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February 25, 2022

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**Subject: Natural Resources Canada (NRCan) Written Submission for the Marathon Palladium Project**

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Dear Debra Sikora,

Please find attached NRCan's written submission for the Joint Review Panel hearings for the Marathon Palladium Project (the Project) as requested in your letter of December 17, 2021.

NRCan's written submission is guided by the August 2011 Environmental Impact Statement Guidelines issued for the Project and the mandate and expertise of NRCan.

Other than a possible explosive permit should the project proceed, NRCan is non-regulatory and the focus of our technical review covers geology, seismicity, acid rock drainage and metal-leaching, groundwater and caribou habitat and landscape functional connectivity.

NRCan's conclusions identify areas of uncertainty and our recommendations suggest mechanisms for resolution.

If you have any questions or concerns regarding this submission, please contact Marie-Eve Lenganh by email at <Email address removed>

Sincerely,

*Original signed by*

**Caroline Cloutier**

Senior Director, Impact Assessment and Science Capacity  
Office of the Chief Scientist  
Natural Resources Canada

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**Natural Resources Canada's Final Submission to the Joint Review Panel regarding the  
Marathon Palladium Project proposed by Generation PGM Inc.**

February 25, 2022

Signed on behalf of Natural Resources Canada

*Original signed by*

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**Caroline Cloutier**

Senior Director, Impact Assessment and Science Capacity  
Office of the Chief Scientist  
Natural Resources Canada

February 25, 2022

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Date Signed



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## ABBREVIATIONS

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Agency	Impact Assessment Agency of Canada
ARD/ML	Acid Rock Drainage and Metal Leaching
CanLad	Canada Landsat Disturbance
CASFRI	Common Attribute Schema for Forest Resource Inventory
C2C	Composite-to-Change
CEAA	Canadian Environmental Assessment Act
CFS	Canadian Forest Service
CNFDC	Canadian National Fire Database Composite
DDF	Disturbance Data Foundation
ECA	Environment Compliance Approval
ECCC	Environment and Climate Change Canada
EMMP	Environmental Monitoring and Management Plan
EIS	Environmental Impact Statement
FireMARS	Fire Monitoring, Accounting and Reporting System
FRI	Forest Resources Inventories
GIS	Geographic Information System
GRT	Government Review Team
GSC	Geological Survey of Canada
HDPE	High Density Poly Ethylene
IR	Information request
JRP	Joint Review Panel
LSCR	Lake Superior Coastal Range
LMS	Lands and Minerals Sector
MAGPlot	Multi-Agency Ground Plot
MECP	Ministry of the Environment, Conservation and Parks
MEND	Mine Environment Neutral Drainage
MRSA	Mine Rock Storage Area
Mt	Million tonnes
NBAC	National Burned Area Composite
NBCC	National Building Code of Canada
NAG	Net Acid Generation
NDMNR	Ministry of Northern Development Mines, Natural Resources and Forestry
NRCan	Natural Resources Canada
NFI	Natural Forest Inventory
OGSMRD	Ontario Geological Survey Miscellaneous Release Data
PAG	Potentially acid generating
PGM	Platinum Group Metals
PSMF	Process Solids Management Facility
RSA	Regional Study Area
SARA	Species at risk Act
SSA	Site Study Area
SIR	Supplemental Information Request
WMP	Water Management Pond



## EXECUTIVE SUMMARY

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NRCan participated in the environmental assessment of the Marathon Palladium Project as a Federal Authority with relevant technical expertise and as a federal regulator under the *Explosives Act*. Both these roles are derived from the departments mandate to ensure the country's natural resources are developed sustainably, competitively and inclusively.

NRCan has provided expertise in the areas of geology, seismicity, hydrogeology, Acid Rock Drainage and Metal-Leaching (ARD-ML), caribou habitat suitability and landscape functional connectivity and economic considerations. NRCan may be required to issue a permit pursuant to Section 7.1(a) of the *Explosives Act*.

NRCan researchers reviewed the Proponent's documentation and provided 12 recommendations for additional information and monitoring to further reduce the potential for adverse environmental affects, as defined under the *Canadian Environmental Assessment Act* (CEAA 2012) and as related to our mandate. This additional work will resolve uncertainties in potential long-term effects and to focus the deployment of mitigation and monitoring measures.

NRCan is generally satisfied with the Proponent's geological characterisation of the project site and the associated effects of mine operations on groundwater and the potential for acid rock drainage and metal leaching.

Nevertheless, the method used to report groundwater model results relating to discharge to surface waters creates uncertainty in how project operations may affect surface water flows and wetlands. Recommendations are provided for the model results to be presented in detail for an improved understanding of expected changes in groundwater discharge. Recommendations are also provided for long-term monitoring as related to potential seepage from the Mine Rock Storage Area (MRSA) and the Process Solids Management Facility (PSMF).

Data gaps also contribute to uncertainty in the risk of ARD-ML with recommendations addressing better definition of the leaching potential of waste rock proposed for construction, additional sampling and testing of mine rock during operations for a more representative distribution of results, a sensitivity analysis of mine rock to improve water quality predictions and to ensure adequate water treatment, mitigation and monitoring measures are in place and to specifically assess the potential releases of platinum group metals and concentrations in surrounding receptors.

NRCan's Canadian Forest Service researchers recommend methodological improvements to the assessment of woodland caribou habitat suitability and connectivity to better assess project risks to range connectivity. Given that off site mitigation plans lack sufficient detail, the degree to which off-site mitigation measures may improve inter-range connectivity cannot be readily determined.

NRCan concludes that with the implementation of the groundwater and ARD-ML recommendations for further mitigation and monitoring, the associated project impacts are reasonably assessed, within normal ranges and can be managed through modern site management practices. The extent to which the project may affect caribou habitat remains uncertain until additional work can be completed.



## 1 INTRODUCTION

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### 1.1 Departmental Mandate

Natural Resources Canada (NRCan) is committed to improving the quality of life of Canadians by ensuring the country's abundant natural resources are developed sustainably, competitively and inclusively. NRCan develops policies and programs that seek to enhance the contribution of the natural resources sector to the economy, improve the quality of life for all Canadians and conducts innovative science in facilities across Canada to generate ideas and transfer technologies. NRCan is an established leader in the fields of energy sources and distribution; forests and forestry; minerals and mining; earth sciences; energy efficiency and science and data.

Scientists, technical specialists and economists from the Lands and Minerals Sector (LMS) and the Canadian Forest Service (CFS) of NRCan are participating in the environmental assessment of the proposed Marathon Palladium Project.

Since 1842, the Geological Survey of Canada of LMS has produced cutting-edge, authoritative geoscience to support mineral exploration, climate change research, marine and coastal resilience, and natural hazards mapping.

CanmetMINING is a world-class leader in the research and development of mining innovation technologies related to extraction, processing and reducing impacts to the environment. Research scientists from CanmetMINING can support the review of areas of the Project related to mine waste management, acid rock drainage and metal leaching, and potential impacts to sediment and water quality.

Also within LMS, the Explosives Regulatory Division, ensures that manufacturers, importers, exporters, and vendors of explosives, as well as those who store explosives or sell restricted components, comply with Canada's *Explosives Act* and its regulations.

The Policy and Economics Branch of LMS ensures that Canada's minerals sector is innovative, sustainable, and globally competitive. Its work helps to provide governments, industry and communities – including Indigenous peoples – with the knowledge they need to make informed, evidence-based policy decisions. The branch provides advice on a range of economic and policy issues in both the domestic and international context.

NRCan's Canadian Forest Service (CFS) provides science and policy expertise, and advice on national forest sector issues. CFS promotes environmental leadership in Canada's forest sector, a visionary approach to sustainable forest management planning and policies, as well as a science and research-based understanding of forests.

### 1.2 NRCan's Participation in the Joint Review Panel Environmental Assessment

Since the beginning of the assessment of the project in 2010 (CIAR #9), NRCan has been participating as a Federal Authority in the environmental assessment by Joint Review Panel (JRP) of the Stillwater Inc. (now Generation PGM Inc.) (the Proponent) proposed Marathon Palladium



Project (the Project), providing specialist or expert information or knowledge pursuant to Section 25 of the *Canadian Environmental Assessment Act*, 1995.

In January 2014, the environmental assessment of the Project was paused at the request of the Proponent for a period of 6 years (CIAR #680). The environmental assessment resumed in July 2020 (CIAR #692) under the provisions of the *Canadian Environmental Assessment Act*, 2012.

NRCan's participation in the environmental assessment of the Project has involved the provision of scientific and technical expertise pursuant to Section 20 of the *Canadian Environmental Assessment Act*, 2012 in areas within our mandate relevant to the project. In addition, based on the information provided by the Proponent to date, NRCan identified that it may be required to issue a permit or license pursuant to Section 7.1(a) of the *Explosives Act* to allow the Project to proceed.

This submission responds to the JRP December 17, 2021 Letter of Request (CIAR#962) to provide a technical written submission, make an oral presentation and participate actively in the public hearing. To date, NRCan has provided advice to the Impact Assessment Agency of Canada (the Agency) and the JRP on:

- Geology;
- Hydrogeology and groundwater;
- Geochemical characterization, acid-rock drainage and metal leaching;
- Caribou habitat suitability and functional landscape connectivity;
- Economic considerations for the Project;
- Slope stability.

NRCan notes that although it provided slope stability expertise in the 2012 review, this expertise is no longer available. Given the changes in the pit design for the Project, the 2012 advice no longer applies.

