Integration of Cree traditional ecological knowledge (TEK) into the revegetation process of the Eleonore mine tailings storage facility

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Abstract

The Eleonore mine is located on Cree territory, in northern Quebec, and the Cree community is involved in the site reclamation process. The tailings storage facility (TSF), located in the territory of VC-29's trapline, will be reclaimed with an engineered cover and revegetated to comply with regulations. However, the presence of certain deep-rooted plants, which are prioritized by the tallyman of VC-29 (the guardian of the territory), must be compatible with the technical performance of the engineered cover. This paper documents the vision of the tallyman of VC-29 (the Tallyman) and the different stakeholders regarding the revegetation scenario of the Eleonore mine TSF based on the co-design process put in place by the mine. Semi-structured interviews were conducted with stakeholders (the Tallyman, the Eleonore mine, the Québec ministère du Développement durable et de la Lutte Contre les Changements climatiques, the Québec ministère de l'Énergie et des Ressources naturelles, and the Cree Nation Government). All stakeholders agreed on the importance of integrating traditional ecological knowledge (TEK) into the Eleonore TSF revegetation process (although this is not required by the Quebec government). The differences in views were mainly related to the TSF revegetation scenario. Based on his TEK, the Tallyman prefers using only jack pine as a risk management strategy to divert the animals from the reclaimed TSF, as he believes the TSFs are toxic areas. Other stakeholders prioritize the technical aspects of the TSF reclamation to ensure the integrity of the cover system (avoid erosion and deep roots) to control contaminants and conserve biodiversity, both in the short and long term. Finally, this paper documents, and integrates, where possible, the expectations of the Tallyman into the Eleonore mine TSF revegetation scenario.

Keywords: Tallyman of VC-29, Eleonore mine, Cree Traditional ecological knowledge, Tailings storage facility, Revegetation.

1 Introduction

Mining activities can have major environmental impacts on the land-based livelihoods and traditional activities of communities (Downing et al., 2002). Indeed, Indigenous communities often rely on natural resources (like fisheries and forest resources) that may be disrupted by mining activities (LeClerc and Keeling, 2015; Horowitz et al. 2018). They also have cultural and spiritual relationships to landscapes (Richmond and Big-Canoe, 2018) that may be destroyed or degraded by mining activities (Horowitz et al., 2018; Lewis et al., 2021). These impacts can lead in turn to a loss of social cohesion, growing inequalities, changes to traditional land use practices, and an increase in mental health diseases (Gibson and Klinck, 2005; Horowitz et al., 2018; Myette and Riva, 2021). In response to these issues and growing calls for reform, mining countries and mining

companies have devoted increasing attention to the environmental and social impacts of their activities. On the one hand, mining companies are beginning to understand the need to involve Indigenous communities and take into account their traditional ecological knowledge (TEK)[e] in mining activities (Collins, 2015). On the other hand, mining countries have implemented laws and rules to compelling mining companies to involve (via informed consultation and participation) Indigenous communities in the process of mining activities (Clark and Clark, 1999; Bhattacharya, 2000; Bradshaw, et al., 2015; Nygaard and Vigdis, 2016; Atlin et al., 2017; Rodon et al., 2018a; Kuokkanen and Rauna, 2019; Papillon et al., 2020; Prno et al., 2021).

Thus, several mining countries (such as Canada and Australia) have started to require proponents to review TEK during their environmental assessment processes (Wiles, McEwen and Sadar, 1999; Collins, 2015; Haalboom, 2016; Bainton and Holcombe, 2018; Prno et al., 2021). In Canada, for example, the TEK of northern Indigenous peoples has been officially integrated over the last 40 years into the environmental management and, in some cases, the approval processes of mining projects (Atlin and Gibson, 2017; Huntington, 2018; Beckett et al., 2021). However, TEK integration into the reclamation process and the design for closure is emerging and less studied (Poirier and Brooke, 2000; Rodon and Lévesque, 2015; LeClerc and Keeling, 2015; Tsosie, 2015; Costa, 2015; Sandlos and Keeling, 2016; Bainton and Holcombe, 2018; Beckett et al., 2021). Nowadays, the reclamation of mining sites can no longer be focused only on technical engineering activities. Industry best practices (ICMM, 2008) and academic research both highlight the need to involve Indigenous communities and incorporate their TEK in the reclamation process (Wiles et al., 1999; Sistili, et al., 2006; Vanspronsen et al., 2007;

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[e] TEK or TK (traditional knowledge) has been defined as:
"*a cumulative body of knowledge and beliefs, handed down through the generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment*" (Berkes, 1995).
"a body of knowledge built up by a group of Indigenous people through generations of living in close contact with the land. Indigenous knowledge is cumulative and dynamic. It builds upon the historic experiences of a people and adapts to social, economic, environmental, spiritual and political change" (Impact Assessment Agency of Canada, 2020).

Chaloping-March, 2008; Beckett and Keeling, 2019; Dance, 2015; Monosky and Keeling, 2021). In 2015, Xavier et al. emphasized that mining companies should engage local values, needs, priorities, and visions for the future in the reclamation planning goals (Xavier, Veiga and Van Zyl, 2015). Indigenous knowledge, for example, can help to address the historical damage and displacement related to mining activities (Sistili et al., 2006), understand plants and animals of the region and how to sustainably restore local resources (Johnson, 1992), and integrate prospects and priorities of Indigenous communities with regard to land use after mine closure (Wiles et al., 1999; Reo, 2011; Collins, 2015). Establishing a collaborative relationship with the local community is the best strategy for TEK incorporation into reclamation planning. Indeed, consulting with the local community, including them in decision-making (Baker and McLelland, 2003; Beckett and Keeling, 2019), and considering their TEK as complementary knowledge to Western science (Fidler, 2009; Whitelaw, McCarthy and Tsuji, 2009) will help facilitate this process. However, this collaboration can be challenging due to the mutual skepticism between mining companies and local communities, the problematic nature of how TEK is defined and deployed in reclamation (Sistili et al., 2006; McBeath and Shepro, 2007; Tsosie, 2015; Sandlos and Keeling, 2016), and the experiences of local communities with the mining industry and its impacts on the environment, especially at the post-closure stage (Poirier et Brooke, 2000).

Despite its demonstrated necessity, there is still very little research on collaboration with Indigenous people and their TEK integration into mine reclamation and only a few guidelines and little knowledge of best practices (Collins, 2015; Baeten, 2018; Beckett, et al., 2019; Getty and Morrison-Saunders, 2020). In response to this knowledge gap, this article aims to document the vision of the Indigenous Cree community of a tailings storage facility (TSF)[f] revegetation scenario and the perceptions of government and the mining

f Structure built for the purposes of storing the uneconomical ore and water from the milling process (Mining Association of British Columbia, 2021).

industry through the case study of the Eleonore mine, located in Quebec, Canada. This article analyzes the governance process of TEK integration into the TSF revegetation, the parties' visions of the TSF revegetation scenario, and the critical challenges of TEK integration into the TSF revegetation. The findings highlight the importance of early integration of TEK and continuous community engagement in mine reclamation guidelines and practices, as well as the importance of following local Indigenous land use governance and consultation protocols.

