TECHNICAL SUPPORTING DOCUMENT

Mary River Project | Phase 2 Proposal | FEIS Addendum | August 2018

TSD 08

Landforms, Soils, and Permafrost Assessment





LANDFORMS, SOIL AND PERMAFROST TECHNICAL SUPPORTING DOCUMENT SUMMARY

The Landforms, Soil and Permafrost Assessment Technical Supporting Document provides an assessment of the Phase 2 Proposal's effects on landforms, soils and permafrost and includes new information collected or published since submission of materials for the Approved Project. The Phase 2 Proposal builds on the extensive baseline studies and assessments carried out since 2011 for the larger Approved Project and is thus closely linked to the FEIS and previous addendums.

The Phase 2 Proposal has the potential to alter landforms, soils, and permafrost due to alterations to ecologically sensitive land, and changes to the thermal regime of permafrost. Designing infrastructure to reduce effects on soil and permafrost continues to be a key focus of engineering on the Project.

The descriptions of the surface geology, subsurface geology, topography, geochemistry, hydrogeology, geomechanics, protected areas, special management areas, and conservation areas have not changed since the Approved Project for the Mine Site and Milne Port. Several effects assessed for the Approved Project also remain unchanged in the context of the Phase 2 Proposal. These effects include operation of the Mine Site, Tote Road, and Milne Port. North Railway construction presents the most substantial ground disturbance footprint associated with the Phase 2 Proposal.

The North Railway will cross glaciofluvial deposits and a large esker. However, these landforms are not ecologically important given the abundance of glaciofluvial deposits (including eskers) in the area. The rail construction will also remove existing bedrock outcrops, however, these bedrock outcrops are not currently used by cliff-nesting raptors. Engineering mitigation measures such as foundation design at Milne Port, embankment design, and drainage have been considered to reduce stability concerns due to changes to geohazard risks, including the degredation of permafrost, and the North Railway has avoided major ice-rich features to a large degree.

Quarrying and rock cuts are unlikely to result in metal leaching and acid rock drainage (ML/ARD) as most of the affected rock is sedimentary and the remaining granitic rocks present in the area are predicted to be low potential for ML/ARD. As a mitigation strategy, the Borrow Pit and Quarry Management Plan (Baffinland 2014b) prescribes site-specific geochemical testing of rocks prior to quarrying. Construction of the North Railway will involve substantial disturbance of potential fossil-bearing rock, however, the creation of rock cuts along the railway will provide new exposures allowing for further paleontological exploration.

Based on the present assessment and planned mitigation, Project activities proposed as part of the Phase 2 Proposal are not predicted to result in significant adverse residual effects on landforms, soils and permafrost.

RÉSUMÉ DU DOCUMENT D'ASSISTANCE TECHNIQUE PORTANT SUR LES RELIEFS, LE SOL ET LE PERGÉLISOL

Le document d'assistance technique portant sur les reliefs, le sol et le pergélisol comporte une évaluation des effets de la proposition de la phase 2 sur les reliefs, le sol et le pergélisol et comprend de nouveaux renseignements recueillis ou publiés depuis la soumission des documents pour le projet approuvé. La proposition de la phase 2 est fondée sur les études préliminaires et les évaluations complètes réalisées depuis 2011 pour l'ensemble du projet approuvé et est donc étroitement à l'énoncé des incidences environnementales (EIE) et aux addendas précédents.

La proposition de la phase 2 pourrait altérer les reliefs, les sols et le pergélisol en raison des modifications apportées aux terres écosensibles et des changements affectant le régime thermique du pergélisol. La conception d'une infrastructure visant à réduire les effets sur le sol et le pergélisol demeure un élément clé de l'ingénierie du projet.

Les descriptions de la géologie de surface, de la géologie souterraine, de la topographie, de la géochimie, de l'hydrogéologie, de la géomécanique, des aires protégées, des aires de gestion spéciales et des aires de conservation n'ont pas changé depuis le projet approuvé pour le site minier et le port de Milne. Plusieurs effets évalués pour le projet approuvé demeurent également inchangés dans le contexte de la proposition de la phase 2. Ces effets comprennent l'exploitation du site minier, du chemin Tote et du port de Milne. La construction du chemin de fer du Nord présente l'empreinte de perturbation du sol la plus importante associée à la proposition de la phase 2.

Le chemin de fer du Nord traversera des dépôts fluvioglaciaires et un grand esker. Cependant, ces reliefs ne sont pas uniques sur le plan écologique étant donné l'abondance de dépôts fluvioglaciaires (y compris les eskers) dans la région. La construction du chemin de fer éliminera également les affleurements rocheux existants, mais ces affleurements rocheux ne sont pas actuellement utilisés par -les rapaces qui nichent dans les falaises. On a estimé que des mesures d'atténuation, comme la conception des fondations au port de Milne, la conception de digues et le drainage, réduiraient les problèmes de stabilité causés par les risques géologiques, y compris la dégradation du pergélisol, et le tracé du chemin de fer du Nord a évité de nombreuses zones à forte teneur en glace.

L'exploitation de carrières et les coupes de roche sont peu susceptibles d'entraîner une lixiviation des métaux et le drainage rocheux acide (LM/DRA) car la majeure partie de la roche affectée est sédimentaire et les roches granitiques restantes présentes dans la zone présentent un faible potentiel de LM/DRA. À titre de stratégie d'atténuation, le plan de gestion des puits d'emprunts et des carrières (Baffinland, 2014b) prescrit des essais géochimiques propres aux sites avant l'exploitation de carrières. La construction de la voie ferrée du Nord entraînera une perturbation importante de roches potentiellement fossilifères, mais la création de coupes de roche le long de la voie ferrée fournira de nouvelles expositions permettant une exploration paléontologique plus poussée.

Selon la présente évaluation et les mesures d'atténuation prévues, les activités du projet proposées dans le cadre de la proposition de la phase 2 ne devraient pas entraîner d'effets résiduels négatifs importants sur les reliefs, le sol et le pergélisol.

ᓄᓇᐅᑉ ᓴᓇᒪᓂᖓ, ᐃᔾᔪᖅ ᐃᑭᐊᖓᓗ ᖁᐋᖑᐃᓐᓇᓲᖅ ᐱᔭᕇᑐᔪᑦ ᐃᑲᔪᐃᔾᔪᑎᑦ ᑎᑎᖅᑲᑦ ᐅᓂᒃᑳᓚᐊᑦ

ᑖᓐᓇ ᓄᓇᐅᑉ ᓴᓇᒪᓂᖓ, ᐃᔾᔪᖅ ᐃᑭᐊᖓᓗ ᖁᐊᖑᐃᓐᓇᓲᖅ ᕿᒥᕐᕈᐃᓂᕐᒧᑦ ᐱᔭᕇᑐᔪᑦ ᐃᑲᔪᐃᔾᔪᑎᑦ ᑎᑎᖅᑲᑦ ᐅᓂᒃᑳᓚᐊᑦ ᐱᑕᕐᑲᖅᑎᑦᑎᕝᕙᑦ ᕿᒥᕐᕈᐃᓂᕐᒥᒃ ᓴᓇᒪᓂᖓ ᐱᓕᕆᐊᑉ ᒪᕐᕈᕆᓕᖅᑕᖓᓄᑦ ᐅᒃᑑᑎᖓᑕ ᐊᒃᑐᐃᓂᕐᑲᕐᓂᖏᑕ ᓄᓇᐅᑉ ᓴᓇᒪᓂᖓ, ᐃᔾᔪᖅ ᐃᑭᐋᖓᓗ ᖁᐋᖑᐃᓐᓇᓲᑉ ᐃᓚᕐᑲᖅᓗᓂᓗ ᓄᑖᓂᒃ ᑐᑭᓯᐅᒪᔾᔪᑎᒃᓴᓂᒃ ᑲᑎᖅᓯᒪᑦ ᑎᑎᕋᐅᓯᐅᔪᓪᓘᓐᓃᑦ ᑕᐃᑲᙵᓂᑦ ᑎᑎᕋᐅᓱᑦ ᓯᕗᓪᓕᖅᐹᑦ ᑐᓐᓂᕆᔭᐅᓚᐅᖅᑎᓪᓗᒋᑦ ᐊᖏᖅᓯᒪᔭᒧᑦ ᐅᔭᕋᖕᓂᐊᕐᓂᕐᒧᑦ. ᐱᓕᕆᐊᑉ ᒪᕐᕈᕆᓕᖅᑕᖓᓄᑦ ᐅᒃᑑᑎᖓ ᐃᓚᒋᐊᕆᔭᕐᑲᖅᑐᖅ ᕐᑳᖓᒍᑦ ᐊᖏᕌᔾᔪᑦ ᑐᙵᕙᑦ ᖃᐅᔨᓴᕙᓃᑦ ᐊᕙᑖᓄᑦ ᑕᒪᓐᓇᓗ ᕿᒥᕐᕈᐃᓂᖅ ᑕᐃᑲᖓᑦ 2011–ᒥ ᑖᔅᓱᒧᖓ ᐃᓗᐃᑦᑑᔪᒧᑦ ᐊᖏᖅᓯᒪᔭᒧᑦ ᐅᔭᕋᖕᓂᐊᕐᓂᕐᒧᑦ ᑕᐃᒫᒡᓗ ᐊᒃᑐᐊᓂᕐᑲᖅᐳᖅ ᑭᖑᓪᓕᖅᐸᑉ ᐅᓂᒃᑳᖏᓄᑦ FEIS ᓯᕗᓂᐊᒍᓪᓗ ᐅᐃᒍᕆᐊᖅᑕᐅᓂᑰᔾᒃᑯᑦ.