NRCan is a member of the Government Review Team (GRT) for the environmental assessment, led by the Agency and the Provincial Ministry of Environment, Conservation and Parks (MECP) which coordinates government departments and agencies participating in the review process. The GRT identifies technical issues, facilitates discussions between federal and provincial departments, and with the Proponent on issues that cut across departmental mandates and promotes a consistent approach amongst departments for submissions. In addition, NRCan participates in the whole-of-government approach to consultation with Indigenous Peoples.

A chronological summary of NRCan's participation in the assessment of the Marathon Palladium Project is summarized below:



### 1.2.1 NRCan's Participation: 2010-2013

1.2.1.1 **October 2012** (CIAR #314): NRCan filed 28 information requests (IR) to the JRP addressing hydrogeology, geology, slope stability, acid rock drainage, metal leaching and tailings management. The JRP subsequently determined that the Environmental Impact Statement (EIS) was not sufficient to proceed to the public hearing and sent information requests to the Proponent in November 2012 (CIAR # 334).

1.2.1.2 **July 2013** (CIAR#550): NRCan affirmed that most of the Proponent's responses to its information requests were sufficient, and identified two additional IRs seeking further definition concerning hydrogeology and geochemical characterization of waste rock and process solids. These information requests were included in the second deficiency statement on August 30, 2013 (CIAR #564).

1.2.1.3 **December 2013** (CIAR#601): In its final submission, NRCan reviewed the Proponent's responses to the supplemental information requests (CIAR#587, and specifically CIAR # 573, CIAR#672 and CIAR #574) and considered that the Proponent's responses were sufficient and addressed the information requested adequately.

### 1.2.2 NRCan's Participation: 2020-2021

1.2.2.1 **July 2021** (CIAR #901): In response to the JRP's April 20, 2021 request to review the EIS Addendum (CIAR #727) and supporting documents (CIAR #722, CIAR#741), NRCan filed 12 information requests concerning hydrogeology, acid-rock drainage and metal leaching, caribou habitat, economic considerations and explosives manufacturing and storage. The sufficiency of the Proponent's responses to these information requests are discussed in this final submission.

The following sections present the issues raised by NRCan's technical experts, the associated technical analyses, a discussion of the extent to which NRCan's issues have been addressed by the Proponent and, where applicable, recommendations for consideration by the JRP.



## 2 GEOLOGY

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### 2.1 Bedrock Geology

#### 2.1.1 Context

The project area is characterized by moderate to steep hilly terrain with a series of interconnected creeks and lakes surrounded by dense vegetation. Outcrops are common within the Project area and overburden ranges from 3 to 10 m in thickness. The general elevation around the mine site is slightly higher than the overall regional topography. Ground surface elevations in the area of the proposed site range from approximately 180 to over 560 meter above sea level with a gradual decrease in elevation from north to south. The Project area is situated along the eastern margin of the Proterozoic Coldwell Complex, which is part of the Keweenawan Supergroup of igneous, volcanic and sedimentary rocks as outlined in the Proponent's updated Feasibility Study for the Project (CIAR#741).

#### 2.1.2 Approach to Review and Results

In October 2012 (CIAR #314), NRCan reviewed the 2012 EIS Main Report (CIAR#224) and provided information requests to the JRP with respect to bedrock geology.

NRCan comments highlighted a lack of adequate presentation and completeness of data in Proponent's regional bedrock geology. Specifically, NRCan recommended to the JRP that the Proponent be requested to:

- Include maps properly labelled and of the appropriate resolution of surface and bedrock geology to better understand and to properly frame the geological context of the project site;
- Provide detail on the site bedrock structural characterization of the rock formations impacted by the project, metamorphic grade of the Coldwell Complex, and surrounding geology showing the Thiel fault.

In June 2013 (CIAR#489), in response to information request 9.1.2, the Proponent provided updated geological maps of structures in the area confirming that faults were either absent or did not appear to have any significant impact on the groundwater flow.

In June 2013 (CIAR#489), in response to the information request 9.1.2, the Proponent confirmed that the structure of the Coldwell Complex is notable for the near absence of structural fabric and that the project area had not undergone significant geologic deformation or metamorphism since its formation.

In October 2012 (CIAR #314), NRCan also requested the Proponent provide the Project's deposit ore mineralogy, as these minerals can contain sulfur and other elements in small concentration.

NRCan noted that the concentration of these elements had been established further under Table 5.1.3 *Average Sulphur Contents of Mine Rock Types* and Table 5.1.4 *Summary of Bulk-Element*



*Content and ABA for Mine Rock Samples* of the 2012 EIS Main Report ([CIAR#224](#)). Furthermore, this specific information regarding the PGM mineralogy is also available in Good et al. (2017).

In July 2021([CIAR#901](#)), NRCan informed the JRP that it was satisfied with the Proponent's characterization of bedrock geology in the initial project assessment in 2012-2014.

### 2.1.3 Conclusion

NRCan is satisfied with the Proponent's characterization of bedrock geology and has no further comments or recommendations.

## 2.2 Surficial Geology

### 2.2.1 Context

The site is on the Canadian Shield and is mapped as mostly bedrock in the Ontario Geological Survey Miscellaneous Release Data (Ontario Geological Survey, 2011). A review of section 2.1 of the Soils Baseline Report Update ([CIAR#722](#)) indicates that site investigations encountered more sediment over bedrock than mapping might suggest. Maximum thickness reported generally correlate with the previous mapping with thickest sediment along the Pic river. Given the proximity to glaciofluvial sands and mapping of till veneer the sediment over bedrock thicknesses are within ranges to be expected. The distribution of sites presented in Figure 2-1 *Soil sampling on the Marathon Palladium Project site* ([CIAR#722](#)) is adequate to support estimates of sediment variability.

### 2.2.2 Approach to Review and Results

NRCan reviewed the 2012 EIS Main Report ([CIAR#224](#)) and provided information requests to the JRP with respect to surficial geology.

In October 2012([CIAR #314](#)), NRCan recommended the JRP request the Proponent:

- provide additional maps to describe the project site surficial geology;
- provide additional detail on whether the grain size data were derived from literature or laboratory analyses;
- additional details on the analytical methods with respect to the geochemistry of the overburden samples.

In response to the information request 14.1 and 14.2 ([CIAR#489](#)), the Proponent provided a more detailed assessment of the regional geology as recommended and confirmed that the grain size distribution data were generated from samples collected on-site.

As for the additional details on the geochemistry of the overburden samples, this information was provided in the EIS Addendum ([CIAR #727](#)).

In July 2021([CIAR#901](#)), NRCan informed the JRP that it was satisfied with the Proponent's characterization of surficial geology in the initial project assessment in 2012-2014.



### 2.2.3 Conclusion

NRCan is satisfied with the Proponent's characterization of surficial geology and has no further comments or recommendations.



## 2.3 Regional Seismicity

### 2.3.1 Context

Seismic hazard assessment is the study of expected earthquake ground motions on the earth. In Canada, the development and evaluation of regional earthquake hazard models for applications in the National Building Code of Canada (NBCC) is the responsibility of the GSC within NRCan. The seismic hazard maps prepared by the GSC are derived from the statistical analysis of past earthquakes and from advancing knowledge of Canada's tectonic and geological structure and are updated as new information becomes available, both at the national and international levels.

### 2.3.2 Approach to Review and Results

NRCan reviewed section 4.2.3 of the EIS Addendum (CIAR #727) and supports the Proponent's characterization of the Project area as being within a region of relatively low seismicity.

NRCan notes that the peak ground acceleration corresponding to the 1 in 2,475 year earthquake event was used for design. This value corresponds with the guidance in the most recent Canadian Dam Association Safety Guidelines (CDA, 2013) for a dam classified as high consequence.

### 2.3.3 Conclusion

NRCan is satisfied with the Proponent's characterization of seismicity and has no further comments or recommendations.



## 3 HYDROGEOLOGY AND GROUNDWATER

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### 3.1 Context

Groundwater provides drinking water to about one third of all Canadians and up to 80% of the rural population. Some Canadian aquifers (stores of groundwater) are under threat and vulnerable to climate change and human interference. Responsibility for managing Canada's groundwater resources is shared across several federal departments, provinces and territories. Provinces have direct responsibility for managing groundwater, however, under the *Canada Water Act*, the federal government has co-management responsibilities with the provinces for waters where there is a "significant national interest in the water resource management", which includes international (with the United States) or provincial boundary waters. NRCan's Groundwater Program was created in 2002 to address the need for information to support groundwater resource management by filling the knowledge gaps on groundwater supply as well as on the sustainable use of the resource.

NRCan's review was guided by Section 2.6 and 2.7 of the EIS Guidelines issued for the Project (CIAR#150). The main topics of NRCan's review included the following:

1. Localised lowering of the water table caused by dewatering of mine pits. Such changes can affect natural discharge to streams and the resulting baseflow, especially during dry or winter months.
2. Localised increases in water table levels under structures such as the Process Solid Management Facility (PSMF) and Mine Rock Storage Area (MRSA). Such changes can alter vertical and horizontal groundwater flow patterns and transport contamination greater distances from the mine site.
3. Potential sources, travel directions and receptors of groundwater contamination (commonly resulting from metal leaching).

### 3.2 Approach to Review and Results

#### 3.2.1 2012 Groundwater Information Requests (IRs)

In October 2012, NRCan submitted these 9 groundwater IRs (CIAR #314) developed to better understand the relationship between project components, groundwater systems, and resulting potential impacts on surface water, for which recharge and seepage rates were of special importance.

#### 3.2.2 2021 Groundwater Information Requests (IRs)

The review resumed in June 2020 with a modified design for the mine pit, PSMF and MRSA as presented in the EIS Addendum (CIAR #727), the updated baseline studies (CIAR #722) and the feasibility study (CIAR#741).



