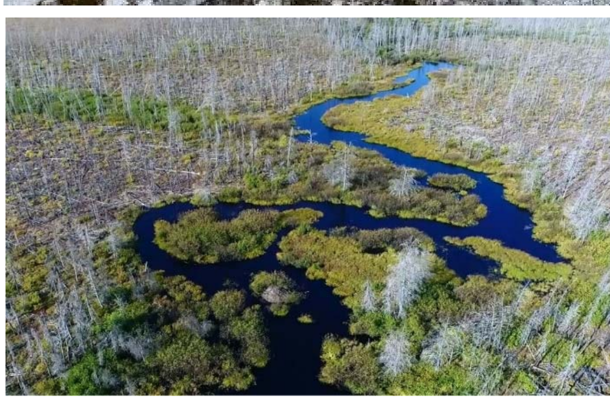
GALAXY

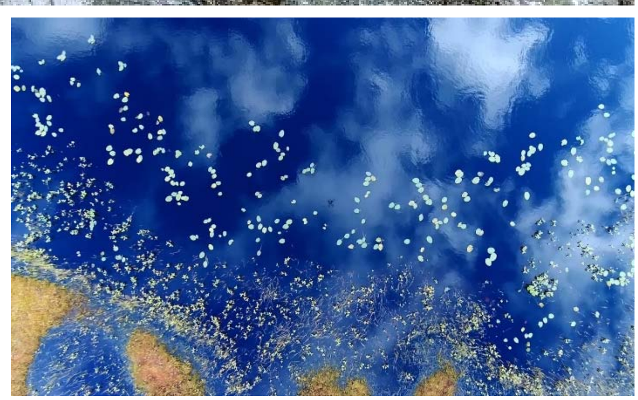
JAMES BAY LITHIUM MINE

ENVIRONMENTAL IMPACT ASSESSMENT

CHAPTER 3: PROJECT ALTERNATIVES

JULY 2021 (VERSION 2)





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3 PROJECT ALTERNATIVES

To meet the requirements of provincial and federal guidelines, GLCI analyzed alternatives for specific components of its project.

First, some general criteria were established from the outset, thereby influencing the location of infrastructure. It was then determined that all the project's components would be located west of the Billy-Diamond highway, to avoid any interference with these infrastructures, mainly for safety and traffic reasons. This choice also made it possible to minimize the travel distances on site and the scope of transport infrastructure to be built. In addition, since the site is primarily comprised of wetlands, the effort was focused on reducing the overall footprint of the project rather than on the positioning of each of its components. Lastly, safety distances **related to blasting** were also to be considered around the pit, namely, a 200-m radius of total exclusion (no construction) and a 500-m radius of partial exclusion (restricted construction zone).

Therefore, considering the nature and location of the deposit and in the light of the general criteria set out above, **the following aspects were excluded from the alternative study**:

- **Mining and material extraction method:** Exploitation of the resource partially or completely underground has not been assessed since the project targets spodumene pegmatite on the surface. In addition, for **technical and economic** reasons, open-pit mining is the method typically preferred for mining this material.
- **Concentrator location for processing: In 2018,** this component **was** positioned in the only **available** sector located near the pit. The few small areas without a wetland were favoured for geotechnical considerations. In fact, the bearing capacity of the soil at this location was confirmed as adequate for receiving production equipment, without major excavation of existing soil. **In the current project (2021), the concentrator was moved adjacent to Billy-Diamond highway in an area where geotechnical work confirmed the soil's good bearing capacity. This change made it possible to reduce the amount of peat and materials (silt) to be excavated before beginning construction, to eliminate the access road, to shorten the transport distances for ore to the plant as well as for waste rock to the stockpiles, thereby reducing GHG emissions associated with mine operation activities. These changes also made it possible to reduce the surface areas affected. Relocating the concentrator enabled stockpiles to be repositioned near the pit, reducing the transport distances for waste rock to the stockpiles.**
- **Workers' camp site: In 2018 as in 2021,** the **workers'** camp was positioned near the main infrastructure, including the concentrator and the pit, to minimize the transport of workers. In fact, the camp is within walking distance of buildings, which will help to reduce the fleet of vehicles **and thereby reduce the risks of mechanical breakdowns with environmental impacts (e.g., oil leak) as well as** the GHG emissions associated with them.
- **Road alignment:** The site selected **in 2018** for the concentrator **was 750 m** from Billy-Diamond highway and outside the exclusion radius of the pit. **Therefore, a 750-m access road had to be built in the peatland, the other** needs being limited to site access and various roads connecting the infrastructures (pit, concentrator, waste rock and overburden stockpiles, water treatment plant, dike and explosives warehouse) for a total of just over 8 km of roads to build. **Unlike 2018, the construction of an access road is not necessary in the current project (2021), and needs are still limited to access to the site and to various infrastructures. The roads to be built are shorter compared to 2018, as distances between infrastructures have been reduced. Two-lane roads are still planned. The principles from 2018 will still be followed, namely: prioritizing the shortest route with a few curves to follow the topography, limit speed and improve driving safety; distancing roads from watercourses by at least 60 m, as stipulated in the *Regulation respecting standards of forest management for forests in the domain of the State*.**

— **Water supply:** Since the project site is located in an isolated environment, there are only two viable options for the site's water supply: developing a well (or wells) or transporting water to the site. For economic and environmental reasons, the decision was made to develop water supply wells. **According to the hydrogeological characteristics of the area, the aquifer identified as exploitable would be the bedrock aquifer. Based on the studies conducted, the rock permeability varies depending on its nature and degree of fracturing. A water search will help target areas suitable for potable water exploitation and development of open wells in bedrock. Their diameter is to be determined, but will most likely vary between 6 and 8 in, with a depth of 30 to 100 m. It will be possible to withdraw the water volume required for the workers' camp thanks to a submersible pump installed in the well. The number of wells to be developed will depend on the aquifer capacity at the boreholes. At the moment, two wells are proposed. They should be located near the administrative and industrial area.**

Furthermore, the components for an assessment of the technological alternatives or location has been carried out as follows:

— waste rock, tailings and overburden stockpiles (location);
— domestic wastewater treatment (technology);
— mine water management and final effluent discharge points (location).

The alternative analysis conducted as part of the 2018 ESIA for these components is presented in the following sections. The alternative analyse was not redone but the changes related to project optimization are described in detail for each project component included in the analysis.

Finally, an assessment of possible energy sources was conducted for the mine site (process and buildings) and the mobile equipment. **Changes related to the 2021 project are presented, when applicable. It should be noted that as alternative options become available, GLCI will continually evaluate them in an effort to maximize new and innovative mining practices on site, reduce emissions and continually strive toward sustainable mining.**

3.1 WASTE ROCK, TAILINGS AND OVERBURDEN STOCKPILES

The first step in this alternative analysis consists of preselecting the possible deposition methods. Afterwards, the techniques selected undergo a comparative analysis based on different locations.

3.1.1 DEPOSITION METHODS

ALTERNATIVE ANALYSIS (2018)

The alternative analysis conducted in 2018 considered the following deposition techniques at a high level:

— the deposit as a mixture (process tailings with waste rock);
— the use of the pit as a deposit place;
— the hydraulic deposit of tailings (in sludge form) as well as a separation of coarse and fine tailings;
— the production of **filtered** tailings that can be stacked;
— the production of thickened tailings.

The quantities considered for the assessment were 233.4 Mt of waste rock and 36.4 Mt of tailings[1]. Since the data concerning the density for these materials were not available at the time of the study, assumptions were made, namely, 2.4 t/m^3 for waste rock and 1.7 t/m^3 for tailings, giving them volumes of 100 Mm^3 and 20 Mm^3 respectively. In addition, considering the acid generation potential identified in the preliminary results of the geochemical technical assessment, it was assumed that protection would be installed to prevent leakage to the environment whether it be a stockpile or a retention basin.

1 Based on data available on January 5, 2018. **The discrepancy between the quantities considered for the waste rock deposition method assessment and the geochemical study is due to the availability of data at the time the reports were written. The 233.4 Mt of waste rock refers to a storage capacity that was used in the design of the stockpile in January 2018. Finally, the May 2018 mine plan indicates a total of 133.3 Mt of waste rock (including 5.9 Mt of overburden) that would accumulate in the waste rock stockpile.**

The values used for the design of stockpiles were:

WASTE ROCKS

- **In situ rock density= 2.77 t/m³**
- **Particle size= 0-700 mm**
- **Void ratio= 35%**
- **Apparent density= 2.05 t/m³**

TAILINGS

- **In situ rock density= 2,77 t/m³**
- **Particle size= 0-15 mm**
- **Void ratio= 65%**
- **Apparent density= 1.68 t/m³**

The hydraulic deposit was rejected from the outset due to limited space on the site and to the absence of favourable topographic features. Moreover, this option would increase the environmental risks because of the sludge lagoons, in addition to increasing the footprint.

The thickened tailings option was not selected in the analysis because the reduction in water content does not provide any technical or economic benefit nor does it contribute to reducing the environmental risk associated with deposits of tailings. In fact, given the particle size distribution of tailings, their water content is low.

Finally, considering the lack of information available on the economic viability of extracting the resources that will be left in the deposit once the operation phase is completed, the deposit-in-the-pit option was not assessed.

Therefore, the remaining management options all involve a stack of dried tailings, either as a mixed deposit (co-disposal) or by arranging a separate deposit for the tailings (co-mingling) in the same stockpile. At this stage, the deposit techniques are considered equivalent for the purposes of the analysis, the co-disposal presenting minor differences with the co-mingling regarding the areas and volumes required.

PROJECT OPTIMIZATION (2021)

Further to the project optimization exercise, a decision was made to pile waste rock and filtered tailings in four co-deposition piles. The advantages of co-deposition include:

- **improves physical stability of the stockpile slope in waste rock embankment zones;**
- **accelerated consolidation and better shear strength of tailings;**
- **reduced risk of embankment failure and loss of containment of tailings;**
- **less dust creation and erosion of tailings;**
- **improved opportunities for progressive closure.**

Disposing of tailings and waste rock in depleted areas of the pit was also considered has been selected as part of the new design. Additionally, following kinetic testing of the waste rock and tailings by WSP between 2018 and 2020, which showed to be not potentially acid-generating, it was determined that no protection from leakage into the environment would be required. Details are presented in Chapter 4.

