TECHNICAL MEMORANDUM

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TO Joan Plant
Amaorq Minerals

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POTENTIAL FAILURE MODES ANALYSIS FOR THE NALUNAQ MINE DTSF

1.0 INTRODUCTION

Nalunaq A/S ("Nalunaq") has engaged WSP (UK) Ltd ("WSP") to provide support for the design of the Dry Stack Tailings Storage Facility (DTSF) to be constructed at the Nalunaq Mine in southern Greenland.

WSP will be carrying out a Dam Breach Assessment (DBA) to assess the potential consequences of a hypothetical failure of the DTSF. The Dam Breach Assessment must consider potential failure modes that are physically possible and credible. This technical memorandum provides a Potential Failure Modes Assessment (PFMA) for the proposed Nalunaq DTSF.

A PFMA and a DBA are intended to provide an enhanced understanding of what the consequences could be if a failure of the DTSF was to occur. In that sense, they assume that a hypothetical failure will occur. They do not consider the probability of failure, which may be very small.

2.0 DESCRIPTION OF THE NALUNAQ DTSF

2.1 General Project Information

The design criteria for the DTSF are summarized in Golder (2020b). The process plant is planned to operate at 300 t/day for a design life of 5 years at 95% availability. The nominal tailings storage capacity of the DTSF is 550,000 t. The tailings will be filtered to a moisture content of about 10 – 12%, then they will be hauled by truck and placed into the DTSF in lifts and compacted. An in situ dry density of 1.7 t/m3 is used for planning purposes.

2.2 Natural Hazards

Golder (2020a) provides an assessment of natural hazards associated with the Nalunaq Project. Natural hazards that could potentially affect the DTSF include the following:

- Rockfall – Golder (2020a) used GIS tools and drone imagery to map the condition of the valley slopes in the Kirkespirdalen valley. Much of the valley slopes are covered with talus. In places debris flows have occurred which have removed the talus from the upper slopes, created large gullies leading to the valley floor and resulted in tongues of debris extending into the floodplain. Notably, a debris flow has been mapped to the north of the DTSF site.
- Avalanche – all of the site is at risk of avalanche to a greater or lesser extent. In particular, the process plant and DTSF area are at risk from avalanche from the slopes immediately above. A desk based study

of risk has been undertaken (Golder, 2020a) which recommended that studies be advanced to inform risk management and mitigation measures to reduce the risk to personnel, plant and equipment.

- Flood – the area of the proposed DTSF and process plant are within the braided channel of the Kirkespir River. Golder (2020c) presents the results of a flood hazard evaluation, which includes predicted flow depths and velocities in the river for storms of various return periods with the proposed DTSF in place.
- Earthquake – A seismic assessment for the site (Golder, 2020e) recommended that a PGA of 0.2 g be adopted for the design.

2.3 DTSF Design

The design of the proposed DTSF is described in the Design Report (Golder, 2020d).

Some modifications to details of the design were described in Golder (2022) as follows:

- Construction of an ice deflection groyne upstream of the DTSF;
- Upgrading the existing secondary river channel into an engineered subdrain under the DTSF;
- Construction of the scour prevention trench by infilling the trench with large boulders scavenged off the talus slopes, rather than using gabion baskets;
- Excavating a pre-existing ridge off a 10,000 m^2 section of the floodplain adjacent to the DTSF and Process Plant areas, as per the flood risk assessment report (Golder, 2020c);
- Replacing the former sidehill ramp road to the top surface of the DTSF with a haul road on the floodplain together with two ramps up the sidehill of the DTSF itself;
- Lowering the grade on the DTSF platform fill by 0.6 m (to the predicted 1 in 100-year flood level);
- Adding a three-layer fill (coarse transition, fine transition and filter) against the talus slope on the hillside where the DTSF will abut;
- Revising the cross-section of the DTSF perimeter berm;
- Removing the liner from the sedimentation pond (so water can leak out, but sediment will be retained);
- Putting granular surfacing on the base and ramp of the sedimentation pond (so trucks can remove sediment);
- Allowing for the placement of 32,500 m^3 of run-of-mine waste rock into the interior of the DTSF to act as finger roads;
- Allowing for the progressive placement (at 9 levels) of an erosion protected drainage ditch where the DTSF tailings fill abuts the hillside;
- Allowing for an erosion protected drainage chute to bring runoff down the south end of the DTSF;
- Providing for the progressive placement of a sand filter and erosion protection on the completed sideslopes of the DTSF.