Furthermore, it is important to note that, while we agree that there are many definitions for TEK/TK, in the context of this study we have considered its holistic definition mentioned above (see also Berkes, 1995; Dale and Armitage, 2011; Parlee, 2012; Keats and Evans, 2020; Impact Assessment Agency of Canada [IAA], 2020, for more information). We recognize that the terminology around TEK/TK is evolving, and refers to detailed knowledge and understanding of local environments as well as cultural practices, knowledge and expertise. Therefore, in this paper, in addition to the Tallyman's bio-cultural knowledge, we consider his beliefs, understandings and opinions to be TEK. We also suggest this knowledge is relevant to "technical" questions around tailings reclamation, revegetation, etc. Accordingly, the Tallyman's opinion or understanding of a TSF and the Eleonore mine TSF revegetation scenario is considered to be TEK. We draw on a wide range of literature on the inclusion of TEK/TK in industrial development and environmental review processes to support this claim.

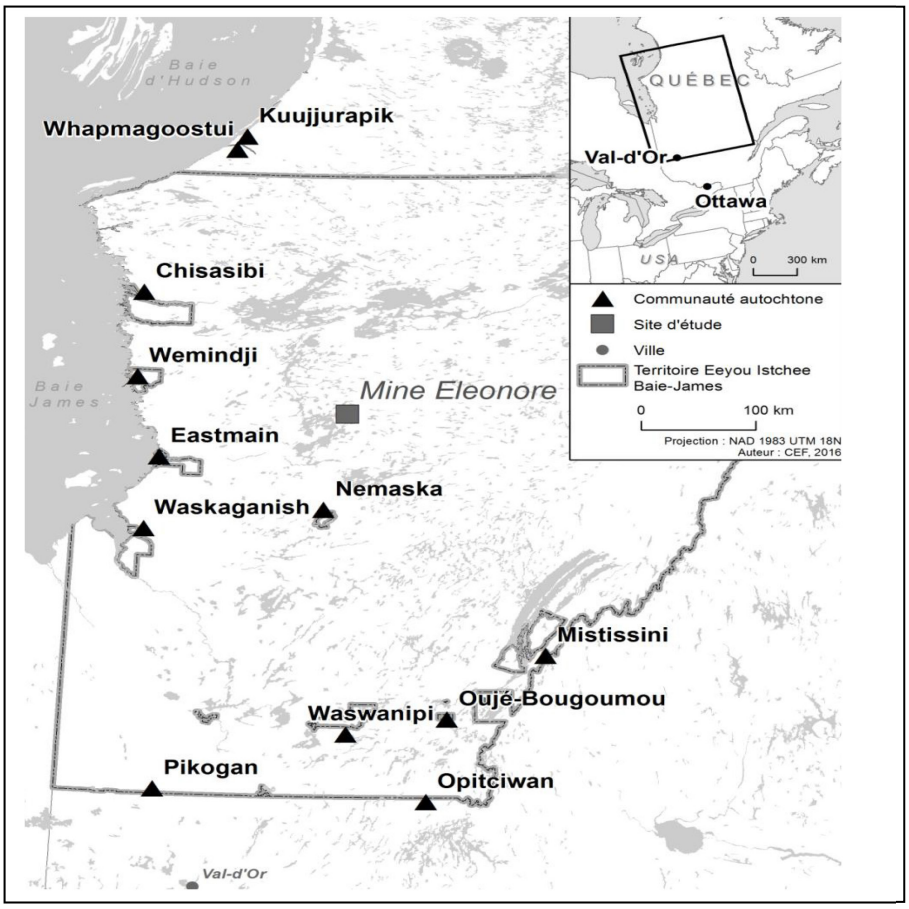
2 Background and methods

2.1 Study area and Eleonore mine description

Newmont Corporation's Eleonore gold mine (52º 42 'N, 76º 4' W) is an underground operation located in the territory of the regional government of Eeyou Istchee, James Bay, in northern Quebec, Canada. It is located approximately 350 km north of Matagami and 190 km east of the Cree community of Wemindji (Golder et associés, 2009) (Fig 1). The Eleonore mine site is located in the bioclimatic domain of the spruce-moss forest in the boreal zone (Saucier et al. 2009). The typical forest vegetation that surrounds the mine

includes jack pine (*Pinus banksiana* Lamb.), paper birch *(Betula papyrifera* Marshall.), leatherleaf (*Chamaedaphne calyculata [L.]* Moench), and black spruce (*Picea mariana* [Mill.]) (Golder et associés, 2010). In this region, the growing season is short (about three months) (Gouvernement du Canada, 2020). The climate is subpolar, and the average annual temperature is -2.9 °C (Gouvernement du Québec, 2019). The average monthly temperatures rise to 13.7°C in July (the warmest month of the year) and fall to -23.2 °C in January (the coldest month of the year). Precipitation is most abundant in September. The average annual precipitation at the meteorological station "La Grande Rivière A" is 684 mm.

Underground mine operations began in October 2014 by Goldcorp. The first gold pour was on October 1, 2014, and it achieved commercial production on April 1, 2015 (Newmont, 2020). In April 2019, Newmont partnered with Goldcorp and became the owner of the mine (Newmont, 2020). The gold ore at Eleonore mine comes from the Roberto deposit and is processed on-site using a conventional circuit that includes crushing, grinding, gravity, flotation, and cyanidation. Eleonore mine produces between 500,000 and 600,000 ounces of gold per year (LeDevoir, 2015). The desulphurized and filtered tailings are potentially contaminated neutral drainage (CND) generators and contain arsenic (As) (Poirier, Pabst, Painchaud and Sara, 2021). They are co-disposed with waste rock in the TSF; about 16.0 Mt of tailings and waste rock will be stored in the TSF by the end of mining operation (currently scheduled for 2028) (Poirier et al., 2021). To control fluid movement into the tailings, the TSF will be reclaimed using a low saturated hydraulic conductivity cover with geomembrane (GM). More information on the use of GM for mine site reclamation can be found in: Bussière and Guittonny, 2021; Maqsoud et al. 2020; Rarisson, 2021; and Rarisson et al., 2022. Then, the reclaimed TSF will be revegetated to comply with regulations.



175 *Fig1. Eleonore mine location (ÉEM impact., 2019)*

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2.2 Eeyou Istchee and the James Bay Cree

Eleonore mine is situated in Eeyou Istchee, the homeland of the Cree Nation in Quebec. The Cree Nation is composed of approximately 14,500 people who live in nine village communities located on the shore of James Bay and Hudson Bay as well as inland (Affaires autochthones et du Nord Canada, 2019). Cree traditional territory, which extends over 400,000 km^2 (see Figure 1), supports a mixed economy involving traditional hunting, fishing, and trapping activities as well as paid employment in the industrial and service sectors. The territory is divided into over 300 traditional family hunting grounds and traplines, ranging in size from approximately 230 to several thousand km^2 (the average trapline size is 1,200 km^2) (Feit, 1985; Whiteman, 2004; Cree Nation, 2022). Each trapline is managed by a tallyman (Kaanoowapmaakin), a senior hunter, and a land steward (Whiteman, 2004; Carlson, 2009).

