Natural Resources Canada Technical Submission for the Environmental Assessment of Fortune's Proposed NICO Mine Project

June 22, 2012

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Non-Technical Summary

Natural Resources Canada (NRCan) has legislated responsibilities under the federal *Explosives Act* for facilities that manufacture explosives. Fortune Minerals Ltd.s' NICO Cobalt-Gold-Copper-Bismuth Mine Project proposes explosives manufacturing at the mine site during its operational phase. NRCan has advised the Mackenzie Valley Environmental Impact Review Board (MVEIRB) that the department may be a regulatory authority for the purposes of the environmental assessment under the *Mackenzie Valley Resources Management Act*.

NRCan's participation in the MVEIRB review of the proposed NICO Project is also in the context of our role as an established leader in science and technology in the fields of minerals and metals and the earth sciences. Key scientific and technical experts from the department have been involved throughout the Government review of the technical reports submitted by Fortune, submitting information requests, and advising other regulators, parties and the Board of our findings.

In this report, NRCan provides specific comments on the following topics:

- Deposit Geology and Geophysics;
- Hydrogeology;
- Geotechnical Science, Permafrost, Terrain Sensitivity;
- Geotechnical Engineering;
- Surficial Geology, Geohazards and Stratigraphy; and
- Mine Waste Management – Metal Leaching and Acid Rock Drainage.

Where possible, NRCan has provided recommendations to the MVEIRB to assist in its decision-making process.

NRCan is willing to respond to any questions regarding our technical review by the MVEIRB, the Proponent, and other parties involved in the project in support of the environmental assessment process.

1. Introduction

Natural Resources Canada (NRCan) involvement in the Mackenzie Valley Environmental Impact Review Board's (MVEIRB) review of the Fortune Minerals Ltd.s' NICO Cobalt-Gold-Copper-Bismuth Project is both within the context of our regulatory role under the *Explosives Act*, and in our capacity as a source of science and technology expertise in the fields of minerals and metals and the earth sciences.

1.1. Regulatory Role

NRCan is responsible for administering the *Explosives Act* and regulations, and pursuing the advancement of explosives safety and security technology. Our principal priority is the safety and security of the public and of all workers involved in the explosives industry in Canada. Through the Explosives Regulatory Division (ERD), NRCan provides services and support to the explosives industry, including manufacturers, importers, distributors, and users of explosives.

A licensed explosives factory is a fixed site for the manufacture of blasting explosives, or in the case of bulk explosives manufacturing, the site with the facilities necessary to clean, decontaminate and repair vehicles that support satellite sites, customer sites and temporary sites from which trials and demonstrations may be conducted and where the manufacture of product occurs. A magazine licence is required to store all explosives for sale or use. Licensed facilities are inspected on a regular basis by NRCan regulatory officials. Licences are not permitted to lapse until ERD is satisfied that remediation and decommissioning has been satisfactorily carried out.

Fortune's proposal for the NICO Mine requires explosives manufacturing and storage at the mine site during the operational phase of the project. NRCan's regulatory and statutory responsibilities under the *Explosives Act* creates specific obligations for the department as a regulatory authority and responsible minster under *Mackenzie Valley Resource Management Act.*

The Proponent's explosives supplier will apply for a licence from ERD for the explosives factory and magazine and be required to follow specific guidelines and standards. For instance, it must be confirmed that the locations for the explosives facility are in keeping with the Quantity-Distance tables which give the minimum permissible distance between a site containing a quantity of explosives and a susceptible sites requiring protection. Other licence conditions include a spill contingency plan, an emergency response plan and operating and maintenance procedures.

1.2. Expertise

Specific areas of NRCan expertise that have been engaged in the Proposed NICO Project Environmental Assessment Review are:

- Deposit Geology and Geophysics;
- Hydrogeology;
- Geotechnical Science, Permafrost, Terrain Sensitivity;
- Geotechnical Engineering;
- Surficial Geology, Geohazards and Stratigraphy; and

- Mine Waste Management – Metal Leaching and Acid Rock Drainage.

NRCan has participated in:

- Comments on Proponent's Assessment Report (DAR) Draft Terms of Reference (TOR), Oct.16, 2009;
- Initial Review of the Draft Screening Report (DAR), Sept. 2011;
- Submission of Information Requests (IR) Round 1, Oct. 7, 2011;
- Review of IR Responses, Dec. 2012 – Jan. 2012;
- Meeting with the Proponent to discuss IR Responses, Jan. 26, 2012;
- Participation in Technical Meeting, Yellowknife, Feb. 7-9, 2012;
- Side-meeting with the Proponent to discuss IR Responses, Feb. 8, 2012;
- Submission of Technical Report, June 22, 2012; and,
- Interdepartmental Coordination Meetings.

For our technical review, the preliminary assessment of the Proponent's Assessment Report (DAR) for Fortune's NICO Mine (Sept. 2011) identified additional information required for NRCan to conduct a technical review. Requests for additional information were submitted to the MVEIRB regarding issues related to baseline terrain and geotechnical conditions and mine waste management.

The information provided by Fortune in its response to our information requests and during the Jan. 26 and Feb. 8 meetings, as well as the Feb. 2012 Technical Meeting was helpful in providing NRCan with a better understanding of how the conclusions in the DAR were reached.

At this phase in the EA review process, NRCan has the necessary information to complete its technical review and offer the following comments and recommendations for consideration by the MVEIRB. It is recognized that some of the recommendations are intended to provide guidance on factors that should be considered in final project design or subsequent monitoring and follow-up plans.

2. Deposit Geology and Geophysics

2.1. Relevant Sections of the Terms of Reference

Sections: 3.2.4 Description of Existing Environment; 3.2.5 Development Description; 3.3 Impacts on the Biophysical Environment; Appendix A Existing Environment; Appendix B Development Description; Appendix D Closure and Reclamation; Appendix G Terrain; Appendix J Biophysical Environmental Monitoring and Management Plans; Appendix L Cumulative Effects.

2.2. Documents Reviewed

DAR, May 2011:

- Concordance Table,
- Section 1 Introduction
- Section 2 Alternatives,

- Section 3 Project Description (especially Section 3.4), DAR Figures 3.2-1 and 3.4-1 (p. in 3-4 and 3-17),
- Annex A NICO Geochemistry Baseline,
- Section 18 Biophysical Monitoring Plans,
- Appendix 18.I AEMP,
- Section 19 Effects of the Environment on Development,
- Appendix 1.III Commitments,
- Appendix Figure 7-III.1.1,
- Section 10.4.2.1.2; Appendix IV-2b in Annex I; Appendix IV-2a and 2b.

2.3. General Comments

The approach taken and the studies undertaken by the Proponent to assess the geology and geophysics related environmental impacts of the project are very extensive and in depth; as are the supporting geology and geophysics data, documents, studies and models. In particular and for the current needs of this environmental assessment, the Proponent has characterized the deposit geology, stratigraphy and extreme transformation of precursor rocks at deposit-scale during mineralization, the mineralogy, the ore grade and the material properties. The Proponent has also provided the physical and chemical characteristics of mine rock and tailings, supported by cross sections, maps based on borehole logs, sampling and testing results. All geology and geophysics related components listed in Appendix 1.I (Section 11 of Biophysical Environment of Appendix A in Appendix 1.I), in addition to those requested in Section 1d of Appendix G in Appendix 1.I, that were known at the time the DAR was filed, have been taken into account.

2.4. Infrastructure Siting - Resource Potential

Mine and access infrastructure should preferably be sited at locations with among other qualities, low resource potential.

2.4.1. Proponent's Conclusion

While the terms of reference do not require to justify infrastructure siting, condemnation drilling was conducted to a depth of 223 metres at one locality within the co-disposal facilities, outside the zones of potential ore indicating geophysical anomalies (Appendix Figure 7-III.1.1).

2.4.2. NRCan's Conclusion and Rationale

Infrastructure has been described in sufficient detail and has been planned to take into account all scopes of the DAR and terms of reference as provided in the reports, documents, and appendices. On-going NRCan research in and around the NICO development suggests that further condemnation drilling be taken into account (See list of references).

2.4.3. NRCan's Recommendations

As this subject is outside the scope of the Terms of Reference, NRCan has no recommendation. However, the Proponent may wish to consider additional condemnation drilling and geophysical modelling at the co-disposal site.

