Greenland Mineral and Energy Limited

Kvanefjeld Project

Environmental Impact Assessment

Draft

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Greenland Minerals and Energy Limited

ENVIRONMENTAL IMPACT ASSESSMENT

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GLOSSARY

µg/m³	Micrograms per cubic metre
ALARE	As Low As Reasonable Achievable
AMR	Act on Mineral Resources in Greenland
BAT	Best Available Technology
BEP	Best Environmental Practice
BMP	Bureau of Minerals and Petroleum
BFS	Bankable Feasibility Study
BWM	International Convention on the Control and Management of Ship's Ballast Water and Sediments
Bq	Becquerel
CBC	Convention on Biological Diversity
COPC	Contaminants Of Potential Concern
CRSF	Chemical Residue Storage Facility
dB(A)	A weighted decibel
DCE	Danish Centre for Environment and Energy
DWT	Deadweight Tonnage
EAMRA	Environmental Agency of the Mineral Resources Area
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	US Environmental Protection Agency
EU	European Union
FIFO	Fly-In/Fly-Out
FTSF	Flotation Tailings Storage Facility
GHG	Greenhouse Gas
GME	Greenland Minerals and Energy A/S (Nuuk)
GMEL	Greenland Minerals and Energy Limited (Perth)
Gy	Gray
GWQC	Greenland Water Quality Criteria
HDPE	High Density Poly-Ethylene (pipeline)
HFO	Heavy Fuel Oil
IAEA	International Atomic Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IMO	International Maritime Organization
kV	Kilovolt
kW	kilowatts
MARPOL	International Convention for the Prevention of Pollution from Ships
MLSA	Mineral Licence and Safety Authority
MRA	Mineral Resources Authority

NAAQO	Canada's National Ambient Air Quality Objective
NEA	Nuclear Energy Agency
NERI	National Environmental Research Institute
NO_x	Oxides of Nitrogen
OECP	Organisation for Economic Co-operation and Development
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation
PBT	Persistent Bio-accumulative Toxic
PDCA	Plan-Do-Check-Act
PEL	Pacific Environment Limited
PM	Particulate Matter (dust)
PM_{10}	Particulate matter less than 10 microns in diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
Ppm	Parts per million
REE	Rare Earth Elements
REP	Rare Earth Phosphate
PNEC	Predicted No Effect Concentration
SIA	Social Impact Assessment
Sv	Sievert
ToR	Terms of Reference
TREO	Total Rare Earth Oxide
TSP	Total Suspended Particles
TWP	Treated Water Placement
UNESCO	United Nations Educational, Scientific and Cultural Organization
vPvB	very Persistent very Bio-accumulative
WHO	World Health Orginazation

1. NON-TECHNICAL SUMMARY AND CONCLUSIONS

The Environmental Impact Assessment (EIA) for the proposed Kvanefjeld Multi-element Project is part of Greenland Mineral and Energy's application for an exploitation licence, which will be submitted to the Mineral Licence and Safety Authority (MLSA) in the 4th quarter of 2015.

A comprehensive technical description of the project is presented in the Feasibility Study (GMEL 2015) and the Social Impact Assessment - SIA (Niras 2015) has also been prepared as per MLSA requirement and guidelines.

This EIA complies with guidelines issued by BMP (now MLSA) in 2011 and the Greenland Mineral Resources Act of 2010. The EIA report will be available in English, Greenlandic and Danish. A number of technical reports prepared in English and comprising detailed technical descriptions and assessments to support the EIA (see below) are available from the GMEL website.

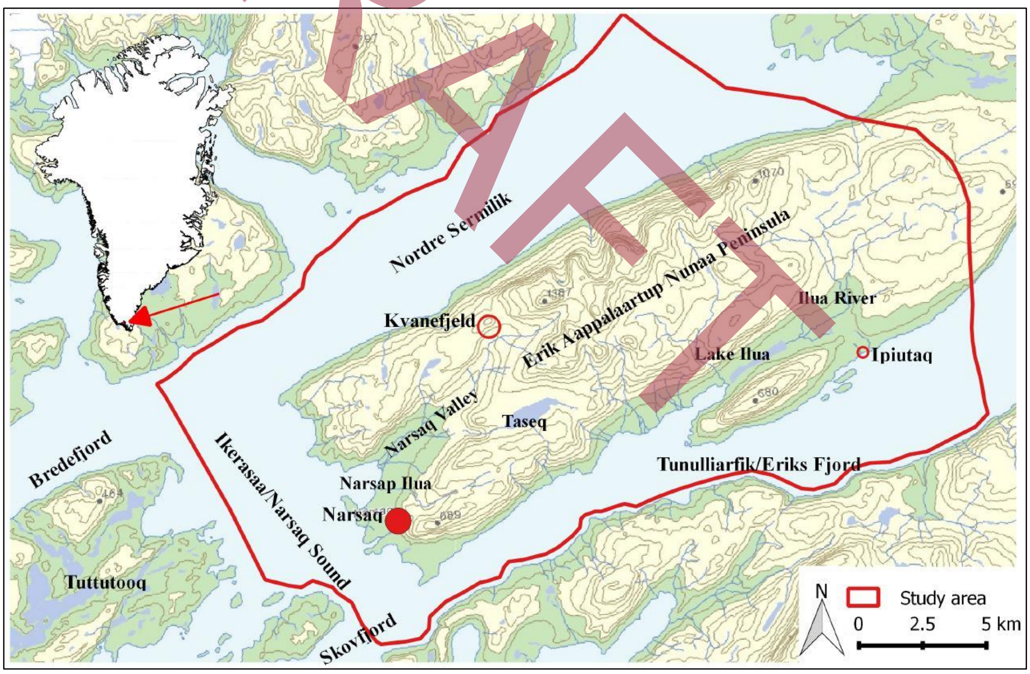

Figure 1-1: The Study area in connection with the Kvanefjeld project

The EIA report has been prepared by the independent consultant Orbicon A/S (Denmark). Orbicon was contracted by GMEL. GMEL has also contracted the following independent consultants who contributed to the EIA: Pacific Environment (Australia) for assistance in air quality reviews; Arcadis (Canada) for assistance in radiological reviews, and DHI (Denmark) for assistance with fjord modelling.

1.1. The proposed Kvanefjeld Multi-element Project

The Kvanefjeld is located c. 8 km from Narsaq Town, see Figure 1-1. The Study area is in the arctic region and consists of lowlands from the coast to about 200 m above sea level, an upland mountainous part between 200 – 600 m and a highland part with elevations between 600 – 1200 m. The Kvanefjeld is located in the highland part.

The Kvanefjeld project will treat 3.0 million tonnes of ore per year to extract products of Rare Earth Elements, uranium, zinc and fluorspar. The mine life is expected to be at least 37 years. During this period the mine will be operated 24 hours a day and 365 days per year.

The main components of the project are the mine pit at Kvanefjeld, two processing plants (Concentrator and Refinery) in Narsaq Valley, two tailings facilities in Taseq basin, slurry and water pipelines, a 13 km access road and a new port at Narsap Ilua (Figure 1-2). The project also includes worker accommodations, administrative and maintenance facilities, power plant and fuel storage.

The ore is to be excavated as an open mine pit using drilling, blasting and power shovels. Waste rock (rock with too low content of valuable minerals) will be hauled to designated deposit areas close to the mine pit.

Large haul trucks will transport ore from the mine pit to the Concentrator where the coarse ore is crushed to fine particles and suspended in water to form slurry. At the Concentrator zinc is recovered in the flotation processes. The final zinc concentrate is packed in containers for sale and transported to the port. The slurry then passes through further flotation stages to concentrate the Rare Earth and uranium minerals into 8% of the original ore mass.

The remains of the ore – known as tailings – are pumped through a 5 km pipeline to the Taseq basin where it is deposited underwater.

The Rare Earth/uranium concentrate is pumped from the Concentrator through a pipeline to the Refinery approximately 1 km away for further processing. At the Refinery, the mineral concentrate passes through several chemical processes using acid and chemical additives. The final products are four Rare Earth products and uranium oxide (also called yellow cake). The Rare Earth products are packed in containers and transported by trucks to the port where they are stored before being shipped abroad. The uranium oxide is packed in steel drums that are loaded into containers and transported to the port by trucks.

The tailings from the Refinery are pumped through a pipeline to a separate tailings pond to the northeast of the Taseq basin. The two tailings ponds in the Taseq basin are separated by an embankment. The tailings fractions are kept separate to make it possible to recover further Rare Earth metals from the Refinery tailings with future technologies. Both tailings ponds will have a water cover at all times to avoid release of radon and wind dispersal of the fine tailings material. An embankment will also be constructed at the outlet. This is necessary to accommodate tailings from 37 years of production and still maintain a 10 meter water cover. The two embankments are gradually built higher during the production period. No water from the tailings ponds will enter Narsaq Valley through Taseq River. Excess water is pumped back through a pipeline and recycled at the processing plants. Any released water passes through a treatment plant before being placed into Nordre Sermilik. Fresh water for the production is sourced from Narsaq River.

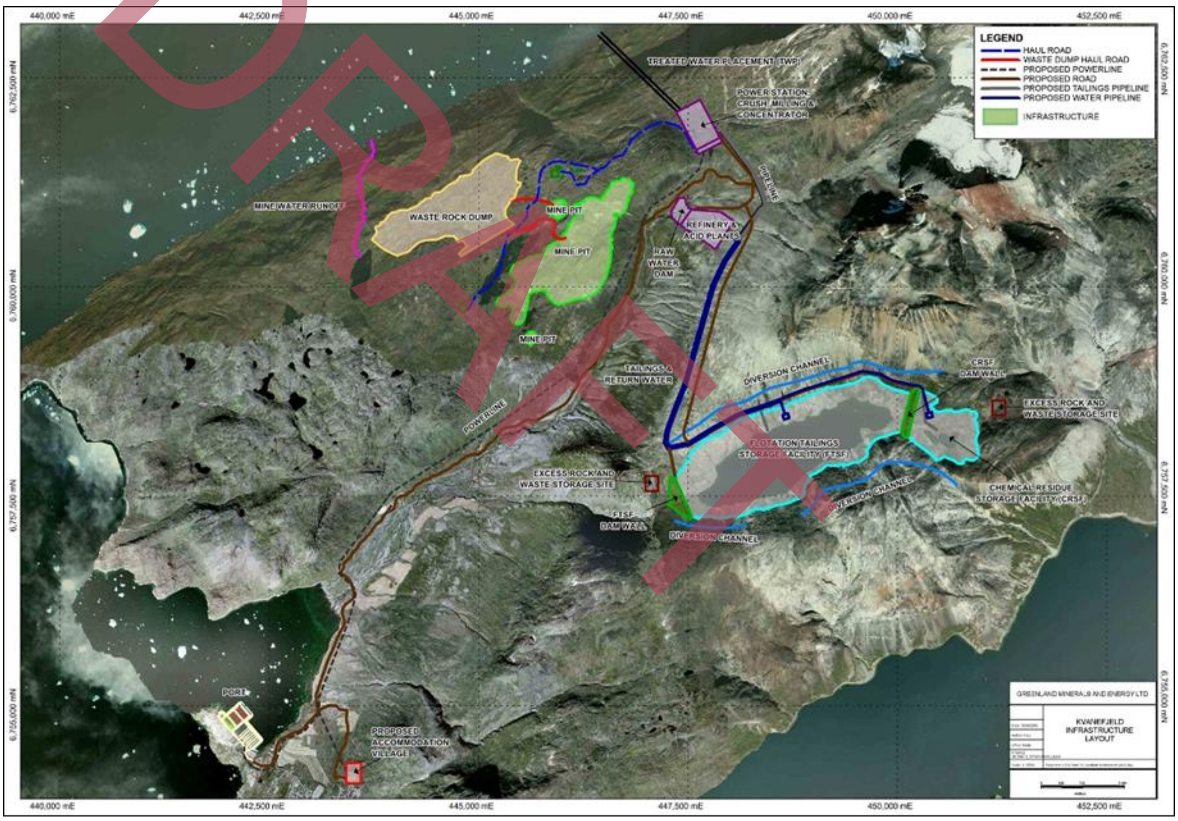

Figure 1-2: The location of the main facilities of the Kvanefjeld Project

When the mine closes and the deposition of tailings ends, a cleaning process of the water in the two tailings ponds is initiated. For 6 years water will be pumped from the tailings ponds to the treatment plant, where fluoride is removed, before the water is discharged to Nordre Sermilik. This will cause the water level in the tailings ponds to drop significantly. When the cleaning is completed, rain and snowfall will slowly fill the ponds again and will eventually overflow the embankments and flow first into Taseq River, Narsaq River and finally the fjord.

A 13 km gravel access road will be constructed from the new port to the process plants to bring workers, materials, spare parts, explosives and goods to the mine and to transport mine products to the port. The transport will take place during construction and operation as well as closure phase when equipment and materials will be removed from the site. Supplies will arrive at the port on container ships.

Electrical power for the project will be provided by a 59 MW HFO-fired combined heat and power plant at the Concentrator. Fuel will be shipped to the port by tankers and stored in large tanks at the port. Trucks will transport the fuel to smaller storage tanks at the power station. An overhead transmission line will be constructed from the power plant to the Refinery and to the new port.

Accommodations and service facilities are provided for approximately 800 employees during the operational phase. Approximately 325 of these will be recruited from Greenland while the remaining will be on a temporary fly-in/fly-out basis and accommodated in a custom build village built in the outskirts of Narsaq.

1.2. Time phases of the project

The Kvanefjeld project will consist of three phases:

- Construction phase – 2-3 years during which facilities will be established;
- Operation phase – 37 years when mining and export will take place;
- Closure phase – 6 years for closing down, removing constructions and transporting equipment, materials out of the site and cleaning water in tailings ponds.

A few activities such as monitoring will continue beyond the closure phase in a post-closure period.

1.3. EIA procedures

The Mineral Resources Act of 2010 states that an exploitation licence is required for mining of minerals. The Act also requires that an EIA must be prepared before the licence can be granted. The aim of the EIA is to identify, predict and communicate potential environmental impacts of the planned mining project. The EIA is to assess potential impacts in all phases of the project, i.e. construction, operation, closure and post-closure.

The EIA identifies mitigation measures to eliminate or minimize negative environmental effects, which have been incorporated into the project design. Environmental management and monitoring plans are to be provided to cover the full time span of the project.

The EIA defines a "Study Area" - the area potentially influenced by the mine project including the close vicinity of the project components and infrastructure. The study area is well defined by the areas where construction occurs and structures are built. Another expression used in the EIA is "the footprint" of the project. This refers to the area around the project where direct impacts occur, such as loss of habitat or disturbance of animals.

To provide essential and detailed information for the EIA the following studies have been carried out:

- Air Quality Assessment (Pacific Environment Limited, Australia)
- Greenhouse Gasses Assessment (Pacific Environment Limited, Australia)
- Noise Assessment (Orbicon)
- Radiological assessment (ARCADIS Canada)
- Uranium Product Transportation Assessment (ARCADIS Canada)
- Radiation Monitoring Plan Outline (ARCADIS Canada)
- Hydrology and Climate (Orbicon)
- The Natural Environment of the Study Area (Orbicon)
- Geochemical/Environmental testwork (SGS Lakefield Oretest)
- Water Quality Assessment of Tailings Water and Waste Rock Run off (Orbicon)
- Local Use Study (Orbicon)
- Archaeological surveys (Greenland National Museum & Archives)
- Oil and chemicals and assessment of potential impacts of spills (Orbicon)
- Kvanefjeld Marine Discharges and Fjord Dynamics - Modelling and Interpretation of Ecotoxicology Studies (DHI)
- Eco toxicological tests (DHI)
- Flotation Tailings and Chemical Residue Storage Facilities Feasibility Study Kvanefjeld Rare Earth and Uranium Project, Greenland (Amec Foster Wheeler Earth & Environmental (UK) Ltd.)

These reports are available from GMEL's website.

BMP (now MLSA) guidelines require a period where baseline sampling must take place in order to document the natural levels including seasonal and annual variations. Baseline field sampling and baseline studies for the Kvanefjeld Project were carried out from 2007 to 2014.

The Mineral Resources Act embraces principles of sustainable use in mineral exploitation, Best Available Techniques (BAT) and Best Environmental Practice (BEP) in project planning. The EIA is conducted in parallel to the engineering project design. The EIA addresses any remaining potential environmental impacts.

1.4. Public Consultations and Hearing

Public consultations and hearing is a required part of the EIA process to inform the public and gather public comments and concerns.
Since 2008 workshops, interviews and public information meetings were held as part of the parallel Social Impact Assessment (SIA) process.
A public hearing period for the Terms of Reference (ToR) for the EIA was arranged by the Greenlandic authorities and comments and viewpoints raised was gathered in a "White Paper" document with responses from GMEL and suggestions on how public concerns will be addressed in the final ToR for the EIA.

The EIA will be submitted to MLSA in late 2015; MLSA then conducts a review of the EIA and issues comments; the EIA will then be updated in accordance to MLSA comments (if needed) and re-issued for the purpose of public hearing and translated to Greenlandic and Danish.

The Greenlandic authorities will arrange a public hearing period for the draft EIA and viewpoints raised will be gathered in a new "White Paper". This document will include responses from GMEL and suggestions on how the various public concerns will be addressed in the final EIA.

After the public hearing the EIA report will be revised. If the project is approved, an exploitation license would then be granted according to the Mineral Resources Act. The license will state any specific conditions that the project must fulfil during construction, operation and closure. If approved, specific permits will also be needed for various components of the project before construction may begin.

1.5. Alternatives considered

BMP (now MLSA) guidelines require that the EIA describes key alternatives considered and the reasoning behind the choices made.

<u>Zero alternative</u>
The "zero-alternative" is simply that the Kvanefjeld mining project is not implemented. The zero alternative means that the Study Area will remain as is and the impacts discussed in this EIA report will not occur. Other social and economic impacts, including job-creation, income generation, etc. for the Greenlandic society will not occur. The impact of the project and other alternatives are compared to the 'zero-alternative'.

Processing technology

Two processing alternatives were considered:

- A "concentrates-only" (mechanical processing) alternative, which produces the simplest form of Rare Earth intermediate product that permits cost effective transportation to another location for further processing. However, since it is a requirement of the Greenland Government that as much processing of ore that is practically possible must take place in Greenland, this alternative was not selected.

- A "Greenland separation plant" which includes Concentrator and Refinery and additional chemical processing would permit the separation and production in final form of the 15 Rare Earth elements of the Kvanefjeld ore. Because the metallurgical processing of Rare Earth is one of the most complicated businesses in the mining and chemical industry, which require a very complicated extraction technology, this alternative was not selected.

Location of mine facilities

An alternative location for the accommodation facility, processing plants, tailings ponds and port at Ipiutaq was considered. This would require the ore transported by haul trucks through a tunnel from the pit at Kvanefjeld. Following public consultations this scenario was abandoned and the development of the mine design was focused on the Narsaq Valley – Taseq basin – Narsap Ilua area.

Location of tailings facilities

Considerations to locate the tailings ponds on top of the mountainous plateau southwest of Kvanefjeld was performed. However, this would require construction of very large embankments to create ponds suitable for deposition of 37 years of tailings. For this reason this alternative was abandoned.

Location of port

A number of alternative locations of the new port at Narsap Ilua were considered. This included the north side of the bay, but this would conflict with a Norse farm ruin and would require large scale blasting. A location just south of the outlet of Narsaq River was also considered but this would require large scale dredging to allow for berthing of ships.

Energy supply

The energy supply is based on fossil fuel generators but hydropower was also considered since the hydropower energy potential at Johan Dahl Land is adequate to meet the power requirements for the project. This would require damming and diversion of 3 lakes and construction of a diversion tunnel. In addition, a 55 km power line is required. The capital cost for all this would change the entire project significantly and extend the construction time of the mine project. For these reasons hydropower is not part of the proposed project but remain an interesting option which could form part of an overall southern Greenland energy system.

1.6. Impacts on the environment

1.6.1 Landscape alterations and visual impact

Construction of the Kvanefjeld Project will result in landscape alterations that will be visible in the surrounding area. Structures in the new port area will be visible from Narsaq. On land, the new access road and the processing plants will be visible in Narsaq Valley, but not from Narsaq Town. The mine area on Kvanefjeld including the pit will be visible from the highest part of Narsaq Valley but not from the lowlands or Narsaq.

The area of the processing plants and adjacent facilities will change during the construction period due to excavation, levelling and construction of several large structures. All of these alterations will be visible during the entire project period. During closure phase structures will be removed.

The areas which will be visibly altered during the operation phase are the open mine pit and deposits of waste rock. The top of Kvanefjeld will gradually disappear. This will be visible from viewpoints around the area. The waste rock deposits will also be visible though these will tend to blend in with the surroundings. The mine pit will only be visible from very close to the pit. The same applies to the embankments at the tailings ponds in the Taseq basin.

The visual impact on the landscape is an unavoidable part of the mining project and cannot be eliminated by mitigation measures. The physical alterations will be localized within the Study Area but visible from a large area around the project. Some of the alterations will be permanent while others will be removed or reduced during the closure phase. The overall landscape and visual impact is a medium impact in the construction and operational phases.

1.6.2 Hydrology – surface water, groundwater and marine waters

The Kvanefjeld project will source water from Narsaq River and from the tailings ponds. Over the course of a year, about one third of the water flowing in upper Narsaq River will be used for process water. After recycling and treatment this water will be placed into Nordre Sermilik.

The natural outflow from Taseq Lake will be blocked by an embankment during the operational and closure phases. Excess water from tailings and precipitation is pumped back to the processing plant for reuse.

In the post-closure phase, water will again flow out of the Taseq basin to Taseq River.

Another major hydrological consequence of the project is that the Taseq and pond to the north-east of Taseq will gradually fill with tailings. Although water cover will be maintained, the water volume of the tailings ponds will be reduced.

Overall, the hydrological changes will not alter the water flow significantly and the impact on the hydrology will be low.

1.6.3 Noise

Noise sources during the construction phase will be temporary and limited. Blasting and grading will be used to prepare level areas for lay down areas, access road, buildings and haul roads at the mine.

Construction of the access road will be of short duration in each location as the construction process moves from port to the process plant area. Ship traffic will bring containers of supplies and construction components to the Study Area and these will be trucked to the areas needed.

During the operational phase, most noise sources will be continuous with constant level both day and night. The most important sources are the mine area (pit, haul roads, processing plants and power plant), the access road connecting the mine area and new port area. There will also be short occasional noise sources, including blasting every two days with multiple shots potentially blasted at the same time.

The noise load from the project was modelled for the operational phase and compared to the background sounds on a quiet day (30 dB(A)). It was found that noise loads above the background level are limited to the Kvanefjeld areas, the Narsaq Valley and the port area.

Noise caused by trucks, busses and other vehicle traveling on the access road extends 800-1200 meters on both sides of the road, depending on terrain. This will not increase the noise level in Narsaq Town.

The project-related traffic noise level calculated for the five summer houses in Narsaq Valley closest to the road increases to 38.0 dB(A) during day, 38.3 dB(A) during evening and 38.7 dB(A) at night, that is only slightly above the natural background levels. Compared to Danish guided noise limits for summer housing during the day, evening and night, the calculated noise levels are below the limit during daytime (40 dB(A)), but exceed the 35 dB (A) limit slightly during evening and night.

The noise footprint caused by project operations at the new port will exceed 70 dB(A) in a small area where containers are unloaded. The area where the average noise load exceed the 30 dB(A) background level extends about 1,800 m from the center of the new port. The noise level in the residential areas in Narsaq and where the accommodation building for works will be constructed will be less than 40 dB(A) and thereby meet the Danish noise guidelines for noise levels in towns.

To conclude, the modelled noise load distribution generated by project operations shows that the area of the 70 dB(A) industrial footprint is very small and limited to the mine area, the processing plant areas, a narrow corridor along the road and to the new port.

The predicted noise increases associated with the project will be well below Danish guideline limits in residential areas in Narsaq. Traffic noise will exceed the Danish evening and night limit of 35 dB(A) for summer houses by up to 3.7 dB(A) at two cottages in Narsaq Valley. No known sensitive wildlife areas will be impacted by operational noise of the mining activities.

1.6.4 Air quality

The Kvanefjeld Project will have air emissions of some regulated components in the operation phase from diesel machinery, trucks, power generation, heating and engine emissions from road and ship transport.

There will also be emissions of fugitive dust from mine excavation and blasting, material handling and transport on unpaved roads. Dust stirred by mine trucks when hauling ore and waste rock will be the main dust source.

Dispersion modelling was performed to predict the ambient levels of air pollutants NO_2, SO_2 and dust during the operational phase and compare them with Greenland ambient air quality limit values.

Outside the mine area the emissions of all modelled components (NO_2, SO_2 and $H2_S$) are found to be well below Greenland guideline values (and Canadian guidelines where Greenland values are not available).

The modelling shows that high concentrations of dust in the air (Total Suspended Particulates - TSP) and of less than 2.5 and 10 microns in diameter ($PM_{2.5}$ & PM_{10}) are only recorded close to the haul roads on the Kvanefjeld. Outside the mine area the concentrations are well below the Greenland guideline values.

Most dust is predicted to deposit on Kvanefjeld and on the mountainous plateau to the south-west of Kvanefjeld. Outside this area the deposition amounts are well below the Greenland guidelines.

To conclude, emissions of oxides of nitrogen and sulfur compounds from the Kvanefjeld project will not result in significant impact.

The particulate emissions from the Kvanefjeld project will not result in any significant impact. High concentrations of air borne particles (TSP, PM_{10} and $PM_{2.5}$) will only occur in the mine area. At Narsaq Farm (in Narsaq Valley), in Narsaq Town, at Ipiutaq and the farms further to the northeast at Qassiarsuk dust concentrations will at all times be well below the Greenlandic guidelines (and Canadian guidelines for TSP which is not addressed in the Greenland guidelines).

1.6.5 Greenhouse gas emissions

The Kvanefjeld Project will have energy consumption based on fossil fuel combustion, with associated emissions of carbon dioxide (CO_2). CO_2 is a greenhouse gas (GHG) that contributes to global warming and climate change.

A total of 0.35 million tons CO_2 emissions per year is estimated for the project and will increase Greenland's CO_2 emissions by 63%. However, the 523 tons of uranium oxide produced by the Project annually will be used to produce electricity at nuclear power plants outside Greenland. This is comparable to the electrical power produced by a 2 giga watt (GW) typical European coalfired power station saving 11 million tonnes per year of carbon dioxide emissions.

1.6.6 Radiological emissions

Some of the activities in connection with the Kvanefjeld mine operations can cause release of radioactivity to the air and water.

Therefore, a radiological assessment has been carried out that consists of the following main steps: First, the potential releases from the mine as well as the processing and refining are estimated and the radiological contaminants of concern are identified. Next, the estimates of releases are used with studies that were prepared as part of the Kvanefjeld project that looked at the dispersion in air and water. Then radionuclide concentrations due to mine activities are estimated for soil, water, plants and animals at different locations within a study area. These concentrations are used in association with behavior characteristics (e.g. what and how much is eaten) and established dose coefficients to estimate radiological dose to selected plants, animals and people. Effects of the health of wildlife are then determined by comparing the total radiological dose (natural background dose and dose due to project activities) to a selected dose limit. If the dose is below the protective dose limit, then it can be concluded that the health of the species is not at risk. For humans the dose due to project activities is compared to a dose safety benchmark.

The potential radioactive releases from the project are identified as:

- Dispersal of dust containing radionuclides, which settles on the soil and vegetation, and is transferred through the food chain to animals and humans;
- Release of radon gas and radon progeny to the air, which is inhaled by wildlife and humans; and

- Placement of contaminated water into Nordre Sermilik, which may impact marine plants and animals and ultimately humans when ingested.

No contamination of freshwater (lakes and rivers) is expected during operations.

To calculate the radiological dose exposure to animals, plants and humans the INTAKE pathways model was used. This model is developed for use in simulating environmental transfer, uptake and risk due to exposure to radionuclides released to the environment. Using this model the dose was calculated for a large number of plants and animals (including sheep and reindeer) and for people.

For all the modelled organisms, the conclusion is that the increase in dose due to project activities is extremely low. The calculated dose values have been compared to known reference values, where no harmful effects of chronic radiation have been observed in natural populations. All studied organisms are far below the reference values implying that there will be no adverse effects to animals or plants.

For people in Narsaq, the background dose range was modelled to between 4000 and 5000 µSv/year (exposure to radon makes up approximately 60% of this). The estimated dose due to project activities for resident people in Narsaq and Ipiutaq was modelled to between 16 and 25 µSv/year. At the sheep farms around Qassiarsuk the dose due to project activities is expected to be even lower.

In conclusion, the radiological impacts of the Kvanefjeld project to plants and animals associated with marine, freshwater and terrestrial habitats in the studies area as well as to people in Narsaq and Ipiutaq (and elsewhere) are very low and the estimated dose to all these receptors is far below limits for radiation impact.

1.7. Water environment

1.7.1 Freshwater quality

During the Operations and Closure phases, no wastewater from the project will flow into streams or rivers in Narsaq Valley. Excess water from the two tailings ponds in the Taseq basin will be decanted and re-cycled before eventually placed in Nordre Sermilik after wastewater treatment. During the six year Closure Phase the water in the tailings ponds is pumped to the wastewater treatment plant and gradually replaced by precipitation and run off from the catchment area. This improves the water quality in the ponds. When the water quality meets the Greenlandic and International water quality criteria the treatment is stopped and the water level is allowed to rise in the two ponds and overflow the embankments into Taseq River.

In order to assess the water quality in the tailings ponds a comprehensive dynamic simulation model has been developed. The model simulates the concentrations and flows through almost a 100 years lifespan of the project. The simulation includes 46 elements from the periodic table (including uranium, thorium and radium-226) and 15 reagents.

The modelling work shows that the concentration of certain elements and reagents present in the tailings ponds exceed ambient water quality criteria during the Operations Phase. However, in the Post-closure phase (that is after cleaning) all elements and reagents will be below the Greenland ambient water quality criteria and Predicted No Effect Concentrations (PNEC) for the reagents, downstream of the confluence of Taseq River with Narsaq River. With one exception, the same applies to Canadian guidelines for elements where no Greenlandic values are available. The exception is fluoride for which the Canadian ambient water quality guidelines cannot be fulfilled because of the high natural levels of fluoride in Narsaq River.

Due to the low levels of radionuclides in the water from the tailings ponds, which are far below Canadian guideline values (no Greenlandic values exist), no radiological effects to the freshwater ecosystems of the rivers are expected. An estimation of the radiation dose for Arctic char in Narsaq River during Post-closure shows that the dose from the project is negligible and that there is not expected to be any adverse effects on fish.

1.7.2 Water quality in fjords

Except for the two tailings ponds in Taseq basin and a small stream next to Kvanefjeld, no water from the project will flow into lakes or streams during the Operations and Closure Phases. The Project will have two releases to the marine environment:

- A stream from the mine area and comprise mine water and run off from the waste rock stockpile. This water flows via a natural watercourse into Nordre Sermilik.
- A stream from the processing plants via a pipe into Nordre Sermilik at a depth of more than 40 meters. This water has a temperature of 12^{o}C.

The composition of the released water into the fjord was reviewed to determine the required dilution in order to obtain concentrations in the environment below Predicted No Effect Concentration (PNEC). It was also tested if the contaminants are known to be bio-accumulative toxic and eco-toxicological testing was carried out to determine if the discharged water would be acute and chronic toxic to algae, copepods or fish.

A hydro-dynamic model for the fjord system was developed and the quality and quantity of all major contaminants in the streams were modelled in terms of temperature, concentration and flow. The main conclusions of the study are:

- The required dilution to obtain a concentration below PNEC for all contaminants in the discharged water is estimated to 1612. This dilution is obtained within an area of 1-3 km^2 along the coast of Nordre Sermilik and at depths between - 50m and - 20m;
- None of the chemical species in the discharged process water is assessed to be bio-accumulative toxic or subject to significant bioaccumulation and biomagnification.
- The area affected by the thermal plume (12^{o}C) was negligible and little or no impacts on marine life in the fjord are expected.
- The potential impact on the primary production of phytoplankton in fjords in South Greenland and potential impact on fish is expected to be very limited; and
- The copepods/crustaceans are likely to be the most sensitive species to the chemical species but with the modelled dilution regimes, no acute and no chronic effects should be expected. The copepod *Calanus finmarchicus*, which is an important component of the marine ecosystem, is assessed only to have very limited contact with the chemical species in the effluents as it migrates vertically in the broader water column (50 -600 m).

All chemical species in the discharged water meet the Greenland water criteria except for arsenic, cadmium and mercury, which require a dilution of up to 5. This dilution will take place locally near the discharge diffusor and is therefore not considered an exceedance of the Greenland water quality criteria.

1.8. Living environment

Disturbance during construction and operation due to project activities could impact wildlife and vegetation on the land, rivers, lakes and fjords in the Study area. Disturbance includes the active scaring of animals, but also when a habitat becomes unavailable to animals, for example if ptarmigan are excluded from an area with vegetation because it is close to a haul road and, when a habitat is lost, for example when an area is overlaid by infrastructure.

<u>Terrestrial mammals and birds</u>
Noise and visual disturbances from mine activities can potentially disturb birdlife and mammals. The re-profiling to accommodate the project will lead to some loss of natural vegetation and displacement of most terrestrial animals from the area.

The White-tailed eagle is the only bird known to occur in the area, which is sensitive to disturbance. Eagles are particularly sensitive to disturbance close to the nest during the breeding season. Since no nesting sites are known from the Kvanefjeld or Narsaq Valley this is not assessed as an issue.

Arctic fox and Arctic hare are the only terrestrial mammals in the area. Both usually habituate well to human activities where they are not hunted but since the hunting pressure in South Greenland is generally high, they will probably stay well clear of the project facilities.

The construction activities will cause localised disturbance of terrestrial birds and mammals but since no breeding sites are known of White-tailed eagles from the Kvanefjeld area, the disturbance impact of terrestrial mammals and birds is assessed as Low.

No construction works will take place in areas with rare plants or habitats. The overall footprint of the mine infrastructure is small compared to the distribution of similar habitat in South Greenland. Typically, low densities of animals occur in these habitats none of which are known to be rare or threatened in Greenland. The significance of lost terrestrial habitats due to the Project are therefore assessed as Very Low

Marine animals

The fjords around the proposed mine site are important to a range of marine birds and mammals that potentially could be disturbed by project activities. Of particular significance are ringed seals all year and harp seals during summer, sea bird colonies at Akullit Nunaat and flocks of wintering eider duck in the fjords and Arctic char during summer.

The building of the new port facility at Narsap Ilua will cause temporary under-water noise from blasting and ramming, increased turbidity of the seawater close to the port and a loss of inter-tidal habitat. During the construction and operational phases, ships calling in at the new project port will generate noise both above and below water and visual disturbance above water.

Disturbance from the construction works will be local and temporary and will take place in an area with low numbers of marine animals. The impact of this is therefore assessed as Low. Only 1- 2 ships a week will serve the Kvanefjeld Project and the disturbance impact of this on marine animals is assessed as Low.

Little specific knowledge exists about the marine flora and fauna of Narsap Ilua but no marine mammals or sea birds are specifically associated with this part of the fjord. The loss of foraging ground for Arctic char due to the construction of the port is believed to be insignificant since very large areas of similar habitat type is common and widespread along the shore of the fjords in the region. The loss of marine habitat is assessed to have Very Low significance.

Freshwater organisms including fish

Construction works in connection with the bridges across Narsaq River and the building of embankments at Taseq might cause short-term increases in the turbidity in

Narsaq and Taseq Rivers. This could disturb freshwater organisms including Arctic char in Narsaq River. The use of the Taseq basin for tailings deposition will most likely make them unsuitable for supporting aquatic life.

Since any rise in turbidity due to construction works will be temporary (and short term) the disturbance of the Arctic char and the freshwater ecosystem in general are accessed as of Very low importance. No significant impact on the freshwater fauna and fauna of rivers are expected during the operational phase.

Taseq River, Taseq Lake and the pond east of Taseq are all fishless and inhabited by a species poor invertebrate fauna consisting of animals which are common and widespread in South Greenland. Almost no vegetation is found along the shore or in the lakes. The loss of freshwater habitat when using Taseq Lake and the pond east of Taseq for deposition of mine residuals will therefore be limited, and the significance is assessed as Very Low.

1.8.1 Waste

Waste produced during the construction period and operational phase includes domestic waste, construction waste, iron and metal scrap, tires from mobile equipment and various types of hazardous waste (oily waste, chemical waste, batteries, etc.).

All solid waste will be shipped to Qaqortoq for incineration. Sewage from all buildings will be treated in a treatment plant. Hazardous waste is registered, handled and shipped to Denmark for treatment and disposal in compliance with Danish and EU requirements. When possible waste products are recycled.

In conclusion the waste handling will be carried out according to good environmental practice with a high degree of recycling where applicable. The impact of waste production to the environment is assessed to be of Low significance.

1.9. Hindrance of traditional land use

The present use of the Study area by people from Narsaq and visitors can continue as today throughout the mine life with the following exceptions:

- For security reasons access to the mine area, for example to collect semi-precious gemstones will not be permitted;
- A 1 - 2 km 'no hunting' security zone from all mine facilities will be introduced;
- There will be a no-fishing zone around the treated water placement point in Nordre Sermilik; and
- For security reasons hiking (and driving) on the new road between the port and the mine area will not be possible.

1.10. Disturbance of heritage site

Two heritage sites are located within the Study area: A rock shelter along the shore of Taseq and a tent foundation and shooting blind situated on the tip of the Tunu peninsula close to the location of the new port.

Before any construction works take place in the vicinity of these sites, Greenland National Museum and Archives will be notified so that a staff member can photograph and measure the structures as part of the archaeological registration.

1.11. Risk assessment

Identifying significant environmental risks is an important part of doing an overall environmental impact assessment for mining projects. A screening of potential significant environment risks events identified the following:

1. Tailings embankment failure or overflow;
2. Spill of oil and chemicals; and
3. Spill of uranium product (yellow cake).

1.11.1 Tailings embankment failure or overflow

A leak or collapse of the embankment that separates the two tailings ponds will have no immediate environmental impact because the embankment is designed to accommodate the water (and tailings) of both ponds. A major leak or collapse of the Taseq Lake embankment will cause some or all of the water to flow to Taseq River, and to the lower part of Narsaq Rivers before reaching the fjord.

Only small amounts of tailings will be washed out, even in case of a total collapse of the embankment. This is because the viscosity of the tailings is too high for them to flow like water. The tailings have compacted to squeeze out the water leaving a minor amount of pore water. The tailings are expected to de-water under the pressure of layers of tailings to ~70%. If all the water leaves the tailings ponds, the top layer of exposed material will dry up and could be dispersed by strong winds.

During the operation phase, the water in the tailings ponds will have elevated (relative to natural waters) concentrations of some salts, radionuclides and reagents. If this water flows to rivers in Narsaq Valley it will have severe consequences for the aquatic life, in particular the impacted section of Narsaq River. The impact on marine life in the fjord will be lower due to the dilution.

Wind dispersal of mildly radioactive tailings could potentially lead to pollution of the impacted areas. Such a scenario is limited to summer months during the operational phase. In winter the tailings ponds are covered by thick ice and when the deposition of tailings ceases at mine closure, the tailings will be covered by a thick layer of rock fill. The tailings, which mostly consist of silt, with a particle size between PM_{15} and PM_{30}, would probably not be dispersed outside the Taseq basin if it was allowed to dry up and exposed to strong winds.

The tailings embankments for the Kvanefjeld project will be constructed in accordance with best international practice and the design includes analysis of their stability both under static and seismic conditions. Rock fill and a conservative wall angle design will be used and the embankments will be equipped with a geo-membrane dual liner to protect against seepage. Both embankments will be constructed to withstand extreme inflow of water for example due to exceptional snow melting under føhn wind event. For these reasons, a major embankment leak or collapse is highly unlikely.

1.11.2 Spill of oil and chemicals

Significant amounts of oil and chemicals are used for production. These products will be shipped to the new mine port where they are unloaded and stored. Oil and chemicals are transported to the mine site by trucks and stored in smaller tanks and warehouses. The saleable mine products are transported in containers to the port by truck where they are stored before being shipped abroad.

Several of these activities could lead to significant spills, in particular shipping in the fjords, unloading from ships to land based storage and during land transport.

A major shipping accident could give rise to large spills of oil, chemical or mine products. Due to currents in the fjords, oil leaked to the marine environment will be transported over long distances quickly, and the narrow fjords will make shoreline contamination likely.

The consequences of an oil spill to the marine life, including birds may be significant. In particular, birds are extremely vulnerable to oil.

Unloading from ships to land based storage and land transport are other activities that may lead to spills. The majority of operational spills are small and chemical spills at the port will typically consist of small quantities limited to one container.

Since the amounts of oil and chemicals spilled in connection with unloading or loading accidents are mostly small, the impact on the environment will be local and relatively small. Effects of oil spills on the Arctic vegetation will likely be localised, but as Arctic flora has very slow growth rates, effects can be long lasting, stretching into decades. In comparison to the likelihood of large shipping accidents, the risk of spills caused by operational events is higher, but the consequences are much lower.

1.11.3 Spill of uranium product

The uranium product (yellow cake) produced at the Refinery, will be packaged in steel drums which are loaded into containers and transported to the port where they are loaded into vessels and shipped abroad. Scenarios for potential transportation accidents involve spills of yellow cake to rivers and harbour and spill on land.

A spill of yellow cake to the Narsaq River or Narsap Ilua may, when not frozen, have short-term as well as long-term implications. In the short-term the impacted water may be unsuitable for supporting aquatic life. This period varies between water bodies, but is usually in the order of days or weeks. In the long term, the released material needs to be cleaned up and area remediated. Depending on the cleaning extent and efficiency, the long-term quality of sediment may be impacted resulting in undesirable exposure of benthic invertebrates and other biota, which are exposed to contaminated water and sediments.

In case of an accident involving the release of uranium products on land, both flora and fauna and members of the public (and workers) could be exposed to external gamma radiation as well as inhalation of airborne yellow cake particles. Calculations of the inhalation dose if a person is exposed to yellow cake dust concentration in connection with an accident show that the exposure will be very low. In addition, the dose from gamma radiation in connection with 10 hours of clean-up would be well below the recommended radiation dose limit of the public of 1mSv per years (over natural background level). The same applies to wildlife and with an effective clean-up of spilled material no significant effect is expected to plants and animals.

1.12. Environmental Management Plan

The Environmental Management Plan (EMP) describes how the mine company intend to manage each environmental aspect identified in the EIA:

- Potential impacts to the environment;
- Mitigation measures for each impact;
- Who is responsible for each commitment;
- Construction phase management;
- Operational phase management; and
- Closure phase management.

A framework EMP is tabulated in spreadsheets in the EIA, which are laid out with the following divisions:

- Project activity – the activity associated with the mining project, which has been identified to possess a potential impact or risk to the environment;
- Environmental impact – description of the negative impact of the activity;
- Action – the mitigating measure or actions identified to prevent or minimize the adverse environmental impact;

- Project stage - the stage in the life of the mine where the measures, actions, or principles have effects;
- Frequency and/or timing – the frequency or timing when the action should take place; and
- Responsibility – parties responsible for ensuring the action, measure, or principle is done.

The EMP and work procedures will be periodically reviewed and updated over the life of the mine.

1.13. Closure plan

There will be a six-year closure phase after mine operation ends. During this period, water will be pumped from the two tailings ponds to the treatment plant and after cleaning, released into Nordre Sermilik. This will cause the water level in the ponds to drop significantly. When the cleaning has been completed, rain and snowfall will gradually fill the ponds and they will eventually overflow into Taseq River.

Principles for mine closure are summarized in the EIA and the environmental impacts assessed. These principles are summarised by the following points:

- The mine pit will remain open for natural flooding;
- Except for the accommodation village, all buildings and major structures will be dismantled and removed;
- Foundations will be removed where possible, or covered by natural materials to blend into the natural surroundings;
- The haul roads will be reclaimed while the roads connecting Narsaq and the mine port with the mine area as well as the track between the mine area and Taseq are left intact to facilitate future inspections and monitoring activities;
- The power line connecting the on-site plant with the port area is removed. Any culverts that could act as hydraulic conduits at closure are removed;
- The mine port is left as constructed (if agreed with the authorities); and
- The tailings storage embankments and diversion channels are left as constructed. When the six years closure phase ends, the return water pipelines are removed and the tailings storage facilities are left to fill naturally with water. The treatment plant and pipelines are removed.

An option to move the tailings deposited in the Taseq basin back to the pit at mine closure was considered. Since the tailings can only be removed with water it would require that the solids is re-suspended into a slurry and pumped through a pipeline to the pit. This option is not practical for the following reasons:

- After 37 years of deposition the tailings have compacted considerably making their re-suspension very difficult. It is estimated that the tailings are 70%+ solids with high viscosity and are therefore not in a pumpable condition;

- Even if the tailings at the bottom of the Taseq basin are able to be pumped it will take a long time and considerable cost to move it to the pit because of the massive volume;
- Re-slurring of the tailings will result in the release of salts trapped in the pores of the consolidated solids. This will result in tailings water contamination, which then will have to be contained in the pit; and
- It will not be practically possible to provide separation of the two tailings fractions if deposited in the pit, which will prevent future recovery of valuable residues with new technologies.

A post-closure phase of control and monitoring activities will follow the closure phase.

1.14. Monitoring Plan

An Environmental Monitoring Program (EMP) will be implemented in accordance with the Greenlandic guidelines to monitor residual effects of the Project and the effectiveness of implemented mitigation measures.
The EMP for the Kvanefjeld Project will comprise of the following key-elements:

1. Air Quality and Dust Monitoring;
2. Sea and Freshwater Monitoring;
3. Soil and Terrestrial Biota Monitoring;
4. Tailings Facility Monitoring; and
5. Meteorological Monitoring;

The EIA report includes a framework for the monitoring plan, including proposed parameters. One of the expected key parameters will be the radionuclide content in air, dust, water, soil and biota. In addition, it is proposed to monitor radon, thoron and gamma radiation.

The conceptual monitoring plan also suggests a sampling frequency for each parameter and propose monitoring durations. Where relevant the programme includes control sites where no expected Project impacts are likely to be experienced.

The EMP will be developed and updated throughout the mine life.