During the 1970s, in the context of the massive James Bay hydroelectric project development, the Cree created a structured political organization called the Grand Council of the Crees of Quebec (Morantz, 2002; Secrétariat aux affaires autochtones du Québec, 2019). In 1975, the Cree (along with Inuit in Northern Quebec) signed the James Bay and Northern Quebec Agreement (JBNQA) with the governments of Canada and Quebec (Rodon, 2014; Rodon, 2017). This agreement gave the Cree the exclusive ownership of territories covering 5,544 km^2 and the exclusive rights of hunting, fishing, and trapping on an area of 69,995 km^2 (Affaires autochtones du Québec, 2019).

Under the JBNQA, the Cree assumed responsibility for and control of the governance of health, social services, education, and income security in their territory (Rodon, 2014). These benefits allowed the James Bay Cree to create Cree institutions and administrative organizations, and many enterprises contributing to its economic development (Rodon, 2014). However, the implementation of this agreement created some conflicts with resource development and management. Thus, in 2002, the Quebec government and the Cree nation agreed to resolve these issues by signing a new collaboration called the "*Paix des Braves*", the Peace of the Braves (Rodon, 2014; Affaires autochtones du Québec,

2019). As well as establishing a framework for Cree Nation self-government, this agreement granted the Cree a greater share in resource revenues and a larger role in land and resource management in Eeyou Istchee.

The Cree community closest to Eleonore mine is Wemindji, also called Iyiyuuch (which means "the people" in the Cree language. The population of the Wemindji Cree Nation is estimated at 1,444 (Statistique Canada, 2017) who live mainly in Wemindji Cree village (Carlson, 2008; Secrétariat aux affaires autochtones du Québec, 2019; Affaires autochtones du Québec, 2019). The Wemindji Cree Nation is governed by an elected band council with headquarters in Wemindji. In Cree culture, the tallyman is the guardian of the territory, and a recognized leader in an Indigenous system of trapline management. The tallyman exercises particular responsibility for land and resource management within defined trapline territories, and “the tallymen’s ecologically embedded knowledge, beliefs, and practice formed the basis for their cultural legitimacy as leaders and decision makers about local natural resource management” (Whiteman, 2004, p. 427). Thus, in the context of mine development and reclamation planning, the tallyman plays a particular role related to Indigenous participation, alongside the Cree Nation Government.

2.3 Governance approach of Eleonore mine to integrate the Cree community into the reclamation process

In Canada, the Crown has a legal duty to consult and accommodate Indigenous communities in relation to land and resource development (Papillon and Rodon, 2017; Bradshaw et al., 2018). This consultation process is often delegated to mining companies, which has led many mining companies to negotiate resource revenue sharing agreements through Impact and Benefit Agreements (IBA) or similar agreements with Indigenous communities (Prno et al., 2010). These agreements are a means to facilitate the acceptability of development projects on Indigenous lands, since they establish guidelines for Indigenous employment and community development, and include provisions for profit sharing (Rodon et al., 2018b), environmental management, and biodiversity conservation (Descôteaux, 2015). Through these agreements, Indigenous communities are increasingly

233 able to obtain a share of the revenue from resource development that takes place in their
234 territory, as well as participate to varying degrees in project governance and oversight
235 (Rodon et al., 2018b).

236 In 2011, Eleonore mine signed a collaboration agreement (the "Opinagow Collaboration
237 Agreement") with the Cree. This agreement establishes a collaborative relationship
238 amongst the mine, the Cree Nation of Wemindji, the Grand Council of the Cree of Eeyou
239 Istchee, and the Cree Nation Government during mining activities, while respecting the
240 traditional and cultural values of the Cree (GoldCorp, 2015; Descôteaux, 2015). In the
241 agreement, the mine commits to involve the Cree Nation, as well as particular
242 communities, in the entire mine site reclamation process (GoldCorp, 2015).

243 To integrate the Cree in the reclamation process, Eleonore mine uses a "co-design
244 approach." This approach involves Indigenous people and local communities as partners
245 in the project design process (Sanders, 2002; Muller, 2002; Sanders, 2008; Mager 2008;
246 Botero and Hyysalo, 2013; Moser, 2016; Marin, Ely, and Van Zwanenberg, 2016; Daly et
247 al., 2021). Reclamation co-design includes common steps that make it relevant for projects
248 with Indigenous people: (a) stakeholder consultation, (b) problem definition, (c) idea
249 generation, and (d) collaborative work to make decisions and build the project (Frow,
250 Nenonen, Payne and Storbacka, 2015; Bradford, et al., 2018; Zamenopoulos and Alexiou,
251 2018).

252 By following these steps, Eleonore mine's operator aims to inform, consult, and involve
253 the Cree Nation in the TSF reclamation process (Fig 2). First, the mine must consult the
254 environment committee (composed of Eleonore mining employees, the Cree Nation
255 Government [CNG], representatives of the Cree Nation of Wemindji, and the Tallyman [or
256 his representative] responsible for the land where the TSF is located) in the preparation,
257 updating, and implementation of the mine reclamation plan. Secondly, the mine must
258 include the Cree community in the mine site reclamation activities. Thirdly, the company
259 must ensure that the reclamation will consider the future use of the site by the Cree Nation.

Fourthly, it must consult local land users to determine the plant species to be used in the revegetation scenario of degraded sites (GoldCorp, 2015).