2.5. Infrastructure Siting - Uranium mineralization

2.5.1. Proponent's Conclusion

The Proponent states that potential effects of Operation/Extraction/Drilling, Blasting, and Ore Transport (DAR Section 10.4.2.1.2, p. 10-44) were taken into account. Emission calculations and mitigation of emissions are well explained (Section 10.4.2.1.2 p. 10-46; Table 10.3-1, p. 10-25). As for Fugitive Dust that could originate from blasting, it is stated that Sources of Fugitive Dust and Metal Emissions within the NICO Facility will be identified when the project is developed and that a management plan will be implemented. Borrow Source sediments will be crushed to make aggregates for roads and other infrastructure (DAR Section 3.3.1.3 Site Infrastructure) and source regions have been identified (Figure 3.2-2). Samples for aggregates have been tested for their trace metal composition and leachates, including uranium content, from Borrow Sources (DAR Table 3.4-2, p. 3-20 and DAR Section 3.4.2.4, p. 3-24) and, type 1 mine rock and sub-economic mine rock that could be used as aggregate (Section 3.4.3, p. 3-25; Table 3.4-5, p. 3-27; Section 3.4.2.1, p. 3-22; Appendix Attachment 3.I.Ib). The study established that uranium did not pose problems for Type 1 mine rock nor for Borrow Sources material.

2.5.2. NRCan's Conclusion and Rationale

A corridor of uranium anomalies (named the Southern Breccia) occurs 1 km to the South of NICO and trends parallel to the orientation of the NICO deposit in a NW-SE striking direction. This corridor includes many of the historic uranium occurrences found by government mapping projects (in the 1990's) and private sector mineral exploration projects (e.g., in the 1970's and 1980's). NE-SW faults dissect the uranium-bearing corridor and displaced some of its southern components further towards the south-west.

Uranium concentrations documented in rocks within the NICO project area reach a maximum of 22 ppm for bulk samples extracted from the ore zone (Appendix IV-2b in Annex I) and 48 ppm in drill core sample 10-991 from a black 'schist' forming part of the waste rock. Within the delineation drilling and the analyses of representative bedrock samples, uranium concentrations do not exceed the 50 ppm background value.

The geological setting of the Project Area and the development have been appropriately documented by the Proponent. The chemistry of all major rock types have been documented (10 SON Air Quality; Annex I NICO Chemistry Baseline). On-going NRCan research revealed that there may be slight uranium anomalies across the north-east end of Borrow Source 1.

Northwest Territories Assessment Report 080960 provides a vast amount of data on the distribution of uranium anomalies in the bedrock of the area including across all areas currently planned for building infrastructure. Their very dense traverses scanned for uranium anomalies are complementary to NRCan's observations, collectively providing excellent coverage.

2.5.3. NRCan's Recommendations

NRCan recommends that the Proponent consider, during final detailed design, the potential localized uranium anomalies near Borrow Source 1. NRCan is willing to work in collaboration with the Proponent.

2.6. References

Corriveau, L., Hayward, N., Craven, J., Montreuil, J.F., Enkin, R., Jackson V., Lauzière, K., Roberts, B., Ootes, L., Mumin, A.H., 2011a. Iron oxide copper-gold systems in the Great Bear magmatic zone: Setting the stage for the next cycle of exploration. In Fischer, B.J. and Watson, D.M. (compilers), 39th Annual Yellowknife Geoscience Forum Abstracts. Northwest Territories Geoscience Office, Yellowknife, NT, YKGSF Abstracts Volume 2011, p. 29.

Corriveau, L., Montreuil, J.-F., Hayward, N., Enkin, R., Craven, J., Roberts, B., Kerswill, J., Lauzière, K., Brouillette, P., Boulanger-Martel, V., Simard, S., 2010. Delineation of fluid pathways and resulting alteration and breccia signatures of IOCG systems, Great Bear Magmatic Zone, Northwest Territories. In Palmer, E. (compiler), 38th Annual Yellowknife Geoscience Forum Abstracts, Northwest Territories Geoscience Office, Yellowknife, NT, YKGSF Abstracts Volume 2010, p. 8.

Corriveau, L., Mumin, H., Montreuil, J.-F., 2011b. The Great Bear magmatic zone (Canada): The IOCG spectrum and related deposit types. SGA2011 - The 11th Biennial SGA Meeting of The Society for Geology Applied to Ore Deposits, Antofagasta, Chile, Transaction volume.

Corriveau,L., Mumin, A.H., Ootes, L., Montreuil, J.F., Jackson, V., Pelleter, E., Acosta Gongóra, P., 2011c. The Great Bear magmatic zone: The IOCG spectrum and related deposit types. Prospectors and Proponents Association of Canada Meeting, Toronto, March 5-9, 2011.

Enkin, R., Montreuil, J.F., Corriveau, L., Differential exhumation and concurrent fluid flow at the NICO Au-Co-Bi-Cu deposit and Southern Breccia U-Th-REE-Mo anomaly, Great Bear magmatic zone, NWT - A paleomagnetic and structural record. Geological Association of Canada – Mineralogical Association of Canada annual meeting, Program with Abstracts, v. 35, p. 41.

Hetu, R.J., Holman, P.B., Charbonneau, B.W., Prasad, N., and Gandhi, S.S., 1994. Multiparameter airborne geophysical survey of the Mazenod Lake area, Northwest Territories, 1993 (NTS 85 N/10 and parts of 85 N/11, 14, 15). Geological Survey of Canada, Open File 2806.

McMartin, I., Corriveau, L., Beaudoin, G., 2011a. An orientation study of the heavy mineral signature of the NICO Co-Au-Bi deposit, Great Bear magmatic zone, Northwest Territories, Canada. Geochemistry: Exploration, Environment, Analysis, 11, 293-307.

McMartin, I., Corriveau, L., Beaudoin, G., Averill, S.A., Kjarsgaard, I., 2011b. Results from an orientation study of the heavy mineral and till geochemical signatures of the NICO Co-Au-Bi deposit, Great Bear magmatic zone, Northwest Territories, Canada. Open File report, Geological Survey of Canada 6723, 1 CD-ROM.

Montreuil, J.-F., Corriveau, L., Ootes, L., Jackson, V., Gélinas, L.-P., 2010. Breccias as markers of tectono-hydrothermal evolution of iron oxide-bearing hydrothermal systems in the Great Bear Magmatic Zone. In Palmer, E. (compiler), 38th Annual Yellowknife

Geoscience Forum Abstracts, Northwest Territories Geoscience Office, Yellowknife, NT, YKGSF Abstracts Volume 2010, p. 85.

Potter, E.G., Corriveau, L., Montreuil, J.-F., 2010. Iron-oxide-copper-gold ±U in the Great Bear magmatic zone: Nature of U mineralization in IOCG systems. In Palmer, E. (compiler), 38th Annual Yellowknife Geoscience Forum Abstracts, Northwest Territories Geoscience Office, Yellowknife, NT, YKGSF Abstracts Volume 2010, p. 91.

Thomas, M. and Olson, R.A., 1978. Eldorado Nuclear Limited, exploration 1977 and 1978, Loo, BW and C mineral claims, Lou Lake, Mackenzie Mining district, NWT. Northwest Territories Assessment Report 080960, maps

3. Hydrogeology

3.1. Relevant Sections of the Terms of Reference

Sections: 3.2.4 Description of Existing Environment; 3.2.5 Development Description; 3.3 Impacts on the biophysical environment; Appendix A Existing Environment Biophysical environment 11); Appendix B Development Description; Appendix D Closure and Reclamation; Appendix G Terrain; Appendix J Biophysical environmental monitoring and management plans; Appendix L Cumulative Effects.

3.2. Documents Reviewed

DAR, May 2011:

- Concordance Table,
- Section 1 Introduction,
- Section 2 Alternatives,
- Section 3 Project Description,
- Appendix 3.II CDF Management Plan, Section 3.II.5.4,
- Appendix 3.III Water Management Plan,
- Appendix 3.III Water Management Plan: Sections 3.III.3.2.4 and 3.III.3.2.5,
- Section 7 KLOI, Section 7.5,
- Section 11 SON Water Quantity,
- Appendix 11.I Groundwater Modelling, e.g. Section 11.1.5, Section 11.1.2.5, Table 11.I.2-1, and Section 11.I.6.2,
- Appendix 11.II Effects of Freshwater Extraction,
- Appendix 11.III Effects on Surface Water Quantity,

  Appendix 11.IV Flooded Open Pit Filling Scenario,
- Section 18 Biophysical Monitoring Plans,
- Appendix 18.I AEMP,
- Appendix 1.III Proponent Commitments.

NRCan Information Requests 1.8 and 1.9.

Response to NRCan Information Requests 1.8 and 1.9. EA0809-004 Information Request Responses – Fortune Minerals 1323814935.

Attachment to Response to NRCan Information Request 1.9: EA0809-004 IR Responses NRCan 1-9-Attachment D 1323889256.

3.3. General Comments

Field characterization and numerical groundwater flow modelling are described in the EIS's hydrogeology section. The assessment is well done and provides quantitative values such as water budgets, pumping rates throughout the mine's life and even after closure. However a few items under four topics remain to be clarified, and are described below.

3.4. Parameter Quantification

For an accurate prediction of project effects on groundwater flow, an appropriate groundwater flow model and appropriate input parameters and boundary conditions are required.