### 3.2.2.1 June 2021 Clarification Questions

Following presentations by the Proponent on the new project design and operations plan, NRCan submitted 9 questions directly to the Proponent seeking additional clarification concerning the groundwater model. A summary of questions and responses follows. Complete text can be found in Annex C of [CIAR #901](#).

#### Clarification Question 1

In Question 1, NRCan requested confirmation that the modelled recharge for the baseline, end of operations, and post-closure was consistent with the previous assessment and applied uniformly at 79 mm/yr. The Proponent confirmed that recharge was unchanged from the 2012 model at 79 mm/year for each of the model scenarios. NRCan was satisfied with this response.

#### Clarification Question 2 and 3

In Question 2 and 3, NRCan requested additional detail on how the MRSA and PSMF were incorporated into the model. The Proponent confirmed that the structure of the MRSA was added to the groundwater flow model as a layer of high permeability material on top of the existing ground surface. The MRSA was represented as an area of 1,630,212 m<sup>2</sup> and a maximum thickness of 127 m. The materials for the PSMF were simulated using material placed in a single layer in the groundwater flow model, placed on top of the existing ground surface. The tailings were assumed to have a hydraulic conductivity of 1x10<sup>-6</sup> m/s. The High-Density Polyethylene (HDPE) liner on the upstream side of the rock fill was simulated as a no flow boundary which would conservatively assume no toe seepage and, therefore, seepage from the PSMF would be directed out the base of the facility. The PSMF was simulated with a combined footprint of approximately 2,669,000 m<sup>2</sup> and a maximum height of 77 m. NRCan accepted the response, but requested additional detail in IR2 and IR3 in July 2021.

#### Clarification Question 4

In Question 4, NRCan requested clarification of the model layer for which the groundwater elevation and drawdown maps were generated, and the geological unit which they represent. The Proponent confirmed that the water table was generated from the model output as the hydraulic head in the topmost active layer within the model, which is model layer 1 in areas where the PSMF or MRSA are present, or the topmost active layer within the open pit. The hydraulic heads in model layers 1 and 2 were checked to confirm that the water table was not perched beneath the PSMF or MRSA. NRCan was satisfied with the response.

#### Clarification Question 5 and 6

In Question 5 and 6, NRCan sought clarification on maps showing water table drawdown and depth to water table for each of the assessment periods. The Proponent confirmed that the simulated water table drawdown for the end of operation and in closure are presented in Figure 12 *Simulated Water Table Drawdown at End of Operation* and Figure 14 *Simulated Water Table Drawdown at Post Closure (Pit Lakes)* respectively, of the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum ([CIAR#727](#))) as well as in Figures 6.2.3.4 and 6.2.3.5 of Chapter 6 of the EIS Addendum.



The simulated water table drawdown is relative to the predicted water table elevation contours for baseline conditions as presented in Figure 9 *Predicted and Measured Groundwater Elevations – Baseline Conditions* of the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum [CIAR#727](#)). NRCan was satisfied with the response. The Proponent confirmed that there are no maps presented in the EIS addendum that show simulated depth to water below ground surface. For each of the assessment periods, the groundwater table is presented as water table elevation contours and water table drawdown relative to baseline conditions.

#### Clarification Question 7 and 8

In Question 7 and 8, NRCan requested clarification on the model particle tracking around the MRSA and water management pond (WMP) particularly at end of operations and post-closure. The Proponent attached Figure 15 (end of operations) which had been updated to present the 100-year travel of particles released from the PSMF and MRSA (Annex C of [CIAR #901](#)). Also attached were updated Figure 15 *Particle Traces from Stockpiles, PSMF, and Water Management Pond to Open Pit and Receiving Environment Under Dewatering Conditions (Year 12)* and Figure 16 *Particle Traces from Stockpiles, PSMF, and Water Management Pond to Open Pit and Receiving Environment at Post Closure (Pit Lakes)* from the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum ([CIAR#727](#))), which include the particle tracks from the water management pond for the end of operation and in closure (once a pit lake has formed), respectively. NRCan was satisfied with the response.

#### **3.2.2.2 July 2021 Groundwater IRs**

On July 26, 2021, NRCan submitted 4 groundwater IRs to the JRP ([CIAR #901](#)) seeking further detail on the groundwater model results. These were reformulated and forwarded to the Proponent on July 30, 2021([CIAR#913](#)). The Proponent responded in August 2021 in the Responses to Information Request #4 Groundwater Modelling ([CIAR#917](#)). Where the responses were not considered sufficient, NRCan recommendations are provided to the JRP for longer term monitoring to reduce uncertainty.

**NRCan Information Request 1** (generally reformulated in JRP IR 4-4):

#### *Groundwater Discharge to surface water*

NRCan Information Request 1 requested further detail on the groundwater discharge to individual surface water features around the Project site under baseline, end of operations, and post-closure conditions. Changes to groundwater-surface water interaction can vary within a sub-watershed, and these changes are not possible to assess with the results provided.

NRCan has reviewed the Proponent's responses and while some are satisfactory, uncertainties remain in the presentation of the numerical model results relating to groundwater-surface water interaction within the local study area during operations and into post closure.

For Stream 102, 103, 104, 106, 108 and 116, the modelled relationship between groundwater elevations and discharge requires further context and verification to validate the model with respect to potential changes to surface water flow. The request is based on the groundwater discharge to



lakes and watercourses presented in Table 6.3, and the groundwater elevation drawdown presented on Figure 12 *Simulated Water Table Drawdown at End of Operation* and Figure 14 *Simulated Water Table Drawdown at Post Closure (Pit Lakes)* of the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum ([CIAR#727](#))).

NRCan recommends that the Proponent provide model results for the groundwater – surface water interaction for the individual surface waterbodies represented in the numerical model to guide project monitoring.

**NRCan Information Request 2** (reformulated in JRP IR 4-5):

*MRSA Water Balance*

NRCan requested additional detail to support the assessment of the MRSA water balance and possible pathways for contaminant migration.

As the IR relates to MRSA drainage in the event that the coarse rock channel becomes restricted, the Proponent provided a reasonable assessment of the groundwater flow paths for seepage from the MRSA should the channel be restricted. No further information is requested by NRCan.

As the IR relates to changes in groundwater elevation due to the MRSA, the applied recharge within the footprint of the MRSA is unchanged from baseline conditions, yet model results indicate an increase in groundwater elevations as percolation through the facility exceeds the infiltration capacity of the overburden. Additional details regarding depth to the water table from the original ground surface were requested from the Proponent for the baseline, end of mining, and post-closure periods to determine whether seepage from the MRSA is likely to occur within the shallow units with discharge to adjacent ditches and waterbodies. These results are requested to support the development and evaluation of the long-term monitoring program.

Figures showing these results were provided to NRCan on July 7 2021 (Annex C of [CIAR#901](#)). For the end of mining (*Figure 2 Predicted Depth to Ground Water – End of Operation*) and post-closure conditions (*Figure 3 Predicted Depth to Ground Water – Post Closure*), it is not clear that the contours shown are relative to original ground surface, as depth to the water table is increased relative to baseline conditions below the MRSA. In contrast, drawdown contours in the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum [CIAR#727](#)) show a rise in groundwater elevation during these phases.

Additional details are required to facilitate the review of the water balance for the MRSA. These details include:

- the recharge flux through the MRSA under the three modelled conditions;
- depth to the water table from the original ground surface under the three modelled conditions; and,
- zone budget results for the seepage from the facility, relating seepage discharge to recharge flux using a mass balance approach.

NRCan recommends that the Proponent include the requested details in reporting model results to guide the development of the detailed groundwater monitoring program.



### **NRCan Information Request 3** (reformulated in JRP IR 4-4)

#### *PSMF Seepage*

NRCan requested further detail to support the assessment of the main pathways for potential seepage migration from the PSMF. This included a rationale for the exclusion of the seepage collection basins and ditch network from the groundwater model, the effect of the seepage collection basins and ditch network on the quantity of groundwater seepage from the PSMF and a rationale for the lower overall recharge through the PSMF relative to baseline conditions, and the simulated rise in groundwater elevations under these conditions.

The responses regarding the simulation of the seepage collection basins and ditches are sufficient and there are no further requests or recommendations.

Regarding the seepage quantity, the Proponent's response does not appear to be consistent with the technical information provided in the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum ([CIAR#727](#))) and further information is requested.

Based on the total seepage flux from the PSMF reported in Tables 6.4 *Predicted Groundwater Discharge from MRSA, Ore Stockpile, PSMF, and Water Management Pond to Receiving Environment at End of Operation* and Table 6.5 *Predicted Groundwater Discharge Rates from MRSA, PSMF, and Water Management Pond to Receiving Environment at Post Closure (Pit Lake)* of the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum ([CIAR#727](#))) and the simulated footprint of the facility (2,669,000 m<sup>2</sup> as provided in the Annex C of [CIAR#901](#)), the equivalent recharge rate for the facility is lower than that applied on the original ground surface under baseline conditions. Although the overall flux through the footprint of the PSMF appears to have decreased in operations and post-closure relative to baseline conditions, simulated groundwater elevations are reported to rise by over 10 m as shown on Figure 12 *Simulated Water Table Drawdown at End of Operation* and Figure 14 *Simulated Water Table Drawdown at Post Closure (Pit Lakes)*. It is also noted that despite the information stated in the response, the technical document states that the fine-grained consolidated material within the PSMF are assigned a higher permeability (at  $1 \times 10^{-6}$  m/s (Hydrogeology Updated Effects Assessment Report, Appendix D4 of the EIS Addendum([CIAR#727](#))) than the upper model layers at  $1 \times 10^{-7}$  m/s (Table T *Groundwater Flow Properties* of the Baseline Report, Hydrogeology, Supporting Information Document 14 to the EIS ([CIAR#227](#))). Further reporting on the groundwater modelling results are required to resolve these inconsistencies.

