized by a plant cover of the shrubland and open forest type. The overhanging vegetation is dominated by the shrub layer; 43% of the riparian vegetation consists of the shrub layer, while 10 to 15% is made up of arboreous, herbaceous and moss layers. There is no aquatic vegetation. A great deal of organic matter has accumulated upstream and downstream from the culvert where an obstacle is causing this material to jam. A high-intensity disturbance is caused by the use of the railway bed as a roadway and by the culvert that restricts the flow of the stream. No fish were observed in this segment, but the data collected indicate that it is a probable fish habitat.

#### *RLC-6 to RLC-10*

No stream bed was observed and no characterization was carried out. There might be some flow during snowmelt. It should be noted that stations RLC-8 and RLC-9 are considered to be outside the scope of this study since they are located on a secondary branch of the railroad that will not be rebuilt.

#### *RLC-11*

The characterization of this station was carried out at two points, one upstream and one downstream from the culvert. A series of waterfalls and rapids was noted upstream, and a cascade is present downstream. The waterfall and the cascade constitute a natural obstacle that impedes fish movements.

RLC-11 has a flow varying from 0.73 to 1.41 m<sup>3</sup>/s, a mean velocity varying from 0.37 to 0.53 m/s, and a mean depth varying from 0.33 to 0.38 m. The wet width varies from 1.00 to 1.60 m. The width at the NHWL, however, is 10 m upstream and 4.20 m downstream, with the height of the NHWL above the normal water level varying between 1.20 and 1.40 m. The substrate is composed mainly of gravel and pebbles (80%) and organic matter (10%). At this station, the slope of the segment is 5%. The physical and chemical values of the stream are as follows: temperature of 5.6°C, pH of 7.4, conductivity of 77 µmhos/cm and a turbidity indicating fairly clear water with 0.66 NTU (Photos RLC-11: 11-16). The study of the vegetation shows that this station is characterized by plant cover of the shrubland type and that there is no aquatic vegetation. The riparian vegetation is dominated by the moss layer (80%), whereas the overhanging vegetation is made up of a shrub layer. No fish were observed in this segment, but the data collected indicate that it is a probable fish habitat.

*RLC-12 to RLC-16*

No stream bed was observed and no characterization was carried out. There might be some flow during snowmelt.

*RLC-17*

No stream bed or water is associated with this culvert. No characterization was carried out (Photos RLC-17: 11-16).

*RLC-18 to RLC-25*

No stream bed was observed and no characterization was carried out. There might be some flow during snowmelt.

*RLC-26*

The characterization of this station was carried out at two points, i.e. in pool-riffle segments upstream and downstream from the culvert. Downstream from this station, the stream flows into Bean Lake, Lejeune Lake and Abel Lake.

RLC-26 has a flow varying from 0.88 to 4.72 m<sup>3</sup>/s, a mean velocity varying from 0.30 to 0.54 m/s, and a mean depth varying from 0.35 to 0.42 m. The wet width varies from 6 to 7 m. The width at the NHWL, however, is 7 m upstream and 25 m downstream, with the height above the normal water level varying between 0.30 and 0.60 m. From 55 to 80% of the bottom is covered by a medium substrate (pebbles and gravel). A fine substrate (sand) covers between 5 and 20%, and a coarse substrate (blocks) between 10 and 15%. The slope of this segment varies from 1 to 2% at this station. The physical and chemical values of the stream are as follows: temperature of 9.6°C, pH of 7.4, conductivity of 152 µmhos/cm (Photos RLC-26: 17-22). The study of the vegetation shows that this station is characterized by a plant cover of the treeland type downstream and the closed forest type upstream. The riparian vegetation is composed for the most part of shrub and herbaceous strata, whereas the overhanging vegetation is dominated by the shrub layer. Submerged plants constitute 10 to 30% of the aquatic vegetation. Fish were observed in this segment (unconfirmed species). It is therefore a potential spawning ground for brook trout. Michel Ashini-Goupil, who is from Schefferville, knows it as a fishing ground. Consequently, this station should be considered a confirmed, important fish habitat.

*RLC-27*

Three sampling points, two downstream and one upstream, were measured on this stream. The characterization of the upstream point was carried out in a section that included a cascade and a pool. The characterization of the downstream stations was carried out in two sections of rapids and in a cascade section.

RLC-27 has a flow varying from 1.23 to 4.86 m<sup>3</sup>/s, a mean velocity varying from 0.15 to 1.05 m/s, and a mean depth varying from 0.26 to 0.42 m. The wet width varies from 3.60 to 7 m. The width at the NHWL, however, varies between 15 and 30 m, with the height of the NHWL above the normal water level varying between 0.5 and 0.8 m. From 20 to 75% of the bottom is covered by a medium substrate (pebbles and gravel). A fine substrate (sand) covers between 5 and 30%, and a coarse substrate (blocks) between 5 and 70%. The substrate is also made up of organic matter that covers between 5 and 10%. The slope of this segment varies from 1 to 2% at this station. The physical and chemical values of the stream are as follows: temperature of 8.3°C, pH of 8.1, conductivity of 144 µmhos/cm and turbidity of 3.60 NTU (Photos RLC-27):

23-34). The study of the vegetation shows that this station is characterized by a plant cover of the shrubland or open forest type. The riparian vegetation is composed equally of a shrub layer and a herbaceous layer, while the overhanging vegetation is dominated by the shrub layer. The aquatic vegetation is composed of 10 to 60% submerged plants and 15% floating plants.