3.4.1. Proponent's Conclusion

In Appendix 3.III Water Management Plan Table 3.III.3-4 was presented, with assumed runoff coefficients for runoff from natural ground, from prepared ground, from ponds, from wet tailings, from dry tailings beach, from open pit, from mine rock and from sloped till cover. Infiltration factors for CDF, perimeter dyke and till cover are presented in Section 3.III.3.2.5.

In Appendix 11.1 Groundwater Modelling section Table 11.I.4-3 a summary is presented of 3D Groundwater Model Input Parameters such as hydraulic conductivity, total assumed thickness, porosity, specific yield, and specific storage of overburden (silt till), fracture bedrock, shallow bedrock, intermediate bedrock and deep bedrock.

3.4.2. NRCan's Conclusion and Rationale

Some of the coefficients and numerical values used in the report appear not to be physically based. For instance, precise values for runoff coefficients shown in Table 3.III.3-4, coefficients of infiltration for CDF, perimeter dyke and till cover of Section 3.III.3.2.5 are provided, but without uncertainty ranges nor real justification, e.g. beyond a statement such as "based on project experience". It is not clear in which project(s) and how these coefficients were determined, i.e. measured or modelled.

In addition, it is not clear how recharge rates of 10 mm/y in lowlands and 30 mm/y in highlands were estimated. Recharge is an important parameter in the present context and should have been studied in more detail.

Finally, specific yield values provided in Table 11.I.4-3 appear either as significantly overestimated (18% for silty till, in contrast to a value of 6% suggested in Todd, 1980) or underestimated (0.2% and 0.034% for fractured bedrock are very low). It is unclear how these values were determined. With such low values, there would not be any permeability or flow in these formations.

NRCan notes that the mean value provided for annual precipitation varies throughout the documents, sometimes being stated as 281 mm/y, while elsewhere an annual total of 343 mm/y is given. That is a ~20% difference.

3.4.3. NRCan's Recommendations

NRCan recommends that the Proponent provide:

- Explanation in which projects, where and how the runoff coefficients and infiltration coefficients for CDF, perimeter dyke and till cover shown in Table 3.III.3-4 were determined;
- Clarification of how recharge rates of 10 mm/y in lowlands and 30 mm/y in highlands were estimated;
- Explanation of how the specific yield values in Table 11.I.4-3 were determined; and,
- Clarification of what the correct mean precipitation value is for the NICO site.

3.5. Groundwater Levels

The development of a piezometric map is an important part of a groundwater characterization study. This map, that will provide groundwater flow patterns, should be based on accurate groundwater level measurements or, if not available, on a strong relationship between topography and groundwater levels.

3.5.1. Proponent's Conclusion

In Appendix 11.I Groundwater Modelling: Section 11.I.2.3 the Proponent used topography, stream levels, and a mean groundwater depth to extrapolate to locations with unknown groundwater levels to produce a piezometric map.

3.5.2. NRCan's Conclusion and Rationale

The method used by the Proponent to produce a piezometric map should be based on a good linear relationship between these two parameters (using available data). However, this is not the case here. Available data (82) provide a poor coefficient of determination (R2) of 0.19, while a statistically acceptable level of significance for a good linear relationship between topography and mean groundwater depth probably requires a value of about 0.7, and the closer it is to 1.0, the better.

It is unclear how groundwater levels, except where streams are located, were estimated in lowlands. Since most of the LSA / development footprint consists of lowlands, this information is important. It is also unclear which method of interpolation was used.

It is not clear whether groundwater levels were measured during packer tests, and if vertical hydraulic gradients were estimated. Such information would help to predict if additional water will enter the open pit or seep through the co-disposal facility floor.

3.5.3. NRCan's Recommendations

NRCan recommends that the Proponent provide:

- Explanation why the piezometric map was produced using the topography as an indicator of mean groundwater depth, while the correlation between topography and groundwater levels is very low;
- Clarification how groundwater levels were estimated in lowlands, beyond streams;

- Explanation which method of interpolation was used to create the piezometric map; and,
- Clarification if groundwater levels were measured during packer tests, and if vertical hydraulic gradients were estimated.

3.6. *Conceptual and Numerical Modelling*

Accurate conceptual and numerical modelling is required for accurate prediction of project effects on groundwater flow.

3.6.1. Proponent's Conclusion

The conceptual and numerical modelling are described in detail in Appendix 11.1.

3.6.2. NRCan's Conclusion and Rationale

Although a conceptual model is presented in the groundwater modelling report, it would be useful to obtain at least one cross-section showing borehole logs with their depth, depth to bedrock and stratigraphy, as well as associated piezometric levels (at different depths, if available) to better understand the hydrogeological context.

It is not clear how the hydraulic conductivities (K) of the 1st, 5th and 6th layers of the conceptual model (shown in Fig. 11.1-9) were selected. The graph of K versus depth of Fig.11.1-7 shows that only two hydraulic tests were performed close to the depth of the open pit floor (~180 m). These tests seem to correspond to the last interval of boreholes 03-282 and 03-283. One shows indeed a K value close to 1×10^{-9} m/s (9×10^{-10}), but the other shows a value of 3.5×10^{-8} m/s, which is more than an order of magnitude higher. It is unclear if the K values were measured before or determined *a posteriori* during numerical modeling. If the latter is true, it is unclear if different combinations of K and recharge values were tried. An obvious advantage of lower K values is that the modeled drawdown is very local.

Similarly, for the upper bedrock layer, K values shown graphically appear to be almost uniformly distributed between 10^{-6} to 10^{-8} m/s. It is unclear if the high value for layer 1 (10^{-6} m/s) was selected to be on the conservative side for infiltration. Nonetheless, most of this infiltrated water probably flows towards streams. It is unclear if the modelled discharge (outflows) in different areas were compared with low flow values. Only a comparison with hydraulic heads is provided in the documents. This is not enough to calibrate a numerical model.

Values from local hydraulic testing, provided on Fig. 11.1-7, obviously vary widely. It is unclear why not at least one pumping test was conducted, which could have provided a more reliable value and for a larger area. It is unclear if such a test is planned and if planned, at which time the Proponent plans to do such a test.

Inspection of the residuals obtained during validation of the numerical model shows that modelled hydraulic heads when elevations exceed 295 m are systematically and significantly under-estimated (-14.4 m on average). It is unclear if the reason for this underestimation could be a locally under-estimated recharge.

NRCan did not see a justification to neglect runoff for the situation, when the open pit floor will be situated at a lower elevation than a large part of the watershed. Water from the upstream part of the watershed could flow in the open pit and since runoff coefficients are often much larger than the percent of estimated recharge (from precipitation), it may have a considerable impact on the amount of water to be extracted from the pit by pumping.

3.6.3. NRCan's Recommendations

NRCan recommends that the Proponent provide:

- Cross-sections showing borehole logs with their depth, depth to bedrock and stratigraphy, as well as associated piezometric levels (at different depths if available) to better understand the hydrogeological context;
- Clarifications how hydraulic conductivities (K) of the 1st, 5th and 6th layers of the conceptual model (shown in Fig. 11.1-9) were selected;
- Explanation if the K values were measured before or determined *a posteriori* during numerical modeling;
- Clarification if different combinations of K and recharge values were tried in groundwater flow model runs;
- Explanation if the high value for layer 1 (10^{-6} m/s) was selected to be on the conservative side for infiltration;
- Clarification if the modelled discharge (outflows) in different areas were compared with measured low flow values, and how the model was calibrated;
- Explanation why not at least one pumping test was conducted, if a pumping test is planned, and if it is planned, when it will be conducted;
- Clarification if the reason for this underestimated hydraulic heads could be a locally increased recharge; and,
- Justification to neglect runoff in this work, since the open pit floor will soon be situated at a lower elevation than a large part of the watershed.

3.7. Groundwater Quality

Groundwater quality could potentially be influenced by water flow through the CDF into the uppermost groundwater aquifer. Therefore a good characterization of potential CDF water flow pathways and CDF material properties is essential.

3.7.1. Proponent's Conclusion

Information on water flow pathways through the CDF, and hydraulic conductivities are provided in Chapter 7, Appendix 3.II.

3.7.2. NRCan's Conclusion and Rationale

It is unclear how groundwater is protected against water infiltrating through the tailings since the co-disposal facility (CDF) appears to consist of waste material placed directly on natural ground (see Fig. 3.II.5-2). NRCan did not find the expected K value of the thickened tailings. It would be helpful to have further information on the expected groundwater flow through the CDF, and from the CDF into the underlying material, since this has important implications for the groundwater quality.

3.7.3. NRCan's Recommendations

NRCan recommends that the Proponent provide:

- Information on the expected K value of the thickened tailings; and
- Information on the expected groundwater flow through the CDF, and from the CDF into the underlying material.