NRCan recommends that detailed reporting of the model results be provided by the Proponent to clarify the implementation of the facility within the numerical model, and support the development of the detailed groundwater monitoring program.

### **NRCan Information Request 4** (reformulated in JRP IR 4-4)

#### *Groundwater Model Particle Tracking*

NRCan requested further detail on the modelled particle tracks from the MRSA and PSMF to better understand the main pathways for contaminant migration related to seepage from the PSMF and MRSA, and the suitability of the groundwater monitoring and adaptive management plans.



Groundwater modelling results presented in the Hydrogeology Updated Effects Assessment Report (Appendix D4 of the EIS Addendum(CIAR#727)), and updated in the July 2021 response to the initial technical questions (Annex C of CIAR#901) indicate that seepage travel times from mine facilities to receptors are on the order of centuries (i.e., post closure particle tracking results for 100 year travel times do not reach seepage discharge points). As these travel times limit options for monitoring and mitigation, it is recommended that monitoring plans recognize these timescales and provide monitoring options within the life of the mine.

NRCan recommends that the Proponent report on the potential uncertainty in the seepage flow pathways and travel times from these facilities. This information is required in the development of monitoring plans that account for this uncertainty as well as the potentially long travel times.

### **3.3 Conclusions and Recommendations**

#### **3.3.1 Seepage Flux from the Mine Rock Storage Area (MRSA) and the Process Solids Management Facility (PSMF)**

The results of the numerical model for the end operations and post-closure simulations suggest persistent groundwater mounding under both the MRSA and the PSMF. Groundwater mounding, or local increases in the water table, drives outward seepage from these facilities towards receiving waterbodies. The quantity, direction, and travel time of this seepage influences the water quality of the receiving waterbodies, potentially presenting a risk to fish, fish habitat, wetlands, water supply wells and other groundwater – surface water interactions. The numerical model results indicate that seepage from these facilities predominately flows through bedrock, resulting in travel times on the order of decades to centuries prior to eventual discharge to surface water bodies including the Pic River, Hare Lake and its tributaries, and Angler Creek (with a portion discharging to the open pits).

As a guide for long term monitoring, NRCan suggests that complete flow balances be documented for each facility showing that flow into the facility is equivalent to the outward seepage under steady-state conditions. Inconsistencies in the reported permeability of the tailings material relative to the underlying overburden (i.e. Is the long term permeability of the tailings greater or less than that of the underlying overburden?) between the EIS Addendum and the IR responses should be resolved and factored into the monitoring program design.

NRCan offers two recommendations to address the reporting of the model results:

1. The Proponent should provide detailed reporting of model results discussed above to ensure clarity on reported seepage quantities and flow pathways to be used in the design of the detailed groundwater monitoring program.
2. When developing the detailed groundwater monitoring program, the Proponent should account for the long travel times, consistent with groundwater model results.



### 3.3.2 Discharge to Surface Water

The rugged terrain of the mine property creates a number of small sub watersheds, each with groundwater discharge supporting stream flow, especially in dry and winter months. Mine development will progressively alter groundwater levels and flow directions within these sub watersheds with potential adverse effects on stream flow. A reasonable level of confidence is necessary in the groundwater model in these areas to properly understand the localized changes to groundwater-surface water interaction in each sub watershed.

The model results are presented on a sub watershed basis, reporting the net change in groundwater discharge to surface water for the entire sub watershed. As groundwater elevations both increase and decrease within a single sub watershed as a function of proximity to mine facilities (resulting in net discharge increases and decreases), the reporting of net change may overlook local variations at individual waterbodies. Additionally, the reported changes in groundwater discharge in select watersheds (102, 103, 104, 106, 108, 116) are not consistent with the reported changes in groundwater elevations (e.g., For Watershed 104 groundwater discharge is doubled as a result of mining development despite reported groundwater elevation drawdown). These results suggest the possibility for localized changes in groundwater discharge to surface water that are not reported and may effect surface water flow.

The method used to report groundwater model results relating to discharge to surface waters creates uncertainty in how project operations may affect surface water flows and wetlands. Recommendations are provided for the model results to be presented in detail for an improved understanding of expected changes in groundwater discharge. Recommendations are also provided for long-term monitoring as related to potential seepage from the MRSA and the PSMF.

To guide monitoring measures, NRCan recommends that the Proponent report forecasted changes to groundwater- surface water interaction for the individual surface waterbodies represented in the numerical model, and that reported flux changes are consistent with reported changes in groundwater elevations.



## 4 GEOCHEMICAL CHARACTERIZATION, ACID-ROCK DRAINAGE AND METAL LEACHING

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Acid rock drainage and metal leaching (ARD/ML) can result from the excavation of sulphidic geological materials associated with mining operations and can impact drainage quality. When exposed to oxygen, sulphide minerals oxidize and liberate acid and chemical species that can be transported by water. The resulting drainage chemistry may be acidic or neutral and may contain elevated concentrations of chemical species such as sulphate, metals, metalloids, and non-metals, as well as nitrogen species such as nitrate and ammonia, which are a by-product of blasting. Problematic drainage from mining activities can have potential effects on water and sediment quality.

Adequate planning for tailings and mine rock management relies on robust characterization of the ARD/ML potential of all mine waste in combination with iterative predictions of contaminant releases from tailings and mine rock over the mining life-cycle. The subsequent prediction of contaminant dispersion into the receiving environment can identify risks to the health of people and the environment. In turn, robust mine waste management can mitigate deleterious effects on water quality, vegetation, wildlife and aquatic life and possible impacts to human health.

### 4.1 Acid rock drainage and metal-leaching

#### 4.1.1 Context

The ARD/ML potential of mine waste materials at a project site (namely overburden, waste rock, ore and low-grade ore, tailings, pit walls and any materials excavated for construction) is evaluated through the geochemical characterization of materials to be produced by each mine facility. These studies include the collection of sufficient samples that are spatially and compositionally representative of the materials to be generated from mining activities. These samples are subjected to a series of laboratory and field tests to evaluate their ARD/ML potential. The Mine Environment Neutral Drainage (MEND) report 1.20.1 provides detailed guidelines for the implementation of geochemical characterization studies.

Type 1 material is defined as rock with less than 0.18 weight percent (wt%) sulphur and considered Non-potentially acid generating (non-PAG) material. Potentially acid generating (PAG) material is referred to as Type 2. The Type 1 process solids are thickened tailings that constitute the rougher and Platinum Group Metals (PGMs) scavenger streams while the Type 2 process solids are a conventional slurry made up of the first cleaner tailings. Mine rock generated during the life of the mine will be tested on site and segregated into Type 1 and 2 during excavation according to sulphur content.

#### 4.1.2 Metal-leaching under neutral conditions

##### Approach to Review and Results

NRCan reviewed the EIS Addendum (CIAR #727), supporting documents and the Proponent's Response Package (CIAR#950).



According to the Proponent's EIS Addendum, 85-90% of the mine rock is predicted to be Type 1, which has been assessed to be non-PAG. The Proponent plans to use Type 1 mine rock for construction (roads, dams and other site infrastructure) or store it permanently in the MRSA. During operations, drainage from the MRSA, which does not have the potential to affect water quality of the receiving environment, will be collected and pumped back to the WMP and managed with the other contact water sources of the site.

In July 2021 (CIAR#901), NRCan noted that Type 1 mine rock subjected to kinetic testing demonstrated potential for neutral drainage (e.g. neutral contact water with elevated species such as sulphate, aluminum, arsenic, copper and uranium). PGMs were not analyzed in this testing and therefore their potential release rates from Type 1 mine rock remain unknown. While the Proponent proposed the standard practice field testing of materials to evaluate weathering rates including neutral drainage from Type 1 mine rock, NRCan notes that they intend to complete this testing on run of mine materials as they become available during operations. The timing of these tests is therefore more suited to support mine closure and will therefore not address risks associated with the use of Type 1 mine rock during operations for construction purposes.

#### Conclusions and Recommendations

As the Proponent intends to use Type 1 mine rock for construction purposes, NRCan is of the view that the environmental risks associated with neutral metal leaching during operations needs to be further considered as it could lead to impacts on the aquatic environment. NRCan therefore recommends that the Proponent consider the development of an approach to identify Type 1 material with neutral leaching potential during operations and prior to its use for construction purposes. This could be included as an update to the Mine Rock Segregation Program, outlined in the Table of Commitments of the EIS Addendum (CIAR#727).

Additionally, NRCan is of the view that neutral leaching from type 1 mine rock used for construction or stored in the MRSA could impact the quality of contact water. NRCan recommends that the management of Type 1 rock in the MRSA consider follow-up monitoring and mitigation, in the event that neutral drainage with elevated concentrations of metals, including PGMs, be identified.

#### 4.1.3 Type 2 Mine Rock volume estimates

##### Approach to Review and Results

NRCan reviewed the Appendix D11, Surface Water Quality Effects Assessment of the EIS Addendum (CIAR #727) and identified spatial gaps in the distribution of the geochemical characterization samples in the pit block model images, notably in the east and west pit walls of the North Pit and in all pit walls of the Central and South pits. These types of spatial gaps are common at the EIS stage and are generally addressed as the project progresses.

In July 2021 (CIAR#901), NRCan noted that the spatial gaps in the distribution of geochemical characterization samples could lead to an underestimation of the volume of Type 2 mine rock requiring management in the PSMF or as backfill in the South and Central pits. The gaps in the



distribution of samples in the pit walls also poses the risk that contaminant release from Type 2 rock is underestimated in the water quality predictions.