No fish were observed in the three stations downstream from the culvert, but the data collected indicate that it is a very suitable habitat. However, fish were observed at the station upstream from the culvert, which means that the downstream segment is fish habitat, since the culvert is not itself an obstacle, and fish can probably traverse under high water conditions. In two of the stations downstream from the culvert, a weak disturbance was observed that was related to the railway line and adjacent secondary roads.

#### RLC-27a

The characterization of this station was carried out at two points, one in the cascade section upstream from the culvert, and the other in a segment of the channel with a uniform bed downstream from the culvert.

RLC-27a has a flow varying from 0.88 to 0.97 m<sup>3</sup>/s, a mean velocity varying from 0.16 to 0.33 m/s, and a mean depth varying from 0.45 to 0.62 m. The wet width varies from 3.80 to 4 m. However, the width at the NHWL is 10 m upstream and 6 m downstream, and this line is located 1.40 m above the normal water level. The substrate is made up of 45% of pebbles and gravel, 30% fine substrate (sand and silt), 15% coarse substrate (block) and 10% organic matter. The slope of this segment varies from 1 to 2% at this station. The physical and chemical values of the stream are as follows: temperature of 8.3°C, pH of 8.3, conductivity of 122 µmhos/cm and turbidity of 4.78 NTU (Photos RLC-27A: 35-40). The study of the vegetation shows that this station is characterized by a plant cover of the shrubland or open forest type. The riparian vegetation is composed for the most part of a shrub layer (50%) and a moss layer (28%), whereas the overhanging vegetation is dominated by the shrub layer. The aquatic vegetation is composed of 5% of emerged plants and 5% pf submerged plants. Vehicles cause a disturbance on the railway bed. Fish were observed in this segment (species not confirmed). Fill substantially reduces the hydraulic radius at the culvert inlet. This station should be considered a confirmed, important fish habitat. Once again, the fish should be able to traverse the culvert under high water conditions. A strong disturbance related to mine waste was observed on the site.

#### AR-1

The characterization of this station was carried out at four points: upstream from three culverts in a pool; and downstream in a cascade section just below the culverts that form a waterfall at least 1 m high.

Points AR-1 Upstream-1 and AR-1 Downstream are located immediately adjacent to the ends of the culvert. Their flow varies from 0.76 to 3.83 m<sup>3</sup>/s., their mean velocity from 0.26 to 1.36 m/s. and their mean depth from 0.19 to 0.30 m. The wet width is 6.10 m upstream and 3.70 m downstream. The width at the NHWL, however, varies between 10 and 15 m, and this line is located at 0.40 m above the normal water level. The substrate of the downstream station is mainly coarse (80% blocks), but it also includes 15% pebbles and gravel and 5% fine substrate (sand). The substrate of the upstream station is mainly made up of gravel and pebbles (up to 90%), fine substrate (sand) (8%) and only 2% coarse substrate (blocks). The slope of this segment varies from 2 to 3% at this station. The physical and chemical values of the stream are as follows: temperature of 7.7°C, pH of 7.3, conductivity of 35 µmhos/cm and turbidity of 0.80 NTU (photos AR-1: 41-46). The study of the vegetation shows that this station is characterized by a plant cover of the open forest type. The riparian vegetation is composed for the most part of shrub and herbaceous layers, whereas the overhanging vegetation is dominated by the arboreous layer. The aquatic

vegetation is composed of 30 to 80% submerged plants. No fish were observed in this segment, but the data collected indicate that it is very suitable habitat for fish. Use by vehicles causes disturbance to the rail bed. In the past, fish were observed in this segment.

#### *AR-1 Upstream-2*

Upstream from this station there is a pond. However, the characterization of this station was carried out in a section where there were rapids downstream from the culvert (photos AR-1 upstream-2: 53-55). The rapids may create an obstacle for fish at this station. This point is located 360 m upstream from the main access road.

AR-1 Upstream-2 has a flow of  $0.61 \text{ m}^3/\text{s}$ , a mean velocity of  $0.86 \text{ m/s}$ , and a mean depth of  $0.14 \text{ m}$ . The wet width is  $0.38 \text{ m}$ . The width at the NHWL is  $5 \text{ m}$ , and this line is located at a height of  $0.25 \text{ m}$  above the normal water level. The substrate is made up mainly of gravel and pebbles (70%), fine substrate (20%) and coarse substrate (10%). The physical and chemical values of the stream are as follows: temperature of  $6.6^\circ\text{C}$ , pH of 7.8, conductivity of  $20 \mu\text{mhos/cm}$  and turbidity of  $0.47 \text{ NTU}$ . The slope of this segment is null at the pond and was not measured in the downstream rapids. The study of the vegetation shows that the riparian and overhanging vegetation is dominated by the shrub layer, while aquatic vegetation is non-existent. Use by vehicles causes disturbance to the rail bed. No fish were observed in this segment, but the data collected indicate that it is very suitable habitat for fish. According to Michel Ashini-Goupil, who is originally from Schefferville, fish are historically present on the site.