ᐱᓕᕆᐊᑉ ᒪᕐᕈᕆᓕᖅᑕᖓᓄᑦ ᐅᒃᑑᑎᖓ ᓴᖅᑮᔾᔪᓐᓇᖅᑐᖅ ᐊᓯᔾᔨᓂᕐᒥᒃ ᓄᓇᐅᑉ ᓴᓇᐅᒪᓂᐊᓂᒃ, ᐃᔾᔪᖅ ᐃᑭᐋᖓᓗ ᖁᐋᖑᐃᓐᓇᓲᒥᒃ ᐱᓪᓗᒍ ᐊᓯᔾᔨᔭᕐᑲᕐᓂᐊᕐᓂᕐᒋᑦ ᐃᒃᐱᖕᓂᖅᓴᕋᐃᑦᑐᑦ ᓄᓇᖏᓐᓂᒃ, ᐊᓯᔾᔨᐅᑎᓗᒋᓪᓗ ᖃᒥᑕᖅᓯᒪᔪᑦ ᐆᓇᔾᔪᓂᐊᑕ ᐃᓪᖁᓯᖏᓐᓂᒃ. ᓴᓇᔭᐅᓂᖏᑦ ᐱᕐᑯᑎᕐᔪᐊᑦ ᐊᒃᐸᓯᖕᓂᖅᓴᐅᕐᑯᒧᑦ ᐊᒃᑐᐃᓂᖏᓄᑦ ᐃᔾᔪᓄᑦ ᖁᐋᖑᐃᓐᓇᓲᒧᓪᓗ ᑲᔪᓰᓐᓇᖅᐳᖅ ᓵᙱᔭᓇᔭᐅᓪᓗᓂ ᓴᓇᔪᓪᓇᔾᕐᔪᐊᓄᑦ ᐅᔭᕋᖕᓂᐊᕐᕕᖕᒥᑦ.

ᐅᓂᒃᑳᓇᔭᐅᓂᖏᑦ ᓄᓇᐅᑉ ᐋᖅᑭᒃᓯᒪᓂᖓ, ᓄᓇᐅᑉ ᐃᑭᐊᖓᑕ ᐋᖅᑭᒃᓯᒪᖓ, ᓄᓇᐅᑉ ᕐᑲᐸᖏᑦ, ᓄᓇᐅᑉ ᐃᓚᐅᕈᑎᒃᓴᕐᑲᕐᓂᖓ, ᐃᒪᐅᑉ ᑰᒃᑕᓐᓂᖏᑦ, ᓄᓇᐅᑉ ᐊᐅᓚᓂᖏᑦ, ᓴᐳᒥᔭᑦ, ᐊᔾᔨᕐᑲᖏᑦᑐᑦ ᐊᐅᓚᑕᐅᔪᑦ ᐃᓃᑦ, ᒥᐊᓂᕆᔭᐅᓲᓪᓗ ᓂᔾᔪᑎᓄᑦ ᓄᓇᖏᑦ ᓱᕋᒃᓯᒪᙱᑦᑖᑦ ᑕᐃᑲᙵᑦ ᐊᖏᖅᓯᒪᔭᖅ ᐅᔭᕋᖕᓂᐊᕝᕕᒃ ᐅᔭᕋᖕᓂᐊᕐᕕᐅᑉ ᐃᓂᖓᓄᑦ ᕿᙳᐊᑕᓗ ᐅᒥᐊᔾᔪᐊᓚᓐᖓᕙᖓ. ᖃᔅᓯᓪᓚᑦ ᐊᒃᑐᐃᓃᑦ ᐊᖏᖅᓯᒪᔭᒧᑦ ᐅᔭᕋᖕᓂᐊᕐᓂᕐᒧᑦ ᓱᕋᒃᓯᒪᙱᓪᓚᑦ ᐃᓱᒪᒋᓪᓗᒍ ᑖᓐᓇ ᐱᓕᕆᐊᑉ ᒪᕐᕈᕆᓕᖅᑕᖓᓄᑦ ᐅᒃᑑᑎᖓ. ᐊᒃᑐᐃᓂᕐᑲᕐᓂᖏᑦ ᐃᓚᕐᑲᖅᑐᑦ ᐊᐅᓪᓚᑦᑎᓂᕐᒥᒃ ᐅᔭᕋᖕᓂᐊᕐᕕᐅᑉ ᐃᓂᖓᓂᒃ, ᕿᙳᐊᓄᑦ ᐊᖅᑯᑖ, ᐊᒻᒪᓗ ᕿᙳᐊᑕ ᐅᒥᐊᔾᔪᐊᓚᓐᖓᕙᖓ. ᐅᐊᖕᓈᒍᑦ ᓄᓇᓯᐅᑎᑯᑖᖅᑲᕐᕕᒃ ᓴᓇᔭᐅᓂᖓ ᓵᖅᑮᓇᔭᖅᑐᖅ ᐊᖏᓛᖑᔪᒥᒃ ᐊᒃᑐᐃᓂᕐᑲᕐᓗᓂ ᓄᓇᒥᒃ ᓴᓇᔭᐅᓇᓱᒃᑎᓪᓗᒍ ᐊᖅᑯᑖ ᐃᓗᐊᒍᑦ ᐱᓕᕆᐊᑉ ᒪᕐᕈᕆᓕᖅᑕᖓᓄᑦ ᐅᒃᑑᑎᖓᑕ.

ᐅᐊᖕᓈᒍᑦ ᓄᓇᓯᐅᑎᑯᑖᖅᑲᕐᕕᖓ ᐃᑳᓇᓂᐊᖅᑐᖅ ᓯᕐᒥᕚᓃᑦ ᓴᓂᕌᒍᑦ ᑲᑕᒑᓂᕙᓂᖕᒋᓂᒃ ᐊᒻᒪᓗ ᐅᖓᓪᓚᓘᖓᑯᑖᒃᑐᒥᒃ ᓇᖅᓴᖅᔪᐊᐸᓗᖕᒥᒃ. ᑭᓯᐊᓂᓕ, ᑖᒃᑯᐊ ᓄᓇᐅᑉ ᓴᓇᐅᒪᓂᖕᒋᑦ ᐆᒪᔪᓄᑦ ᐊᑑᑎᓗᐊᙱᓪᓚᑦ ᐊᒥᓲᓂᖕᒋᓐᓄᑦ ᓯᕐᒥᓄᑦ ᑲᑕᒑᕙᓃᑦ (ᐱᖅᑲᓯᐅᑎᔪᑦ ᓯᐅᕋᔮᑯᑖᑦ) ᓇᖅᓴᖓᓃᑦᑐᑦ. ᓄᓇᓯᐅᑎᑯᑖᑉ ᓴᓇᔭᐅᓂᖓ ᐲᔭᐃᓚᔭᕆᕗᖅ ᖃᐃᓱᖕᒑᑉ ᐅᔭᕋᖕᒋᑦᑕ ᑭᒡᓚᖓᓃᑦᑐᓂᒃ, ᑭᓯᐊᓂ, ᑕᒪᒃᑯᐊ ᐃᕙᕝᕕᐅᕙᙱᑦᑐᑦ ᓂᕿᑐᖅᑎᓄᑦ ᑎᖕᒥᐊᓄᑦ. ᑭᓯᓚᐅᕈᓯᕐᓄᑦ ᖃᐅᔨᓴᕐᑎᒃᑯᑦ ᓱᕋᐃᓗᐊᖅᑕᐃᓚᓂᕐᒧᑦ ᐋᖅᑭᒃᓯᒪᔭᕐᑦ ᐃᓚᖅᑲᖅᑐᑦ ᑐᙵᕙᖓᑕ ᓴᓇᔭᐅᒪᓂᐊ ᕿᙳᐊᑕ ᐅᒥᐊᔾᔪᐊᓚᓐᖓᕙᖓᓂ, ᓯᕙᖓᓂᖓ ᐊᖅᑯᑎᓚᐊᑉ ᓴᓇᔭᐅᒪᓂᖓᓗ, ᐃᒪᐃᔭᐃᔾᔪᑎᒃᓴᖏᑦᑐ ᐃᓱᒪᕆᔭᐅᓯᒪᕗᑦ ᓱᕋᕐᕋᑯᓇᐅ ᐊᖅᑯᑖ ᓄᓇᐅᑉ ᐅᓗᓐᐊᓇᐅᑎᓲᕆᓄᑦ, ᐱᖅᑲᓯᐅᑎᓪᓗᒍ ᓄᖑᓴᐃᓂᖅ ᖁᐋᖑᐃᓐᓇᓲᑉ ᐃᑭᐊᖓ, ᐊᒻᒪᓗ ᐅᐊᖕᓈᒍᑦ ᓄᓇᓯᐅᑎᑯᑖᖅᑲᕐᕕᒃ ᓴᓂᖅᑯᑎᓯᒪᔪᖅ ᖁᐊᖅᓯᒪᓂᖅᑲᓗᐊᕐᓂᐅᓲᑉ ᓄᓇᖏᓐᓂᒃ ᐊᔪᖏᓐᓂᓪᓚᒦᒥᒍᑦ.