3.1.2 LOCATION OF WASTE ROCK AND TAILINGS STOCKPILES

ALTERNATIVE ANALYSIS (2018)

In total, four scenarios were selected for comparative analysis **completed in 2018**. For calculation purposes, a slope of 2.5H:1V was selected for the waste rock stockpile and mixed material stockpile, while a slope of 5H:1V is applied to the tailings stockpile. Note that no bed or access ramp was considered in the calculations at this stage.

The Pugh decision matrix was selected as a decision support tool. Multi-criteria analysis was conducted to determine the best option for locating stockpile from an environmental, technical, economic and socioeconomic point of view. Criteria were then developed for each of these categories, with the aim of differentiating the options between them. The criteria were measured using quantitative or qualitative indicators. A weight[2] has been assigned to each of them based on its relative importance within the same category. The categories themselves are also weighted, with the environment considered the most important. Option 1 is defined as the reference scenario with a score of zero for each of the indicators, except for those that were clearly favourable or unfavourable for this scenario from the start. The other three options receive scores of -2 (worse), 0 (neutral) or +2 (best) compared to option 1.

The four options are summarized below and the technical details for each of them are provided on Table 3-1. Their location is shown on Map 3-1.

Table 3-1 Details of assessed stockpile options

Parameter	Option 1	Option 2	Option 3	Option 4	
				North	South
Stockpile capacity (Mm^3)	120	77.5	120	20	100
Stockpile elevation (m)	300	330	280	255	290
Stockpile height (m)	94	128	68	53	84
Retention basin capacity (Mm^3)	1.05	0.43	1.65	0.24	1.05
Required WTP capacity (estimate) (m^3/s)	0.3	0.3	0.06	0.45	

Option 1

The first option is tailings and waste rock deposit in the form of a mixture. The stockpile is located south of the pit, near the Billy-Diamond highway and the truck stop. Two peripheral ditches collect the water, and an auxiliary pumping station is needed to transport them to the retention basin.

Option 2

Option 2 is tailings and waste rock deposit as a mixture. The stockpile is located on the north side of the pit. The two bodies of water and the mining property line are constraints that reduce the capacity of the stockpile. A peripheral ditch collects water flowing by gravity toward the retention basin.

Option 3

Option 3 is also tailings and rock waste deposit as a mixture. The stockpile is located on the west side of the pit. The stockpile extends outside the property line and encompasses a body of water. For this reason, creek CE3 and the Asini Kasachipet Lake must be dry. No peripheral ditches are required, and the water is directed toward the gravity retention basin.

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2 The weighting factors can vary depending on what is being analyzed (herein the location of stockpiles and the domestic wastewater treatment system). The reason for this is that the cost (economic value), technical feasibility and environmental consequences differ from one infrastructure to another. For example, the estimated budget can be more restrictive or the scope of impacts on the environment more significant for a given infrastructure compared to another.

A weighting grid was used to establish the weighting. The importance of the criteria, or categories of criteria, was determined based on the project description (including deadlines which depend on the technical feasibility and are associated with the environmental process) and characteristics of the receiving environment. The assessment of alternative analysis is an exercise that took place during the pre-project period, completed by a group of experienced professionals who have a good understanding of the components of the project and who have in-depth expertise of alternative analysis for mining projects in northern environments in Quebec and in impact assessment. The weighting attributed to each of the indicators within a given group were arbitrarily assigned by the project team. The weightings assigned to various criteria were selected and agreed upon by the technical experts involved in the alternative analysis and by GLCI representatives.

Option 4

The last option involves the development of two separate stockpiles for tailings and waste rock. The waste rock stockpile is located to the south of the pit, near the Billy-Diamond highway and the truck stop. The tailings stockpiles can be found on the north side of the pit. Each of the stockpiles requires two peripheral ditches. First, a pumping station steers the water from the ditches of the northern stockpile toward its retention basin, then a second pumping station transfers the water from the northern basin to the southern basin.

Table 3-2 presents the alternative assessment summary, Table 3-3**a** presents the decision matrix by count **and Table 3-3b presents the justification for the weight given to the indicators**. The highest score was assigned to Option 2 with 746 points. This option also offers the best performance from an environmental and socioeconomic point of view. Option 4 was the best in technical terms while Option 1 was the most economical.

Table 3-2 Summary score of the assessment of site alternatives for waste rock and tailings stockpiles

Score	Option 1	Option 2	Option 3	Option 4
Environment	0	110	-90	-60
Technical	0	-65	-40	25
Economic	0	-3	-82	-102
Socioeconomic	-65	190	160	65
Total before weighting	-65	232	-52	-72
Total weighted	**-130**	**746**	**-326**	**-391**

Note: The weighting factors are: environment = 4, technical = 1, economic = 3, socioeconomic = 2.

- **A factor of 4 was given to the environment score due to the potential impacts related to the location of stockpiles. The environment score is the most important of the scores considered.**
- **A factor of 1 was given to the technical score, as there is little difference between the location options. The technical score is the least important of the scores considered.**
- **A factor of 3 was given to the economic score, given the financial impact that each location option may have.**
- **A factor of 2 was given to the socioeconomic score as there are there are only slight variations between options.**

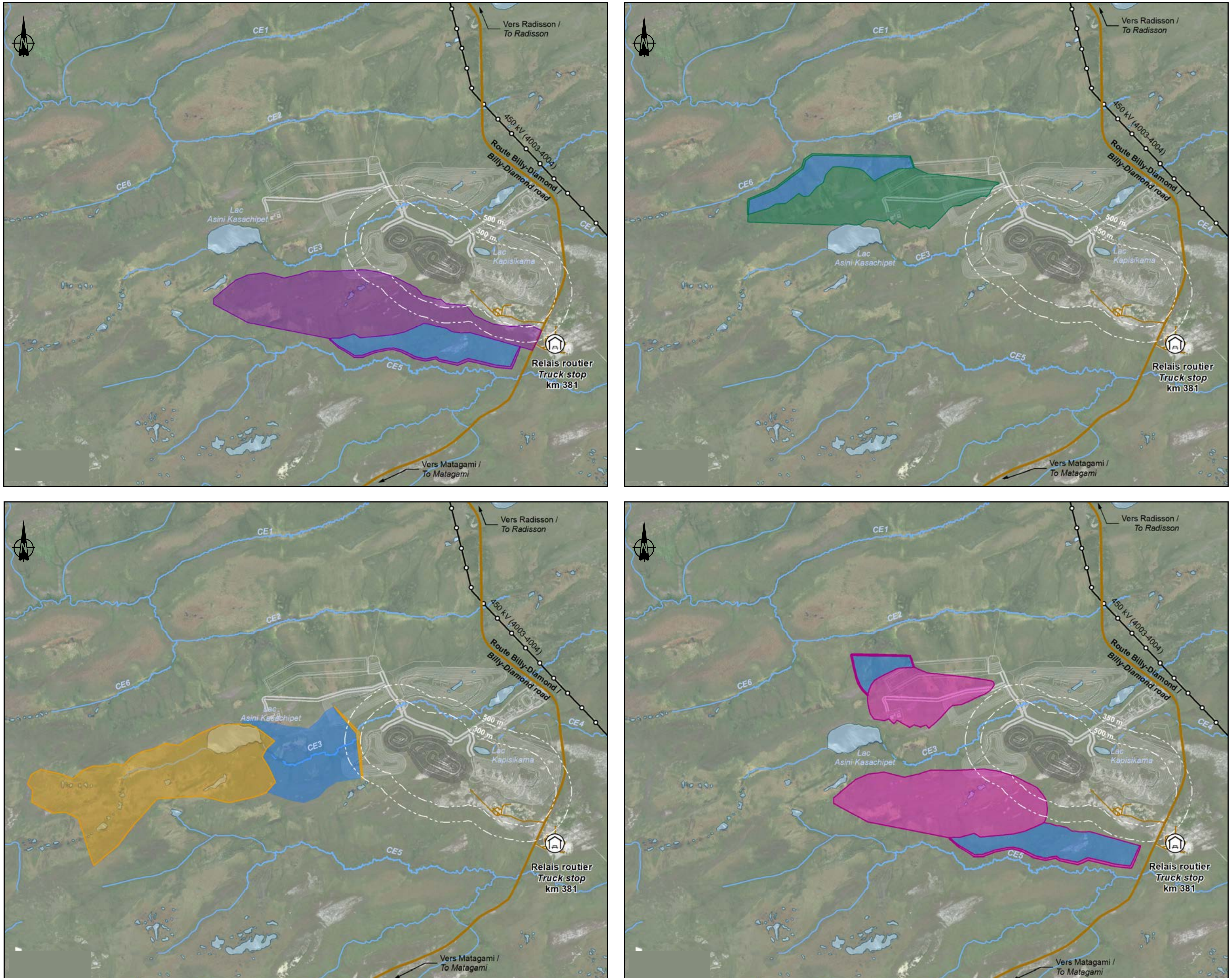
Since the environmental component is the most important category of the assessment, the criteria for wildlife and aquatic habitat put Option 3 at a significant disadvantage, as it requires the destruction of fish habitat. In addition, a permit is required for this option, which leads to delays in the project schedule.

The economic component is also important, especially the indicators with the most weight, the installation of waterproof membranes and closure. These two indicators are unfavourable for Options 3 and 4.

Considering the above, Options 3 and 4 are considered the worst and are abandoned at this stage.

Option 2 is more beneficial than Option 1 from an environmental and socioeconomic point of view. In fact, Option 1 is at a disadvantage because it affects creek CE2 downstream from the stockpile. In addition, certain socioeconomic indicators (atmospheric emissions, noise, traditional way of life and landscape) are unfavourable to Option 1 since the stockpile is located near the truck stop and creek CE5, in addition to presenting the highest final elevation.