4. Geotechnical Science, Permafrost, Terrain Sensitivity

4.1. Relevant Sections of the Terms of Reference

Section 3.2.4, Appendices: A, 3.2.5; B, 3.3, 3.3.8, C, G.

4.2. Documents Reviewed

DAR, May 2011:

- Sections: 1, 2, 3, 6, 9, 11, 13, 17, 18, 19, 20,
- Appendices: 1.III, 3.I, 3.II, 3.III,
- Annex, F (climate), G, H.

Response to Information Requests NRCan IR 1-4, 1-8, 1-9, 1-11, AANDC IR -10, 16

Golder and Associates Technical Memorandum, Feb. 21, 2012.

Undertaking No. 6 Co-Disposal Facility Covers.

Golder and Associates Technical Memorandum, Feb. 8, 2012. Case studies co-disposal practices in mine waste management.

Transcripts of Feb. 7–9, 2012 Technical Sessions.

Summary of Undertakings and Commitments, Feb. 17, 2012.

Response to Round 1 Information Requests including the following attachments:

- NRCan 1-4 Attachment A - Geotechnical Report,
- NRCan 1-4 Attachment B,
- NRCan 1-5 Attachment A - Route Evaluation,
- NRCan 1-7 Attachment A,
- NRCan 1-9 Attachment A,
- NRCan 1-9 Attachment B.

Golder and Associates Technical Memorandum Feb. 21 2012. Undertaking No.6 Co-Disposal Facility Covers.

Golder and Associates Technical memorandum Feb. 8 2012. Case Studies Co-Disposal Practices in Mine Waste Management.

Summary of Undertakings and Commitments, Mackenzie Valley Review Board, Feb. 17 2012.

4.3. Impacts Related to the Access Road

Relevant to Key Line of Inquiry, Water Quality; Subject of Note, Terrain and Soils.

Vegetation clearing and disturbance of the ground surface associated with road construction can lead to warming and thawing of frozen ground, ground settlement, terrain instability, changes to drainage and erosion which may have implications for terrestrial and aquatic ecosystems and also the performance of the road. The proposed NICO Project Access Road (NPAR) traverses terrain with variable material, drainage and permafrost conditions (DAR Section 19) and the impacts on the environment and on the project would also be expected to vary along the route.

4.3.1. Proponent's Conclusion

The Proponent acknowledges that clearing of vegetation for road construction can result in permafrost degradation, thaw settlement and alterations of drainage (e.g. DAR Section 13, Table 13.3-1). With the implementation of design features and mitigation including limiting the footprint, avoidance of stripping of organic layer, installation of culverts and avoidance of high ice content soil (as much as possible), the impacts on the environment will be minimized (DAR Section 13.3). Although thawing of the ground may be ongoing following construction, stabilization and re-establishment of permafrost in equilibrium with the climate will eventually occur although it may take decades (DAR Section 13.3.2.2). Changes in the ground thermal regime and subsequent ground movements and drainage changes can also have impacts on the road performance. With ongoing maintenance and the design features described above the Proponent concludes that impacts on the road performance will be minimal (DAR Section 19.2.1.3, response to NRCan IR 1-5 Attachment A).

4.3.2. NRCan's Conclusion and Rationale

NRCan generally agrees that with appropriate design and implementation of mitigation techniques, the impact of NPAR on the surrounding environment and the impact of environment on the road can be minimized. However, adequate information regarding subsurface materials along the proposed route and an assessment of the terrain sensitivity will be required for design of the road and associated mitigation. The DAR (DAR Section 13, Annex H) did not provide large scale route alignment sheets identifying terrain types and potential terrain sensitivity issues. In addition there have been no geotechnical boreholes drilled along the route and the description of characteristics of the subsurface materials is largely restricted to the upper 1 m. NRCan indicated in NRCan IR 1-5 that detailed large scale alignment maps focusing on the road corridor were required.

An example of a case in which such maps were provided would be the alignment maps for the winter access road for the Prairie Creek Mine which identify sensitive areas and where there is potential for instability (see for example, Prairie Creek Mine documents submitted to Mackenzie Valley Review Board – details below). In its response to NRCan IR 1-5, the Proponent provided larger scale maps but it is unclear if the mapping itself has been done at a larger scale. Although maps such as Figure 1 and 2 in NRCan IR 1-5 Attachment A are helpful, more detailed mapping of terrain conditions and terrain sensitivity will be required for final route selection and the detailed road design. The Proponent indicates in response to NRCan IR 1-5 that geotechnical investigations will be done after the route is approved by the Tlicho Government. However, some investigations may be required to determine the route that is to be approved. Detailed investigations, including test pits, will also be required at potential borrow sites, which have to date been based on limited test pits and grab samples (Response to NRCan IR 1-7). NRCan supports the Proponent's plans to conduct further investigations to finalize borrow site selection which will also allow a better assessment of the area to be disturbed to support road construction and maintenance activities.

NRCan also requested in NRCan IR 1-6, information regarding any analysis (such as thermal analysis) that has been done to support the road and assessment of impacts. In the response was stated that only a conceptual evaluation has been done rather than a detailed analysis. The Proponent appears to rely on small scale maps such as Heginbottom et al. (1995) for ground ice information which is inadequate for more site specific thaw strain evaluations, which are required for design. Although detailed analysis may not be required at this stage, some analysis supported by site specific geotechnical investigations would be required to support detailed design including determination of appropriate embankment heights to limit thaw and other mitigation techniques. Analysis should also consider issues such as increased snow thickness at the base of embankments, migration of surface and subsurface water (cross drainage) into the base of the subgrade and infiltration through the thawed embankment, all of which may effect the ground thermal regime (and result in permafrost degradation) particularly of the side slopes (e.g. Kondratiev, 2010; de Grandpré et al. 2010, 2012).

Although the rate of permafrost thaw may decrease over time following vegetation clearance (as shown for e.g. in Smith et al. 2008; Burgess and Smith 2003), stabilization of the ground thermal regime may not necessarily occur under warming climate conditions even with vegetation recovery (Smith and Riseborough, 2010). Clearance of vegetation and changes to the ground surface can also result in a greater response of the ground thermal regime to variability and change in climate over time. In addition, changes in drainage conditions and increases in subsurface water flow can further warm the ground beneath and in the vicinity of the embankment (e.g. de Grandpré et al. 2010, 2011). Changes in moisture conditions that accompany thaw will also have an influence on vegetation growth along the disturbed right-of-way. Effects related to the initial disturbance associated with road construction may therefore continue over the long-term.

4.3.3. NRCan's Recommendations

NRCan recommends the following in order to identify sensitive areas along the road corridor and to support final route selection and road design to ensure environmental effects are minimized:

- Conduct detailed terrain analysis supported by geotechnical investigations to characterize terrain sensitivity along the proposed route and to identify areas of potential instability. The product associated with this analysis will be large scale route alignment sheets that include this detailed information;
- Conduct thermal analysis and determine potential ground settlement for representative terrain types to support detailed road design including determination of embankment height and other mitigation measures (such as drainage control). The analysis should consider changes in snow cover and drainage that may influence the ground thermal regime; and
- Include in the assessment of environmental impacts, consideration of longer term effects associated with vegetation removal and changes in permafrost and drainage conditions along the road corridor.

NRCan recommends the following with respect to environmental monitoring and management plans:

- Environmental monitoring and management plans include installation of instrumentation in addition to visual inspections to monitor changes to the ground thermal regime and ground movements especially in sensitive areas; and
- Monitoring and mitigation/management plans be developed that define the criteria for the need for mitigation and selection of the appropriate mitigation technique.

4.3.4. References

Burgess, M.M., and Smith, S.L. 2003. 17 years of thaw penetration and surface settlement observations in permafrost terrain along the Norman Wells pipeline, Northwest Territories, Canada. In Proceedings of 8th International Conference on Permafrost. Edited by M. Phillips, S.M. Springman, and L.U. Arenson. Zurich Switzerland. July 2003. A.A. Balkema, pp. 107-112.

de Grandpré, I., Fortier, D., and Stephani, E. 2010. Impact of groundwater flow on permafrost degradation: implications for transportation infrastructures. In GEO2010, 63rd Canadian Geotechnical Conference and the 6th Canadian Permafrost Conference. Calgary, Sept 2010. GEO2010 Calgary Organizing Committee, pp. 534-540.

de Grandpré, I., Fortier, D., and Stephani, E. 2012. Degradation of permafrost beneath a road embankment enhanced by heat advected in groundwater. Canadian Journal Earth Sciences, 49. doi: 10.1139/E2012-018

Heginbottom, J.A., Dubreuil, M.-A., and Harker, P.A. 1995. Canada -- Permafrost; National Atlas of Canada Ottawa: Geomatics Canada, National Atlas Information Service, and Geological Survey of Canada, Plate 2.1, (MCR 4177).