1.15. Conclusion

The Kvanefjeld Project is a large mining project with major developments and activities. The mine area including the pit and the processing plants are located around 8 km from Narsaq while other facilities, including a new port, will be situated around one km from town.

The construction of the Kvanefjeld Project will result in landscape alterations that will be visible in the surrounding area. Structures in the new port area will be visible from Narsaq. The new access road and the processing plants will be visible in Narsaq Valley, but not from Narsaq Town. The mine area on Kvanefjeld including the pit and the tailings facilities at Taseq basin will be visible from the highest part of Narsaq Valley only, but not from the lowlands or Narsaq.

Despite the size and complexity of the project, the overall conclusion is that the environmental impacts in terms of contaminations (including radiological impacts) and disturbances will be limited. The environmental footprint is limited in geographical scale, and environmental significance with few permanent impacts after the mine project has terminated.

The reasons for the limited impacts are a combination of several beneficial conditions:

- In order to comply with the applicable Greenlandic and international standards/guidelines, the project has included approaches, control measures and technologies in the design that are considered to be Best Available Techniques and Best Environmental Practices. This will limit contaminations potential and emissions from the processes.

- Radiological emissions in the form of dispersal of dust containing radionuclides, release of radon and discharge of water containing radionuclides to the fjords are so low that the increase in radiological dose in plants, animals and people due to project activities is estimated to be extremely low.

- Unavoidable consequences of noise, dust and visual disturbance and other nuisances associated with mining projects are only in limited conflict with the environment and people.

- The area around the project infrastructure is vast, enabling wildlife that might be disturbed by the activities to find equivalent areas in the region without significant influence to the overall wildlife population. No endangered or vulnerable habitats or species will be impacted by project activities.

The EIA main conclusions are as follows:

Impacts on the physical environment
Landscape alterations will be unavoidable, and the constructions will imply visual impact, mostly in the Construction and the Operations Phases. Landscaping at the closure phase will to a large extent diminish the visual impact, and natural developments will further reduce them in the long run. The mine pit, the waste rock stockpile and the embankments in the Taseq basin will remain as changed landscape. Over time, the mine pit will fill with water and the pit becomes a lake. The tailings in the Taseq basin will remain below the water surface and will not be visible. Overall, the impact on landscape is assessed to be of medium significance.

High concentrations of air borne particles (TSP, P_{10} and $P_{2.5}$) and oxides of nitrogen and sulfur will only occur in the mine area. Outside the mine area dust and emissions are well below Greenland guideline values. The impact of air emissions is assessed as low.

Energy for the project will be supplied by fossil fuel, which will be used in generators, engines and vehicles. During the Operational Phase, the project will account for an increase of Greenland's CO_2 emission by about 63 % compared to the present level.

The project's noise footprint will be very small and limited to the mine area, the processing plant areas, a narrow corridor along the access road and to the new port. Predicted noise increases are well below Danish guideline limits in residential areas in Narsaq. The impact is assessed as low.

During the Construction and Operational Phases, no water from the project will be discharged to the freshwater environment. Outlet to the marine environment will be from the industrial plant at the mine site to Nordre Sermilik. Concentrations of some metals and reagents near at the outlets are assessed to be above guideline values for ambient water quality or predicted no effect concentrations (named PNEC). A dilution factor in the order of 2000 will be required to obtain non-toxic levels for the most critical parameters including safety margins. The required dilution can be obtained in the marine area on local scale of 1 – 3 km^2 and in a vertical confined lens of water when the outlet is constructed sub-surface. Based on the EIA assessment terminology the overall impact on the marine environment is assessed to be of medium significance.

Impacts on the natural environment
The construction and operational activities will cause localised disturbance of animals and loss of terrestrial and freshwater habitats. Typically, low densities of animals and plants occur in these habitats none of which are known to be rare or threatened in South Greenland.

The disturbance from ships in relation to marine mammals, bird colonies and wintering flocks of birds in the fjords have been assessed. These impacts are assessed to be low.

No disturbance sensitive, threatened or rare species or habitats will be impacted by the project. On this basis, the overall impact on the natural environment is assessed to be low.

Radiological emissions

For animals, plants and humans, the increase in radiological dose due to project activities is extremely low. The calculated dose values have been compared to known reference values, where no harmful effects of chronic radiation have been observed in natural populations. All studied organisms are far below the reference values implying that there will be no adverse effects.

For people in Narsaq, the background dose range is modelled to between 4000 and 5000 µSv (exposure to radon makes up approximately 60% of this). The estimated dose due to project activities for resident people in Narsaq and Ipiutaq is modelled to between 16 and 25 µSv. At the sheep farms around Qassiarsuk the dose due to project activities is expected to be even lower.

In conclusion, the radiological impacts of the Kvanefjeld project to plants and animals associated with marine, freshwater and terrestrial habitats in the studies area as well as to people in Narsaq and Ipiutaq (and elsewhere) are very low and the estimated dose to all these receptors is far below benchmark values.

Risk assessment

Environmental risks include the risk of tailings bank failure or overflow and release to the environment of harmful substances such as uranium product (yellow cake), fuels or chemicals. There is substantial international experience in minimizing these risks in the arctic mining industry. Risks will be minimized by general precautionary measures in construction and production schemes, presence and use of adequate equipment and in staff training. All these measures reduce the likelihood of incidents and the impact of these to a very low level.

2. INTRODUCTION

2.1. Kvanefjeld Project

Greenland Minerals and Energy Limited (GMEL) is planning to develop a multi-element mine project at Kvanefjeld in Greenland. The Kvanefjeld Multi-element Project (Kvanefjeld Project) will treat 3.0 million tonnes per annum of ore to extract Rare Earth Elements (REE), uranium, zinc and fluorspar.

2.2. Project setting

Kvanefjeld is situated approximately 8 km from the town of Narsaq in South Greenland and approximately 45km from Narsarsuaq where the nearest airport is located (Figure 2-1).

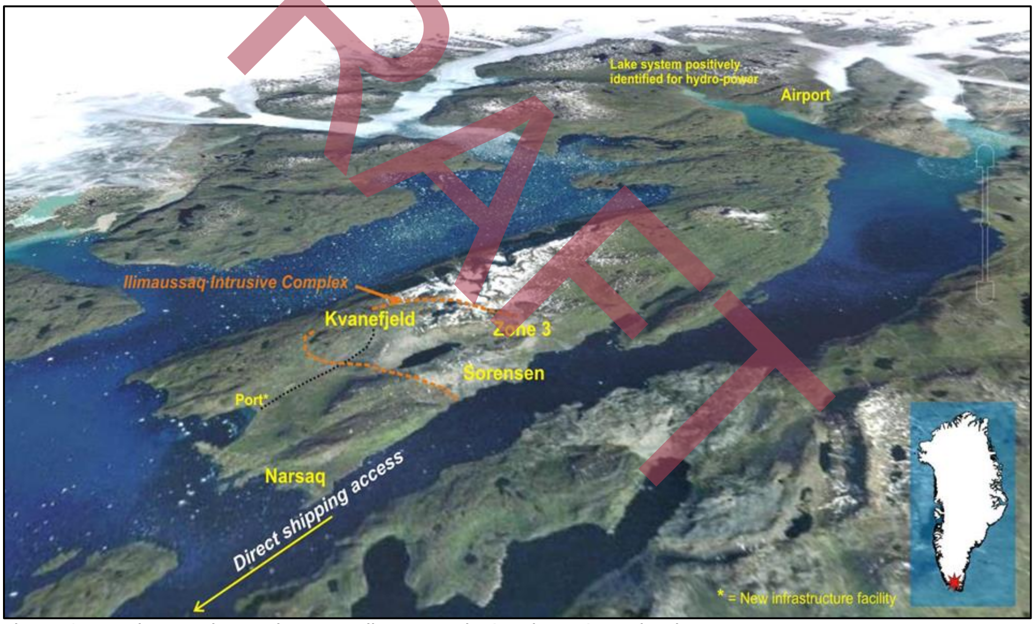

Figure 2-1 Project setting and surrounding areas in Southern Greenland

2.3. The mine company

GMEL is an Australian mine company based in Perth and listed on the Australian Securities Exchange. Greenland Minerals and Energy A/S is a Greenlandic subsidiary of GMEL with headquarters in Nuuk. In 2007, GMEL acquired a majority stake in the licence to explore the Kvanefjeld Project area and in 2011 moved to 100% ownership of the Kvanefjeld Project.

2.4. Environmental Impact Assessment for the Kvanefjeld Project

Before a mining project can be granted a licence to operate, the Greenland Self Government requires that an Environmental Impact Assessment (EIA) is prepared that assess the project's likely environmental impacts and propose measures to avoid or minimise any adverse impacts.

GMEL has appointed Orbicon A/S (Denmark) in cooperation with Orbicon Grønland A/S to prepare the EIA for the Kvanefjeld Project.

The impact assessment for the Kvanefjeld project is prepared in compliance with the official guideline of the Greenland authorities, "BMP guidelines – for preparing an Environmental Impact Assessment (EIA) Report for Mineral Exploitation in Greenland" 2nd Edition, January 2011" (Bureau of Minerals and Petroleum 2011). Since 2011 the Greenland authorities have developed the guidelines further and introduced a procedure with public hearing of the terms of reference for the EIA.

2.5. Geographical scope of EIA

The geographical areas assessed in this EIA are defined according to the following terms:

"**Project footprint"** means the area directly influenced by the mine project including the close vicinity to the project components and infrastructure i.e. few hundred meters from the open pit mine area, the process plant facilities, the access road, pipeline, port site, etc.

"Study Area" means the geographical area of recognizable or potential impact for disturbances of the natural flora and fauna or from pollutants (noise, dust, water pollution, etc.). This area is shown in Figure 2-2.

"Global Area" Some environmental issues are not confined to geographical areas but has a global perspective e.g. emission of greenhouse gasses.

It should be noted that the EIA is not assessing transport of the products outside the Greenlandic waters or any further processing of the products abroad.

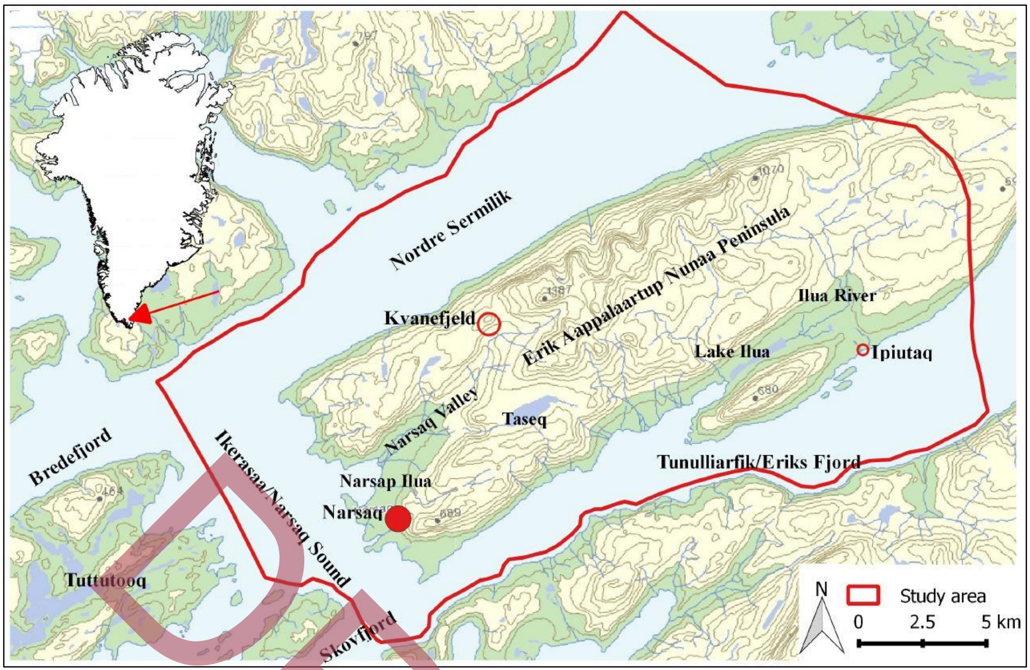

Figure 2-2: Study area

3. ADMINISTRATIVE AND LEGISLATIVE FRAMEWORK AFFECTING THE PROJECT

3.1. Introduction

Greenland is part of the Kingdom of Denmark. Autonomous local governance was introduced to Greenland in 1979 followed in 2009 by a new Act of Greenland Self Government, which among others states that Greenland can take over the administration of natural resources. In 2009, Naalakkersuisut (the Government of Greenland) took over the mineral resource administration from Denmark, including the administration of environmental issues in relation to mine projects.

Currently the Environmental Agency of the Mineral Resources Area - EAMRA (Miljøstyrelsen for Råstofområdet) is the administrative authority for environmental matters relating to mineral resources activities, including protection of the environment and nature, environmental liability and Environmental Impact Assessments (EIA).

The Mineral Licence and Safety Authority - MLSA (Råstofstyrelsen) is the administrative authority for licence issues and is the authority for safety matters including supervision and inspections.

3.2. Greenlandic legislation

Subsequent to the establishment of Greenlandic responsibility for regulation and management of the mineral sector, a new Act on Mineral Resources in Greenland (AMR), came into force on 1 January 2010 (Greenland Parliament Act no. 7 - 7 December 2009).

This act (with amendments in 2013 and 2014) is the backbone of the legislative regulation of the sector, regulating all matters concerning mineral resource activities, including environmental issues (such as pollution) and nature protection.

Since Uranium is one of the mine products, the following international guidelines and standards are also relevant in connection with this EIA:

International Atomic Energy Agency Safety Standard:

- Occupational radiation protection in the mining and processing of raw materials, IAEA Safety standards series No. RS-G-1.6, Vienna 2004. 95 p. (supersedes IAEA Safety Series No. 26);

- Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development, IAEA Nuclear Energy Series No. NF-T-1.1.; and

- Best practice in environmental management of uranium mining. International Atomic Energy Agency, 2009.

The OECD Nuclear Energy Agency (NEA):

- Managing Environmental and Health Impacts of Uranium Mining. OECD Nuclear Energy Agency (NEA), 2014.

3.3. The Mineral Resource Act

The Mineral Resources Act (the Act) with amendments is generally similar to the previous Mineral Resource Act of 1998. However, there are several new provisions including new chapters concerning the environment, nature and the climate. Further, the Act now specifically stipulates that an EIA must be prepared before permission to exploit minerals can be granted.

Among the key issues addressed by the provisions are the following:

- Planning and selection of all activities and construction in a manner to cause the least possible pollution, disturbance or other environmental impacts (§ 53);
- Use of best available techniques, including less polluting facilities, machinery, equipment, processes and technologies should be applied (§ 52);
- Avoid impairment or negative impacts on the climate (§ 56);
- Avoid impairment of nature and the habitats of species in designated national and international nature conservation areas and species (§ 60).

In order to conduct mining activities in Greenland, a licensee must first apply for and obtain an exploitation licence for the area. An exploitation licence is granted pursuant to § 29 in the Mineral Resources Act and requires submission to the authorities of the following documents:

- An application with key information on the proposed mining project;
- A Bankable Feasibility Study (BFS);
- An Environmental Impact Assessment (EIA) and
- A Social Impact Assessment (SIA).

If an exploitation licence is granted, the licensee needs to apply for and obtain an approval of the exploitation plan from the Greenlandic Government (§ 19) and specifically of the closure plan (§ 43). This approval will typically have to be updated several times during the course of the mine operation.

Provided that the § 19 and § 43 approvals are granted, all specific constructions, processes, vehicles, devices etc. must each have their individual approvals pursuant to § 86 in the Mineral Resources Act. Normally, the authorities will request a single application for all § 86 approvals in order to make a single § 86 approval that in one document specifically approves all these details. This single § 86 approval is to be renewed every year.

3.4. International obligations

Greenland has ratified a number of international conventions regarding nature and biodiversity, either as a direct member or through its membership of the commonwealth of Denmark and the Faeroe Islands. Of particular relevance to the Kvanefjeld project are the following:

The Convention on Biological Diversity (CBD) on the conservation of biological diversity, sustainable use of its components and fair and equitable sharing of benefits arising from genetic resources. The CBD guides national strategies and policies and implements themes such as sustainable use and precautionary principles. Its application to the Project will be through the implementation of national laws and regulations, in particular the Mineral Resource Act.

The Ramsar Convention on the protection of wetlands of international importance.

International Union for Conservation of Nature (IUCN) is an International organisation dedicated to natural resource conservation. IUCN publishes a "Red List" compiling information from a network of conservation organizations to rate which species are most endangered.

UNESCO’s World Heritage Convention is a global instrument for the protection of sites of cultural and natural heritage. In 2004, Ilulissat Icefjord was admitted onto UNESCO's World Heritage List.

3.5. Shipping regulations

Maritime regulations in Greenland are identical to the Danish regulations and supplemented with specific regulations for navigation in arctic regions. The majority of the regulations are technically oriented and not relevant for the EIA.

Regulations and codes administered by IMO (International Maritime Organization) as well as international conventions adopted by Denmark also apply to Greenland.

Several international rules and conventions are targeting environmental issues and a few shall be highlighted including the MARPOL convention and the annexes (1973/78 International Convention for the Prevention of Pollution From Ships); the BWM convention (2004 - International Convention for the Control and Management of Ships' Ballast Water and Sediments), and the OPRC convention (1990 - International Convention on Oil Pollution Preparedness, Response and Co-operation).

Due to the special navigational conditions in Greenland, a safety package containing special Greenland topics have been issued by the Danish Maritime Authorities (cf. http://www.dma.dk/Ships/Sider/Greenlandwaters.aspx). The safety package includes the following orders and recommendations relevant for the EIA:

- Danish Maritime Authority Order no. 417 of 28. May 2009: "Order on technical regulation on safety of navigation in Greenland territorial waters";
- IMO recommendation A.1024 (26) "Guidelines for ships operating in polar waters".

A special agreement has been entered between the MLSA and the Danish Maritime Authority regarding "Guideline on investigation of navigational safety issues in connection with mineral exploitation projects in Greenland as basis for navigation in the operational phase". The guideline is specifying the contents of a navigational safety investigation to be carried out prior to starting the exploitation activities. The study should be documented in a report submitted to the Greenland authorities (but is not a part of the EIA).

4. THE EIA PROCESS

4.1. The purpose of the Environmental Impact Assessment

The aim of the EIA (according to the Greenland guidelines) are:

- To estimate and describe the nature and the environment as well as the possible environmental impacts of the proposed project;
- To provide a basis for the consideration of the proposed project for Naalakkersuisut (the Government of Greenland);
- To provide a basis for public participation in the decision-making process; and
- To give the authorities all information necessary to determine the conditions of permission and approval of a proposed project.

4.2. The Greenlandic procedure for preparing an EIA for mineral exploitation

The Greenlandic guidelines for preparing an EIA report for mineral exploitation in Greenland outlines the workflow, requirements and quality criteria the EIA must meet.

<u>Workflow</u>

The first step in the process is the scoping where the environmental issues to be addressed in the EIA report are identified. After preliminary consultations with the Greenland authorities and their scientific advisors, the scoping report and Terms of Reference (ToR) are published for public pre-consultations. Following evaluation of the comments received the scoping and ToR for the EIA the documents are revised and forwarded for approval by the Mineral Resources Authority (MRA).

The next step in the process is 2-3 years of environmental baseline studies, project related studies and other studies necessary to compile the information needed for the EIA (see below).

A draft EIA report will then be prepared and forwarded to the MRA. Following feedback from MRA and its scientific advisors the EIA report is revised (if needed) and published for public consultations for 8 weeks. During this period public hearing meetings are held in relevant towns and settlements.

Following the public hearing a white paper is prepared with the comments and questions raised during the public consultations, and the answers by the mine company and its advisors.

The mine company eventually submits a final EIA draft report including the white paper to MRA for Naalakkersuisut's approval.

The content of the EIA report

The overall structure of the EIA report is pre-defined in the EIA guidelines which also describe the requirements in terms of topics to be addressed and standards to be meet. This includes specific Greenland water quality and air quality criteria for mining activities.

4.3. Environmental baseline sampling

MRA requires two to three years of environmental baseline studies to adequately characterise an area prior to project start. Between 2007 and 2014 Orbicon has carried out environmental baseline studies with the purpose to document the natural background levels in the study area. The sampling included lichens, seaweed, mussels, freshwater fish, marine fish, water and sediment from rivers, lakes and the fjord following a protocol developed by Danish Centre for Environment and Energy - DCE (formerly National Centre for Environment and Energy - NERI), Aarhus University. In addition to sampling in the Study areas, samples have also been collected from a reference area.

A climate station has also been operated on the plateau of the Kvanefjeld since 2010 and the flow in Narsaq River and several tributaries have been continuously measured since 2010.

Background dust concentrations in ambient air and deposition rate, in and around Narsaq, has been monitored and the elemental composition has been analyzed.

4.4. Environmental studies

To provide the information needed for the EIA assessment a number of laboratory tests and external assessments have also been prepared. The studies have been documented in a number of technical reports. This includes the following:

- Air Quality Assessment (Pacific Environment Limited, Australia)
- Greenhouse Gasses Assessment (Pacific Environment Limited, Australia)
- Noise Assessment (Orbicon)
- Radiological assessment (ARCADIS Canada)
- Uranium Product Transportation Assessment (ARCADIS Canada)
- Radiation Monitoring Plan Outline (ARCADIS Canada)
- Hydrology and Climate (Orbicon)

- The Natural Environment of the Study Area (Orbicon)
- Geochemical/Environmental testwork (SGS Lakefield Oretest)
- Water Quality Assessment of Tailings Water and Waste Rock Run off (Orbicon)
- Local Use Study (Orbicon)
- Archaeological surveys (Greenland National Museum & Archives)
- Oil and chemicals and assessment of potential impacts of spills (Orbicon)
- Kvanefjeld Marine Discharges and Fjord Dynamics - Modelling and Interpretation of Ecotoxicology Studies (DHI)
- Eco toxicological tests (DHI)
- Flotation Tailings and Chemical Residue Storage Facilities Feasibility Study Kvanefjeld Rare Earth and Uranium Project, Greenland (Amec Foster Wheeler Earth & Environmental (UK) Ltd.)

5. PROJECT DESCRIPTION

5.1. Introduction

This section summarises the proposed mine project. Full technical details of the project can be found in the feasibility study /GMEL 2015a/. The description follows the basic flow path of the ore from the mine, through the process as product or mine residue (tailings). The supporting infrastructure and labour requirements are also described. When completed the mine will be operated 24 hours per day and 365 days per year. The expected construction time is 2-3 years and the operational time is expected to be 37 years followed by a six years closure phase – see Table 5-1.

	Duration	Year	Period
Construction phase	2-3 years	-	2017 - 2020
Operation phase	37 years	0 - 37	2021 - 2058
Closure phase	6 years	38 - 43	2059 - 2065
Post-closure phase	-	44 -	2066 -

Table 5-1: Time line of Kvanefjeld Project

5.2. The Mining Process – an overview

The Kvanefjeld mine will be an open pit mine with standard drill / blast / truck / shovel mine operations. The mine will treat 3.0 million tonnes of ore per year to extract products of Rare Earth Elements, uranium, zinc and fluorspar. Roughly half of the material that is mined in the pit has a too low content of the minerals sought for to be used. This material – called waste rock – is transported by trucks to the waste rock deposited close to the pit.

From the pit the ore will be transported by mine trucks to the Concentrator plant (see Figure 5-1). Here the ore is first crushed and milled. The fine material is then mixed with water to achieve a slurry. From the slurry a zinc concentrate is removed. The next steps concentrates the rare earth and uranium minerals into 8% of the original mass. What is left – the tailings – is transported through a pipeline to the Taseq basin where it is deposited underwater.

The rare earth and uranium concentrate is pumped through a pipeline to the Refinery. Here the concentrate passes through a number of chemical processes to produce a uranium product (uranium oxide – yellow cake) and four rare earth products. The tailings from the Refinery is pumped to the Taseq basin where it is deposited in a separate tailings pond. The products are loaded into containers and transported by trucks to a new port at Narsap Ilua where they are shipped abroad. Reagents and supplies are delivered to a new port at the Tunu peninsula for intermediate storage. When required they are transported by truck to the processing plants. Power for the project is supplied by a combined heat and power plant situated next to the Concentrator.

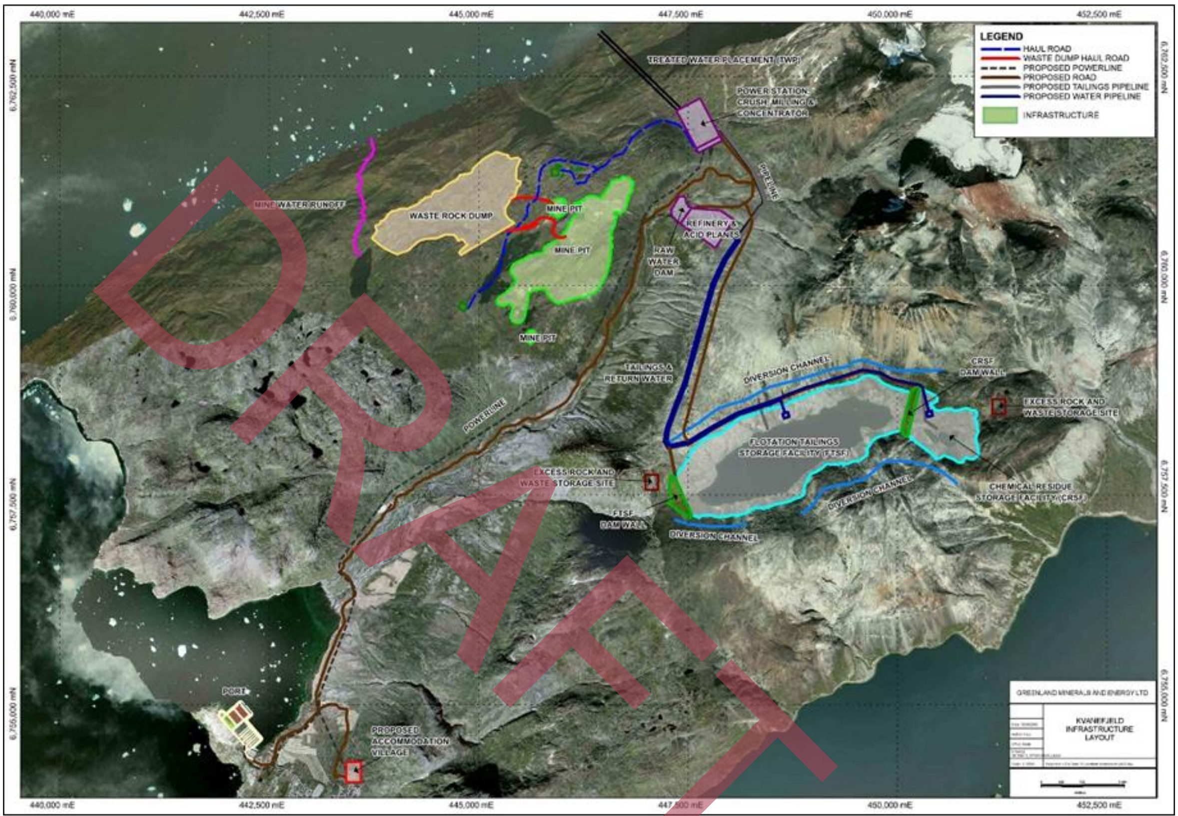

Figure 5-1: Overall Project layout

Tailings are deposited in two tailings ponds in the Taseq basin. The two tailings fractions are kept separate to make it possible to recover further rare earth metals from the tailings pending marked conditions and future technologies. The two tailings fractions are separated by an embankment. Both tailings ponds will have a water cover at all times. An embankment will also be constructed across the outlet of Taseq Lake. This is necessary to accommodate the amount of tailings produced during the 37 years mine life and still keep a 10 meter water cover. The two embankments will be built gradually higher during the production period. Both the tailings embankments will be sealed. Water from the tailings ponds is pumped back to the Refinery for reuse. When reuse is not possible anymore the water passes through a treatment plant next to the Concentrator before it is placed in Nordre Sermilik.

When the mine closes and the deposition of tailings ends a cleaning process of the water in the two tailings ponds commences. During an estimated six years period water will be pumped from the two tailings ponds to the treatment plant and is subsequently released into Nordre Sermilik. This will cause the water level in the ponds to drop significantly. When the cleaning has been completed, rain and snowfall will gradually fill the ponds again and they will eventually overflow into Taseq River – Narsaq River and the fjord.

5.3. The production size

The pit will be located at the Kvanefjeld plateau which is essentially a plateau, with the ore body outcropping at surface and the highest grade material occurring in the upper zones. This means that the waste material moved per tonne of ore (strip ratio) is extremely low. The expected strip ratio is only 1 tonne waste per 1 tonne ore over the first 30 years of operation. The waste rock is deposited on the Kvanefjeld plateau next to the pit (Figure 5-2).

With a crusher feed target of 3.0 Mtpa and an average waste to ore strip ration of 1:1, the average total material movement from the mine is c. 5.9 Mtpa. The total mine production over the first 30 years is 90.9 Mt at an average mine grade of 0.0362% Uranium oxide U_3O_8 and 1.29% Total Rare Earth Oxide (TREO).

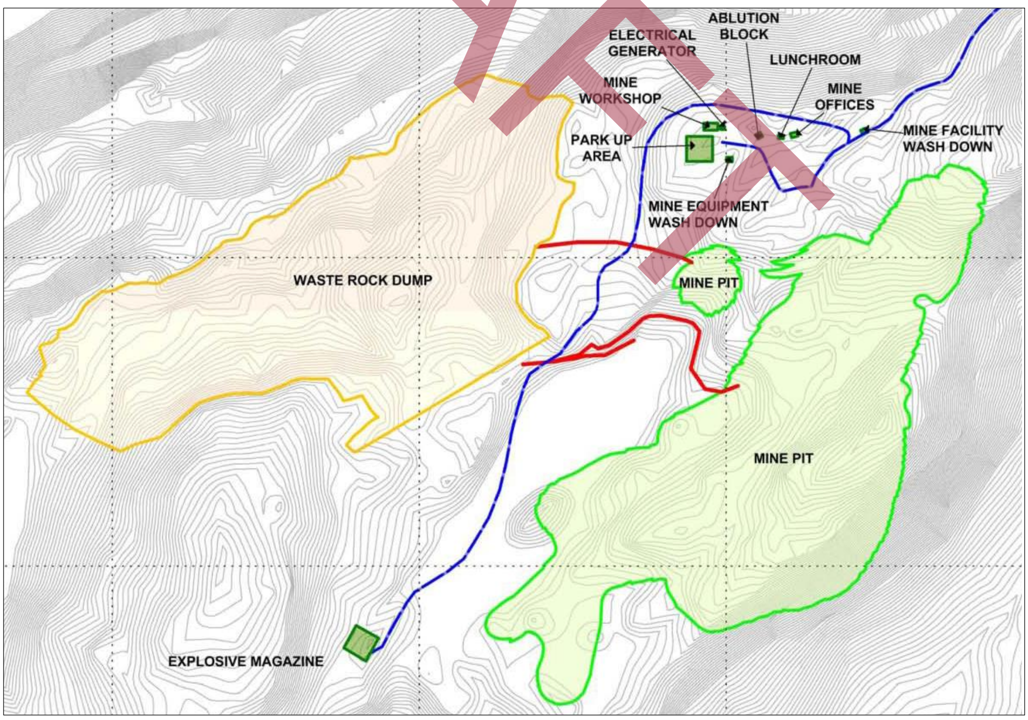

Figure 5-2: Mine pit, waste rock dump and mine site infrastructure. Red and blue lines are haul roads

5.4. Mine Site Infrastructure

Mining site infrastructure will be located apart from the infrastructure associated with the Project's processing facilities (Figure 5-2). As a result there will be modest duplication of Project infrastructure. There will be limited access to the mining area and mining facilities and all vehicles will have to be thoroughly washed down prior to leaving mining areas or facilities.

5.4.1 Mine workshop

A mine workshop will be built to cater for maintenance of the heavy mobile equipment including trucks, excavators and ancillary equipment. A smaller light vehicle facility will also be constructed to provide for maintenance of mine light vehicles. The workshops have been sized to ensure that the mobile fleet and drill rigs can be serviced in an appropriate environment.

5.4.2 Electricity Generation

There will be two diesel generators, each rated to 500 KW, located in a dedicated building to provide power for mine workshops (lighting, heating, welding, compressors and other equipment), mine offices, ablutions, pumps and mine site lighting. These generators will be independent from the power supply to other project facilities.

5.4.3 Wash Down Facilities

In order to remove any dust from vehicles departing the mine area a wash-down facility will be built to be used by all vehicles leaving the mine area. The facility will operate automatically and operators will not be required to leave the cabins of their vehicles during wash down.

5.4.4 Waste Water Disposal

Tanker trucks will be used to transport waste water and sewage from the holding tanks in the mine areas for treatment and disposal at the concentrator facility.

5.4.5 Mine Offices, Messing and Ablutions

Mine technical and management staff will be housed in offices in the mining facility area. It is estimated that approximately 50 people will be working in the mine on day shift. Assuming that breaks for the different mine crews will be staggered, lunch room facilities will accommodate 30 persons at any one time. Sufficient toilets, showers and change rooms are installed for 50 personnel of whom approximately 35 will be labourers.

5.4.6 Explosives Magazine

The explosives magazine will be located at the south end of the pit, away from the infrastructure and will be accessed by a gravel road. The explosives and detonators will be stored separately in an approved explosive magazine building.

5.4.7 Haul roads

From the pit the ore is transported by mining trucks along a 1.5 km haul road to the Concentrator. Other haul roads will be constructed between the pit and the waste rock deposit. A third road will be between the pit area and the explosive magazine. The haul roads between the pit and the Concentrator and Waste rock area will be 25 m wide while the road to the magazine will be 6 m wide.

5.5. The Processing Plant

There are two processing plant sites located at the upper end of the Narsaq Valley (Figure 5-1, Figure 5-3). They will also operate for 365 days per year and 24 hours per day. The purpose of the processing plants are to extract the rare earth, uranium and zinc pro-ducts from the ore. The two different processing plants are as follows:

1. <u>Concentrator</u> – Uses physical methods to separate the minerals from the surrounding rock;

2. <u>Refinery</u> – Uses chemical methods to separate the rare earths and uranium from contaminants.

5.6. The Concentrator

At the Concentrator the ore is first crushed and ground to a much smaller particle size and mixed with water to achieve a slurry. Zinc minerals are first removed from this slurry using a froth flotation circuit to produce a high grade zinc sulphide concentrate for sale.

The next flotation stage concentrates the rare earth and uranium minerals into 8% of the original ore mass and produces a mineral concentrate. This produces c. 250,000 tonnes of rare earth/uranium concentrate per year, which is sent via a pipeline to the Refinery ~ 1 km away, for further processing. The remaining material – tailings – is deposited in the Taseq basin.

5.7. Water treatment facility

The excess water from the concentrator will contain high levels of soluble fluoride. A water treatment facility next to the concentrator will precipitate the fluoride utilising calcium chloride to form saleable calcium fluoride (fluorspar). After precipitation the fluoride level in the excess water will be reduced to approximately 100 ppm and placed in Nordre Sermilik.

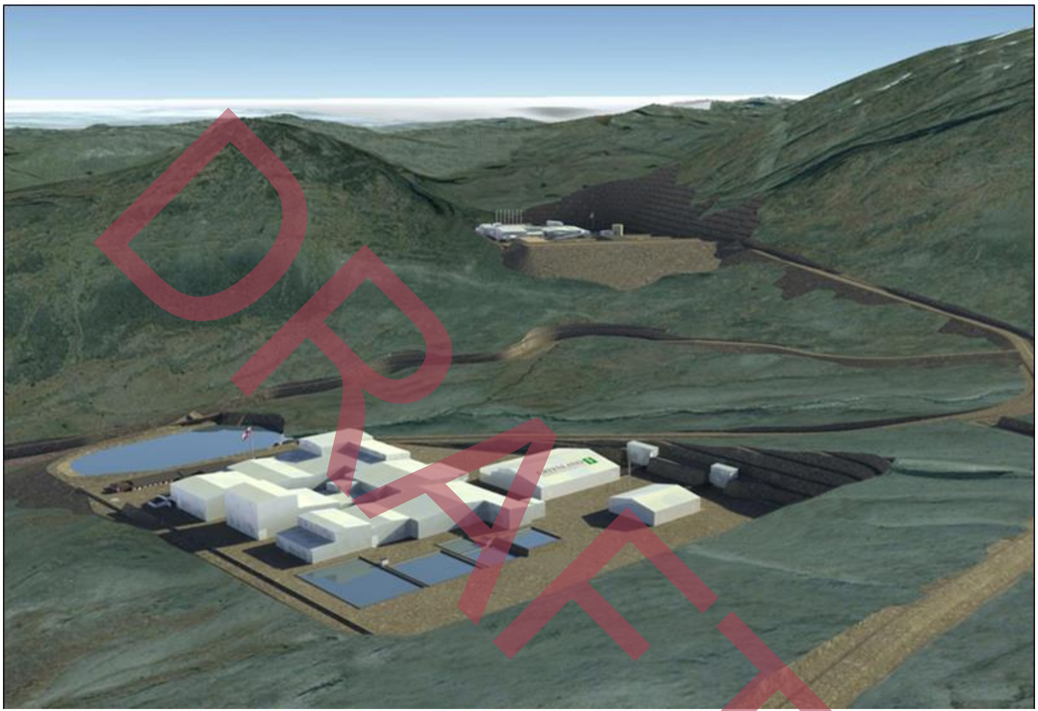

Figure 5-3: 3D Drawing of the Refinery (Foreground) and Concentrator

5.8. The Refinery

At the Refinery the concentrate is leached at atmospheric conditions in a counter current sulphuric acid leaching circuit. The solution produced is subsequently sent to the uranium circuit for recovery. After conditioning with caustic, the leach solids are re-leached in hydrochloric acid at cool atmospheric conditions to produce rare earth chloride solution. At this stage, four rare earth products are produced from the rare earth chloride solution with solvent extraction:

- Lanthanum (La) Oxide 99% grade = 4,500 tonnes per year
- Cerium (Ce) Hydroxide 99% grade = 7,600 tonnes per year
- Mixed Lanthanum and Cerium Oxide = 3,700 tonnes per year
- Mixed Critical Rare Earth Oxide (Pr to Lu) = 7,900 tonnes per year

All products are transported to Europe for sale, apart from the Mixed Critical Rare Earth Oxide, which is transported to a separation plant for toll separation for separation into 14 different rare earth oxides.

A uranium by-product is produced from the solution produced from the sulphuric atmospheric leaching. Another solvent extraction process is used to recover the uranium selectively from the sulphate solution. Two stages of precipitation are then performed on the uranium solution to further purify the uranium. The final product is uranium oxide U_3O_8 (yellow cake) which is directly saleable to power utilities.

Due to the large quantity of hydrochloric acid consumed by the refinery, a chlor-alkali plant has been incorporated to produce acid. This has the added benefit of producing a caustic soda by-product, another major refinery plant reagent.

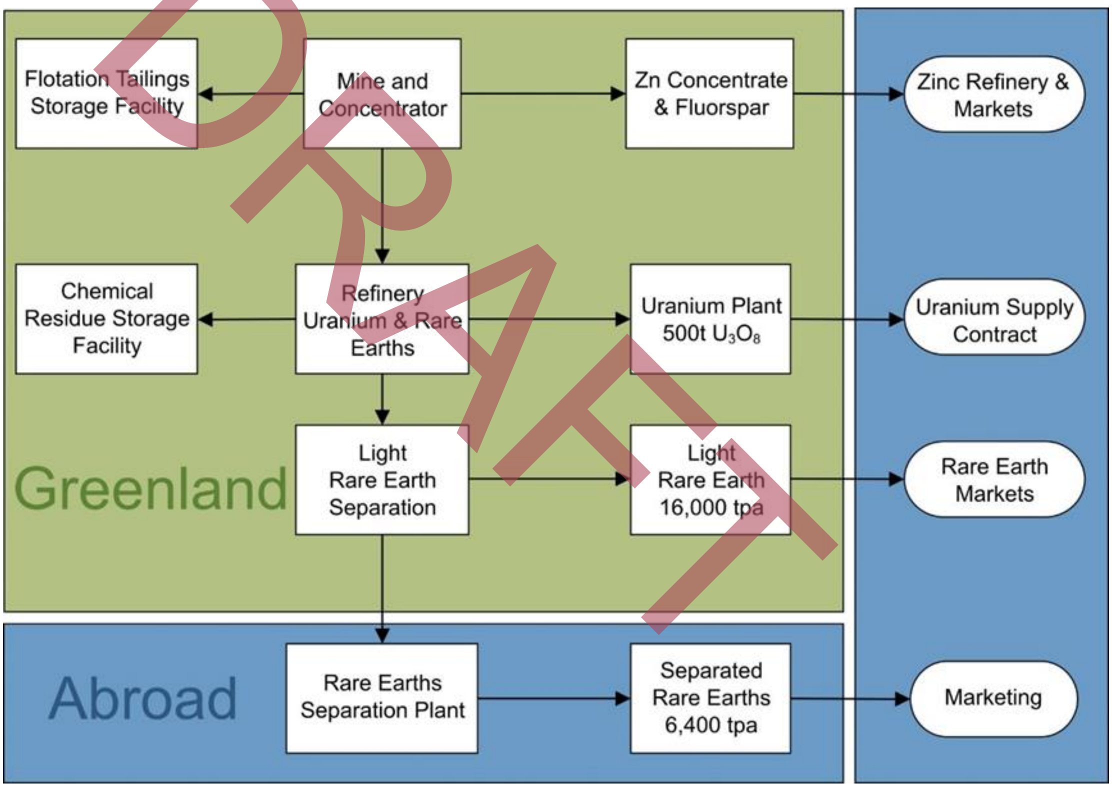

Figure 5-4: Diagram Showing Main Process Plant Steps

Sulphuric acid is also produced on site by treating elemental sulphur, which is imported to site. The production of concentrated sulphuric acid also produces excess energy, which is captured to produce electricity and building heating.

A variety of reagents are used at the Refinery be used to facilitate the process. Table 5-2: Reagents expected to be used in the production summarises their use and consumption.

Reagent Function	Used for	Purpose	Annual consumption Tons
Zetag 8140 * Concentrator Flocculent.	Zinc flotation	Thickener flocculent for zinc sulphide concentrate - to promote particle sedimentation to enable recovery of zinc product from process	1.2 - 3.0
SNF FO4800H Concentrator Flocculent.	Rare Earth Phosphate (REP) flotation	Thickener flocculent for REP concentrate - to promote particle sedimentation to enable recovery of REP concentrate from process	150-400
Magnafloc 155 Refinery Flocculent (Anonic).	Refinery impurity removal.	Thickener flocculent for anionic impurities - to promote particle sedimentation to enable removal of impurities in the refinery circuit	75 - 180
Magnfloc 430 * Refinery Flocculent (Cationic).	Refinery impurity removal and product recovery	Thickener flocculent for cationic impurities and cationic products - to promote particle sedimentation to enable removal of impurities, and recovery of products in the refinery circuit	20 - 60
RM1250 * Refinery Coagulant.	Silica agglomeration	Thickener agglomerate for silica impurities - to promote agglomeration of fine silica particles to enable their removal from uranium product liquor.	60 - 160
Sodum iso-butyl xanthate (SIBX) Flotation Collector.	Zinc flotation	To float the zinc sulphides, thereby separating these from the ore.	125 - 320
Copper sulphate (CuSO4.5H2O) Flotation Activator.	Zinc flotation	To activate the surface of the zinc sulphide particles thereby improving the efficiency of their flotation.	25 -60
Aero 6494 Flotation Collector.	REP flotation	To float the rare earth-bearing minerals, thereby separating these from the non-value mineral tailings.	1 000 – 2 700
Sodium Silicate Flotation Depressant.	Zinc and REP flotation	Depressant - prevents the flotation of the non-value mineral tailings	2,300 – 5,800
Polyfroth W22C Flotation Frothier	Zinc and REP flotation	To reduce the bubble size and increase froth stability in the flotation process	110 - 280
Sodium Carbonate	Rare Earth product precipitation	To precipitate rare earth intermediate products from process liquors in the refinery circuit	12,000 – 30,000
Sulphur	Sulphuric acid (H_2SO_4) production	To produce sulphuric acid in the Sulphuric Acid Plant, used to leach rare earths and uranium from the REP concentrate in the refinery circuit	16,000 – 41,000

Sodium Chloride	Hydrochloric acid (HCl) and caustic soda (NaOH) production	To produce hydrochloric acid and caustic soda in the Chloralkali Plant, used to respectively to leach rare earths and to raise pH of process liquors (for product precipitation and impurity removal) in the refinery circuit	35,000 – 87,000
Limestone	Impurity removal	To raise pH of process liquors in the refinery circuit	30,000 – 77,000
Caustic Flake (NaOH)	Product precipitation and Impurity removal	To precipitate cerium product, and to raise pH of process liquors in the refinery circuit	1,400 – 5,000
Calcium Chloride	Water Treatment	To precipitate fluoride from the Treated Water Placement stream entering Nordre Sermilik.	6,900 – 17,500
Pyrolusite	Rare Earth leaching	To oxidise rare earth species during acid leaching process to improve rare earth recovery.	300 - 750
Haematite	Rare Earth leaching	To precipitate phosphate species during acid leaching process to improve rare earth recovery	0 – 15,000
Hydrogen Peroxide	Product precipitation and Impurity removal	To precipitate uranium product, and to precipitate impurities from refinery process liquors	125 - 300
Lime	Impurity removal	To raise pH of process liquors in the refinery circuit	3,800 – 9,500
Barium Chloride	Impurity removal	To precipitate impurities from refinery process liquors	1,800 – 4,500
Sodium Hydrosulphide	Impurity removal	To precipitate impurities from refinery process liquors	60 - 200
Alamine 336 * Solvent Extraction Extractant	Uranium solvent extraction	To extract uranium species from process liquors in the refinery circuit, thereby removing these from impurities and enabling production of pure uranium product	2.5 - 10
Isodecanol * Solvent Extraction Phase Modifier	Uranium solvent extraction	To improve the solubility of the extractant in the organic diluent, thereby ensuring effective removal of uranium from the liquor phase	1.0 – 5.0
PC-88A or Ionquest 801 * Solvent Extraction Extractant	Rare earth solvent extraction	To extract rare earth species from process liquors in the refinery circuit, thereby removing these from impurities and enabling production of pure rare earth products	70 - 175

Shellsol D70 * Solvent Extraction Diluent	Rare earth solvent extraction	To provide the organic phase needed to carry the extractant, thereby ensuring effective removal of rare earths from the liquor phase	160 - 500
Uranium IX Resin CleanTeQ R603B	Impurity removal	To remove uranium impurities from the rare earth process liquor stream in the refinery circuit	0.1 – 1.0
Accepta 2827/2302 Cooling Water Biocide	Cooling water treatment	To prevent the growth and build-up of microbiological organisms in the cooling water system, thereby ensuring optimum performance of process plant cooling systems	140 - 500
Accepta 2319 Cooling Water Inhibitor	Cooling water treatment	To prevent the formation of rust in equipment associated with the cooling water system, thereby ensuring optimum performance of process plant cooling systems	5 -30

Table 5-2: Reagents expected to be used in the production

5.9. The Power plant

A 59 MW HFO-fired Combined Heat and Power station will be built adjacent to the Concentrator. This power plant will service the processing facilities, the port and the accommodation village. The power station will have a waste heat recovery system which will generate hot water that will be used for process heating in the concentrator, as well as heating of buildings at the concentrator and refinery sites.