At the time of preparation of the project description, the location of the stockpile was to the south of the pit (Option 1). During consultations with the Cree of Eastmain, the tallyman of trapline RE2 indicated that, among the watercourses in the study area, creek CE5 was the one his family valued. The concerns of this stakeholder, in addition to the results of the assessment, led to the selection of Option 2, despite its lack of required capacity (78 vs. 120 Mm^3). Option 2 was considered the best and was recommended. Optimization of the design of the stockpile at the engineering stage has made up for the shortfall in volume. **To increase capacity, the surface area of the waste rock stockpile was increased. Specifically, the western section of the basin was eliminated, and the stockpile was extended to the property's northern boundary. This also made it possible to standardize the stockpile's elevation at 300 m.**



Variantes des haldes / *Stockpile Alternative*

- Option 1 / *Option 1*
- Option 2 / *Option 2*
- Option 3 / *Option 3*
- Option 4 / *Option 4*
- Bassin de rétention / *Retention basin*

Composantes du projet (2021) / *Project Component (2021)*

- Fosse / *Pit*
- Infrastructures minières / *Mining infrastructure*
- Zone tampon / *Buffer zone*

Infrastructures / *Infrastructure*

- Route principale / *Main road*
- Route d'accès / *Access road*
- Ligne de transport d'énergie / *Transmission line*
- Relais routier / *Truck stop*

Hydrographie / *Hydrography*

- CE3 Numéro de cours d'eau / *Stream number*
- Cours d'eau permanent / *Permanent stream*
- Cours d'eau à écoulement diffus ou intermittent / *Intermittent or diffused flow stream*
- Plan d'eau / *Waterbody*

GALAXY

Mine de lithium Baie-James / James Bay Lithium Mine

Carte / *Map* 3-1
Options d'emplacement de la halde à stériles /
Waste Rock Stockpile Location Options

Sources :
Orthoimage : Galaxy août / august 2017
Données du projet / Project data : Galaxy 2020

0 500 1 000 m
UTM, fuseau 18, NAD83

Juillet / *July* 2021

Dessin : A. Masson
Approbation : C. Martineau
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Table 3-3a Multi-criteria analysis for the location of tailings stockpiles[1]

Criteria	Indicator	Weight[2]	Option 1			Option 2			Option 3			Option 4		
			South stockpile (reference scenario)			North stockpile			West stockpile			2 separate stockpiles		
			Score[3]	Weighted result	Justification[4]	Score	Weighted result	Justification	Score	Weighted result	Justification	Score	Weighted result	Justification
1 Environmental elements														
1.1: Hydrology	Number of affected drainage basins	10	0	0	2 drainage basins	2	20	1 drainage basin	2	20	1 drainage basin	-2	-20	3 drainage basins
1.2: Total ground footprint	Area	10	0	0	3,075,000 m^2	0	0	3,097,745 m^2	-1	-10	3,624,000 m^2	-1	-10	3,822,500 m^2
1.3: Fauna and aquatic habitats	Habitat destruction. Impact of the hydrologic budget on watercourses and fish popula-tions.	50	0	0	No habitat destruction. Moderate impact of the hydrologic budget on CE5. Negligible impact of the hydrologic budget on CE3. CE5 is home to the largest fish population of all of the five watercourses inventoried.	2	100	No habitat destruction. Low impact of the hydrologic budget on CE2.	-2	-100	Habitat destruction: 188,500 m^2 of lake habitat and 2,830 m of watercourses. Strong impact of the hydrologic budget on CE3.	0	0	Effluent in CE5. No habitat destruction. Low to moderate impact of the hydrologic budget on CE5. Very low impact of the hydrologic budget on CE2. Negligible impact of the hydrologic budget on CE3. CE5 is home to the largest fish population of all of the five watercourses inventoried.
1.4: Fauna and terrestrial habitats	Wetlands area	20	0	0	3,003,000 m^2	0	0	3,023,960 m^2	0	0	3,406,400 m^2	-1	-20	3,673,500 m^2
1.5: Threatened or vulnerable species	Presence or absence of threatened or vulnerable species	10	0	0	No plant species, mammals, birds, reptiles or fish with a special status.	-1	-10	Presence of a plant likely to be designated threatened or vulnerable. No mammals, birds, reptiles or fish with a special status.	0	0	No plant species, mammals, birds, reptiles or fish with a special status.	-1	-10	Presence of a plant likely to be designated threatened or vulnerable. No mammals, birds, reptiles or fish with a special status.
Subtotal		**100**		**0**			**110**			**-90**			**-60**	

Score: -2 = worst, 0 = neutral, 2 = best.

Table 3-3a Multi-criteria analysis for the location of tailings stockpiles (cont.)[1]

			Option 1			Option 2			Option 3			Option 4		
			South stockpile (reference scenario)			North stockpile			West stockpile			2 separate stockpiles		
Criteria	Indicator	Weight[2]	Score[3]	Weighted result	Justification[4]	Score	Weighted result	Justification	Score	Weighted result	Justification	Score	Weighted result	Justification
2	**Technical elements**													
2.1: Stability of the works	Maximum stockpile height	5	0	0	94 m	-2	-10	128 m	2	10	69 m	1	5	53 m (North) and 84 m (South)
2.2: Simplicity of design and construc-tion	Length and height of the levees	5	0	0	h = 6.5 m l = 2.5 km	0	0	h = 5.5 m l = 2.7 km	2	10	h = 6.9 m 1.0 km	-2	-10	h = 6 m l = 5.2 km
2.3: Water manage-ment system design	Number of facilities and their capacity	10	0	0	1 pumping station 1 WTP Capacity: 0.3 m^3/s	1	10	0 pumping stations 1 WTP Capacity: 0.3 m^3/s	2	20	0 pumping stations 1 WTP Capacity: 0.06 m^3/s	-2	-20	2 pumping stations 1 WTP Capacity: 0.3 + 0.15 m^3/s
2.4: Access roads and hauling roads design	Qualitative assessment (maximum slope, number of water-course crossings)	5	0	0	One watercourse crossing (from the plant to the stockpile), slope of 10%, 90 m of vertical relief	-1	-5	One watercourse crossing (from the plant to the stockpile), slope of 10%, 120 m of vertical relief	0	0	One watercourse crossing (from the plant to the stockpile), slope of 10%, 65 m of vertical relief	-1	-5	One watercourse crossing (from the plant to the stockpile), slope of 10%, 80 m of vertical relief
2.5: Stockpiles design	Stockpile capacity	30	0	0	120 Mm^3	-2	-60	78 Mm^3	0	0	120 Mm^3	2	60	120 Mm^3 + available capacity
2.6: Ease of stockpile develop-ment	Qualitative assessment	10	0	0	Access: easy, near the James Bay road. Proximity of physical barriers: One section near a watercourse, not contiguous to the property lines. Surface: plan with a slight slope, one section near a watercourse.	-1	-10	Access: surrounded by wetlands, far from any road. Proximity of physical barriers: contour of the stockpile half on the property line or near a watercourse. Surface: slight slope.	-2	-20	Access: surrounded by wetlands, far from any road, watercourse crossing. Proximity of physical barriers: acquisition of land required and encroachment on a lake and watercourse. Surface: slight slope, inside a valley.	-1	-10	Access: surrounded by wetlands, far from any road. Proximity of physical barriers: sections of the contour of the stockpile half on the property line or near a watercourse. Surface: slight slope.
2.7: Land ownership and permits	Qualitative assessment	30	0	0	Inside the property lines, no fish habitat compensation required.	0	0	Inside the property lines, no fish habitat compensation required.	-2	-60	Land acquisition and fish habitat compensation (lakes and watercourses) required.	0	0	Inside the property lines, no fish habitat compensation required.
2.8: Blasting risk manage-ment	Presence of infrastructu re inside the exclusion zones.	5	0	0	Stockpile partially inside the restricted construction zone.	2	10	Stockpile outside the restricted construction zone.	0	0	Retention basins and levees inside the restricted construction zone.	1	5	One of the two stockpiles partially inside the restricted construction zone.
Subtotal		**100**		**0**			**-65**			**-40**			**25**	
Score: -2 = worst, 0 = neutral, 2 = best.														

Table 3-3a Multi-criteria analysis for the location of tailings stockpiles (cont.)[1]

Criteria	Indicator	Weight[2]	Option 1: South stockpile (reference scenario) – Score[3]	Option 1 – Weighted result	Option 1 – Justification[4]	Option 2: North stockpile – Score	Option 2 – Weighted result	Option 2 – Justification	Option 3: West stockpile – Score	Option 3 – Weighted result	Option 3 – Justification	Option 4: 2 separate stockpiles – Score	Option 4 – Weighted result	Option 4 – Justification
3 Economic elements														
3.1 Capital expenditures (CAPEX)														
3.1.1: Surrounding ditches	Length of ditches	3	0	0	4,150 m ($3.5M)	1	3	1,150 m ($1M)	2	6	None	-1	-3	5,700 m ($4.8M)
3.1.2: Surrounding levees	Volume of levees	4	0	0	205,000 m^3 ($4.7M)	1	4	116,000 m^3 ($2.7M)	2	8	65,000 m^3 ($1.5M)	-2	-8	290,000 m^3 ($6.7M)
3.1.3: Protection for the stockpiles and basins	Total area to seal/keep dry	50	0	0	3,075,000 m^2 ($67M)	0	0	3,097,745 m^2 ($68M)	-1	-50	3,624,000 m^2 ($80M)	-1	-50	3,822,500 m^2 ($84M)
3.1.4: Water treatment	WTP capacity	2	0	0	0.30 m^3/s ($2M)	0	0	0.30 m^3/s ($2M)	2	4	0.06 m^3/s ($400K)	-2	-4	0.45 m^3/s ($3M)
3.1.5: Water management														
3.1.5.1: Pumping stations	Number of auxiliary pumping stations	1	0	0	One pumping station to steer the ditch water to the retention basin ($100,000).	2	2	No auxiliary pumping station required.	2	2	No auxiliary pumping station required.	-2	-2	Two auxiliary pumping stations required ($200,000): • one from the North stockpile ditches to its retention basin; • one to transfer the water from the North stockpile to the South stockpile facilities.
3.1.5.2: Pipes	Pumping distance	1	0	0	3,345 m from the WTP to the plant and 1,055 m between the ditches	2	2	1,745 m from the WTP to the plant	2	2	1,165 m from the WTP to the plant	-1	-1	5,090 m from the WTP to the plant and 1,055 m between the ditches
3.1.6: Fish habitat compensation and land acquisition	Qualitative assessment	1	0	0	No compensation required. No acquisition required.	0	0	No compensation required. No acquisition required.	-2	-2	Fish habitat compensation required. Land acquisition required.	0	0	No compensation required. No acquisition required.
3.1.7: Closing costs	Area to restore	24	0	0	3,075,000 m^2 ($37M)	0	0	3,097,745 m^2 ($37M)	-1	-24	3,624,000 m^2 ($43.5M)	-2	-48	3,822,500 m^2 ($46M)
3.2 Operating expenses (OPEX)														
3.2.1: Transportation of waste rock	Distance from the pit to the stockpiles	7	0	0	3.1 km from pit to stockpile	-1	-7	4.0 km from pit to stockpile	-2	-14	5.3 km from pit to stockpile	0	0	3.1 km from pit to tailings stockpile
3.2.2: Transportation of tailings	Distance from the plant to the stockpiles	7	0	0	2.7 km from the plant to the stockpile	-1	-7	3.4 km from the plant to the stockpile	-2	-14	4.5 km from the plant to the stockpile	2	14	1.9 km from the plant to the tailings stockpile
Subtotal		**100**		**0**			**-3**			**-82**			**-102**	
Score: -2 = worst, 0 = neutral, 2 = best.														