#### *AR-1 Upstream-3*

The characterization of this station was carried out in a step-pool section. A waterfall  $0.30 \text{ m}$  high caused by the culverts represents an obstacle for fish (photos AR1 Upstream-3: 56-58). This point is located 200 m upstream from the main access road.

AR1 Upstream-3 has a flow of  $3.10 \text{ m}^3/\text{s}$ , a mean velocity of  $0.59 \text{ m/s}$ , and a mean depth of  $0.35 \text{ m}$ . The wet width is  $4.10 \text{ m}$ . The width at the NHWL is  $15 \text{ m}$ , and this line is located at a height of  $0.7 \text{ m}$  above the normal water level. Forty per cent of the stream bottom is composed of medium substrate (pebbles and gravel) and another 40% of coarse (blocks) substrate. Fine substrate (sand and silt) covers 20% of the stream bottom. The physical and chemical values of the stream are as follows: temperature of  $7.6^\circ\text{C}$ , pH of 8.0, conductivity of  $35 \mu\text{mhos/cm}$  and turbidity of  $0.46 \text{ NTU}$ . The slope of this segment is 2% at the pond and was not measured in the downstream rapids. The study of the vegetation shows that the riparian vegetation is composed of the shrub layer (43%) and the herbaceous layer (20%), while the overhanging vegetation is dominated by the shrub layer. The aquatic vegetation is made up of 50% of submerged plants. Use by vehicles causes disturbance to the rail bed. No fish were observed in this segment, but the data collected indicate that it is very suitable habitat for fish.

#### *AR-2*

The characterization of this station was carried out at two points: in one section of channel with a uniform bed upstream from the culvert; and in one section of step-pool, where there were waterfalls downstream from the culvert.

AR-2 has a flow varying from  $0.08$  to  $0.10 \text{ m}^3/\text{s}$ . These values are from the measurements taken at the inlet and outlet of the culvert, where the mean velocity was respectively  $0.84$  and  $1.22 \text{ m/s}$ . The measurement points upstream and downstream are in a pond, and the widths were not measured. Organic matter made up between 60 and 80% of the bottom, fine substrate between 10 and 30% and medium substrate (gravel

and pebbles) 10%. At this station, the slope of the segment is 2%. The physical and chemical values of the stream are as follows: temperature of 6.4°C, pH of 6.5, conductivity of 8 µmhos/cm and turbidity of 1.00 NTU (photos AR-2: 47-52). The study of the vegetation shows that this segment is characterized by a swamp and that submerged plants occupy an area varying from 10 to 30%. Fish were observed downstream from this segment; consequently, it should be considered a confirmed fish habitat.

### 3.3 Summary of the Survey

During this fish habitat survey, brook trout were observed in four streams, i.e. stations AR-2, RLC-26, RLC-27 (upstream) and RLC-27a (Table 2). Station RLC-26 seems to be a spawning ground for brook trout. No fish was observed at the various points of station AR-1, but the data collected indicate that it is a very suitable habitat for fish. According to Michel Ashini-Goupil, fish are historically present in this segment. Evidence of fishing (old earthworm jar) was also found at this spot.

Obstacles were observed at seven sampling points. The culverts at stations AR-1 and AR-2 create significant waterfalls, which are impassable to fish. Natural obstacles created by a cascade downstream from the culvert at AR-1 Upstream-2 and a waterfall created by the culvert at station AR-1 Upstream-3 limit fish movement. There is a partial obstruction at the culvert inlets at stations 27 and 27A that limits fish passage part of the year.

According to NML, four culverts need to be improved before the circulation of trains is permitted. These are stations RLC-7, RLC-12, RLC-17 and RLC-24. There is no stream bed and no fish habitat at any of those stations. The other stations surveyed have no visible stream bed: not only was there no measurable water flow, but there was no trace of water or any indication at all of the presence of a stream, even an intermittent one. Some of these culverts are located in dry valleys that could drain snowmelt, but it is very unlikely that these valleys would become productive fish habitats at those times.