ᑐᐊᐸᓕᐅᕐᓂᖅ ᖄᖅᑎᓇᓂᕐᓗ ᖃᐃᙱᒍᓂᒃ ᓴᖅᑮᓪᓗᐊᖕᒋᑦᑐᖅ ᓴᕙᕋᔭᒃᓴᐅᑉ ᐃᓯᐊᕿᓲᖕᒋᓂᒃ ᓯᓚᐃᓐᓇᒧᓪᓗ ᓄᖑᓴᐃᓱᑦ ᐅᔭᕋᖕᓂᒃ (ML/ARD) ᐱᓪᓗᒍ ᐊᒃᑐᖅᑕᐅᓂᐊᖅᑐᖅ ᐅᔭᕋᒃ ᒌᖅᑲᑦᑕᖅᓗᓂ ᑲᑖᓂᒌᖓᒪᑦ ᖃᓚᕇᖓᓚᔪᖅ ᐊᒥᐊᒃᑯᓂᑯᑦ ᐅᔭᕋᑦ ᖃᐃᙶᖕᒋᑦ ᓂᕆᐅᕆᔭᐅᓪᓗᑎᒃ ᐊᒃᐸᓯᒃᑐᒻᒪᕆᖕᒥᒃ ᓄᖑᓴᐃᔾᔪᑎᒃᓴᓂᒃ ML/ARD ᓱᕋᐃᓗᐊᖅᑕᐅᓚᒪᓂᕐᒧᑦ ᐊᑐᓚᒃᓴᓚᐊᖑᓪᓗᓂ, ᑐᐊᐸᓚᓇᓂᕐᒧᑦ ᑐᐊᐸᓚᐅᕝᕙᓄᓪᓗ ᑲᒪᒋᔭᐅᔾᔪᑎᖕᒋᓄᑦ ᐸᕐᓇᐅᑖ (ᐹᕙᓐᓈᓐ 2014ᐱ) ᐊᑐᕐᑯᔮᓯᒪᕗᖅ ᓄᓇᒧᑦ ᑐᕌᖓᔪᓂᒃ ᖃᐅᔨᓴᕈᑎᓂᒃ ᐅᔭᕋᖕᒋᓂᒃ ᓯᕗᓂᐊᒍᑦ ᑐᐊᐸᓚᓇᓂᐊᑕ. ᓴᓇᔭᐅᓂᖓ ᐅᐊᖕᓈᒍᑦ ᓄᓇᓯᐅᑎᑯᑖᖅᑲᕐᕕᒃ ᐃᓚᖅᑲᕐᓂᐊᖅᑐᑦ ᐊᖏᔪᒥᒃ ᓴᓂᕐᕙᐃᓂᕐᒥᒃ ᐃᑦᑕᕐᓂᓴᐃᑦ ᓴᐅᓂᕙᓂᖕᒋᓂᒃ ᐃᓚᓚᖕᓂᒃ, ᑭᓯᐊᓂᓕ, ᖃᐃᙶᑦ ᖄᖅᑎᓇᔭᐅᔪᑦ ᓵᖅᑮᓂᐊᓇᕗᑦ ᐃᑦᑕᕐᓂᓴᐃᓂᐊᑕ ᐃᓚᖅᑯᓯᖕᒋᓐᓂᒃ ᐅᔭᕋᕿᓐᓂᑯᕙᓂᑐᕐᑲᕐᓂᒃ ᕿᒥᕐᕈᐃᔭᐅᔪᓐᓇᖅᑐᓂᒃ.

ᑐᙵᓪᓗᓂ ᐅᓪᓗᒥ ᕿᒥᕐᕈᐃᓂᐅᔪᒧᑦ ᐸᕐᓈᖑᔪᓄᓪᓗ ᓱᕋᐃᓗᐊᖅᑕᐃᓚᓂᕐᒧᑦ, ᐅᔭᕋᖕᓂᐊᖅᑐᑦ ᐱᓕᕆᓂᖕᒋᑦ ᐊᑐᖅᑕᐅᔪᒪᔪᑦ ᐃᓚᒋᔭᐅᔪᑦ ᑖᔅᓯᒪ ᐱᓕᕆᐊᑉ ᒪᕐᕈᕆᓕᖅᑕᖓᓄᑦ ᐅᒃᑑᑎᖓᒍᑦ ᒥᒃᓵᓄᑦ ᓴᖅᑮᓚᔭᕆᑦᑐᖅ ᐊᖏᔪᒥᒃ ᐱᐅᙱᑦᑐᒥᒃ ᓄᓇᐅᑉ ᓴᓇᔭᐅᒪᓂᖓᓄᑦ, ᐃᔾᔪᕐᒥᒃ, ᐃᔾᔫᑉ ᐃᑭᐋᖓᑦ ᖁᐋᖑᐃᓐᓇᓲᖅ ᐃᓗᓕᖕᒋᓂᒃ.

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT - PHASE 2 PROPOSAL

TECHNICAL SUPPORTING DOCUMENT NO. 8 - LANDFORMS, SOIL AND PERMAFROST ASSESSMENT
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ABBREVIATIONS

the Project .... Mary River Project
AMEC .... AMEC Earth & Environmental
ARD .... acid rock drainage
Baffinland .... Baffinland Iron Mines Corporation
FEIS .... Final Environmental Impact Statement
Golder .... Golder Associates Ltd.
Hatch .... Hatch Ltd.
IQ .... Inuit Qaujimajatuqangit
KP .... Knight Piésold Ltd.
LSA .... local study area
ML .... metal leaching
NIRB .... Nunavut Impact Review Board
Non-PAG .... non-acid generating
NWB .... Nunavut Water Board
QIA .... Qikiqtani Inuit Association
ROW .... right-of-way
RSA .... regional study area
TRSA .... Terrestrial Regional Study Area
TSD .... technical supporting document

1 – INTRODUCTION

1.1 OVERVIEW OF THE PHASE 2 PROPOSAL

The Mary River Project (the Project) is an operating iron ore mine located in the Qikiqtani Region of Nunavut (Figure 1.1). Baffinland Iron Mines Corporation (Baffinland; the Proponent) is the owner and operator of the Project. As part of the regulatory approval process, Baffinland submitted a Final Environmental Impact Statement (FEIS) to the Nunavut Impact Review Board (NIRB), which presented in-depth analyses and evaluation of potential environmental and socioeconomic effects associated with the Project.

In 2012, NIRB issued Project Certificate No 005 which provided approval for Baffinland to mine 18 million tonnes per annum (Mtpa) of iron ore, construct a railway to transport the ore south to a port at Steensby Inlet which operates year-round, and to ship the ore to market. The Project Certificate was subsequently amended to include the mining of an additional 4.2 Mtpa of ore, trucking this amount of ore by an existing road (the Tote Road) north to an existing port at Milne Inlet, and shipping the ore to market during the open water season (NIRB, 2014). The total approved iron ore production was increased to 22.2 Mtpa (4.2 Mtpa transported by road to Milne Port, and 18 Mtpa transported by rail to Steensby Port). This is now considered the Approved Project. The 18 Mtpa Steensby rail project has not yet been constructed, however 4.2 Mtpa of iron ore is being transported north by road to Milne Port currently. Baffinland recently submitted a request for a second amendment to Project Certificate No.005 to allow for a short-term increase in production and transport of ore via road through Milne Port from the current 4.2 Mtpa to 6.0 Mtpa.

The Phase 2 Proposal (the third project certificate amendment request) involves increasing the quantity of ore shipped through Milne Port to 12 Mtpa, via the construction of a new railway running parallel to the existing Tote Road (called the North Railway). The total mine production will increase to 30 Mtpa with 12 Mtpa being transported via the North Railway to Milne Port and 18 Mtpa transported via the South Railway to Steensby Port. Construction on the North Railway is planned to begin in late 2019. Completion of construction of the North Railway is expected by 2020 with transportation of ore to Milne Port by trucks and railway ramping up as mine production increases to 12 Mtpa by 2020. Shipping from Milne Port will also increase to 12 Mtpa by 2020. Construction of the South Railway and Steensby Port will commence in 2021 with commissioning and a gradual increase in mine production to 30 Mtpa by 2024. Shipping of 18 Mtpa from Steensby Port will begin in 2025.

Phase 2 also involves the development of additional infrastructure at Milne Port, including a second ore dock. Shipping at Milne Port will continue to occur during the open water season, and may extend into the shoulder periods when the landfast ice is not being used to support travel and harvesting by Inuit. Various upgrades and additional infrastructure will also be required at the Mine Site and along both the north and south transportation corridors to support the increase in production and construction of the two rail lines.

1.2 SCOPE

This Technical Supporting Document (TSD) provides an assessment of the Phase 2 Proposal's effects on landforms, soils and permafrost. Included in this assessment are issues related to geology and geomorphology as well as paleontology.

The descriptions of the surface geology, subsurface geology, topography, geochemistry, hydrogeology, geomechanics, protected areas, special management areas, and conservation areas have not changed from what was presented in the FEIS (Baffinland, 2012).

Additional geotechnical investigations and evaluations have been completed at areas where new infrastructure is proposed as part of the Phase 2 Proposal, including the following:

- Milne Port Infrastructure:
    - Preliminary Geotechnical Recommendations for Infrastructure at Milne Inlet (Hatch, 2017a)
- Second Ore Dock:
    - Geophysical Seismic Survey for a Proposed Fixed Dock (Geophysics GPR International Inc., 2014)
    - 2017 Milne Port Ore Dock No. 2 Geotechnical Factual Data Report (Hatch, 2017b)
- Railway:
    - Railway Geotechnical Site Investigation Factual Report (Hatch, 2018)
    - Railway Geotechnical Recommendations (Hatch, 2017c)
    - Railway Terrain Evaluation (Hatch, 2017d)

Additional geochemistry evaluations relevant to construction of the North Railway have also been undertaken (Hatch, 2017e).