#### Conclusions and Recommendations

In order to address the uncertainty related to the noted spatial data gaps, NRCan recommends that additional sampling and testing of mine rock be completed as material becomes available in these areas through future drilling programs, including samples representative of the anticipated pit walls. This should be completed as the project progresses through provincial permitting to refine Type 2 volume estimates in support of engineering design, and then further refined during operational testing for segregation.

NRCan recommends that this additional sampling and testing be added to the Proponent's Mine Rock Segregation Program commitment to *perform ongoing testing that will be carried out during operations to assess the metal leaching and acid-generating potential of mine rock being removed to confirm water quality predictions* outlined in the Table of Commitments of the EIS Addendum (CIAR#727).

Additionally, NRCan recommends that the Environmental Monitoring and Management Plan (EMMP) include operational monitoring and adaptive management strategies to offset the risk of inadequate management of Type 2 rock (mine waste and pit walls) and subsequent impacts to water quality.

#### 4.1.4 Water Quality Predictions in the MRSA (Sensitivity analysis)

##### Approach to Review and Results

In July 2021 (CIAR#901), NRCan noted to the JRP that the Proponent did not provide a sensitivity analysis for the Type 2 mine rock contamination in the MRSA and discuss its implications for MRSA contact water quality and potential impacts to receiving water quality. As noted in the EIS Guidelines issued for the project (CIAR #150), the Proponent is required to provide a sensitivity analysis to assess the effects of imperfect segregation of rock and to evaluate the risk associated with segregation of Type 1 and Type 2 rock.

NRCan notes the results of a sensitivity analysis of Type 2 mine rock in the MRSA was not considered in the updated contact water quality predictions for this project component. Higher than anticipated Type 2 volumes in the MRSA could have implications for seepage and runoff quality in operations and post-closure.

##### Conclusions and Recommendations

NRCan recommends that during permitting the Proponent complete a sensitivity analysis of Type 2 mine rock in the MRSA and use these results to update the seepage and runoff quality estimates for the MRSA in operations and post-closure. This ensures adequate water treatment, mitigation and monitoring measures are in place.



#### 4.1.5 Pit lake water quality

##### Approach to Review and Results

In July 2021 (CIAR#901), NRCan noted that kinetic testing was completed only on mine rock that predominantly contains the sulphide mineral chalcopyrite. However, it is noted that at depth in the Marathon Palladium deposit, rock contains more pyrrhotite than chalcopyrite. Pyrrhotite is documented to oxidize more rapidly than chalcopyrite. Therefore, NRCan notes data gaps associated with the mineralogical representativeness of kinetic tests.

This could have implications for the predicted timing to onset of acidic conditions. It is currently estimated that Type 2 mine rock will not produce ARD/ML prior to final submergence in the pits in post-closure. However, in the event that ARD/ML initiates sooner than predicted, pit lake water quality estimates should account for the oxidation of Type 2 rock prior to submergence in the pit, including the washing of oxidation products during pit filling.

As noted in the EIS Guidelines issued for the project (CIAR #150), the Proponent was required to evaluate the potential impacts to water quality at all project components. The current pit lake water quality estimates consider loading rates from Type 1 rock only and are not sufficiently conservative to account for potential acidification of Type 2 mine rock (including exposed waste, low grade ore, and ore) in the pit walls, benches and floor as well as backfilled Type 2 material.

In July 2021 (CIAR#901), NRCan requested that the Proponent provide an assessment of runoff from the pit walls to the pit lake that considers the risk associated with the potential development of acidic drainage from the pit walls and implications on pit lake water quality.

In November 2021, in Response Package #5, IR-17 (CIAR #950) the Proponent described a sensitivity analysis to evaluate the potential for acidic conditions to develop from exposed pit walls, whereby 10% of the pit walls were assumed to be Type 2 mine rock. However, these tests did not generate acidic conditions through the duration of testing and therefore, the evaluation of ARD potential is based on the neutral test drainage only. Further, a discussion on the mineralogical representativeness of the humidity cells or estimates of lag time to onset of ARD to justify the use of these test results for the sensitivity analysis was not provided.

##### Conclusions and Recommendations

NRCan is of the view that the results of the sensitivity analysis are not sufficiently conservative to evaluate the potential for acidic conditions to develop from exposed pit walls and benches and backfilled Type 2 waste, thus, the potential impacts of ARD on the pit lake water quality in post-closure.

To address the uncertainties, NRCan recommends the Proponent implement a testing program to evaluate the reactivity of both chalcopyrite-rich and pyrrhotite-rich Type 2 mine rock. Run of mine rock from the deeper pyrrhotite rich material will not likely be available at the start of operations and consideration to sourcing this material from another means (i.e. drill core) is recommended.



Until the results from these tests are obtained, NRCan recommends that the Proponent temporarily consider more conservative “proxy” Type 2 loading rates based on other analyses that could be completed ahead of operations. This could include analysis of the leachate from Net Acid Generation (NAG) tests completed on a subset of Type 2 mine rock samples, or laboratory-based kinetic tests on both chalcopyrite-rich and pyrrhotite-rich Type 2 rock with prior depletion of neutralization potential to achieve acidic conditions more rapidly. The pit lake water quality estimates for post-closure should consider acidic loading rates from the “proxy” until the field test loading rates are available.

## 4.2 Platinum Group Metals

### 4.2.1 Context

Platinum group metals (PGMs) include platinum, palladium, rhodium, iridium, osmium, and ruthenium. PGMs are of great importance in many modern technologies and products. With the emergence of new technologies requiring PGMs, it can be expected that more extraction projects involving PGMs will be developed and that there will be a need to consider potential PGMs exposure to people and the environment.

### 4.2.2 Approach to Review and Results

NRCan reviewed the EIS Addendum ([CIAR#727](#)) and noted that PGMs were not identified as contaminants of potential concern because there are currently no federal or provincial water or sediment environmental quality criteria in Canada for these emerging metals. As such, they were not considered in the Proponent’s approach to mine waste management (process solids and waste rock) monitoring and closure plans for the Project.

In July 2021 ([CIAR#901](#)), NRCan identified a growing list of toxicity studies suggesting Palladium could be more toxic and soluble than was understood during the 2012 EIS review (Le Faucheur et al. 2021; Hourtané 2019; Rioux 2018; Zimmerman and Sures 2018; Zimmerman et al. 2017; Racine 2016; Chen et al. 2015; Tétreault 2014; Fortin et al. 2011; Roy 2009;). As such, NRCan recommended to the JRP that the Proponent use the drill core exploration data and provide a mass balance presenting conservative release rates of PGMs from waste rock, process solids, site contact water, effluent sludge and effluent. In the absence of PGMs water and sediment quality criteria, this information would serve as an estimate to support the review of the proposed tailings and waste rock management plans.

In November 2021, in Response Package #5 IR-18 ([CIAR #950](#)), the Proponent indicated that PGMs in mineralized zones of the Project deposit are present at relatively low levels. Given these low values and the intrinsic value of PGM’s ore to the Project, the Proponent specified that great care will be taken to avoid losses of PGMs at every stage of the mining and milling process.

The Proponent proposed to initiate additional laboratory leaching experiments in order to increase the understanding of the potential mobility of PGMs from mine waste materials. In addition, and as noted in the Proponent’s Response Package #5 IR-16 ([CIAR 950](#)) the Proponent proposed to



develop field leaching experiments using representative run of mine materials during operations. However, a PGM monitoring plan was not proposed by the Proponent.

#### 4.2.3 Conclusions and Recommendations

While the release of PGMs in the environment may be low, NRCan is of the view that releases to water and accumulation in sediments over time should be monitored as release to surface water and build-up in sediments could potentially affect aquatic organisms (Ek et al. 2004).

In order to estimate inventory and release rates of PGMs from the Project, NRCan reiterates its recommendation that the Proponent provides a mass balance presenting conservative release rates from mine rock, process solids (and how it affects levels of PGMs in site contact water), effluent sludge. These mass balance calculations would then provide estimated effluent concentrations.

NRCan recommends the Proponent use the estimated effluent concentrations of PGMs to predict water and sediment quality in Hare Lake, Pic River and Stream 106 during project operations and post-closure. As there are currently no environmental guidelines for PGMs, these estimated predictions could be used as compliance triggers during environmental monitoring, while environmental guidelines are being developed.

Given the uncertainty in PGMs loading predictions from the initial mass balance calculations, and the unknown potential impacts to water quality, monitoring and contingencies will be needed to address potential impacts to surface waters. NRCan supports the Proponent commitment to initiate leaching experiments to estimate release rates of PGMs from waste rock and tailings. NRCan recommends that the results of these experiments be used to update water and sediment quality predictions for PGMs in Hare Lake, Pic River and Stream 106 during project operations from the requested mass balance predictions. NRCan then recommends these predictions are verified using a water and sediment quality monitoring program meeting both provincial and federal requirements. NRCan therefore recommends that the Proponent include PGMs in its monitoring program and supports the MECP approach to include PGMs monitoring in its Environmental Compliance Approval (ECA), along with appropriate compliance trigger mechanisms.

The comparison of updated water/sediment quality predictions to water and sediment monitoring data from the environmental monitoring program will inform any necessary additional waste rock and tailings management decisions pertaining to PGMs.



## 5 CARIBOU HABITAT SUITABILITY AND FUNCTIONAL LANDSCAPE CONNECTIVITY

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Boreal populations of woodland caribou (*Rangifer tarandus caribou*; hereafter ‘caribou’) are classified as threatened under Schedule 1 of the *Species at Risk Act* (SARA, 2002).