**Table 2. Streams with potential fish habitat and types of obstacle found**

Point #	Fish present	Comments on the potential of fish habitat *	Obstacle to passage of fish	Type of obstacle
RLC-5a Upstream	no	probable potential habitat	no	-
RLC-5a Downstream	no	probable potential habitat	no	-
RLC-11 Upstream	no	probable potential habitat	no	-
RLC-11 Downstream	no	probable potential habitat	yes	cascades downstream from culvert
RLC-26 Upstream	yes	habitat confirmed	no	-
RLC-26 Downstream	yes	habitat confirmed	no	-
RLC-27 Upstream	yes	habitat confirmed	no	-
RLC-27 Downstream	no	habitat confirmed	yes	jam at opening
1	no	habitat confirmed	no	-
RLC-27 Downstream	no	habitat confirmed	no	-
2				
RLC-27 Downstream				
3				
RLC-27a Upstream	yes	habitat confirmed	yes	fill at opening
RLC-27a Downstream	yes	habitat confirmed	no	-
AR-1 Upstream	no	possible potential habitat	yes	waterfall caused by culvert
AR-1 Upstream	no	possible potential habitat	yes	cascades downstream from culvert
AR-1 Upstream	no	possible potential habitat	no	-
AR-1 Downstream	no	possible potential habitat	yes	waterfall caused by culvert
AR-2 Upstream	no	probable potential habitat	no	-
AR-2 Downstream	yes	habitat confirmed	yes	waterfall caused by culvert

\* Few signs indicate a possible potential habitat; many signs indicate a probable potential habitat; and the presence of fish indicates confirmed habitat

#### **4 CONCLUSION**

New Millennium Capital Corporation retained the professional services of Groupe Hémisphères to enhance knowledge of the fish habitat along the railway line and main access road. The primary goal was to characterize the fish habitat in streams crossed by the infrastructure forming part of the proposed mining project. The work consisted in a survey of fish habitat.

With respect to the planned rail line, 29 culverts were covered during two ground surveys. Of these 29 culverts, five (5) contain streams that can be considered to be potential or confirmed fish habitat. Stations RLC-26 (NL), RLC-27 (NL) and RLC-27a (NL) are confirmed habitats, while stations RLC-5 (QC) and RLC-11 (QC) are probable or possible fish habitats.

With respect to the main access road, the two (2) culverts are possible fish habitats, i.e. stations AR-1 (QC) and AR-2 downstream (QC).

No fish habitat will be affected by the reconstruction of the railway. The reconstruction requires no new culverts nor the repair of any culverts in which a permanent or intermittent stream is present. The same is true for the use of the main access road, which is in excellent condition currently and will meet all future needs.

There are obstacles created by the existing culverts at stations RLC-27 (NL), RLC-27a (NL), AR-1 (QC), AR-1 Upstream-3 (QC) and AR-2 (QC). These permanent obstacles to fish movements have existed for more than fifty years.

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## APPENDICES



## APPENDIX I

### FIELD PHOTOGRAPHS



(1)



RLC-3a (view from upstream)

(2)



RLC-3a (view looking downstream)

(3)



RLC-3a (view from downstream)

(4)



RLC-17 (view looking upstream)

(5)



RLC 17 (view from downstream)

(6)



RLC-5a (view looking upstream)

(7)



RLC-5a (view looking upstream)

(8)



RLC-5a (view looking upstream)

(9)



RLC-5a (view looking upstream)

(10)



RLC-5a (view looking downstream)

(11)



RLC-11 (view looking upstream)

(12)



RLC-11 (view looking upstream)

(13)



RLC-11 (view from downstream)

(16)



RLC-11 (view looking downstream)

(14)



RLC-11 (view looking downstream)

(17)



RLC-26 (view from upstream)

(15)



RLC-11 (view looking downstream)

(18)



RLC-26 (view looking upstream)

(19)



RLC-26 (view looking upstream)

(20)



RLC-26 (view from downstream)

(21)



RLC-26 (view looking downstream)

(22)



RLC-26 (view looking downstream)

(23)



RLC-27 (300 m upstream)

(24)



RLC-27 (view from upstream)

(25)



RLC-27 (view looking upstream)

(26)



RLC-27 (view looking downstream)

(27)



RLC-27 (view looking downstream)

(28)



RLC-27 (view looking downstream)

(29)



RLC-27 (upstream)

(30)



RLC-27 (view from upstream)

(31)



RLC-27 (view looking upstream)

(34)



RLC-27 (view from downstream)

(32)



RLC-27 (view from downstream)

(35)



RLC-27a (view looking upstream)

(33)



RLC-27 (view looking downstream)

(36)



RLC-27a (view from upstream)

(37)



RLC-27a (view from upstream)

(40)



RLC-27a (view looking downstream)

(38)



RLC-27a (view looking downstream)

(41)



AR-1 (view looking upstream)

(39)



RLC-27a (view looking downstream)

(42)



AR-1 (view looking upstream)

(43)



AR-1 (view looking upstream)

(46)



AR-1 (view looking downstream)

(44)



AR-1 (view from downstream)

(47)



AR-2 (view looking upstream)

(45)



AR-1 (view from downstream)

(48)



AR-2 (upstream)

(49)



AR-2 (view looking upstream)

(50)



AR-2 (view looking downstream)

(52)



AR-2 (view looking downstream)

(53)