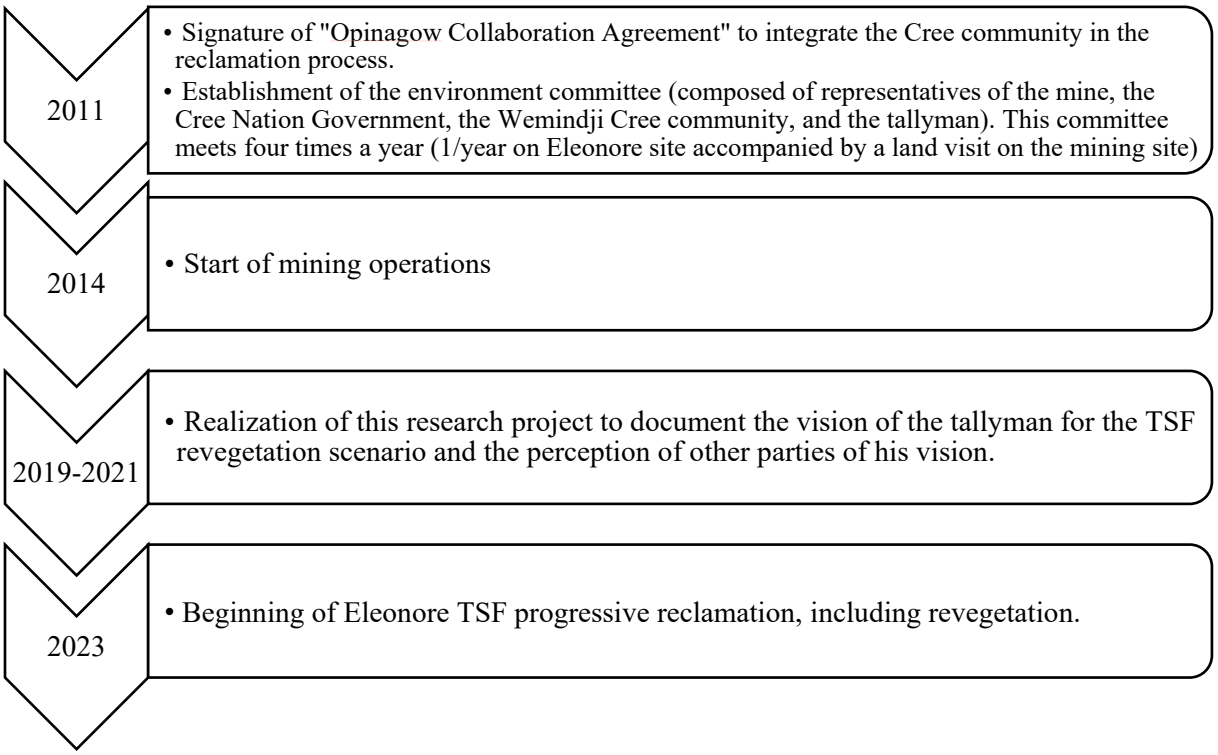

Fig 2. Governance approach of the mine to integrate the Cree into the reclamation process

The Eleonore mine site is on category 3 land:[g] more precisely, in the territory of VC-29's trapline. The road connecting the mine to James Bay is built on the VC-22 and VC-28 traplines (Newmont, 2020). Based on Cree land governance practices noted above, the Tallyman must be directly consulted on matters related to the mine reclamation. Since the TSF is on the territory of the Tallyman and his family, he will be the main user of the reclaimed mine site after closure. This person is thus central to the mine site reclamation and particularly for TEK integration into the revegetation process. At this stage, after 10 years of the "co-design" process, but before the beginning of the TSF reclamation, this

[g] Provincial public lands with exclusive hunting, fishing, and trapping rights for certain species, only for the Crees and Naskapis (Gouvernement du Québec et Nation Crie, 2012).

study was undertaken in collaboration with the mine and the Cree Nation. It documents the vision of the Tallyman for the TSF revegetation scenario and the perception of other parties of his vision.

It should be noted that this study was proposed by researchers as part of the research program of the NSERC-UQAT Industrial Research Chair on mine site reclamation, and was approved by the mine, which partly funds the chair research program. The project was conducted by an independent environmental scientist, doing PhD studies at UQAT in accordance with the principles of the UQAT research ethics committee. Ethical considerations were carefully planned and taken into account for the interviews, and an ethics certificate was obtained in October 2020 from le Comité de l'éthique de la recherche de l'Université du Québec en Abitibi-Temiscamingue (CER-UQAT). The PhD student received a scholarship from UQAT. He was put in contact with the Tallyman and the environment committee and CNG representatives by the mining company. This study was not part of the Opinagow Collaboration Agreement. The researcher collaborated independently with the Tallyman, the mine, the CNG and Quebec government, during the study.

2.4 Data collection

This project commenced in June 2019 with a meeting with the Eleonore mine environment committee, which includes representatives from both the mine and the Cree Nation. The purpose of this meeting was to explain the project, gather their opinions on the TSF revegetation scenario, identify the main parties, and visit the TSF and the surrounding territory with the representatives. This first stage of data collection was also an opportunity for the researcher to become familiarized with all the parties (including the Tallyman). The parties and participant selection criteria were specified (through a review of relevant reclamation regulations in Quebec) and are summarized in Table 1. This study prioritized participants directly involved with or having knowledge of mine reclamation regulations and revegetation scenarios.

Table 1

301 Parties and participant selection criteria.

Interview #	Parties	Role and responsibilities	Participant selection criteria
1	Ministère de l'Énergie et des Ressources naturelles (MERN)	Responsible for the analysis and approval of the TSF reclamation plan	Mine site reclamation experts
2	Ministère de l'Environnement et de la Lutte contre les Changements climatiques (MELCC)	Responsible for the analysis and validation of the TSF reclamation plan	Mine site reclamation experts
3	Eleonore mine	Responsible for the TSF reclamation	Managers of the TSF reclamation
4	Cree Nation Government (CNG)	Member of the Eleonore environment committee	Workers from Environment department
5	The Tallyman of VC-29	Final land user after reclamation Holder of the TEK on the land to be rehabilitated	Eleonore TSF is located on his territory

302 Two weeks before the interviews, participants were given a consent form and
303 questionnaire. Then, semi-directed interviews were conducted with them by video
304 conference (due to COVID-19) in December 2020 and January, February, and March 2021.
305 In total, seven people were interviewed: the Tallyman, two people from Eleonore mine,
306 one from the MELCC, two from the CNG, and one from the MERN.

307 The interview with the Tallyman was conducted first. The key objectives of this interview
308 were to:

309 • inform the Tallyman about the Eleonore TSF reclamation plan involving a cover
310 system to prevent the contamination of his territory;
311 • understand his opinion (based on his cultural and traditional knowledge point of
312 view) of TSFs and their reclamation;
313 • identify his concerns and expectations for the revegetation scenario of the Eleonore
314 TSF; and
315 • identify the types of vegetation that he prioritizes in the revegetation scenario for
316 the TSF and the reasons for his choices.

During this interview, the Tallyman was asked to show the researcher, in the area surrounding the Eleonore mine site, the types of vegetation that he prioritizes in the revegetation scenario of the TSF. Finally, the key objective of the interviews with the rest of the participants was to solicit their perceptions of the vegetation types chosen by the Tallyman for the revegetation scenario of the TSF.

Data collection was considered complete when all the questions were addressed, and the key objectives of the interviews were achieved. The interview with the Tallyman was approximately three hours. While the interviews with the rest of the participants (the mine, the CNG, the MELCC and the MERN) each lasted approximatively 1 hour 30 minutes. All the interviews were recorded on a digital recording device. The recordings were then transcribed verbatim in French except that of the Tallyman, which was recorded in English.

2.5 Data analysis

First, the interview transcripts were validated with the participants. Then, interview data were assembled and analyzed through thematic analysis. This involved sorting the data according to themes (Oplatka, 2001) and examining the relationship between respondents' views and repeated comments contained in the interview transcripts (Ackerman et al., 2018). The responses contained in the interview transcripts were categorized into the following themes: (1) the governance process for TEK integration into the Eleonore TSF revegetation process; (2) specific and divergent visions and objectives of the Eleonore TSF revegetation scenario; and (3) challenges of integrating TEK into the Eleonore TSF revegetation process. The following sections present the main results according to the three themes as articulated by the stakeholders.