Table 3-3a Multi-criteria analysis for the location of tailings stockpiles (cont.)[1]

			Option 1			Option 2			Option 3			Option 4		
			South stockpile (reference scenario)			North stockpile			West stockpile			2 separate stockpiles		
Criteria	Indicator	Weight[2]	Score[3]	Weighted result	Justification[4]	Score	Weighted result	Justification	Score	Weighted result	Justification	Score	Weighted result	Justification
4 Socioeconomic elements														
4.1: Atmos-pheric emissions	Qualitative assessment at the truck stop	40	-1	-40	Majority of the hauling carried out near the km 381 truck stop	2	80	Majority of the hauling carried out far from the km 381 truck stop	2	80	Majority of the hauling carried out far from the truck stop	1	40	Part of the hauling carried out near the truck stop
4.2: Noise nuisance	Qualitative assessment at the truck stop	25	-1	-25	Majority of the hauling carried out near the km 381 truck stop	2	50	Majority of the hauling carried out far from the km 381 truck stop	2	50	Majority of the hauling carried out far from the truck stop	1	25	Part of the hauling carried out near the truck stop
4.3: Upholding of the traditional lifestyle	Qualitative assessment of loss of hunting, fishing or gathering zones, as well as loss of access.	20	0	0	Pond for active goose hunting and beaver tapping downstream on creek CE5.	2	40	No traditional activity identified in the surrounding area.	2	40	No traditional activity identified in the surrounding area.	0	0	Pond for active goose hunting and beaver tapping downstream on creek CE5.
4.4: Landscape	Qualitative assessment of the perspec-tive and relief, compared with the existing topogra-phy.	10	0	0	Maximum elevation of the stockpile: 300 m	2	20	Maximum elevation of the stockpile: 330 m	0	0	Preliminary result, directly proportional to the maximum elevation of the stockpile: 280 m	0	0	Preliminary result, directly proportional to the maximum elevation of the stockpile: 290 m
4.5: Archaeo-logy	Number of sites with archaeo-logical potential	5	0	0	None	0	0	None	-2	-10	Three sites with potential near the infrastructure	0	0	None
Subtotal		**100**		**-65**			**190**			**160**			**65**	

Score: -2 = worst, 0 = neutral, 2 = best.

Notes:

1 - All of the waste rock / tailings and overburden alternatives studied are located in areas with comparable surface deposits (peatland and sand). This aspect was therefore not specifically included in the technical analysis because it is of equal value for all sites. However, surface morphology is considered in item 2.6 of the table.

2 - The "Weight" column contains a value that is determined based on the importance of the indicator. Thus, the more important the indicator, the higher the value in the "Weight" column. The importance of the indicators (i.e., the weight) is determined by experts involved in the alternative analysis who compared all the indicators and discussed the importance of each one. Following the discussions among the experts, a consensus was reached, with the values in the "Weight" column being settled on.

3 – The "Score" column refers to the evaluated option (either option 2, 3 or 4) compared to option 1, which is the reference option. A value from -2 to 2 is assigned to each of the options. Since option 1 is the reference option, it is considered to have a score of 0. The other options are compared with option 1. The best options are given a 1 or 2 score, and the worst options are given a -1 or -1 score.

4 – The "Justification" column indicates the elements that led to the score value given.

Table 3-3b Indicator weight justification

Criteria	Indicator	Weight	Justification
1. Environmental elements			
1.1: Hydrology	Number of affected drainage basins	10	Indicator with a low value as there are only slight variations between the options
1.2: Total ground footprint	Area	10	Indicator with a low value as there are only slight variations between the options
1.3: Fauna and aquatic habitats	Habitat destruction Impact of the hydrologic budget on watercourses and fish populations	50	Indicator with the greatest importance given regulations on the protection of watercourses and fish habitats, as well as the concerns of the stakeholders consulted
1.4: Fauna and terrestrial habitats	Wetlands area	20	Indicator with a high value given the role of wetlands in ecosystems, their ecological value, regulations for their protection and the concerns of stakeholders consulted
1.5: Threatened or vulnerable species	Presence or absence of threatened or vulnerable species	10	Indicator with a low value as there are only slight variations between the options
Subtotal		**100**	**Subtotal of 100 calculated for the environmental elements**
2. Technical elements			
2.1: Stability of the works	Maximum stockpile height	5	Indicator with the lowest value as there are only slight variations between options and it has few consequences compared to other indicators
2.2: Simplicity of design and construction	Length and height of the levees	5	Indicator with the lowest value as there are only slight variations between options and it has few consequences compared to other indicators
2.3: Water management system design	Number of facilities and their capacity	10	Indicator with an intermediate value given its complexity compared to other indicators
2.4: Access roads and hauling roads design	Qualitative assessment (maximum slope, number of creek crossings)	5	Indicator with the lowest value as it is less complex than other indicators and it has few consequences compared to other indicators
2.5: Stockpiles design	Stockpile capacity	30	Indicator with the greatest importance given the impacts related to it, which are more significant compared to other indicators

Table 3-3B Indicator weight justification (cont.)

Criteria	Indicator	Weight	Justification
2. Technical elements (cont.)			
2.6: Ease of stockpile development	Qualitative assessment	10	Indicator with an intermediate value given its complexity compared to other indicators
2.7: Land ownership and permits	Qualitative assessment	30	Indicator with the greatest importance given the impacts related to it, which are more significant compared to other indicators
2.8: Blasting risk management	Presence of infrastructure inside the exclusion zones	5	Indicator with the lowest value as it has few consequences compared to other indicators
Subtotal		**100**	**Subtotal of 100 calculated for the technical elements**
3. Economic elements			
3.1: Capital expenditures (CAPEX)			
3.1.1: Surrounding ditches	Length of ditches	3	Value determined based on costs compared to other indicators
3.1.2: Surrounding levees	Volume of levees	4	Value determined based on costs compared to other indicators
3.1.3: Protection for the stockpiles and basins	Total area to seal/keep dry	50	Indicator with the highest value as it is most expensive compared to other indicators
3.1.4: Water treatment	WTP capacity	2	Value determined based on costs compared to other indicators
3.1.5: Water management			
3.1.5.1: Pumping station	Number of auxiliary pumping stations	1	Value determined based on costs compared to other indicators, least expensive indicator
3.1.5.2: Pipes	Pumping distance	1	Value determined based on costs compared to other indicators, least expensive indicator
3.1.6: Fish habitat compensation and land acquisition	Qualitative assessment	1	Value set to 1 as there is little or no compensation required based on the options considered
3.1.7: Closing costs	Area to restore	24	One of the most expensive indicators compared to other indicators

Table 3-3B Indicator weight justification (cont.)

Criteria	Indicator	Weight	Justification
3.2 Operating expenses (OPEX)			
3.2.1: Transportation of waste rock	Distance from the pit to the stockpiles	7	Value determined based on costs compared to other indicators
3.2.2: Transportation of tailings	Distance from the plant to the stockpiles	7	Value determined based on costs compared to other indicators
Subtotal		**100**	**Subtotal of 100 calculated for the economic elements**
4. Socioeconomic elements			
4.1: Atmospheric emissions	Qualitative assessment at the truck stop	40	Highest value given how important air quality is for health
4.2: Noise nuisance	Qualitative assessment at the truck stop	25	High value given the importance of the truck stop and given the number of people who visit it
4.3: Upholding of the traditional lifestyle	Qualitative assessment of loss of hunting, fishing or gathering zones, as well as loss of access	20	Value based on concerns raised by stakeholders. This is not the highest value since the most popular areas for traditional activities are located away from the infrastructure. Still, maintaining the traditional lifestyle remains one of the most important indicators.
4.4: Landscape	Qualitative assessment of the perspective and relief, compared with the existing topography	10	The landscape continues to be important to people as they move about and rely on landscape features as landmarks.
4.5: Archaeology	Number of sites with archaeological potential	5	There is little archaeological potential in the areas considered for infrastructure. The potential does, however, exist.
Subtotal		**100**	**Subtotal of 100 calculated for the socioeconomic aspects**

PROJECT OPTIMIZATION (2021)

As part of the project optimization exercise, the four waste rock stockpiles were positioned near the pit to reduce transportation distances for excavated material. Additionally, two waste rock stockpiles located near the mine will be expanded into the pit once mining of the area is complete. This will reduce the size of the waste rock stockpiles to the north of the mine.

It should be noted that the alternative analysis for the location of the waste rock and tailings storage facilities was not revised as a whole although requested by the Joint Assessment Committee in July 2020. However, following the value engineering exercise, the geochemical characterizations of the materials to be stored as well as the hydrogeological characteristics of the storage sites, in particular the hydraulic conductivity of the underlying stratigraphic units estimated from essays conducted on-site, and the direction of groundwater flow were considered (see Chapter 4).

Finally, the waste rock stockpiles are now partially located within the exclusion zones for blasting activities. However, since traffic on the waste rock stockpiles is not continuous on all 4 stockpiles at once, the decision was made to manage presence on the stockpiles via a specific procedure. Thus, during blasting, it will be important to ensure that no one is in the zone.