AR-1 Upstream-2 (view looking upstream)

(51)



AR-2 (view from downstream)

(54)



AR-1 Upstream-2 (view looking downstream)

(55)



AR-1 Upstream-2 (view looking downstream)

(56)



AR-1 Upstream-3 (view looking upstream)

(57)



AR-1 Upstream-3 (view looking downstream)

(58)



AR-1 Upstream-3 (view looking downstream)

## APPENDIX II

### FIELD SHEET USED TO CHARACTERIZE FISH HABITAT



HABITAT DU POISSON

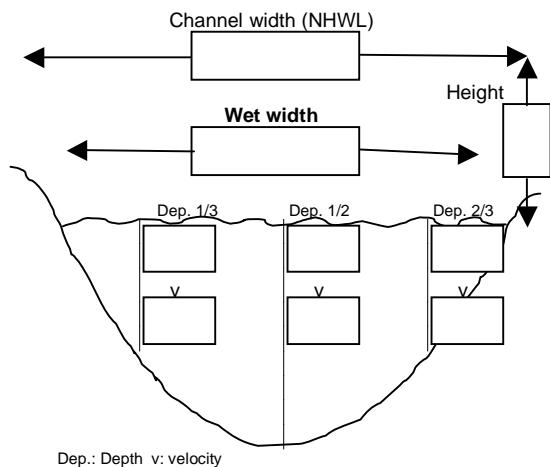
Project \_\_\_\_\_ Date \_\_\_\_\_  
Team \_\_\_\_\_ No \_\_\_\_\_

SECTION CHARACTERIZATION

Section # \_\_\_\_\_ Location \_\_\_\_\_  
GPS \_\_\_\_\_ Photo \_\_\_\_\_

Ditch  Stream  Permanent   
Stream  Intermittent

DESCRIPTION OF PHYSICAL COMPONENTS



SKETCH

Mean depth of stream \_\_\_\_\_ m  
Mean velocity of flow \_\_\_\_\_ m/s  
Flow \_\_\_\_\_ m<sup>3</sup>/s  
Inclination looking upstream \_\_\_\_\_ %

Substrate of stream bed

Texture	%
Rock	
Block	
Pebble	
Gravel	
Coarse sand	
Fine sand	
Silt	
Clay	
Organic matter	

Stoniness

gravel 2-20 mm  
pebble 2-20 cm  
block > 20 cm  
  
WATER QUALITY  
Temperature: \_\_\_\_\_  
pH: \_\_\_\_\_  
Conductivity: \_\_\_\_\_  
Turbidity: \_\_\_\_\_  
Colour: \_\_\_\_\_

Obstacle in vicinity

Use

Comments

Presence of fish: \_\_\_\_\_

DESCRIPTION OF PLANT COVER

Physiognomy

Coverage per layer

Disturbance?

Closed forest

Layer	%cover		Riparian		Overhang		Aquatic
	L	R	L	R	L	R	
A1 (25 cm >)							Emerged
A2 (16-25 cm)							
A3 (10-15 cm)							
B1 (1-10 m)							Floating
B2 (-1 m)							
C1 (+1 m)							
C2 (-1 cm)							
D							

Open forest

Treeland

Shrubland

Grassland

RIPARIAN WETLAND

Marsh

Swamp

Wet meadow

Peat bog

Type	Intensity			
	L	M	H	VH
Road maintenance				
Logging				
Ornamentation				
Clearing				
Urban planning				

Layer: A: arboreous; B: shrub; C: herbaceous D: moss



### APPENDIX III

#### TYPES OF STREAMS AND WATER QUALITY

**TYPES OF STREAMS AND WATER QUALITY**

Point #	Stream bed	Section type	Physical and chemical			
			Temp. (°C)	pH	Conductivity (µmhos/cm)	Turbidity (NTU)
RLC-1	no	-	-	-	-	-
RLC-2	no	-	-	-	-	-
RLC-3	no	-	-	-	-	-
RLC-3a	no	-	-	-	-	-
RLC-4	no	-	-	-	-	-
RLC-5	no	-	-	-	-	-
RLC-5a upstream	yes	pool	10.4	6.7	5	0.83
RLC-5a downstream	yes	channel with uniform bed	-	-	-	-
RLC-6	no	-	-	-	-	-
RLC-7	no	-	-	-	-	-
RLC-10	no	-	-	-	-	-
RLC-11 upstream	yes	rapid	-	-	-	-
RLC-11 downstream	yes	cascade	5.6	7.4	77	0.66
RLC-12	no	-	-	-	-	-
RLC-13	no	-	-	-	-	-
RLC-14	no	-	-	-	-	-
RLC-15	no	-	-	-	-	-
RLC-16	no	-	-	-	-	-
RLC-17	yes	-	-	-	-	-
RLC-18	no	-	-	-	-	-
RLC-19	no	-	-	-	-	-
RLC-20	no	-	-	-	-	-
RLC-21	no	-	-	-	-	-
RLC-22	no	-	-	-	-	-
RLC-23	no	-	-	-	-	-
RLC-24	no	-	-	-	-	-
RLC-25	no	-	-	-	-	-
RLC-26	yes	pool riffles	-	-	-	-
RLC-26 downstream	yes	pool riffles	9.6	7.4	152	-
RLC-27 upstream	yes	pool, cascade	-	-	-	-
RLC-27 Downstream-1	yes	rapid	-	-	-	-
RLC-27 Downstream-2	yes	rapid	8.3	8.1	144	3.60
RLC-27 Downstream-3	yes	cascade	-	-	-	-
RLC-27a	yes	cascade	8.3	8	122	4.78
RLC-27a downstream	yes	channel with uniform bed	-	-	-	-
AR-1 Upstream-3	yes	pool, waterfall, step pool	7.6	8	35	0.46
AR-1 Upstream-2	yes	pool, cascade	6.6	7.8	20	0.47
AR-1 Upstream-1	yes	pool	-	-	-	-
AR-1 downstream	yes	waterfall	7.7	7.3	35	0.80
AR-2 upstream	yes	channel with uniform bed	-	-	-	-
AR-2 downstream	yes	step pool, waterfall	6.4	6.5	8	1.00