Fuel for the power plant will be stored at the port and transported to the power station site in road tankers as required. The tankers will discharge the fuel into day tanks adjacent to the power station.

5.10. Water balance

Water for the Concentrator and Refinery operations is provided by the following sources:

- Narsaq River
- Recycled water from the two tailings facilities

Around 400 m^3/h of freshwater will be sourced from Narsaq River. An embankment will be constructed across the river near the Refinery to create a pond. This pond (the Raw Water Dam) will be sized to contain 4 weeks of water supply for the production. If the water flow in Narsaq River during winter is found to be too low to meet the production demand a water treatment facility is included in the design to recycle process water.

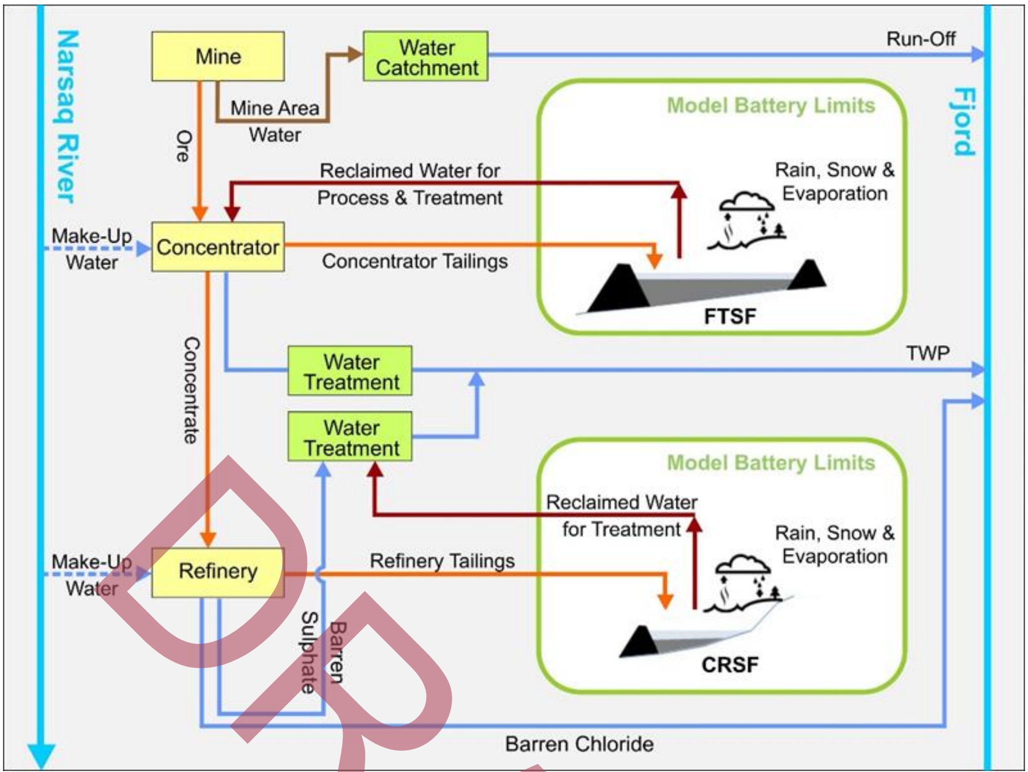

Figure 5-5: The water balance of the two tailings facilities (FTSF and CRSF)

Water is recycled within both the Concentrator and Refinery to minimize water consumption. This includes recovering decant water from each of the tailings facilities and re-using it in the process plants (Figure 5-5). However, a minimum water layer of 6 m is provided in the tailings ponds to ensure subaqueous disposal and this is managed by the amount of decant water which is recycled back to the processing plants. The decant water is pumped from the tailings facilities to the Concentrator and Refinery in pipelines adjacent to the pipes that transport the tailings slurry to the tailings facilities.

Excess water produced from the processing plants is first treated and then placed into Nordre Sermilik as Treated Water Placement (TWP).

During mine production the water level of Kvane Lake next to the pit will be lowered to avoid water from seeping into the pit. The rainwater and snow that ends up in the pit (pit water) is pumped through a pipe to a small lake west of the pit together with water from Kvane Lake (Figure 5-6). Water that drains from the waste rock piles also runs into this lake. The natural outlet of this lake is into Nordre Sermilik (mine water runoff). The Kvane river flows will also be reduced removing a Narsaq river tributary which normally contains water naturally elevated in fluoride and uranium. This means that during production all water in streams, ponds and lakes on the Kvanefjeld plateau will be diverted and diluted before placement into Nordre Sermilik. The hydrology is specifically designed to prevent release of mine water into Narsaq Valley and Narsaq River.

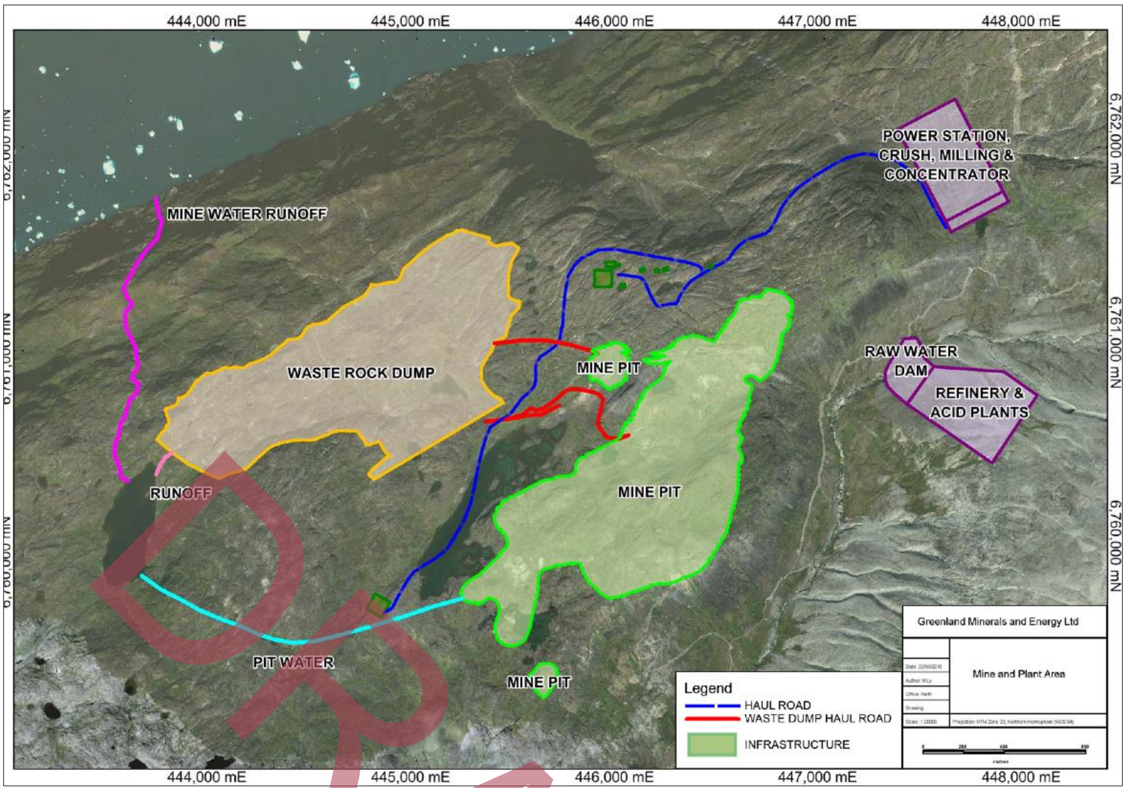

Figure 5-6: Pit water runoff from the waste rock dump and excess water in Kvane Lake between the dump and the pit is directed into a small lake which has a natural outlet in the fjord (mine water runoff)

5.11. Tailings Storage Facilities

Tailings from the Concentrator and the Refinery will be stored in two separate storage areas at the Taseq basin named the Flotation Tailings Storage Facility (FTSF) and the Chemical Residue Storage Facility (CRSF) - Figure 5-7. The tailings will be covered by several meters of water at all times. The key advantages of subaqueous tailings storage include prevention of radon gas release and eliminating of dust generation.

In the operations phase two slurry streams of tailings are generated from the Concentrator and from the Refinery, respectively:

1. The main part of the tailings (~90%) are remains from the physical extraction of zinc, uranium and REEs through a flotation process at the Concentrator. The tailings named ‘flotation tailings’ are pumped in a pipeline to the western part of the FTSF.

2. The second tailing stream (~10%) is the remains from the extraction and refining of REEs and uranium at the Refinery. These tailings are pumped in a separate pipeline to the CRSF.

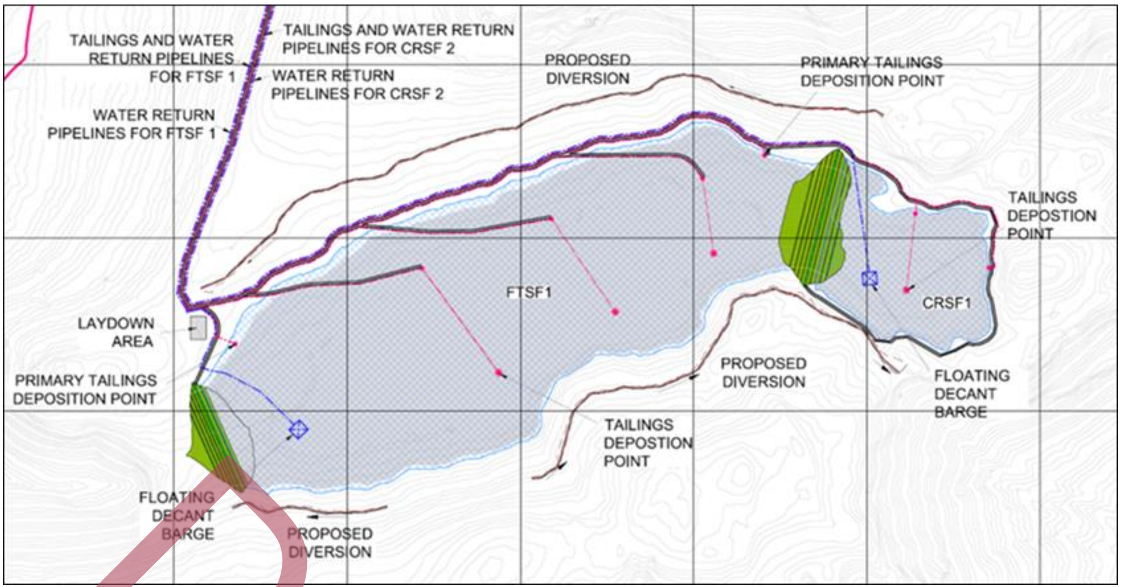

Figure 5-7: FTSF and CRSF in Year 30.

An impervious embankment is constructed to prevent any seepage to Taseq River and to increase the storage capacity in the FTSF. Likewise an embankment is constructed between the CRSF and the FTSF. The embankments will be sequentially constructed during the Operations Phase and the tailings volume and pond area will gradually increase in the Operations Phase. Typical cross section through the CRSF and the FTSF embankment are depicted in Figure 5-8. The embankment height will eventually reach 45 and 46 m respectively above the original ground level.

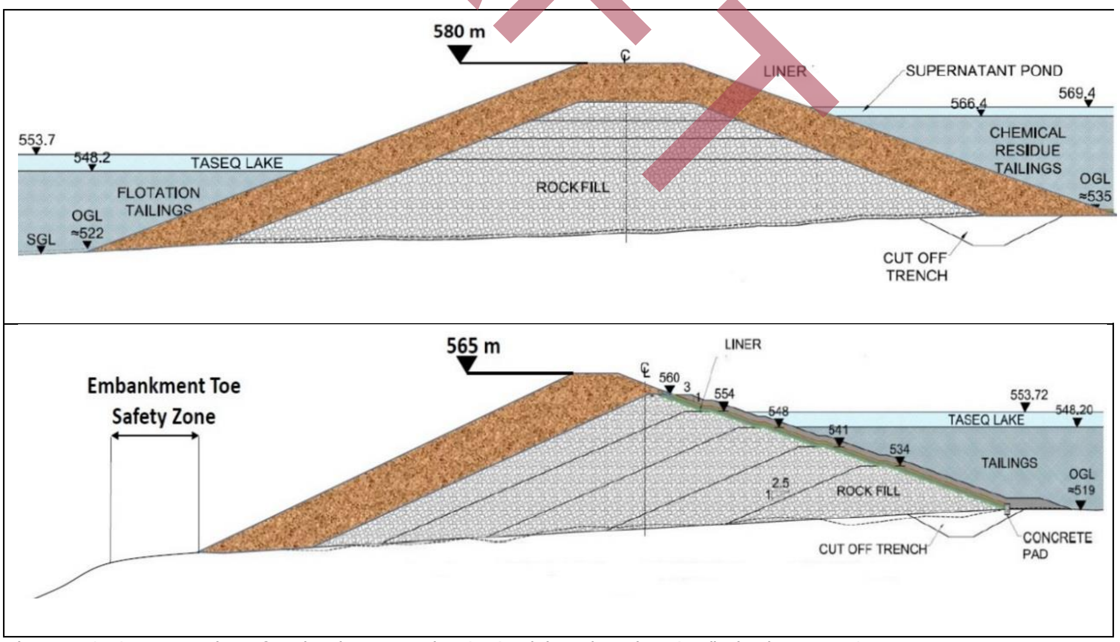

Figure 5-8: Cross-section of embankment at the CRSF (above) and FTSF (below) at year 37

In order to prevent excess water pressure, diversion channels will be constructed. The channels will have dimensions of around 4 m of bottom width and at least 2 m of depth and are planned to partly divert melt water and precipitation run off away from the ponds (see Figure 5-7).

The tailings ponds will be used across the following three phases:

1. The Operations Phase – where the mine and processing facilities are in operation, producing zinc, Rare Earth Elements (REE) and uranium products, and discharging tailings to the two tailings facilities;

2. The Closure Phase – following the termination of the mine operation, where the supernatant (liquor) from the two tailings facilities are returned to the processing facilities for treatment prior to placement in Nordre Sermilik; and

3. The Post-Closure Phase – following the closure of the processing facilities, the rehabilitation of the mine and processing facility sites, and the full demobilization of the project workforce, during which time run-off and precipitation accumulate in the FTSF and CRSF resulting in the eventual overflow of the contents of the two tailings facilities into the Taseq River and subsequently into the Narsaq River.

The progressive water flows and water quality the three phases are illustrated in Figure 5-9 to Figure 5-11.

Operations Phase

In the operations phase tailings slurry is discharged subsurface into the tailings pond. The main input to the amount of elements and reagent in the supernatant is from displaced pore water from compaction of the slurry (from 60%w/w to 70%w/w for the FTSF and 40%w/w and 50%w/w for the CRSF). The water (supernatant) in the tailings ponds is decanted and re-circulated to the process plant. In this way no discharge of supernatants will take place to the Taseq River downstream of the embankments in the operations phase.

Excess water will be cooled and treated prior to Treated Water Placement (TWP) to Nordre Sermilik.

The tailings layer will increase throughout the operations phase. At the end of the period (year 37) the maximum of tailings thickness will be 68 m in the FTSF and 40 m in the CRSF inclusive of compaction. The main FTSF embankment has been increased five times having a total height of 46 m from the initial situation.

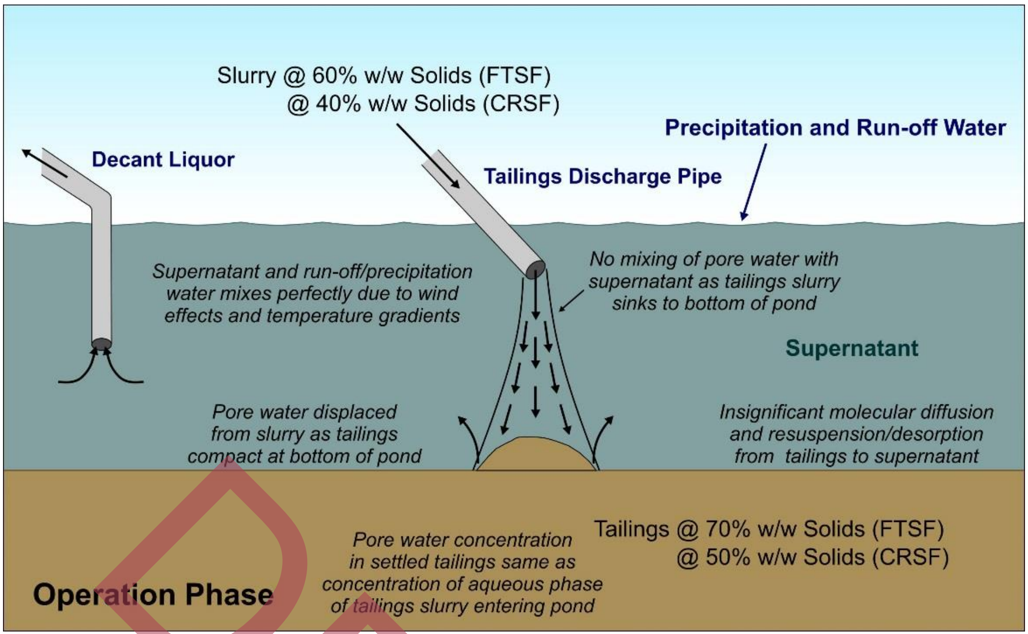

Figure 5-9: Operations Phase

Closure Phase

After mine closure the water in the tailings ponds will be treated to produce water suitable for release. At the beginning of the Closure Phase a graded barren rock layer (varying in size from 25 mm at the base of the layer to 0.5 m at the top) is evenly distributed in thickness of 1 – 1½ m on the top of the tailings deposits. This will prevent re-suspension of tailings into the supernatants during windy conditions.

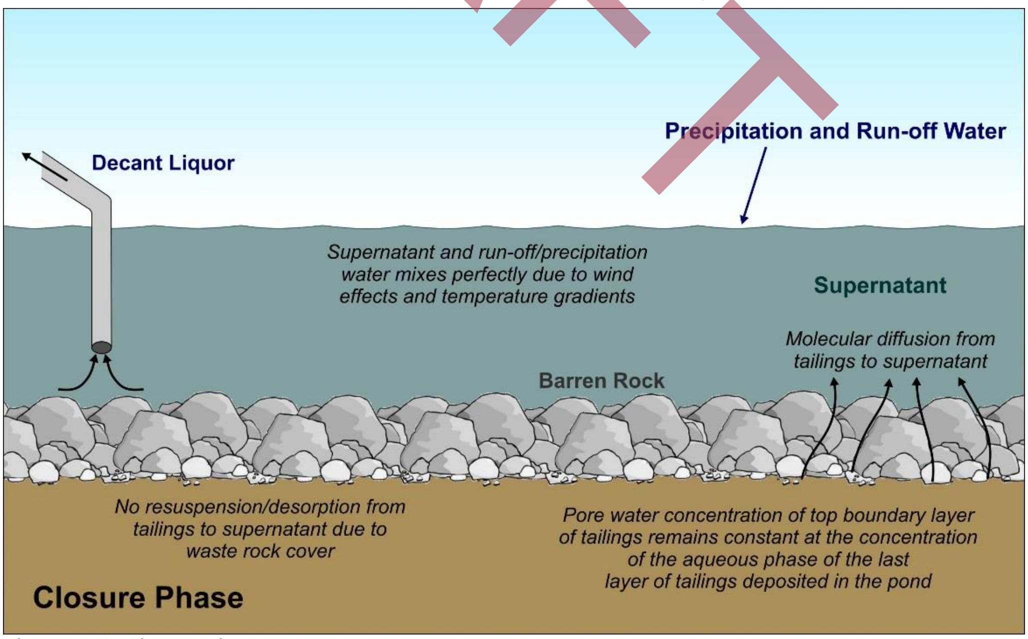

Figure 5-10: Closure Phase

The supernatant continues to be decanted to the water treatment facility and fluorspar produced as by-product. The treated water is discharged to Nordre Sermilik after treatment. The liquor volume in the ponds is replenished with precipitation and run-off from the catchment area and the water quality is gradually improved via dilution. However, the water levels are gradually decreasing as the decant rate exceeds the run-off and precipitation contribution.

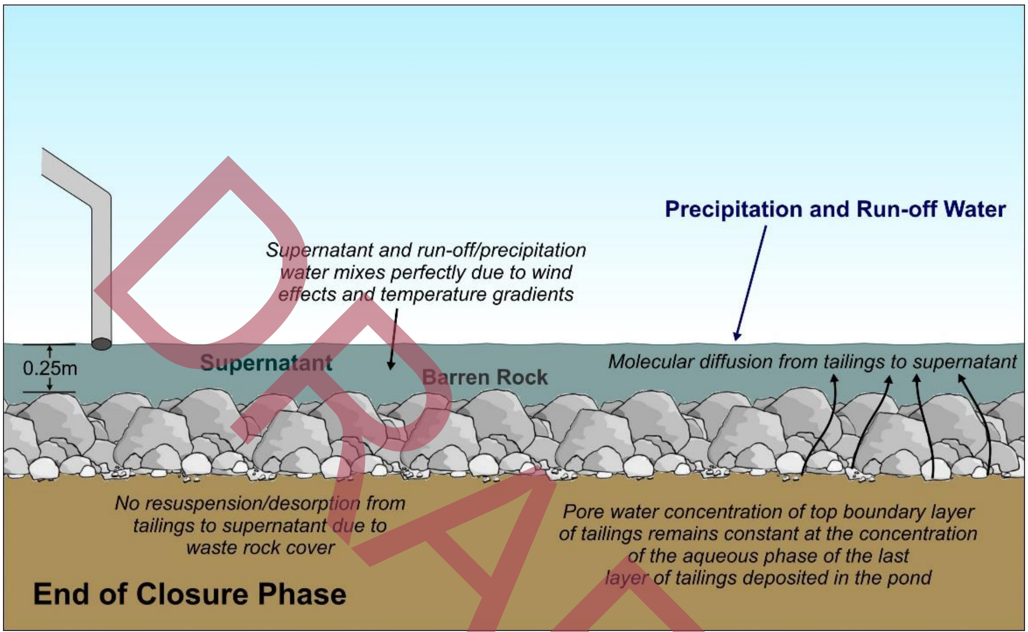

Figure 5-11: End of the Closure Phase

At the end of the closure phase the supernatant depths are lowered to around 0.25 m above the top of the barren rock layer and the water quality has reached levels that possess no harm to the environment. The decanting of the supernatant to the water treatment facilities is therefore terminated. This is the start of the post-closure phase.

Post-closure Phase

The water level will increase gradually over the first year(s) in the post closure phase and eventually reach the crest level of the embankment and start to overflow downstream into the Taseq river/Narsaq river system. The function of the diversion channels will gradually cease out due to natural erosion and in-fill of soil and gravel.
The water depth above the barren rock will be 10 m in the FTSF and 8 m in the CRSF year around and only small fluctuations will be observed due to variation in precipitation / evaporation over the year. The hydrology in the Taseq Valley will in broad terms revert to the existing conditions before the mining operation.

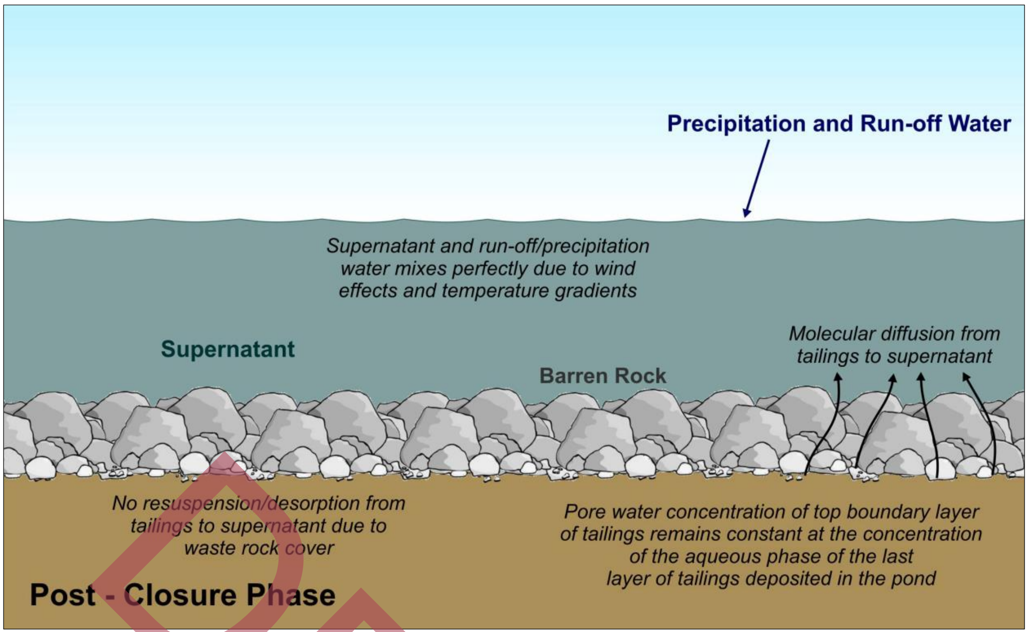

Figure 5-12: Post-closure Phase

5.12. The Harbour Facilities

A new port will be built to service the project and to facilitate imports of reagents, fuel, consumables etc. and the export of saleable products. The port will be located on the eastern shore of the Tunu Peninsula, which is on the southern side of the Narsap Ilua (Figure 5-13). The port allows for the berthing of fully geared ships up to Handy-Max size (max. 65,000 DWT) carrying either bulk or containers. The port utilisation is expected to be 20% of the year with ships docked for up to 5 days at a time (approximately 15 ships a year).

Figure 5-13: The location of the new harbor

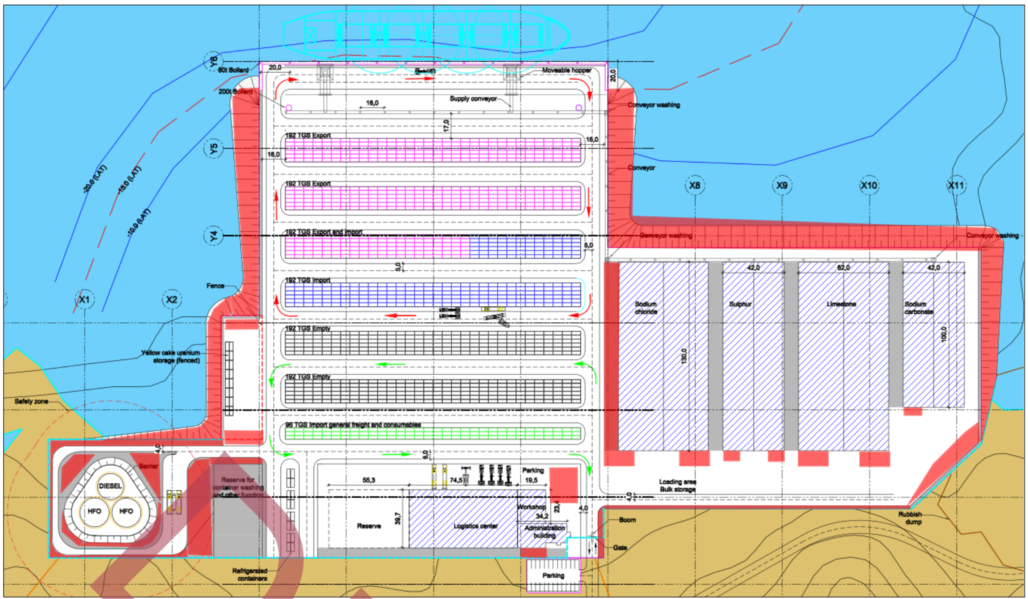

Figure 5-14: Plan view of the new port

The port is designed with a 240m quay frontage with conveyors for bulk cargo, and mobile stackers for containers. Adjacent to the quay, an area will be prepared for container stacking and covered bulk storage for both imports and exports. The anticipated annual flow of cargo imported to the port and the port site storage requirements are summarised in Table 5-3.

Location	**Import**	**Rate**	**Import storage (2-3 months supply)**
Mine	Diesel	6 300 m^3/a	2 065 m^3 - tankage
Power Plant	Heavy Fuel Oil	50 000 m^3/a	11 574 m^3 - tankage
All	General freight	42 000 t/a	17 500t - containers
Concentrator	Calcium chloride	13 850 t/a	9 233t – bulk
Concentrator/Refinary	Spares	4 750 t/a	3 167t - containers
Concentrator/Refinary	Miscellaneous liquid reagents	2 350 t/a	1 567t – ISO tanks
Concentrator/Refinary	Miscellaneous liquid reagents	4 825 t/a	3 217t - containers
Concentrator/Refinary	Miscellaneous solid reagents	13 750 t/a	9 167t – containers
Refinary	Sodium chloride	69 600 t/a	29 000t – bulk
Refinery	Limestone	61 000 t/a	25 417t - bulk
Refinery	Sulphur	32 400 t/a	13 500t – bulk
Refinery	Sodium carbonate	23 900 t/a	9 958t - bulk

Table 5-3: Anticipated annual cargo imported to the new port (per year) and the storage requirements

The anticipated annual flow of cargo exported from the new port is summarised in Table 5-4.

Location	Export	Rate	Export storage (2-3 months production)
Concentrator	Zinc concentrate	14 500 t/a	8 458 t – containers
Concentrator	Flourspar	16 200 t/a	9 450 t – containers
Refinery	Sodium hypochlorite	17 000 t/a	9 917 t – ISO tanks
Refinery	Mixed Critical Rare Earth Oxide	7 850 t/a	4 579 t – containers
Refinery	Cerium Hydroxide	6 950 t/a	2 896 t – containers
Refinery	Lanthanum Oxide	4 300 t/a	1 792 t – containers
Refinery	Lanthanum/Cerium oxide	3 900 t/a	1 625 t – containers
Refinery	Yellow Cake (Uranium oxide)	557 t/a	418 t - containers

Table 5-4: Anticipated annual cargo exported from the new port with the port site storage requirements

5.13. The Accommodation

It is anticipated that ~ 800 personnel will be required for the Project operation and approximately 325 of these personnel will be recruited locally from within the southern Greenland area (Table 5-5). The remaining personnel will be accommodated on a temporary fly-in/ fly-out (FIFO) basis in a custom built village to be located on the outskirts of Narsaq. FIFO staff are based in Europe (and North America) and fly to the Kvanefjeld work site where they work for a number of days and are then flown back to their home country for a number of days of rest.

	Pioneer phase	Construction phase	Operations phase
Greenlandic Workers	50	200	325
FIFO Foreign Workers	369	896	400
FIFO Management & Technical	53	75	62
Total	**472**	**1171**	**787**

Table 5-5: Labour Requirements for Various Stages of the Project

The accommodation village will be provided with an access road off a new road connecting the mine and plant to the harbour. The village will be supplied with power (from the process plant power station), water and sewerage treatment. A large centre is envisaged with recreation facilities, meeting rooms, canteen, laundry, and internet connection.

5.14. Transport Facilities

5.14.1 Airports

The FIFO workforce is expected to utilise the Narsarsuaq airport as the Greenland entry point. The existing heliport at Narsaq may require an extension to existing passenger facilities, but the airport at Narsarsuaq is considered adequate to handle additional passenger loads resulting from the Kvanefjeld construction and operation. Additional commercial and chartered flights between Narsarsuaq and Nuuk, Reykjavik and Copenhagen, and the UK may be necessary for the increased volume of passengers.

5.14.2 Roads

In addition to the haul roads in the pit area, a new dual-lane unsealed road (8 m wide) will be built to connect the new port to the concentrator and refinery sites. The distance from the port to the concentrator is approximately 10 km. This road will run adjacent to the Narsaq River and requires two river crossings, one of which will comprise the Raw Water dam wall. The road will be used for all material movements to and from site, and will be used for transporting personnel between Narsaq and the mine, concentrator and refinery using a dedicated bus service.

A new dual-lane sealed road (8 m wide) will also be built from the port to the accommodation village.

A new track will be built to connect the concentrator, refinery, and tailings ponds in the Taseq basin. The track will be single lane (4 m wide) and accessed using 4WD vehicles only. This maintenance track will follow the two tailings pipelines as well as the concentrate and filtrate return pipelines and allow maintenance personnel to access the entire length of the pipelines. The length of the maintenance track is approximately 9 km, and will require two river crossings.

Specialised fuel trucks will transport heavy fuel oil (HFO) from the port to the power plant at the concentrator site. Personnel will generally commute by bus between the accommodation village and the work sites at the mine, concentrator and refinery.

5.14.3 Pipelines

The concentrates as a slurry via HDPE (High Density Poly-Ethylene) pipelines. Also the recycled water from the tailings facilities will be returned to the concentrator and refinery via HDPE pipelines. All pipelines will be run above ground in a piping corridor, will be mounted on supports and will be insulated to prevent the slurry/water from freezing.

5.14.4 Power lines

Power supply for the project will be generated by a power station located on the concentrator plant site. In order to supply power to the refinery, port and accommodation village, two 11 kV transmission lines will be run on above ground cable ladders to the refinery plant site. From there an 11 kV overhead transmission line will be built down to the outskirts of Narsaq. The transmission lines will follow the road from the concentrator to the refinery and down to the port and the accommodation village. The lines will cover a distance of ~ 11 km.

5.15. Waste management

5.15.1 Solid waste

All solid waste will be pressed into bales and shipped to Qaqortoq for incineration. Accumulators, batteries, electronic devices, glass, etc. will be stored temporary in containers and periodically handed over to the Qaqortoq waste handling facility for further disposal according to regulations and after mutual agreement.

Hazardous waste is handed according to the Kommuneqarfik Kujalleq regulation concerning hazardous waste (Regulations for disposal of hazardous waste /Regulativ for bortskaffelse af miljøfarligt affald, 2009). In general hazardous waste is shipped to Denmark and handled in compliance with a comprehensive EU initiated legal framework. Hazardous waste shall be registered and traced using code standards (EC waste list / EAK koder (Europæiske Affalds Koder)).

5.15.2 Wastewater

A sewage system to collect sewage from all buildings in the harbor, the accommodation village and visiting ships will be installed. Sewage will be treated in a treatment plant, containing mechanical, biological and chemical treatment, prior to being discharged to the fjord at the north end of the Tunu Peninsula.

Tanker trucks will be used to transport waste water and sewage from the holding tanks in the mine areas for treatment and disposal at the concentrator facility.

5.16. Alternatives considered

During the design phase of the project a number of alternatives have been considered. This includes a large number of metallurgical processes which were eliminated for technical, practical, or economic reasons. Several alternative project configurations were also examined.

These alternative project configurations and one project enhancement were examined in more detail:

- The “Concentrates-Only” option;
- The Mechanical (Concentrator) and Chemical processing (Refinery) option;
- The “Greenland separation plant” option; and
- The hydropower option.

In addition, several geographical alternatives for the location of the port, mine village and processing plants were considered.

5.16.1 Processing alternatives

Three processing alternatives were considered:

Scenario 1	**“Concentrates-Only” (mechanical processing)** The ore is crushed and ground and mechanically separated into two concentrates. One concentrate includes a mixture of REE and uranium, the other is a zinc concentrate.
Scenario 2	**Mechanical (Concentrator) and Chemical processing (Refinery):** REE and uranium are chemically separated and become two products. The uranium is further chemically processed into Uranium oxide (yellow cake). The REE product is further processed into four rare earth products.
Scenario 3	**“Greenland separation plant”:** Through additional chemical processing the REE products are separated into 15 different rare earth oxides.

<u>Concentrates-Only Alternative</u>
The concentrator stage involves the separation of minerals using physical separation methods only. This option was developed to provide a customized solution to the lack of infrastructure, high cost and lack of chemical industry skills in Greenland. This option would produce three products:

1. Rare Earth and uranium bearing mineral concentrate;
2. Zinc mineral concentrate; and
3. Fluorspar chemical precipitate.

This option produces the simplest form of Rare Earth that permits cost effective transportation to another location for further processing and avoids the high cost of building a complex chemical processing facility in Greenland.

Greenland Separation Plant
This option considered the feasibility of constructing a complete Rare Earth separation complex in Greenland to produce 15 Rare Earth separated oxides. Because the metallurgical processing of Rare Earths is one of the most complicated businesses in the mining and chemical industry the separation into individual rare earth oxides is very difficult. It requires a very complicated extraction technology, which again requires a very expensive processing plant and involved building the necessary expertise and skills required for running a rare earth processing facility. For these reasons GMEL has taken the strategic decision not to develop an in-house version of Rare Earth separation technology.

Mechanical (Concentrator) and Chemical processing (Refinery)
It is a requirement of the Greenland Government to value add to mining products as much practically possible must take place in Greenland. GMEL has opted for Scenario 2 where a zinc concentrate, uranium oxide and four Rare Earth products are produced in Greenland. This option requires that some of the Rare Earth products will be further processed outside Greenland.

5.16.2 Location of mine facilities

Two potential locations for the the accommodation facility, processing plant (Concentrator & Refinery), and port were considered:

- The East Scenario where the processing plant, accommodation facilities are at Ipiutaq and the port at Illunnguaq opposite Nunarsarnaq 15 to 20 km northeast of Narsaq. The ore would be transported by haul trucks through a tunnel from the pit at Kvanefjeld. This scenario requires that the waste rock and tailings deposition takes place in the Ipiutaq area.

- The West Scenario where all mine facilities are situated in Narsaq Valley and near surroundings and with the port at Narsap Ilua (Narsaq Bay).

Following public consultations the “East Scenario” was abandoned and the development of the mine design was focused on Narsaq Valley - Narsap Ilua area.

5.16.3 Alternatives for the location of the tailings facilities

Two options for tailings facility locations were considered within the West Scenario (Figure 5-15). One option is to have the two tailings ponds southwest of the pit-waste rock area on top of the mountainous plateau. However, this would require construction of very large embankments to create the ponds for deposition of the tailings under water. The other option is to use the natural impervious basin (Taseq Lake) as FTSF and the small pond east of Taseq for the CRSF. This requires much smaller embankments. For these reasons GMEL opted for the Taseq solution.

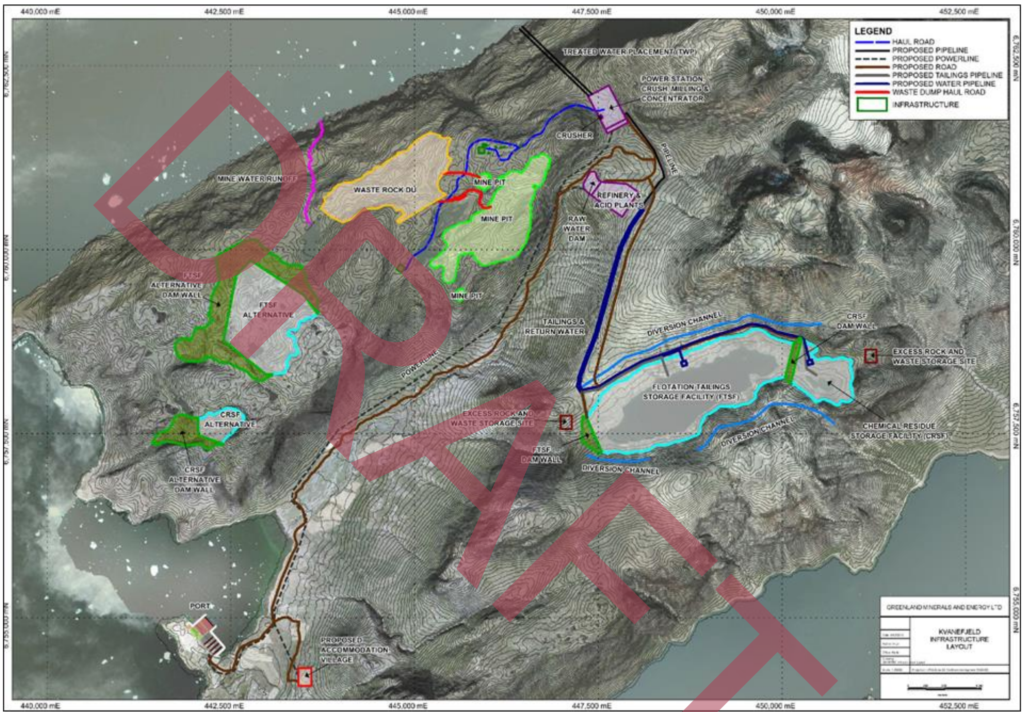

Figure 5-15: Location of mine facilities including two options for the tailings facilities. One option is on the plateau southwest of the pit. The other is to use Taseq Lake

5.16.4 Alternative port locations

A number of alternatives were considered for the port location at Narsap Ilua. One option was to have the quay along the north side of the bay. However, this option was abandoned because it would conflict with a Norse farm ruin and would also require large scale blasting to create space for container stacking and storage of bulk cargo. A location just south of the outlet of Narsaq River was also considered, but this would require large scale dredging to allow for berthing of 65,000 DWT ships.

5.16.5 The application of hydropower

The application of hydropower for the Project was first studied by Risø in the 1980's. Johan Dahl Land (Figure 5-16) was identified as providing a potentially suitable source for hydropower. GMEL therefore asked two experienced hydropower plant specialists to determine the feasibility of applying hydropower to the Kvanefjeld project. This study has shown that the hydropower energy potential at Johan Dahl Land is adequate to meet the electrical power requirements (c. 35MW) for treating 3 million tons per year of ore but would require a hydropower plant design consisting of damming and diverting 3 elevated lakes in the Johan Dahl area to provide adequate energy supply. A diversion tunnel will be built which feeds lake water to hydro turbines for electricity production. The electricity would be transmitted to the project site from John Dahl Land by an above-ground 55 km power line. Figure 5-16 shows the location of hydro dams and power line leading to the project site.

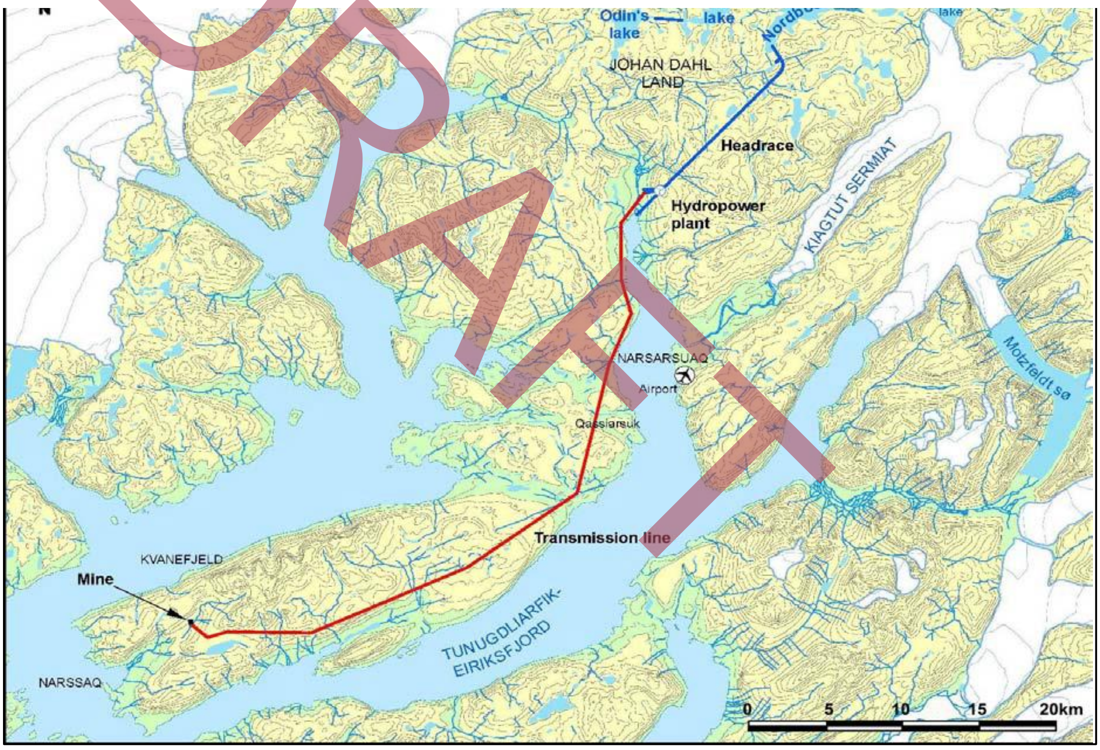

Figure 5-16: Location of hydropower plant and transmission line (red line) to the mine

The capital cost to build a hydropower plant including the 55 km power line is estimated at c. 1.9 billion DKK increasing the capital costs significantly. In the current economic climate the hydropower plant is therefore not significantly more cost effective than conventional oil fired power plants. Building a hydropower plant would also extend the construction time of the mine project by ~ 2 years. For these reasons hydropower is not part of the base case Kvanefjeld Feasibility Study. However the use of hydropower is an interesting option which could form part of an overall southern Greenland energy system or part of a future expansion of the project.

5.16.6 The “zero-alternative”

The “zero-alternative” is that the Kvanefjeld project is not implemented. For Greenland the consequences of the *“zero-alternative”* are that the Study area and its surroundings will not be exposed or impacted by project activities as described in this EIA report. The on-going radiation impact of the large uranium and thorium deposition in Kvanefjeld remain the same. Furthermore, for better or for worse, there will be no social impact, no social benefits, no job-creation, no revenues for the Greenlandic society, etc. as described in the SIA report.