3.1.3 LOCATION OF OVERBURDEN STOCKPILES

ALTERNATIVE ANALYSIS (2018)

In 2018, prior to the geotechnical investigations, an area north of the pit had been identified as preferable for accommodating the overburden stockpile. The results of the field campaign made it possible to calculate the volumes of unconsolidated deposits and organic matter (mainly peat) that would have to be stored in this stockpile.

These volumes were considerably higher than anticipated. Therefore, the north footprint had to be increased and the overburden stockpile split up into two stockpiles, one for organic matter and the other for unconsolidated deposits.

At this point, it was agreed that a second mining effluent would be developed in the sector harbouring organic matter and unconsolidated deposits, by delineating drainage basins on the territory. In fact, the stockpiles cover a significant enough overall area that if the runoff water had been pumped toward the main retention basin, it would have modified the nearby water levels and watercourse flows. Furthermore, the geochemical characteristics of the superficial deposits were an indication that the latter were not leaching metals and had no acid generating potential.

A second option was explored west of the pit. A comparative analysis was performed to identify which option would best support the project. The locations of the various options analyzed are illustrated on Map 3-2. The main findings of this analysis were as follows:

- The North option called for a stockpile several metres in height close to the Billy-Diamond highway (which created some worry as to possible problems with visibility on the road).
- Kapisikama Lake, creek CE4 and a special status plant in the North sector also curtailed the available storage options.
- The West option was located further from the pit (longer route for stripping). After an examination, however, it was determined that most of the materials stored in the stockpiles would be peat from the waste rock stockpile and topsoil stripping from the concentrator area.
- The North option was partially located in a terrestrial environment, which would limit losses associated with wetlands.
- The West option was fully within the limits of a single drainage basin, meaning any impacts would have only involved a portion of one watercourse.

After having carefully considered all this information, the West option was selected.

PROJECT OPTIMIZATION (2021)

As part of the optimization exercise, the decision was made to pile the organic material and unconsolidated deposits into a single stockpile. This overburden and peat storage facility (OPSF) was positioned between the west waste rock and tailings storage facility (WRTSF) and the main water management pond (WMP). The location of the OPSF was chosen taking into account the site topography in order to decrease the need for excavation and backfill during construction. This is detailed in chapter 4.

Relocation of the OPSF allowed for the WRTSF to be moved closer to the pit, thereby shortening waste rock transportation distances and reducing GHG emissions.

The second mining effluent, planned in the 2018 design, was removed from the development plan. All water from the site is now directed to the main water management pond and then discharged into the final effluent in CE2 (see Section 3.3).

3.2 DOMESTIC WASTEWATER TREATMENT

3.2.1 DESIGN CRITERIA

The workers' camp must have a domestic wastewater treatment system for personnel during the mine's construction and operation phases. Design criteria were developed to evaluate the various possible treatment technologies. These criteria, based on the number of people requiring service and the requirements of the *Guide pour l'étude des technologies conventionnelles de traitement des eaux usées d'origine domestique* (MDDELCC 2017), are as follows:

System capacity

- Unit flow for a camp: 200 L/pers/d
- Unit flow for the cafeteria: 12 L/pers/d

- Number of meals served in the cafeteria: breakfast 100%, lunch 20%, dinner 100%
- Construction phase:
  - number of people: 280
  - total flow of water to be treated: 280 pers * 200 L/pers/d = 56,000 L/d
- Operation phase:
  - number of people: 150[3]
  - total flow of water to be treated: 150 pers * 200 L/pers/d = 30,000 L/d

Disposal site (in the case of an absorption or leaching field)

- Maximum grade: 10%
- Depth of rock: > 2.5 m
- Depth of water table: > 2.5 m
- Permeability of site: very permeable and homogeneous on a horizon up to 2.5 m
- Distance of site from bodies of water: ≥ 200 m from a lake and ≥ 100 m from the tributary stream of that lake
- Distance of site from drinking water supply wells: ≥ 100 m

3.2.2 TREATMENT TECHNOLOGIES CONSIDERED

Seepage of treated water into the soil has been preferred from the outset, even though some technologies offer a tertiary treatment option that discharges treated water directly into a watercourse. The environmental requirements for water seepage into natural soil are far less stringent than for discharge into a watercourse, even with tertiary treatment. Considering that the flow to be treated is higher than 10,000 L/d (10 m³/d), the treatment systems considered that include seepage into soil require a low-pressure feed system.

The following four technologies were studied:

- absorption field with a seepage bed for very permeable soil;
- absorption field, Enviro-Septic technology for permeable to very permeable soil;
- modular units combined with mobile units (Bionest SA-10000 and KODIAK technology), with a leaching field;
- rotating biological contactor type modular unit (Ecoprocess, MBBR technology).

The first three technologies may or may not be combined with a retention basin, as described below, to reduce the scale of the treatment system selected. For MBBR technology, since the system cannot be reduced, there would be no benefit to adding a basin.

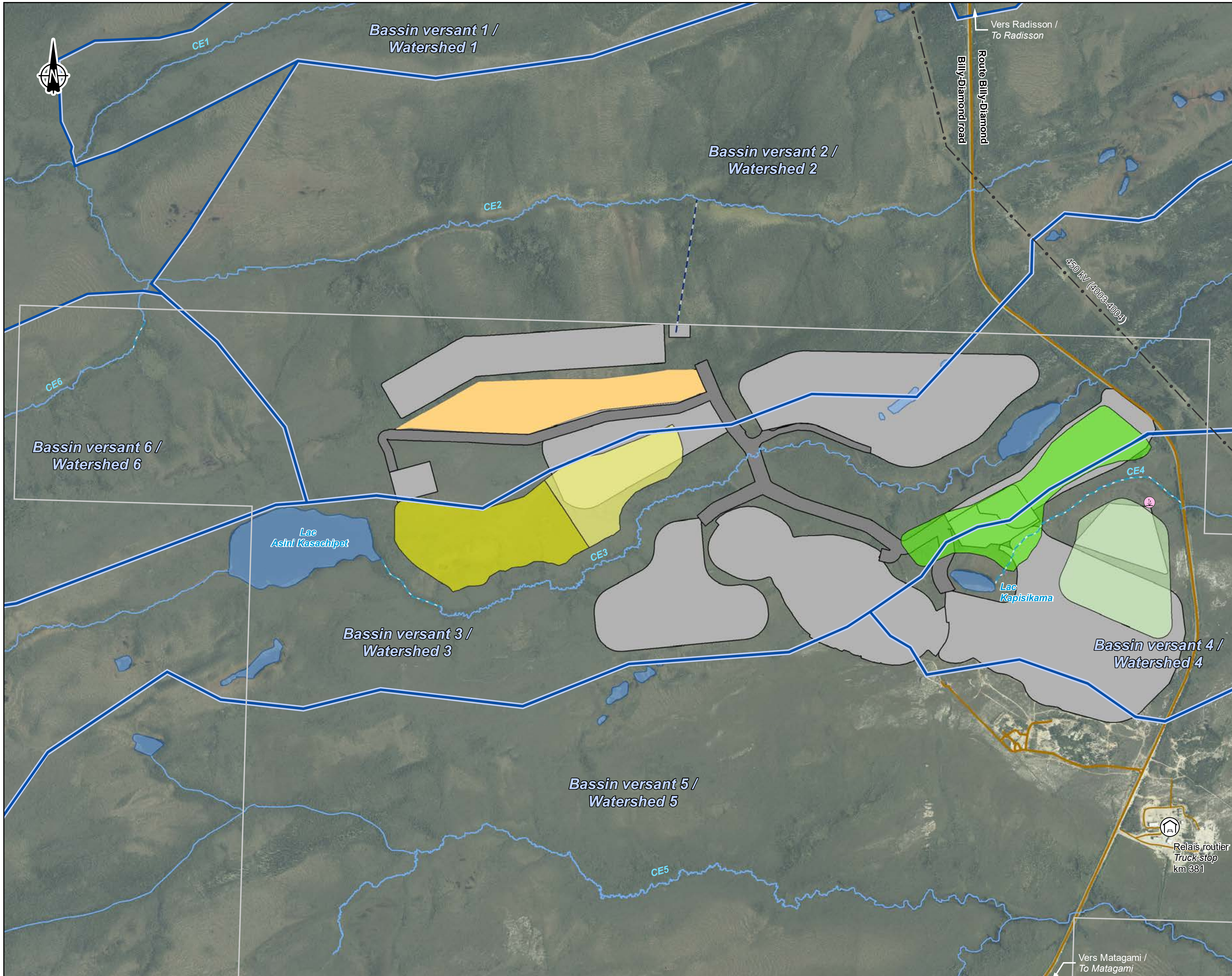
Absorption field with seepage bed

For this conventional technology, the soil thickness below the absorption field after the water table rises must be 0.9 m. This space may have to be increased to 1.5 m depending on the proximity of lakes and watercourses. The natural sand below the seepage bed must be very permeable. A septic tank provides primary treatment upstream. The absorption field is then supplied by a low-pressure feed system (LPFS) and a dosing (pumping) station. The field is divided into three separate areas, each supplied by a force main fitted at the outlet of the dosing station. Each main is shut off one at a time to give one section a break. Regular environmental monitoring is required during the year through sampling below the seepage bed.

Absorption field, Enviro-Septic technology

This advanced secondary treatment absorption field allows for a seepage rate of up to 50 L/m². A smaller soil thickness of 0.3 m is required below the absorption field after the water table rises. The sand filter must meet certain specifications and be certified by a laboratory. Just like the seepage bed, a septic tank provides primary treatment upstream, and the absorption field is then supplied by an LPFS and a dosing station. The absorption field works the same way, meaning that it is divided into three separate areas, each of which is given a break one at a time. Regular environmental monitoring is required during the year through sampling below the seepage bed. Enviro-Septic must visit annually.