1.3 STAKEHOLDER CONSULTATION

Generally, community representatives have not raised concerns around landforms, soils and permafrost at community meetings. These aspects have not been raised during recent public consultation activities focused on the Phase 2 Proposal (Baffinland, 2018a). It was not raised during previous public consultation events (FEIS Volume 2, Appendix 2A and FEIS Addendum Volume 2, Appendix 2A; Baffinland 2012 and 2013). The following comments were made during the work of the Qikiqtani Inuit Association (QIA) with its project committees, when committee members were asked if pollution from the Project was going to increase climate change:

> *"We would like to see the train go through the thicker soils for safety purposes, since there is climate change it would be safer to travel."* (QIA's Igloolik Project Committee Meeting, September 15-21, 2011)
>
> *"Soil was studied and from the studies they are saying not much planting area and that in studies it says there is not much, not enough food for the animals. This is life in high arctic we live on what we have, we try and survive on what is there. And from the soil that is much under it is permafrost and it's not deep to dig it. And if they are going to dig deep they are going to impact it. If they are going to use the land to make the roads they will have to scrape it not dig it."* (QIA's Hall Beach Project Committee Meeting, September 12, 2011)
>
> *"I am going back to climate change…., since it will go to our air and how is it going to impact the permafrost I like to know how many inches permafrost is going to be less?"* (QIA's Hall Beach Project Committee Meeting, September 12, 2011)

Inuit Qaujimajatuqangit studies (IQ) have documented feedback on changes to the permafrost regime in the context of observations of the effects of climate change (Gérin-Lajoie et al. 2016; Baffinland, 2014). Elders have advocated that they can see evidence of a warming climate in the Baffin Region, including warming temperatures and thawing permafrost.

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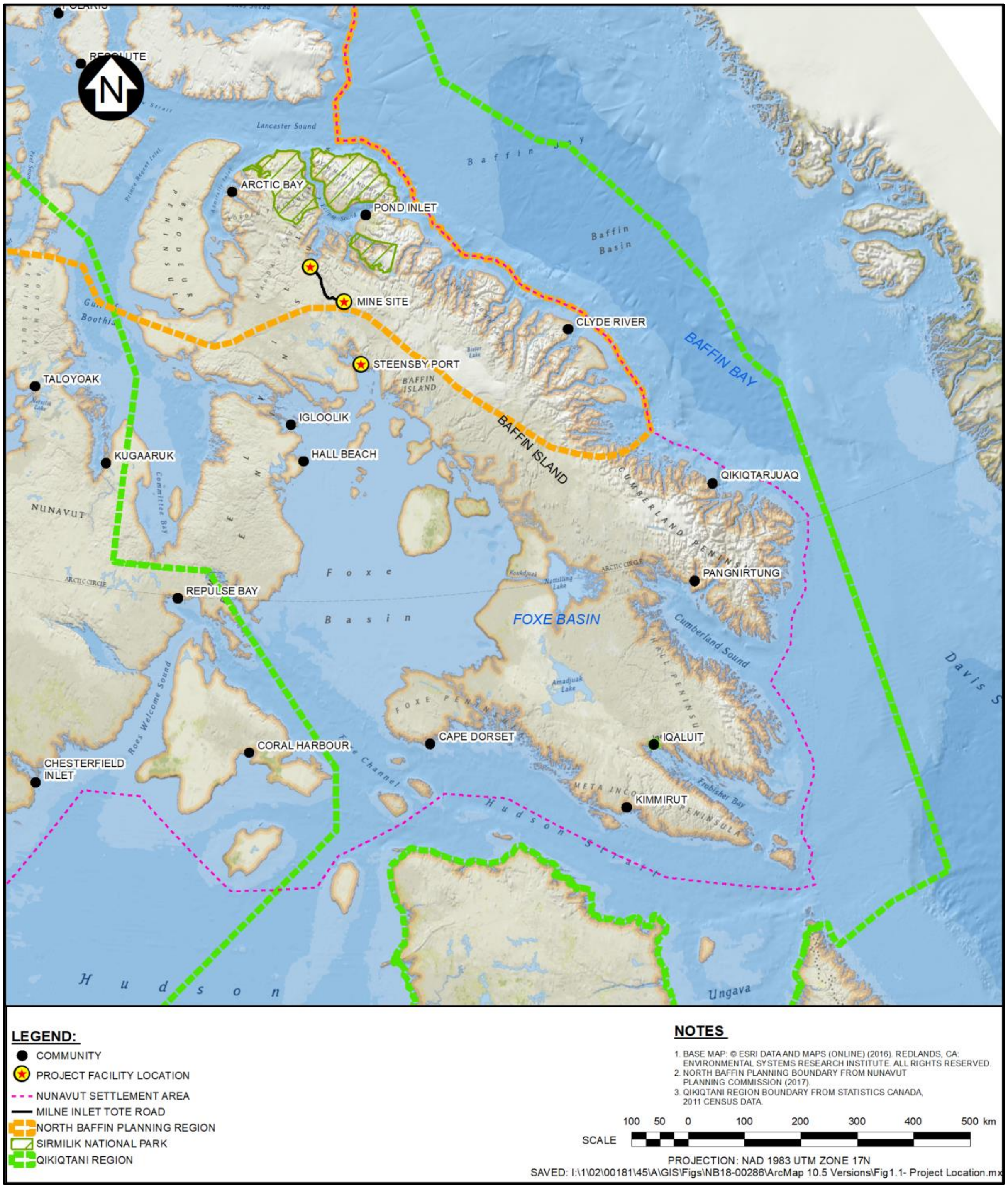

Figure 1.1 Project Location Map

2 – LANDFORMS, SOILS AND PERMAFROST ASSESSMENT

2.1 BACKGROUND

The Qikiqtani Region is underlain by continuous permafrost with occurrences of massive ground ice (Natural Resources Canada, 2013). Permafrost describes soil or bedrock that remains at or below freezing (0ºC) for two or more years. Permafrost is a thermal condition, and therefore its occurrence depends on climate. The average annual air temperature in the region ranges from -12.8ºC at Clyde River to -16.3ºC at Pond Inlet Port (FEIS Volume 5, Section 1.1.2).

Soil development in Arctic environments is influenced by the interaction of factors associated with characteristics of surficial deposits (parent material), topography, local climate, biotic influences, hydrology and permafrost, and time. Almost all of the soil moisture in permafrost occurs in the form of ground ice, which in turn occurs in several different forms. The distribution of ground ice is influenced by soil texture; in general, fine-grained soils (rich in clay and silt) and organic soils contain more ground ice than coarse-grained soils (sand and gravels). The quantity of ice in the ground can vary widely.

Surficial landforms in the Terrestrial Regional Study Area (TRSA) are the result of the recent, widespread glaciation on Baffin Island (Figure 2.1). The surficial deposits include thick, undisturbed and unconsolidated deposits of till on slopes and hillsides, glaciolacustrine sediments associated with historic lakes or coastal regions, glaciofluvial and alluvial deposits along waterways in valley bottoms, marine and glaciomarine deltaic sediments and lateral or end moraine till deposits.

These surficial landforms are not particularly unique in themselves; however, subsequent periglacial processes (including the presence of and thawing of ground ice (i.e., thermokarsts), soil and rock weathering, mass movement and erosion) continue to be the dominant forces shaping the landscape of the region. These processes result in ground ice accumulation, frost heaving, sorting of materials within the upper soil matrix, fracturing of the upper bedrock profile and the development of patterned ground (tundra polygons), drumlins, pingos and thermokarst lakes.

Fragile landscapes in the TRSA are generally associated with frost/thaw sensitive till blankets and the presence of massive ground ice within glaciofluvial deposits. Pingos and drumlins are examples of such phenomenon. No pingos were identified during the geotechnical investigations, but a drumlin was identified in recent geotechnical studies (Hatch, 2017d). Areas of high potential for ground ice content are present along the Tote Road alignment and in the vicinity of the Mine Site.

Impacts to permafrost and soils may occur from activities that change the thermal conditions of the ground. Activities that have the potential to change the thermal condition of underlying soils include:

- Changes to the grounds natural surface cover or other excavations (i.e., removal of surficial organic cover, open pit, quarries and borrow areas, cut and fill operations along roads and railway alignments)
- Infilling or the placement of materials on the ground surface (i.e., landfilling, stockpiles), and particularly from those materials or structures that can be a source of heat to the ground (i.e., stormwater ponds, buildings, etc.)
- Changes to surface drainage patterns that occur from the placement of materials on the ground surface, localized settlement, or due to diversions

- Structures that change the amount of solar radiation received by the ground
- Structures that can cause drifting that insulates the ground from cold temperatures during winter, resulting in warmer ground temperatures

The physical response of the terrain to permafrost degradation is mainly dependent on the ice content of the frozen material (Dyke et al., 1997 in Smith and Burgess, 2004). Where ice-rich materials are present, an increase in thaw settlement and thermokarst activity will probably accompany a disturbance in the thermal regime, from either the Project's ground disturbance activities, or from climate change. Soil strength due to ice bonding will be reduced as unfrozen water content of the frozen ground increases in response to a rise in ground temperature. This may lead to ground instability and an increased incidence of slope failure (Smith and Burgess, 2004).

The previously assessed effects of the Project on landforms, soils and permafrost were as follows:

- **Thaw Settlement and Weakening -** Thaw settlement is caused by the loss of ice volume due to melting. Melting may occur when the thermal regime of permafrost soil is disrupted or changes. Thaw settlement may occur naturally, as evidenced by thermokarst terrain that consists of irregular depressions and hummocks formed by the differential melting of massive ground ice. Ground disturbance activities such as excavation/cuts, fills, and changes to drainage patterns can change the thermal regime and induce thaw settlement. Therefore, road and railway construction, the development of borrow areas for aggregate, and the clearing of project development areas have the potential to affect sensitive landforms.

  Thaw weakening is soil losing strength due to inability of the soil to dissipate excess pore pressures during melting. This weakening occurs more often with soils that are fine-grained and saturated. These soils cannot support the weight of vehicles and equipment and, if excess weight is applied to these soils, severe rutting and erosion may occur, which in turn can further impact the rate of thermal degradation.