6. EXISTING ENVIRONMENT

6.1. Topography

The landscape in South Greenland is characterised by relatively high and steep mountains and by low islands and peninsulas in the coastal areas. This landscape is largely formed through glaciation, which has carved the long, narrow and deep fjords.

The Kvanefjeld is a 690 m high mountain, situated on the Erik Aappalaartup Nunaa peninsula close to Narsaq town. South of Kvanefjeld is the Narsaq Valley and Narsaq River, which drains the valley and surrounding mountains into the fjord at Narsap Ilua Bay.

Figure 6-1: Narsaq River and the Kvanefjeld to the left

6.2. Geology

The Kvanefjeld is located inside the northwest margin of the Illimaussaq intrusive complex, which is one of the intrusive complexes of the Gardar igneous province in South Greenland. The layered nature of the complex is attributed to four successive pulses of magma. The first pulse produced an augite syenite, which now forms a marginal shell. This was followed by intrusion of a sheet of peralkaline granite that is mostly preserved in the roof of the complex. The third and fourth stages make up the bulk of the intrusion. Stage four produced the agpaitic lujavrites and kakortokites that formed from volatile-rich alkaline magmas that were extremely enriched in incompatible elements such as rare earth elements, lithium, beryllium, uranium, and high-field-strength elements such as niobium and tantalum.

Steenstrupine is the dominant host to rare earth elements and uranium in all mineralisation styles. It is a complex sodic phospho-silicate mineral and mineralogical studies suggest that it commonly contains between 0.2% and 1% U_3O_8, and hosts approximately 50% of the uranium at Kvanefjeld. Other minerals that are important hosts to REEs include the phosphate mineral vitusite, and to a lesser extent, cerite and monazite. Aside from steenstrupine, uranium is also hosted in unusual sodic silicate minerals that are rich in yttrium, heavy REEs, zirconium and tin. Minor uranium is also hosted in uranothorite and monazite. Zinc is mostly hosted in sphalerite, which is the dominant sulphide throughout the deposit.

6.2.1 Seismicity

Data published by the United States Geological Survey, the Global Seismic Hazard Assessment Program and seismic hazard studies available for Greenland show that the peak ground acceleration value estimated over a period of 475 years (Operating Basis Earthquake) for the project site is 0.04 g. Based on this value, and the seismic hazard classification in the 2011 World Health Organisation E-Altas of Disaster Risk for the European Region, the seismic hazard for the Study area is considered very low. This means there is a very remote probability of an earthquake being large enough to cause the failure of mining facilities such as the tailings embankments.

6.2.2 Metal content in soils

Slightly elevated concentrations of zinc and lead are observed in soil samples collected in Narsaq Valley (Table 6-1) indicating some influence of Kvanefjeld resource. No other metal concentrations appear to be elevated from expected background concentrations.

	Unit	Soil sample 1 Narsaq Valley	Soil sample 2 Narsaq Valley
Acid extractable lead	ug/g	70	87
Acid extractable zinc	ug/g	300	380

Table 6-1: Concentrations of lead and zinc in soil samples from Narsaq Valley

6.3. Uranium and thorium associated background radioactivity

Natural occurring radionuclides such as uranium and thorium are present in all soils and rocks. The Kvanefjeld resource carries significant concentrations of uranium and thorium, about 300 ppm and 800 ppm, respectively. Over time natural processes, in particular glaciation, wind and water erosions, appear to have dispersed uranium and thorium bearing mineralization into Narsaq Valley and onwards towards the fjord and Narsaq town. This dispersal of exposed mineralization around the Kvanefjeld area has led to levels of radionuclides that are higher compared to global average soil.

In order to quantify the naturally occurring radioactive material in the Study area a series of studies have been carried out which are summarized and discussed in Arcadis /2015a/. Below is a brief overview of the key radiological background data analyzed by the independent expert radiation consultant.

6.3.1 Ambient Radon and Thoron Concentrations

Radon gas (radon-222) is member of the uranium-238 decay series and is created when its precursor, radium 226, decays. This decay process is continuous resulting in the ongoing release of radon into the pores and fissures of the radium bearing material. Radon is soluble in water under pressure, as in groundwater, and some fraction of the radon in pore space will be dissolved in groundwater and released as the groundwater is depressurized. Radon emits alpha radiation when decaying. When inhaled the alpha radiation from radon in lungs can be cancer-causing for humans.

Similar to the U-238 series, another isotope of radon, Rn-220 or thoron, is released from thorium-bearing materials. Because of its short half-life (55 s), thoron is not usually considered a significant occupational or environmental concern.

It should be noted though, because of normal atmospheric dispersion radon and thoron exposure outdoors is not a concern. However radon exposure in unventilated, enclosed areas can be an issue in some cases.

Radon and thoron has been measured in a number of locations in the Study area. In Narsaq town outdoor radon is approximately 10Bq/m^3 while closer to the proposed mine area radon is approximately 40 Bq/m^3. Around the globe the average outdoor radon level typically varies between 5 and 15 Bq/m^3 but in areas of high natural uranium and thorium (such as in Norway) radon levels can reach 75 Bq/m^3. Consequently, the concentration of radon and thoron in Narsaq are at average levels and are somewhat higher in some areas close to the Kvanefjeld.

6.3.2 Dust

Naturally occurring radionuclides will also be found in dust from suspended soil. Because natural processes over time has transported uranium and thorium bearing mineralization from the Kvanefjeld into Narsaq Valley, dust from the valley and other areas surrounding the Kvanefjeld may contain naturally elevated levels of radioactive particles.

To quantify the natural concentration of radioactive elements on dust particles, filters used to monitor the ambient dust concentrations were analyzed for a number of radioactive elements. Concentrations of these elements in ambient air were subsequently estimated as summarized below. The data shows that uranium and thorium in dust is at very low levels.

Table 6-2: Concentrations of Radioactive Elements on Particles (data from 2011-2012)

Location	Uranium Concentration (ng/m^3)	U-238 (µBq/m^3)	Thorium Concentration (ng/m^3)	Th-232 (µBq/m^3)
Narsaq Farm	0.021	0.26	0.142	0.58
Narsaq Town	0.005	0.06	0.098	0.40
Narsaq Point	0.006	0.07	0.068	0.28

Note: 1 g Uranium = 12350 Bq of U-238 and 1 g Thorium = 4100 Bq of Th-232

6.3.3 Gamma radiation exposure

The presence of the naturally-occurring radionuclides in the ground also leads to external gamma exposure. To quantify the gamma radiation level at the Kvanefjeld, in Narsaq valley and Narsaq town a survey was carried out in 2014.

It was found that levels in the Town of Narsaq were low and similar to reference areas; levels tend to be higher near some sections of the roadway (Figure 6-2). The Coastal Plain shows only slightly higher gamma radiation levels than the Town of Narsaq with a tendency for gamma radiation to increase in the north toward the valley area. In the Narsaq Valley including the Narsaq farm area, gamma radiation levels are higher probably due to the movement of mineralized rock from higher elevations due to gravity or water/ice transport. The highest levels tend to be adjacent to the river. Gamma radiation levels in the Kvanefjeld area are generally higher reflecting the higher baseline radionuclide content associated with the mineralization.

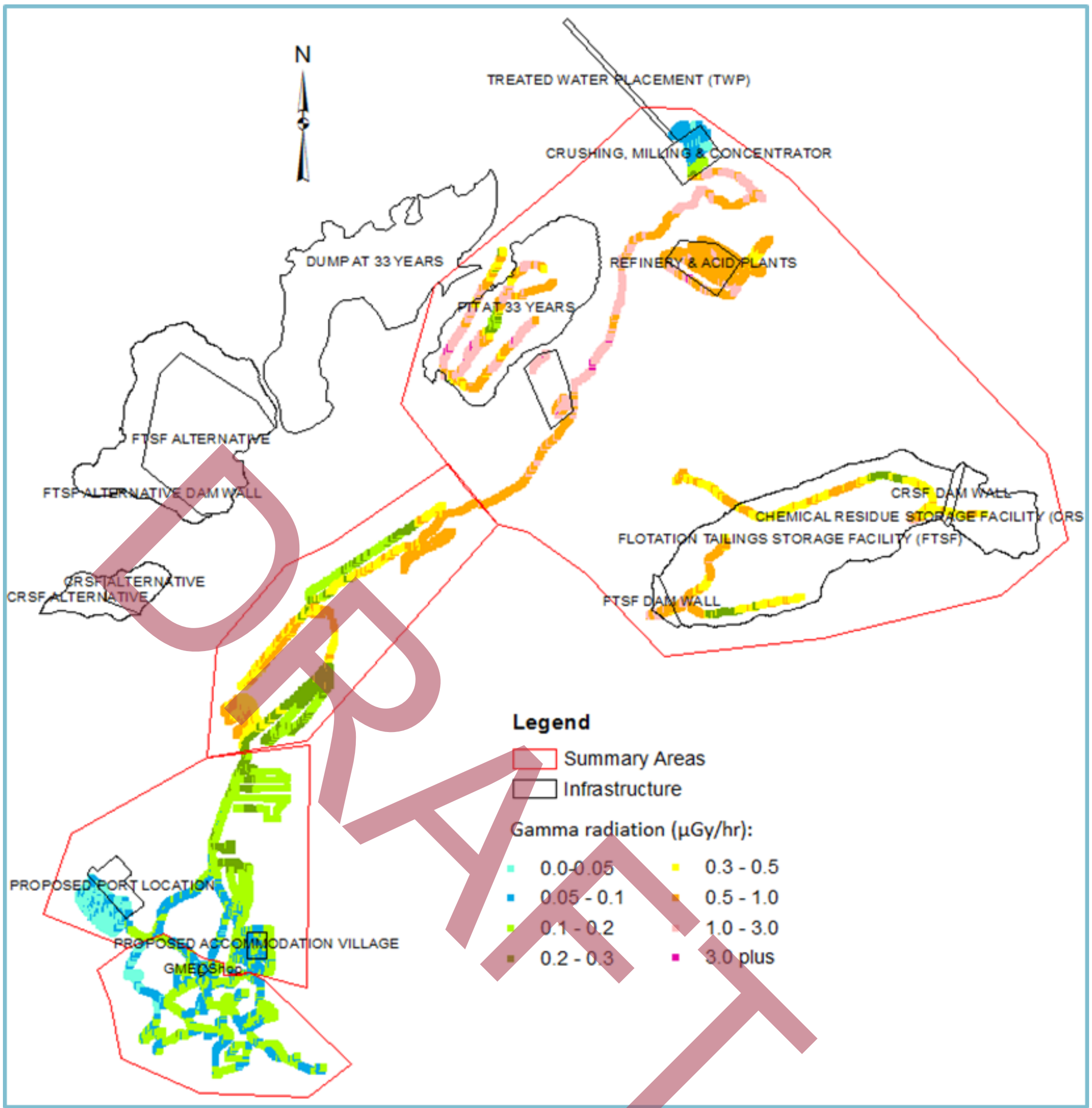

Figure 6-2: Results of gamma radiation exposure measurements in 2014 in Narsaq Town (bottom left), in Narsaq Valley, the mine area (including Kvanefjeld) and at Taseq Lake. The contours of the future mine and infrastructure are also indicated

6.3.4 Baseline levels in soil, sediment and water

Radioactivity measurement shows that soils from Narsaq Valley, marine sediment from Narsap Ilua and sediment from Narsaq River are enriched in thorium and uranium relative to typical background levels which are usually in the order of 2-15 ppm, and with a thorium/uranium ratio of 2.5 to 2.7 (Table 6-3). This indicates some influence of the Kvanefjeld resource possibly resulting from erosion. Sediment collected close to the Kvanefjeld (upper Narsaq River – Table 6-3) showed higher levels of uranium and thorium than sediment from the river mouth (lower Narsaq River).

Table 6-3: Results of radioactivity measurements of soil and sediment from the Study area (collected in 2014)

Parameter	Unit	Soil	Marine sediment	Freshwater sediment	
				Lower Narsaq River	Upper Narsaq River
Thorium (Th)	ppm	78	30	61	190
Uranium (U)	ppm	29.5	9.5	23	61
Uranium-238[a]	Bq/g	0.36	0.12	0.28	0.75
Radium-226	Bq/g	0.44	-	0.23	-
Lead-210	Bq/g	-	-	0.24	-
Polonium-210	Bq/g	-	-	0.23	-
Thorium-232[b]	Bq/g	0.32	0.12	0.25	0.78
Radium-228	Bq/g	-	0.099	0.34	0.61

Note: (a) 1 g U = 12350 Bq of U-238; (b) 1 g Th = 4100 Bq of Th-232

Radioactivity measurement in water showed concentrations of uranium in freshwater and sea water were at averages of about 0.003 and 0.001 mg/L, respectively. For perspective, the Canadian water quality guideline for the protection of aquatic life is 0.015 mg/L U.

Thorium was consistently below detection limits, which is appropriate as thorium has a low solubility under neutral pH conditions. The only detectable measurement of thorium was for the Kvanefjeld River at about 0.002 mg/L.

Radium-226 and lead-210 concentrations in rivers and sea water in the Study area averaged at 0.04 and 0.15 Bq/L, respectively and these are lower than the respective Canadian drinking water guidelines.

6.3.5 Baseline levels in flora and fauna

Samples of lichen, plants, sea weed, mussels, fish and seals from the Study area have been analyzed to document the background concentrations of radionuclides in representative species of the resident flora and fauna.

With the exception of Snow lichens, thorium was not found to be concentrated in any of the organic samples due to its low solubility. Snow lichens from Narsaq Valley show indications of accumulation, which is likely the result of dust dispersion from exposed rock and soils in the valley. This is more evident in samples from the upper Narsaq Valley close to Kvanefjeld while lichens collected close to the fjord (Lower Narsaq Valley) had a lower value (Table 6-4). Lichens from a reference station 28 km south southwest of Kvanefjeld showed very low values.

Table 6-4: Results of radioactivity measurement of Snow lichens and grass from Narsaq Valley and reference station (2014)

Parameters	Unit	Snow lichen Lower Narsaq Valley	Snow lichen Upper Narsaq Valley	Snow lichen reference station	Grass Lower Narsaq Valley
Thorium	ppm	1.2	4.7	<0.1	<0.1
Uranium	ppm	0.6	1.6	<0.1	0.53
Uranium-238[a]	Bq/g	0.007	0.020	<0.0012	0.0065
Radium-226	Bq/g	0.029	0.088	<0.01	0.01
Lead-210	Bq/g	0.26	-	-	-
Polonium-210	Bq/g	0.21	0.45	0.26	<0.01
Thorium-232[b]	Bq/g	0.005	0.019	<0.0004	<0.0004
Radium-228	Bq/g	<0.05	-	-	-

Note: (a) 1 g U = 12350 Bq of U-238; (b) 1 g Th = 4100 Bq of Th-232; all wet weight basis

A very low concentration of uranium was found in Blue mussels and sea weed from Narsap Ilua where Narsaq River discharges. Samples of mussels and sea weed collected further away at Narsaq port, Nordre Sermilik and at the reference stations in Bredefjord showed uranium levels below the detection limit.

Analyses of Arctic char from Narsaq River as well as marine fish and Ringed seal from the fjords around Narsaq indicated no significant concentration of radionuclides.

The radionuclides are also below detection in Ringed seals from Bredefjord/Nordre Sermilik with the exception of polonium-210 where 0.040 Bq/g was recorded in meat and 0.16 Bq/g in liver. Polonium is known to biomagnify through the aquatic food chain and higher trophic level animals that consume fish (such as seals) are known to have naturally elevated levels of polonium. This is particularly obvious for sedentary seal species living in an area with slightly elevated concentrations of radionuclides, such as Ringed seal in the fjords around the Kvanefjeld. For comparison, Po-210 levels in a (migratory) Harp seal from the Bylot Sound at Thule were found to be 0.008 Bq/g fresh weight in flesh and 0.043 Bq/g fresh weight in liver /Nielsen 2015/.

6.3.6 Summary and conclusions - background radiation

Outdoor radon concentrations in Narsaq Town are at an average level while the values are slightly elevated in the Narsaq Valley close to the Kvanefjeld deposit. Dust collected in Narsaq Town and at the Narsaq farm (in lower Narsaq Valley) contained very low levels of radioactive elements. Gamma levels in the Town of Narsaq were low but increased slightly up through the Narsaq Valley towards Kvanefjeld.

Soil from Narsaq Valley, marine sediment from Narsap Ilua and sediment from Narsaq River are enriched in thorium and uranium with the highest values in sediment from the upper Narsaq River close to Kvanefjeld. Concentrations of uranium and thorium in water from Narsaq River are very low.

Marine fish from the fjords around Narsaq had no significant concentration of radionuclides. Also mussels and sea-weed had very low concentrations, mostly below the detection limit.

Snow lichens from Narsaq Valley showed potential for accumulation of radionuclides, which is likely the result of dust dispersion from exposed rock and soils close to the Kvanefjeld deposit.

Ringed seals from Bredefjord/Nordre Sermilik showed elevated levels of polonium-210 in particular in the liver. This is probably due to bioaccumulations as this species is at the highest tropic level of the marine food chain.

6.4. Climate

At a regional scale, the North American continent and the North Atlantic Ocean mainly influence the weather in South Greenland. However, the Greenland Inland Ice also has a heavy influence on the local climate. Another key factor is the year round low sea surface temperature, which causes the South Greenland waters and coastal areas to be part of the arctic climatic zone, with average summer temperatures below 10 °C. The following description of the climate (temperature, precipitation and wind) is based on Orbicon /2014a/.

6.4.1 Temperature

Situated only 40 km from the open ocean the local area is influenced by an oceanic weather type causing cool summers and relatively mild winters. No long temperature series are available but data from weather stations in nearby towns provides a good indication of the average monthly temperature throughout the year. This includes Qaqortoq some 30 km southwest of Kvanefjeld which has an even more oceanic climate being located only 15 km from the open sea and Narsarsuaq 35 east of Kvanefjeld which has a more continental climate (Figure 6-3). In Qaqortoq the average January temperature is – 5.5°C, while the average temperature in the warmest months (July and August) is 7.2ºC. In Narsarsuaq, the average January temperature is – 6.8°C, but 10.3°C in July. Compared to these towns the weather in Narsaq takes an intermediate position.

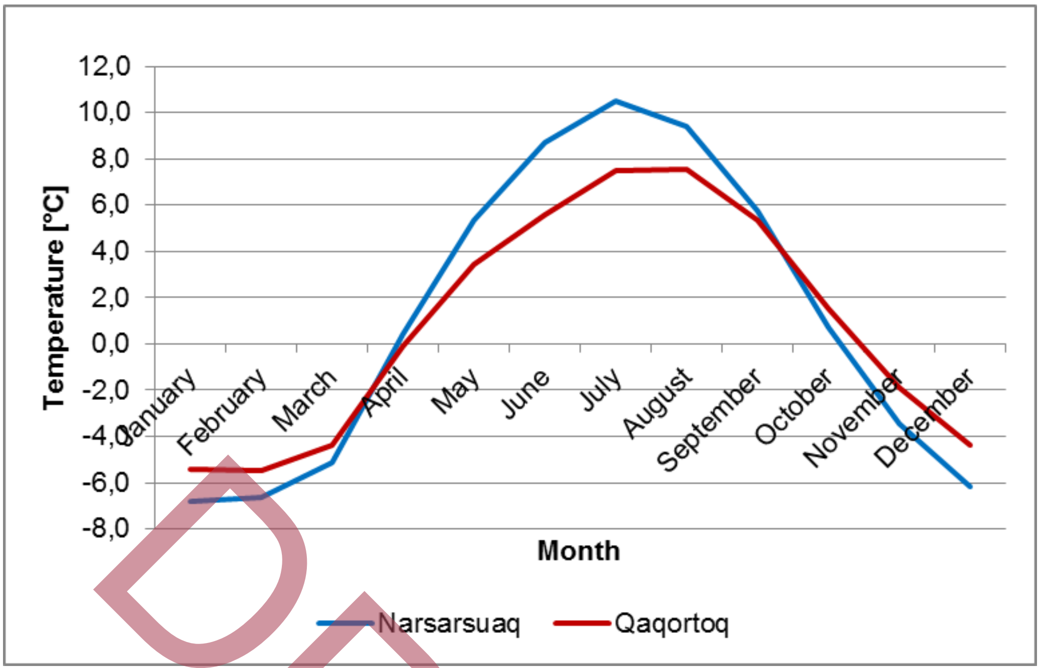

Figure 6-3: Average monthly temperature in Narsarsuaq and Qaqortoq (1961-2008) – from Orbicon 2014a

Because of the elevation, the temperature at Kvanefjeld is lower than in Narsaq. Figure 6-4 shows the temperatures recorded by a weather station on the Kvanefjeld at 650 m altitude. Several warm foehn incidents (see below) can be seen as high temperatures recorded for a few hours even during mid-winter (see 6.4.3).

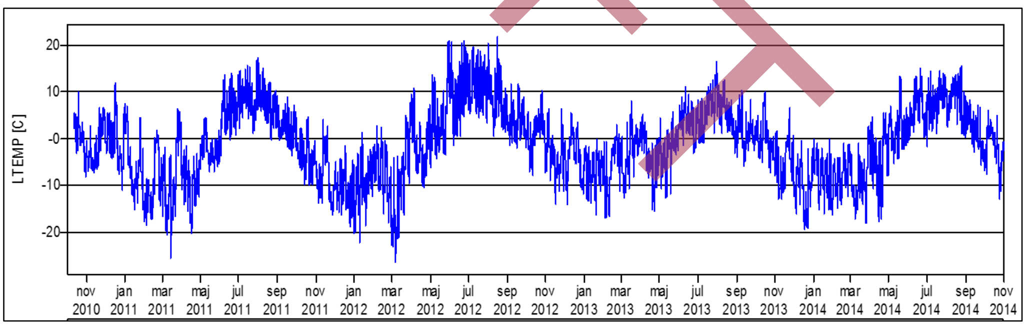

Figure 6-4: Temperature (degree C) recorded by the metrological station at Kvanefjeld between November 2010 and November 2014

6.4.2 Precipitation

The annual average precipitation is 858 mm at Qaqortoq but only 615 mm at Narsarsuaq. Monthly data from 1987-2001 suggests that the precipitation in Narsaq is only slightly lower that in Qaqortoq (Figure 6-5).

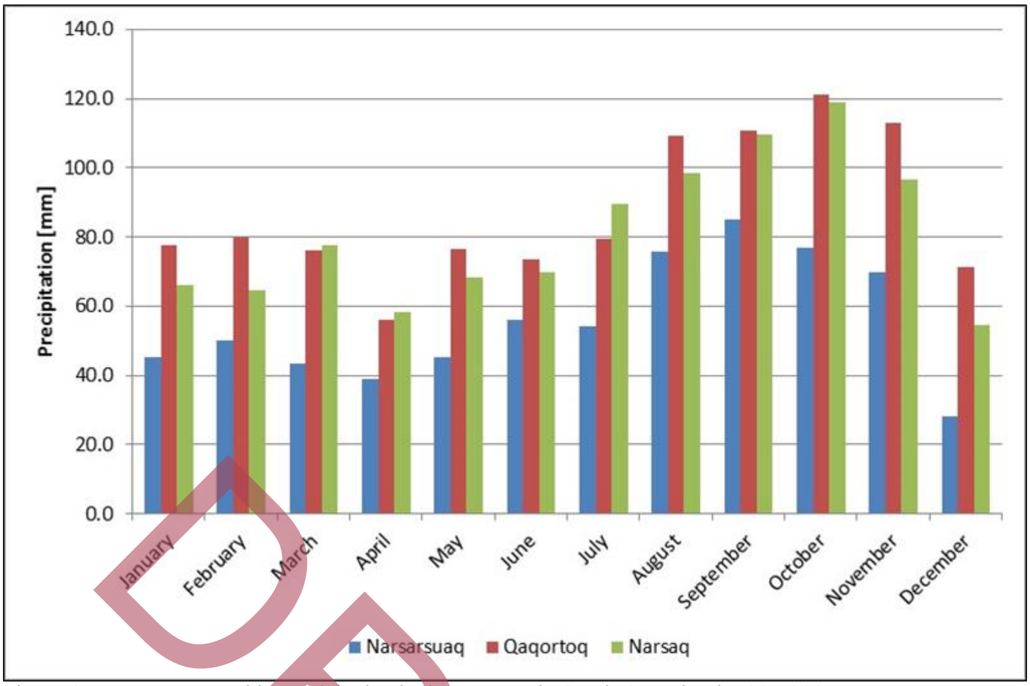

Figure 6-5*: Average monthly precipitation in three towns in South Greenland, 1987-2001*

The precipitation pattern at Kvanefjeld is similar to the one in Qaqortoq/Narsaq but the total is somewhat higher since precipitation generally increases 3% per 100 meter of altitude. During winter where precipitation is falling as snow, the snow depth is typically highest in February where 20 cm in Narsarsuaq and 41 cm in Qaqortoq is typical.

6.4.3 Wind

Figure 6-6 shows the wind speed and direction recorded by the weather station at Kvanefjeld between 2010 and 2014. The predominant wind directions are from North East and South East. Most strong winds are recorded in the North East direction.

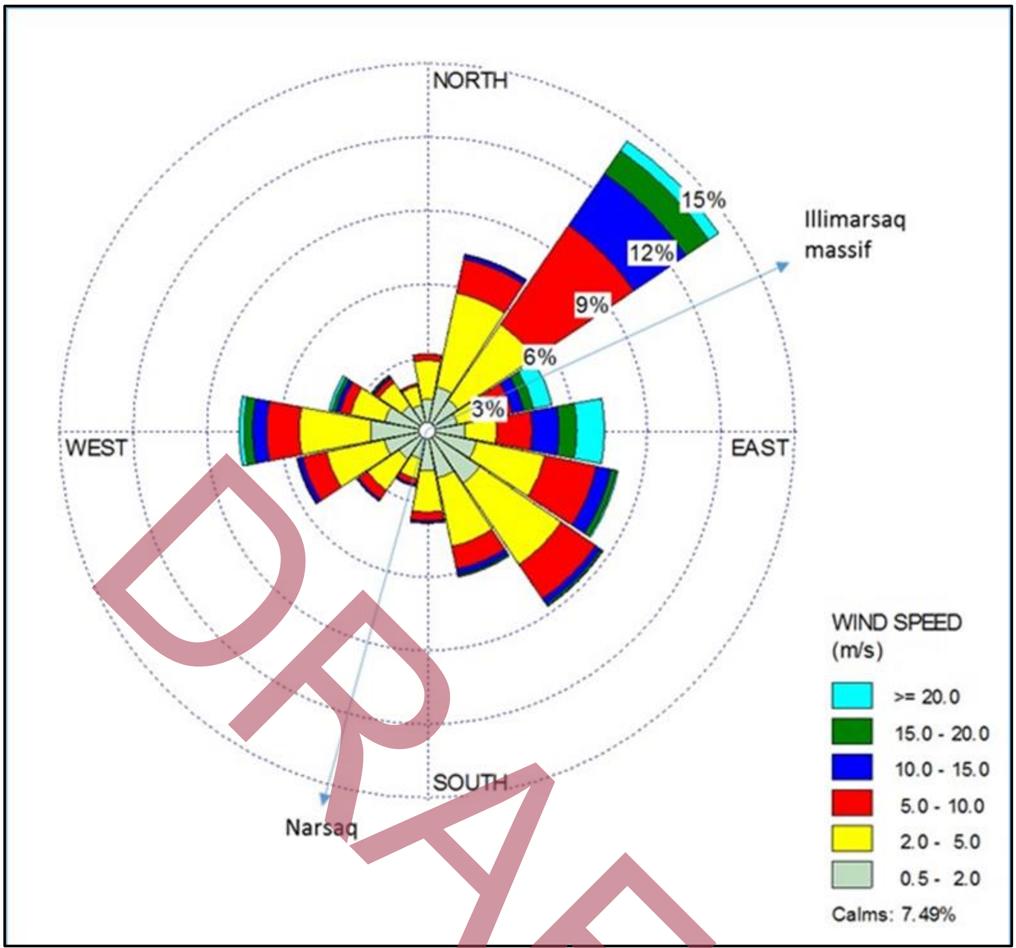

Figure 6-6: Wind directions and speed recorded from weather station at 680 m on Kvanefjeld. The data covers the period 2010 - 2014

Foehn winds are outbursts of dry and relatively warm air and are relatively common in South Greenland. Foehns arise through adiabatic compression of the air sweeping down from the inland ice cap. The relative humidity drops to 30-40%, and the temperature rises by up to 15-20 °C within an hour, remaining elevated for up to a day or two. The effect of the foehn wind is particularly marked in winter, when it can result in rapid melting of the snow. Foehn winds are quite common in the Kvanefjeld area.

6.5. Air quality

A baseline dust and pollutant monitoring programme in the surroundings of the proposed Kvanefjeld mine, including in the town of Narsaq, has been running since August 2011. The monitoring stations are located at the farm in Narsaq Valley, in Narsaq town and to the south of Narsaq at Narsaq Point. The description below of the baseline air quality is based on the “Kvanefjeld Multi-element Project Air Quality Baseline Monitoring” report by AirQuality.dk /2013/.

The EU daily and annual limit values for PM_{10} (particulate matter less than 10 µm) are 50 and 40 µg/m^3 respectively. There are no limit values or guidelines for hourly or shorter interval PM_{10} concentrations.

Even the highest short peak values recorded do not come close to the daily or annual limit values. The highest 10-minute PM_{10} concentration was 24.0 µg/m^3.

The overall average of the PM_{10} concentrations is about 1.0 µg/m^3 at the farm in Narsaq Valley. This is only 2.5% of the EU annual limit value. Typical PM_{10} values in Europe are on the order of 40 times higher – near or above the annual limit value.

There are a few higher short peaks in the PM_{10} data at Narsaq Town, compared to the Farm. This may be due to local road dust or dust from the harbour area.

Except for Chlorine (Cl), gadolinium (Gd), terbium (Tb), Lead (Pb) and Thorium (Th), the average element concentrations are within a factor two of the “the continental crust” values, which can be considered representative of a “global average” mineral dust. Chlorine in the PM_{10} samples averages 18% of the crust content. The concentrations of gadolinium, terbium, lead and thorium in the PM_{10} samples are considerably higher than the upper continental crust averages for these compounds – with enrichment ratios of 27.2, 10.76, 10.9 and 4.4 respectively.

Nitrogen dioxide (NO_2) comes from both long-range transport and local combustion sources, but the baseline levels are very low. The diurnal variation of NO_2 is also expected to be weak. There are slightly higher average NO_2 concentrations at the Narsaq Town station compared to the two stations outside of town (2.7 µg/m^3 versus 1.5 and 1.4 µg/m^3). This probably reflects vehicle traffic in Narsaq.

Most of the sulphur dioxide (SO_2) samples indicated a very low concentration, below the 0.1 µg/m3 detection limit of the SO_2 passive samplers. The main source of SO_2 is long-transport, international ship traffic along the coast of Greenland, and ship traffic to Narsaq harbour.

Ozone (O_3) levels are fairly high and primarily due to long-range transport.

Ammonia (NH_3) is quickly removed from the atmosphere during transport, but there are some local sources such as livestock. NH_3 is highly soluble in water, and effectively rinsed from the atmosphere during precipitation. The average NH_3 concentration at the Narsaq Valley farm station is slightly higher than at the other two stations (1.9 µg/m^3 versus 1.2 and 1.5 µg/m^3). This can be due to sheep manure at the nearby farm.

6.6. Fresh water resources

Narsaq River originates from a small glacier at the top of Narsaq Valley. From the glacier, the river runs for about 10 km through the Narsaq Valley before it discharges into the sea at Narsap Ilua. However, the main water source is not melting glacier ice but the many streams and rivers that drain the Narsaq Valley and lakes on the adjacent plateaus. This includes the large Taseq Lake, which connects to Narsaq River through Taseq River. In addition, a number of smaller lakes on the plateau between Kvanefjeld and Narsaq Fjeld drain through the Kvane River into the Narsaq River. Figure 6-7 shows the Narsaq River catchment area and Table 6-5 characteristic discharge values for Narsaq River and its main tributaries.

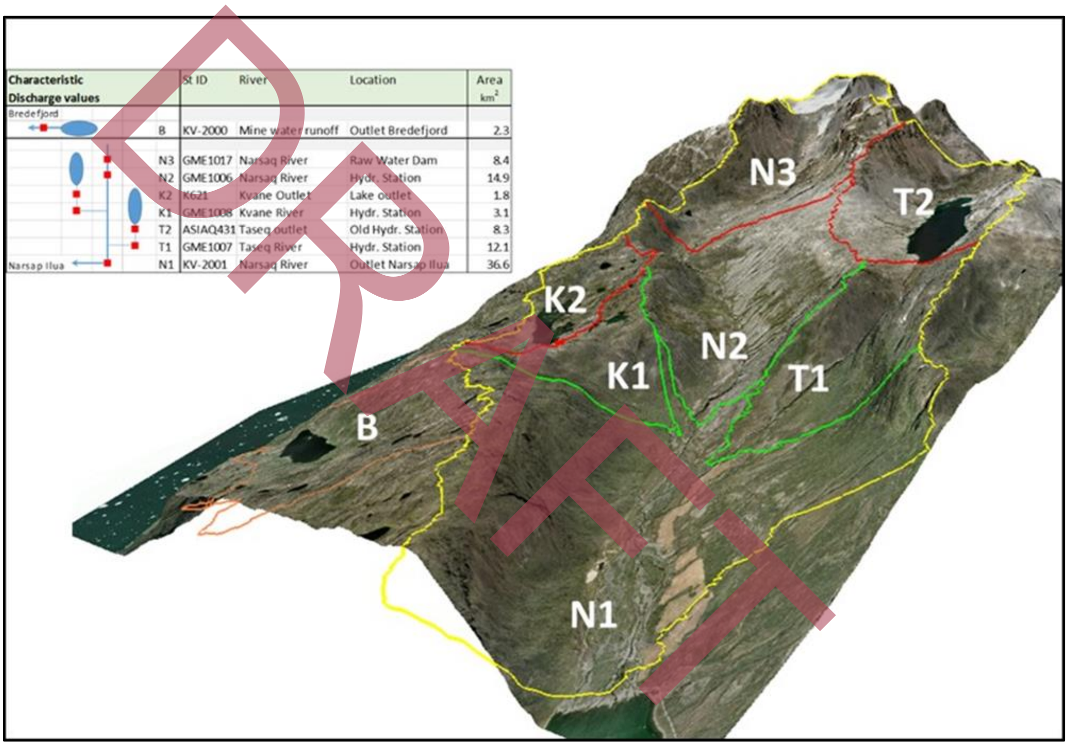

Figure 6-7: Narsaq River catchment area (except "B")

Characteristic Discharge values	ID	River	Location	Area km^2	Altitude m.asl	Q min m^3/s	Qmm m^3/s	Q25% m^3/s	Qavg m^3/s	Qmax m^3/s
Bredefjord	KV-2000	Mine water runoff	Outlet Bredefjord	2.3	0	0.000	0.000	0.004	0.070	1.1
	GME1017	Narsaq River	Raw Water Dam	8.4	490	0.005	0.010	0.040	0.330	3.2
	GME1006	Narsaq River	Hydr. Station	14.9	110	0.010	0.030	0.100	0.520	5.2
	K621	Kvane Outlet	Lake outlet	1.8	525	0.000	0.001	0.007	0.060	0.8
	GME1008	Kvane River	Hydr. Station	3.1	105	0.000	0.002	0.010	0.090	1.2
	ASIAQ431	Taseq outlet	Old Hydr. Station	8.3	510	0.000	0.020	0.060	0.250	3.0
	GME1007	Taseq River	Hydr. Station	12.1	65	0.005	0.030	0.090	0.370	4.4
Narsap Ilua	KV-2001	Narsaq River	Outlet Narsap Ilua	36.6	0	0.035	0.105	0.300	1.150	12.4

Table 6-5: Characteristic discharges (Q) at selected sites in the Narsaq River catchment. All results are based on daily average discharge values modelled for the 50-year period 1964-2013

6.6.1 Narsaq River

Narsaq River is by far the largest river in the Narsaq Valley. The flow varies considerably during the year with most runoff from April/May to October (Figure 6-8). During mid-winter, much of the river is usually covered by ice and snow, but even during very cold spells some water flows below the ice cover.

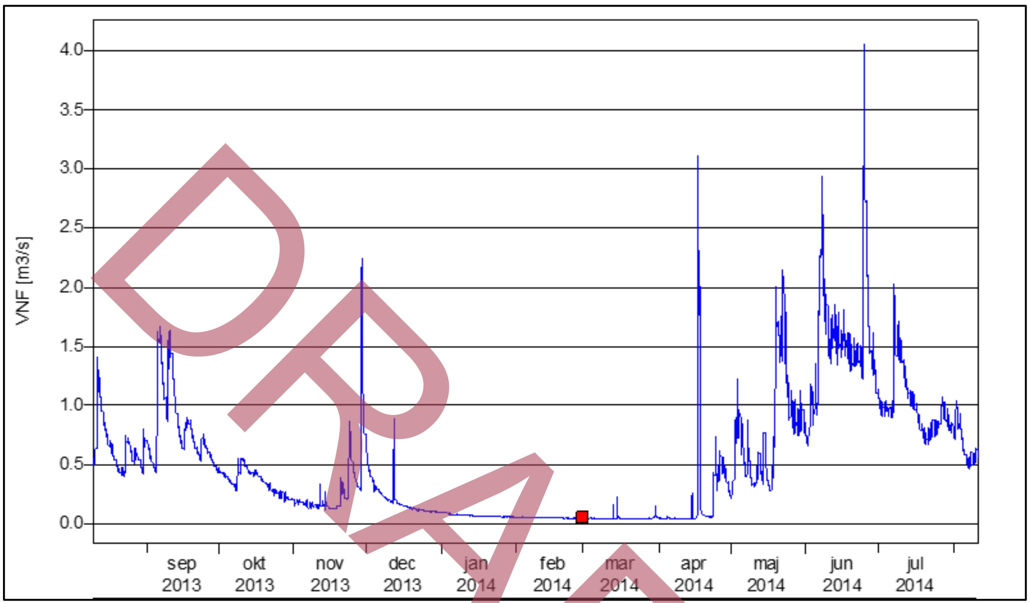

Figure 6-8: Water flow (m^3/s) in Narsaq River between September 2013 and July 2014 recorded at a measuring station in central part of Narsaq Valley. Red dot marks time for low-flow winter calibration measurement

6.6.2 Lake Taseq

Taseq is the largest lake in the Narsaq River catchment area. It is situated 520 m above sea level and is about 2.5 km long, 0.5 – 0.7 km wide and over 30 m deep. Taseq is connected to Narsaq River through Taseq River. In winter the lake is ice covered and the outflow from the lake stops. However, groundwater from the surrounding slopes (T1 in Figure 6-5) feeds into Taseq River and secures some flow even during mid-winter.

6.6.3 Other lakes and ponds

Several small lakes and ponds are found on the plateau between Kvanefjeld and Narsaq Fjeld (K2 in Figure 6-5). These water bodies drain through Kvane River into Narsaq River. However, other lakes further to the southwest (B in Figure 6-5) are not part of the Narsaq River catchment area and drain into Nordre Sermilik.

6.6.4 Water quality

Due to a high content of the water soluble mineral villiaumite (NaF) Narsaq River, Lake Taseq and Taseq River (and Narsaq drinking water) have elevated concentrations of fluoride (F). In Narsaq River the fluoride content increases significantly from the upper reaches to its mouth in the fjord (Table 6-6). This is in contrast to most lakes and ponds on the Kvanefjeld plateau, which has fluorine content between 0.02 and 0.83 mg/l.

Locality	Fluoride (F)	Chloride (Cl)	Sulphur (SO_4-S)	Sulphate (SO_4)
Narsaq River site 1	0.58	0.9	0.20	0.60
Narsaq River site 2	0.88	1.3	0.26	0.78
Narsaq River site 3	2.7	1.8	0.34	1.02
Narsaq River site 4	2.9	1.9	0.35	1.05
Narsaq River site 5	2.9	2.3	0.38	1.13
Narsaq River site 6	3.0	2.3	0.38	1.12
Lake Taseq	2.0	3.9	0.40	1.21
Taseq River	1.7	3.8	0.51	1.53
Lake Kvane	0.83	2.5	0.30	0.89
Kvane River	5.6	3.6	0.63	1.90

Table 6-6: Content of fluoride, chloride, sulphur and sulphate in mg/l in samples collected 14 and 15 August 2009. The position of the sampling stations is shown in Figure 6-9

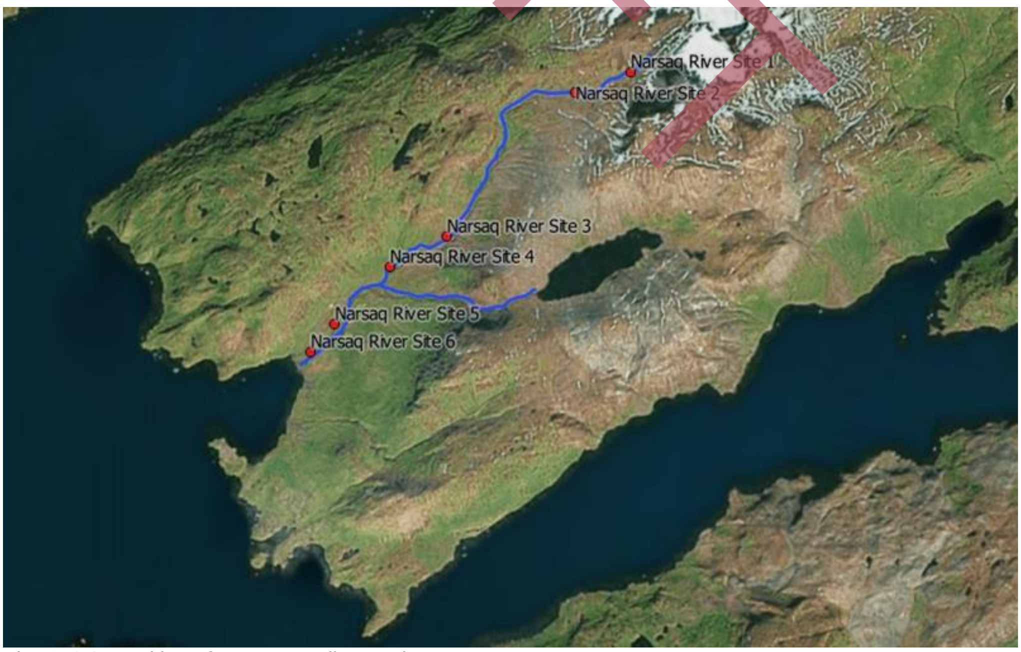

Figure 6-9: Position of water sampling station

The water quality of the Narsaq River catchment has been subject to an assessment described in the “Water Quality Assessment of Tailings - Water and Waste Rock Run off” report /Orbicon 2015b/. In this study a wide selection of water samples are included from different times of the year. This study concludes the following:

- Fluoride concentration varies enormously with values between 1 and 28 mg/l, with a median value in Narsaq River upstream Kvane River of 15 mg/l. All results from all sites exceed international guidelines for freshwater environments (e.g. The Canadian guidelines of ambient water quality ~ 0.12 mg/l). The WHO drinking water guidelines of 1.5 mg/l are likewise also exceeded by the Narsaq River.
- Uranium (U) concentration varies between ~0 and 2.8 µg/l, with median values around 0.5 µg/l. However, the level is well below international guidelines (e.g. the Canadian guidelines of 15 µg/l). The baseline level of uranium as well as thorium (Th) in Narsaq River is higher compared to Kvane Lake and Taseq Lake.
- Baseline level of arsenic (As) is usually below the Greenland Water Quality Criteria - GWQC (4 µg/l) although one sample in Narsaq River exceeds the criteria.
- Concentration of cadmium (Cd), chrome (Cr(III)), copper (Cu), and lead (Pb) is below the GWQC at all sites.
- Concentration of zinc is usually below GWQC in Narsaq River but above GWQC in Kvane Lake.
- The maximum concentration of phosphorus (Tot-P) exceeds the GWQC (20 µg/l) in Narsaq River. However, the median value is well below GWQC and around 0.5 µg/l.
- Very significant seasonal variation in concentrations can be observed in the data. In the summer period with high run off the concentration of salts is very low. In winter periods with low flow (mainly groundwater influenced) much higher concentrations of around 100 µg/l of dissolved phosphorous are observed. This indicates that the origin of the river water determines the dissolved element content.

The report concludes that baseline concentration levels of fluoride are around two orders of magnitude (x 100) above international ambient water quality guidelines in parts of Narsaq River and one order of magnitude above WHO drinking water standards. All sampling sites in Narsaq River, Kvane Lake and Taseq Lake have median values that exceed the ambient water quality criteria by at least a factor of 5. From time to time elements of arsenic, zinc, and phosphorus are recorded in levels exceeding the ambient water criteria. The variations might be explained by the heterogenic geological features of Kvanefjeld and the marked seasonal variation of the water sources with a distinct surface run off in spring and summer while winter run off is influenced by groundwater from the bed rock layers determining different chemical composition.

6.6.5 Narsaq drinking water

Drinking water for Narsaq is sourced from the two rivers Napassup Kuva (main source), and Kukasik and from the small stream Landnamselven/Qorlortunnguaq /Orbicon 2012a/. All three watercourses drain from mountains just northeast of Narsaq (Tasiigaaq and Qaqqarsuaq) – see Figure 6-10 - and their catchment area is clearly separated from the catchment area for Taseq Lake (Figure 6-11).