3 **In 2021, the total flow of water to be treated was calculated for 180 people during the operation phase, giving 36,000 L/d.**



Limite de propriété / *Property limit*

Variante des haldes / *Stockpile Alternative*

Option nord / *North Option*

Halde à matière organique / *Organic matter stockpile*

Halde à dépôts meubles / *Unconsolidated deposit stockpile*

Option ouest / *West Option*

Halde à matière organique / *Organic matter stockpile*

Halde à dépôts meubles / *Unconsolidated deposit stockpile*

Composantes du projet (2021) / *Project Component (2021)*

Route / *Road*

Effluent minier / *Mine effluent*

Infrastructures minières / *Mining infrastructure*

Halde à matière organique / *Organic matter stockpile*

Infrastructure / *Infrastructure*

Route principale / *Main road*

Route d'accès / *Access road*

Ligne de transport d'énergie / *Transmission line*

Relais routier / *Truck stop*

Espèce végétale susceptible d'être désignée / *Plant Species Likely to be Designated*

Carex sterilis

Hydrographie / *Hydrography*

CE3 Numéro de cours d'eau / *Stream number*

Cours d'eau permanent / *Permanent stream*

Cours d'eau à écoulement diffus ou intermittent / *Intermittent or diffused flowstream*

Plan d'eau / *Waterbody*

Bassin versant / *Watershed*

GALAXY

Mine de lithium Baie-James / James Bay Lithium Mine

Carte / *Map* 3-2
Options d'emplacement des haldes à mort-terrain / *Overburden Stockpiles Location Options*

Sources :
Orthoimage : Galaxy août / august 2017
Données du projet / Project data : Galaxy 2018

0 185 370 m
UTM, fuseau 18, NAD83

Juillet / *July* 2021

Dessin : A. Masson
Approbation : C. Martineau
201-12362-00_c3-2_wspT316_halde_depot_210629.mxd

wsp

Fixed unit, Bionest technology with leaching field

This technology is an advanced secondary treatment system whose Bionest treatment components are inserted into a reactor composed of fixed modular units (SA-10000) or mobile units (Kodiak). Both types of unit can be combined depending on the project scope and duration. The group of modular units would be installed permanently to meet needs during the operation phase (30,000 L/d), whereas the group of mobile units could be used temporarily to fill additional needs during the construction phase (26,000 L/d). The treated water would be discharged into a leaching field.

- SA-10000 modular units:
  - oversized septic tank (V= 2.3 * Q) required upstream, with pumping station;
  - 3 buried units, measuring 6 m x 2 m x 2 m, with a capacity of 10,000 L/d each;
  - biofilm mounted on filament requiring a recirculation station and forced ventilation;
  - regular environmental monitoring, sampling at Bionest outlet and annual visit by supplier.
- Kodiak mobile units:
  - 3 above-ground units, mounted in insulated containers, with a capacity of 11,000 L/d each;
  - oversized septic tank (V= 2.3 * Q) included in each unit;
  - biofilm mounted on filament requiring a recirculation station and forced ventilation;
  - possibility of reselling the units at the end of the construction phase;
  - regular environmental monitoring, sampling at Bionest outlet and annual visit by supplier.
- Leaching field:
  - LPFS-type installation;
  - use of natural soils suitable for seepage;
  - minimum soil thickness of 0.3 m below the field after the water table rises.

Fixed unit, Ecoprocess MBBR technology with leaching field

This treatment solution works with a Moving Bed Biofilm Reactor (MBBR). The treatment process consists of four stages: primary settling, which allows secondary sludge to be stored, a buffer tank, an MBBR-type secondary aerobic treatment and secondary settling. The secondary settling separates the sludge that formed in the biological reactor and discharges clarified water to a seepage area (in this case, a leaching field).

The reactor is designed based on the flow and load to be treated. Installation on the site is fixed and permanent. Regular environmental monitoring is required during the year through sampling at the reactor outlet, and a visit from the supplier is required annually.

Retention basin

A retention basin can be set up to store surplus domestic wastewater during the construction phase for offsite treatment. The basin would have a storage capacity that meets the needs of 130 people for one month, that is, a filling volume of 780 m^3 given a daily flow of 26,000 L/d. The collected water would be drained periodically at a rate of one to two tanker trucks per day. During the operation phase, a permanent treatment system would be installed to serve the 150 expected workers. This option requires a prior agreement between the mine and the owner of the sanitary treatment system.

Tables 3-4 and 3-5 summarize the design criteria and features of the various systems studied, depending on whether or not they will be combined with a retention basin.

Table 3-4 Domestic water treatment systems, scenario without basin

Treatment chain components	Absorption field Seepage bed	Enviro-Septic absorption field	Bionest SA-10000 and Kodiak	Ecoprocess MBBR
Grease trap, kitchen (15 m^3)	1	1	1	1
Septic tank	84 m^3	84 m^3	3 X 23 m^3	2 X 46 m^3
Pumping station	1	1	3	1
Sanitary treatment	2,800 m^2 seepage 3,700 m^2 total to soil (37 m x 100 m) Total load of 30 L/m^2/d for very permeable soil	1,680 m^2 seepage 2,200 m^2 total to soil (22 m x 100 m) Total load of 50 L/m^2/d for very permeable soil	3 biological reactors SA-10000 (permanent) Flow treated: 30,000 L/d 3 biological reactors Kodiak (temporary)	Ecoprocess MBBR, secondary settling and 8 Ecoflo units
Leaching field with LPFS	Not applicable	Not applicable	560 m^2 seepage 725 m^2 total to soil (18 m x 40 m) Total load of 100 L/m^2/d for very permeable soil	Included under Ecoflo units
Specific material required	840 m^3 of crushed stone LPFS pipes	1,170 m^3 of laboratory-certified sand filter (quality of natural sand at site to be determined) Enviro-Septic pipes	170 m^3 of crushed stone LPFS pipes	30 m^3 of crushed stone
Estimated budget (purchase and installation)	$580,000	$785,000	$900,000, including resale of Kodiak units	$580,000
Notes	Hypothesis of very permeable soil available with water table at more than 2.5 m deep. Distance of less than 400 m from camp. Lake and stream more than 200 m away.	Hypothesis of very permeable soil available with water table at more than 1.5 m deep. Distance of less than 400 m from camp. Lake and stream more than 200 m away.	Hypothesis of very permeable soil available with water table at more than 1.5 m deep. Lake and stream more than 200 m away. SA-10000 units can be replaced with a unit built on site. At the end of the construction phase, the Kodiak units can be resold.	Hypothesis of very permeable soil available with water table at more than 1.5 m deep. Distance of less than 400 m from camp. Lake and stream more than 200 m away.

Table 3-5 Domestic water treatment systems, scenario with basin

Treatment chain components	Absorption field Seepage bed	Enviro-Septic absorption field	Bionest SA-10000 and Kodiak
Grease trap, kitchen (24 m^3)	1	1	1
Septic tank	45 m^3	45 m^3	3 X 23 m^3
Pumping station	1	1	2
Sanitary treatment	1,500 m^2 seepage 2,000 m^2 total to soil (40 m x 50 m) Total load of 30 L/m^2/d for very permeable soil Flow treated: 30,000 L/d	1,200 m^2 seepage 1,500 m^2 total to soil (30 m x 50 m) Total load of 40 L/m^2/d for permeable to very permeable soil Flow treated: 30,000 L/d	3 biological reactors SA-10000 (permanent - mining operation phase) Flow treated: 30,000 L/d
Leaching field with LPFS	Not applicable	Not applicable	300 m^2 seepage 400 m^2 total to soil (20 m x 20 m) Total load of 100 L/m^2/d for very permeable soil
Retention basin (1,500 m^3)	1 (35 m x 15 m) Flow to be treated off site: 26,000 L/d	1 (35 m x 15 m) Flow to be treated off site: 26,000 L/d	1 (35 m x 15 m) Flow to be treated off site: 26,000 L/d
Specific material required	450 m^3 of crushed stone LPFS pipes Geomembrane and sand for basin base Access road to basin for tanker truck	800 m^3 of laboratory-certified sand filter (quality of natural sand at site to be determined) Enviro-Septic pipes Geomembrane and sand for basin base Access road to basin for tanker truck	90 m^3 of crushed stone LPFS pipes Geomembrane and sand for basin base Access road to basin for tanker truck
Estimated budget (purchase and installation)	$575,000	$735,000	$765,000
Notes	Hypothesis of very permeable soil available with water table at more than 2.5 m deep. Distance of less than 400 m from camp. Lake and stream more than 200 m away.	Hypothesis of very permeable soil available with water table at more than 1.5 m deep. Distance of less than 400 m from camp. Lake and stream more than 200 m away.	Hypothesis of very permeable soil available with water table at more than 1.5 m deep. Lake and stream more than 200 m away. The three SA-10000 units can be replaced with a unit built on site.

3.2.3 METHODOLOGY

To characterize the alternative technologies for domestic wastewater treatment, indicators were formulated in the categories deemed relevant based on the context and the issues involved in this project (economic, technical and environmental aspects). The following weightings were selected for these categories: economic (5), technical (3) and environment (2). The indicators were then assessed, qualitatively or quantitatively, using a scale from 1 (worst) to 5 (best). **As such, there is no quantitative scale related to these scores, as the options are ranked by their position relative to the others. The justification for these weightings is related to: the significant cost difference for the options to ultimately achieve similar treatment results; the technical advantages and disadvantages of the options; as well as by taking into account an expected minor environmental impact, since the technologies examined are considered effective and have been used for a long time. Thus, for the various analysis criteria, the weights were established as follows (rating from 1 to 5 in ascending order of importance):**

- **Environment: Equivalent and equally important consideration must be given to the impact on surface water and on groundwater.**
- **Technical: The operability criterion was considered the most important due to the major impact a malfunction caused by poor operation would have. The complexity of equipment operation was considered, along with the time and effort required to maintain and confirm proper operation. The effort and expertise required for the system design / specification were considered important, while those required to design the collection system were less significant. The ease of the validation and approval process in terms of the Regulation respecting the application of section 32 of the Environment Quality Act was considered to have a moderate impact on system selection.**
- **Economic: The upfront purchase cost was considered very important since the system is essential from the very beginning of the project, in addition to all the other construction and equipment procurement expenses before production starts. Use and operating costs for the system are given less consideration since the developer will be in the production phase and will therefore be generating income.**

A quantitative analysis was performed for the technologies studied (scenario 1) but was not completed for the combination of these technologies with a retention basin (scenario 2) since the transport costs for emptying the basin were not known at the time the study was performed. The results and the detailed analysis are presented in Tables 3-6 and 3-7.