3 Results

3.1 Governance process for TEK integration into the Eleonore TSF revegetation process

3.1.1 Quebec government

First and foremost, as the MERN representative explained, the Quebec provincial government is the legislative authority with respect to mine closure and reclamation [MERN representative (Interview #1)]. The province requires mining companies to plan and perform the reclamation of their mining sites, subject to approval. The reclamation plan approval is renewed every five years. Representatives of both ministries (MELCC [Interview #2] and MERN) mentioned the important regulatory and technical aspects related to the reclamation process: physical and chemical stability of mine waste, securing mining openings and dikes according to environmental standards, revegetating mining sites, and considering climate changes on reclaimed sites [Interviews #1 and 2]. For instance, according to Quebec regulations, a mining site is satisfactorily reclaimed if the water leaving the site has concentrations of potentially contaminating elements below defined thresholds. Water quality monitoring is mandatory for 10 to 20 years depending on the type of contaminants potentially present in the water.

However, TEK is not one of the elements required by the Quebec government in the reclamation process [Interview #2]. Indeed, while the government requires the development of an advisory committee (with, among others, representatives of the local community) to be set up at the beginning of the mining project, which could include the Indigenous community, the government does not specifically require that mining companies integrate TEK into their mine site reclamation plans [Interview #1]. As indicated above, integrating the TEK of the Tallyman into the Eleonore TSF revegetation process is not legally required in the Quebec Mine Reclamation Guidelines. However, if the mine decides to do so, the Quebec government will not disagree, as long as it does not affect the technical aspects of the reclamation. The MELCC representative commented that integrating the Tallyman into the TSF revegetation process is very interesting, but that the species chosen by him should not negatively impact the performance of the cover system: “The choice of the scenario should be done on the basis of scientific studies, in addition to the Tallyman’s TEK” [Interview #2]. In addition to the TEK, the mine should consider the other aspects of the revegetation scenario (such as the technical, biological, and chemical aspects of the TSF revegetation).

3.1.2 Eleonore mine

Mine representatives emphasized the involvement of Indigenous partners in its activities and the integration of the TEK of the Tallyman into the TSF revegetation process as part of Newmont's governance approach [Mine representative (Interview #3)]. This community involvement is described in the "Opinagow Collaboration Agreement," drawn up between the mine and the Cree Nation, and in Eleonore mine's "Global Certificate of Authorization" delivered by the MELCC. Company officials mentioned that TEK integration into its TSF revegetation process is necessary, even if the Quebec government does not require it:

> We are not obliged by the government to take into account all the Cree's opinions [...], however, for the renewal of our certificates of authorization, we are obliged to give the reasons (which may be technical, economic, etc.) why we were not able to take into account one or more of the Cree's opinions […] [Interview #3].

Integrating the Tallyman's knowledge in the TSF revegetation process is not clearly specified in the "Opinagow Collaboration Agreement" [Interview #3], but in Cree culture, the Tallyman is "the guardian of the territory" [Interview #3]. So, logically, the Tallyman must be part of the decision-making process in the TSF revegetation and the reclamation of the rest of the mine site.

Eleonore representatives discussed several reasons why integrating the Tallyman's TEK into its TSF revegetation process is very important. First, doing so provides knowledge about the ecological services of the Cree territory that must be considered in the revegetation process. Secondly, it informs the mine about types of plant species that the Tallyman thinks will adapt to the substrate of the territory. Thirdly, it provides information that can be used to secure its works and workers on the mine site: "Often, the Cree community makes comments related to the safety of the works and that of the workers. We find it interesting" [Interview #3].

3.1.3 CNG and the Tallyman

The Cree Nation Government participants considered that TEK integration into mining reclamation processes, including revegetation, is essential. For the CNG, it is impossible to revegetate a mine site without using TEK of the territory in which it is located. This allows the reclamation plan to consider the future use of the territory by the local community. "In a nutshell, we think it is important to value TEK and use it in the revegetation process of Eleonore TSF" [The CNG (Interview #4)].

The CNG confirmed that the mine integrates the Tallyman's TEK into the TSF revegetation process through the environment Committee (of which the CNG and the Tallyman [or his representative] are members). This committee meets about four times a year and includes discussions about TEK integration into the Eleonore TSF revegetation process: "We [including the Tallyman] are well involved in the TSF revegetation process. There is a good relationship between us and other parties, including the mine" [Interview #4]. As Eleonore is one of the first modern mines in their territory, CNG officials emphasized that their collaboration with the mine helped inform them of different issues related to mine reclamation. "It is an opportunity for us to learn new knowledge of mining reclamation process. It is a capacity building for us" [Interview #4].

Finally, the Tallyman confirmed that he has a good relationship with the mine. As one of the members of the environment committee since 2011, he is involved in the mine TSF revegetation process. He emphasized that taking his knowledge into account in the TSF revegetation process is very important to him for several reasons. In particular, he does not want the mine to introduce exotic or southern species into the TSF revegetation scenario. He wants the vegetation of his territory to remain natural for future generations.

3.2 Specific (and divergent) visions and objectives for the Eleonore TSF revegetation scenario

The Tallyman's vision and objective for the Eleonore TSF revegetation scenario, as well as other actors' responses to it, are summarized in Table 2.

Table 2

425 Revegetation scenario favored by the Tallyman for the Eleonore TSF revegetation scenario
426 and the perceptions of the other parties about it.

The Tallyman's preferences	Other Parties perceptions of the Tallyman's expectations		
	CNG	Quebec government	Eleonore mine
Prefers using only jack pine in the TSF revegetation scenario to divert the animals from the reclaimed site, as he believes the TSFs are toxic areas.	The Tallyman and his family have their own reasons for their choice. The Tallyman has primary responsibility for his territory.	The mine can use the Tallyman's choice, if scientific studies demonstrate that it does not affect, in the short and/or the long term, the performance of the engineered covers and obeys the requirements of the Quebec government. The government does not impose a revegetation scenario on a mining company.	The mine will use the choice of the Tallyman if scientific studies demonstrate that it follows the Quebec government requirements. But, to control erosion, ensure the integrity of the cover system, compensate for the loss of wetlands, and conserve the biodiversity, he must accept the use of herbaceous and other local species in the revegetation scenario.

427 The Tallyman has a specific scenario in mind for the TSF revegetation. In his view, TSFs
428 are areas that can contaminate plants, animals, and the food chain. Therefore, he does not
429 want plants or trees to grow on Eleonore's TSF: specifically, plants that can attract animals
430 (like bears, moose, rabbits, geese). He does not want the mine to use herbaceous plants in
431 the TSF revegetation scenario. Eleonore mine informed him that they are going to reclaim
432 the TSF with a cover system to keep contaminants inside the tailings. But he remains
433 adamant:

434 > I prefer that they use cover systems if my opinion matter. But for us [tallymen and
435 > their families] TSF is a toxic area. It is dangerous for plants, animals and for human
436 > beings. The Tallyman of Porcupine Gold mine at Timmins in Ontario advised me
437 > that I should not hunt on the TSF after mine closure or the reclamation process
438 > [Interview #5].