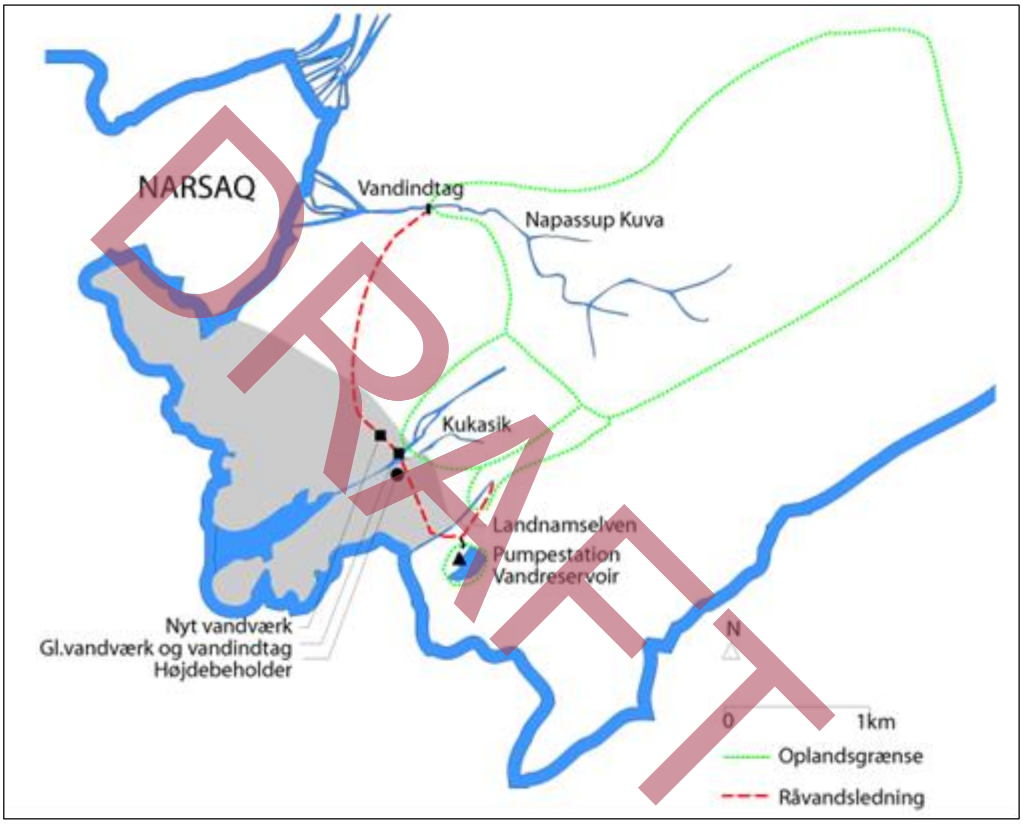

Figure 6-10: Narsaq Town (grey marking) and the three sources for drinking water: Napassup Kuva, Kukasik and Landnamselven

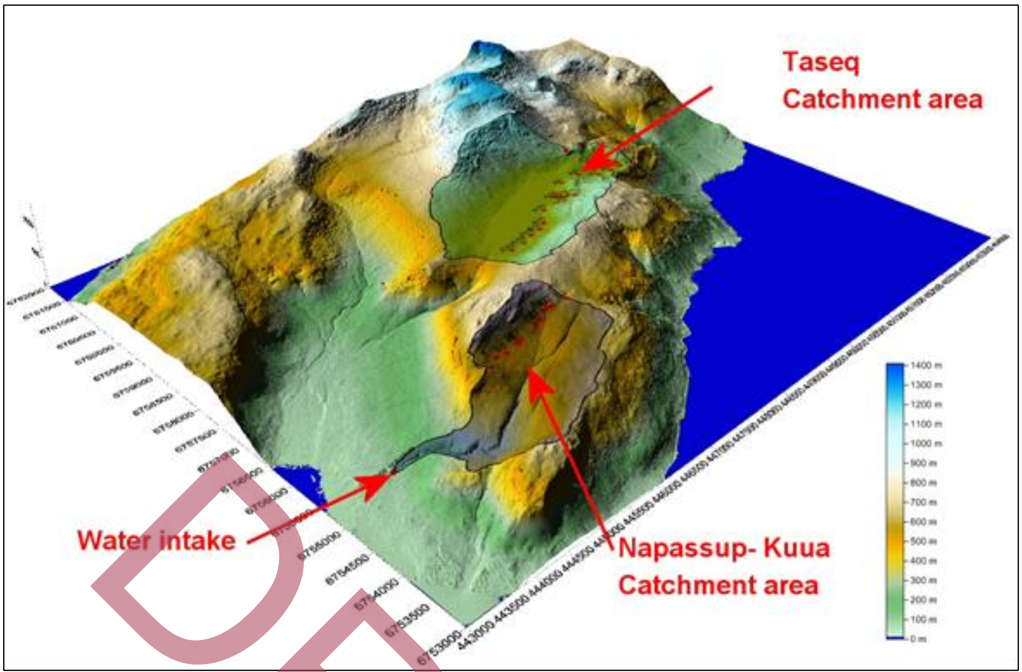

Figure 6-11: The topography of the Taseq catchment area and the Napassup-Kuua River catchment area which also include the other two streams that supply drinking water to Narsaq /Orbicon 2012b/

6.7. Marine Waters

6.7.1 Sea Ice

The seas off South and West Greenland, north to 65-67° N, are ice-free throughout the year. This open-water-area (Åbenvandsområdet) is primarily caused by the relatively warm north or northwest flowing West Greenland Current. In the fjords of South Greenland, the ice situation is different. Here three types of sea ice occur:

- Short-lived fast ice may occur in the inner part of the fjord during winter. This type of ice cover is extremely variable both within each winter period and between winters. In recent years, fast ice has mostly been limited to the heads of fjords, with the remaining parts of the fjords otherwise ice-free during winter. Figure 6-12 shows the extensive fast ice in the fjords at Narsaq during the cold winter 2011-2012. It should be noted that access by ship to Narsaq was still possible;

- Icebergs and growlers originating from glaciers in the Ikersuaq/Bredefjord – Sermilik system, but also at the head of Tunulliarfik/Eriks Fjord, are common all year. During summer icebergs and growlers can cover large parts of Nordre Sermilik and sometimes Ikersuaq/Bredefjord.

- Multi-year sea ice / drift ice (Storis), flowing with the East Greenland Current, moves southwards along the east coast of Greenland, turns westwards at Cape Farewell and then northward along the south-west coast of Greenland. In some years, wind and waves cause “Storis” to fill up the mouths of the larger fjords of South Greenland including Ikersuaq/Bredefjord and Narlunaq/Skovfjord during spring.

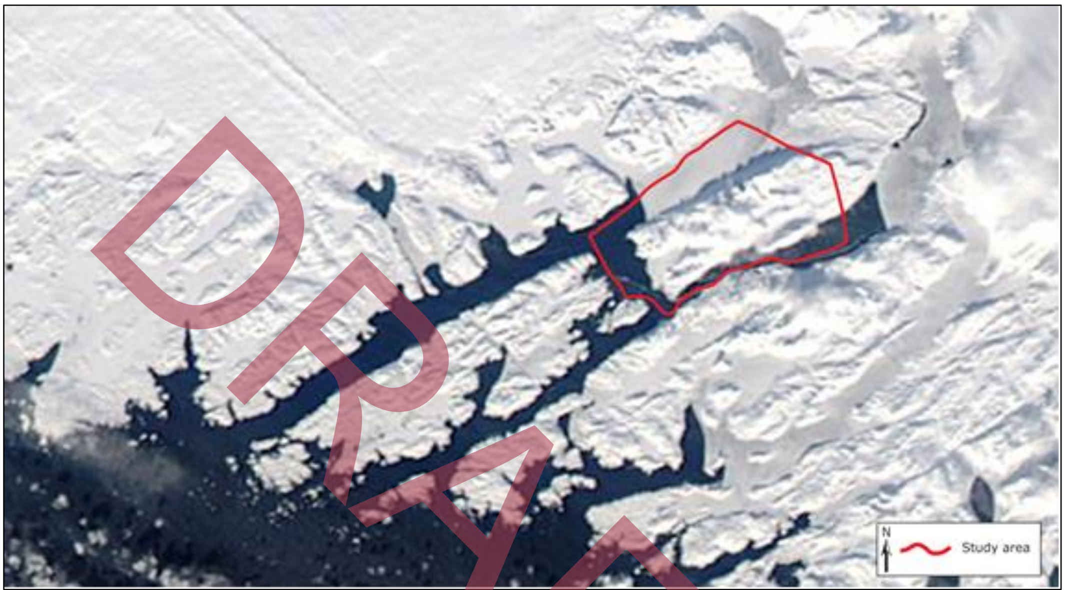

Figure 6-12: The extent of sea ice in the fjord-system around Narsaq during a cold winter (6 March 2012)

6.7.2 Fjord Oceanography

Like most fjords in South and West Greenland, Ikersuaq/Bredefjord, Nordre Sermilik and Narlunaq/Skovfjord are old glacial valleys. These fjords are generally deep, with maximum water depths up to 680 m.

Ikersuaq/Bredefjord and Narlunaq/Skovfjord are also “sill fjords” where low water depths at the mouth of the fjord prevent oceanic water from entering freely; at Ikersuaq/Bredefjord the depth at the entrance is 140 m, while depth at the mouth of Narlunaq/Skovfjord is only 70 m. As the sill strongly limits the exchange of water between the deeper parts of the fjords and the open sea, large-scale circulation of water in the fjords mostly depend on the supply of freshwater that runs into it. The freshwater input comes mainly from rivers, such as the Narsaq River, but also as icebergs from glaciers.

In the sill fjords, the inflow of freshwater form a surface layer of brackish water causes a higher water level in the fjords than outside /Mosbech *et al*. 2004/. This difference in water level forces the brackish surface water out of the fjords. On its way towards the mouth of the fjord, the brackish water becomes increasingly saline since the surface water mixes with the underlying water. In order to replace the saline water entrained by the surface current, an undercurrent of more saline water flows into the fjords at intermediate depths /Mosbech *et al*. 2004/.

During winter, the fresh water inflow to the fjords is reduced because lakes and rivers freeze and the precipitation on land falls as snow. The surface salinity in the fjord therefore increases to the levels found in the coastal waters outside the fjord, decreasing circulation in the fjord to a minimum.

Because of the reduced exchange of salt water with the ocean, sill fjords are fragile marine ecosystems. In addition, the quantity and quality of freshwater inflow from rivers are of particular importance to the marine flora and fauna, as these water sources are one of the main drivers of the water exchange in these fjords.

6.8. Vegetation

The vegetation in South Greenland is largely determined by temperature and precipitation with follows an oceanic-inland/continental gradient and an altitude gradient. Such gradients are obvious when moving inland through long and narrow fjords towards Narsaq. In the outer fjord area, vegetation growth is suppressed by cold ocean currents, drift ice, salt spray and wind while vegetation below 200 m altitude, with south-facing exposure at the head of the fjords, inland, locally develops into dense birch and willow scrub.

In the Narsaq Valley – Kvanefjeld area length of snow cover, water supply, temperature, soil and wind exposure and other parameters further influence the distribution of plant communities and the species composition within them.

The following description of the vegetation in the Study area is based on Ernberg Simonsen /2014/ who carried out field surveys in August 2013 and September 2014.

Narsap Ilua Bay and lower Narsaq Valley (0 – c. 200 m altitude)

The dominant vegetation type in this lowland is dwarf-shrub heath made up mainly by Bog bilberry, Crowberry, Glandular birch and Northern willow and with patches of mosses, grasses and sedges. On some south exposed slopes more species rich plant communities are developed with species such as Common harebell and Alpine Meadow-rue. Northern Green Orchid grows commonly along most of the streams in the lowland.

An unusual vegetation community is found close to the Narsaq River mouth, which includes rare species such as Autumn gentian, Golden gentian, Alpine gentian and Common butterwort. In particular Autumn gentian (Figure 6-13) is rare in Greenland, know only from three sites.

Figure 6-13: Autumn gentian

<u>Higher reaches of Narsaq Valley and the Kvanefjeld plateau (c. 200 – 680 m altitude)</u>

With increasing altitude different types of dwarf-shrub and lichen-grass-sedge heaths dominates but open rocky terrain, snow beds and smaller fens are also widespread. Herb slopes with high plant species diversity grow along some of the streams.

The dwarf-shrub heath at medium altitude is dominated by Crowberry, Glandular birch, Bog bilberry and Northern willow with Stiff sedge, Northern bent grass and with the herbs Alpine club moss in the lower vegetation layer. Mosses and lichens also cover large areas. One individual of Bog rosemary was found on the Kvanefjeld plateau. This species is very rare in Greenland with only two previous records from South Greenland. On some north facing slopes a snow bed plant community occurs dominated by Dwarf-willow, Hare's-foot sedge, Starwort mouse-ear, Starry saxifrage and Pigmy buttercup. The aquatic plant Common Mare's-tail is found in some of the ponds and smaller lakes on the Kvanefjeld plateau.

Round-leaved orchid - Greenland rarest orchid - has previously been recorded between the existing gravel road and Narsaq River at c. 300 m altitude went unrecorded during the survey in 2014.

Figure 6-14: Lichen-grass-sedge heath on the Kvanefjeld plateau

Upper northern slopes of Narsaq Valley and Lake Taseq (c. 350 – 650 m altitude)

At high altitude on the north facing slope of Narsaq Valley much of the ground is covered with loose stones and rock. This area has very limited plant cover with the most common species being Three-leaved rush, Moss campion, Trailing azalea, Purple saxifrage and Stiff sedge. Locally, Northern green orchid and Small white orchid grow close to streams.

The slopes surrounding Taseq are also mostly without vegetation and has only very few species of vascular plants. In a few places with more even terrain higher plant diversity is found. To the northeast of Taseq the terrain increases gradually in height creating a smooth south facing slope without scree. This area is covered by grasses and sedges as well as many species of herbs, such as Alpine Lady's-mantle, Alpine meadow-rue, Dandelions and Procumbent sibbaldia.

Figure 6-15: Scree on upper eastern slopes of Narsaq Valley towards Taseq

Figure 6-16: The banks of Lake Taseq has few species of vascular plants

6.9. Fauna

The following description of the fauna in the Kvanefjeld area is based on Orbicon /2014b/ and focuses on mammals, birds and fish. These animal groups are often considered good indicators of the overall biodiversity of an area.

6.9.1 Terrestrial mammals

Arctic fox and Arctic hare are the only wild terrestrial mammals in the Study area. Domestic caribou (reindeer) has been introduced to the island Tuttutooq where the population currently number around 300 animals.

Arctic fox *Alopex lagopus* is the only terrestrial carnivore in South Greenland. In spite of massive persecution, it is still common and widespread and has been recorded from the Kvanefjeld area. The Arctic fox is a very opportunistic feeder. In the Study area birds (especially young) probably make up an important part of the diet during summer while fish found along the shore of the fjord are important during winter. Foxes are present in the Study area throughout the year.

Arctic hare *Lepus arcticus* is a relatively uncommon mammal in South Greenland most years but the population show large fluctuations in numbers. It has been recorded in small numbers at high altitude in the mountains surrounding the Narsaq Valley. Little seems to be known about the general life history of Arctic hare in Greenland. However, hares are generally considered resident and sedges, grasses, willow and other plants are believed to be the primary food items.

6.9.2 Marine mammals

17 species of marine mammals, mainly whales and seals, are present in the south-eastern David Strait, off the coast of South Greenland. Most of the whales, and at least one seal species, usually remain offshore and only occasionally enter the fjords. Similarly, occasional polar bears that arrive in South Greenland between February and May with the drift ice (Storisen), rarely make it into the fjord area before they are culled, and are consequently not dealt with here.

Ringed seal (*Pusa hispida*) is generally common in Greenland waters, but less so along the south-western coastline. It is believed to be mainly stationary in South Greenland, where it favours fjords with ice. Ringed seal haul-out and moult exclusively on fast-ice, and they maintain several breathing holes in ice during winter. Ringed seals typically breed at the head of fjords, where fast ice forms during winter. The pups are born in snow dens on the sea ice in March/April. It feeds on a broad range of prey, including fish and crustaceans. Ringed seals are common in the fjords around Erik Aappalaartup Nunaa, particularly in Nordre Sermilik north of the peninsula, where they probably also breed.

Ringed seals are subject to large-scale unregulated hunting and are regularly on sale at the local market “Brættet” in Narsaq. It is listed as “least concern” on the provisional Greenland Red List of threatened species.

Hooded seal (*Cystophora cristata*) is a large seal. During the summer months, small numbers of hooded seals are regularly encountered in the fjords at Erik Aappalaartup Nunaa where they feed mainly on larger fish, such as Atlantic cod, Greenland halibut and in particular redfish caught at large depths (down to 800 m or even deeper). Hunting of Hooded seal is unregulated in Greenland. It is listed as "Least concern" on the provisional Greenland Red List of threatened species.

Harp seal (*Phoca groenlandica*) is a common non-breeding visitor to Greenland fjords during the summer months. In late autumn – early winter, the harp seals leave Greenland waters again and return to the breeding grounds.

Harp seal is the most numerous seal species in South Greenland fjords during summer, when it penetrates deep into the fjords. During this time of the year, harp seals typically form feeding groups of 5 – 20 animals, which mostly forage on capelin. It is also common in the fjords at Erik Aappalaartup Nunaa from May until autumn, and is regularly on sale at the local market "Brættet" in Narsaq. The hunting in Greenland is unregulated. It is listed as "Least concern" on the provisional Greenland Red List of threatened species.

Minke whale (*Balaenoptera acutorostrata*) is common along Greenland's south and west coasts. It arrives at South Greenland in spring and early summer, from wintering grounds in the Atlantic Ocean, and leaves Greenland again in November.
It is a regular visitor to the fjords of southern Greenland, and within the study area it sometimes occurs at the Qaqortup Ikera/Julianehåbsfjorden and in Qaqortup Imaa where it is hunted. The hunting of minke whales in Greenland waters is regulated. It is listed as "Least concern" on the provisional Greenland Red list of threatened species.

Fin whales (*Balaenoptera physalus*) are summer and autumn visitors to South Greenland, occurring between June and October. They usually remain offshore, along edges of banks, where they feed on krill and small schooling fish. However, it is also a regular visitor to the fjords of South Greenland, and within the study area it sometimes occurs at the Qaqortup Ikera/Julianehåbsfjord, and occasionally even in Qaqortup Imaa where it is hunted. The hunting of fin whales in Greenland waters is regulated. It is listed as "Least concern" on the provisional Greenland Red list of threatened species.

In recent years the population of humpback whale (*Megaptera novaeangliae*) in Greenland waters has increased significantly. It is now quite common in some fjords of West Greenland during summer where it feeds on krill and small fish e.g. capelin and sand eels. In South Greenland it is less numerous but in some years small numbers occur in the fjord. In 2008 at least three different animals were observed at Narsaq. Subsistence harvest has recently been permitted again in Greenland.

Figure 6-17: Humpback whale in Bredefjord in June 2008

Harbour porpoise (*Phocoena phocoena*) is a small toothed whale that occurs throughout the year in the waters of South Greenland. It is generally quite common in Greenland waters, but most porpoises remain offshore, with only few penetrating into the fjords. Harbour porpoises feed on fish in the upper water layers.
Hunting in Greenland of the species is unregulated. It status on the provisional Greenland Red list of threatened species is not assessed due to lack of data. Little exact knowledge is available about its status in the fjords around Erik Aappalaartup Nunaa, but it is probably a relatively common visitor in small numbers.

6.9.3 Birds

The terrestrial and freshwater bird fauna in South Greenland is relatively poor in species with only five species of passerine birds being widespread and common in this part of Greenland.
The seas and coastal areas have a richer bird fauna, both with respect to species numbers and number of individuals. This includes birds that breed in Greenland, but also large numbers of birds from other breeding sites in the northern Atlantic, that overwinter off the coast of West- and South Greenland. Most seabirds that breed in Greenland are colonial breeders, but no large colonies are known from the south coast of Greenland between Ivituut and Nanortalik, which includes the study area and neighbouring waters.

A very important wintering area for sea birds has been identified off the coast of South Greenland. This area attracts large numbers of Brünnich's Guillemot, Common Eiders and different species of gulls from Northern Greenland (eiders and gulls) and Iceland and Svalbard (guillemots).

The bird species discussed below are the ones believed to occur regularly on and around the Erik Aappalaartup Nunaa peninsula (breeding and/or wintering):

Mallard (*Anas platyrhynchos*) is the only dabbling duck that regularly breeds in South Greenland. It is a widespread and relatively common breeding bird at lakes and shallow coasts. In South Greenland, the Mallard is mainly sedentary, but moves to the outer coast in winter. Mallards are regularly observed throughout the Erik Aappalaartup Nunaa peninsula, mostly along the coast. It is likely that a few Mallards breed at wetlands in the area.

Common Eider (*Somateria mollissima*) has a widespread, but fragmented breeding population in Greenland, typically breeding on small islets and skerries along the coast No breeding colonies of eiders are known along the shore of the Erik Aappalaartup Nunaa peninsula but large numbers winter off South Greenland. In addition several hundred eiders regularly spend winter on the fjords at the Erik Aappalaartup Nunaa peninsula. Usually, most are seen in Tunulliarfik/ Skovfjord south of the peninsula, where they feed on mussels. The Common Eider is listed as “Vulnerable” in the regional Greenland Red List because it has declined dramatically during the last 50-100 years due to intensive, unsustainable hunting.

Red-breasted Merganser **(***Mergus serrator*) is a rather common species along the Greenland south and west coasts and part of the east coast. It breeds at lakes and shallow fjords and bays. They feed primarily on fish. Small flocks are quite common in the fjords around the Erik Aappalaartup Nunaa peninsula and on Lake Ilua. It is likely that a few occur along the shores of the peninsula – particularly in the Ilua area, but definite proof is lacking.

Ptarmigan (*Lagopus mutus*) is widespread and common throughout Greenland, but it is subject to marked annual fluctuations in numbers. On the Erik Aappalaartup Nunaa peninsula, it mainly occurs in up-land areas where it feeds on plant material.

White-tailed Eagle is confined to Greenland’s south and west coasts north to Upernavik. In recent years the population has increased and now numbers 150-200 pairs. But since the breeding population is still relatively small it is listed as “vulnerable” on the regional Greenland red list.

White-tailed Eagles are mainly found in coastal areas where they feed on fish. The nest is typically placed on ledges on steep cliffs. The adults normally remain within the breeding areas throughout the year while the young birds move to the outer coastal areas during winter. Breeding White-tailed eagles are present at the nest from around

1. March to early September. Egg laying typically takes place at the beginning of April. During the breeding period, eagles are known to be very sensitive to disturbance.

White-tailed Eagles are commonly observed at the Erik Aappalaartup Nunaa peninsula. However, no signs of breeding have been observed near the proposed mine sites or near the port site.

The Peregrine Falcon is quite common in South Greenland where it typically nests on ledges on steep cliffs in the inland. One pair regularly breeds on a ledge on a steep mountain side near the mouth of Narsaq River. Peregrines feed mainly on medium-size birds. It is a migrant that arrive in May and depart in August-November. It is listed as “least concern” on the Greenland Red List of threatened species.

Gyrfalcon occurs throughout Greenland, but is nowhere common. It nests on ledges on steep cliff sides and primarily feeds on large birds such as gulls. The size of the Greenland breeding population is estimated to c. 500 pairs and due to the small population it is listed as “Near Threatened” in the regional Greenland red list. No breeding sites of this falcon are known from the Study area but single birds have been observed at Killavaat Alannguat a few times during field work between 2007 and 2014.

Figure 6-18: Young Gyrfalcon at Narsaq

Ringed Plover breeds almost all over Greenland, but is most common in High Arctic areas. It typically breeds on sand beaches and gravel fields along the coast. It arrives to Greenland in May and the last birds leave in early October. One, perhaps two pairs of Ringed Plovers breed regularly at Narsaq River delta.

Purple Sandpiper is a relatively common and widespread wader in Low Arctic Greenland. It is protected in Greenland and breeds in shrub heath along the fjords or near the coast. Outside the breeding season, it occurs mostly along the coast, where it forages in the inter-tidal zone. Small numbers of this wader might breed on the Erik Aappalaartup Nunaa peninsula, although definite proof is missing. The nest is usually found in the dwarf-shrub heaths.

Iceland gull, Glaucous gull, Great Black-backed gull, Lesser Black-backed gull, Hering gull and Black-legged Kittiwake occur in the fjords around the Erik Aappalaartup Nunaa peninsula and have their nearest breeding sites in the glacier fjord at Akullit Nunaat, north of the central parts of Brede Fjord. Iceland gull and Glaucous gull are by far the most common gulls the Study area. Lesser Black-backed gull and the kittiwake are migratory and leave the Greenlandic fjords in winter.

Black Guillemot is a widespread auk in Greenland, which breeds along most of the coasts in South Greenland. It is usually strictly sedentary, leaving the breeding areas only when forced away by ice. It feeds mostly on small fish. This auk is not breeding at the coast of the Erik Aappalaartup Nunaa peninsula, but several small colonies are found in neighbouring fjords.

Brünnich's Guillemot is by far the most common and widespread auk in Greenland. No breeding colonies are found in the fjords near Narsaq but single birds or small flocks are sometimes observed in the fjords around Erik Aappalaartup Nunaa during winter. It is listed as "vulnerable" on the provisional Greenland Red List of threatened species due to the large decline of the Greenland breeding population.

Snow bunting, Common wheatear, Redpoll and Lapland bunting are common breeders in the Narsaq Valley and at Kvanefjeld. These birds are common and widespread throughout south and west Greenland. Raven is probably also breeding in small numbers but no definite information is available.

6.9.4 Fish

The Arctic char (*Salvelinus alpinus*) is a habitat generalist found in streams, at sea and in all habitats of oligotrophic lakes throughout Greenland. Arctic char life histories are very variable, both within and between localities. The Arctic char population in Greenland rivers typically consists of resident fish (non-anadromous) and anadromous fish that migrate to the sea during summer when they have reached a certain age.

The distribution and general biology of the Narsaq River population of arctic char was studied in 1981. Orbicon has subsequently reassessed the distribution in Narsaq River by means of electrofishing and determined the distribution in the Ilua River. This shows that Arctic char is very common in the lower part of the Narsaq Rivers but are lacking from the lakes connected to the river including Taseq. Another char population occurs in the Ilua river system (Figure 6-19). Char appear to be lacking in the other streams and lakes of the Erik Aappalaartup Nunaa peninsula.

The Arctic char population in the Narsaq and Ilua Rivers are believed to be mainly anadromous but a resident non-anadromous population coexists with seagoing char in the rivers.

The seagoing Arctic char in Narsaq River start to migrate into the fjords when around 4 years old and c. 15 cm long. The seaward migration probably starts at ice break-up in the river with the fish returning from late July.

Figure 6-19: Distribution of Arctic char in rivers, streams and lakes on Erik Aapplaartup Nunaa peninsula

The Arctic char in Narsaq River typically reached sexual maturity when they were around 5 years old that is after their first sea run. Spawning in Narsaq River is from late August to beginning of October. Most spawn in the main stream on sites with gravel bottom, 30-35 cm depth and modest currents. The female dig a depression before laying the eggs and cover the eggs with gravel by tail beats after fertilization. The eggs hatch the following spring.

During winter, most of the Greenland’s rivers are covered by thick ice and the water flow is very restricted. This time of the year, the char spend in the deepest parts of the rivers. In Narsaq River, the chars probably winter in the deepest sections of the river near the outlet. In spring, the fish spread out to utilize all water-covered areas below the rapid c. 5 km upstream.

Studies in the Narsaq River have shown that the smaller fish mainly eat chironomid larvae while the larger fish mostly feed on chironomid pupae and adults. Cannibalisms probably also takes place.
Chars generally have a very slow growth rate while in rivers where the main food is insect larvae. During winter, they probably eat nothing. Stationary fish will therefore typically grow less than 2 cm per year and reach a maximum length of around 25 cm.
The char that move into saltwater during summer fed on planktonic amphipods, copepods and fish, and their food intake rates and growth is much higher than in resident char. The 1981 study found that the average length of seagoing fish was 23 cm, 28 cm and 33 cm for 4, 5 and 6 year old fish, respectively.

In October 1981, at a time when all the seagoing fish were believed to have returned to the river, an attempt was made to assess the number of char in Narsaq River /Grønlands Fiskeundersøgelser 1982/. At this time some of the shallow parts of Narsaq River were dry and the char population limited to the main stream in an area covering 20,800 m^2. The char population was estimated at 31,000 fish of which 8,300 was three years or older (that is potentially seagoing) and the stock of anadromous char in August was estimated to be 1,200 fish. The char stock in Narsaq River todays is believed to be of the same order of magnitude.

The Arctic char is the only fish known to occur in freshwater in the Narsaq – Kvanefjeld area. This is in contrast to the fjord where many fish species occur but generally, little is known about species, which are not utilized commercially or in connection with local subsistence fishery. The following accounts therefore focus on key fish species that are utilized in the fjords at Narsaq.

Atlantic cod (*Gadus morhua*) is currently quite common in fjords around the Erik Aappalaartup Nunaa peninsula but throughout the 20th century, it fluctuated widely in numbers and distribution due to climatic changes.

Lumpsucker (Cyclopterus lumpus) spends most of the year in deep offshore waters but in the late winter, it migrates to shallow water to spawn and it is then common along the coasts of the fjords in the Narsaq area. In recent years lumpsucker fisheries has become increasingly important in the fjords at Narsaq. It is mainly the females, which are fished for the roe.

Greenland cod or uvak (*Gadus ogac*) occurs along the coasts and fjords north to Upernavik and is common in the fjords around the Erik Aappalaartup Nunaa peninsula. In commercial fisheries, it is considered inferior to the Atlantic cod, but it has some subsistence importance.

Spotted wolffish (*Anarhichas minor*) probably occurs in all deep parts of the fjords around the Erik Aappalaartup Nunaa peninsula. Its abundance has decreased in recent years but it still has considerable subsistence importance.

Atlantic salmon (*Salmo salar*) occurs along Greenland's coast from August to about November, when on foraging migration from the American and European continents. In some years the Atlantic salmon is quite common in Narlunaq Skovfjord, and in Qaqortup Ikera/Julianehåbfjord and small numbers probably also enter the fjords around the Erik Aappalaartup Nunaa peninsula.

Capelin (*Mallotus villosus*) is an ecological key species because of its role as an important food resource for larger fish, seabirds and marine mammals. It is also exploited both commercially and for subsistence fishery. Capelin is believed to common along the shore of the Erik Aappalaartup Nunaa peninsula, although no exact data is available.

Redfish (Sebastes spp.) are quite common in the deep parts of the fjords that surround the Erik Aappalaartup Nunaa peninsula, although no exact data is available.

6.10. Threatened species

Among the animals and plants recorded from the Erik Aappalaartup Nunaa peninsula five species of birds and one orchid species are listed as "Vulnerable" or "Near threatened" on the regional Greenland Red List of threatened species /Boertmann 2007/ see Table 6-7.

Species	Status in study area	Main habitat	Greenland red-list status	Importance of Erik Aappalaartup Nunaa peninsula to population
Common Eider	Visitor	Outer coast, fjords	Vulnerable (West Greenland population)	Low
Gyrfalcon	Visitor	Inland, coast	Near threatened	Low
White-tailed Eagle	Potentially part of territory	Coastal, inland	Vulnerable	Medium
Black-legged Kittiwake	Visitor	Offshore, coastal, fjords	Vulnerable	Low
Brünnich's Guillemot	Visitor	Coastal, offshore, fjords	Vulnerable	Low
Round-leaved orchid	Recorded once some years ago	Dwarf shrub heath close to stream (?)	Vulnerable	Unknown

Table 6-7: Threatened species recorded from the Erik Aappalaartup Nunaa peninsula

6.11. Protected areas

No protected areas are designated close to the Erik Aappalaartup Nunaa peninsula – see Figure 6-20.

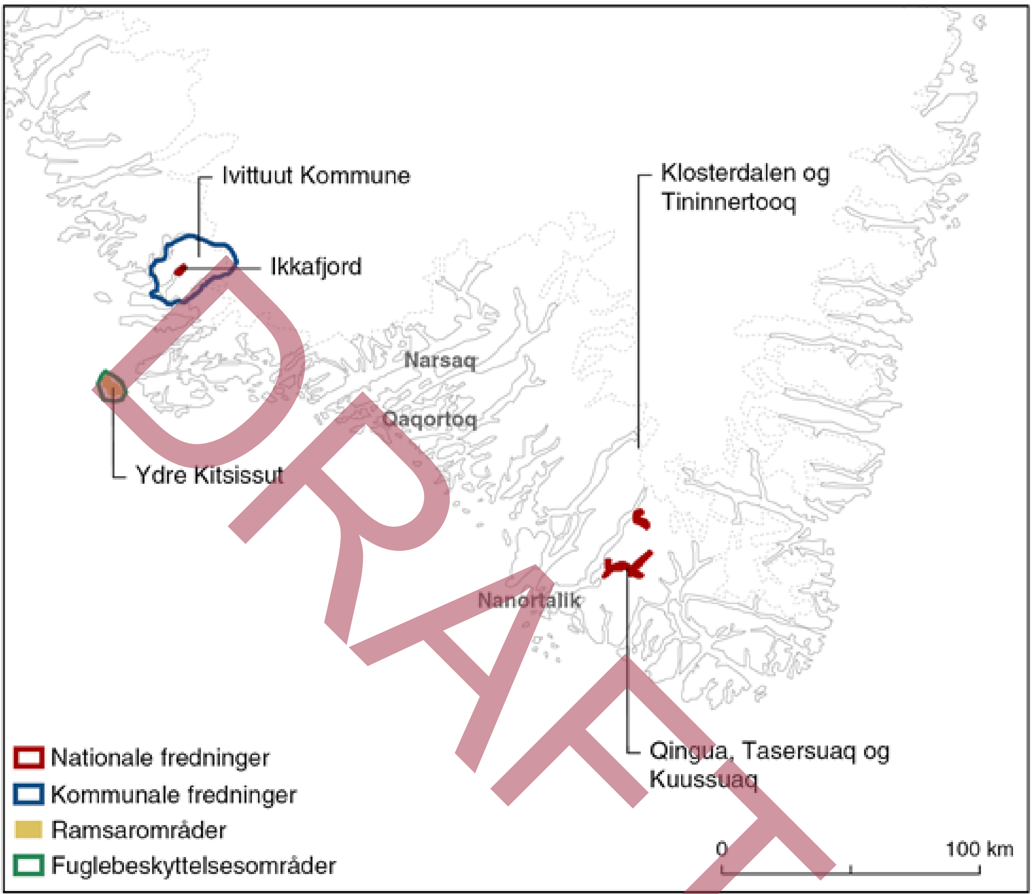

Figure 6-20: Protected areas in South Greenland. Areas marked with red are protected according to national legislation. Areas marked with blue are protected according to local legislation. Areas marked with yellow are Ramsar Sites. Areas marked with green are Important Bird Area (IBA) (from Boertmann 2005)

6.11.1 Sea bird colonies and wintering areas

A few small sea bird colonies are found in the glacier fjords at Akullit Nunaat, to the north of the central part of Brede Fjord. The sea birds breeding at the colonies are black guillemot and different gull species /Boertmann 2004/. A few of these birds might occasionally forage in the fjords that surround the Erik Aappalaartup Nunaa peninsula.

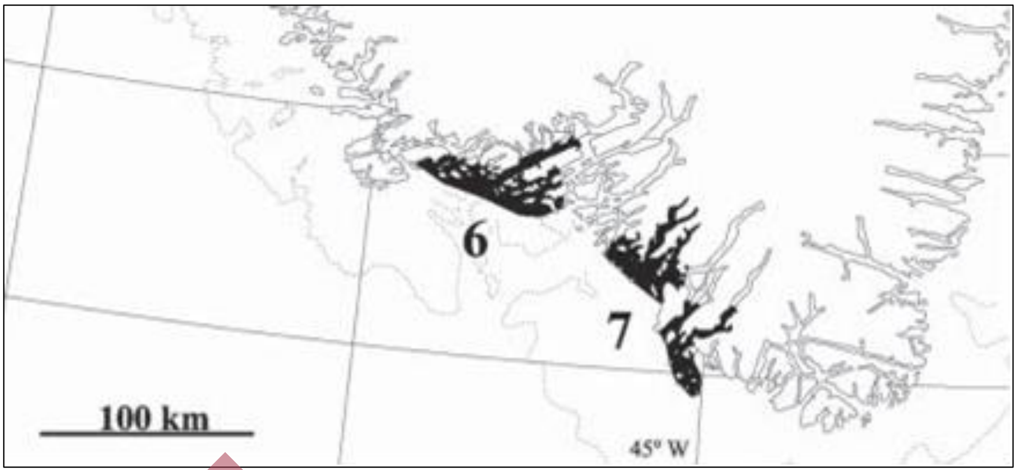

Figure 6-21: Important areas for wintering sea birds off South Greenland and in neighbouring fjords (dark areas). The northern part (area 6) is particularly important to Common Eider, Harlequin Duck and Brünnich's Guillemot while the southern part (area 7) is mainly important to Common Eider. From Boertmann et al. 2004

The sea off South Greenland is a hot spot for wintering sea birds /Boertmann *et al*. 2004/. Most of the wintering sea birds remain off shore, but some move into the fjords and are recorded in the fjords at Erik Aappalaartup Nunaa peninsula (Figure 6-21). The majority of these are Common Eider and Brünnich's Guillemot.

6.12. Socio and economic setting

Kvanefjeld is located around 8 km north-east of Narsaq. This small town with around 1.600 inhabitants is situated at the southern tip of the Erik Aappalaartup Nunaa peninsula and is the nearest town to the project. Qaqortoq (c. 3.000 inhabitants) some 28 km south south-east of the Kvanefjeld is the second-closest town.

Other settlements around the Kvanefjeld is a former sheep farm – now cattle farm - and five summerhouses in the lower part of the Narsaq Valley. Another sheep farm is located at Ipiutaq some 15 km east of Kvanefjeld.

6.12.1 Local use of the Narsaq - Kvanefjeld area

The following is based on a local use study carried in 2011 and 2015 /Orbicon 2014c/. Hunting and fishing are important livelihood activities in the Narsaq area, and provide an important source of income and subsistence to many families. The majority of local fishing vessels are small-scale operations in the fjords around Narsaq. Around 30 persons in Narsaq have fishing as their primary source of income. In addition, 10-15 people have a commercial licence and supplement their income with fishing. In most years Atlantic cod, redfish, Arctic char and wolfish are the most significant fish species. In late winter and spring lumpsucher fishing for the roe is very important.

Although less significant as a commercial activity, seal hunting is an important source of income, mainly through private sale and distribution of meat, as well as subsistence for many families in Narsaq. Around five persons are full time seal hunters. Seals are hunted in the fjords around Narsaq, in particular in Bredefjord and Nordre Sermilik. The most important species is Ringed seal, but during the summer months, many Harp seals are also shot.

During winter Ptarmigan and hare hunting is popular among many citizens of Narsaq. This is primarily recreational hunting that takes place high in the mountains north-east of Narsaq.

Gem fossicking for the creation of commercial jewellery or personal souvenirs takes place throughout the Kvanefjeld area. The semi-precious stone “Tuttupit” is by far the most popular, and is predominantly found on the Kuannersuit itself. One person in Narsaq has currently a small-scale mining permit to collecting stones in the Kvanefjeld area. An additional 4 to 5 people sell stones collected elsewhere in the area, either polished into jewellery or as raw rocks to collectors or jewellers.

The single farm in Narsaq valley stopped sheep rearing in 2014 to focus on cattle breeding. It is expected that the farm will close when the construction of the mine commences.

Tourism in and around Narsaq is quite limited. Most tourists usually arrive at Narsaq as part of a South Greenland tour, and the focus of the visit is activities within the town. However, some tourists come on their own, stay at the small hotel in town and visit the Narsaq valley.

Angling for Arctic trout in Narsaq River, berry picking in autumn and hiking in the mountains around Narsaq is very popular among Narsaq citizens.

6.12.2 Archaeology and cultural heritage

The Greenland National Museum and Archives have investigated the archaeological interests in the territory around Kvanefjeld on behalf of GME. The following account is based on their study reports /Kapel 2009, Myrup 2010/.

A large number of archaeological sites are found along the shore of Erik Aappalaartup Nunaa peninsula (Figure 6-21). The majority of these are Inuit remains stemming from the Thule culture (1300 A.D.-Historical times) and historical Inuit settlements. These include traces of permanent winter settlements in the shape of turf-wall houses and tent foundations, which were used seasonally.

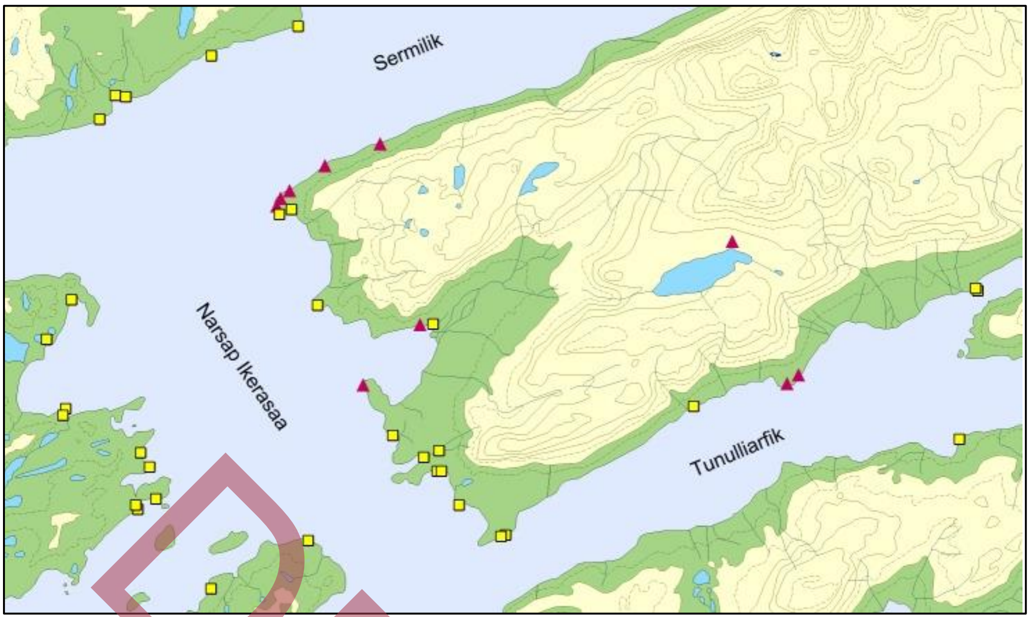

Figure 6-22: Archaeological sites at Narsaq/Kvanefjeld (yellow squares and red triangles). The red triangles are sites that were discovered during the 2010 field survey

Norse settlement established 982- c.1500 included a large farm and a church at Narsap Ilua/Dyrnæs just north of the mouth of Narsaq River. Today, a ruin group consisting of 18 individual constructions (including remains of several stone buildings with surrounding turf walls).

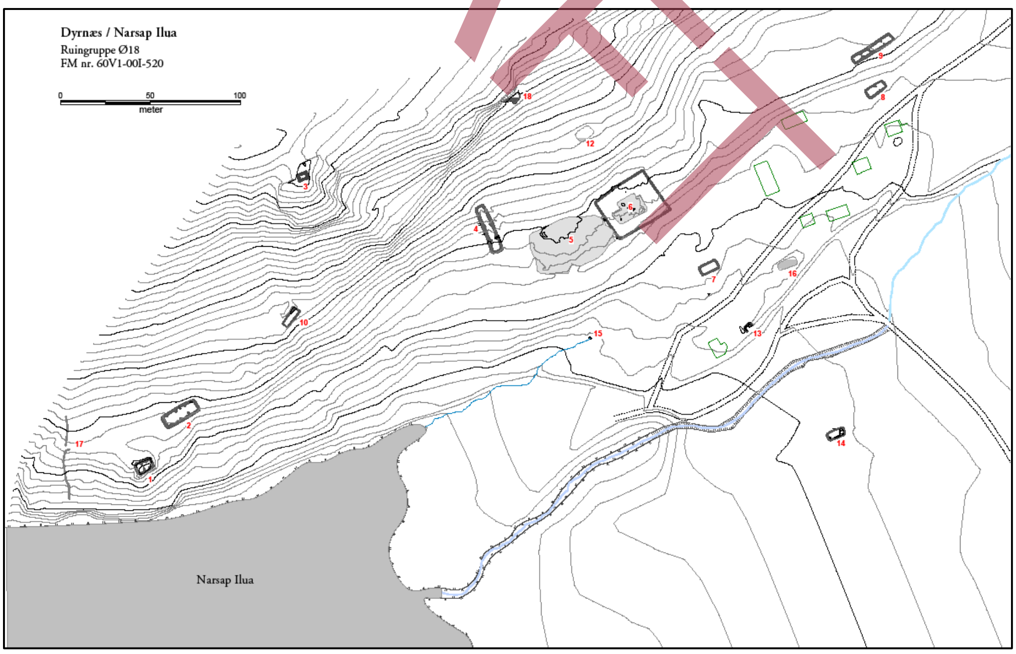

Figure 6-23: The ruin group at Dyrnæs just north of the mouth of Narsaq River

7. IMPACT ASSESSMENT METHODOLOGY

This section considers the methodology used to assess, and where possible, mitigate potential environmental impacts from the proposed Project. As stated in the BMP (now EAMRA) guidelines focus is on identifying potential pollution and disturbance impacts. The identification of impacts is based on the source (from the mine project), a pathway and a receptor. The main receptors are considered to be land, air and water and the associated flora and fauna of these elements. Generally, human receptors are not discussed due to the minimal number of people in the Study area (other than the staff of the Project) and the significant distance to the nearest town (8 km). Exceptions are the potential impact from noise, dust and radioactivity due to project activities.

Consequently the impact assessment considers:

- the activities related to the proposed Kvanefjeld Project that are the source of emissions, disturbances or other effects;
- the likely emissions, disturbances or other effects;
- the receptors that can be impacted by these effects;
- the pathways between the sources and the receptors;
- the potential impact to the receptors and how they may vary for the different stages of the mine life; and
- ways to mitigate the impacts.

This has been done in the following way:

- <u>Mine activities that could potentially cause an impact</u> have been identified from the project description of the new mine (Chapter 5). This was done by systematically looking at each project element or activity in all stages of the mine life (construction, operation, closure and post-closure).

- <u>The potential impacts – emissions, disturbances or other effects – induced by mine activities</u> were identified through consideration of the information presented in Chapter 8, 9 and 10.

- <u>The receptors considered susceptible to impact</u> were sourced from the environmental baseline description in Chapter 6.