Kondratiev, V.G. 2010. Some geocryological problems of railways and highways on permafrost of Transbaikal and Tibet. In GEO2010, 63rd Canadian Geotechnical Conference and the 6th Canadian Permafrost Conference. Calgary, Sept 2010. GEO2010 Calgary Organizing Committee, pp. 541-548.

Smith, S.L., Burgess, M.M., and Riseborough, D.W. 2008. Ground temperature and thaw settlement in frozen peatlands along the Norman Wells pipeline corridor, NWT Canada: 22 years of monitoring. In Ninth International Conference on Permafrost. Edited by D.L. Kane and K.M. Hinkel. Fairbanks Alaska. Institute of Northern Engineering, University of Alaska Fairbanks, Vol.2, pp. 1665-1670.

Smith, S.L., and Riseborough, D.W. 2010. Modelling the thermal response of permafrost terrain to right-of-way disturbance and climate warming. Cold Regions Science and Technology, 60: 92-103.

4.4. Management of Waste Rock and Tailings

Relevant to Key Line of Inquiry, Water Quality; Subject of Note, Terrain and Soils.

Mine waste rock and tailings will be stored and managed within the co-disposal facility (CDF). The CDF must be designed to limit contact of infiltrating water with potentially acid generating or metal leaching material and prevent seepage to the surrounding environment in order to minimize impacts to soils, and surface and subsurface water.

4.4.1. Proponent's Conclusion

The Proponent has concluded that use of a co-disposal facility in which tailings and waste rock will be deposited in the same facility offers a number of advantages including reduced footprint and increased stability (Feb. 8 Technical Memorandum). The Proponent has concluded impacts on water and soil quality related to seepage from the CDF will be minimal (DAR Section 7 and 13, e.g. Tables 7.5-1, 13.3-1). The Proponent has acknowledged (Section 7) that long-term seepage from the CDF can affect downstream surface water quality. Environmental design features will be implemented to reduce the potential for acid generation and metal leaching.

The CDF will be designed to limit runoff and seepage water from contacting tailings and metal leaching mine rock by placing this material in the interior of the CDF and a cover will limit infiltration. Runoff and seepage will not be directly released to the environment but will report to seepage collection ponds and to a treatment facility. The performance of the CDF and associated dams and dykes do not depend on the presence of frozen conditions and their integrity will not be affected by thawing permafrost including that which may occur under a warming climate. A conservative approach has been taken for the stability analysis for the CDF as modelling has been done as if only tailings are deposited (DAR Appendix 3.II). A monitoring program will be implemented to ensure that instability does not develop and CDF performs as planned.

4.4.2. NRCan's Conclusion and Rationale

NRCan generally agrees that with appropriate design and an effective monitoring and management plan, impacts related to seepage from the CDF can be minimized. Given the relatively warm permafrost (temperatures generally >-2°C) in the project area and the potential for a warmer climate in the next few decades, NRCan agrees with the Proponent's plans to not depend on frozen conditions for stability and performance of the CDF and associated dams and dykes. Frozen conditions, should they develop in the CDF however, will further limit seepage and enhance performance of the CDF.

The Proponent has concluded that there is a low potential for permafrost in the CDF area and that soils generally have low ice content (DAR Section 19.2.1). Permafrost thaw beneath the CDF is expected but any resulting settlement would be localized and is not expected to affect the stability of the CDF or water quality (e.g. Feb. 27, 2012 Transcript). Borehole logs with in the CDF footprint (NRCan IR 1-4 Attachment A), generally indicate that sediments have low ice contents but there is ice-rich fine-grained material reported for some boreholes (e.g. GA-10-15S, GA-10-20D). NRCan generally agrees with the Proponent's conclusion. However, there are a limited number of boreholes within the CDF footprint and further investigations during detailed design would improve the characterization of subsurface materials and their sensitivity. Creep settlement may also occur beneath the CDF which could also lead to deformation in the cover material and the potential for seepage. Refinement of the stability analysis during detailed and final design would therefore benefit from additional geotechnical investigations.

Although the CDF does not rely on permafrost for chemical stability, frozen conditions may develop over time. Also, there is the possibility of formation of frozen and unfrozen layers within the pile and also increased porewater pressure due to porewater expulsion as freezing occurs. This along with frost heave and thaw settlement may lead to instability in the pile and possible deformation of the cover. The Proponent has indicated in response to AANDC IR-16 (see also Feb. 7, 2012 Transcript) that they do not expect this to be an issue as tailings will be dewatered which will reduce the amount of water available to form ice lenses. Each layer that is deposited will have a slope of 2% which will also remove water. The Proponent has also committed (No. 15) to develop a CDF performance monitoring program using instrumentation such as piezometers and slope inclinometers to monitor performance of the CDF (DAR Appendix 3.II, Feb. 8, 2012 Transcript).

There is a potential for fine-grained ice rich material at dam and dyke alignments (e.g borehole GA-05011, NRCan IR 1-4 Attachment A, EBA-01 and EBA-02, NRCan IR 1-4 Attachment B). However, depths to bedrock are within 3.7 m and the thickness of ice-rich material is generally thin (NRCan IR 1-5 Attachment B). Removal of any frozen material prior to construction will ensure that key trenches for dams and dykes associated with CDF including seepage collection ponds, are founded on competent bedrock and limit potential for thaw settlement and instability (DAR Section 3, Appendix 3.III, Response to NRCan IR 1-11). Lining of dams will also be utilized to limit seepage (DAR Section 7). The design of dams, dykes and seepage collection ponds have considered the possibility of large precipitation events (DAR Appendix 3.III, Section 11, 17, 19). Sensitivity analysis has also been conducted for the site water balance to evaluate the effect of extreme precipitation events (Response to NRCan IR 1-8). NRCan agrees that the design approach is reasonable.

4.4.3. NRCan's Recommendations

Recognizing that design of the CDF is at a preliminary design level, NRCan recommends the following for detailed and final design of the CDF:

- The Proponent conduct further geotechnical investigations within the footprint of the CDF to improve the characterization of foundation materials and to support the detailed design;
- The Proponent refine the seepage and stability analysis for the CDF incorporating the new information from detailed geotechnical investigations. This will also include updated creep analysis and consideration of effects related to the possible presence of frozen and unfrozen layers within the pile such as porewater expulsion and elevated pore pressures; and
- The Proponent follow through on commitments to develop an effective CDF monitoring and management plan which includes installation of instrumentation (such as piezometers, slope inclinometers, settlement plates, thermistors). Plans should also include a definition of triggers (or critical values) that determine the need for implementation of mitigation and the criteria for selection of mitigation techniques.

5. Geotechnical Engineering

Three of the main elements of this proposed project are: the open pit, the underground mine workings and the tailings-waste rock co-disposal facility (CDF). Slope stability (of the open pit mine and CDF) is an important part of the designs of these elements. Open pit slope stability determines the pit geometry and its footprint. Stability of the underground mine workings also influences the open pit design. The size of the underground mine and the open pit determine the volume of material to be stored in the CDF, which determines the footprint of the CDF. The footprint of the CDF is also dependent on slope stability of the facility. Stable slopes are important.

5.1. Relevant Sections of the Terms of Reference

Sections: 3.2.4 Description of existing environment; 3.2.5 Development Description; 3.3 Impacts on the biophysical environment; Appendix A Existing Environment Biophysical environment 11); Appendix B Development Description; Appendix D Closure and Reclamation; Appendix G Terrain; Appendix J Biophysical environmental monitoring and management plans; Appendix L Cumulative Effects

5.2. Documents Reviewed

The following documents or sections relevant to geotechnical engineering and slope stability have been reviewed or referenced in the review comments:

DAR, May 2011:

- Section 3: Project Description: 3.5: Mining; 3.7; Mine rock management; 3.8: Tailings and mine rock co-disposal facility,
- Section 13: Subject of note: terrain and soils; 13.2.2.2: Permafrost potential in the regional and local study areas,
- Section 17: Accidents and malfunctions: 17.3.1: Mining; 17.3.3: Co-disposed tailings and mine rock,
- Section 19: Effects of the physical environment on the development: 19.2.1.3.1: Co-disposal facility; 19.2.1.3.2: Open pit/underground workings; 19.2.6.1: Crown pillar failure; 19.2.6.2: Open pit slope instability,
- Appendix 1.I: Terms of Reference,
- Appendix 1.II: Concordance Table,
- Appendix 3.II: Co-disposal facility management plan.

Response to Information Requests NRCan IR 1-11 and attachments.

5.3. Open Pit Slope Stability

5.3.1. <u>Proponent's Conclusion</u>

DAR Section 3.5 Mining:

[Page 3-28] "Both open pit and underground mining methods will be utilized during the life of mine." "The ultimate depth of the underground mine workings at the termination of underground mining will be approximately 170 m below ground surface at the portal elevation. At the end of operations, the Open Pit will be approximately 1450 m long by 500 m wide by 230 m deep (Figure 3.5-1)."