439 But, if the mine must revegetate the TSF, he said that he prefers only jack pines (*Pinus*
440 *banksiana* Lamb.) to keep animals away, because, according to his TEK, animals are not
441 interested in that type of tree. Apart from jack pine, the Tallyman says he does not want
442 any other type of plants on the reclaimed site. He told the mine not to use the topsoil on the
443 TSF, because topsoil could have some seeds of natural plants that will grow on the TSF
444 and attract animals.

> I do not want them [exotic or southern species] in my territory. These species can modify wildlife habitats and cause the presence of exotic insects, which will undoubtedly influence the fauna in my territory. I want future generations in my territory to be able to hunt like I do. If I have a choice, I want the vegetation of my territory to remain natural [the Tallyman (Interview #5)].

Furthermore, Eleonore mine informed him that the reclaimed TSF will be sloping and plants on it must be suitable to avoid erosion, windthrow, and deep rooting. But in his point of view, jack pine is suitable to avoid windthrow and deep rooting, and grows on different land, on rock, slopes, hills, etc. [Interview #5].

According to the CNG and the Quebec government, the final mine TSF revegetation scenario is still unknown. Indeed, the CNG has not yet received a reclamation scenario proposal from the mine [Interview #4]. However, the CNG representatives considered that the Tallyman has his reasons to make this choice for the TSF revegetation scenario and declined to comment on his opinions, "since we are not specialists on the TSF revegetation" [Interview #4] and the Tallyman has primary responsibility for his territory. For the MELCC, it was too early to identify the specific TSF revegetation scenario, because it is still under study by the mine. The MELCC representative clarified that the revegetation scenario should be presented in the next revision of the mine reclamation plan. The key consideration for the MELCC representatives is that the selected scenario must not affect, in the short and/or the long term, the performance of the geomembrane cover system:

> […]. If the mine shows us, through scientific studies, by integrating the aspect of climate change, that the roots of jack pine do not affect (in the short and/or the long-term) the performance of the chosen cover scenario, the ministry will not refuse its use in the revegetation scenario [Interview #1].

Nevertheless, the MELCC representative remained skeptical on the use of jack pine on the cover system, because "it is not a species used in revegetation scenarios on cover systems. [...] According to my experiences and knowledge, it does not seem to me a good choice. It seems to be a species with deep rooting. But the studies will tell" [Interview #2].

Eleonore mine representatives confirmed it has not yet determined the revegetation scenario of its TSF, which is still under study. However, mine officials confirmed plans to use native plant species and take into account as much as possible the preferences of the Tallyman and that of the rest of the Cree community:

> The criteria for selecting the revegetation scenario of Eleonore TSF are: (a) the use of native plants in the scenario, (b) valuing the choice of the Cree community, including that of the Tallyman, and (c) taking into account the integrity of the cover system. This point (c) is really important for us; it ensures the integrity of the cover system and thus protects the environment [Interview #3].

Eleonore mine officials believe that the Tallyman's choice is very limited, because they could not use only one species in the Eleonore mine TSF revegetation scenario. First, they have an offsetting plan to respect (which consists of compensating for the loss of wetlands impacted by the construction of the infrastructure of the mine). In this offsetting plan (fully developed with the Cree community including the Tallyman), the mine plans to revegetate the degraded areas to compensate and restore the biodiversity [Interview #3]. Therefore, Eleonore mine officials consider that herbaceous plants and shrubs should also be kept on the reclaimed TSF, because there is an ecological structure to be respected in connection with their offsetting plan [Interview #3].

Secondly, another important element of the TSF revegetation scenario is to prevent water erosion: "If we plant only jack pine at every 2 m on the reclaimed site, we will not be able to stop erosion" [Interview #3]. From a technical perspective, erosion is one of the factors that can cause a loss of efficiency of the cover system used on the TSF.

> [...], if we only plant jack pine on the reclaimed TSF, we will have cracks (about 2 feet [61 cm] deep), which will be created after one year because of water erosion. That is what is currently happening on the not reclaimed TSF slopes, as we know. There are many slopes at the Eleonore TSF compared to traditional tailings facilities [Interview #3].

The priority of the mine is to stabilize the site and protect the cover system with GM that will control the contamination of the environment. That is why, in response to the Tallyman's preferences and the constraints in following them, the mine stated that to use jack pine in the revegetation scenario, scientific studies need to demonstrate that this plant can ensure the stability of the site, combat water erosion, and will not affect the performance of the cover system. These aspects of performance are part of the requirements of the Quebec government. Secondly, the mine needs to use herbaceous plants on reclaimed TSF to quickly stabilize the site against water erosion. The site could later be colonized by shrubs and trees according to a natural plant succession process.

The Quebec government requires the vegetation to be stable and sustainable over time. However, the risk of a monoculture is that if the jack pine does not develop well on the site, it will be necessary to make corrections (to correct the TSF revegetation scenario). Mine officials suggested that the plant species on the TSF will vary over time, since the ecosystem is dynamic. This is one of the elements that must be studied to determine if these new plant species affect, in the long term, the performance of the cover system. Finally, the objective of the Eleonore TSF revegetation is to bring the site back as much as possible to its previous, natural state. So, mine officials commented, "we must not fool ourselves that we can stop animals entering the revegetated TSF" [Interview #3]. Overall, the site is difficult to control: "Whatever we plant on the reclaimed TSF, it will, later, be colonized by other plant species" [Interview #3]. Thus, despite its commitment to incorporate TEK into the reclamation scenario, the mine is faced with a challenge to reconcile the Tallyman's vision with the technical and regulatory requirements for mine reclamation.

3.3 Challenges of integrating TEK into the Eleonore TSF revegetation process

Despite ten years of discussions supported by the environment committee, the TSF revegetation scenario has been discussed only recently. Now, as the mine approaches the revegetation, the more apparent the challenges related to the integration of the Tallyman's TEK have become, and therefore the need to deepen the dialogue with him [Interview #3]. Incorporating the Tallyman's TEK and the technical aspects of the TSF reclamation in the

co-design process presents several challenges, including the Tallyman's understanding of the TSF, divergent visions for the TSF revegetation, and the difficulties of reconciling these with regulatory requirements. Often, the Tallyman is skeptical of what the mine tells him about the technical aspects of the TSF reclamation process. According to the mine, the Tallyman should have access to a trusted external resource, possibly from the CNG, which could provide independent technical information [Interview #3].