Unlike other ungulate species such as moose (*Alces alces*) or white tailed deer (*Odocoileus virginianus*) that prefer edge habitats, caribou require large areas of mature, intact coniferous forest to survive and reproduce. These environments facilitate spatial separation from predators, which is critical for caribou population persistence. Suitable caribou habitat is thus defined as a natural environment meeting caribou life history requirements that is likely to be utilized by animals engaged in foraging, resting, reproductive and predator avoidance behaviour.

Habitat/landscape connectivity refers to ‘the degree to which the landscape facilitates or impedes movement among resource patches’ (Taylor et al. 1993). At local scales, functionally connected habitat networks facilitate the movement of individuals among suitable patches in their search for food, cover, and reproductive mates (Bauduin et al, 2020; O’Brien et al. 2006). At broader scales, functionally connected landscapes facilitate genetic exchanges between populations (Coulon et al. 2004), thereby increasing population resilience to environmental and demographic stochasticity (Lande 1993).

Anthropogenic landscape disturbances such as forest harvesting, oil and gas and mineral extraction and associated road network development can hinder or disrupt functional landscape connectivity for boreal caribou, which tend to avoid such features (Leblond et al. 2011). They also promote early seral forest conditions, which favour competing deer and moose populations and their predators (James and Stuart-Smith, 2000; Latham et al., 2011; Wittmer et al., 2005). When the magnitude of cumulative disturbances and landscape fragmentation compromises the ability of caribou to space away from their principal predators (grey wolves (*Canis lupus*) and black bears (*Ursus americanus*)), populations inevitably decline (Rudolph et al. 2017). Maintaining connectivity between suitable habitats is therefore critical for population recovery on managed forest landscapes.

The Canadian Forest Service of NRCan provided expertise to the JRP in the following areas:

- Spatial optimization and modelling of caribou habitat suitability and connectivity in forest landscapes;
- Caribou space use behavior and habitat selection modeling;
- Demographic responses of caribou populations to cumulative landscape disturbances; and
- Boreal caribou conservation ecology.

NRCan’s experts are supporting the review of ECCC who is the federal lead for caribou protection and recovery as per the *Species at Risk Act*.



## 5.1 Connectivity Pathways

### 5.1.1 Context

Protecting wildlife corridors is a common management objective in regions of industrial or natural resource activity. In the boreal forest of Canada, anthropogenic disturbances have negatively affected woodland caribou populations, which are more susceptible to predation on disturbed landscapes than on undisturbed ones. Various recovery efforts have been proposed for protecting caribou populations, including the creation of large regions with mature, intact forest habitat and wide movement corridors between isolated caribou ranges. Wide corridors are especially critical when landscapes are highly fragmented, such as in north-central boreal Ontario, where the Lake Superior Coast Range (LSCR) is separated from the Pagwachuan and Nipigon Ranges by a 100+ km swath of managed forest (Bauduin et al., 2020; Yemshanov et al, 2021).

Effective habitat corridors for caribou are ones that maintain networks of suitable habitat that are sufficiently large to support the movements of caribou between core habitats and refuge areas without functioning as an ecological trap (Courbin et al. 2009).

### 5.1.2 Approach to Review and Results

NRCan reviewed all material supplied by the Proponent related to boreal caribou, including, but not limited to the EIS and supporting documents ([CIAR #224](#), [CIAR #227](#)), the EIS addendum ([CIAR #727](#)), responses to Information Requests ([CIAR #757](#) and [CIAR #950](#)), and Proponent's Additional information on Caribou ([CIAR #976](#)).

NRCan noted that the Proponent did not provide details on how the Project is expected to influence the functional connectivity of habitats facilitating caribou movements within the LSCR, as well as between the LSCR and continuous caribou ranges to the North (e.g. Nipigon, Pagwachuan) over the life cycle of the Project.

In July 2021 ([CIAR #901](#)), NRCan requested that the Proponent provide maps of suitable habitat and connectivity to support its review.

In November 2021, the Proponent provided updated maps of potential movement pathways (figures 10 and 11) in Response Package #6 IR-21 ([CIAR#950](#)). These maps did not include a description of how they were developed or provide scientific justification to describe how connectivity between suitable caribou habitat in the landscape was assessed.

In a letter to the JRP ([CIAR#954](#)), ECCC stated that it could not provide advice or technical analysis regarding the potential impacts to connectivity within and between ranges without the scientific justification to describe how connectivity was assessed. NRCan supports this position.

In January 2022 ([CIAR #976](#)), the Proponent explained that the maps (Figure 10: *Potential east-west connectivity in the SSA* and Figure 11: *Potential east-west connectivity in the SSA with respect to topography*) provided in the Response to Information Request IR 6-12 ([CIAR #950](#)) were based on a qualitative analysis of features that may influence the potential permeability of the landscape to caribou movement within the LSCR and adjacent discontinuous distribution (Additional Caribou information, p. 1). At the same time, the Proponent provided supplementary information



derived from semi-quantitative analyses of habitat suitability estimated over hexagonal grids at three different scales (50, 500 and 5000 ha resolution). These supplementary results were intended as evidence to support the Proponent's previous delineation of potential east-west movement corridors relative to the proposed mine site (CIAR#950).

The stated goal of these semi-quantitative analyses of habitat suitability (CIAR #976) was *to identify where the greatest potential barriers to caribou movement exist in the Project landscape and broader study area before and after the proposed development*. Results of the studies indicated that the Project would have a negative impact on connectivity at 50 ha and 500 ha hexagonal resolutions, *particularly in the western portion of the Project footprint (SSA) (CIAR #976, p. 5)*. The Proponent also *assumed that caribou, if present along the mainland Coastal Range, would not pass through the mine site during active operations (CIAR #976, page 2)*.

As stated on page 6 of the Proponent's Additional information on Caribou (CIAR #976): *previous studies have shown that caribou avoid natural and anthropogenic disturbances at distances from 1 to 10 km (Dyer et al. 2001, 2002; Leblond et al. 2011)*. However, in their determination of landscape resistance to caribou movement, the Proponent employs maximum buffers of 22.5 m to reflect the zone of influence surrounding linear features. In addition, harvested areas were not buffered at all, yet these are known to be avoided by caribou (Beauchesne et al. 2013). This significant underestimation of current and future anthropogenic footprint has likely produced an overly optimistic portrayal of habitat condition and functional connectivity for woodland caribou.

In summary, while the supplementary information provided indicates the Project is expected to negatively impact caribou habitat suitability and connectivity, the methodologies used by the Proponent limit NRCan's ability to conduct a thorough assessment in this regard.

### 5.1.3 Conclusion and Recommendations

The Proponent's response to IR6-21 (CIAR#950), suggest that the Project would have a negative impact on the availability and functional connectivity of suitable caribou habitat for the lifespan of the Project. However, methodological concerns with the Proponent's assessment of boreal caribou habitat suitability and connectivity limit NRCan's ability to evaluate in quantitative terms the short and long-term impacts of the project on intra and inter-range connectivity of woodland caribou habitat.

In addition, NRCan is of the view that the information and analyses provided by the Proponent (CIAR#976) are not sufficient to substantiate the delineation of the potential caribou movement pathways around the Site Study Area (SSA) depicted in the Connectivity Study Area map (figure 10, Additional Caribou Information, CIAR#976, p.15), as requested in IR6-21. NRCan therefore recommends that the Proponent re-evaluate suitable caribou habitat, using zones of influence consistent with the scientific literature on individual caribou responses to linear and other anthropogenic features. Once adequate buffers have been applied, NRCan recommends the Proponent conduct a new assessment of the Project's projected impact on intra- and inter-range caribou habitat connectivity.

Furthermore, NRCan would like to note that it supports the conclusions and recommendations brought forward by ECCC, including an updated assessment that demonstrates how intra- and



inter-range connectivity will be maintained consistent with caribou population recovery and persistence.

## 5.2 Off-site Mitigation Measures

### 5.2.1 Context

To offset the potential loss of suitable habitat and functional connectivity within the mine-site area, the Proponent proposes measures outside of the mine footprint to improve conditions elsewhere within the LSCR. Off-site mitigation measures proposed by the Proponent in the EIS Addendum (CIAR#727) and Draft Proposed Caribou Habitat Off-site Mitigation Report (CIAR#757) include road decommissioning, rehabilitation and revegetation of disturbed areas, including retired road networks and roadside landings. The goal of these measures is to compensate for, and attenuate where possible, the potential impacts of the Project on intra- and inter-range caribou habitat connectivity.

### 5.2.2 Approach to Review and Results

In July 2021 (CIAR#901), NRCan noted that further information is needed to characterize how these measures will collectively improve caribou habitat, such as details on the sequence, duration, completion and anticipated effectiveness of the proposed off-site habitat mitigation measures, as they relate to caribou habitat connectivity.

NRCan also requested that the Proponent indicate how the off-site mitigation measures would improve connectivity between suitable caribou habitats within the Coastal range and between the Coastal range and the continuous caribou ranges north of Lake Superior.

In November 2021, Reponse Package #6 IR-21 (CIAR #950), the Proponent stated that *the Site Study Area (SSA) will be unsuitable for caribou use during operations. At closure, even with rehabilitation, the Site Study Area will likely be less suitable as habitat for caribou than it is currently.* However, the Proponent provided no further substance with respect to progressive rehabilitation measures or the post-closure plan, including the location and timing of activities.

In January, 2022 (CIAR#976), the Proponent reiterated that *most of the Project footprint will be actively utilized while the mine is operational, however, efforts will be taken to progressively reclaim and close out inactive areas where practicable.* The Proponent also outlined a conceptual, high-level 3-phase post-closure plan.

### 5.2.3 Conclusion

NRCan is of the view that there is insufficient information to properly evaluate the effectiveness of the off-site mitigation measures proposed by the Proponent and determine the degree to which off-site mitigation measures may improve inter-range connectivity.