[Page 3-30] "Information from the drilling program has been used to calculate the optimum design for the safe excavation of the ore body. The Open Pit at maximum size is expected to have a surface length of 1450 m, surface width of 500 m, and depth of 230 m. The walls of the pit will be sloped to prevent the pit walls from collapsing while the Open Pit mine is being excavated. Open Pit wall stability is a priority safety issue and is the focus of specific geotechnical engineering design requirements. The final Open Pit design equates to a 50° overall pit slope angle and a 75° batter (bench face angle) slope angle, with a 24 m wide pit ramp at a 10% gradient."

DAR Section 19.2.1.3.2 Open Pit/Underground Workings:

[Page 19-7] "The Open Pit slopes are designed to be stable under operating conditions. Given the competent character of the wall rocks, for which overall slope failure is not a concern, the slopes were designed to control the expected failure mechanism, and bench widths are designed to capture most sliding blocks and wedges of rock at the bench scale."

[Page 19-7] "The competent nature of the rocks that comprise the Open Pit slopes and the generally favourable orientation of joints in the rocks are such that slope failures will be limited to ravelling and small rock fall."

DAR Section 3.7.2 Mine Rock:

[Page 3-44] "The NICO Project is expected to generate approximately 96.9 Mt of Mine Rock during the predicted mine life."

DAR Section 3.8 Tailings and Mine Rock Co-Disposal Facility:

[Page 3-46] "Tailings and Mine Rock will be co-disposed in a single facility [CDF]."

[Page 3-47] "The NICO Project is projected to generate approximately 30 Mt of flotation tailings."

5.3.2. NRCan's Conclusion and Rationale

The Terms of Reference (ToR) (Appendix 1.I) state:

[Page 9] "Potential impacts of the physical environment on the development, such as changes in the permafrost regime, other climate change impacts, seasonal flooding and melt patterns, seismic events, geological instability, and extreme precipitation must be considered in each of the applicable items of this Terms of Reference.";

[Page10] "The Proponent will provide a description, map and rationale for all of the chosen geographic and temporal boundaries used during its impact assessment."; and,

[Page 31] "Describe potential impacts of NICO Project operations on terrain stability and vice versa." "Describe how the geotechnical stability of all engineered structures at the NICO mine site will be ensured against a range of climate, seismic and precipitation scenarios.".

The DAR described the mining methods and the size of the open pit. Although it stated "information from the drilling program has been used to calculate the optimum design for the safe excavation of the ore body", no information was provided as to how the final 50° slope angle was decided and what pit slope stability conditions were used as design basis.

Although some descriptions were provided as stated previously, NRCan did not see the slope stability related requirements of the TOR being met by the EIS.

For any rock condition (competent or poor), a design can be developed that maximizes the mine economy while slope stability is maintained at an acceptable level. Other than "competent rock", NRCan could not determine how slope stability was factored into the pit design. The basis of the Proponent's conclusion needs more explanation.

An explanation was missing how the joint orientation for all slopes around the pit is universally favourable. In other words, NRCan does not understand how the general rock joint orientation can be favourable to a slope at one side of the pit, and still be favourable to the slope at the opposite side of the same pit.

The above quantities mentioned in pages are directly related to the open pit design, which is dependent of slope stability.

In summary, NRCan acknowledges that the open pit is subject to detailed engineering design at a later stage. However, a preliminary level pit slope stability analysis supports if the mine design including its footprint, is based on reasonable assumptions. Without such information, it is difficult to assess the adequacy of the current DAR.

NRCan did not find information in the EIS that supports the open pit design. No pit slope stability analysis was provided. Therefore, it is difficult to assess the rationale of the proposed pit geometry/layout.

As a result NRCan requested information about slope stability in Information Request – NRCan 1.11, Items i and iv. The Proponent did provide a technical memorandum on open pit slope design recommendations which is much appreciated. However, the memorandum did not include the open pit slope stability analyses.

5.3.3. NRCan's Recommendation

NRCan recommends the Proponent provide information about the open pit slope stability analysis.

5.4. CDF Slope Stability - Strength Parameters Assumed for Glacio-Lacustrine Material

5.4.1. Proponent's Conclusion

Appendix 3.II Co-Disposal Facility Management Plan:

Section 3.II.5.4.4 Stability Analysis, page 3.II.19: "In order to provide an understanding of the general stability of the CDF, stability analyses were carried out on the cross sectional area considered to be the most critical." "Two-dimensional stability analyses were performed using the commercially available limit equilibrium slope stability program SLOPE/W (Version 2007)."

There is a layer of glacio-lacustrine deposit as part of the CDF foundation as depicted on page 3.II.21. "The thickness of the glacio-lacustrine deposit ranges from 2.9 to 6.2 m." (page 3.II.3).

Appendix 3.II [Page 3.II.19]"Table 3.II.5-3 provides a summary of the strength properties that were used in the stability analyses for the foundation soils, mine rock and tailings materials."

The glacio-lacustrine layer was assumed in Table 3.II.5-3 (page 3.II.19 of Appendix 3.II) as having a friction angle of 22° with zero cohesion. The material strength values were assumed "based on Golder's experience on similar materials." (page 3.II.19).

5.4.2. NRCan's Conclusion and Rationale

The weak foundation layer is a critical issue to the CDF slope stability. Based on NRCan's knowledge, fine grained glacio-lacustrine materials often cause slope stability problems. From NRCan's experience, the friction angle of similar materials can be as low as 10°. A tailings dam in Canada experienced serious instability problems because of such materials that exhibited a 10° friction angle. That particular dam had to be flattened resulting in a toe extension to a great distance from the original design. Should the glacio-lacustrine material at the NICO site have a similar friction angle, the CDF slope may have to be flattened considerably to meet stability requirements. If that is the case, the proposed footprint and feasibility of the CDF may be at question.

5.4.3. NRCan's Recommendation

NRCan recommends that the Proponent clarify how the 22° friction angle was derived for the glacio-lacustrine unit.

5.5. Critical Slip Surface Assumed in Slope Stability Analysis

5.5.1. Proponent's Conclusion

Appendix 3.II, Section 3.II.5.4.4, page 3.II.21 presents two slope stability models.

5.5.2. NRCan's Conclusion and Rationale

It was noted on the models that circular slip surfaces were assumed. While this is a common practice for relatively homogeneous materials, it may have underestimated the impact of the weak glacio-lacustrine layer in the foundation. With the circular slip surface assumption, only a small segment of the slip surface traverses through the weak layer. In other words, the factor of safety may have been over estimated by excluding most of the weak layer. From the reviewer's experience, a slope's factor of safety is often significantly lower when non-circular slip surfaces are forced to run through a weak foundation material such as the glacio-lacustrine layer in this case. The combined effect of this with that discussed above could be a significant reduction of the factor of safety of the CDF slopes. If that is the case, the CDF slope may have to be further flattened, which would enlarge the footprint of the CDF and the environmental effects associated with the proposed CDF may need to be re-assessed.

5.5.3. NRCan's Recommendation

NRCan recommends that the Proponent provide further information to justify the use of a 22° friction angle for the glacio-lacustrine material and the use of circular slip surface in a cross section in which a weak foundation layer exists.

5.6. Underground Mine Workings

5.6.1. Proponent's Conclusion

DAR Section 3.5, p.3-28 states: "Both open pit and underground mining methods will be utilized during the life of mine." "The ultimate depth of the underground mine workings at the termination of underground mining will be approximately 170 m below ground surface at the portal elevation. At the end of operations, the Open Pit will be approximately 1450 m long by 500 m wide by 230 m deep (Figure 3.5-1)." "Figure 3.5-1 illustrates the Open Pit and underground mines upon completion of mining."

DAR Section 3.5, p.3-31 states: "The principal [underground] mine levels (i.e., the 80/85 m, 105/110 m, 142/155 m, 179 m, and 217 m levels) will be accessed from surface via the mine ramp. The underground mining method will be retreat-transverse and longitudinal blast hole, open-stoping, and generally mined from the bottom up, and from east and west to the center of the ore body, without backfill."

DAR Section 19.2, p.19-17: "The potential for geological instability to affect the NICO Project is considered low. Crown pillars on the decline and portal area are comprised of competent rock. The underground workings, decline and portal will be mined out by the deepening Open Pit. Should any workings not be mined out, and a crown pillar assessment indicates potential risk, to ensure that ground collapse into these tunnels does not progress to surface, creating a hole, the shallower portions of the portal area and decline will be back filled with rock. This will prevent collapse. Access to the portal will be prevented by the installation of barriers."

5.6.2. NRCan's Conclusion and Rationale

Little information was provided in the DAR about the underground mine workings. It is noted that Figure 3.5-1 illustrates only the Open Pit. No information is available about the underground mines on this figure.