It is important to emphasize that the Quebec government's requirements for mine site reclamation focus more on technical aspects than on TEK integration into the reclamation process. Indeed, the MELCC representative recognizes that integrating the Tallyman's expectation into the Eleonore TSF revegetation process may be challenging. The Quebec government urges the mine to continue to consult with the Tallyman to satisfy his concerns. However, the government's hierarchy between technical and TEK aspects is clear:

> The species chosen by the Tallyman should not have a negative effect on the technical aspects of the TSF revegetation scenario. The choice should be made on the basis of scientific studies, in addition to the TEK of the tallyman. […] Eleonore mine should consider first the technical aspects of the TSF revegetation scenario [Interview #2].

If scientific studies demonstrate that the Tallyman's preferences have a negative effect on technical aspects of TSF revegetation scenario, the mine should use other plant species in order to meet the Quebec government technical requirements, because "the MELCC will not accept the reclaimed TSF to be left without vegetation" [Interview #2]. The revegetation of the reclaimed TSF site is required to prevent erosion and limit water infiltration to the tailings [Interview #2].

According to the CNG, although collaboration on the TSF revegetation process involves opportunities for all parties, it also presents challenges. For the CNG, the main challenge associated with this collaboration is "the reconciliation of the different parties' expectations" on the Eleonore TSF revegetation process [Interview #4]. To meet this challenge and have a TSF revegetation that integrates the expectations of all parties, CNG

urges ongoing dialogue and discussions until the completion of the revegetation process, because “the mine must not force a solution or an opinion on the Tallyman and the Cree” [Interview #4]. The Cree government recommends that Eleonore mine give time to the Tallyman and all the Cree representatives to discuss family concerns and come back later with an answer that reflects the opinion of the Cree community.

4 Discussion

4.1 TEK integration into the TSF reclamation process

The interview results demonstrate that there is a recognition among all parties that TEK integration is important for mine closure and reclamation success. This is in line with the recommendation of Sistili et al. (2006), Xavier et al. (2015), Beckett and Keeling (2019), and Daly et al. (2021) for mine closure success. These authors recommend that mining companies should work with Indigenous communities to understand and apply local expertise for TEK integration into reclamation planning. Although Quebec’s formal mine reclamation regulations do not require this integration, the existing agreements between Eleonore and the Cree Nation (including the Tallyman) provide a context for doing so, through the environment committee. In general, this kind of negotiated agreement between mining companies and Indigenous communities often conpensates for these shortfalls in regulations. However, this could influence the free, prior, and informed consent of local communities, since ethical aspects may not be respected in these agreement processes (Papillon and Rodon, 2017). Therefore, these agreements between mining companies and Indigenous communities need to be regulated by the governments of mining countries. This weakness in the regulations is indicative of the need for TEK integration in mining reclamation processes (Beckett et al., 2020; Monosky and Keeling, 2021) to pressure mining companies to adopt approaches that incorporate TEK in mine site revegetation processes. This understanding was confirmed by the representative of the MERN in this study. Furthermore, the lack of regulations does not necessarily mean that mining companies will meet only the bare minimum requirements in their reclamation processes (Beckett, et al., 2020).

584 The process of TEK integration through early planning and consultation at Eleonore is a
585 positive approach and reflects best practices (Collins, 2015). The approach used by
586 Eleonore mine is similar to that used by New Gold Cerro San Pedro Mine, in Mexico,
587 although the New Gold case was focused on post-mining land use and economic
588 development. This mine used a participatory approach to define the company's Integrated
589 Closure Strategy (Costa, 2015). A committee (composed of representatives of the mine,
590 the local community, and the local government) was set up to discuss the social aspects of
591 closure. The approach was based on dialogue with key parties (the local community in
592 particular) to identify the social impacts of closure and to build together a feasible
593 sustainability path forward. Lessons learned included, among others, the relevance of
594 engaging local community from an early stage to achieve responsibility for a prosperous
595 future (Costa, 2015). These lessons will influence how New Gold plans and implements
596 reclamation in the future.

597 Similarly, the Red Dog mine in Alaska set up a committee to discuss reclamation with the
598 local community (the Inupiat) and to take into account their concerns (Hockley and
599 Coulter, 2010). The process took four years and was realized through several information
600 and communication sessions with the Inupiat (Hockley and Coulter, 2010). This strategy
601 of establishing a committee for TEK integration into reclamation processes is emerging in
602 Canada. In 2018, the Raglan mine created a subcommittee to develop a mine closure plan
603 that integrates social aspects (Beckett, Keeling and Monosky, 2021; Closure Plan
604 Subcommittee of Raglan Mine, 2021). This subcommittee includes representatives from
605 the mine, the communities (Salluit and Kangiqsujuaq), the Makivik Corporation, and third-
606 party experts in technical and social reclamation (Closure Plan Subcommittee of Raglan
607 Mine, 2021). The presence of experts in technical and social reclamation on this
608 subcommittee and its creation prior to reclamation are some of the advantages of the
609 Raglan mine's strategy.

610 *4.2 Advantages and challenges of integrating TEK into the TSF reclamation process*

611 All parties agree on the advantages of TEK integration into the Eleonore TSF reclamation
612 process. These advantages suggest that governments, mining companies, and Indigenous
613 communities should collaborate to integrate TEK into the processes for mine reclamation
614 success. First, this allows TEK to complement Western science in reclamation planning
615 (Vanspronsen et al., 2007). Tsuji and Ho (2002) think that we should not talk about TEK
616 *integration* into technical (Western science) aspects of reclamation, but rather the
617 *complementarity* between the two, since TEK can provide information that is not available
618 in Western science (such as historical and cultural information) (Sistili et al., 2006). For
619 example, TEK integration is crucial to understand plants and animals of the region and how
620 to sustainably manage local resources (Johnson, 1992). Secondly, it allows reclamation
621 plans to take into account Indigenous concerns about the long-term environmental and
622 social legacy of the mine (Sandlos and Keeling, 2016). This approach addresses potential
623 social conflicts and promotes the social acceptability of future mining projects in mining
624 areas. Thirdly, it allows integration of the prospects and priorities of Indigenous people
625 with regard to land use after mining reclamation (REO, 2011; Collins, 2015).

626 Nevertheless, as illustrated by the Eleonore case, TEK integration into mining reclamation
627 and combining the social and technical aspects in the reclamation process remains
628 challenging. The Tallyman considers that TSFs are toxic areas that can contaminate plants,
629 animals, and the food chain. The risk of contamination of plants and animals on the
630 Eleonore TSF was mentioned several times during the interviews with the Tallyman. These
631 understandings and concerns are in line with other research on industrial and other
632 contaminants (Cassady, 2007; VanSpronsen et al., 2007). Indigenous people consider mine
633 sites as toxic areas (Sandlos and Keeling, 2016) and mine wastes as something deadly
634 (Poirier and Brooke, 2000). These understandings have important implications both for
635 technical reclamation scenarios and for post-mining land use planning.