- <u>The pathways between the sources and the receptors</u>

Overall there are two types of impacts to consider;

(1) Direct impacts where the source can immediately effect the receptor e.g. noise (such as blasting) at the mine site affecting birds and mammals; and

(2) Indirect impacts which occur when one medium is affected which then affects the eventual receptor e.g. contamination of river which eventually impacts upon fish and seals in fjords.

The following chapters identify mine activities that could lead to a potential impact of the physical, air, water and natural environment. If a mine activity can potentially impact both the physical and natural environment it is discussed under each of these headings.

For each impacts there is first a brief description of the type of potential impact (e.g. noise from blasting, land clearance etc.). This is followed by a description of the potential receptors of the impact (e.g. noise from blasting can scare Arctic hare away from the Study area). The passage is completed by an assessment of the severity of the impact to specific receptors. If possible, proposals to mitigation are given.

When applicable, the information is then summarized in an Impact Assessment Table (see Table 7-1).

Impact during phases of the life of mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Short term	Medium	Definite	High
Mitigation measures • During detailed design and sighting of infrastructure avoid as far as possible areas with continuous vegetation. This can be done by fine-scale mapping of sensitive areas around the power plant, access roads and port.				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Short term	Low	Possible	High

Table 7-1 In this example, the dark shaded bar would indicate that the impact is mainly applicable to the construction phase of the mine project with minor applicability during operation (light shading) and no applicability at closure and post-closure (no shading). Without mitigating the activity will have an impact on the Study area, short term duration and have Medium impact on the environment. It is further definitive that the impact will take place and the confidence of this assessment is high i.e. it is based on robust data. With mitigating in place the activity will have only an impact on the Project footprint, short term duration and have Low impact

The impact table identifies (1) the <u>phase of the mine operation</u> in which the impact could occur, (2) the <u>spatial extent</u> (size of area) of the impact, (3) the <u>duration</u> of the impact, (4) the <u>significance</u> to the environment, (5) the <u>probability</u> that the impact will occur, and (6) the confidence by which the assessment has been made. This is followed by a list of proposed mitigating measures (if relevant) and a bar with an assessment of the spatial extent, duration, significance, probability and confidence when mitigation has been taken into account.

For the purpose of this EIA study the following terminologies are used in the Impact Assessment Table:

Spatial scale of the impact:

- *Project footprint*; that is within the footprint of the mine project, i.e. confined to the activities per see, the infrastructure itself and the very close vicinity hereof (few hundreds of meters away);
- *Study area*; within a few km from the activity (about 0- 5 km);
- *Regional*; within a distance up to 50 – 75 km from the project area;
- *Global.*

Duration (reversibility):

Duration means the time horizon for the impact. The term also includes the degree of reversibility, i.e. to what extent the impact is temporary or permanent (i.e. irreversible).

- *Short term;* the impact lasts for a short period without any irreversible effects;
- *Medium Term;* the impact will last for a period of months or years but without permanent effects or definitely without irreversible effects;
- *Long term;* the impact will be long lasting (> 15 years) e.g. cover the entire lifetime of the operational phase. Permanent and close to irreversible effects might be ascertained;
- *Permanent;* the impact will last for many decades and have irreversible character.

Significance of the impact:

- *Very low;* very small/brief elevation of contaminants in local air/terrestrial/freshwater/marine environment by non-toxic substances (when concerning emissions) and decline/displacement of a few (non-key) animal and plant species from mine site and/or loss of habitat in the mine area (when concerning disturbance);
- *Low*: small elevation of contaminants in local air/terrestrial/freshwater/marine environment by non-toxic substances and/or very small temporary elevations of toxic substances (when concerning emissions) and decline/displacement of key animal and/or plant species and/or loss of habitat in the Study area (when concerning disturbance);
- *Medium*: some elevation (above baseline, national or international guidelines) of contaminants in local or regional air/terrestrial/freshwa-

ter/marine environment including toxic substances or decline/displacement of key animal and/or plant species and/or loss of habitat at local level;

- *High*; significant elevation of contaminants (above baseline, national or international guidelines) in local and regional air/terrestrial/freshwater/marine environment including toxic substances or decline/displacement of key animal and/or plant species and/or loss of habitat at regional level.

<u>*Probability that the impact will occur:*</u>

- *Improbable;*
- *Possible;*
- *Probable;*
- *Definite.*

<u>*Confidence that the assessment is correct:*</u>

- *Low* - data are weak;
- *Medium* - data from Greenland or other parts of the Arctic (in particular Canada) points to the conclusion;
- *High* – data from the Study area or neighbouring parts of South Greenland are conclusive.

8. IMPACT AND MITIGATION IN THE CONSTRUCTION PHASE

The Construction phase is planned for ~3 years. During this phase all the construction works and installations are completed, which enable the production and export of the mine products. The construction works include the following activities:

- Preparation of the pit area (including pre-stripping);
- Road building (main access road, local roads at port and haul roads at mine sites);
- Construction of new port facilities;
- Installing of Concentrator including primary crusher, ball mill and power plant;
- Construction of Refinery and acid plant;
- Preparation of tailings facilities including building of lined embankments;
- Building of pipelines for tailings slurry and water;
- Temporary and permanent quarters and facilities for staff; and
- Supporting facilities i.e. water supply facility, wastewater facility, etc.

The works will begin at the new port site, with the establishment of a landing site, accommodation facilities and storage. It will immediately proceed with the establishment of the new road to the mine area. This will be followed by the construction of the power plant and the establishment of the processing plants, pipelines, and storage at the port, export wharf etc.

This chapter contains the impact assessment of the construction works and is divided into six sections:

- Section 8.1 evaluates the consequences of the construction works on the **Physical environment**, that is landscape alterations and erosion but also noise and light;
- Section 8.2 focuses on the impacts the construction works might have on the **atmospheric setting** in terms of airborne pollution (dust) and climate change (from greenhouse gasses);
- Section 8.3 looks at the potential impact from construction works on the **water environment** (lakes, streams, rivers and the fjord) in terms of changes of flow pattern and water chemistry;
- Section 8.4 looks at the potential impacts on the **living environment** (animals and plants) of the study area and their habitats during construction. This assessment looks at both the potential direct disturbances and loss of habitat;
- Section 8.5 deals specifically with the **waste issue** including the potential impact of hazardous waste from the construction works;
- Section 8.6 discuss and assess the risk of introducing invasive non-indigenous species with ballast water; and
- Section 8.7 contains an evaluation of any impact on **land use** and **cultural heritage** sites.

8.1. Physical Environment

This section deals with the physical changes to the landscape due to the construction of the mine. This includes direct physical alterations, which may result in a visual impact or indirect impacts, e.g. alterations of the surface of the landscape. Some impacts will be temporary, in the sense that they are only relevant during the construction phase, while others will be permanent. This section also covers the potential erosion caused by construction works and any impacts from noise and light during the initial phase of the project.

8.1.1 Stripping of the mine pit area

The top rock layer of the outcrop at Kvanefjeld is removed during the Construction phase (pre-stripping). The material – which has to low concentrations of the minerals that are sought for – is deposited as a rock pile next to the pit. These changes to the topography are permanent.

Changes to the topography due to pre-stripping (and the subsequent mining) at Kvanefjeld and the deposition of waste rock will have little or no visible impact from Narsaq town or Narsaq Valley. The significance of the permanent changes to the topography is therefore considered Low.

Impact during phases of the life of mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Low	Definite	High
Mitigation measures • Limited mitigation possible; however the aesthetic impact can be lowered by planning the pre-stripping to blend as far as practical with the surrounding landscape				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Low	Definite	High

Table 8-1: Assessment summary of pre-stripping

8.1.2 The use of Taseq and adjacent pond for tailings deposition

A lined permanent embankment will be constructed across the outlet of Taseq Lake and between Taseq and the pond to the northeast of the lake. The water bodies behind the embankments will be used for deposition of flotation tailings (Taseq) and chemical residue (the pond northeast of Taseq). The height of the embankments and the size will increase during mine life. Diversion channels will be constructed along the shore of both tailings ponds. Floating decant barges and a laydown area will be constructed. The changes to Taseq and the upstream pond are permanent while the decant barges will be removed at mine closure.

Situated high in a narrow valley behind Talut Mountain, Taseq Lake is not visible from Narsaq or from most of the valley. Even after constructing of the embankments the tailings facilities will have little or no visual impact from town or the valley. The embankments and the diversion channels will be visible in the near field but since they will be covered by local materials (rock and gravel) the visible impact is limited. Over time the embankments will probably also be more or less covered by natural vegetation which will further reduce the visual impact.

Overall the use of the Taseq basin is assessed to have Low impact on the landscape (note that the impact on water chemistry and freshwater ecology is dealt with in Chapter 10.

Impact during phases of the life of mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Low	Definite	High
Mitigation measures • Limited mitigation is possible other than planning the tailings embankments to blend as far as practical with the surrounding landscape				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Low	Definite	High

Table 8-2: Assessment summary of landscape changes when using Taseq basin for tailings deposition

8.1.3 Landscaping for other mine facilities and infrastructure construction

The construction of other mine facilities and related infrastructure facilities will require some re-profiling of the landscape. The most important will take place where the two processing plants and port are established. A new 13 km road will also be constructed between the port and the two processing plant sites and a service road will connect the tailings management facilities at Taseq basin with the two processing plant sites. Two pipelines and a new service road will connect the chemical plant with the tailings facilities. Most of the changes to the topography are permanent.

Some of the facilities such as the processing plants will be widely visible from the Narsaq Valley and from the fjord (but not from Narsaq town). Also the new port and road between the port and the mine area will be visible from the valley but only to a very limited degree from Narsaq town. Following the decommissioning of buildings and machines at mine closure natural vegetation re-growth will take place through natural plant succession and over time restore the plant cover.

Overall the impact on the landscape will be "medium" because – although several facilities will be visible in the Narsaq Valley - the footprint of the project is relatively small compared to the surrounding area. Also there is no current or future expected competing land use.

Impact during phases of the life of mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Medium	Definite	High
Mitigation measures • Limited mitigation is possible, however the aesthetic impact can be lowered by planning roads to blend as far as practicable with the surrounding landscape				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Medium	Definite	High

Table 8-3: Assessment summary of re-profiling of the landscape for mine facility and infrastructure construction

8.1.4 Erosion

In this context erosion is defined as transport of soil, sand and gravel by the forces of water, ice or wind. A number of construction activities during operation can potentially lead to erosion. These are:

- Preparation of construction sites;
- Construction of roads between port and mine area;

- Pipeline alignments;
- Stripping of the mine pit area;
- Redirection of drainage;
- Blasting of rocks to provide granular material for construction - for example for the tailings embankments; and
- Construction of port.

Generally erosion is not expected to be an issue since most construction works will take place in areas with consolidated rock. Limited local erosion could potentially take place where the Refinery, Port and road between mine area and port is constructed. By taking erosion into account when selecting construction methods and routing of the alignments no significant erosion is expected.

In conclusion with these approaches and methodology the potential impact from erosion is assessed as *Low*.

Impact during phases of the life of mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Low	Definite	High
Mitigation measures • Take erosion into account when selecting construction methods and routing of the alignments				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Low	Definite	High

Table 8-4: Assessment summary of erosion during construction phase

8.1.5 Noise

During the construction phase significant noise will be generated by:

- mobile equipment in connection with excavation and construction of the port, the access roads and pipelines, processing plants and mine area facilities, and the pre-stripping of the pit area;
- drilling and blasting in the port area and the mine area;
- transport of supplies and machinery from port to the plants and mine area; and,
- ship transport and ships at wharf.

The noise load from land sources will be temporary in each working area. Some underwater blasting is expected in connection with the construction of the wharf for the new port. Limited blasting will also take place in the mine area. Grading will take place to prepare level surfaces for lay down areas, access road right-of-way, and during construction of haul roads. Construction of the access road to the mine area will be of short duration in each location, as the construction process moves from the port towards the process plant area.

Ship traffic associated with the construction will increase noise levels at Narsaq. But due to the low speed and the new ports distance from town the average noise contribution from ship traffic to the port will be below the 35 dB(A) guideline for night time noise in residential areas.

Overall the noise impact in the construction phase is expected to be about the same or less than the noise loads which have been calculated and modelled for the Operational phase. These results are presented and discussed in section 9.3.1

8.1.6 Light

The construction activities will take place day and night, year around. In dark periods the construction areas will be illuminated. The consequences of such “ecological light pollution” where artificial light alters the natural light regimes in ecosystems are generally little known. The serious consequences of light in otherwise dark areas, such as the attraction of migratory birds with the risk of collisions with tall lighted structures are well described. But since artificial light will mainly be needed during the winter months when almost no bird migration takes place this will not be an issue at Kvanefjeld.

8.2. Atmospheric setting

8.2.1 Dust and air emissions

Emissions of dust and gaseous air pollutants during the Construction phase are mainly expected from the following activities:

- Blasting and excavation at the new port, pit site, main access road, pipelines and process plants; and
- Emissions from ships, mobile equipment and power generation.

Dust emissions from construction activities will be local and temporary. A large part of the mechanically generated dust is expected to be of relatively large particle size, and falls quickly to the ground. Construction of the access road will involve a steadily moving construction process, and the associated dust emissions will move with the progressing construction. This limits the amount of time that any particular area is exposed to the dust from the active construction area.

By adopting the Best Available Technique (BAT) principle, particular emissions from the power plant, trucks and other sources during construction will be kept to a minimum and these emissions are not considered to have a significant impact on the air quality in the area.

Overall the dust and air emissions during the Construction phase are deemed to be no greater than occuring during the Operational phase. The assessment of impact of the operational phase will therefore also be representative of the emissions that can occur during the construction phase. These aspects are further discussed in section 9.2.1.

8.2.2 Greenhouse gas emissions

During construction greenhouse gas emissions (GHG's) are mainly due to diesel combustion in mobile sources such as excavators, bulldozers and trucks. The total amount of fuel combusted during the construction phase is estimated to be much smaller than the estimated 60 million liters of fuel per year (mobile and stationary combustion combined) during the operational phase. Hence the greenhouse emissions of the construction phase are minor compared to the operation phase. For further description reference is made to section 9.2.2.

8.3. Water Environment

8.3.1 Hydrological changes of rivers and lakes during the construction phase

The following major hydrological changes will take place during the construction phase:

- The natural outflow of Taseq and the pond behind will be blocked by embankments and all water that enters the lake and pond will be pumped through a pipeline to the Refinery. The water will be recycled and treated prior placement into the fjord (Nordre Sermilik). Diversion channels will be constructed to direct rainwater and water from melting snow away from the tailings ponds. Some of this water will be directed to Taseq River;
- The natural flow of Kvane River into Narsaq River is blocked and the water diluted prior to entering to Nordre Sermilik;
- A new bridge will be constructed across the lower section of Narsaq River; and

- An embankment with a sluice will be built across the Narsaq River at the Refinery to create a raw water pond where water can be sourced for the production.

The reduced flow of Kvane River into Narsaq River will have limited impact on the flow in Narsaq River, since this watercourse contributes only c. 5 % of the average annual flow in Narsaq River /Orbicon 2014a/. The construction of the embankments at Taseq will further reduce the inflow in Narsaq River by c. 17 %. These figures refer to the average flow throughout the year. During winter the hydrological changes will have very little or no impact on the flow in Narsaq River because no or very little water flows out of Kvane Lake and Taseq Lake during this period of the year.

The new bridge across Narsaq River will be designed to cause no significant flow constrictions to the river. The construction of the raw water dam itself has little impact on the hydrology of Narsaq River. Around 400 m^3/h of freshwater will be sourced from Narsaq River for the production at the Refinery. With an average flow of c. 1200 m^3/h at this site and c. 4100 m^3/h downstream near the outlet this will have a small impact on the flow.

In conclusion, the changes to the hydrology of rivers and lakes during construction has limited impact on the overall hydrology of the area but significant impact on Kvane and Taseq Rivers which may see reduced flow in upper sections. However, in the lower sections of these watercourses some water flow is expected to be maintained because water will seep to the streams from the underground.

8.3.2 Freshwater quality

No significant impact on the freshwater quality is expected. See Chapter 10 for a discussion of the freshwater quality during operation and closure/post-closure phases.

8.4. Living Environment

The potential impact of the construction activities to animals, plants and their habitats are covered in this section. The potential impacts may in principle be characterized as follows:

Disturbances
For the purpose of this EIA “disturbance” includes (1) the active scaring of animals, for example noise from blasting, (2) when a habitat becomes unavailable to animals, for example if ptarmigan are excluded for utilizing an area with vegetation because it is close to a haul road and (3) when a habitat is lost.

The following specific potential disturbance impacts will be discussed:

- Disturbance of terrestrial mammals and birds (disturbance type 1 & 2);
- Disturbance of marine mammals and seabirds due to shipping (disturbance type 1 & 2);
- Loss of terrestrial habitat (disturbance type 3);
- Loss of freshwater habitat (disturbance type 3); and
- Loss of marine habitat (disturbance type 3).

Impacts due to spills of oil and chemicals

The consequences of spills of oil and chemicals during construction is assessed.

Other impacts

The following potential impacts will also be discussed:

- Mortality of animals due to road accidents; and
- Introduction of invasive non-indigenous species with ballast water.

8.4.1 Disturbance of terrestrial mammals and birds (disturbance type 1 & 2)

Several construction activities can potentially disturb animals, and in particular mammals and birds:

- Noise and vibrations. In particular the intermittent blasting noise, which can be heard at a significant distance from the mine, has the potential of startling mammals and birds; and
- Visual disturbances from personnel, vehicles, buildings and other project structures which might cause mammals and birds to avoid utilising habitat in the mine area.

Bird and mammal species react very differently to noise and visual disturbances. Among the birds known to occur in the Study area which are considered sensitive to disturbance is the White-tailed eagle, in particular close to its nest during the breeding season. Although White-tailed eagle is commonly observed in the Study area, no nesting sites are known from this area including Kvanefjeld or Narsaq Valley.

Among the birds that breed in the Study area, only the Raven is known to be sensitive to noise or visual disturbance. Therefore ravens will probably avoid breeding within 1-2 kilometres from the mine area. Ravens are generally low density breeding birds in Greenland and the mine project is not believed to lead to a significant reduction in the population of nesting pairs in the region.

Two terrestrial mammals occur in the Kvanefjeld area; Arctic fox and Arctic hare. These animals usually habituate well to human activities where they are not hunted.

However, since the hunting pressure in South Greenland is generally high, foxes and hares will probably stay well clear of the project facilities.

Construction activities may cause localised disturbance of terrestrial birds and mammals. Since no breeding sites are known for White-tailed eagles from the Study area, the disturbance impact of terrestrial mammals and birds is assessed as Low.

Impact during phases of the life of mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Definite	High
Mitigation measures • Restrict the movement of staff members outside the construction areas to minimize the general disturbance of wildlife				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Definite	High

Table 8-5: Assessment summary of disturbance of terrestrial mammals and birds

8.4.2 Disturbance of marine animals

Construction works at the new port facility at Narsap Ilua will cause temporary underwater noise from blasting and ramming and increased turbidity of the sea water close to the port. Ships bringing machinery, materials etc. to the port site during the construction period will generate noise both above and below water and visual disturbance above water. This could potentially result in disturbances and displacements of marine mammals, sea birds and fish.

The existing data suggests that only few marine mammals (if any) occur regularly in the Narsap Ilua, but that seals and occasionally also whales are found in Narsap Ikerasaa and adjacent fjords. Flocks of sea birds (mainly eider duck) winter in the fjords around Narsaq, including in Narlunaq/Skovfjord and Narsaq Ikerasaa/Narsaq Sund. If ships arrive through Bredefjord as opposed to typically Skovfjord, the ships can potentially disturb sea bird colonies. Arctic char that spawn and winter in Narsaq River migrate through Narsap Ilua to the surrounding fjords during summer to feed.

Of particular significance are:

- Ringed seals all year and harp seals during summer;
- Sea bird colonies at Akullit Nunaat;
- Flocks of wintering eider duck; and
- Arctic char during summer.

Construction works (blasting, ramming)

Seals are common in the fjords at Narsaq. However, severe disturbance is not considered likely, as seals in general display considerable tolerance to underwater noise.

Sea bird colonies at Akullit Nunaat

Ship to and from the project port that use Bredefjord (instead of Skovfjord) will pass several small sea bird colonies at Akullit Nunaat at a distance of a few kilometers. This is unlikely to disturb the breeding sea birds since experience from other parts of Greenland has shown that breeding seabirds are only disturbed if a ship is within a few hundred meters of the colony /Christensen *et al*. 2012/.

Wintering sea duck

Flocks of wintering eider ducks that rest and forage in the fjords might be temporarily disturbed by ships calling in at the port in Narsap Ilua. But due to the low number of ships expected to call in at the new port (up to 1 -2 ships a week) this disturbance is considered insignificant.

Disturbance of Arctic char

Char migrating from Narsaq River into the fjords in spring and back in late summer-autumn pass close to the new port site. Noise and increased turbidity in Narsap Ilua during the construction of the new port could potentially disturb the migrating fish. Since the construction works are temporary only with infrequent blasting and ramming and with increased turbidity limited to a small area, the disturbance of migrating char during the construction period is considered insignificant.

Overall disturbance of marine animals

The construction works at the new port will be local and temporary taking place in an area with low numbers of marine animals. The impact of the construction works are therefore assessed as low.

Due to the low number of vessels serving the Kvanefjeld project during construction (and operation) disturbance from shipping in the fjords is assessed as Low.

Impact during phases of the life of mine

Construction	Operation	Closure	Post-closure

Importance of impact without mitigation

Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Short term	Low	Definite	Medium

Mitigation measures

- Low speed while in fjords
- Keep good distance to flocks of wintering sea birds (when possible)

Importance of impact with mitigation

Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Short term	Low	Definite	Medium

Table 8-6: Assessment summary of disturbance of marine animals due to project activities

8.4.3 Disturbance of freshwater organisms including fish (disturbance type 2)

Construction works in connection with the bridges across Narsaq River and the building of embankments at Taseq might cause short-term increases in the turbidity in Narsaq and Taseq Rivers. This could disturb freshwater organisms including Arctic char in Narsaq River. Since any rise in turbidity due to these construction works will be temporary (and short term) the disturbance of the Arctic char and the freshwater ecosystem in general are accessed as of very low importance.

Impact during phases of the life of mine

Construction	Operation	Closure	Post-closure

Importance of impact without mitigation

Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Short term	Very Low	Definite	Medium

Mitigation measures

- Minimise the disturbance of the water in Narsaq River and Taseq River when building new bridges and embankments by keeping the construction period as short as practically possible

Importance of impact with mitigation

Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Short term	Very Low	Definite	Medium

Table 8-7: Assessment summary of disturbance of freshwater organisms including fish

8.4.4 Loss of terrestrial habitat

Rock movements to accommodate the new port, the Concentrator, Refinery and other buildings, construct roads and prepare the mine area will lead to loss of natural vegetation and displacement of most terrestrial animals from the specific area.

The vegetation in the Study area is mostly dominated by terrestrial habitats and plant species which are common and widespread in South Greenland. An exception is an unusual vegetation community found close to the Narsaq River mouth, which includes twol rare plant species /Orbicon 2014b/.

No construction works will take place in the area with the rare plant species and the overall footprint of the mine infrastructure is small compared to the distribution of similar habitat in South Greenland. Typically, low densities of animals occur in these habitats none of which are known to be rare or threatened in Greenland. Overall the significance of lost terrestrial habitat due to the Project is assessed to be *Very Low*.

Impact during phases of the life of mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Long term	Very Low	Definite	High
Mitigation measures • Minimize the area to be disturbed by planning infrastructure to have as small a footprint as possible				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Long term	Very Low	Definite	High

Table 8-8: Assessment summary of loss of terrestrial habitat.

8.4.5 Loss of freshwater habitat

The construction of the embankment across the outlet of Taseq and in the pond east of Taseq will change the hydrology of Taseq River significantly. Deposition of tailings in Taseq and the pond east of Taseq will permanently change the lakes.

The use of Taseq and the depression east of Taseq for tailings deposition will most likely make them unsuitable for supporting aquatic life. Lake Kvane will become part of the mine area and will be emptied of water.

Taseq River, Taseq Lake. Lake Kvane and the depression east of Taseq are all fish-less. Studies of the freshwater ecology have shown that the river and lakes are inhab-ited by a species poor invertebrate fauna consisting of animals which are common and widespread in South Greenland. Almost no vegetation is found along the shore or in the lakes. The loss of freshwater habitat when using Taseq Lake and the pond east of Taseq for deposition of mine residuals will therefore be limited, and the significance is assessed as Very Low.

Impact during phases of the life of mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Signifi-cance*	*Probability*	*Confidence*
Project footprint	Permanent	Very Low	Definite	High
Mitigation measures • No mitigating possible				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Signifi-cance*	*Probability*	*Confidence*
Project footprint	Permanent	Very Low	Definite	High

Table 8-9: Assessment summary of loss of freshwater habitat

8.4.6 Loss of marine habitat

The new port will require re-profiling of a section of the shore. The re-profiling will be permanent. This will lead to loss of inter-tidal habitat and could potentially impact pop-ulations of marine animals and plants. This includes Arctic char from the Narsaq River population that migrates into the fjord during the summer months.

Little specific knowledge exists about the marine flora and fauna of Narsap Ilua. Ob-servations during the ecological baseline sampling suggest that no marine mammals or sea birds are specifically associated with this part of the fjord. The loss of foraging ground for Arctic char due to the construction of the port is believed to be insignificant since very large areas of similar habitat are common along the fjords in the region.

The loss of marine habitat at the port site is therefore assessed to have Very Low significance.

Impact during phases of the life of mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Very Low	Definite	High
Mitigation measures • No mitigating possible other than limiting the impact area as much as possible				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Permanent	Very Low	Definite	High

Table 8-10. Assessment summary of loss of marine habitat

8.4.7 Contamination of terrestrial habitats

A number of activities in connection with the construction works can potentially cause contamination of terrestrial habitats:

- Accidents in connection with transport, storage and handling of hazardous materials such as fuel, grease, paint and chemicals; and

- Blasting for construction and pre-stripping can cause elevated levels of nitrates.

Contamination of the surface soil and the vegetation by oil or other hazardous materials potentially pose a risk to animals, plants and their habitats. Hydrocarbons, such as jet fuel and Arctic diesel can have toxic effects. Due to their organic nature, small spills of hydrocarbons are generally broken down by bacteria in the soil, however this process is much slower in the arctic climate and even small oil spills can kill the vegetation which subsequently requires decades to re-establish.

Blasting in connection with the construction works and the associated ammonia contamination from the explosives is difficult to mitigate. The blasting could therefore lead to a local nutrient enrichment.

The most serious contamination of terrestrial habitats during construction would probably be an oil spill. However, the minor volumes of individual tanks used during construction limits the potential impacts of accidents.

The likelihood of a major spill occurring on land is low, but contingencies need to be worked out. Lesser operational spills are more likely to occur, but the effects are likely to be localized, and comparatively easy to combat. The small amounts of explosive to be used will only cause insignificant increases in ammonia levels. For a further discussion of the risk and impact of oil and chemical spills reference is made to the Environmental Risk Assessment (Chapter 11).

In conclusion: The environmental impacts of fuel and chemical spills on land during construction are assessed to be confined to the Study area (i.e. local scale). The potential loss or depletion of terrestrial habitat due to contamination is consequently assessed as Low.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Medium term	Low	Possible	High
Mitigation measures • Prepare contingency plans in collaboration with appropriate authorities. Efficient combat organization in place. Proper equipment readily available				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Medium term	Low	Possible	High

Table 8-11: Assessment summary of impacts on terrestrial habitats from pollution during construction phase

8.4.8 Contamination of freshwater and marine habitats

Accidents in connection with transport, storage and handling of building materials such as fuel, grease, paint and chemicals can potentially cause contamination of nearby freshwater bodies. Contamination of the lakes and streams by oil or other hazardous materials from project activities could potentially pose a risk to animals, plants and their habitats. Hydrocarbons, such as jet fuel and Arctic diesel, can have toxic effects.

The quantities of fuel, machines and other cargo that will be shipped to the port during the construction phase is believed to be similar or smaller to the operational phase. Therefore the impact on marine and freshwater habitats will be similar for both phases. For a further discussion of the risks and impact of oil and chemical spills reference is made to the Environmental Risk Assessment (Chapter 11).

8.5. Contamination of environment from domestic and industrial waste

During the construction period waste in addition to domestic waste will comprise of construction waste and debris, iron and metal scrap, tires and hazardous waste (oily waste, chemical waste, batteries, etc.).

All solid waste will be pressed into bales and shipped to Qaqortoq for incineration. Handling of hazardous of waste will follow the regulation of Kommune Kujalleq
In general hazardous waste in the municipality is shipped to Denmark and handled in compliance with the comprehensive EU initiated legal framework. A sewage treatment facility will be installed to treat and neutralize the domestic waste before it is discharged into the fjord.

In conclusion the waste handling system in the construction phase will minimize any impact on the environment. The impact is assessed to be local and of very low significance.

Impact during phases of the life of the mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Medium	Medium	Possible	High
Mitigation measures • Strict enforcement of waste handling procedures • Continues update waste management manual				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Short term	Very Low	Improbable	High

Table 8-12: Assessment summary of contamination of environment from waste

8.5.1 Fauna Traffic Incidents

The Project could potentially lead to increased direct mortally among animals and birds due to traffic collisions.

The movement of trucks and other vehicles along the haul and service roads represents a risk for animals. However, given the lay-out of the road system within the Study area this is unlikely to be a major danger for the wildlife. Furthermore, since a speed limits of 40 km/t will be introduced and drivers are instructed to be aware of animals moving close to roads this risk is considered to be Very Low.

8.6. Introduction of invasive non-indigenous species with ballast water

Ships calling in at the Kvanefjeld project port site will discharge ballast water before loading cargo. The ballast water can contain non-indigenous species that could potentially establish themselves in the South Greenland fjords. When introduced in new areas, these species could thrive and become a threat to indigenous species and the local ecosystem.

In 2004, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) was adopted. It is a new international convention to prevent the potentially devastating effects of spreading of harmful aquatic organisms carried by ships' ballast water. The convention will come into force 12 months after ratification by 30 States, representing 35 per cent of world merchant shipping tonnage. The convention is expected to come into force in 2016.

The BWM will require all ships to implement a Ballast Water and Sediments Management Plan. All ships are required to carry out ballast water management procedures to a given standard. The IMO Marine Environment Protection Committee has already adopted guidelines, which are developed to assist in the implementation of the BWM Convention.

To minimize a potential introduction of non-indigenous species, regulations of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM) should be followed.

Provided that vessels that call in at the Kvanefjeld Project port follow the BWM regulations, the risk of introducing invasive non-indigenous species with ballast water is assessed as Very Low.

8.7. Land Use and Cultural Heritage

Human presence and land use in the Study area is covered extensively in the *Social Impact Assessment study* /NIRAS 2015/ and in the *Local Use Study Kvanefjeld* /Orbicon 2014c/. This section focuses on what extent the construction works will hinder the traditional use of the Study area and if culturally significant sites are disturbed.

8.7.1 Hindrance of traditional land use

Farming
Within the Study area Narsaq farm in the Narsaq Valley is the only farm which has been active in recent years. Before the construction works are initiated it is expected that a mutual agreement is reached with the owner and GMEL allowing GMEL to be responsible for the farm. In the construction (and operation) phase no farming is planned to take place.

Hunting of hare and ptarmigan
Some hunting of hare and ptarmigan takes place in the Kvanefjeld area, but most hunting of these animals is in the mountains further away from Narsaq.

During the construction (and operation) phase a 'no hunting' security zone on land will be requested by GMEL to avoid shooting accidents. The exact area to be included in this zone is to be determined by the authorities but it is expected to include an area of 1 - 2 km from all facilities.

Berry picking
In particular many women from Narsaq pick crowberries and bilberries in late summer and autumn. The favorite sites are southeast of town and on the hills to the north, but some also pick berries in the lower parts of Narsaq Valley.

Except within the working area of the new road between the port and the mine area, berry picking will be possible as previously performed in Narsaq Valley (and elsewhere).

Search of gemstones
Currently one person from Narsaq has a small-scale mining permit to collect semi-precious gemstones (Tuttupit) at Kvanefjeld. It is believed that an additional 4-5 persons from Narsaq regularly searches for gemstones in the area.

For security reasons access to the mine area will not be permitted during the construction (and operation) phase of the project. It should be noted that there are other locations in the area where these semi-precious gemstones are also found.

Seal hunting
Seal hunting takes place in Nordre Sermilik and in some parts of the other fjords around Narsaq.

No significant restrictions in the seal hunting is expected except for a 'no hunting' security zone requested by GMEL in Narsap Ilua to avoid shooting accidents. This is believed to have very little importance as the bay is rarely used for seal hunting. The important seal hunting in Nordre Sermilik can continue unaffected except very locally around the discharge point from the Refinery, where a 'no hunting' security zone will be requested by GMEL.

Fishing
Some professional and recreational fishing takes place in the fjords around Narsaq, including in Nordre Sermilik /Orbicon 2014c/. Char fishing in the lower parts of Narsaq River is popular among Narsaq citizens.

Fishing will generally be unaffected by the construction works. Only very locally, close to the new port site, will fishing not be possible. There will also be a no-fishing zone around the discharge port from the Refinery in Nordre Sermilik, but this will probably have no practical importance as fishing in this area is usually impossible due to the high number of small icebergs. The char fishing in Narsaq River will continue during the construction period.

<u>To conclude</u>, very limited conflicts are expected with the present use of the Study area.

8.7.2 Recreational use and tourism

Walking, running, hiking (and car driving) are presently popular recreational uses of Narsaq Valley among citizens in Narsaq and a small number of tourists.

For security reasons hiking (and driving) on the new road between the port and the mine area will not be possible. The mine area and a zone around the various facilities will also be closed for the public. However most of the valley will remain unaffected by the construction works and open for recreational use.

8.7.3 Disturbance of heritage site

The Greenland National Museum & Archives have identified a number of heritage sites within the Study area. This includes the Norse farm Dyrnæs on the shore of Narsap Ilua and several Neo-Eskimo settlements /Kapel 2009, Myrup 2010/.

Two of the sites can potentially be affected by the construction works: a rock shelter along the shore of Taseq (Taseq 60V2-0IV-071) and a tent foundation and shooting blind situated on the tip of the Tunu peninsula (Nuugaarmiut 60V1-00I-169) close to the location of the new port /Myrup 2010/.

Before any construction works take place in the vicinity of these sites Greenland National Museum and Archives will be notified so that a staff member can photograph and measure the structures as part of the archaeological registration.

9. IMPACT AND MITIGATION OF OPERATIONAL PHASE

The Operational phase is planned for 37 years. During this phase ore will be extracted from the open pit at Kvanefjeld, hauled by large mine trucks to the Concentrator and subsequently moved to the Refinery to produce the mine products. The mine products are then transported to the port by trucks and shipped abroad.

Excess ore – tailings - is moved through pipelines to Taseq basin where they are stored under water in two compartments separated by an embankment.

Water for the processing of ore is sourced from Narsaq River and recycled from the tailings ponds. After recycling some processing water is treated prior to placement in Nordre Sermilik.

This chapter contains the impact assessment of the Operational phase. Some of these impacts are assessed to have the same effects on the environment as under the construction phase. In these cases, only a brief account is given and reference is made to the section in chapter 8 that deals with the subject.

The Operational phase chapter is divided into the following sections:

- Section 9.1 on the **physical environment** (landscape alterations, erosion, noise and vibrations);
- Section 9.2 on the **atmospheric setting** (dust and carbon dioxide emissions);
- Section 9.3 assess the **radiological emissions** due to project activities;
- Section 9.4 on the **water environment** (lakes, streams, rivers and the fjord) in terms of changes of flow pattern and water chemistry.
- Section 9.5 on **living environment**
- Section 9.6 on **waste issues**
- Section 9.7 on **local use** and **cultural heritage**

9.1. Physical Environment

9.1.1 Landscape alterations

The landscape directly affected during the Operational phase is the pit area, where the ore is extracted, the area where waste rock is deposited and the tailings ponds. Over time, the pit will become deeper and larger and the waste rock stock pile will increase in size. During the operational phase the tailings pond embankments will gradually be built higher and the size of the lakes behind them will increase. Rock and gravel for the embankments will be sourced from the near surroundings. At a smaller scale, materials (gravel etc.) will be excavated for road maintenance purposes, but no major excavations for new constructions are envisaged to take place during the operational phase.

To conclude, the landscape alterations during operation phase are Very Low.

Impact during phases of the life of the mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Long term	Very Low	Definite	High
Mitigation measures • Plan the waste rock stock pile and embankments to blend as far as practical with the surrounding landscape				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Project footprint	Long term	Very Low	Definite	High

Table 9-1: Assessment summary of landscape alterations during operations

9.1.2 Erosion

Erosion is not expected to be an issue during operation since the earth works during operation will almost exclusively take place in areas with consolidated rock.

9.1.3 Noise and vibrations

Activities during the Operation phase of the Kvanefjeld project will result in a permanent increase in the ambient noise level near several of project facilities. This section discusses the modelled noise load due to project activities and is based on a specific noise study conducted by Orbicon /2015a/.

Noise is usually defined as unwanted sound. The human ear responds logarithmically to sound stimuli. A logarithmic scale known as decibels (dB) is used to measure noise levels. The scale represents a logarithmic ratio of sound pressure levels compared to the threshold of hearing (0 dB). The notation dB(A) means that different sound frequencies are weighted according to the frequency response of the human ear, known as "A-weighting" – see Figure 9-1 for examples.

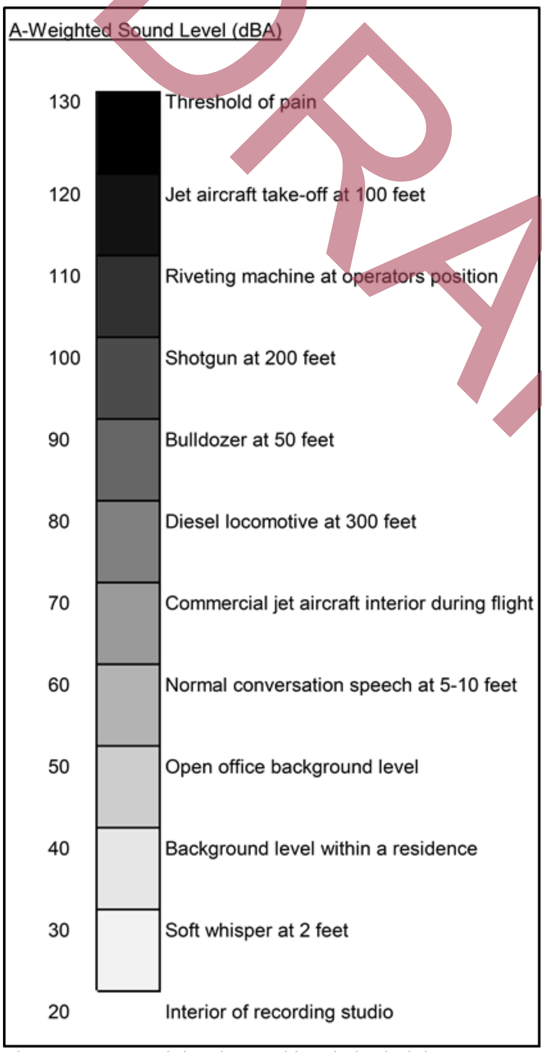

Figure 9-1: A-Weighted sound levels in dB(A)

The perception of noise from a particular source depends in part on the level of background sounds in an area. Wind speed is an important parameter affecting natural background sound levels in natural areas and background sound levels rapidly increase with increasing wind speed. In the Kvanefjeld area, the most common 10-min average wind speed is 2-5 m/sec which occurs 35% of the time. This wind speed range corresponds to a minimum natural background noise level of 30 dB(A). Above 3 m/s, the median sound level increases by 3 dB per m/s of wind speed. This implies that a 2 m/s increase in median wind speed roughly corresponds to a doubling of the back-ground sound level (6 dB).

9.1.3.1. Noise assessment of the Kvanefjeld project

In the following 30 dB(A) is used to define the ambient noise level that characterize the existing "baseline" acoustical environment. Project operational activities that generate noise that exceed this value define the noise footprint of the project. To identify the major sources of project noise a screening was carried out. This identified the following activity areas as the potentially most significant noise sources during operations:

- The mine area (pit, haul roads, processing plants and power plant);
- The access road connection the mine area and the new port; and
- The new port area.

Noise loads for each of these areas were subsequently calculated using SoundPlan software. The Danish guideline limit for noise loads in industrial areas of 70 dB(A) was used to assess the noise impact of the project operation activities. This limit applies to the property boundary of an enterprise ("fence line"). Since the Kvanefjeld project has no clear boundary line, the spatial pattern of noise loads was calculated and described for the entire working area for the identified noise sources and the area that surrounds them.

9.1.3.2. The noise load in the mine area

The modelled noise load distribution generated by project operations in the open pit area, along the haul roads and at the two plant sites is shown in Figure 9-2. Noise loads above the 30 dB(A) background level is limited to the Kvanefjeld areas and the upper parts of the Narsaq Valley.

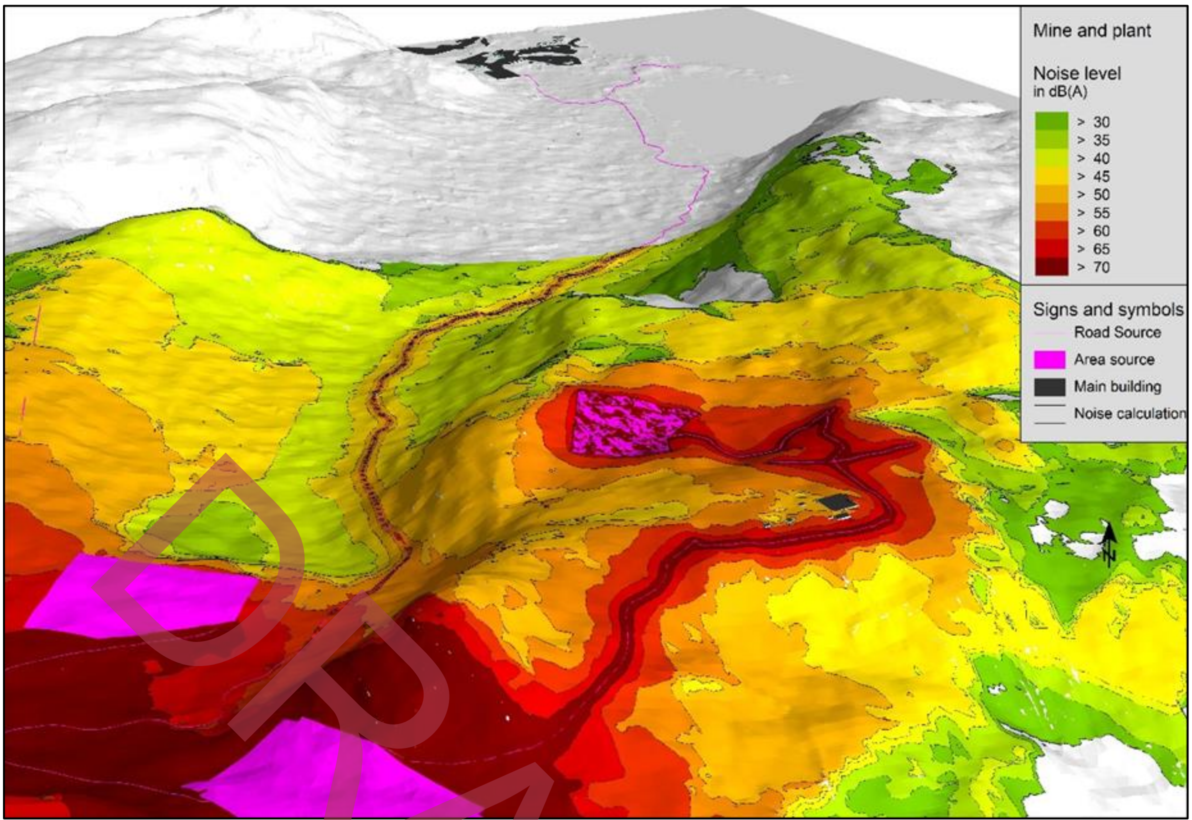

Figure 9-2: Calculated noise load for mine area (center) and processing plants (lower left) during operation

9.1.3.3. The access road connecting the mine area and the new port

The noise footprint caused by trucks, busses and other vehicle traveling on the road between the mine area and the new port is shown in Figure 9-3. Noise levels above the 30 dB(A) background level extends 800-1200 meters on both sides of the road, depending on terrain. Traffic on the road to the mine area will not increase the noise level in Narsaq town.

The noise-sensitive receivers closest to the mine road are five summer houses situated just north of Narsaq town in Narsaq Valley. The project-related traffic noise level calculated for the houses closest to the road increases to 38.0 dB(A) during day, 38.3 dB(A) during evening and 38.7 dB(A) at night, that is only slightly above the natural background levels /Orbicon 2015a/. Compared to Danish guided noise limits for summer housing during day, evening and night, the calculated noise levels are below the limit during daytime (40 dB(A)), but exceed the 35 dB (A) limit slightly during evening and night. It should be noted that the assumptions included in the noise assessment are very conservative and probably overestimate the noise loads.