## APPENDIX IV

### STREAM HYDROLOGY

## STREAM HYDROLOGY

Point #	Channel width (m)	Wet width (m)	Height (m)	Depth (m)			Velocity (m/s)		
				1/3	1/2	2/3	1/3	1/2	2/3
RLC-1	-	-	-	-	-	-	-	-	-
RLC-2	-	-	-	-	-	-	-	-	-
RLC-3	-	-	-	-	-	-	-	-	-
RLC-3a	-	-	-	-	-	-	-	-	-
RLC-4	-	-	-	-	-	-	-	-	-
RLC-5	-	-	-	-	-	-	-	-	-
RLC-5a upstream	-	1.10	0.80	0.10	0.11	0.11	0.18	0.03	0.00
RLC-5a downstream	10.15	4.50	0.80	0.03	0.03	0.03	0.01	0.01	0.01
RLC-6	-	-	-	-	-	-	-	-	-
RLC-7	-	-	-	-	-	-	-	-	-
RLC-10	-	-	-	-	-	-	-	-	-
RLC-11 upstream	10.00	1.60	1.40	0.13	0.03	0.04	0.59	0.13	0.40
RLC-11 downstream	4.20	1.00	1.20	0.09	0.06	0.08	0.88	0.68	0.02
RLC-12	-	-	-	-	-	-	-	-	-
RLC-13	-	-	-	-	-	-	-	-	-
RLC-14	-	-	-	-	-	-	-	-	-
RLC-15	-	-	-	-	-	-	-	-	-
RLC-16	-	-	-	-	-	-	-	-	-
RLC-17	-	-	-	-	-	-	-	-	-
RLC-18	-	-	-	-	-	-	-	-	-
RLC-19	-	-	-	-	-	-	-	-	-
RLC-20	-	-	-	-	-	-	-	-	-
RLC-21	-	-	-	-	-	-	-	-	-
RLC-22	-	-	-	-	-	-	-	-	-
RLC-23	-	-	-	-	-	-	-	-	-
RLC-24	-	-	-	-	-	-	-	-	-
RLC-25	-	-	-	-	-	-	-	-	-
RLC-26	7.00	6.00	0.30	0.75	0.90	0.95	0.34	0.40	0.15
RLC-26 downstream	25.00	7.00	0.60	0.36	0.55	0.30	0.54	0.55	0.54
RLC-27 upstream	15.00	7.00	0.70	0.14	0.24	0.07	0.95	1.00	1.20
RLC-27 Downstream-1	18.00	3.60	0.80	0.22	0.28	0.22	0.65	1.20	0.79
RLC-27 Downstream-2	30.00	5.70	0.50	0.35	0.36	0.35	0.28	0.76	0.50
RLC-27 Downstream-3	20.00	6.50	0.70	0.65	0.55	0.55	0.42	0.00	0.02
RLC-27a	10.00	4.00	1.40	0.30	0.88	0.41	0.14	0.21	0.12
RLC-27a downstream	6.00	3.80	1.40	0.19	0.27	0.21	0.13	0.67	0.18
AR-1 Upstream-3	15.00	4.10	0.70	0.42	0.43	0.40	0.61	0.57	0.58
AR-1 Upstream-2	5.00	0.38	0.25	0.21	0.18	0.18	0.49	0.99	1.09
AR-1 Upstream-1	10.00	6.10	0.40	0.50	0.45	0.47	0.18	0.32	0.27
AR-1 downstream	15.00	3.70	0.40	0.11	0.28	0.24	0.87	1.38	1.82
AR-2 upstream	-	-	-	-	-	-	-	-	-
AR-2 downstream	-	-	12.00	-	-	-	-	-	-