- **Slope Instability -** Slope instability is the failure of a natural or constructed slope to resist landsliding. Thermal degradation and thaw weakening may lead to the instability of slopes. A slope failure could block, interrupt or destroy a section of a railway line. Failed upslope material could block culverts, leading to ponding of water and thermal degradation adjacent to the railway embankment.

Effects to landforms, soils and permafrost can have a material effect on Project components. Designing infrastructure to reduce effects on soil and permafrost continues to be a key focus of engineering on the Project. This included designing to account for the impacts of climate change. The effects to landforms, soils and permafrost were assessed for the Approved Project to be not significant (Baffinland 2012; 2013). Monitoring and observations to date has been consistent with these predictions.

Figure 2.1 Surficial Geology along the North Railway Alignment

2.2 PROJECT MONITORING

Monitoring of landforms, soils and permafrost typically consists of geotechnical inspections. Bi-annual geotechnical inspections are conducted each July and September in accordance with Type A Water Licence requirements. All engineered structures are inspected at the Mine Site and Milne Port, including:

- Mining areas
- Waste rock stockpiles
- Roads, bridges and culverts
- Bulk fuel storage facilities
- Quarries
- Polishing/Waste Stabilization Ponds
- Hazardous and non-hazardous waste containment areas
- Landfill and landfarms
- Runoff containment facilities associated with ore and waste rock storage

Geotechnical inspection reports are filed annually with the Nunavut Water Board (NWB) under the Company's Type A Water Licence (No. 2AM-MRY1325; NWB, 2015). The inspections focus on ensuring that new and existing structures conform with design bases; identify any settlement, cracking and seepage; and monitor the relative stability of pit and quarry walls. The most recent geotechnical inspections did not identify any major concerns (Martin, 2017a; 2017b).

A number of borrow areas located adjacent the Tote Road, developed in 2007 when the Tote Road was first constructed to support all-season use, have shown signs of degradation (Tetra Tech EBA Inc., 2015), primarily because ice-rich material was beneath the excavation limits and the thaw stable insulating surface layer (active layer) had been removed. Monitoring and remediation of the borrow areas is ongoing. The North Railway will interact with several former borrow areas that are located within the railway right-of-way (ROW).

Between 2006 and 2008 more than fifty ground temperature monitoring instruments (thermistor cables) were installed and monitored to determine typical ground temperatures in the overburden and bedrock across the study area (FEIS, Volume 6, Section 2.1.1.4). In October 2017, thermistors were installed within two drillholes at Milne Port (Well#1, Well#2). Each drillhole contains a series of thermistors, which range in depths from 0.5 m to 4.5 m below grade. Monitoring shows temperatures ranging from -2 to -22˚C in the active layer, and from -3 to -7˚C at a depth of 4.5 m below grade.

In Baffinland's Climate Change Strategy, a commitment has been made to monitor both the mean annual temperature of permafrost (at a given depth below surface), and active layer thickness (Baffinland, 2018b). Both have been designated as essential climate variables by the Global Climate Observing System Program of the World Meteorological Organization (Smith and Brown, 2009; Biskaborn et al., 2015).

2.3 ASSESSMENT METHODOLOGY

The methods used herein to assess effects to landforms, soils and permafrost is consistent with the Final Environmental Impact Statement (FEIS; Volume 6, Section 2.3.1).

The assessment is supported by geophysical surveys, geotechnical site investigations and a terrain evaluation work as described in Section 1.2. These investigations were conducted within a local study area (LSA) surrounding the Project infrastructure and immediate area.

2.4 CLIMATE CHANGE CONSIDERATIONS

A warming of permafrost has been documented to have occurred in the TRSA over the past couple of decades, in the order of 0.1 to 0.15°C annual increase in ground temperatures at 15 m depth (Richter-Menge and Mathis, 2016; Gross et al., 2011; Smith, 2011). The Climate Change Assessment compiled by Knight Piésold Ltd. (KP) with contributions from other authors (Baffinland, 2018b) describes Inuit and scientific observations regarding climate change, and provides the most current forecasts regarding the potential impacts of climate change on the physical environment, including permafrost. Moderate climate change forecasts predict a 3.5 to 4°C warming of permafrost over the 100-year period in the Project region, and more extreme climate change scenarios predict a median warming of 6.4°C by 2081 to 2100. Additional discussion is provided in Baffinland (2018b).

Increasing ambient atmospheric temperatures induces a reduction in the extent of permafrost by altering the thermal regime of permafrost soils. Depending upon the ground conditions, altering permafrost can cause both thaw settlement and weakening, as well as slope instability. These changes are occurring naturally and will continue even in the absence of the Project. Climate change may act cumulatively with the Project to increase the severity of these effects.

2.5 EFFECTS ASSESSMENT

Potential interactions of the Phase 2 Proposal with landforms, soils and permafrost are identified in Table 2.1.

Table 2.1 Phase 2 Proposal Interactions with Landforms, Soils and Permafrost

Project Infrastructure or Activity	Level of Interaction		
	Landforms	**Geochemistry**	**Paleontology**
Mine Site			
Minor changes to site drainage (no meaningful new diversions)	1		
Tote Road			
Replace Tote Road culverts downstream of select North Rail crossings that will receive diverted flows from other streams	1		
Increased downstream flows at upsized Tote Road culverts located downstream of North Rail crossings with diverted flows	1		
North Railway			
New PDA resulting in loss of additional terrestrial habitat	2		2
Prepare site area and construct access trail	2		
Quarry, crush, screen, haul and place aggregate (including rock cuts)	2	2	2
Construct rail embankment, superstructure, bungalows, etc.	2		
Install additional communication towers along corridor	1		
Construct permanent culvert crossings (and temporary culvert crossings at two bridge locations)	1		

Project Infrastructure or Activity	Level of Interaction		
	Landforms	Geochemistry	Paleontology
Construct bridges with piers at four large crossings (the same crossings with bridges along the Tote Road)	2		
Milne Port			
Expanded PDA resulting in loss of additional terrestrial habitat			
Construct second ore dock (includes pile driving but no blasting or dredging)	2		
Construct additional ore stockpiles and material handling facilities	1		
Construct railway lines, rail maintenance facilities	2		
Construct ancillary port facilities (additional fuel storage, etc.)	1		

NOTES:

1. INTERACTIONS ARE RATED AS FOLLOWS:
   0 - NO INTERACTION.
   1 - MINOR INTERACTION POST-MITIGATION, DISCUSSION ASSESSMENT.
   2 - MAJOR INTERACTION SUBJECT TO DETAILED ASSESSMENT.

The key interactions requiring further assessment include quarrying, construction of the rail embankment, bridges and the second ore dock. Each of these have the potential to affect landforms, soils and permafrost. These are assessed further below.

There are a number of other minor interactions (identified with a “1” in Table 2.1) that can be addressed by standard mitigation and/or are of low environmental consequence. These minor interactions were considered in the FEIS and are therefore not evaluated in this assessment.

Quarrying has the potential to interact with wildlife habitat, in particular with raptor nests on bedrock outcrops. Quarrying (and rock cuts along the railway) may also present potential geochemistry concerns with the freshly exposed material (or extracted material) potentially resulting in metal leaching and acid rock drainage (ML/ARD), or potentially interacting with paleontological resources. These interactions are discussed further below.

2.5.1 Potential Effects of Construction on Unique or Valuable Landforms

Unique or valuable landforms are determined based primarily on their geomorphological interest and/or ecological significance. As mentioned in Section 2.1, periglacial processes continue to be the dominant forces shaping the landscape of the region. These processes result in the development of a number of unique periglacial features. Ecologically important landforms include areas, which provide important wildlife habitat niches, or soil substrate, which is able to sustain vegetation growth.

Activities associated with the Phase 2 Proposal that have the potential to affect the abundance and distribution of unique and valuable landforms are those described in Section 2.1. These activities include excavations, infilling, activities and/or infrastructure that result in changes to surface drainage, or the placement of structures that may change the thermal regime of the ground through changes in the amount of solar radiation, snow drifting, etc. The key landforms that were identified within the LSA and their potential interaction with the Project are summarized as follows:

- **Glaciofluvial Deposits -** These features are abundant within the TRSA, and are often ice rich. Glaciofluvial deposits provide potential denning habitat to carnivores (foxes and wolves). In responding to the Government of Nunavut's information request 19 during review of the FEIS, Baffinland noted that the PDA overlaps with 2% of the glaciofluvial wolf denning habitat in the TRSA.
- **Eskers -** Eskers are typically elongated and elevated sinuous ridges of glaciofluvial material formed from sands, gravels, cobbles, and boulders deposited in the glacial melt water channels flowing below or within glaciers. Besides being a unique geomorphological landscape feature, eskers provide several ecological functions. For example, the annual pattern of groundwater flow within the esker active soil layer governs soil moisture and nutrient regimes in lower sections of eskers and adjacent ecosystems. This landform allows for the growth of specific culturally valued vegetation, such as blueberry, and crowberry. In other parts of Nunavut such as the mainland where the landscape is dominated by boulder fields and shallow morainal veneers over bedrock, the unconsolidated, coarse mineral material of eskers provides valuable denning sites for wildlife. Within the TRSA, however, there is an abundance of glaciofluvial materials that provide denning habitat for carnivores.

  Only one esker has been identified in terrain evaluations and geotechnical investigations conducted for the North Railway (Hatch, 2017c; Hatch, 2017d; Hatch, 2018). The railway will cross this esker at approximately chainage CH98+200, on the south shore of David Lake.
- **Drumlins -** Drumlins are unique glacial landforms, which have a unique morphology (elongate shape). One drumlin has been identified within the LSA near chainage 77+000 North Railway. This specific landform will be avoided by the North Railway.
- **Bedrock Outcrop (Cliffs) -** Bedrock outcrop is an important landform for cliff-nesting raptors such as peregrine falcon, rough-legged hawks and other species (EDI, 2017). Cliff-nesting raptors are abundant within the Regional Study Area (RSA) during the breeding season, and this landform is also well-represented in the RSA such that this wildlife habitat is not limiting (EDI, 2017). The North Railway and related footprint (including quarries) will not displace any cliff raptor nests, but will be located close to several existing raptor nests. Construction of the North Railway will involve considerable quarrying and cutting through rock, both of which will result in the exposure of new rock faces that may be suitable cliff-nesting habitat.