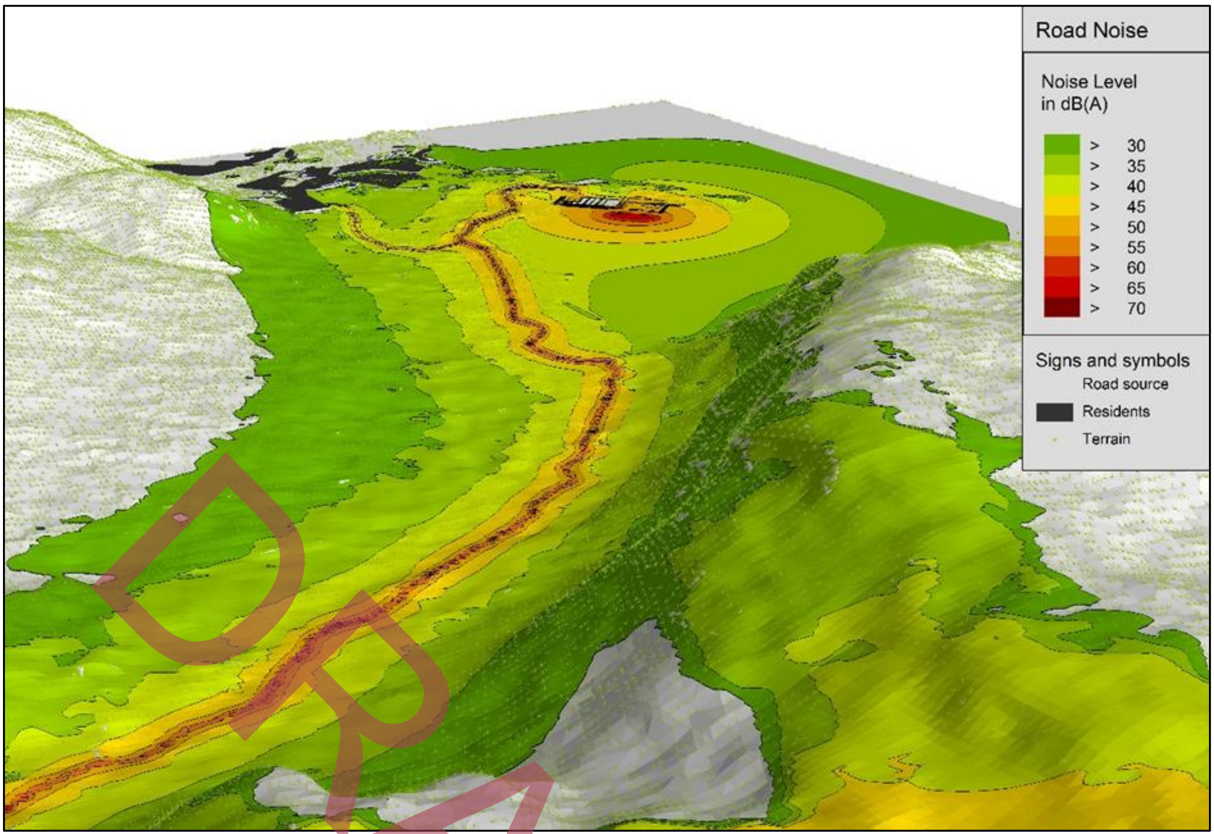

Figure 9-3: Calculated noise load along access road and in the new port area

9.1.3.4. The new port area

The noise footprint caused by project operations at the new port is shown in Figure 9-4. The calculated noise load will exceed 70 dB(A) in an small area where containers are unloaded /Orbicon 2015a/. The area where the average noise load exceed the 30 dB(A) background level extends about 1,800 m from the center of the new port.

The noise level in the residential areas in Narsaq and where the accommodation building will be constructed will be less than 40 dB(A) and thereby meet the Danish noise guidelines for noise levels in towns.

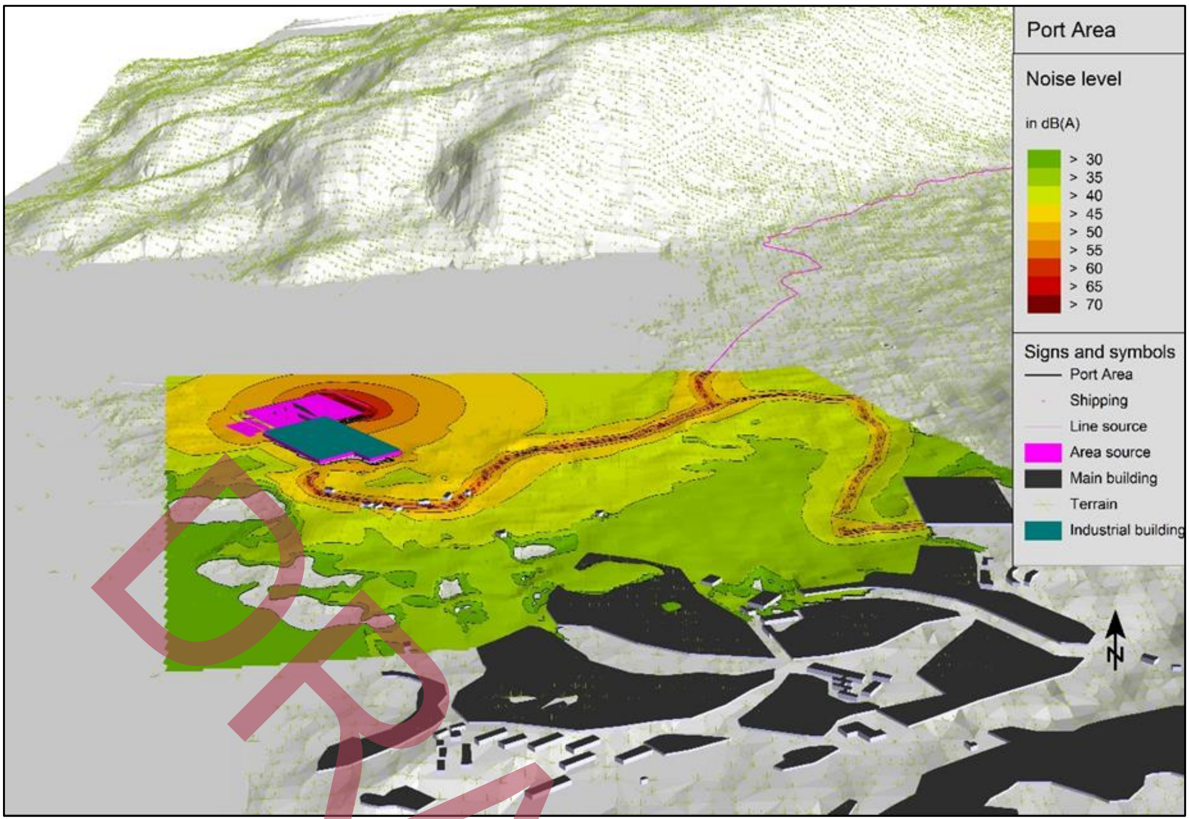

Figure 9-4: Calculated noise load in and around the new port during the operation phase

9.1.3.5. Blasting

Blasts in the open pit are expected to be fired every two days with multiple shots potentially blasted at the same time.

The nature and magnitude of noise from blasting operations in the pit area will depend critically on the blasting regime chosen, the nature of the rock to be blasted, the size and depth of the charge, the type of explosive, the local topography, and the detonation sequence. There are at present no reliable national or international guidelines to accurately predict human response to blast noise. However, because the closest habitations around the site are at distances of approximately 8 km from the nearest point of blasting neither the air blast nor the ground vibration are likely to have any damaging effect on humans or buildings in Narsaq.

9.1.3.6. Conclusion

The modelled noise load distribution generated by project operations shows that the area of the 70 dB(A) industrial footprint is very small and limited to the mine area, the processing plant areas, a narrow corridor along the access road and to the new port.

The predicting noise increases associated with the project will be well below Danish guideline limits in residential areas in Narsaq. Traffic noise will exceed the Danish evening and night limit of 35 dB(A) for summer houses by up to 3.7 dB(A) at two cottages in Narsaq Valley. No known sensitive wildlife areas will be impacted by operational noise of the mining activities.

To conclude, the noise modeling results show that no significant noise impacts are identified for the project. Overall, the noise impact is assessed as Low.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Definite	Medium
Mitigation measures • Avoid blasting during evenings and at night				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Definite	Medium

Table 9-2: Assessment summary of noise load during Operational Phase

9.1.4 Light

The mine area, the process plants and the port area will have activities day and night, year around. In dark periods the industrial complexes and the mine pit area will be easy recognizable in the landscape due to lights from buildings, mobile equipment, etc.

The consequences of such “ecological light pollution” where artificial lighting alters the natural light regimes in ecosystems are generally little known. The serious consequences of light, such as the collision of migratory birds with tall lighted structures and the attraction of insects to light are well described. However, since artificial light will mainly be needed during the winter months this will not be an issue at Kvanefjeld.

9.2. Atmospheric setting

9.2.1 Dust and air emissions

During the operation phase, mining activities will generate emissions that can potentially impact the environment (and human health). These emissions include airborne particulates (dust) and particles that settle on the ground. Other potential significant emissions are oxides of Nitrogen (NO_X), sulfur compounds and Black Carbon.

To assess these potential impacts Pacific Environment Limited (PEL) has modelled the contribution of emissions from the Kvanefjeld Project /PEL 2015a/. The modelling study 1) identified sources of significant air emissions; 2) estimated emission rates from these sources and 3) performed dispersion modelling to assess the potential impact on ambient air quality in the Study area and surroundings. For the modelling PEL used a suite of tools including CALMET to combine surface metrological station data to generate three-dimensional metrological fields for a representative year (2012), and CALPUFF for dispersion modeling.

Particulate matter from combustion is mostly very small particles less than 2.5 microns in diameter ($PM_{2.5}$). Mechanically generated dust, such as from material handling and road dust, is mostly coarse particles larger than 2.5 microns in diameter. Such particles up to 10 microns in diameter are denoted PM_{10}. Particles up to about 30 microns in diameter are included in the designation Total Suspended Particulates (TSP). PEL identified $PM_{2.5}$, PM_{10} and TSP as particulate matter sources of significant air emissions performed dispersion modelling to assess the potential impact on ambient air quality in the Study area and surroundings /PEL 2015a/. In addition, TSP dust fall rates were modelled and the metal loads estimated and this was compared to Greenlandic guidelines.

Air pollutants in combustion emissions include oxides of Nitrogen (NO_X) with the key emission source of NO_X typically being NO_2. Other air pollutants in combustion emissions are oxides of Sulfur (SO_X). In this context, the sulfur compounds are documented as sulfur dioxide (SO_2) and Total Reduces Sulfur as Hydrogen Sulfide (H_2S). Black carbon is a component of soot, emitted by incomplete combustion of fuel. Black carbon concentrations are calculated from the main contributors (on-site power station and diesel engines used for mining activities).

To assess the potential impacts PEL /2015a/ modelled ground level concentrations for these key pollutants and the deposition of dust and nitrogen for an area extending 75 km x 75 km with the location of the mine at the center. In addition to ground level concentrations across the model domain concentrations were calculated for 58 "sensitive receptor locations" which include archeological sites, the summer houses in Narsaq Valley, two options for the accommodation village options, four locations in Narsaq and Narsaq Farm (see Figure 9-5). In the following, the predicted results are shown on maps and discussed specifically for a number settlements (and former settlements) within this area. These locations are Narsaq farm in Narsaq Valley, Narsaq town, the sheep farm at Ipiutaq and the sheep farms around Qassiarsuk.

9.2.1.1. Emission estimation

The key emission sources for the operation phase of the project are identified as:

- Mining operations
- Processing plant operations (Concentrator and Refinery)
- On-site power generation

Mining activities are expected to contribute mainly to particle (dust) emissions from material handling, haulage and blasting. Estimates of annual emissions from the various mining activities are based on data compiled by the US Environmental Protection Agency (EPA). The estimated amounts of dust from mining operations are shown in Table 9-3. Clearly, haulage of ore and waste rock is the key source of dust generation.

Mining activity	PM_{10} (kg/year)	TSP (kg/year)	$PM_{2.5}$ (kg/year)
Material handling	29,056	86,844	8,543
Haulage	257,074	1,046,235	75,580
Blasting	2,090	4,018	614

Table 9-3: Estimated amounts of dust generated per year from the key sources of mining activities

The processing plants (Concentrator and Refinery) will be fully enclosed with emission discharges through vents located on the roof. Emissions of interest from the concentrator plant vents include dust, zinc sulfide and calcium fluoride. Emissions from the refinery plant include dust, H_2SO_4 mist, H_2S gas, HCL mist, chlorine gas and gaseous SO_2.

Due to the adopted production methods emissions of zinc sulfide, calcium fluoride, HCL mist and chlorine gas are very low and well below guidelines. Therefore, they were not specifically considered for further evaluation. Emissions from the operation of diesel-fired electricity generators will include solid particles, in addition to gaseous oxides of nitrogen (NO_X) and sulfur (SO_X).

<u>Predicted air quality impact (modelling results)</u>
The results discussed below from the modelling results by PEL /2015a/ are cumulative that is the emissions predicted to be generated by the project and the background emissions (see section 6.5).

9.2.1.2. Dust concentration and deposition

Figure 9-5 shows the maximum 24-hours concentration of Total Suspended Particulates (TSP) in the air in µg/m³ – that is the highest average amount of dust in the air to be expected during any single day. TSP includes particles up to about 30 microns in diameter.

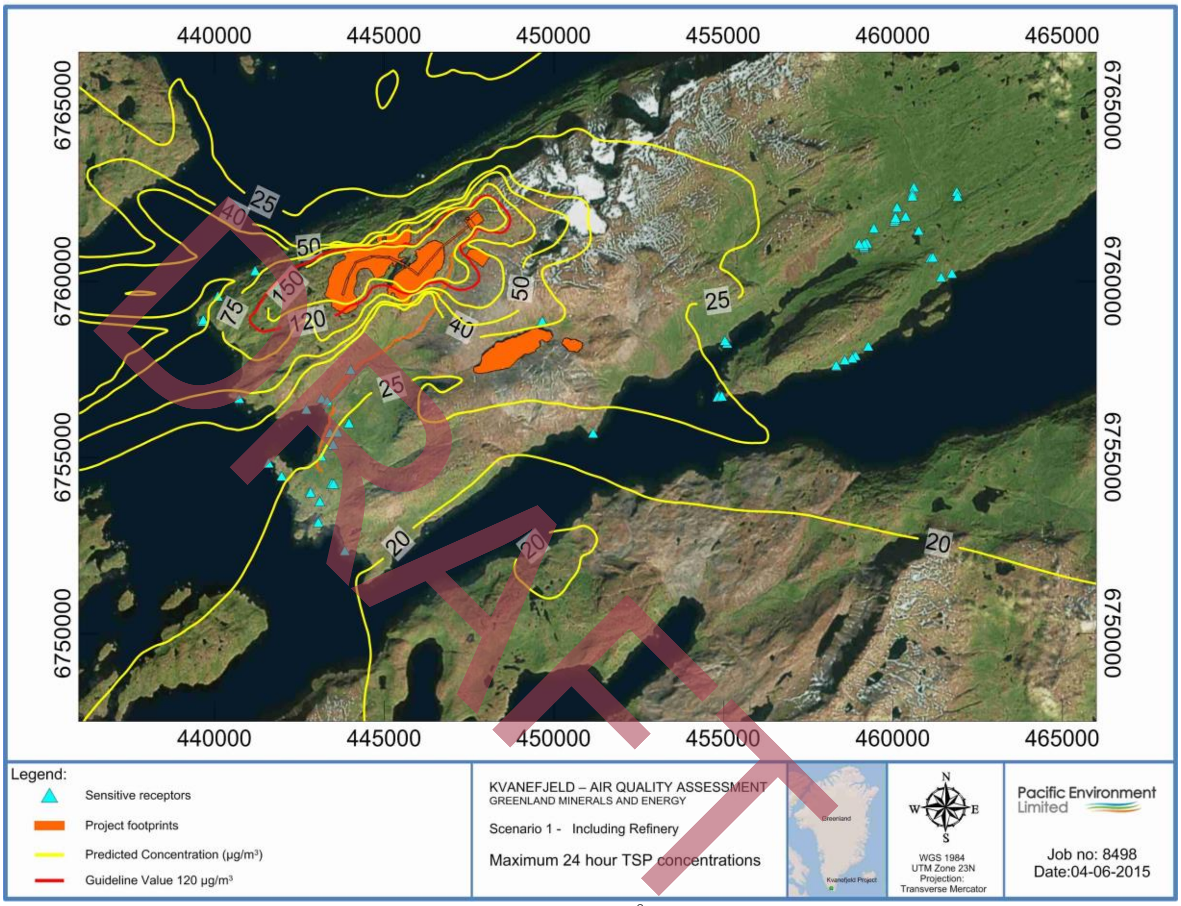

Figure 9-5: The maximum 24-hours TSP air concentrations in µg/m³

The map shows that by far the highest dust values are expected in the mine area close to the pit. In the Narsaq Valley, the values are considerably lower with an estimated concentration of 26.5 µg/m³ at Narsaq farm. In Narsaq town, the TSP concentration is below 25 µg/m³. The same applies to the sheep farm at Ipiutaq and the farms further to the northeast at Qassiarsuk.

Greenland's guidelines for air quality do not address air borne TSP. However, Canada's National Ambient Air Quality Objective (NAAQOs) has a 120 µg/m³ standard for maximum acceptable level during a 24-hour period. The modelling study shows that this standard is not exceeded outside the mining area.

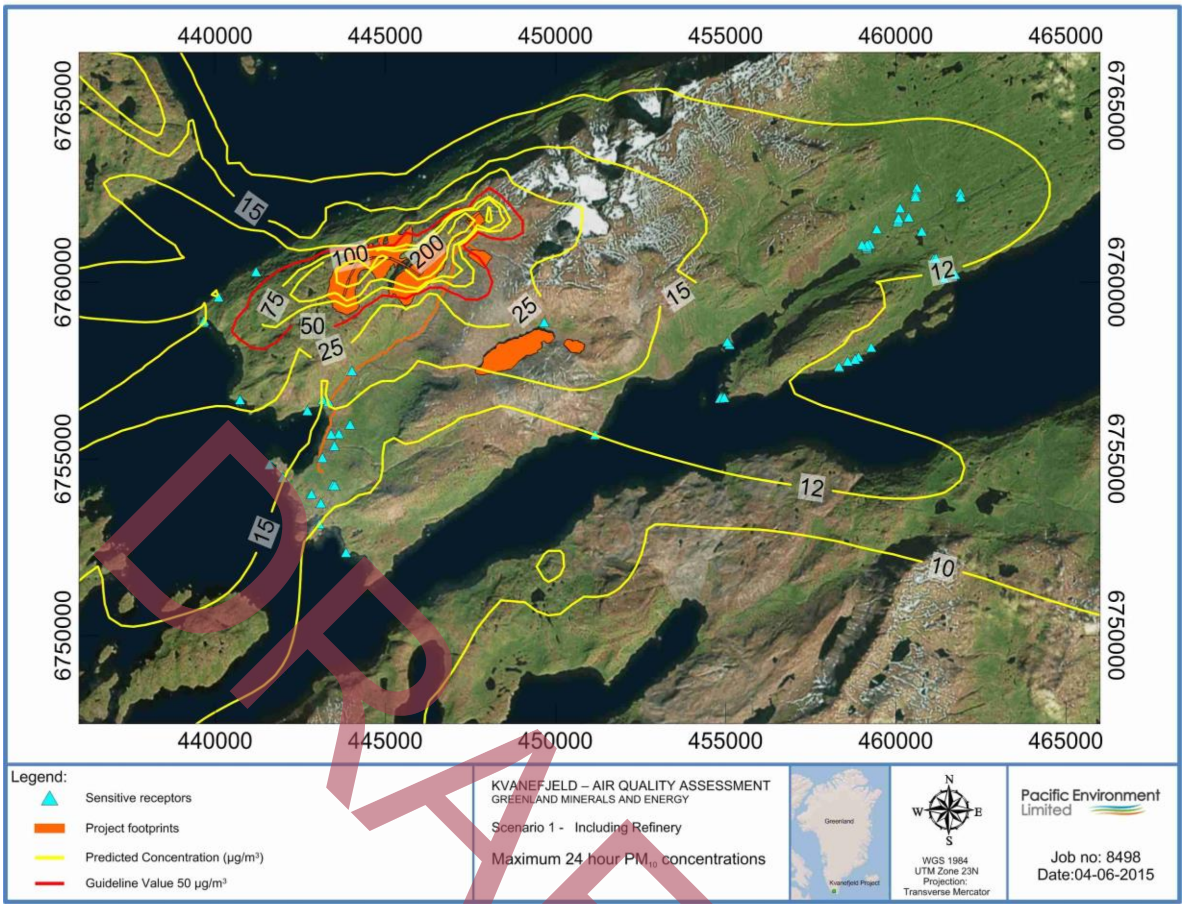

Figure 9-6: The maximum 24-hours PM_{10} concentrations in µg/m^3

Figure 9-6 shows the maximum concentration of particular matter less than 10 microns in diameter (PM_{10}) per cubic meter during a 24-hour period. This is mainly dust stirred by mine trucks when hauling ore and waste rock.

High concentrations are only recorded close to the haul roads on the Kvanefjeld and the concentrations quickly drops below 25 µg/m^3 in the upper Narsaq Valley, to 16 µg/m^3 at Narsaq farm and around 12 µg/m^3 in Narsaq town. Of the predicted 12 µg/m^3 of PM_{10} dust in Narsaq the 9 µg/m^3 is "background dust" – that is the existing dust level caused mainly by dust from the dirt roads in town. The difference of 3 µg/m^3 can be attributed to the Kvanefjeld mining operations only. The maximum 24-hours PM_{10} further away at Ipiutaq and the sheep farms around Qassiarsuk will be below 12 µg/m^3. To conclude, the modelled maximum 24-hours PM_{10} concentrations outside the mine area is well below the Greenland guideline value of 50 µg/m^3.

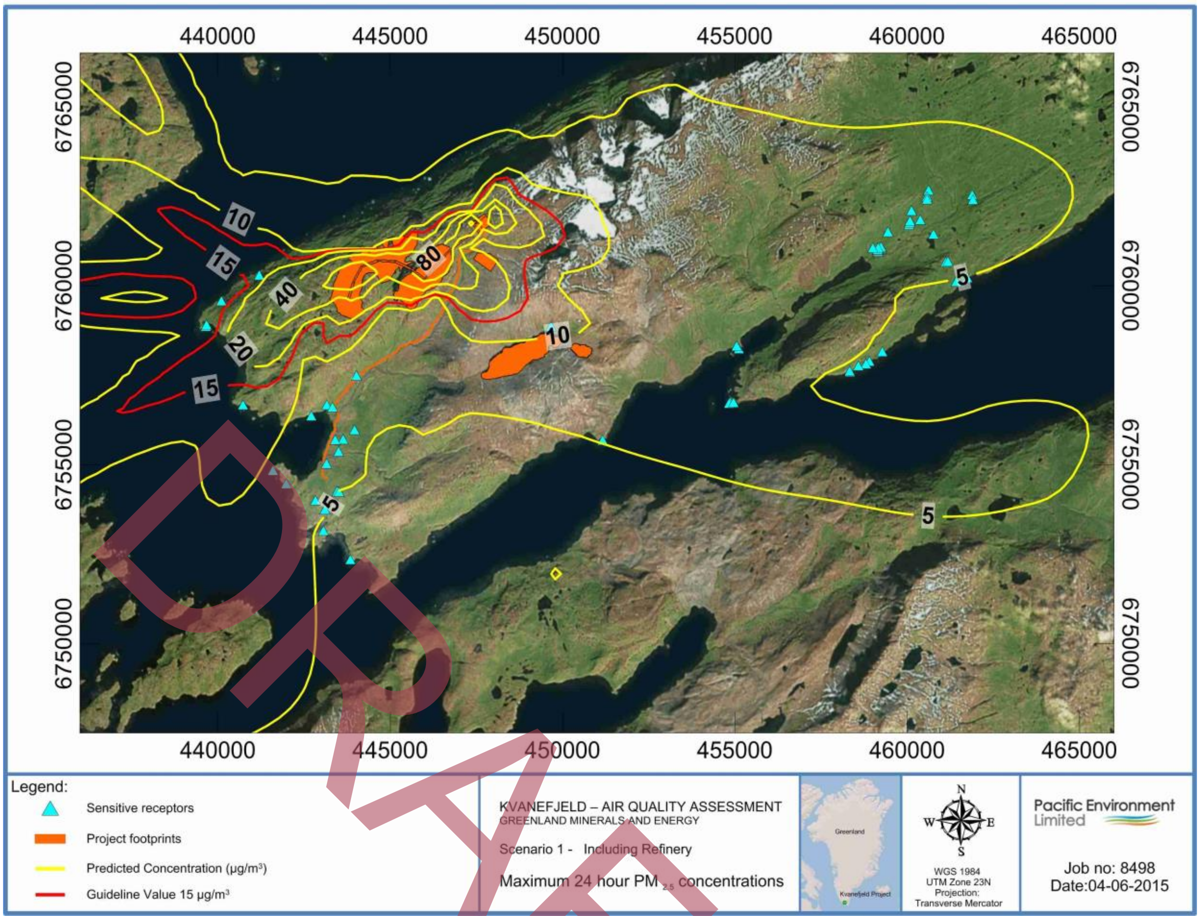

Figure 9-7: The maximum 24-hours $PM_{2.5}$ concentrations in µg/m^3

Figure 9-7 shows the maximum concentration of particular matter less than 2.5 microns in diameter ($PM_{2.5}$) per cubic meter during a 24-hour period.

The distribution of $PM_{2.5}$ is predicted to be very similar to PM_{10} with the highest values recorded close to the pit. However, the amounts of $PM_{2.5}$ will be much smaller than PM_{10}. The highest maximum 24-hour concentration at Narsaq farm in the Narsaq Valley is predicted to 6.4 µg/m^3. In Narsaq town, at Ipiutaq and further away the $PM_{2.5}$ concentrations will be around or below 5 µg/m^3. These values are well below the Greenland guideline value of 30 µg/m^3.

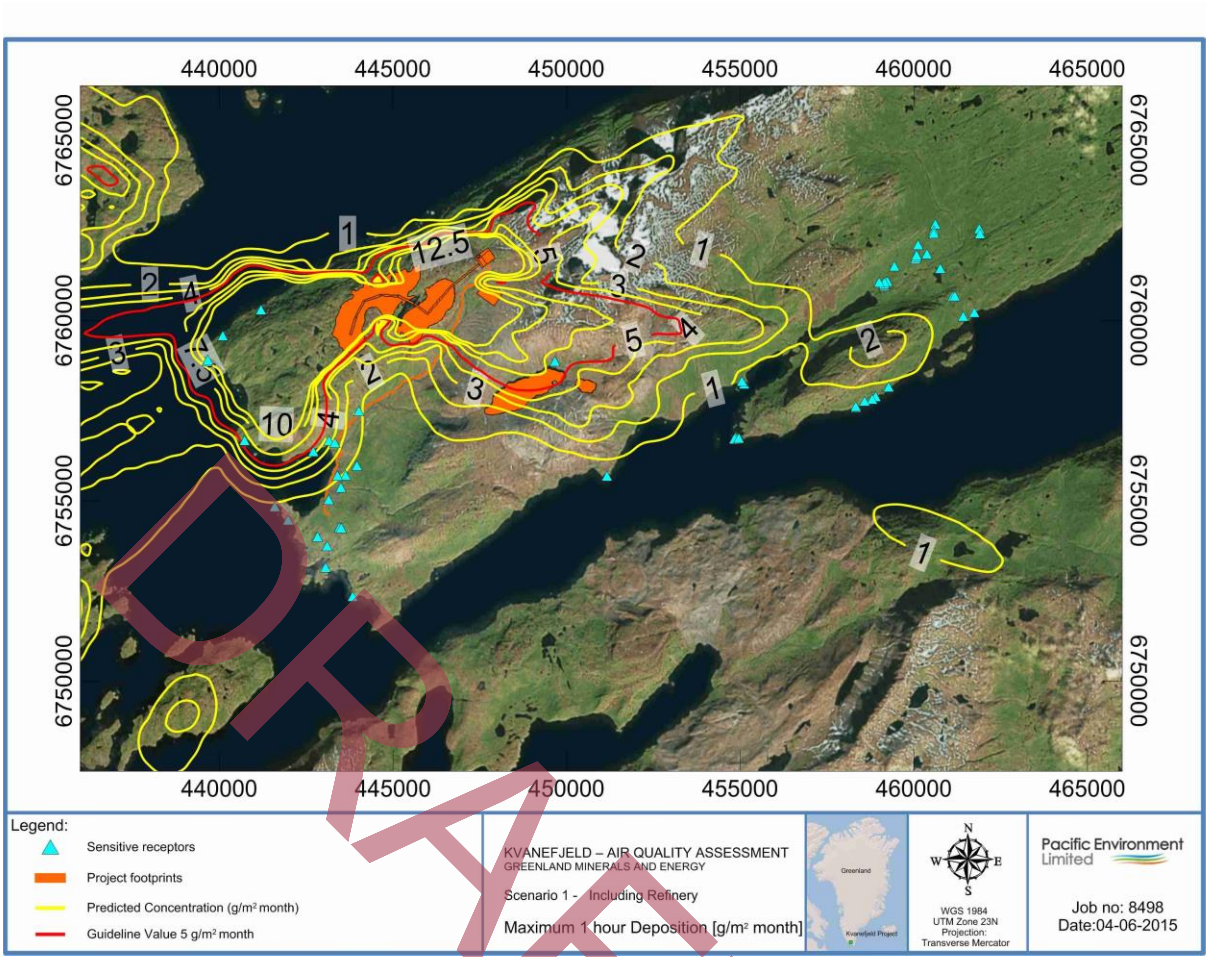

Figure 9-8: Maximum 1-hour deposition of dust (g/m^2/month)

Figure 9-8 illustrates the predicted deposition of dust generated by the project. The calculated dust figures are based on the predicted maximum 1-hour values and show the deposition in gram per square meter if this maximum value lasted for an entire month.

Most dust is predicted to deposit on the Kvanefjeld and on the mountainous plateau to the south-west of Kvanefjeld. Less than 1 g/m^2/month will deposit in Narsaq town, at Ipiutaq and at the sheep farming area further to the northeast around Qassiarsuk. These deposition amounts are well below the Greenland guideline value of 4.0 g/m^2/month.

9.2.1.3. Impact of Dust Deposition

Dust deposition from mining and unpaved roads can impact tundra vegetation, through coating of leaves /Auerbach *et al*., 1997, Myers-Smith *et al*., 2006/.

Dust on vegetation might also impact mammals and birds that feed on the vegetation. Researchers in northern Canada observed a reduction of 50 to 75% in caribou density where calculated dust deposition exceeded about 20 kg/ha/year (5.5 mg/m^2/day) (Boulanger et al., 2012). Caribou density rose quickly to normal frequency at lower dust levels. Caribou are not found in the Kvanefjeld area, but the observations from Canada suggests a dust deposition threshold on the order of 20 kg/ha/year might also be relevant for Arctic hare, sheep and bird such as Ptarmigan which feed on vegetation. The modelling has shown that the area with dust deposition above 20 kg/ha/year (5.5 mg/m^2/day) extends less than a few hundred meters from the mine pits and haul roads and the deposition is below 3 mg/m^2/day at Narsaq farm, Ipiutaq and the farms at Qassiarsuk. The dust footprint for potential impact on vegetation and mammals – including sheep - and birds is thus very small.

9.2.1.4. Metal Deposition

The content of metals in dust deposition (TSP) will reflect the composition of the material from which dust is generated. The composition of dust from travel on gravel haul roads will be similar to the composition of the gravel. The composition of dust from blasting, excavation, handling, storage and crushing of ore and waste rock will depend on the composition of these materials.

The largest source of dust is from the haul roads (c 92%). These gravel roads will be built from waste rock and surrounding country rock so the composition of the dust particles will therefore reflect the composition of this material. Dust emanating from ore is not expected to contribute significantly to the haul road dust load.

Dust particles from other mining activities at the mine site will be generated from waste rock and ore. In the following, these sources are assumed to contribute with equal amounts. To estimate the metal deposition load from haul roads and other sources in the mine area analyses of the composition of waste rock and ore are used (Table 9-4).

Element	Maximum Concentrations Ore µg/g (ppm)	Maximum Concentrations Waste Rock µg/g (ppm)
Arsenic (As)	19	5
Cadmium (Cd)	0.5	< 0.5
Lead (Pb)	474	39
Mercury (Hg)	1	1
Nickel (Ni)	2	10
Thallium (Tl)	3	2

Table 9-4: Maximum concentrations of metals in emitted dust (ppm), based on highest measured concentrations in ore and waste rock samples

The annual deposition load of metals will be proportional to the annual deposition of TSP shown earlier in Figure 9-8. The TSP deposition rates shown on the isolines in this figure can be converted to metal deposition rates by multiplying by the concentrations given in Table 9-5.

Element	Maximum Annual Deposition Load		Greenland Deposition Rates Limit Value
	Narsaq Farm µg/m²/month	Narsaq Town µg/m²/month	µg/m²/month
Arcenic (As)	19	> 19	120
Cadmium (Cd)	0.5	> 0.5	60
Lead (Pb)	479	>479	3000
Mercury (Hg)	1	>1	1.5
Nickel (Ni)	10	>10	450
Thallium (Tl)	3	>3	60

Table 9-5: Comparison of maximum metal deposition loads to Greenland limit values, for arsenic, cadmium, lead, mercury, nickel and thallium

9.2.1.5. Conclusion – particulate emissions

The dust emissions from the Kvanefjeld project will not result in any significant impact. High concentrations of air borne particles (TSP, P_{10} and $P_{2.5}$) will only occur in the mine area. Narsaq Farm (in Narsaq Valley), Narsaq town, Ipiutaq and the farms further to the northeast at Qassiarsuk will see dust concentrations all times well below the Greenlandic guidelines (and Canadian guidelines for TSP which is not addressed in the Greenland guidelines).

The modelled particulate emissions takes into account the high rainfall frequency of the region and long periods of snow cover but not any dust control measures implemented by GMEL. GMEL has developed a Dust Control Plan /GMEL 2015c/ which will include a management plan with dust suppressing activities that will be implemented during operations.

Among the dust suppression activities to be implemented are:

- Wetting of rock stockpiles, concentrates and waste materials with water sprinkler systems (summer);
- Wetting of haul roads with water spray trucks (summer);
- Salting of haul roads to melt ice and snow from the roads. The salt can also increase surface moisture by extracting moisture from the atmosphere (winter);
- Introduce appropriate vehicle speed limits, regular grading and maintenance;

- Introduce drilling dust containment (which capture generated dust during drilling operations);
- Blasting dust mitigations (wetting down the blasting area and activating "fog cannon" which generates fine water mist towards the blasting region (summer));
- Introduce vehicle washing system at the exit point of the mining area to minimize dispersal of dust along roads outside mine area.

With these mitigations in place, the dust generation from mining activities is expected to be reduced considerably and the dust concentration and deposition significantly lower than the modelled values.

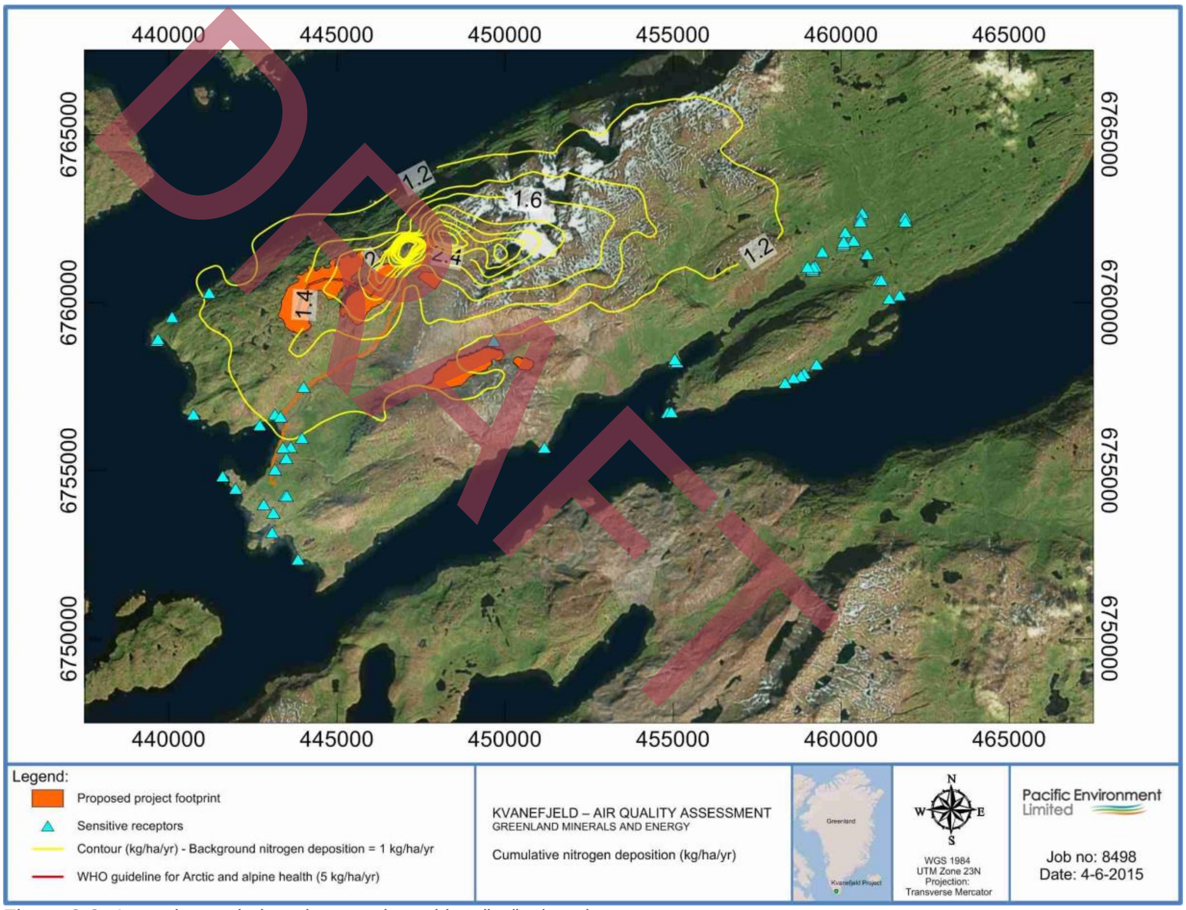

Figure 9-9: Annual cumulative nitrogen deposition (kg/ha/year)

9.2.1.6. Nitrogen compounds

The key emission source of NO_2 is the on-site power station. For NO_2 (24 hour maximum) the model results indicate that outside the mine area the highest NO_2 24-hour-concentration is predicted at Narsaq farm, and is 30.7µg/m^3. The predicted maximum

24-hour concentration in Narsaq, at Ipiutaq and the sheep farms further away is between 18.7 µg/m^3 and 22.9 µg/m^3. These values are all well below the Greenland guideline value of 100 µg/m^3/day.

Most nitrogen deposition occurs in the mine area close to the source (Figure 9-9). At Narsaq Farm in Narsaq Valley, an annual average deposition of 0.011 kg/ha/yr is estimated. Based on an estimated background deposition of 1 kg/ha/yr, the cumulative nitrogen deposition is estimated at 1.011 kg/ha/yr. In Narsaq town, at Ipiutaq and the sheep farms to the northeast at Qassiarsuk the total annual nitrogen deposition is below 1.008 kg/ha/yr.

These predicted cumulative nitrogen deposition results do not exceed the critical load of 5 – 15 kg/ha/year of nitrogen for changes in the ground vegetation in Arctic heaths as defined by WHO /2000/.

9.2.1.7. Sulfur compounds

The main sources of sulfur dioxide (SO_2) are the on-site power plants and the Refinery. Outside the mine area, the modelled concentrations are quite low with 17.8µg/m^3 predicted at Narsaq Farm in Narsaq Valley. The predicted annual average concentration for Narsaq town, Ipiutaq and the sheep farms around Qassiarsuk is between 5.6µg/m^3 and 17.5µg/m^3. Consequently, the predicted SO_2 annual average concentrations outside the mine area are well below the Greenland guideline value of 125 µg/m^3/day.

For Hydrogen Sulfide (H_2S) the model results indicate that outside the mine area the highest H_2S 24-hour maximum concentration is predicted at Narsaq farm, and is 2.0E-09µg/m^3. The predicted maximum 24-hour concentration for Narsaq, Ipiutaq and the farms at Qassiarsuk is between 4.5E-10µg/m^3 and 1.4E-09µg/m^3. Greenland's guidelines for air quality do not address Total reduced sulfur (H_2S) but the predicted values are well below the Canadian assessment limit of 7µg/m^3.

9.2.1.8. Conclusion - Oxides of nitrogen and sulfur compounds

Emissions of oxides of nitrogen and sulfur compounds from the Kvanefjeld project will not result in significant impact. Outside the mine area the emissions of all modelled species (NO_2, SO_2 and H_2S) are found to be well below Greenland guideline value (and Canadian guidelines where Greenland values are not available).

9.2.1.9. Black carbon

Black carbon is a component of soot, emitted by incomplete combustion of fuel. The main contributors of Black Carbon emissions are fuel combustion from the on-site power station and diesel engines used for mining activities. To estimate the amount of Black carbon emitted by project activities the following assumptions were made:

- All $PM_{2.5}$ emissions from the power station are considered to be Black carbon.
- 1% of $PM_{2.5}$ emissions in mining operations is attributed to diesel engine combustion and considered to be Black carbon.
- Background concentration during summer (May-October) is 0.011 µg/m^3.
- Background concentration during winter (November-April) is 0.073 µg/m^3.

Modelling the Black carbon concentrations based on these assumptions indicate that:

- Outside the mine area, the highest Black Carbon is predicted at Narsaq farm with an annual average concentration of 0.09 µg/m^3.
- The highest maximum 24-hour concentration is also predicted at Narsaq farm at 0.664 µg/m^3.

Black carbon emissions in Greenland are generally very low and the modelling results show that activities in connection with the Kvanefjeld project will not change this significantly.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Probable	Medium
Mitigation measures • Minimize dust generation by implementing GMEL's Dust Control Plan • Choose vehicles and other equipment based on energy efficiency technologies to optimize emissions rates • Maintain power plant, vehicles and other fuel powered equipment in accordance with manufacture's specifications to minimize on emissions				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Probable	Medium

Table 9-6: Assessment summary of air emission impact during Operations

9.2.2 Greenhouse gas emissions

Greenhouse gases (GHG) play an important role in regulating the earth's temperature. Anthropogenic greenhouse gases, such as the burning of fossil fuels (e.g. coal and oil) causes the GHG levels in the Earth's atmosphere to increase significantly.

The following is based on an assessment by Pacific Environment Limited /PEL 2015b/. The GHGs evaluated in the context of the Kvanefjeld project are carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). The GHG emissions are estimated based upon methods outlined in the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for national greenhouse gas inventories.

The emissions sources considered for this assessment are:

- Mobile combustion: including emissions due to diesel combustion in mobile sources.
- Stationary combustion: including emissions generated due to fuel consumption for power generation.
- Direct emissions of carbon dioxide from the refinery.

9.2.2.1. Mobile combustion

Diesel will be combusted in haul trucks, mining equipment (i.e. wheel dozers, excavators, front-end loaders and drills), light vehicles and service vehicles. The total vehicles fuel consumption is estimated at 6,402,000 L/year and the forecasted fuel economy value to 2.4 km/L.

Emissions of CO_2 were calculated by multiplying estimated fuel consumption with a default emission factor (see Table 9-7) and an energy content factor of 0.00363 GJ/L; whereas CH_4 and N_2O emissions were calculated using the kilometers travelled and the fuel economy technology approach.

Diesel consumption – mobile consumption	Emission factor	Units
CO_2	74.1	Kg CO_2-emissions/GJ
CH_4	5×10^{-05}	Kg CO_2-emmisions/km
N_2O	3×10^{-05}	Kg CO_2-emissions/km

Table 9-7: Table 9-8. IPCC emission factors

The total GHG emissions from fuel combustion from vehicles are estimated at 17,215 tonnes per year of which 99% are CO_2 emissions.

9.2.2.2. Stationary combustion

The GHG emissions from the on-site power plant is calculated using the same energy content factor and emission factors as for mobile combustion (see above). A total of 251,339 tonnes of GHG emissions per year was estimated from fuel consumption in generators. More than 99% of the GHG's are CO_2.

9.2.2.3. Emissions from Refinery Facilities

Assuming 24 hours operations and 365 days a year, the estimated CO_2 emissions are shown in Table 9-9. The total CO_2 emissions from the refinery are estimated to be 77,749 tons of CO_2 per year. Emissions of CH_4 and N_2O are not relevant to the refinery's activities.

Equipment description	Flow rate m^3/h	Density CO_2 (kg/m^3)	GHG emissions (tons CO_2/year)
Product calciners	80,000	1.364	24.857
Tank vent gas	4,000	1.713	33.007
Steam boiler	14,000	1.224	12.610
Mine diesel generator	750	0.920	508
Tailings diesel generator	10,000	0.920	6.768
Total			**77.749**

Table 9-9: Estimated GHG emissions from Refinery

9.2.2.4. Total GHG emissions

A total of 0.35 million tons CO_2 emissions per year is estimated for the project. The combined CH_4 and N_2O emissions are 14.5 tonnes GHG per year.

The annual CO_2 emissions in Greenland were 555.303 tonnes in 2013 /Grønlands Statistic 2015/. Taking this figure into account the Kvanefjeld project will increase Greenland's CO_2 emissions in Greenland by 63%.

The CO_2 emissions in Greenland will increase from currently around 9.7 t CO_2 per capita per year to 15.9 t CO_2 per capita per year in the operational period. Since the population of Greenland is very small compared to other countries and there is practically no industry in Greenland, any new energy demanding industries will alter the per capita emission significantly.

A comparison of CO_2 emission in absolute terms gives another perspective. The annual Danish CO_2 emission (2013) from energy consumption is approximately 43 million tons CO_2. The existing CO_2 emission from Greenland is around 1.3 % of the emission from Denmark. In the operational phase of the Kvanefjeld Project, this will increase this to 2.1 % (assuming all other quantities remain constant).

Furthermore, the 523 tons of Uranium oxide produced by the Project annually will be used to produce electricity at nuclear power plants outside Greenland. This will lead to a reduction in CO_2 emissions of c. 7 million tonnes/years compared to power produced by an average European power station /GMEL 2015b/.

9.3. Radiological emissions

9.3.1 Introduction

Some of the activities in connection with the Kvanefjeld mine operations can cause release of radioactivity to the air and water that potentially can be harmful to animals, plants and humans.

This section summarizes the radiological studies and the assessment that has been carried out and is reported in Arcadis /2015a/. It should be noted that the account below is a shortened description of the radiological assessment. For the full description, reference is made to Arcadis /2015a/.