Given the uncertainties associated with the insufficient information provided, NRCan is of the view that a full assessment of the effectiveness of the proposed off-site measures to compensate



for the loss of suitable caribou habitat around the Project site and the projected negative impacts to intra-range habitat connectivity cannot be completed.



## 6 ECONOMIC CONSIDERATIONS

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### 6.1 Context

The Policy and Economics Branch of LMS provides expert advice on a range of economic and policy issues related to the minerals and metals sector in both the domestic and international context.

NRCan's role focused on supporting other governmental departments and agencies with the provision of methodological advice for economic analysis, and the provision of background economic information on the Canadian mining industry in general.

### 6.2 Approach to Review and Results

In July 2021 ([CIAR #901](#)), NRCan recommended the JRP request a description of local barter and subsistence economies to assess their resilience to the Project and potential local economic effects. NRCan also recommended that the JRP request the Proponent to discuss how skills and expertise developed in the local workforce through the life of the Project could be transferable to other opportunities upon closure of the Project, and contribute to the development of the community.

In September 2021, the Proponent responded in Response Package #7 ([CIAR#921](#)) that it was committed to provide community benefits to the local Indigenous population through training, jobs, business opportunities and financial participation, which are outlined in Community Benefit Agreements (CBA). However, since these agreements are proprietary and confidential, the details have not been disclosed.

### 6.3 Conclusion

NRCan understands the information currently available is limited and confidential and is therefore satisfied with the Proponent's response and has no comments or recommendations.



## 7 SUPPLEMENTAL INFORMATION FOR THE JRP'S CONSIDERATION

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In its December, 17, 2021 Letter of Request ([CIAR#962](#)) to provide a technical written submission, make an oral presentation and participate actively in the public hearing, the JRP requested that NRCan provide advice on the potential effects to forestry and cumulative effects in the region including those due to forest harvesting on species of vegetation.

Although NRCan did not provide advice on this specific topic throughout the review, the Canadian Forest Service (CFS) of NRCan provided expertise on a number of topics relevant to this topic focused on caribou as described in section 5 of this final submission. In particular, NRCan provided advice on spatial optimization and modelling of caribou habitat connectivity in forest landscapes, caribou space use behavior and habitat selection modeling, and demographic responses of caribou populations to cumulative landscape disturbances in support of ECCC's review related to their responsibilities under the *Species at Risk Act*.

For JRP consideration, NRCan has provided below a summary of CFS active research focused on cumulative effects and forestry and recommendations of relevant data and publications sources that could be useful to the JRP in their assessment or future studies in the area.

### 7.1 Context

The science of cumulative effects involves analyzing how landscape level disturbances interact with each other. Researchers analyze whether these interactions are positive or negative and measure their risk to the environment. They also determine how multiple disturbances change the forest by examining indicators such as tree health and threatened species at risk, including woodland caribou.

As part of supporting open science and cumulative effects, CFS manages a national program which conducts science related to understanding, assessing and reducing the risk of cumulative effects on forests. CFS researchers are involved with developing knowledge, strategies and tools to help manage the cumulative effects of resource development projects, working collaboratively with national partners, jurisdictions, Indigenous communities and other stakeholders in academia and industry. Further, CFS research is also developing evidence-based tools to improve land reclamation and forest landscape restoration. For example, current work includes improving habitat quality for woodland caribou.

CFS continues to expand its understanding of the cumulative effects and impacts of development activities in Canada. Canadians continue to benefit from the use of this scientific and technical advice provided by CFS expertise. Some examples of the science funded to advance cumulative effects related objectives include:

- Development of a framework that can help address cumulative impacts, that also looks at the socio-economic impacts, in particular on Indigenous communities;
- Development of a model to better understand the impacts of cumulative effects on forest water resources;



- Determination of cumulative ecological and socioeconomic effects of forest management, natural disturbance, and climate change in Ontario's managed forests;
- Targeting forest reclamation practices and developing indicators designed to protect and restore water resources and maximize carbon capture in a cumulative effects landscape;
- Analysis of the footprint of mining activities on diversity and terrestrial ecosystem processes throughout a mine's life cycle; and
- Assessing the long-term economic interactions between industrial forestry activities, non-renewable resource extraction and caribou recovery with the application of spatial optimization models.

## 7.2 NRCan Available Data and Publications

While NCan has not been previously involved in the review of potential cumulative effects associated with this project, it has provided a list of available data and relevant references below that may assist in reviewing cumulative effects relating to this project such as in relation to soils, vegetation and disturbance mapping. These data are accessible through the Government of Canada's Open Science and Data Platform, the National Forest Information System, the Canadian Wildland Fire Information System and the Canadian National Fire Database.

### 7.2.1 NRCan Available Data

- National Forest Inventory (NFI) Ground plot data - Canada's NFI ground plots are a stratified random sample of select Canadian terrestrial ecozones. Ground plots are re-measured periodically. Data from ground plots include field measurements, compiled attributes and descriptions made at a point inside or adjacent to a photo plot. Ground plot data include individual large-tree and small-tree measurements, shrub tallies, understory vegetation sampling, vegetation cover, stump assessments, woody debris data, surface substrates, site descriptions and soil measurements<sup>1</sup>.
- Disturbance Data Foundation (DDF) - The DDF is a warehouse of geospatial data about forest disturbances. The system collects disparate agency data, applies transformations that harmonize data for analysis, and provides a portal to access both original and harmonized data. These data provide the foundation for understanding the cumulative effects of forest disturbances in Canada.<sup>2</sup> The DDF also includes the below listed disturbance datasets National Burned Area Composite (NBAC), Composite-to-Change (C2C) Forest Disturbance dataset, Canada Landsat Disturbance (CanLaD), and the Canadian National Fire Database (CNFDB).

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<sup>1</sup> <https://osdp-psdo.canada.ca/dp/en/search/metadata/NRCAN-FGP-1-35c3556c-e48d-41a7-ac50-652257b0a8e8>

<sup>2</sup> [https://ca.nfis.org/forestdisturbances/index\\_eng.html](https://ca.nfis.org/forestdisturbances/index_eng.html)



- Common Attribute Schema for Forest Resource Inventory (CASFRI) - Digital Forest Resource Inventories (FRIs) are compiled by provincial and territorial governments and are key inputs into forest management planning. The inventories estimate the location, extent, condition, composition, and structure of the forest resource. Each jurisdiction has developed its own procedures and standards for forest inventories. The Common Attribute Schema for Forest Resource Inventories (CASFRI) standardizes FRI data from each jurisdiction in Canada, allowing a national FRI relational database to be created with continuous coverage.
- *Multi-Agency Ground Plot (MAGPlot) database* – Agglomeration of forest sampling data from multiple sources into a centralized secure online repository for use in pan-Canadian projects. The database will provide centralised access to harmonized, analysis-ready tree-mensuration data from agencies and programs across Canada.
- National Burned Area Composite (NBAC) - The NBAC is a geographic information system (GIS) database and system that calculates the area of forest burned on a national scale for each year since 1986. The data are used to help estimate carbon emissions in Canada. The NBAC is part of the Fire Monitoring, Accounting and Reporting System (FireMARS), jointly developed by the Canadian Centre for Mapping and Earth observation of Natural Resources Canada and the Canadian Forest Service. Data for NBAC are provided by Natural Resources Canada, Parks Canada and provincial and territorial agencies.<sup>3</sup>
- Canada Landsat Disturbance (CanLaD) 2017 - This dataset provides uniform spatial and temporal information on fire and harvest across all provinces and territories of Canada and is intended for strategic-level analysis. The focus of this product is not on minor disturbances such as mining, road or flooding, and therefore should not be used for their identification. This data publication contains a set of files in which areas affected by fire or by harvest from 1984 to 2015 are identified at the level of individual 30m pixels on the Landsat grid.<sup>4</sup>
- Canadian National Fire Database (CNFDB) - *Canadian National Fire Database (CNFDB)* –The CNFDB is a collection of forest fire data from various sources; these data include fire locations (point data) and fire perimeters (polygon data) as provided by Canadian fire management agencies (provinces, territories, and Parks Canada).<sup>5</sup>
- Composite-to-Change (C2C) Forest Disturbance dataset - The first wall-to-wall characterization of wildfire and harvest in Canada at a spatial resolution

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<sup>3</sup> <https://cwfis.cfs.nrcan.gc.ca/datamart/metadata/nbac>

<sup>4</sup> <https://osdp-psdo.canada.ca/dp/en/search/metadata/NRCAN-FGP-1-add1346b-f632-4eb9-a83d-a662b38655ad>

<sup>5</sup> <https://cwfis.cfs.nrcan.gc.ca/ha/nfdb>



commensurate with human impacts. The information outcomes represent > 30 years of stand replacing change in Canada's forests, derived from a single, consistent spatially-explicit data source, derived in a fully automated manner. Time series of Landsat data were used to characterize national trends in stand replacing forest disturbances caused by wildfire and harvest for the period 1985-2011 and 2012-2015 for Canada's 650 million hectare forested ecosystems (White et al. 2017)<sup>6</sup>

### 7.2.2 NRCan available Publications

Barber, Q. E., Bater, C. W., Dabros, A., Pinzon, J., Nielsen, S. E., & Parisien, M. A. 2021. Persistent impact of conventional seismic lines on boreal vegetation structure following wildfire. *Canadian Journal of Forest Research*, 51(11), 1581-1594.

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McIntire, E., Chubaty, A., Cumming, S., Andison, D., Barros, C., Boisvenue, C., & Stewart, F. 2021. Predictive Ecology: a Re-imagined Foundation and Toolkit for Ecological Models.