North Railway construction presents the most substantial ground disturbance footprint associated with the Phase 2 Proposal, and the only component that has the potential to affect unique or valuable landforms. The railway embankment will cross glaciofluvial deposits; however, such deposits are widespread within the RSA. The railway will cross a small portion of a large esker located south of David Lake. The amount of disturbance is small relative to the size of the esker, and the esker is not ecologically significant given the abundance of glaciofluvial deposits (including eskers) in the RSA. Rail construction including quarrying will remove existing bedrock outcrop; however, none of the bedrock outcrops are currently used by cliff-nesting raptors. There is an abundance of such habitat within the RSA (EDI, 2017), and quarrying and rock cuts associated with the Project will create new rock face exposures that can be used by cliff-nesting raptors.

The incremental effects of the Phase 2 Proposal on the abundance and distribution of unique or valuable landforms are rated as low magnitude, modest in geographic extent, are continuous in terms of frequency of the effects, and are permanent (not reversible).

2.5.2 Potential Geohazard Risks

Geohazards are geological or environmental conditions that may cause small or large deleterious effects to site infrastructure. A pre-existing geohazard presented in the RSA is slope creep associated with ice-rich and/or thaw sensitive soils. Geohazards are also potentially created as a result of Project development:

- Cuts in both overburden and rock slopes can cause slope instabilities
- Construction on thaw-sensitive or ice-rich soils can result in settlement
- Blast fractures in bedrock have the potential to accumulate water that freezes causing further degradation of the bedrock, including frost jacking
- Shoreline erosion

These geohazards represent a risk to Project infrastructure and may also cause negative effects to landforms and terrain stability through the degradation of permafrost and resultant erosion. A discussion of the potential geohazards and the engineering design mitigation measures identified to address these geohazards, is discussed below for each major development area of the Phase 2 Proposal. Shoreline erosion may potentially occur due to ship wakes; this is considered in the marine environment assessment (Golder, 2017).

Additional infrastructure at the Mine Site will be modest, limited to larger ore stockpiles and rail load-out facilities. Existing quarry Q1 will be expanded during construction, and a new landfill will be constructed within a portion of the final rock quarry. While ice-rich soils exist within the Mine Site area, the foundation requirements of the additional facilities are minimal and will apply the same design and construction approach as the current facilities. Water management structures (ditching, berms, etc.) have been designed so that runoff passes through the site efficiently and ponding is avoided, since ponding has the potential to induce thaw and subsequent settlement.

2.5.2.1 Risk of Excessive Settlement of Ore Dock

Construction of the ore dock may disturb and change the thermal regime of the sub-sea permafrost. Additionally, climate change can be expected to thaw sub-sea permafrost (Baffinland, 2018b). Both can cause thaw settlement and weakening if ice-rich soils or bedrock are present in the vicinity of the ore dock.

Offshore site investigations were completed from the sea ice at the proposed second ore dock (Hatch, 2017a, GPR, 2014 and Hatch, 2017b). The seafloor in this area generally consists of well drained sandy soils to depths of 42 m below the sea floor (Hatch, 2017b). Very low strength soils comprised of sensitive fine grained materials were identified from surface to 3 m depth, however beneath this layer are sands and silty sands with adequate strength (Hatch, 2017b). No massive ice or bedrock was encountered during the drilling. Geophysical surveys indicate that competent bedrock is likely present at a depth of 90 to 140 m below sea level (Geophysics GPR International, 2014). Isolated patches of sub-sea permafrost have been reported previously where soft marine clay overlies till and bedrock and permafrost was identified in one of 22 boreholes located in the area of a proposed dock during feasibility study investigations in 1965 (Samson and Tordon, 1969). At the location previously noted to contain permafrost, the permafrost was present in a clay stratum at a depth of about 12 m, and consisted of ice lenses and ice crystals within sections of unfrozen clay with a temperature just below 0°C. The authors noted that the frozen soil identified would be highly susceptible to relatively minor disturbance and may have serious consequences on construction of harbour facilities. A 1972 feasibility study focused on dock facilities that would be located on the east side of the Milne Inlet beach, and not at the current facilities (Hudson Bay Mining and Smelting Co. Ltd. and Anglo American Corporation of Canada Limited, 1972).

Given the presence of well-drained soils and absence of ice at the dock location identified for the Phase 2 Proposal, settlement induced by ore dock construction and climate warming is not expected.

The new dock will include a sheet pile primary structure, with spacer barges to provide a dock face at the required draft depth of 19 m below the low tide elevation. The new dock design will be consistent with the design of the current dock, either with the proprietary open cell sheet pile design or another equivalent design. The sheet piles will be driven into the sea floor to a minimum depth of 17 m, thereby avoiding the effects of the shallow low strength soils. There is no shallow bedrock that would limit the proposed approach to sheet pile installation (Hatch, 2017b). No dredging or blasting will be required to construct the dock.

2.5.2.2 Risk of Excessive Settlement of Additional Milne Port Infrastructure

Much of the Milne Port area has been found to contain ice rich soils (Hatch, 2017a, Hatch, 2018, Hatch, 2017d). Substantial ground ice has been found in a deep excavation near the new ore dock, and within the vicinity of the existing Water Building (Hatch, 2017a). The foundation settlement due to the thawing of ground ice should be limited by design measures. As such, thermal insulation may be used for the proposed Milne Port buildings, and adfreeze piles may be used for deep foundations. In order to avoid frost heave, the length of the pile in the active zone will be wrapped with polyethylene film to break the adfreeze bond in the active layer.

Table 2.2 summarizes the proposed foundation types for the additional port infrastructure.

Table 2.2 Proposed Milne Port Infrastructure Foundations

Proposed Infrastructure	Potential Foundation Option
Rail car rotary tipper building	Shallow foundation on rock or adfreeze pile on permafrost
Ship loaders	Adfreeze pile
Elevated conveyors	Adfreeze pile or shallow foundation
Bridge foundations for railway	Adfreeze pile
Conveyor transfer towers and drive houses	Adfreeze pile
Ground level yard conveyor and stacker/reclaimer	Rockfill embankment with shallow foundation
Crushing and screening buildings	Shallow foundation
Rail workshop	Shallow foundation (possibly on rock)

2.5.2.3 Risk of Excessive Settlement of Rail Embankment

Potential geo-hazards associated with the North Railway consists of ice-rich areas, and slope stability failures in both overburden and rock. Excessive settlement of the rail embankment may occur where ice-rich soils are present along the rail alignment, and may occur due to:

- Extreme natural events
- Permafrost degradation due to:
  - Poor quality construction materials
  - Poor construction methods
  - Overlooked geotechnical conditions

Extreme natural events such as a substantial freshet or storm event can result in flood conditions that cannot be passed by culverts along the railway. For this reason, culverts and bridges have been designed to accommodate the 1:200-year flood event plus a contingency for ice buildup (KP, 2017).

Permafrost degradation represents perhaps the greatest risk to settlement of the railway embankment. Permafrost degradation can cause thaw settlement and weakening or slope instabilities (Section 2.1). Creep settlement of high embankments over ice rich permafrost is another mode by which railway settlement may occur (i.e. surface loads exceed strength of the ice within the foundation soil matrix). The rate of creep settlement generally increases as the permafrost warms. If excessive settlement of the railway embankment were to occur undetected, there is a potential for train derailment causing property damage, negative environmental impacts, and possible human injury or fatality. Such an event can be the result of how the embankment is constructed, including unforeseen geotechnical conditions, poor construction materials or poor construction methods.

The potential for permafrost warming due to a warming climate increases the risk of permafrost degradation (Baffinland, 2018b). Comprehensive geotechnical site investigations help identify areas where the risk associated with excessive settlement is the greatest. Geotechnical site investigations were completed along the north rail alignment in 2010, 2016 and 2017 (AMEC, 2010a, Hatch, 2018, Hatch, 2017c, and Hatch, 2017d). These geotechnical site investigations include the identification of suitable aggregate sources for construction.

The North Railway will be constructed mostly adjacent the Tote Road, over a variety of ground conditions (Hatch, 2017d). A substantial proportion of the railway will be built on rock, including a cumulative total of 25.5 km of rock cuts (Baffinland, 2018c). Starting from Milne Port as 0+000, the following potential problem areas have been identified by geotechnical investigations to date (Hatch, 2018):

- **10+000 to 46+000 -** Proposed railway straddles and alternates between till and glacial outwash deposits. The terrain is flat with regularly occurring small water bodies, which are indicative of ground ice.
- **71+300 to 72+600 -** The alignment transitions to a glaciolacustrine deposit with numerous small surface water bodies (thermokarst terrain), indicating the potential for ice-rich soils or ground ice.
- **82+000 to 100+000 -** The proposed alignment traverses alternating glaciofluvial and lacustrine deposits. The lacustrine deposits are locally ice-rich.

The long-term performance of embankments constructed in permafrost regions requires specialized design considerations, particularly in areas dominated by ice-rich soils (i.e., creep and thaw settlement). Interference with these ice-rich zones will potentially impact the thermal regime, leading to permafrost degradation. Impacts to local thermal regimes could be exacerbated by the long-term effects of climate change. Depending on the ice content and the height of the required embankments, creep settlement of frozen ground may also occur. This settlement can lead to changes in the hydrologic patterns (i.e. water ponding at embankment toes) and further degradation of the thermal regime, which can manifest as thaw settlement. General disturbance of the area can lead to other environmental conditions related to thermal degradation, such as erosion, siltation and the ponding of water. Differential settlement can occur at the transition of different ground conditions.