NRCan did not find further information about the rational for the design of the underground mine workings. Also, no information was found about the stability design of the underground stopes and how the underground mine workings would interact with the open pit. It is also not clear how the open pit slope stability would be affected by the underground portals. As a result NRCan requested information about slope stability in Information Request (IR) NRCan 1-11, Items i and iv. The Proponent provided this information in response to NRCan IR-1.11 (Attachment B, Technical Memorandum on Stoping Dimensions Based on Mathews/Potvin Stability Graph Analysis).

5.6.3. NRCan's Recommendation

NRCan is satisfied with the Proponent's response and has no recommendation pertaining to this issue.

6. Surficial Geology, Geohazards and Stratigraphy

6.1. Relevant Sections of the Terms of Reference

Sections: 3.2.4 Description of existing environment, 3.2.5 Development description, 3.3 Impacts on the biophysical environment; Appendix A Existing biophysical environment, Appendix B Development Description, Appendix D Closure and Reclamation, Appendix G Terrain, Appendix J Biophysical environmental monitoring and management plans, Appendix L Cumulative Effects.

6.2. Documents Reviewed

DAR, May 2011:

- Appendix 1.II Concordance Table,
- Section 1 Introduction,
- Section 2 Alternatives,
- Section 3 Project Description,
- Appendix 3.II CDF Management Plan,
- Appendix 3.III Water Management Plan,
- Section 13 SON Terrain and Soils: 13.2; 13.2.2.1.2 Terrain and Soil in the Local Study,
- Annex H NICO SOILS Baseline,

- Section 2.1.3 Field Surveys, Section 3.1.2 Terrain,
- Annex A NICO Geochemistry Baseline,
- Section 18 Biophysical Monitoring Plans,
- Appendix 18.I AEMP,
- Section 19 Effects of the Environment on Development,
- Appendix 1.III Proponent Commitments.

NRCan Fortune NICO Information Request 1-10, Oct. 7, 2011.

Fortune's Response to NRCan Information Requests 1-10.

6.3. General Comments

NRCan reviewed the terrain and soils baseline and project effect prediction provided by the Proponent, and concludes that it is generally sufficient with only a few minor inconsistencies or missing clarifications.

6.4. Discrepancy in Terrain Units

6.4.1. Proponent's Conclusion

Section 13.2.2.1.1 Terrain and Soil in the Regional Study Area provides an overview of eight terrain units mapped in the RSA. Two units of glaciofluvial sand/gravel with till and organics represent over 38% of the area (Table 13.2-1). Their distribution is shown in Figure 13.2-2, which includes an outline defining the local study area.

This section provides an overview of eight terrain units mapped in the LSA. Some regions in Figure 13.2-4a have been classified as "unclassified" (Table 13.2-3), representing 3% of the mine area. The Proponent explains that interference (cloud, haze, shadow) in the Ikonos and Landsat imagery prevented a complete evaluation.

This section provides an overview of soil plots, in which parent material was noted (2.1.4), to verify soil mapping which was derived solely on vegetation analyses. Terrain maps were derived from these data.

The Proponent provides soil plots which lack uniform coverage in the study area. It is unclear if the distribution of sites is appropriate to accurately represent training areas used to establish correlations for the purpose of terrain mapping. Representative distribution generally provides better control.

This section provides an overview of eight terrain units mapped in the RSA based on surficial parent materials and landform patterns.

The Proponent provided a response to NRCan IR 11-10 (ii) for a map of terrain units surrounding some potential borrow pits.

6.4.2. NRCan's Conclusion and Rationale

The terrain unit map of the local study area (Figure 13.2-4a) does not include the same units as in Figure 13.2.-2, and till is not included in Table 13.2-3, which describes terrain map units in the local study area. The same terrain units should be consistent for similar geographic areas.

NRCan notes that there are other sources of data that could have been used to complete the missing information (publically-available National Air Photo Library air photos (NAPL #A11340-326 to 328) for example). It is unclear how the physical and geotechnical properties of the soils/terrain in unclassified areas were determined. It is also not clear how the permafrost potential was assessed (Figure 13.2-6a). Inspection sites from Figure 13.2-1 do not appear to cover these geographic locations.

It is not explained why glacio-lacustrine deposits/soils and till exposed on hillsides have been observed (3.II.2.3 Geotechnical Investigations, Fortune Minerals Limited Proponent's Assessment report), but do not appear on any terrain maps. As a result NRCan requested information about slope stability in Information Request – NRCan 1-11 (i and iv). The Proponent did not provide this information in its response.

Two units of glaciofluvial sand/gravel with till and organics represent 42% of the area (Table 3.1-3). Their distribution is shown in Figure 3.1-1, which includes an outline defining the local study area. The terrain unit map of the local study area (Figure 3.2-1) does not include these same units, and till is not included in Table 3.2-1 which describes terrain map units in the local study area. There seems to be an apparent discrepancy in map units which cover the same geographic area.

Some regions in Figure 3.2-1 have been classified as "unclassified" (Table 3.2-2), representing 3% of the mine area, due to interference (cloud, haze, shadow) in the Ikonos and Landsat imagery which prevented a complete evaluation. However there are other sources of data that could easily have been used to complete the missing information. It is unclear what the consequence is of this information gap for soil erosion risk (Figure 3.4-1).

It is also unclear how permafrost potential was assessed in unclassified areas (Figure 19.216a, in Section 19.2.1.1 of "Effects of the Environment on Development").

The Proponent provided a response to NRCan IR 1-10 (ii) for a map of terrain units surrounding some potential borrow pits. Two of the proposed borrow pits, and their surrounding areas, in Figure 4 remain unmapped. It is unclear how these locations have been identified as potential borrow areas, when no terrain information is provided. While glacio-lacustrine material and till have been identified in soil inspection sites (Table 1, Proponent's Response to NRCan IR 1-10 (i), it is unclear why their presence is not included in existing terrain maps.

6.4.3. NRCan Recommendation

NRCan recommends that, if these figures are to be used in the future for regulatory or other applications, that the following inconsistencies be corrected:

- Figure 13.2-4a and Figure 13.2.-2 should use the same terrain units;
- Figure 3.2-1 should make use of other sources of data to complete "unclassified" regions; and
- glacio-lacustrine deposits/soils and till exposed on hillsides and elsewhere should appear on terrain maps.

7. Mine Waste Management - Metal Leaching and Acid Rock Drainage

7.1. Relevant Section of the Terms of Reference

Terms of Reference for the Environmental Assessment of Fortune Minerals Ltd.'s NICO Cobalt-Gold-Copper-Bismuth Project EA 0809 – 004.

7.2. Geochemical Characterization

Acid rock drainage evaluations including acid base accounting tests must be supported by geochemical and mineralogical data and other tests. Appropriate methods of assessment of mineralized mine rock and should be provided to ensure long-term environmental protection.

7.2.1. Documents Reviewed

DAR, May 2011:

- Annex A (Geochemical characterization of waste rock, ore, and tailings – Report no: 0811180043(5000), p.22, p.30, Table 5-3, Table 5-4,
- Appendix IV-1a,
- Appendix IV-3c,
- Appendix 3.II Co-Disposal Facility Management Plan, page 3.II.9.

Information Request Responses, Dec. 2011: IR NRCan 1-1, Responses 1 and 5.

Fortune's Response to Additional Information Requests from NRCan: Written record of discussions between Golder Associates Ltd. and NRCan. Letter dated Feb. 14, 2012.

7.2.2. Proponent's Conclusion

Fortune Minerals Limited DAR provided assessment of waste rock, ore and tailings using carbonate neutralization potential (CaNP) in determination of the neutralization potential ratio.

For geochemical characterization studies, the DAR acknowledges that the dissolution of non-carbonate minerals in the mine rock samples contributed to the measured neutralization potential values.

7.2.3. NRCan's Conclusion and Rationale

Several mineralized mine rock samples were characterized with lower acid generating potential than calculated by the reviewer. In general, the Proponent was requested to review and verify the acid base accounting assessments. In the IR responses (Dec. 2011), the Proponent noted that the assessment was consistent with assessment practices and based on methods in recognized guidance documents (MEND 1.20.1, 2009). NRCan requested further clarification on the rationale/method for the acid rock drainage evaluation to ensure the acid base accounting tests used were supported by geochemical and mineralogical data.

During the teleconference held on Jan. 26, 2012 NRCan requested the Proponent provide more discussion on the CaNP values, and rationale to support their conclusions. Fortune provided additional explanation, and validation for their conclusions based on the mineralogy, net acid generation testing, kinetic testing and site deposition strategy.

7.2.4. NRCan's Recommendation

NRCan is satisfied with the Proponent's response, and has no further recommendation pertaining to this issue.