## APPENDIX V

### SUBSTRATE COMPOSITION

**SUBSTRATE COMPOSITION**

Point #	Composition of substrate (%)						
	Organic debris	Fine		Medium		Coarse	
		Fine	Sand	Gravel	Pebbles	Blocks	Rocks
RLC-1	-	-	-	-	-	-	-
RLC-2	-	-	-	-	-	-	-
RLC-3	-	-	-	-	-	-	-
RLC-3a	-	-	-	-	-	-	-
RLC-4	-	-	-	-	-	-	-
RLC-5	-	-	-	-	-	-	-
RLC-5a upstream	20	0	10	20	35	15	0
RLC-5a downstream	20	0	10	20	35	15	0
RLC-6	-	-	-	-	-	-	-
RLC-7	-	-	-	-	-	-	-
RLC-10	-	-	-	-	-	-	-
RLC-11 upstream	10	0	8	60	20	2	0
RLC-11 downstream	10	0	8	60	20	2	0
RLC-12	-	-	-	-	-	-	-
RLC-13	-	-	-	-	-	-	-
RLC-14	-	-	-	-	-	-	-
RLC-15	-	-	-	-	-	-	-
RLC-16	-	-	-	-	-	-	-
RLC-17	-	-	-	-	-	-	-
RLC-18	-	-	-	-	-	-	-
RLC-19	-	-	-	-	-	-	-
RLC-20	-	-	-	-	-	-	-
RLC-21	-	-	-	-	-	-	-
RLC-22	-	-	-	-	-	-	-
RLC-23	-	-	-	-	-	-	-
RLC-24	-	-	-	-	-	-	-
RLC-25	-	-	-	-	-	-	-
RLC-26	10	0	20	40	15	15	0
RLC-26 downstream	5	0	5	30	50	10	0
RLC-27 upstream	5	0	5	60	15	15	0
RLC-27 Downstream-1	10	0	30	25	30	5	0
RLC-27 Downstream-2	5	0	5	10	10	70	0
RLC-27 Downstream-3	5	0	15	50	15	15	0
RLC-27a	10	10	20	20	25	15	0
RLC-27a downstream	10	10	20	20	25	15	0
AR-1 Upstream-3	0	5	15	10	30	40	0
AR-1 Upstream-2	0	0	20	20	50	10	0
AR-1 Upstream-1	0	0	8	20	70	2	0
AR-1 downstream	0	0	5	5	10	80	0
AR-2 upstream	80	0	10	5	5	0	0
AR-2 downstream	60	0	30	5	5	0	0

## APPENDIX VI

### COMPOSITION OF PLANT COVER

COMPOSITION OF PLANT COVER

Section #	Plant cover (%)																			
	Arboreous				Shrub				Herbaceous				Moss				Aquatic vegetation			
	VR		SU		VR		SU		VR		SU		VR		SU		Emerg.	Floating	Submerg.	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R				
RLC-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-3a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-5a upstream	10	10	3	5	43	43	80	80	15	15	5	5	10	10	0	0	0	0	0	
RLC-5a downstream	10	10	3	3	4	43	80	80	15	15	5	5	10	10	0	0	-	-	-	
RLC-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-11 upstream	0	0	0	0	53	53	50	50	5	5	0	0	80	80	0	0	-	-	-	
RLC-11 downstream	0	0	1	0	55	58	53	53	5	5	0	0	80	80	0	0	0	0	0	
RLC-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
RLC-26 upstream	25	25	5	5	45	45	6	8	30	30	0	0	20	15	0	0	0	0	30	
RLC-27 downstream	15	2	2	0	18	40	10	20	20	30	5	5	10	10	0	0	0	0	10	
RLC-27 upstream	0	0	0	0	55	58	30	30	30	20	5	0	10	10	0	0	0	0	15	
RLC-27 Downstream-1	30	10	0	0	30	35	8	13	20	15	5	5	5	5	0	0	0	0	40	
RLC-27 Downstream-2	10	10	0	0	33	38	20	5	43	41	5	5	5	10	0	0	0	0	60	
RLC-27 Downstream-3	0	0	0	0	45	53	30	30	80	80	0	5	10	15	0	0	0	15	10	
RLC-27a	<5	<5	0	0	50	50	38	38	15	15	5	5	25	25	0	0	5	0	5	
RLC-27a downstream	0	0	0	0	55	55	38	35	15	15	5	5	30	30	0	0	5	0	5	
AR-1 Upstream-3	2	2	0	0	43	43	30	30	20	20	5	5	5	5	0	0	0	0	50(algae)	
AR-1 Upstream-2	5	5	0	0	55	55	40	40	10	10	0	0	0	0	0	0	0	0	0	
AR-1 Upstream-1	15	13	45	35	20	15	5	5	2	2	0	0	0	0	0	0	0	0	30	
AR-1 downstream	10	<5	0	0	43	45	8	13	30	60	5	5	5	5	0	0	0	0	80	
AR-2 upstream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	
AR-2 downstream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	