Pimentel Da Silva, G.D.; Parkins, J.R.; Nadeau, S. 2020. Social Impact Assessment Methods for Predicting Cumulative Effects involving Extractive Industries and Indigenous People. University of Alberta. 49 p.

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Winder, R., Stewart, F. E., Nebel, S., McIntire, E. J., Dyk, A., & Omendja, K. 2020. Cumulative Effects and Boreal Woodland Caribou: How Bow-Tie Risk Analysis Addresses a Critical Issue in Canada's Forested Landscapes. *Frontiers in Ecology and Evolution*, 8, 1.

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Yemshanov, D., Haight, R. G., Liu, N., Rempel, R., Koch, F. H., & Rodgers, A. 2021. Exploring the tradeoffs among forest planning, roads and wildlife corridors: a new approach. *Optimization Letters*, 1-42.

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<sup>6</sup> <https://www.sciencedirect.com/science/article/pii/S0034425717301360>



## **8 SUMMARY OF RECOMMENDATIONS**

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NRCan's participation in the environmental assessment of the Project has involved the provision of scientific and technical expertise in areas within our mandate relevant to the project. NRCan is offering the following recommendations to the JRP:

### **8.1 Hydrogeology and Groundwater**

1. The Proponent should provide detailed reporting of model results discussed above to ensure clarity on reported seepage quantities and flow pathways to be used in the design of the detailed groundwater monitoring program.
2. When developing the detailed groundwater monitoring program, the Proponent should account for the long travel times, consistent with groundwater model results.
3. To guide monitoring measures, NRCan recommends that the Proponent report forecasted changes to groundwater- surface water interaction for the individual surface waterbodies represented in the numerical model, and that reported flux changes are consistent with reported changes in groundwater elevations.

### **8.2 Acid-Rock Drainage and Metal Leaching**

4. NRCan recommends that the Proponent consider the development of an approach to identify Type 1 material with neutral leaching potential during operations and prior to its use for construction purposes. This could be included as an update to the Mine Rock Segregation Program.
5. NRCan recommends that the management of Type 1 rock in the Mine Rock Storage Area (MRSA) consider follow-up monitoring and mitigation, in the event that neutral drainage with elevated concentrations of metals, including Platinum Group Metals (PGMs), be identified.
6. NRCan recommends that additional sampling and testing of mine rock be completed as material becomes available in the areas un-sampled through future drilling programs, including samples representative of the anticipated pit walls. This should be completed as the Project progresses through provincial permitting to refine Type 2 volume estimates in support of engineering design, and then further refined during operational testing for segregation.
7. NRCan recommends that the Environmental Monitoring and Management Plan (EMMP) including operational monitoring and adaptive management strategies to offset the risk of inadequate management of Type 2 rock (mine waste and pit walls) and subsequent impacts to water quality.
8. NRCan recommends the Proponent complete a sensitivity analysis of Type 2 mine rock in the MRSA and use these results to update the seepage and runoff quality estimates for the MRSA in operations and post-closure. This would ensure adequate water treatment, mitigation and monitoring measures are in place.
9. NRCan recommends the Proponent implement a testing program to evaluate the reactivity of both chalcopyrite-rich and pyrrhotite-rich Type 2 mine rock. Until the results are obtained,



- NRCan recommends that the Proponent temporarily consider more conservative “proxy” Type 2 loading rates based on other analyses that could be completed ahead of operations.
10. NRCan recommends the Proponent use the estimated effluent concentrations of PGMs to predict water and sediment quality in Hare Lake, Pic River and Stream 106 during project operations and post-closure.
  11. When results of leaching experiments to estimate release rates of PGMs from waste rock and tailings will be available. NRCan recommends that they be used to update water and sediment quality predictions for PGMs in Hare Lake, Pic River and Stream 106 and that the Proponent include PGMs in its monitoring program.

### **8.3 Caribou Habitat Suitability and Functional Landscape Connectivity**

12. NRCan recommends that the Proponent re-evaluate suitable caribou habitat, using zones of influence consistent with the scientific literature on individual caribou responses to linear and other anthropogenic features. Once adequate buffers have been applied, NRCan recommends the Proponent conduct a new assessment of the Project’s projected impact on intra- and inter-range caribou habitat connectivity.



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## **ANNEXE : NRCAN'S EXPERTS CVS**

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### **Richard R. Goulet: Statement of Expert Qualifications**

Dr. Goulet has 25 years experience in assessing the impacts of mine waste and effluent on aquatic environments. He is currently research scientist at CanmetMINING where he reviews environmental impact of mining projects across Canada. His main research areas are passive mining effluent treatment, metal and radionuclide toxicity to aquatic species and how DNA and historical profiles in sediment can testify of past impacts to freshwater organism from mining effluent. He joined CanmentMINING in January 2020. Previously, he spent 12 years at the Canadian Nuclear Safety Commission as a risk assessment specialist reviewing environmental assessments of proposed uranium mining and milling projects as well as environmental effects monitoring reports from operating and decommissioned uranium mining and milling sites. In 2008, he was appointed as adjunct professor at the Department of Earth Sciences where he teaches environmental management in both official languages. Previously, he worked at Environment Canada from 2002 to 2007 where he assessed the risks of metal containing substances to the environment. From 2000 to 2002, as a post-doctoral fellow, Dr. Goulet specialized in measuring metal species in sediment and surface water. Dr. Goulet obtained a Ph.D. in biology in 2000 from the University of Ottawa based on his research related to the fate of metals in constructed wetlands used for passive treatment of mining effluent could remove metals from mining effluents. Over this period, Dr. Goulet published 20+ journal papers in scientific journals and wrote numerous recommendation regarding the acceptability of proposed mine waste management projects.

### **Richard R. Goulet Ph.D.**

Senior Research Scientist and Section Head

Mine waste Management and Environmental Assessment group

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### **Jennifer Cole: Statement of Expert Qualifications**

Ms. Cole has been is a registered geologist in good standing with Professional Geoscientists Ontario since 2008. She has over seventeen years of experience in geochemical characterization studies to evaluate the acid rock drainage and metal leaching potential of mine waste. In her current role as a research scientist at CanmetMINING, Ms. Cole reviews baseline geochemical characterization studies submitted as part of environmental impact statements for mining projects across Canada, and completes research to evaluate the effects of mine waste practices on the environment in support of the impact assessment process. Prior to joining CanmetMINING in January 2020, she worked at Golder Associates for 15 years in both Ottawa and Lima, Peru. In her role as a consultant, Ms. Cole completed over 25 projects in mine waste geochemical studies to support mining projects in various stages of project design and mine life. She has participated in baseline environmental impact studies and feasibility studies for projects across Canada and the Arctic as well as internationally in the Caribbean, South America and Africa. She holds a B.Sc. from the Department of Geological Sciences at Queen's University and a M.Sc. from the Department of Geology and Geophysics at the University of Calgary, specializing in aqueous geochemistry.

#### **Jennifer Cole P.Ge. (Ontario)**

Research Scientist

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### **Melissa I. Bunn: Statement of Expert Qualifications**

Dr. Bunn has 15 years of experience characterizing groundwater flow and forecasting anthropogenic effects on groundwater flow using numerical models. She is currently a registered Professional Geoscientist in the province of Ontario, and a research scientist at the Geological Survey of Canada providing expert technical reviews of impact assessment projects throughout Canada. Her research focus is on the conceptualization and modelling of groundwater flow processes, and groundwater-surface water interactions under a changing climate. Prior to joining the Geological Survey in September 2019 Dr. Bunn worked as a consulting hydrogeologist with 8 years of experience in site conceptualization and groundwater modelling related to hydrogeological investigations for impact assessments and groundwater resource studies. Dr. Bunn received a B.A.Sc. in Geological Engineering in 2006, and a PhD in Earth Science in 2011 from the University of Waterloo. Dr. Bunn's PhD research was focused on state-of-the-art field monitoring of pumping tests, and advanced numerical modelling of site and pore scale hydrogeological processes. Dr. Bunn has completed more than 30 technical modelling reports, published 3 peer-reviewed articles, and presented research at more than 5 conferences.

#### **Melissa I. Bunn Ph.D.**

Research Scientist, Geological Survey of Canada, Northern Division  
Lands and Minerals Sector  
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### **Michel G. Houlé: Statement of Expert Qualifications**

Dr. Houlé is a research scientist since 2009 with the Geological Survey of Canada of the Natural Resources Canada and an adjunct professor at several universities in Canada. His scientific research focuses on orthomagmatic Ni-Cu-PGE, Cr-PGE, and Fe-Ti-V mineralization associated with mafic and ultramafic rocks in diverse geologic environments across Canada but also on the physical volcanology, geochemistry, and petrogenesis of komatiites in Precambrian shield. Since joining the Geological of Canada in 2009, Dr. Houlé has led team of scientists and students in order to better understand some major Ni-Cu-PGE and Cr-PGE deposits in Canada and which factors control the genesis of these types of orthomagmatic mineralization associated with mafic and ultramafic rocks. This led him to work in various region across the Archean and Proterozoic domains of the Canadian Shield such as Bird River greenstone belt in Manitoba, the McFaulds Lake, the Shebandowan and the Abitibi greenstone belts in Ontario, the La Grande and the Eastmain greenstone belts and the Cape Smith belt in Quebec, the Melville Peninsula in Nunavut, and the Labrador Trough in Quebec and Labrador. Dr. Houlé received his B.Sc and M.Sc degrees in 1997 and 2000 from Laval University, Québec, Quebec. He received his Ph.D. degree in Earth Sciences from the Department of Earth Sciences, University of Ottawa in 2008. He has many scientific memberships and has received seven awards/honours. He has 20 technical publications to his credit and has participated in numerous scientific conferences.

#### **Michel G. Houlé, Ph.D., P. Geo.**

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