7.3. Ore Processing

To ensure good mine waste management practices, clarification was requested on where the arsenopyrite and pyrite report.

7.3.1. Documents Reviewed

DAR:

- Annex A (p. 22),
- Appendix IV-1a.

Information Request Responses, Dec. 2011: IR NRCan 1-1, Response 1-2i and 2-ii.

Fortune Response to Additional Information Requests from NRCan: Written Record of Discussions between Golder Associates Ltd. and NRCan, Letter dated Feb. 14, 2012.

7.3.2. Proponent's Conclusion

Fortune Minerals Limited DAR noted that the ore (FC5) contained 6.5% arsenopyrite and 2% pyrite.

7.3.3. NRCan's Conclusion and Rationale

NRCan requested clarification on what happens to these minerals during processing, and where they report (i.e. rougher tailings, cleaner tailings or concentrate).

The Proponent responded that "if processed, arsenopyrite and pyrite will be crushed, ground and will report to the waste streams in various amounts, including rougher tailings, cleaner tailings and concentrate. The amount reported to each stream depends on their concentration within the ore.

NRCan requested further information on the milling process, and to identify where arsenic goes after processing. During the teleconference (Jan. 26, 2012) the Proponent outlined the milling process, and noted that the majority of the arsenic is recovered in the final concentrate. NRCan agreed that a summary of the mineral processing, with an explanation of where the arsenic minerals report, would be an appropriate response.

7.3.4. NRCan's Recommendation

NRCan is satisfied with the Proponent's response, and has no further recommendation pertaining to this issue.

7.4. Inconsistency with Reported Claudetite (As_2O_3) Concentrations of the Tailings Compared to the Bulk Chemical Assays

As arsenic is a serious environmental contaminant, these uncertainties should be explained.

7.4.1. Documents Reviewed

DAR, May 2011:

- Annex A, p. 23,
- Appendix IV-1b; Appendix IV-2c.

Information Request Responses, Dec. 2011: IR NRCan 1-8.

Fortune Response to Additional Information Requests from NRCan: Written record of discussions between Golder Associates Ltd. and NRCan, Letter dated Feb. 14, 2012.

7.4.2. Proponent's Conclusion

Fortune Minerals Limited Proponent's Assessment Report reported claudetite (As2O3) concentrations of the tailings (1.3 to 1.9%).

7.4.3. NRCan's Conclusion and Rationale

Proponent's values for claudetite (As_2O_3) in the tailings are inconsistent with the bulk chemical assays. Claudetite concentrations correspond to As concentrations of about 1 to 1.4 wt% which are greater than the reported As assays of 0.02 to 0.2 wt%. It appears that the reported claudetite concentrations are erroneous. The Proponent was requested to review and revise the reported claudetite concentrations of the tailings and provide an explanation for the discrepancy. The response by Fortune noted that differences exist between percentages determined through mineralogy and elemental analyses. NRCan requested further explanation of the discrepancies. The source of the uncertainties should be stated i.e. sampling, analyticial. During the discussion on Jan. 26, an account was provided for the differences, which was detailed in the Proponents letter of Feb. 14, 2012. Differences may be due to a number of reasons, including, sampling, mineralogical analysis, elemental analysis, interpretation.

7.4.4. NRCan's Recommendation

NRCan is satisfied with the response, and has no further recommendation pertaining to this issue.

7.5. References

Mine Environment Neutral Drainage (MEND) Report 1.20.1, 2009 (Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, CANMET – Mining and Mineral Sciences Laboratories, Natural Resources Canada.

8. Summary of NRCan's Recommendations

1. NRCan recommends that the Proponent consider, during final detailed design, the potential localized uranium anomalies near Borrow Source 1. NRCan is willing to work in collaboration with the Proponent.
2. NRCan recommends that the Proponent provide:
    a. Explanation in which projects, where and how the runoff coefficients and infiltration coefficients for CDF, perimeter dyke and till cover shown in Table 3.III.3-4 were determined;
    b. Clarification how recharge rates of 10 mm/y in lowlands and 30 mm/y in highlands were estimated;
    c. Explanation how the specific yield values in Table 11.I.4-3 were determined; and,

   d. Clarification what the right mean precipitation value is for the NICO site.

3. NRCan recommends that the Proponent provide:
   a. Explanation why the piezometric map was produced using the topography as an indicator of mean groundwater depth, while the correlation between topography and groundwater levels is very low;
   b. Clarification how groundwater levels were estimated in lowlands, beyond streams;
   c. Explanation which method of interpolation was used to create the piezometric map; and,
   d. Clarification if groundwater levels were measured during packer tests, and if vertical hydraulic gradients were estimated.
4. NRCan recommends that the Proponent provide:
   a. A few (or at least one) cross-sections showing borehole logs with their depth, depth to bedrock and stratigraphy, as well as associated piezometric levels (at different depths if available) to better understand the hydrogeological context;
   b. Clarifications how hydraulic conductivities (K) of the 1st, 5th and 6th layers of the conceptual model (shown in Fig. 11.1-9) were selected;
   c. Explanation if the K values were measured before or determined *a posteriori* during numerical modeling;
   d. Clarification if different combinations of K and recharge values were tried in groundwater flow model runs;
   e. Explanation if the high value for layer 1 (10-6 m/s) was selected to be on the conservative side for infiltration;
   f. Clarification if the modelled discharge (outflows) in different areas were compared with measured low flow values, and how the model was calibrated;
   g. Explanation why not at least one pumping test was conducted, if a pumping test is planned, and if it is planned, when it will be conducted;
   h. Clarification if the reason for this underestimated hydraulic heads could be a locally increased recharge; and,
   i. Justification to neglect runoff in this work, since the open pit floor will soon be situated at a lower elevation than a large part of the watershed.
5. NRCan recommends that the Proponent provide:
   a. Information on the expected K value of the thickened tailings; and
   b. Information on the expected groundwater flow through the CDF, and from the CDF into the underlying material.
6. NRCan recommends the following in order to identify sensitive areas along the road corridor and to support final route selection and road design to ensure environmental effects are minimized:
   a. Conduct detailed terrain analysis supported by geotechnical investigations to characterize terrain sensitivity along the proposed route and to identify areas

of potential instability. The product associated with this analysis will be large scale route alignment sheets that include this detailed information;

b. Conduct thermal analysis and determine potential ground settlement for representative terrain types to support detailed road design including determination of embankment height and other mitigation measures (such as drainage control). The analysis should consider changes in snow cover and drainage that may influence the ground thermal regime; and

c. Include in the assessment of environmental impacts, consideration of longer term effects associated with vegetation removal and changes in permafrost and drainage conditions along the road corridor.

7. NRCan recommends the following with respect to environmental monitoring and management plans:

   a. Environmental monitoring and management plans include installation of instrumentation in addition to visual inspections to monitor changes to the ground thermal regime and ground movements especially in sensitive areas; and

   b. Monitoring and mitigation/management plans be developed that define the criteria for the need for mitigation and selection of the appropriate mitigation technique.

8. Recognizing that design of the CDF is at a preliminary design level, NRCan recommends the following for detailed and final design of the CDF:

   a. The Proponent conduct further geotechnical investigations within the footprint of the CDF to improve the characterization of foundation materials and to support the detailed design;

   b. The Proponent refine the seepage and stability analysis for the CDF incorporating the new information from detailed geotechnical investigations. This will also include updated creep analysis and consideration of effects related to the possible presence of frozen and unfrozen layers within the pile such as porewater expulsion and elevated pore pressures; and

   c. The Proponent follow through on commitments to develop an effective CDF monitoring and management plan which includes installation of instrumentation (such as piezometers, slope inclinometers, settlement plates, thermistors). Plans should also include a definition of triggers (or critical values) that determine the need for implementation of mitigation and the criteria for selection of mitigation techniques.

9. NRCan recommends the Proponent provide information about the open pit slope stability analysis.

10. For the CDF slope stability modelling, NRCan recommends that the Proponent clarify how the 22° friction angle was derived for the glacio-lacustrine unit.

11. NRCan recommends that the Proponent provide further information to justify the use of a 22° friction angle for the glacio-lacustrine material and the use of circular slip surface in a cross section in which a weak foundation layer exists.

12. NRCan recommends that, if Figure 13.2-4a and Figure 13.2.-2 (DAR: 13 SON Terrain and Soils, Section 13.2) are to be used in the future for regulatory or other applications, that the following inconsistencies be corrected:

a. Figure 13.2-4a and Figure 13.2.-2 should use the same terrain units;
b. Figure 3.2-1 should make use of other sources of data to complete "unclassified" regions; and
c. glacio-lacustrine deposits/soils and till exposed on hillsides and elsewhere should appear on terrain maps.

9. Closing

NRCan appreciates and is willing to respond to any questions regarding our technical review by the MVEIRB, the Proponent, and other parties involved in the project in support of the environmental assessment process.