The railway has avoided major ice-rich features to a large degree, and none of the ice-rich areas that must be crossed are located on a slope. All major cuts are predominantly in rock, and slopes will be cut at stable angles.

The following general mitigation measures will be applied to construction of the North Railway:

- Excavations will be reduced, especially in areas of known ice-rich permafrost.
- Prior to embankment construction, ground disturbance will be reduced and vegetative or organic cover left in place to provide increased protection of the thermal regime.
- In areas where excavation is required, the foundations will be over excavated and backfilled with 1.5 m of non-freeze/thaw susceptible fill to reduce frost heaving and settlement.
- Slopes will be flattened as necessary when being constructed in ice-rich or thaw sensitive materials, and will be protected with thermal and erosion protection material, if required.
- In areas of thaw-sensitive active layer, stabilization berms will be used to reduce the effect of permafrost degradation at the toe of slopes.
- For high embankment fills on ice-rich materials, the side slopes may be flattened substantially or stabilization berms constructed to reduce the creep deformation potential.
- To reduce the rate of creep settlement, embankments thicker than three metres should be constructed with side slopes no steeper than 5H:1V or with toe buttresses.
- For construction during the summer, woven geotextile may be required over unstable ground.
- Proper runoff collection and diversion drainage systems will be used to control runoff and erosion from affecting the modified thermal regime. As part of basic design, thermal modeling will be conducted for each typical embankment condition and configuration to identify the actual permafrost protection measures required and to predict the nature of the active layer and the effect that construction will have on the thermal regime over the life of the Project. The thermal modeling will incorporate potential warming trends resulting from climate change based on world-recognized global warming scenarios.
- Thaw settlements and surface sloughing of cut slopes is expected, particularly during the thaw seasons immediately following construction. The behaviour of both cut slopes and embankment fills will be monitored throughout these thaw seasons and remedial measures will be implemented as necessary. For example, it is expected that many of the cut slopes will need to be monitored as thaw settlements occur. Silt fences and other erosion protection measures will be installed as necessary to prevent siltation of adjacent drainage courses and water bodies.
- Reduce changes to the hydrologic drainage patterns.
- Reduce the potential for the accumulation of snow drifting and snow banks, or mitigate during operations with snow fencing or other measures, to avoid resultant changes to the thermal regime.

The above-listed mitigation measures were proposed for the South Railway (FEIS Volume 6, Section 2). The rail alignment design will be optimized based on the surface and subsurface conditions encountered during the site investigations. The northern alignment will be designed to reduce the risk for short- and long-term problems and such that mitigation of these potential problems can be achieved. Further refinement will be undertaken as the Project advances.

Four rail embankment designs were established as part of a feasibility study completed for the Phase 2 Proposal (Hatch, 2017f), based on sub-grade type:

- **Cuts in Precambrian Rock -** This rail embankment design will be utilized between approximately railway chainages CH 0+000 and 10+000, 82+000 and 85+000 and 95+000 and 105+000. It consists of a layer of sub-ballast material to level the blasted bedrock, followed by a ballast layer. Rock slopes of 8V:1H with benches at 5 m vertical intervals are proposed, subject to detailed engineering design.
- **Cuts in Limestone -** This rail embankment section is between CH 60+000 and 75+000 where the alignment follows shallow or outcropping limestone beds, which show as small mesas or ledges in the terrain. This type of embankment section consists of a layer of sub-ballast material to level the blasted bedrock. The thickness is expected to vary because blasting is expected to produce an irregular surface. The minimum leveling layer thickness is 150 mm. The bedrock is expected to be bedded and the depth of cut should be predominantly less than 5 m. In most areas, the rock should remain stable if cut at 8H:1V.

With each of the rock cut designs described above, a 2 m off-set is planned between the edge of the embankment and the toe of the rock slope to collect debris. This zone should be sloped toward culverts to allow cross-drainage. A soil veneer, expected to be less than a meter thick at most locations, will be stripped and stored in quarries or used to construct diversion berms to route run-off toward creek and streambeds.

The other two sub-types include embankments and cuts on permafrost soils:

- **Embankments on Overburden -** This embankment section is proposed for the railway on undisturbed (uncut) permafrost soil. This type of embankment consists of a layer of compacted run-of-quarry rockfill (run-of-quarry granitic blast rock or limestone blast rock) founded directly on the undisturbed permafrost. A non-woven geotextile will be placed over the permafrost soil where the railway traverses ice-rich and fine-grained soils. A minimum 150 mm thick sub-ballast layer will be placed on the rockfill embankment, with heavy equipment used to force the finer sub-ballast material into the open pore space of the rockfill until a stable base is achieved, prior to final placement of the sub-ballast layer. The combined minimum thickness of the rockfill and sub-ballast materials should be 700 mm for embankments on non-, potentially- and moderately - thaw susceptible permafrost. It should be increased to 1,500 mm on ice-rich soils or highly thaw-susceptible soils. A ballast layer will be placed on top. Embankment side slopes will have gradients on the order of 1.5H:1V to 2H:1V. Ditching or diversion berms will be used to manage run-off.
- **Overburden Cuts -** Cuts in permafrost soil will be avoided to the extent possible; however, based on the behaviour of cuts made for the Tote Road, occasional cuts in permafrost soil can be managed. Boreholes may be advanced at cut locations to determine if ground ice is present and thermal modelling may be used for design and to assess the risk. This type of embankment consists of a 1.5 m layer of compacted run-of-quarry rock fill underlain by a zone of insulation materials, possibly an additional 1.5 m thick layer of rockfill underlain by non- woven geotextile (542 g/m^2), or 100 mm thick rigid expanded polystyrene insulation board covered by nonwoven geotextile (542 g/m^2). A minimum 150 mm thick sub-ballast layer will be placed on the rockfill and will be used to choke the rockfill embankment prior to placing the sub-ballast layer. A ballast layer will be placed on top. Embankment side slopes will have gradients on the order of 1.5H:1V to 2H:1V. Ditching or diversion berms will be

used to manage run-off. The cut side-slopes should be covered with a 500 mm thick layer of Type 12 material to retain the soil as it thaws.

The above designs are subject to change with additional geotechnical investigations and detailed engineering design, which will include thermal modelling of areas where cuts will be made in overburden. Through a number of mitigating actions (i.e. additional geotechnical investigation; the strategy for avoidance of problem areas to the extent possible; detailed engineering design including thermal modelling where applicable; the implementation of the mitigation measures listed above; and proposed monitoring described in Section 2.7), the risk of excessive settlement of the embankment is moderate (moderate consequence and unlikely). An adaptive approach will be taken during rail operations to identify and address issues such as settlement once the railway has been constructed and is operational.

Tote Road Borrow Pit Reclamation

As a part of North Rail construction, Baffinland will conduct progressive reclamation of existing borrow areas located along the Tote Road. These borrow areas were developed in 2007 and 2008 as part of road construction supporting Baffinland’s bulk sample program. The areas have shown signs of degradation, primarily due to the presence of ice-rich material beneath the excavation limits, which was exposed to warming once the insulating surface layer had been removed.

The proposed Railway alignment crosses or is very proximal to 16 of 44 former borrow areas that were assessed in 2014 as a priority to reclaim (Tetra Tech EBA Inc., 2015). Table 2.2 lists the former borrow areas in close proximity to the railway alignment. Of the 16, five were categorized as Priority B, seven as Priority A and four as Priority A+. Priorities A and B are sites that require attention with respect to the management of water and permafrost, and Priority A+ are sites that require attention to protect infrastructure.

Table 2.3 Existing Borrow Areas Requiring Reclamation Next to the North Railway

Priority A+ Sites	Priority A Sites	Priority B Sites
WP-71	WP-68	WP-74
WP-72	WP-6	WP-65
WP-61A	WP-61B	WP-64
WP-37	WP-46	WP-62
-	WP-40	WP-35
-	WP-32	-
-	WP-33	-

Site-specific mitigation measures will be developed for each of these locations. Generally, the approach is expected to involve draining existing water from the borrow pits and backfilling the borrow pits with soils that are not thaw sensitive, with the object of re-establishing the previous thermal regime of the ground to the extent possible. The reclamation of the former borrow areas will be a beneficial effect of the Phase 2 Proposal.

Monitoring Settlement of the Embankment

Despite proper design that accounts for climate change and other factors, some settlement is expected to occur. For this reason, the Railway Management Plan (FEIS Appendix 10D-9.1) identifies regular inspections as well as possible instrumentation within certain sections of the Railway to monitor potential settlement in the embankment. The FEIS version of the Railway Management Plan will be updated to incorporate the north railway, once constructed.

2.5.3 Potential Geochemical Risks at Rock Cuts and Quarries

Three main rock types are expected to be encountered with quarrying and rock cuts associated with the North Railway (Hatch, 2018; and Hatch, 2017e):

- **Km 0 to Km 24 -** Granitic Gneiss bedrock
- **Km 24 to Km 90 -** Dolomitic Limestone bedrock
- **Km 90 to Km 105 -** Quartz Sandstone bedrock with Diorite intrusions, with possible Mafic Gneiss between Km 100 and Km 105

The quarries and rock cuts will expose fresh rock surfaces to weathering and oxidation processes. These materials have the potential to leach metals and/or generate acid rock drainage (ARD/ML).