636 In this study, the parties are approaching the TSF revegetation scenario from very different
637 perspectives and knowledges. For the Tallyman, the key issue is protection of wildlife and
638 concerns about contamination, based on his TEK and experience. For the Quebec
639 government and Eleonore mine, the key issue is the performance and the integrity of the

cover system, based on technical aspects of reclamation. This divergence contributes to making TEK integration a complex and continuing challenge. The case of the Inuit of Nunavik, Quebec, and biomedical researchers on environmental contaminants is an illustration (Poirier and Brooke, 2000). The two groups approached the issue from different directions. The biomedical researchers offered their specific knowledge of the hidden dangers of contaminants on human health. The Inuit, based on their TEK and past experience, developed a particular cultural understanding related these contaminants. For example, "*sukunaktuit"* (which means literally "destructive agents") is the word most commonly used by the Inuit of Salluit, Quebec, for "contaminant" in relation to mercury and asbestos pollution in their territory (Poirier and Brooke, 2000). This contributes to creating a mutual skepticism amongst Inuit and various members of the biomedical community, as well as divergent views of potential harms and mitigation strategies (see also Cassady, 2007; Tyrrell, 2006).

Now, as the TSF revegetation process unfolds, Eleonore mine is discovering the challenges related to the Tallyman's TEK integration. These challenges include the power imbalance between TEK and Western science (see Baker and Westman, 2018; Parlee, 2012) due to the dominance of Western science in environmental assessment and regulation, as well as the existence of many historical, political, social, and cultural barriers that can make interaction and communication between the parties difficult (Parlee, 2012). These challenges could affect the work of the environment committee to achieve a truly co-designed reclamation process. Continued dialogue with the Tallyman is essential to overcoming these challenges (see Daly et al., 2021), but according to the CNG, the mine should not force a revegetation scenario on the Tallyman. These discussions should address how the divergent concerns and perspectives can be incorporated into the TSF revegetation process. Furthermore, the Tallyman does not necessarily trust or believe what the mine tells him about the technical aspects of the process. Including third-party experts in technical and social reclamation (like in Raglan mine's subcommittee) in the Eleonore environment committee, to provide independent technical information and to train mine employees on TEK, could contribute to the success of the dialogue among parties.

From a technical perspective, the use of plants in the revegetation process that do not affect the performance of the TSF cover system was mentioned several times during interviews with Eleonore mine and the Quebec government. They remain concerned that jack pine could develop deep roots that can affect the cover's integrity. Quebec government representatives mentioned that before using jack pine, the mine must consult specialists in TSF revegetation to verify the feasibility of the scenario. This concern appears legitimate, as plants developing deep roots can affect the integrity of cover materials and cause water infiltration or oxygen migration through cover systems above reactive tailings, so reducing cover performance (Guittonny et al., 2018; Bussière and Guittonny, 2021). In a boreal context and on sloping sites (such as the Eleonore TSF), jack pine can develop a taproot system (MELCC, 2017). These taproots can dive deep into the ground up to 3 m (MELCC, 2017) to allow the tree to anchor the ground on the slope and avoid uprooting (Chiatante, Sarnataro, Fusco, Di Iorio, and Scippa, 2003; Danjon et al., 2007a and 2007b). As a result, the roots could reduce cover system performance and cause the dispersal of contaminants from the tailings to the environment (contaminated mine drainage).

On the basis of greenhouse studies, Stoltz and Greger (2006) have shown that jack pine roots were capable of penetrating sealing layers such as clay on various mining sites. Recently, Proteau et al. (2020, 2021) have determined, seventeen years after the construction of the cover system at the Lorraine mine site, the roots of plants colonizing the cover with capillary barrier effects (CCBE) could reach the functional silt layer, despite a protective layer of 30 cm thick at the surface and the high apparent density of the silt (1.6 g/cm^3). However, it should be remembered that each mine site has its own particularities, and the root development of plant species depends on several factors including the abiotic (e.g., soil, topography, climate) and biotic (e.g., competition) environments in which it takes place. Therefore, it is necessary to study the root development of jack pine in the Eleonore TSF context, as requested by the Quebec government, and also to continue discussions with the Tallyman until the end of the revegetation process to take into account his concerns.

The tallyman approach to risk management, based on his TEK and with the aim of minimizing the spread of possible contamination towards hunted fauna, is consistent with technical uncertainties in cover performance identified in the literature. Indeed, some experts highlight the potential impacts of vegetation on the long-term performance of cover systems (Bussière and Guittonny, 2021; Aubertin et al., 2016). At present, due to disciplinary barriers, the engineering design of cover systems is often performed without considering natural processes of ecosystem evolution. These processes take place over hundreds of years, can modify the cover materials and change its long-term performance. Climate change may impact the long-term performance of covers as well. However, the development of reliable future climate data, especially regarding extreme events, is needed to anticipate the long-term performance of cover systems with numerical models (Bussière and Bresson, 2021). Finally, the durability of some man-made materials used in cover systems is documented to be finite under controlled conditions in the technical literature, e.g. high density polyethylene (HDPE) geomembrane liners (Needham et al., 2006; Maqsoud et al., 2021). The issue of the inherent technical uncertainties surrounding long-term cover performance and ecosystem change suggests an additional rationale for engaging with and integrating TEK, based on its contributions to understanding long-term environmental and socio-cultural change (Beckett and Keeling, 2019).

5 Conclusion

This research analyzes the process of TEK integration into the Eleonore TSF revegetation planning by documenting the Tallyman of VC-29's TEK integration into the mine TSF revegetation process through a "co-design approach". Results indicate that the Quebec government recommends but does not require mining companies to integrate TEK in reclamation planning. The co-design approach used by Eleonore mine is a vision of Goldcorp governance (now Newmont) and reflects its commitment to Indigenous involvement in the Opiganow Agreement with the Cree Nation Government. The state of the parties' visions of the Eleonore TSF revegetation scenario is also documented here, after ten years of co-design process. The revegetation vision of the Tallyman is influenced by his understandings that a TSF is contaminated land that will stay contaminated even if

a reclamation method is applied to it. His plant choices are based on his desire to create an environment unattractive to animals. However, further investigation is needed to determine if the plants chosen by the Tallyman can endanger the cover system performance.

The main challenge of this case study appears to be related to reconciliation of the technical aspects of reclamation, in particular government requirements for reclamation performance, with the Tallyman's revegetation vision based on his TEK. Although Eleonore mine collaborates with the Cree Nation on the TSF reclamation through the environment committee process, the planning of the TSF reclamation is more focused on the technical aspects and rooted in Western scientific understandings. The results of this study highlight the importance of early integration and continuous community engagement in mine reclamation guidelines and practices. It is recommended that the Eleonore mine include third-party experts in technical and social reclamation on its environment Committee, continue discussions with the local community, and avoid enforcing a revegetation scenario despite the Tallyman's concerns. It is recommended that the Quebec government adopt laws and regulations to ensure that the TEK of Indigenous people is taken into account in mining reclamation processes while conducting more consultation and dialogue to reach consensus. The insights gained from this research can be applied globally to address the challenges of integrating TEK into mine site reclamation in consideration of community concerns. Combining social and technical aspects of mining reclamation is a best practice that will benefit all mines and local communities during the closure and reclamation process.

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