Table 3-6 Scores for alternative domestic wastewater treatment technologies

Score	Option 1	Option 2	Option 3	Option 4
Environment	1.5	2.5	4.0	4.0
Technical	2.7	2.7	3.0	2.7
Economic	3.4	3.0	2.2	3.3
Total before weighting	7.6	8.2	9.2	9.9
Weighted total	**28.2**	**28.2**	**28.1**	**32.3**
Note: The weighting factors are: environment = 2, technical = 3, economic = 5.				

The weighting factors given in Table 3-6 are explained as follows:

- A factor of 2 is given to the environment score**, as the impact is the least significant of the various options**.
- A factor of 3 is given to the technical score, which represents a middle value.
- A factor of 5 is given to the economic score, since this is the score with the greatest variation between the options and with the most significant impact.

Table 3-7 Multi-criteria analysis of domestic wastewater treatment technology

Criteria	Weighting	Option 1		Option 2		Option 3		Option 4	
		Score	Weighted result	Score	Weighted result	Score	Weighted result	Score	Weighted result
Environmental aspects									
Impact on surface water quality	3	1.0	3.0	2.0	6.0	4.0	12.0	4.0	12.0
Impact on underground water quality	3	2.0	6.0	3.0	9.0	4.0	12.0	4.0	12.0
Subtotal	-	3.0	9.0	5.0	15.0	8.0	24.0	8.0	24.0
Environmental score subtotal	-	-	1.5	-	2.5	-	4.0	-	4.0
Technical aspects									
Collection system design	1	3.0	3.0	3.0	3.0	3.0	3.0	2.5	2.5
Treatment system design	3	1.4	4.1	1.9	5.8	3.4	10.1	3.0	9.0
S. 32 request	2	1.7	3.3	2.3	4.7	4.0	8.0	4.0	8.0
Operation	5	3.8	19.0	3.3	16.5	2.4	12.0	2.0	10.0
Subtotal	-	-	29.4	-	30.0	-	33.1	-	29.5
Technical score subtotal	-	-	2.7	-	2.7	-	3.0	-	2.7
Economic aspects									
Investment cost	5	3.1	15.6	3.0	15.0	2.3	11.7	4.0	20.0
Operating cost	3	4.0	12.0	3.0	9.0	2.0	6.0	2.0	6.0
Subtotal	-	-	27.6	-	24.0	-	17.7	-	26.0
Economic score subtotal	-	-	3.4	-	3.0	-	2.2	-	3.3

3.2.4 RESULTS

The basin scenario, which entails adding a retention basin to each of the technologies studied, is not considered economically advantageous at this stage since transport and off-site water treatment costs must be considered.

Therefore, of the four alternatives studied in the scenario without a retention basin, the rotating biological contactor (Ecoprocess MBBR technology) seems to be the best choice, all criteria combined. It is also the most economical choice.

Nevertheless, after checking the information available at this stage, it was found that an absorption or leaching field could not be installed in the immediate camp environment. According to the results of the geotechnical surveys, the soil in place is not adequate for the installation of such a system on the mine property. In general, the water table is less than one metre from the ground surface and the desired sand horizon is invariably under a layer of peat 0.7 to 1.5 m thick. For this reason, a tertiary treatment was added to the selected alternative.

Thus, the prospective supplier for the rotating biological contactor could also offer the tertiary treatment unit to comply with the disinfection and phosphorus standards required for direct discharge into a watercourse. This system requires a service building (3 m x 4 m) to accommodate dosage pumps for phosphorus removal and the disinfection unit (UV lamp) at the exit of the Ecoflo.

Additional costs for the addition of this tertiary treatment are estimated at $21,000 for the equipment only, excluding delivery, installation and annual operating costs.

3.2.5 EFFLUENT DISCHARGE LOCATION

In 2018, the discharge location **was planned in** creek CE3, through the overburden stockpiles' sedimentation basin or directly into the watercourse. The final choice **was to be** made following further work based on technical and environmental considerations (characterization results, field visit, request for Effluent Discharge Objectives [EDOs] to be filed, etc.).

In 2021, the sanitary effluent discharge location was positioned in CE4 to be nearer to the new location planned for the workers' camp.

3.3 MINE WATER MANAGEMENT AND **FINAL EFFLUENT** DISCHARGE LOCATIONS

In 2018, the project's infrastructure has been positioned to minimize watershed changes (quantities of water to be redirected) and to simplify water management at the site. Thus, since the mining infrastructure was optimized throughout the project design, no alternative analysis was necessary for the position of the mining effluent. The mining effluent site on creek CE2 was selected using videos of the watercourses taken with a drone to position it at the best location along the watercourse, over a 200 m segment. The mining effluent on creek CE3 has been placed near the crossing of the hauling road to facilitate sampling and minimize the footprint. **The effluent discharge locations were positioned on these watercourses in order to retain the current drainage conditions; in other words, respecting the watershed boundaries of the watercourses, while taking into account mine site layout imperatives (i.e., all water that must be treated before being discharged is conducted to a single point on the site). The discharge location on CE3 was chosen because it would have been already affected by the project's development (access road and watercourse crossing), as well as for the purposes of efficiency for monitoring (location to the right of the watercourse crossing by the road).**

In the current project (2021), mining effluent will only be discharged into CE2, in the same location planned for in 2018. There is no effluent anticipated into CE3.

3.4 POWER SUPPLY AT THE MINE SITE

The project, as defined **in 2018, required** 8.3 MW to power the fixed infrastructure. **Now, in 2021, these power needs have dropped to an estimated 8.01 MW.**

Near the project, Hydro-Québec's network includes three 735-kV transmission lines and a 450-kV line from the La Grande-2 and La Grande-2A generating stations, which travel into southern Québec, and a 315-kV line between the Sarcelle and Eastmain-1 generating stations. Also, a 69-kV line from the Muskeg generating station near the former Opinaca airport heads west to supply the community of Eastmain, running 7 km south of the mine site. Using this renewable energy network to supply the concentrator and other project infrastructure was therefore the first option considered.

The construction of a substation of 75 kV or more and a transmission line of 75 kV or more would require an impact assessment as per the requirements of Schedule A of the EQA. Hydro-Québec would be responsible for this assessment since it owns the network. According to Hydro-Québec's representatives, the time required to obtain authorizations and build the infrastructure for this option, which involves a connection to the 315-kV line, is four years, whereas a connection to the 69-kV line would be two years. To optimize management of the preliminary design studies and permit applications, the option to connect to the 69-kV line has been prioritized. With this option, Hydro-Québec **will be able to** supply a maximum of 7.6 MW.

In 2018, other sources of electricity were considered in order to make up the difference. The choices **were** solar, wind, natural gas, liquefied natural gas (LNG) and propane. Natural gas **was** eliminated since there is no distribution system in the area.

Renewable energy seems attractive at first glance because it minimizes GHG emissions and reduces operating expenses (OPEX). However, because it is direct energy, it must be used as soon as it is produced or accumulated in a battery. Since they are still very expensive, batteries increase capital expenditure (CAPEX).

3.4.1 SOLAR AND WIND POWER

A preliminary **assessment** conducted by a specialized firm (Tugliq) revealed that the installation of solar or wind farms first requires local availability studies to determine sunshine constancy, radiation strength as well as wind speed and constancy. It is also important to consider that a wind farm can interfere with airport radars and requires social acceptance by neighbouring communities, mainly because of its visual impact. An environmental impact assessment is required. Finally, the cost of installing wind or solar infrastructure, including accumulators, is too high for a mine with about an **18**-year lifespan, even for one or two megawatts.

The option of powering a few mobile generators using solar panels with accumulators was quickly assessed. However, the project area yields very low radiant exposure, barely 4 kWh/m^2 according to Natural Resources Canada databases. Assuming a conversion efficiency of 35% solar energy to direct current electricity (for polycrystalline solar panels) and then a conversion of 90% direct current electricity to alternating current, the system's total efficiency would be 31.5% versus 35% or more for a generator. Furthermore, the capital cost is considerably higher for a solar system, nearly CAD 2.5/W versus CAD 1/W for generators. This excludes energy storage costs. Currently, very few, if any, solar systems exist in northern First Nations communities, precisely because of the mediocre economic feasibility of this type of project in the north.

3.4.2 LIQUIFIED NATURAL GAS AND PROPANE

These two solutions require pressurized tanks on site and could be used for the mobile fleet. **Vehicle conversion costs and fuel costs are about the same. Compared with propane, LNG emits fewer GHGs but is more difficult to obtain.**

In 2018, GLCI contacted Energir, the natural gas and LNG supplier in Québec, to discuss possibly fueling hauler trucks with LNG. The information sent by Energir (2018) indicated that, for an equal MBTu power supply, the percentage of diesel must be kept at 65%, as there is currently no existing application for fueling trucks of this size with LNG and for keeping the efficiency equivalent to that of diesel. The LNG or RNG (biomethane) effectively reduces GHG, NOx and noise emissions. The use of 35% LNG reduces GHG by 10%, while the use of 35% RNG reduces GHG by 35%. The fuel cost is equivalent to diesel for the mixed diesel-RNG and 27% less for the mixed diesel-LNG. The first issue is that this scenario still requires diesel, which will need to be transported to the James Bay region and then stored. The second issue is the transportation and storage of LNG and RNG on the James Bay territory. Energir proposed two options. The first is road transport only: from the transfer station in Montréal, which is a 1460-km round trip, with one delivery every three days to supply a station that would be built in Matagami. From Matagami to the GLCI site, the ore transport trucks would be equipped with NG engines with a driving range of approximately 1000 km, and they would therefore be able to cover the GLCI-Matagami round trip (765 km). The scenario involving the fueling of both the ore transport trucks and the hauler trucks would entail two shipments from Montreal to Matagami every three days, the construction of the station in Matagami and the construction of a station at the GLCI site.

The GHG emissions from transporting the LNG to Matagami are not accounted for in Energir's presentation. The trips every three days represent about 170,000 km or 340,000 km per year, depending on the option. A load of LNG represents 30,000 m^3 of LNG or RNG, while a diesel tanker can carry up to 55,000 L, meaning fewer trips given the volume saved.