A number of geochemical evaluations have been conducted to establish the metal leaching (ML) or acid rock drainage (ARD) potential of these materials (KP, 2007a,b; AMEC, 2010b; Hatch, 2017e). The sedimentary rocks (limestone and sandstone) identified along the railway alignment are carbonate rich and pose no ML/ARD risk. While the granitic rocks (granite, gneiss and schist) and the diabase contain low sulphide content, due to the relatively low neutralizing potential of these rocks, there is a low risk of ML/ARD (AMEC, 2010b; Hatch, 2017e).

Construction of the North Railway involve the establishment of 36 new quarries. Out of 36 planned quarries, 24 are located in sedimentary rocks (limestone or sandstone), which as mentioned do not present any ARD risk. The remaining 12 quarries are located in granitic gneiss or diorite. A total of 38 rock cuts measuring approximately 25 km in length are also required along the railway right-of-way (ROW). Details are provided in TSD-2 Detailed Project Description: the location of the quarries and rock cuts are shown on figures in Hatch, 2018 and are listed in Hatch, 2017e.

Based on geochemical testing completed to date, the risk of these activities generating ARD/ML within the sedimentary rocks is negligible, and within the granitic and diabase rocks the risk is low but not negligible. Baffinland's Borrow Pit and Quarry Management Plan (Baffinland, 2014) prescribes site-specific geochemical testing of rocks prior to quarrying. As a precautionary measure, quarries and rock cuts within the granitic and diabase rock materials will be subject to geochemical testing to confirm that the material is geochemically suitable.

In the unlikely instance that ARD/ML issues are identified at a quarry, Baffinland will avoid using the quarry. There may be less flexibility if ARD/ML issues are identified at rock cuts. If rock cut areas are found to be acid generating through testing, avoidance will be considered where practical. Alternatively, rock cuts may be managed in consideration of site conditions (e.g., use of non-acid generating materials (non-PAG) over the acid generating material; limestone placement; disposal management). Options may range from do-nothing (if exposed faces are limited and/or runoff from the faces is not of adverse quality) to covering the exposed faces with non-PAG/ML material to placing limestone within seepage paths to increase pH of the runoff and precipitate metals.

2.5.4 Potential Effects on Paleontology from Railway Construction

In 2008, Baffinland commissioned a paleontologist from the Canadian Museum of Nature to conduct a desktop study of paleontological resources in the Project area (FEIS Appendix 6A; Rybczynski, 2008). Most of the bedrock underlying the Project area is Paleozoic and Archean/Paleoproterozoic, with Archean volcanic rocks occurring in more localized areas. Only the Paleozoic formations hold any possibility of containing fossils (Rybczynski, 2008). Three potentially fossil-containing Paleozoic formations have been identified in the area between Milne Port and the Mine Site: the Gallery and Turner Cliffs Formations, the Ship Point Formation, and the Baillarge Formation. These formations contain invertebrate fossils including trace fossils (burrows of invertebrates) and body fossils (including shells and sponges). These deposits were formed prior to the evolution of vertebrates.

The Approved Project did not interact with these fossil-containing formations, since they are present only within the Northern Transportation Corridor (i.e., the Tote Road and proposed North Railway), and construction/upgrades of the existing Tote Road did not require blasting or rock cuts.

Unlike the Tote Road, construction of the North Railway as part of the Phase 2 Proposal will require extensive cut and fill operations within the underlying bedrock, over a cumulative distance of approximately 25.5 km out of the 105 km railway. Additionally, Baffinland will develop 36 new quarries, of which 24 quarries have been confirmed to be limestone or sandstone (TSD-1, Hatch, 2017c). Therefore, construction of the North Railway will involve substantial disturbance of potential fossil-bearing rock.

In Nunavut, paleontological resources are protected by the same legislation and in the same manner as archaeology under the Archaeological and Paleontological Sites Regulations, pursuant to the *Nunavut Act*. Nunavut is unique in applying the same protection measures to paleontological resources as cultural heritage resources. Because the fossil-bearing formations contain marine invertebrates, these fossils are likely uniform in distribution. The creation of rock cuts along the railway will provide new exposures allowing for further paleontological exploration. Thus, disturbance of these formations is not expected to adversely affect paleontological resources, considering the type and nature of distribution of these fossils and the new exposures that will allow for paleontological mapping in the future. Baffinland intends to discuss the interpretation of the legislation relative to the potential paleontological discoveries in the Project area with the Government of Nunavut, to determine the most appropriate actions required.

2.5.5 Significance of Residual Landforms, Soils and Permafrost Effects

Four potential effects to landforms, soils and permafrost have been identified in this assessment:

- Potential effects of construction on the abundance and distribution of unique or valuable landforms
- Potential geohazard risks due to construction of components of the Phase 2 Proposal
- Potential ML/ARD issues related to quarrying and rock cuts along the Northern Transportation Corridor
- Effects to fossil-bearing rocks to be excavated along the North Railway

The assessment of significance of residual effects to landforms, soils, and permafrost is presented in Table 2.12. The effects are predicted to be not significant. This significance determination is contingent upon the successful implementation of the measures described in this report and in Baffinland's current management plans.

Effects to the abundance and distribution of unique or valuable landforms and effects to paleontological resources are expected to occur with a high level of certainty. Thaw settlement effects to Project infrastructure are unlikely to occur, with a high level of certainty at the ore dock and Milne Port infrastructure areas, reflecting the level of geotechnical investigation conducted to support infrastructure design at these locations.

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Table 2.4 Significance of Residual Effects on Landforms, Soils and Permafrost

Residual Effect	Residual Effect Evaluation Criteria					Significance of Residual Effect	Qualifiers	
	Magnitude	Extent	Frequency	Duration	Reversibility		Probability (Likelihood of the Effect Occurring)	Certainty (Confidence in the Effects Prediction)
Effects of construction on the abundance and distribution of unique or valuable landforms	**Level I:** The abundance and distribution of unique or valuable landforms will not be meaningfully affected	**Level I:** Effects are confined to a portion of the LSA	**Level I:** infrequent	**Level III:** Long-term / permanent	**Level II:** Partially reversible	Not significant	Effects will occur	High
Thaw settlement at Milne Port second ore dock	**Level I:** Effect is expected to be minimal, if it occurs at all	**Level I:** confined to the LSA	**Level I:** infrequent	**Level II:** Life of the Project	**Level II:** Partially reversible	Not significant	Effect is unlikely to occur	High
Thaw settlement at Milne Port infrastructure on land	**Level I:** Effect is expected to be minimal, if it occurs at all	**Level I:** confined to the LSA	**Level I:** infrequent	**Level II:** Life of the Project	**Level II:** Partially reversible	Not significant	Effect is unlikely to occur	High
Thaw settlement along the proposed Northern Railway	**Level I:** Effect is expected to be minimal, if it occurs at all	**Level I:** confined to the LSA	**Level I:** infrequent	**Level II:** Life of the Project	**Level II:** Partially reversible	Not significant	Effect is unlikely to occur	Moderate
Ground disturbance of paleontological resources	**Level I:** Affected paleontological resources are widely distributed; project will improve access for study	**Level I:** confined to the LSA	**Level I:** infrequent	**Level III:** Long-term / permanent	**Level III:** Irreversible	Not Significant	Effect will occur	High
Exposure of potentially ML/ARD rock surfaces to the elements (along the North Railway)	**Level I:** Effect is expected to be minimal, if it occurs at all	**Level I:** confined to the LSA	**Level I:** infrequent	**Level III:** Long-term / permanent	**Level II:** Partially irreversible	Not Significant	Effect is unlikely to occur	Moderate

Because the railway is a substantial feature that has been evaluated using terrain evaluation and representative geotechnical investigations, the prediction confidence is rated to be moderate. The remaining uncertainty with respect to thaw settlement effects along the railway will be addressed through additional geotechnical investigations, additional modelling and design measures, the modification of design and/or relocation of sections of the rail embankment, observation during construction, and by monitoring for settlement at higher risk sections of the rail embankment during operations.

The potential that ML/ARD may occur from quarrying and rock cuts is considered unlikely since most of the affected rock is sedimentary and the granitic rocks that will be affected have been tested. The potential for ML/ARD from the granitic rocks is not zero, however, and therefore the certainly is moderate and follow-up geochemical characterization of granitic rocks is proposed at quarries and rock cuts, as described in the Borrow Pit and Quarry Management Plan (Baffinland, 2014).

2.6 MITIGATION AND MONITORING PLAN UPDATES

Three of Baffinland's management plans are relevant to landforms, soils and permafrost:

- Borrow Pit and Quarry Management Plan (Baffinland, 2014) - This management plan describes the mitigation measures identified for the development of quarries, including a requirement to conduct geochemical evaluations prior to developing each quarry.
- Railway Management Plan (Canarail Consultants Inc., 2011a) - This plan describes proposed railway maintenance and monitoring programs at a conceptual level.
- Railway Emergency Plan (Canarail Consultants Inc., 2011b) - An emergency response plan has been developed for the railway that addresses the procedures to be followed in the event of a train accident or derailment.

The two railway management plans were developed for the South Railway and were presented in the FEIS (Appendices 10D-9.1 and 10D-9.2). These two management plans will be updated and adapted for the North Railway.

With respect to geotechnical issues and the risk of settlement of the embankment, the Railway Management Plan states the following:

> *"Due to sensitivity of the permafrost to any changes in the local thermal regime that may be introduced by the construction of the railway embankment, inspection and monitoring that is not railway standard may be required, particularly in the early years of the railway's operation. Based on site specific geotechnical examinations undertaken during detailed design and construction, certain sections of the railway may be equipped with instrumentation to permit the monitoring of ground thermal conditions. If deemed necessary, these may be connected directly into the railway's VHF system so that monitoring is possible from the railway headquarters."*

3 – REFERENCES

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4 – CERTIFICATION

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