VR: riparian vegetation

SU: overhanging vegetation

APPENDIX VII

JUNE 2008 CULVERT STUDY

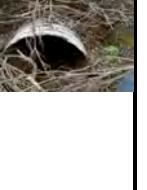
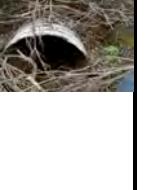
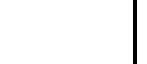


**NEW MILLENNIUM CAPITAL CORP.**

**DSO PROJECT**

Study of all culverts 2008

Study by Roy Logan

DATE	CULVERT NO.	UTM-NORTH	UTM-EAST	DIAMETER	LENGTH	DESCRIPTION	PHOTO (NE/E)	PHOTO (SW/W)
18-June-08	RLC-1	6071815	640561	24"	60'	Culvert in very good condition		
18-June-08	RLC-2	633350	6077819	20"	60'	Culvert in good condition		
18-June-08	RLC-3	632500	6078313	24"	unknown	NE end of culvert in good, condition, SW end hidden		
18-June-08	RLC-4	631462	6078322	24"	55'	NE end dented, otherwise in good condition, SW end partly filled		
18-June-08	RLC-5	631282	6078455	20"	25'	Culvert removed		
18-June-08	RLC-6	629963	6079047	24"	60'	Culvert in very good condition		
18-June-08	RLC-7	629770	6079242	20"	30'	NE and SW ends damaged Partly filled in.		
18-June-08	RLC-8	629089	6080105	24"	50'	Culvert in good condition, stable flow		
18-June-08	RLC-9	628980	6080306	45"	75'	E end in good condition, W end is separated, but in good condition		
18-June-08	RLC-10	628479	6080346	18"	60'	Culvert in good condition		
18-June-08	RLC-11	628380	6080447	40"	50'	Culvert in good condition Stable flow		
18-June-08	RLC-12	627665	6081283	60"	65'	NE end in good condition, SW end separated, section filled in, but flow present		
18-June-08	RLC-13	627870	6081722	20"	60'	Culvert in very good condition		

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DATE	CULVERT NO.	UTM-NORTH	UTM-EAST	DIAMETER	LENGTH	DESCRIPTION	PHOTO (NE/E)	PHOTO (SW/W)
18-June-08	RLC-14	627639	6082071	24"	55'	E end dented, but culvert in good condition		
18-June-08	RLC-15	627460	6082304	24"	60'	Culvert in very good condition		
18-June-08	RLC-16	626762	6082679	24"	65'	Culvert in very good condition		
18-June-08	RLC-17	626170	6083359	24"	60'	E end very dented, W end in good condition		
18-June-08	RLC-18	626076	6083615	24"	50'	Culvert in good condition, erosion caused by water Culvert perhaps not adequate		
18-June-08	RLC-19	626016	6083777	24"	60'	Culvert in very good condition		
18-June-08	RLC-20	625310	6084530	24"	40'	E end in good condition, W end crushed and partly buried		
18-June-08	RLC-21	625114	6084481	24"	30'	N end dented, S end is in good condition		
18-June-08	RLC-22	624517	6084520	20"	50'	N end in good condition, S end in good condition, but a little filled		
18-June-08	RLC-23	623305	6083983	40"	40'	Culvert in very good condition		
18-June-08	RLC-24	623778	6084174	40"	60'	Culvert in poor condition at both ends		
18-June-08	RLC-25	623565	6083872	40"	60'	N end dented, S end in good condition, but a little filled		
19-June-08	RLC-26	641472	6070913	10'	50'	Culvert in good condition, stable flow		
19-June-08	RLC-27	639753	6072554	10'	60'	Culvert in good condition, stable flow		

## APPENDIX VIII

### DESCRIPTION OF CHANNEL PATTERNS USED TO CHARACTERIZE THE STREAMS



## DESCRIPTION OF CHANNEL PATTERNS USED TO CHARACTERIZE THE STREAMS

Channel patterns	Description
Pool	Long, deep zone of a stream frequently located downstream from an obstacle and corresponding to a widening of the stream.
Cascade	Zone of a stream with a steep slope and very steep, irregular banks, in which boulders and rocks dominate. This type of obstacle is usually passable.
Channel with uniform bed	Zone of a stream with medium slope where the flow varies from slow to moderate, the water surface remains smooth. Particle size is average (gravel, pebbles).
Waterfall	Zone of a stream where there is a sharp drop. This segment is usually characterized by large boulders or trees. This type of segment is frequently impassable for fish.
Step-pool	Zone of a stream characterized by pools (low-flow, deep zones) followed by a step created by an obstacle (rock or tree). Flow determined by major elements of bed roughness. Medium slope and flow speed varying from weak to medium.
Rapids	Zone of a stream with a slope > 4%. The flow speed and turbulence are very strong. Particle size is coarse and water is shallow.
Pool riffles	Zone of a stream characterized a sequence of pools and riffles. The flow is usually moderate and the slope low to medium. Particle size is medium.

Source : Adapted from Montgomery and Buffington (1997) and Malavoi (1989)