Consequently, taking into consideration the whole cycle including LNG transportation (and losses during transportation and storage), the anticipated reductions in GHG emissions are negligible. These solutions will increase the project's capital costs without any significant positive impact on the environment, not to mention the additional technological and health and safety risks (accidents). Based on these assessments, a switch to LNG trucks is not as attractive as it would appear initially.

As an alternate power source to the hydropower supplied by Hydro-Québec to meet the demand for the fixed infrastructure at the mine site, propane gas was chosen because of its ease of supply compared with LNG. It **should be** used to heat the buildings in the administrative and industrial sector, which require 1.2 MW. **The 2021 project anticipates using only propane to heat the workers' camp during the construction and operation phases.**

3.5 POWER SUPPLY FOR MOBILE EQUIPMENT

The possibility of obtaining electric motors abroad for hauling and road trucks, as well as for heavy equipment such as excavators and shovels, was examined with a view to reducing GHG emissions. **Mobile equipment (off-road and on-road) accounts for 31 % of the site's diesel consumption, corresponding to 80 % of the CO_2eq emissions during the operation phase. Note that mobile equipment is responsible for 46 % and 42 % of CO_2eq emissions during the site's construction and closure phases, respectively.**

Despite GLCI's willingness, two key issues complicate electrification of the project's mobile equipment: the limited supply of equipment models needed for the project's activities; and the lack of available hydroelectricity from Hydro-Quebec to power the vehicles.

However, because its values include decarbonizing transportation and being a lithium producer, GLCI is interested in establishing a fleet of electric mobile vehicles for its project. The following sections describe the challenges GLCI will have to overcome in order to achieve this.

3.5.1 EQUIPMENT AVAILABILITY

The search for electric options for the main mobile equipment was conducted **with the number one selection criterion being their** respective required capacities, namely:

- Mining trucks: a 60-t to 100-t hauler and a 50-t articulated hauler;
- Excavators: a hydraulic shovel with a bucket capacity of 6 m^3 to 11 m^3 and an excavator with a bucket capacity of 5 m^3;
- 152-mm down the hole drill hammer;
- **Articulated tankers**.

Mining trucks

There are no 100-t electric haulers. Those currently available on the market all have a capacity of **300 t** or more **(200 t for hybrid vehicles)**. However, a conversion test was conducted on a 65-t truck used in a Swiss quarry. Based on this prototype, it would cost $1 million to convert a diesel truck to an electric truck powered by a 600-kWh lithium-ion battery.

Another option would be to power the trucks from an onsite power line. Such a system involves adding a device on the trucks so they can connect directly to the power line, like a tramway. This type of system is usually installed on ramps since loaded trucks consume more energy going back up the slope. This option is advantageous for large-scale projects and is therefore not applicable here. Weather conditions are also a major impediment to installing such a system as freezing rain could lead to power failures.

Graders, Excavators and Loaders

John Deere sells electric or hybrid graders, bulldozers and loaders that have buckets with suitable capacities, however they are not sufficiently robust to withstand the use GLCI intends (handling hard rock such as pegmatite).

Other manufacturers do not offer excavators or loaders of the size GLCI needs. Purchasing them would entail acquiring a larger fleet of such vehicles to meet handling needs, which in turn means more maintenance and a larger maintenance crew, as well as larger workshops and a bigger yard. Komatsu manufactures an electric machine with a 10 m^3 bucket and Hitachi sells one boasting 11 m^3. These are somewhat larger than those envisioned. This option is still being studied.

Drill rigs

Electric drill rigs were considered. A search for suppliers shows that drill rigs handling **appropriate diameters** to deliver the expected results set out in the blasting plan **could be available within two years**.

Tankers

Research into electric articulated tankers failed to identify any on the market.

Auxiliary vehicles

After extensive investigation, a forklift, buses (2) and pick-up trucks (9) are available in electric versions and will be purchased. However, the telescopic forklifts and flatbed truck are only available in a smaller version than what GLCI requires. Electric versions of other equipment (for snow removal and garbage disposal, as well as fire trucks) could not be found on the market, but a close eye is being kept on their development for possible integration.

3.5.2 COMPARABLE PROJECTS

Most of the electrical mining equipment currently available is used in underground mines primarily because they help reduce ventilation costs.

For comparison purposes, note the Lac-à-Paul project, a phosphate deposit that will be operated as an open-pit phosphate mine in Saguenay–Lac-Saint-Jean. However, the scale of the project is not the same. The expected Lac-à-Paul production is much greater than that of the James Bay Lithium Mine project, i.e., on average, 37 Mt of excavated material per year (with peaks of 60 to 90 Mt) compared with 10 Mt for GLCI. The Lac-à-Paul feasibility study includes Komatsu hydraulic excavators (model PC 5500-6 with a 28-m^3 bucket) combined with Caterpillar diesel trucks (model CAT 793F, 226 t). The study shows that the use of electric drill rigs (203.2 mm) is currently being evaluated.

3.5.3 COST-BENEFIT ANALYSIS

A high-level economic assessment was conducted comparing the use of smaller electric shovels available on the market (Komatsu PC 3000, 250-260 t, 10-m^3 bucket) with diesel shovels adapted to the project's size (Komatsu PC-1250, 100 t, 5.75-m^3 bucket). The costs considered included only the initial outlay and energy consumption. The calculations are presented in Table 3-8[4].

4 **The equipment will be purchased over a 3-year period from the beginning of mine construction. The initial outlay corresponds to acquisition of shovels during the start-up period. Maintenance costs are capital investments needed to maintain mining operations. In this assessment, we estimate that 3 electric shovels and 5 diesel shovels will be required for the entire duration of mining operations. As a result, the initial outlay, for one electric shovel, which has twice the capacity of a diesel shovel, corresponds to the purchase of the first shovel for the first three years of operation. Two other electric shovels will be needed to successfully complete the project ($3M initially for one shovel + $12M in maintenance for the 2 other shovels). As for diesel shovels, 1.6 shovels will be needed for the initial period (3 years). Next, 3.3 shovels will be needed to maintain operations to the end of the project, for a total of 5 shovels. Keep in mind that the electric shovel has twice the capacity of the diesel shovel, which explains why 1 electric shovel is needed in the initial period while 1.6 diesel shovels will be needed during the same period, according to the volumes to be processed.**

Although it is likely that the differences between diesel and electric machine costs will change in the next 10 years, the data are not robust enough to estimate this difference. Accordingly, the assessment was conducted using only the available data.

It must be emphasized that the amount of electricity available is limited by Hydro-Québec, so replacing diesel equipment with electric equipment is not easily possible.

Table 3-8 Cost-benefit analysis of electric and diesel shovels

Parameter	PC 1250 Diesel	PC 3000 Electric	Difference
Operations (hrs)	288,000	166,000	122,000
Shovel purchase (qty)	5	3	2
Energy cost ($)[1]	21,500,000	7,000,000	14,500,000
Initial outlay ($)	2,000,000	6,000,000	-4,000,000
Maintenance cost ($)[2]	3,900,000	12,000,000	-8,100,000
Financial aspects			
Undiscounted net profit ($)	2,400,000		
Payback time (years)	15		
Net profit discounted at 5% ($)	-1,500,000		
Internal rate of return (%)	2.62		

1 Based on the following unit costs: diesel $0.940/l and electricity $0.0475/kWh.
2 Represents the cost of replacing the equipment

In general, the results are unfavourable for electric equipment. The calculations show a minimal undiscounted net profit with a long payback period. The energy savings would be cancelled out by the additional costs.

Technical notes from Mining Plus (2018) provide research done on LNG equipment and electric equipment. Fully electric and hybrid equipment are only available for 200 t and larger trucks and shovels larger than 20 m^3. Depending on the shape and size of the GLCI deposit, smaller trucks will be used.

Pilot tests were conducted on equipment of similar size by Teck Resources in Western Canada, using an LNG-diesel mix, which is necessary to ensure power. The results of these tests were kept confidential, but it appeared that the GHG reductions were not significant. The performance of this equipment in northern conditions is also uncertain.

Replacement kits for electrification and LNG are available and cost around $1 million for each piece of equipment. However, these modifications void the equipment manufacturers' warranty. The cost and loss of warranty significantly lessen the benefits of operating with such modified equipment. Some mining projects suggest a modified truck in their feasibility study. This truck is half the size of those recommended for GLCI. We will closely monitor the performance of these trucks based on the climate in James Bay. Nevertheless, among the electrical conversion options under consideration, the supercapacitor technology offered by Effenco seems to be the most suitable, particularly because of its adaptability to the requirements of heavy equipment, its ruggedness, its lifespan and its resistance to temperature fluctuations.

Assuming GLCI uses all electric mobile equipment currently available on the market and which currently meets the needs of the project, this would reduce total diesel consumption by 5.9% compared to the anticipated consumption.

Considering all of the constraints outlined, deploying a fleet of electric mobile equipment that satisfies the needs of the project would lead to a limited reduction in GHGs of 1.8% of the site's total GHGs (1.127 t CO2eq/62 t CO2eq). Furthermore, converting the same vehicles so they run on natural gas from Montreal (trucking) would reduce GHG emissions by 2% compared to running on diesel.

3.5.4 RECOMMENDATION

The market offers a limited choice of electric mining equipment for an open-pit mine like GLCI's. Most of the electric equipment available is for underground facilities due to the savings on ventilation costs. Electric battery trucks are not available for the pits while electric drill rigs and mechanical shovels are available only at capacities that exceed GLCI's needs. Smaller equipment is either no longer available on the market or not recommended by suppliers due to the high cost compared with equivalent diesel equipment. Consequently, given the size of the James Bay Lithium Mine, **most** electric equipment on the market today **is not suitable** for the project and **is therefore not recommended**.

Despite the only slight reduction in GHG emissions that might be achieved by electrifying the site's mobile equipment, GLCI remains on the lookout for any technological advances in the energy sector to reduce its dependence on fossil fuels. As a producer and developer of lithium products used to develop batteries for electric vehicles, GLCI aims to position itself as a pioneer in this field and to implement these new technologies when they become available. As a result, GLCI will certainly seek out available assistance programs and the most fuel-efficient diesel equipment when the time comes to purchase equipment.