3.0 IDENTIFICATION OF POTENTIAL FAILURE MODES

3.1 Static Slope Instability

A sidewall of the DTSF could become unstable due to weakness of the DTSF foundation or of the fill (i.e., the compacted tailings or granular fill), leading to the release of tailings into the river valley. The potential causes are as follows:

- Unidentified weak layers in the DSTF foundation,
- Inadequate compaction of the tailings leading to zones which exhibit contractile behaviour and are therefore susceptible to static liquefaction, or
- An elevated phreatic surface in the tailings (causing reduced effective shear strength) resulting in slope instability.

3.2 Seismic Slope Instability

3.2.1 Seismic Event Leading to Liquefaction of the DTSF Foundation

A large seismic event could lead to liquefaction of the DTSF foundation resulting in an instability of the DTSF sidewall and the release of tailings into the river valley.

- Seismic event leading to liquefaction of a zone in the DTSF foundation that has not been identified as potentially liquefiable

3.2.2 Seismic Event Leading to Liquefaction of the Tailings

A large seismic event could lead to liquefaction of saturated tailings resulting in an instability of the DTSF sidewall and the release of tailings into the river valley. The potential causes are as follows:

- Inadequate compaction of the tailings leading to zones which exhibit contractile behaviour and are therefore liquefiable, or
- An elevated phreatic surface in the tailings (leaving saturated zones susceptible to liquefaction) resulting in slope instability.

3.3 Internal Erosion / Piping

Internal erosion (piping) of into the platform or the perimeter of the DTSF could result in failure of a DTSF sidewall resulting in tailings entering the river valley. The potential causes are as follows:

- Construction material incompatibility (e.g., improper filter design or construction)
- An elevated phreatic surface in the tailings resulting in high hydraulic gradients against the platform fill
- Construction defect (e.g., poor compaction, use of out-of-specification construction materials, gaps in the core filter)

3.4 Erosion by Surface Runoff

Overtopping of the perimeter of the top surface of the DTSF could lead to erosion and the release of tailings into the river valley. Overtopping of the perimeter of the DTSF top surface could result from one of the following:

- Significant precipitation and/or snow melt (rise in water level) combined with plugging of the hillside drainage system
- Locally insufficient crest elevation due to delayed raising of the DTSF wall during operations

- A flood event exceeding the design IDF that cannot be passed by the drainage system
- Blockage of drainage system due to the build-up of snow and ice, blockage by debris from a rock fall or avalanche
- Incorrect placement of tailings close to the inlet of the drainage system

3.5 River Erosion

A flood risk assessment undertaken for the proposed DTSF and Process Plant site (Golder 2020c) concluded that the DTSF would be exposed to flooding from the Kirkespir River during high return period events. Accordingly, the DTSF platform design includes an erosion protection system and a perimeter berm above the design high water level. Further, the DTSF will be protected by an ice deflection groyne and a scour prevention system comprised of boulders placed into a 3 m deep trench.

Failure of the protective measures could result in the erosion of the DTSF perimeter resulting in the release of tailings into the river valley. The potential causes are as follows:

- River flood flows greater than design values due to exceptional runoff of sudden release of ice dams,
- Failure of the erosion protection system due to deficient construction,
- Failure of the anti-scour system due to deficient design or construction, or
- Failure of the anti-scour system due to unanticipated river meandering.

4.0 CLOSURE

We trust that this draft PFMA technical memorandum meets your current requirements and we look forward to discussing potential failure modes with the full project team. Please feel free to contact the undersigned if you have any questions.

WSP Canada Inc.

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KAB/AP/

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