The radiological assessment of the Kvanefjeld Project consists of the following main steps: First, the potential releases from the mine as well as the processing and refining estimated and the radiological contaminants of concern are identified. Next the estimates of releases are used with studies that were prepared as part of the Kvanefjeld project that looked at the dispersion in air and water. Then radionuclide concentrations due to mine activities are determined in receptors such as soil, water, plants, animals and humans at different locations within a study area. These concentrations are subsequently used in association with intake characteristics of receptors and established dose coefficients to estimate radiological dose to each receptor. Effects to the health of wildlife are then determined by comparing the total dose (natural background dose and dose due to project activities) to a selected dose limit. If the dose is below the protective dose limit, then it can be concluded that the health of the species is not at risk. For humans the dose due to project activities only is compared to a dose benchmark[1].

[1] It is standard practice that the calculations of radiological concentrations and dose as well as the risk assessment follow different procedures for the flora and fauna and for humans.

To calculate the radiological concentrations and dose exposure to animals, plants and humans Arcadis /2015a/ used the INTAKE pathways model. This model is developed by Arcadis for use in simulating environmental transfer, uptake and risk due to exposure to radionuclides released to the environment (e.g., air, water, soil).

9.3.2 Potential radioactive releases from the project

A first step is to determine how project activities can potentially contaminate the environment. This is done by carefully examining all planned mine activities and processes. Following a thorough scrutiny Arcadis identified the following potential releases:

- Dispersal of dust containing radionuclides which settles on soil and vegetation and is transferred through the food chain to animals and humans;
- Release of radon gas and radon progeny to the air, which is inhaled by wildlife and humans; and
- Discharge of contaminated water into Nordre Sermilik which may impact marine plants and animals and ultimately humans when they eat them.

No contamination of freshwater (lakes and rivers) is expected during the operation of the planned project.

9.3.3 Contaminants Of Potential Concern (COPC)

A next step in the assessment process is to determine which radiological contaminants in connection with the project are of potential concern.

For the Kvanefjeld project the Contaminants Of Potential Concern (COPC's) are identified as the following long-lived radionuclides in the uranium and thorium decay chains: uranium-238, thorium-230, radium-226, lead-210, polonium-210, radon-222 (radon), thorium-232, radium-228, thorium-228 and radon-220 (thoron).

9.3.4 Development of Conceptual Site Model

When the potential releases from the project are identified and the contaminants of potential concern are determined, a Conceptual Site Model is developed. The Conceptual Site Model encompass information on the area that can potentially be impacted by radiological releases from the project, the animals, plants and people that occur in this area. This assists the understanding of how radioactive contaminants can come in contact with animals, plants, their habitats and people.

First, the geographical area that may be impacted by the releases is defined. Because the radiological releases of concern are identified as dust, radon gas and discharges into the fjord, the area of concern is defined by the potential dispersal of contaminants through these pathways. A specific study of the dispersal of dust and radon during the operational phase was carried out by Pacific Environment and is reported in section 9.2.1. The dispersal of water discharged to Nordre Sermilik was modelled and discussed in a specific study by DHI (section 9.4).

Based on the findings in these two studies the geographical area to be covered by the radiological assessment was decided to comprise the "Study area" (Figure 2-2) and Tuttutooq Island. Outside this area Pacific Environment /2015a/ found the concentrations and deposition of dust to be so low that any impact from radionuclide bearing dust and radon from the Project would be unmeasurable. The same applies to the concentrations of radiological contaminants in marine waters due to dilution in the fjord. Tuttutooq Island southwest of the study area is included to assess any impact on it's introduced reindeer population. Tuttutooq is therefore considered part of the Study area in the following radiological assessment.

With the area to be included in the Site Model defined, the next step is to gather information on the plants and animals that occur in the Study area and gathering information on how they interact (feed on each other). Also knowledge about what people living in the area do, on or near the site and how often, is compiled.

9.3.5 Selection species to include in assessment

It is not reasonably possible to include all species of plants and animals of the Study area in the assessment. Therefore, a number of species are selected that represent a range of habitat preferences (associated by the fjords, freshwater, terrestrial habitats) and food choices (such as predators and herbivores).

Since radioactive contaminants may be transferred – and sometimes accumulated – when one species feeds on another, it is important to include species from all levels of the food chain. This is done by selecting members from all trophic levels based on their dietary characteristics.

The food chain in the Study area consists of four tropic levels. Below is an overview of typical species associated with each level and the species that are selected for the radiological assessment:

Primary producers are plants and algae that manufacture their energy and biomass using only sunlight and inorganic nutrients from the soil or water. Primary producers chosen for this assessment are phytoplankton, Snow lichens, bushes (Salix), grass, berries and sea weed in the fjords.

Primary consumers are the living organisms that eat the primary producers. This includes zooplankton such as tiny water fleas (Cladocerans) and Copepods, which are common in rivers and lakes as well as in the fjords around Narsaq. It also includes terrestrial animals such as Arctic hare and sheep as well as birds such as ptarmigan that all feed on plants. For the purpose of this assessment the following primary consumers are included: benthic crustacean (crustacean that live on the bottom of the fjord floor), Arctic hare, Ptarmigan, Snow bunting, Sheep and Reindeer.

Species/species groups	Main diet	Fraction time spent in area during year
Marine phytoplankton	inorganic nutrients + sunlight	1
Lichens	inorganic nutrients + sunlight	1
Mussels, copepods, shrimp	Zoo- and phytoplankton	1
Leaves from bushes (Salix)	inorganic nutrients + sunlight	1
Grass	inorganic nutrients + sunlight	1
Marine fish	Zooplankton, insects, fish	1
Berries	inorganic nutrients + sunlight	1
Brünnich's guillemot	60% fish, 35% benthic invertebrates, 5% sediment	0.5 (winter)
Common Eider	95% mussels, 5% sediment	0.5 (winter)
Mallard	75% benthic invertebrates, 24% aquatic plants, 1% sediment	1
Purple sandpiper	96% benthic invertebrates, 4% sediment,	1
Ringed seal	60% fish, 40% crustaceans	1
Humpback whale	50% fish, 50% crustaceans	0.1 (summer)
Glaucous gull	50% fish, 35% birds & mammals, 10% benthic invertebrates, 5% sediment	1
Peregrine falcon	80% Snow bunting, 18% ptarmigan, 2% soil	0.5 (summer)
White-tailed eagle	80% fish, 10% birds, 10% soil & sediment	1
Arctic fox	50% small birds, 25% fish, 25% hare	1
Snow bunting	95% seeds, 5% soil	1
Ptarmigan	83% plants, 15% berries, 2% soil	1
Arctic hare	98% plant, 2% soil	1
Sheep	95% plant, 5% soil	1
Reindeer	75% lichens, 22% plant, 3% soil	1

Table 9-10: Typical diet and fraction time spent in area during year for selected plants and animals of the Study area

Secondary consumers are organisms that largely feed on primary consumers, such as small fish and mussels that feed on zoo- (and phyto)plankton but also birds that eat worms and other invertebrates. For the purpose of this assessment the following secondary consumers are included: Purple sandpiper, Brünnich's guillemot, Mallard, Glaucous gull, Atlantic cod and Blue mussels.

Tertiary consumers are found at the top end of the food chain and consist of larger predatory fish species that consume other fish species, seals that feed on fish, the Arctic fox and raptors that feed on large fish (sea eagle) and other birds (Peregrine falcon). Atlantic salmon, Arctic char, Arctic fox, Ringed seal, Peregrine and White-tailed eagle represents the tertiary consumers in this assessment. In addition, the Humpback whale is included here. This species of whale feeds on zooplankton but also on small fish.

It should be noted, that some species could be assigned to several tropic levels. For example, Arctic fox is almost omnivorous in its food choice and could be considered a primary, secondary and tertiary consumer. If a species can be assigned to more than one tropic level it is listed under the highest level to ensure a conservative approach to the assessment.

For the assessment of the dose to people, two groups were identified to be included; Town residents and visitors to the area (residing in the summer houses and using the land for recreational purposes). The traditional Greenlandic diet is characterized by being a fishing-hunting society. The use of traditional foods depends on factors such as availability, seasonal variation and economy. For the radiation assessment it was assumed that there is a strong reliance on local food including fish, seal and sheep. Three age groups were considered for the Town resident: a toddler, a child and an adult. It was assumed that the current land use will continue, although it is acknowledged that sheep farming in the Narsaq valley has already ended. A cautious approach was adopted to ensure exposure is not under-estimated.

9.3.6 INTAKE pathways model inputs

With the potential radioactive releases from the project potential identified, the relevant COPC's recognized and a Conceptual Site Model in place with information on wildlife and people, the modelling of the radiological impacts can be initiated.

The modelling process comprises several steps. The most important are the following:

1. The concentrations of COPC in environmental media during mine operation are calculated for selected animals and plant species in a number of relevant locations within the Study area. The concentrations comprise the natural background values plus the incremental contribution due to project activities.

2. The radiological dose is then estimated for people and each ecological receptor. The dose is the amount of radiation energy absorbed by the body. The dose is estimated from calculated COPC concentrations and established dose coefficients.

3. The potential for an adverse effect on wildlife is then determined by comparing the total dose (background and the project) to a selected dose limit. For humans the dose due to project activities is compared to a dose benchmark.

9.3.7 Calculating the concentrations of COPC

As mentioned in section 9.3.2 the radioactive releases from project activities are identified as dispersal of radioactive dust, radon and discharge of contaminated water into the sea. Below each of these media are discussed further. In addition, the calculation approach for estimating concentrations of COPCs for relevant plants and animals is discussed.

For estimating concentrations in plants and animals, a transfer factor must be taken into account. Transfer factors are values that provide a measure of the partitioning behaviour of COPC between two environmental media, such as water-to-fish, water-to-benthic invertebrates, food-to-animal flesh, and other media.

Dispersal of radioactive dust

The Pacific Environment /2015a/ modelling study identified the sources of dust during operation, and estimated the concentrations at different locations within the Study area. Using this information and data on the content of uranium and thorium in the source material of the dust, concentrations of COPCs at different locations in the Study area were estimated. This information is then used to predict the change in soil concentrations due to dust deposition.

The concentrations in terrestrial vegetation is estimated using the soil concentration and a soil-to-vegetation Transfer Factor. This is done by for broad categories of vegetation such as “browse” (leaves from scrubs), “forage” (grasses), berries and lichen using different Transfer Factors. As an example, the estimated concentration of COPC in lichens at different locations in and around the Study area is shown in Table 9-11. The estimated concentrations include the background value and the impact of contaminated dust from the project.

After calculating the concentrations of COPC in soil and plants (including lichens), the concentrations in the selected animals that reside in various terrestrial habitats of the Study area are determined. This is done for each species by taking into account the food they eat (including the amount), the time the animals spent in the Study area (some are migratory), the estimated concentrations of radionuclides in the plants/animals they feed on and/or live in and Transfer Factors.

COPC	Unit	Narsaq Valley	Taseq Lake	Narsaq Town	Tuttutooq Island
Uranium	µg/g	4.9	2.2	2.4	2.4
Uranium-238	Bq/g	0.061	0.028	0.03	0.03
Thorium-230	Bq/g	0.061	0.028	0.03	0.03
Radium-226	Bq/g	0.061	0.028	0.03	0.03
Lead-210	Bq/g	0.061	0.028	0.03	0.03
Polonium-210	Bq/g	0.061	0.028	0.03	0.03
Thorium	µg/g	15	8.7	9.1	9.1
Thorium-232	Bq/g	0.062	0.035	0.037	0.037
Radium-228	Bq/g	0.062	0.035	0.037	0.037
Thorium-228	Bq/g	0.062	0.035	0.037	0.037

Table 9-11: Estimated concentrations of COPC in lichen at five locations in the Study area (background and project contribution) during the operational phase

Concentrations for selected terrestrial birds and mammals at a number of locations within the Study area is shown in Table 9-12.

COPC	Unit	Narsaq Valley		Ipiutaq		Narsaq town
		Ptarmigan	Arctic fox	White-tailed eagle	Sheep	Glaucous gull
Uranium	µg/g	0.021	$1.8x10^{-5}$	0.007	$2.8x10^{-4}$	0.0029
Uranium-238	Bq/g	$2.6x10^{-4}$	$2.2x10^{-7}$	$1.6x10^{-3}$	$3.4x10^{-6}$	$3.6x10^{-5}$
Thorium-230	Bq/g	$2.6x10^{-6}$	$2.0x10^{-7}$	$2.9x10^{-5}$	$1.1x10^{-6}$	$4.7x10^{-7}$
Radium-226	Bq/g	$1.8x10^{-5}$	$9.7x10^{-7}$	$6.5x10^{-5}$	$1.3x10^{-4}$	$1.4x10^{-6}$
Lead-210	Bq/g	0.002	$2.2x10^{-7}$	$1.1x10^{-3}$	$2.8x10^{-5}$	$2.2x10^{-5}$
Polonium-210	Bq/g	0.005	$5.7x10^{-6}$	$5.8x10^{-3}$	$7.6x10^{-6}$	$1.1x10^{-4}$
Thorium	µg/g	$5.2x10^{-4}$	$4.0x10^{-5}$	$4.4x10^{-3}$	$2.1x10^{-4}$	$8.7x10^{-6}$
Thorium-232	Bq/g	$7.1x10^{-6}$	$1.6x10^{-7}$	$1.8x10^{-5}$	$8.6x10^{-7}$	$3.5x10^{-8}$
Radium-228	Bq/g	$1.4x10^{-5}$	$7.9x10^{-7}$	$5.2x10^{-5}$	$1.0x10^{-4}$	$1.1x10^{-7}$
Thorium-228	Bq/g	$2.1x10^{-6}$	$1.6x10^{-7}$	$1.8x10^{-5}$	$8.6x10^{-7}$	$3.5x10^{08}$

Table 9-12: Concentrations of COPC in mammals and birds at different locations in Study area

Radon

Pacific Environment /2015a/ modelled the dispersion of radon released in connection with the mine operations. This was combined with an estimated radon emission rate for mining of 1.5 $Bq/m^2/s$. This is a small contribution to the natural background and led to an increase of less than 2% to the outdoor radon concentration in the town of Narsaq. In the assessment, the potential impact of radon is only considered in connection with human health.

Discharge of contaminated water into Nordre Sermilik

The Kvanefjeld Project will have two discharge points to the marine environment (see Figure 5-1):

- A stream of water from the mine area that discharges via a natural watercourse; and
- Two pipelines that discharge water from the processing plant (called TWP).

The stream from the mine area consists of mine pit water, waste rock deposit run-off and remaining catchment runoff. This water flows into the fjord through a small surface stream. The concentration of uranium and thorium in this stream has been estimated at 0.0025 mg/l and 0.001 mg/L, respectively. It is assumed that the radionuclides of the water are present in secular equilibrium (the quantity of the radionuclides remains constant due to decay of a parent isotope). The concentrations of COPCs in the fjord water due to the discharge from this stream are calculated for an area close to the discharge point and for Nordre Sermilik – see Table 9-13.

Processing water will be sources from Narsaq River but will also include recycled decant water from each of the tailings facilities. Processing water is placed in Nordre Sermilik as Treated Water Placement (TWP). This water contains low concentrations of uranium and thorium series radionuclides (from the FTSF and ore processing at the Refinery). Before the excess water is discharged to the fjord it is treated which will – among other things – remove significant amounts of lead (and thus lead-210).

The discharge of TWP in Nordre Sermilik will be < 40 meters below the sea surface and modelling conducted by DHI /2015a/ shows that significant dilution is quickly obtained from the release point. Calculated concentrations of uranium and thorium and their radionuclides near the discharge point and in Nordre Sermilik are shown in Table 9-13.

COPC	Unit	Background	Stream runoff	Treated Water Placement	Nordre Sermilik Runoff + TWP
Uranium	µg/L	2	2.003	2.73	2.046
Uranium-238	Bq/L	0.025	0.025	0.034	0.025
Thorium-230	Bq/L	0.025	0.025	0.031	0.025
Radium-226	Bq/L	0.005	0.005	0.005	0.005
Lead-210	Bq/L	0.001	0.001	0.002	0.001
Polonium-210	Bq/L	0.001	0.001	0.001	0.001
Thorium	µg/L	0.25	0.251	0.251	0.250
Thorium-232	Bq/L	0.001	0.001	0.001	0.001
Radium-228	Bq/L	0.001	0.001	0.001	0.0010
Thorium-228	Bq/L	0.001	0.001	0.001	0.001

Table 9-13: Estimated concentrations of COPC at three locations in Nordre Sermilik

With this knowledge about the estimated concentrations of COPC at various points in Nordre Sermilik the concentrations of COPCs in marine animals are calculated. This has been done for three locations: the stream run off, the discharge point for the TWP and for Nordre Sermilik. Examples of the calculated concentrations are shown in Table 9-14. The results for all selected species are available in Arcadis /2015a/.

COPC	Unit	Stream runoff		TWP		Nordre Sermilik Stream runoff + TWP	
		Mussels	Fish	Mussels	Fish	Mussels	Fish
Uranium	µg/g	$6.0x10^{-2}$	$2.0x10^{-3}$	$8.2x10^{-2}$	$2.7x10^{-3}$	$6.1x10^{-2}$	$2.0x10^{-3}$
Uranium-238	Bq/g	$7.4x10^{-4}$	$2.5x10^{-5}$	$1.0x10^{-3}$	$3.4x10^{-5}$	$7.4x10^{-4}$	$2.5x10^{-5}$
Thorium-230	Bq/g	$2.5x10^{-2}$	$1.5x10^{-2}$	$3.1x10^{-2}$	$1.9x10^{-5}$	$2.5x10^{-2}$	$1.5x10^{-2}$
Radium-226	Bq/g	$5.0x10^{-4}$	$5.0x10^{-4}$	$5.1x10^{-4}$	$5.1x10^{-4}$	$5.0x10^{-4}$	$5.0x10^{-4}$
Lead-210	Bq/g	$3.7x10^{-2}$	$1.5x10^{-4}$	$8.8x10^{-2}$	$3.5x10^{-4}$	$3.6x10^{-2}$	$1.4x10^{-4}$
Polonium-210	Bq/g	$1.1x10^{-2}$	$1.1x10^{-3}$	$1.2x10^{-2}$	$1.2x10^{-3}$	$1.0x10^{-2}$	$1.0x10^{-3}$
Thorium	µg/g	$2.5x10^{-1}$	$1.5x10^{-1}$	$2.5x10^{-1}$	$1.5x10^{-1}$	$2.5x10^{-1}$	$1.5x10^{-1}$
Thorium-232	Bq/g	$1.0x10^{-3}$	$6.1x10^{-4}$	$1.0x10^{-3}$	$6.1x10^{-4}$	$1.0x10^{-3}$	$6.1x10^{-4}$
Radium-228	Bq/g	$1.0x10^{-4}$	$1.0x10^{-4}$	$1.1x10^{-4}$	$1.1x10^{-4}$	$1.0x10^{-4}$	$1.0x10^{-4}$
Thorium-228	Bq/g	$1.0x10^{-3}$	$6.1x10^{-4}$	$1.1x10^{-3}$	$6.4x10^{-4}$	$1.0x10^{-3}$	$6.1x10^{-4}$

Table 9-14: Estimated concentrations of COPC in mussels and water at three locations in the Study area

9.3.8 Dose estimates

When the concentrations of radionuclides are determined, the radiation dose can be calculated. The dose is the amount of radiation energy absorbed by the organism.

It is not expected that project activities will contribute to any external radiation in the form of additional gamma doses to wildlife in the area. However, radionuclides deposited in body tissue can potentially lead to internal radiation exposure and the dose from this can continue long after the intake have ceased.

The dose is estimated using the calculated concentration of COPC in plants and animals (from 9.3.7) and a Dose Coefficient, which accounts for radiation and tissue weighting factors, metabolic and bio kinetic information. Values for Dose Coefficients are sourced from international agencies.

Examples of estimated doses for plants and animals in and around the Study area is shown in Table 9-15.

Species	Estimated dose (mGy/d)				
	Narsaq Town	Narsaq Valley	Ipiutaq	Tuttutooq Island	Nordre Sermilik
Snow Lichen	0.24	0.40	0.26	0.24	-
Grasses and herbs	0.0025	0.013	0.013	0.0083	-
Arctic hare	-	$3.6x10^{-4}$	$3.2x10^{-4}$	-	-
Arctic fox	-	$8.6x10^{-5}$	$5.2x10^{-5}$	-	-
Sheep	-	-	$5.2x10^{-4}$	-	-
Reindeer	-	-	-	0.0018	-
Ringed seal	-	-	-	-	0.009
Marine Fish	-	-	-	-	0.015

Table 9-15: Estimated dose (mGy/d) for Snow lichen, a selection of plant groups and a number of animal species

Dose estimation for humans takes into account the food and water intake, the concentration of COPC in the food, the fraction of food from different sources (such as fish and seal) as well as the fraction of radiological activity in each food type remaining after food preparation. In addition, the dose from inhalation of dust and radon in the air is included. Finally, the external dose due to gamma radiation is included.

9.3.9 Risk characterization

To determine if calculated doses are harmful it is necessary to compare them to a value for which it is known that there are no negative effect. Reference dose values or benchmark values, where no harmful effects of chronic radiation have been observed in natural populations, are published by international organizations. The values used for this assessment are shown in Table 9-16. Note that the values differ between animals and plants associated with aquatic and terrestrial environments. The radiation dose limit for a member of public is 1 mSv/yr (1000 μSv/y) over natural background levels.

	Value	Units
Aquatic biota (background + project)	9.6	mGy/d
Terrestrial biota (background + project)	2.4	mGy/d
People (incremental dose to member of the public)	1	mSv/y

Table 9-16: Reference Dose Limits used in the assessment

The final step in this radiological assessment is calculating the Screening Value Index. This is done by dividing the total dose rate (background plus project) received by a receptor (for example a bird) by the relevant Reference Dose Limits from Table 9-16. This implies that as long as the Screening Value Index is 1 or less there will be no adverse effects to animals or plants.

Table 9-17 shows the Screening Index Values for marine animals and plants at the near-field of the two discharge points in Nordre Sermilik and from a far field location in Nordre Sermilik. The Screening Index Values to all receptors are well below 1. In other fjords, the values are even lower.

Species	Stream run off	TWP	Nordre Sermilik
Benthic fish	0.002	0.002	0.002
Pelagic fish	0.002	0.002	0.002
Benthic/crustacean	0.003	0.004	0.003
Vascular plant	0.001	0.001	0.001
Ringed seal	-	-	0.001
Humpback whale	-	-	0.001

Table 9-17: Screening Index Values for marine animals and plants

Screening Index values for terrestrial plants and animals are given in Table 9-18. Again, the values to all receptors are far below 1 implying that there will be no adverse effects to animals or plants. The values outside the Study area, for example at Qassiarsuk are even lower.

Species	Narsaq Town	Narsaq Valley	Ipiutaq	Tuttutooq Island
Snow lichen	0.10	0.17	0.10	0.10
Grasses and herb	0.001	0.005	0.005	0.003
Arctic hare	-	<0.001	<0.001	-
Arctic fox	-	<0.001	<0.001	-
Sheep	-	-	<0.001	-
Reindeer	-	-	-	<0.001

Table 9-18: Screening Index Values for terrestrial receptors (plants and mammals)

Screening Index Values shown for a selection of birds in Table 9-19. The values for all species are far below 1. These values are even lower for areas outside the Study area.

Species	Narsaq Town	Narsaq Valley	Ipiutaq	Nordre Sermilik
Brünnichs guillemot	-	-	-	<0.001
Common eider	-	-	-	0.003
Purple sandpiper	-	-	-	<0.001
Ptarmigan	-	0.002	0.001	--
Snow bunting	-	<0.001	<0.001	-
White-tailed eagle	-	-	0.004	-
Glaucous gull	<0.001	-	0.008	-
Peregrine falcon	-	<0.001	-	-

Table 9-19: Screening Index Values for birds

9.3.10 Human health

The radiological baseline conditions for people including, air, water and soil quality, as well as concentrations in food items consumed by residents and visitors were used along with baseline radon and gamma rates to estimate background doses to human receptors in Narsaq Town and Ipiutaq – Table 9-20. The main sources of dose are the exposure to radon (58%), the consumption of local food, primarily seal and whale (26%) and external gamma (14%).

Receptor	Background Dose (µSv/yr)					
	Inhalation	Ingestion	Radon	Thoron	Gamma	Total
Adult resident	0.17	1095	2421	112	578	4207
Child resident	0.30	1760	2421	112	578	4871
Toddler resident	0.29	2123	2421	112	578	5234
Adult visitor	0.01	42	36	12	81	171

Table 9-20: Estimated baseline radiological dose for resident people and visitors

The calculations of dose due to activities associated with the Kvanefjeld project is presented in Table 9-21. It is assumed that the project impact on thoron concentration in air as well as external radiation is negligible. The main source of exposure is through food ingestion, primarily the consumption of seal.

The doses to all receptors are well below the dose benchmark for members of the public of 1000 µSv/year (1 mSv) as well as below the dose limit of 300 µSv/year that is considered by some agencies for members of the public. It is also seen that the doses associated with the project are a small fraction of those expected from natural background, which may range up to approximately 5000 µSv/year (Table 9-20).

Receptor	Dose (µSv/yr) due to project activities			
	Inhalation	Ingestion	Radon	Total
Adult resident	0.17	9	6	16
Child resident	0.3	15	6	21
Toddler resident	0.3	18	6	25
Adult visitor	0.006	0.4	0.08	0.5

Table 9-21: Estimated radiological dose due to project activities for resident people and visitors

9.3.11 Conclusion

The radiological impacts of the Kvanefjeld project to plants and animals associated with marine, freshwater and terrestrial habitats in the studies area as well as to people in Narsaq and Ipiutaq (and visitors) are very low. The estimated dose to all these receptors is far below benchmark values. Outside the studied area, such as at the sheep farmers around Qassiarsuk the dose is expected to be even lower.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Very Low	Definite	Medium
Mitigation measures • Implement the dust control measures in GMELs Dust Control Plan /GMEL 2015c/				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Very Low	Definite	Medium

Table 9-22: Assessment summary of radiological impacts

9.4. Water environment

Except for the two tailings ponds in Taseq basin and a small stream next to Kvanefjeld, no water from the project will flow into lakes or streams during the Operations (and Closure) Phases.

The Project will have two discharges to the marine environment:

- One stream of water is from the mine area and comprising water from the pit and runoff from the mine area including the waste rock stockpile. This water flows via a natural watercourse into Nordre Sermilik.

- The other stream comes from the processing plants. This water is placed via a pipe into Nordre Sermilik at a depth of more than 40 meters. This water has a temperature of 12^{o}C.

The potential impact of the chemical species of the streams has been assessed regarding the following:

- The potential risk to the marine pelagic environment;

- The potential for impact on sediment dwelling organisms (marine benthic community); and

- The potential for accumulation in the food web.

To assess these potential impacts the Danish Hydraulic Institute DHI /2015a/ developed a hydro-dynamic model for the fjord system (using MIKE 3-D) and modelled the quality and quantity of all major contaminants in the streams in terms of temperature, concentration and flow. The following is based on DHI's assessment /2015a/.

Initially, the contaminants from the effluent were reviewed and ranked according to the required dilution in order to obtain concentrations in the environment below Predicted No Effect Concentration in the marine environment (PNEC). This is the highest concentration in the marine environment at which no effects on the pelagic environment are expected. The PNEC-values were derived by DHI on the basis of the eco-toxicity of the individual contaminants. The required dilution was established on the basis of the concentration in the effluent, the assessed bioavailability and these PNEC-values.

All chemical species of the effluent were assessed to determine if they are Persistent Bioaccumulative Toxic (PBT) or very Persistent very Bioaccumulative (vPvB). In order to complete the understanding of the effluents, ecotoxicology testing was carried out using acute and chronic testing of algae, copepods and fish /DHI 2015b/.

Finally, the estimated concentrations of contaminants in two streams were compared to the Greenland marine and freshwater guidelines. Where no Greenland guidelines were available, Canadian guidelines are used instead.

9.4.1 Mine water stream

During the Operations Phase, runoff from the waste rock stockpile and water from dewatering of the mine pit flows via a natural watercourse into Nordre Sermilik. This stream has three main sources:

1. Mine pit water (from ground water and precipitation);
2. Waste rock stockpile runoff; and
3. Catchment runoff.

The flowrate of these sources is shown in Table 9-23.

Discharge components	Flowrate m^3/hr	Contribution in percent
Mine water (ground water)	33.5	9
Mine water from precipitation	95	25
Waste rock run-off	4	1
Remaining lake catchment	248	65
Total lake discharge (mine area water)	380.5	100

Table 9-23 Composition of flows from the lake to the marine environment

Based on chemical analysis of waste rock and ore the chemistry of the mine water is calculated /GMEL 2015d and Orbicon, 2015b/. From this data the concentrations of elements in the runoff to the fjord was estimated, see Table 9-24. This table also shows the Greenland marine and freshwater guidelines and information on the base-line concentrations in the fjord water. When no Greenland guidelines are available, Canadian guidelines are included (marked with an *).

The outlet concentration of iron is a factor of 3 higher compared with the Greenland marine ambient water quality guidelines. But because a dilution of a factor 3 will occur in the near field of the outlet, it is assessed that iron does not exceed ambient water quality criteria.

Elements	**Greenland Freshwater Criteria**	**Greenland Marine water Criteria**	**Baseline Nordre Sermilik**	**Mine water Outlet**
Arsenic (µg/L)	4	5	30	1
Cadmium (µg/L)	0.1	0.2	-	0.01
Chromium (µg/L)	3	3	-	0.03
Copper (µg/L)	2	2	-	0.4
Iron (µg/L)	300	30	-	100
Lead (µg/L)	1	2	-	1
Mercury (µg/L)	0.05	0.05	-	<0.5
Nickel (µg/L)	5	5	-	0.84
Zinc (µg/L)	10	10	-	9
Phosporous (µg/L)	20		-	130
Fluoride (mg/L)	0.12*		13	13
Potassium (mg/L)			-	0.65
Sulphur (mg/L)			837	0.42
Chloride (mg/L)	120*		13600	9.0
Sodium (mg/L)			-	0
Calcium (mg/L)			246	1.0
Uranium (µg/L)	15*		2	2.5
Manganese (µg/L)			-	6
Molybdenum (µg/L)	73*		7	4
Lithium (µg/L)			117	0
Thalium (µg/L)	0.8*		-	-
Radium (Bq/L)	0.5*		-	0.0

Table 9-24: Greenland (and Canadian) water guidelines, baseline concentrations in Nordre Sermilik and the concentrations of elements in the mine water outlet

The PNEC values and the required dilution for elements that needs a dilution above 1 are shown in Table 9-25.

Element	PNEC µg/L	Required dilution factor
Aluminium	2.5	64
Zink	3.02	3
Ziconium	7.4	1.1
Yttrium	0.72	1

Table 9-25 'Predicted No Effect Concentrations' for selection of elements and the required dilution to meet the PNEC limit

Aluminum is the element that requires most dilution to reach PNEC (64 times dilution). This is estimated to be reached within 100 meters of the discharge point.

Modelling of the movement and dilution of the mine water in Nordre Sermilik shows that the water flows to the southwest along the coast and into Narsaq Sound. The mine water also remains in upper 2 meters of the water column.

In conclusion: the discharge of mine area water was found to have very limited impact on the environment as the critical dilution factor is achieved very close to the discharge point (within 100m) /DHI 2015a/.

9.4.2 Process water

PNEC values for the individual chemical species in the effluent process water were derived from the literature based of a methodology accepted and used within the European Union /ECHA 2008/. The PNEC values and the required dilution are shown in Table 9-26 for the chemical species in the process water that requires the highest dilution.

Chemical species	PNEC µg/L	Required dilution factor
Shellsol D70	2	2282
Caprylic acid	1.4	1252
PC 88A	4.2	826
Alamine 336	0.0143	796
Alkyl Hydroxamic acid	0.26	674
Manganese	0.4	607
Uranium	1	365
W22	1	350
Beryllium	0.03	71
Fluorine	19.6	71
Decanoic Acid	36	49
Barium	11.5	39
Rubidium	52	28
Copper	5.2	27

Table 9-26: 'Predicted No Effect Concentrations' for selection of chemical species and the required dilution to meet the PNEC limit

The elements that requires high dilution factors are reagents used in the production.

<u>Ecotoxicology testing</u>

Ecotoxicology testing was done using acute and chronic testing with several organisms. The conclusion was that algae and fish appeared to be unaffected by the effluent, even at high concentrations. Under certain high concentrations the effluent may impact copepods /DHI 2015b/.

<u>Modelling the fate and spreading of chemical species</u>

The fate and spreading of the chemicals species from the treated water in the fjords in summer and winter was modelled. It was found that for a release below 40 meters depth, the vertical mixing during winter is far lower than compared to the vertical mixing in summer.

The modelling further showed that from the discharge point the water spread in a narrow band westwards along the coast – Figure 9-10. The vertical distribution is shown in Figure 9-11, and shows that the plume remains between – 20 and – 40 meters depth in summer. During the winter the band is narrower and range between – 35 and – 45 m depth.

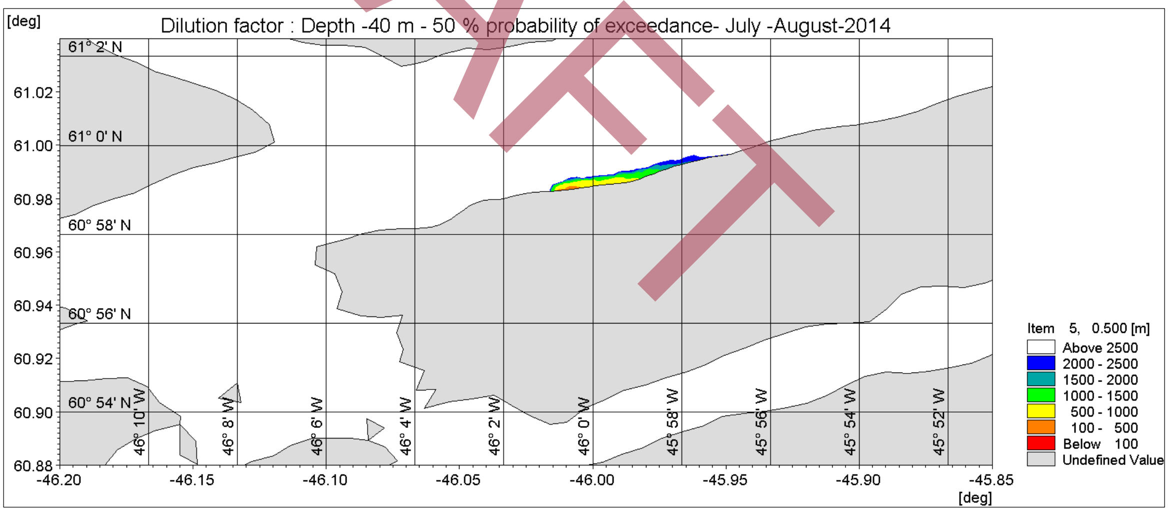

Figure 9-10: 50th percentile dilution factors at an insertion depth of -40 m and for summer situation. The plume is slightly smaller in the winter situation

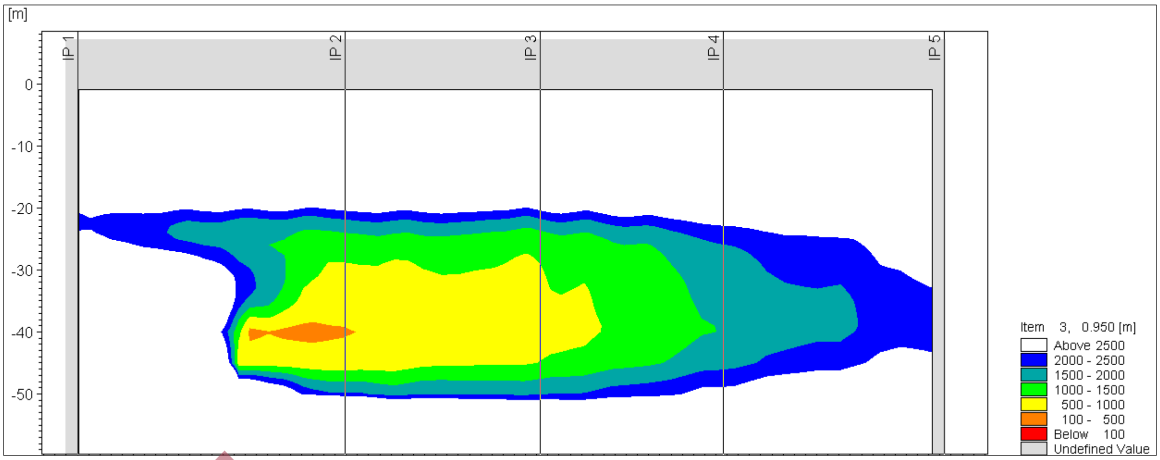

Figure 9-11: Vertical profile of 50th percentile dilution factors at discharge depth of -40 m and summer situation

Based on the modelling DHI /2015a/ concluded the following:

- None of the chemical species in the discharged process water is assessed to be Persistent Bio-accumulative Toxic (PBT) or very Persistent very Bio-accumulative (vPvB);
- The reagents used in the production appear to represent the highest risk, requiring greater dilution than any of the elements released from the mining process;
- The reagent ShellSol D70 requires the highest dilution (2282) to reach PNEC. This corresponds to an area of c. 3 km^2 that extends up to 700 m from the coast at depths between – 20 and – 50 m;
- The required dilution to obtain a concentration below PNEC for all contaminants in the discharged water is 1612. This dilution is obtained within an area of 1-3 km^2 along the coast of Nordre Sermilik and at depths between - 50m and - 20m;
- Regarding bioaccumulation and bio-magnification, it is assessed that:
    - Lanthanum and Yttrium may bio-magnify to a small degree in the food-webs;
    - Manganese will bio-magnify in the food-web and an excess manganese concentration in the food-web is expected as a consequence of the discharge.
- The area affected by the thermal plume (12°C) was negligible and little or no impacts on marine life in the fjord is expected from the observed modelled temperature differences of around 0.5°C within a radius of approximately 250 meters from the release point;

- The potential impact on the primary production of phytoplankton in fjords in South Greenland and potential impact on fish is expected to be very limited;
- The copepods/crustaceans are likely to be the most sensitive species to the chemical species but with the modelled dilution regimes no acute and no chronic effects should be expected. The copepod *Calanus finmarchicus*, which is an important component of the marine ecosystem, is assessed only to have very limited contact with the chemical species in the effluents as it migrates vertically in the broader water column (50 -600 m);
- The pelagic commercially relevant species of deep sea shrimp (*Pandalus borealis*) are also assessed to have only limited contact with the chemical species in the effluent. Locally, larvae from the female red deep sea shrimp may come into contact with the chemicals species in the effluent.

It can be added, that at the outlet all chemical species meet the Greenland water criteria except for arsenic, cadmium and mercury, which require a dilution of up to 5. This dilution is expected to be part of the initial dilution at the discharge diffusor and is therefore not considered an exceedance of the Greenland water quality criteria.

<u>Overall conclusion</u>; a dilution factor in the order of 2000 will be required to obtain no effects levels for the most critical parameters including safety margins. The required dilution can be obtained in the marine area on local scale of 1 – 3 km^2 and in a vertical confined lens of water when the outlet is constructed sub-surface. Based on the EIA assessment terminology the overall impact on the marine environment is assessed to be of medium significance.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Medium	Definite	Medium
Mitigation measures Optimization of diffusor outlet. Possible engineering challenge as it shall be implemented 80 m below sea level				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Medium	Definite	Medium

Table 9-27: Assessment summary of impact of discharge from the project to the marine environment

9.5. Living environment

9.5.1 Disturbance of terrestrial mammals and birds

Generally the disturbance impact from activities during the Operation phase (that is noise and visual disturbances) will be of the same order of magnitude as described for the construction phase and will potentially distress the same species (see section 8.4.1). The visual disturbance of people working at the mine might be less during operation since the personnel will generally work in fewer sites (mainly the pit area) while the noise disturbance from machines and blasting will be of the same order.

In conclusion, based on the findings described in section 8.4.1., noise and visual disturbance during operation will only cause localised disturbance of terrestrial birds and mammals. Since no breeding sites are known of the disturbance sensitive White-tailed eagles inside or close to the Study areas, the disturbance impact of terrestrial mammals and birds is assessed as Low.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Definite	High
Mitigation measures • Restrict the movement of staff members outside the mine area during spring and summer to minimize the general disturbance of wildlife				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Low	Definite	High

Table 9-28: Assessment summary of disturbance of terrestrial animals

9.5.2 Disturbance of marine animals

Since the number of ships calling in at the new project port during the Operational phase is in the same order of magnitude as during construction, the disturbance impact is considered the same. Reference is therefore made to section 8.4.2 for a discussion of the potential disturbance by shipping activities during construction.

Overall activities in connection with the Kvanefjeld project assessed to have Very Low disturbance impact on marine animals in the fjords at Narsaq.

9.5.3 Disturbance of freshwater fish

A significant population of Arctic char lives in Narsaq River. In summer, many of the char leave the river to feed in the fjords, but during winter the entire population is present in the lower section of the river. In years with long periods of sub-zero temperatures the water flow in Narsaq River is much reduced and it could be feared that a further reduction in the flow due to project related changes to the hydrology could impact the survival of the wintering chars.

In the Operation phase no freshwater will flow out of Lake Taseq, which implies that the flow in Taseq River will be restricted to the contribution from the catchment area downstream Taseq plus water captured by the diversion channels that surrounds the lake. The flow in Kvane River will also be reduced because the outflow from Kvane Lake will be derivate to Nordre Sermilik. Finally water will be sourced from the Narsaq River for the mine production and stored in the Raw Water Dam.

During winter the project related changes to the hydrology will have no or only very limited impact on the water flow in the lower section of Narsaq River where the fish overwinter. This is because even before the mine project commences no water leaves Taseq and Kvane Lakes during cold spells since the outflow freezes up. In addition, the flow in Narsaq River at the Raw Water Dam is very low during mid-winter and even if this water is lead into the Raw Water dam this will have no significant impact on the flow further down the Narsaq River.

To conclude, project related changes in hydrology of the Narsaq Rivers and its tributaries is assessed to have no significant impact on the population of Arctic char in the river, even during the critical winter period.

Impact during phases of the life of mine				
Construction	Operation	Closure	Post-closure	
Importance of impact without mitigation				
Spatial extent	*Duration*	*Signifi-cance*	*Probability*	*Confidence*
Study area	Long term	Very Low	Definite	High
Mitigation measures • No mitigating possible				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Signifi-cance*	*Probability*	*Confidence*
Study area	Long term	Very Low	Definite	High

Table 9-29: Assessment summary of disturbance of freshwater fish

9.5.4 Contamination of terrestrial, freshwater and marine habitats

Potential accidents in connection with transport, storage and handling of hazardous materials during the Operations phase are generally the same as during the Construction phase. Similarly, the impacts on terrestrial, freshwater and marine habitats involving hazardous material are mostly the same. Please refer to Section 8.4.7 and 8.4.8 which assess these impacts for the Construction Phase.

9.5.5 Fauna Traffic Incidents

The risks and consequences of traffic incidents to wildlife during the Operational Phase is similar to the situation during the Operational Phase. Reference is made to section 8.5.1.

9.5.6 Introduction of invasive non-indigenous species with ballast water

Since the number of ships calling in at the project port during the operational phase is in the same order of magnitude as during construction the risk of introducing invasive non-indigenous species with ballast water is considered the same. Reference is therefore made to section 8.5.2 for a discussion of this issue.

9.6. Waste Issues

The handling of domestic and industrial waste will follow the procedure established during the construction phase (see section 5.11.1, 5.11.2 and 8.5).

Waste produced during the operation periods includes domestic waste, tires from mobile equipment, and various types of hazardous waste (such as oily waste, chemical waste, batteries). Such waste – and in particular hazardous waste - can lead to significant contamination of the environment.

All solid waste will be shipped to Qaqortoq for incineration. Accumulators, batteries, electronic devices, glass, etc. will be stored temporary in containers and periodically handed over to Qaqortoq waste handling facility for further disposal according to regulations and after mutual agreement.

Hazardous waste is handled according to the Kommuneqarfik Kujalleq regulation concerning hazardous waste (Regulations for disposal of hazardous waste /Regulativ for bortskaffelse af miljøfarligt affald, 2009/).

Sewage from all buildings in the harbor, the accommodation village and visiting ships will be treated in a treatment plant, containing mechanical, biological and chemical treatment, prior to being discharged to the fjord at the north end of the Tuna Peninsula. Tanker trucks will be used to transport waste water and sewage from the holding tanks in the mine areas for treatment and disposal from the concentrator facility.

With proper waste handling procedures in place that are carried out according to good environmental practice, the impact of waste production to the environment is assessed to be Very Low.

9.7. Cultural heritage

The hindrance of traditional use of the Study area will in general be similar to the situation during the construction phase (Section 8.6.1). This implies that:

- For security reasons access to the mine area, for example to collect semi-precious gemstones will not be permitted;
- A 1 - 2 km ‘no hunting’ security zone will be introduced;
- There will be a no-fishing zone around the treated water placement in Nordre Sermilik; and
- For security reasons hiking (and driving) on the new road between the port and the mine area will not be permitted without permission.

To conclude, very limited conflicts are expected with the present use of the Study area.

10. IMPACT AND MITIGATION OF CLOSURE AND POST-CLOSURE PHASE

The initial Operations Phase will develop the current mine reserve for Kvanefjeld for 37 years. There is extensive additional mineral resources in the area which are likely to be economic extending the life of the mine considerably. The Operations Phase is followed by the Closure Phase estimated to last approximately six years (year 38 – 43).

During the Closure Phase buildings and equipment are gradually removed and the natural vegetation restored. A conceptual closure and decommissioning plan for the Kvanefjeld project that details this procedure is included as Appendix 2.

Throughout the Closure Phase liquor from the two tailings ponds will be decanted and pumped to the water treatment plant and the treated water discharged to the fjord. The high content of fluoride in the liquor is precipitated in the water treatment plant to produce fluorspar (CaF_2) – a commercial industrial product used in a wide variety of metallurgical and ceramic processes. This represents a value which will partially off-set the costs associated with the Closure Phase.

Due to the natural inflow to the tailings ponds the water quality in the FTSF and CRSF improves in the Closure Phase. The water level will gradually increase at the end of the Closure Phase and the early Post-closure Phase (>year 44). A few years later around year 48 and 49 the water will overtop the embankment of the CRSF and FTSF and eventually discharge to the freshwater environment of the Taseq River. At that time the hydrological patterns will revert in broad terms to the existing conditions.

In the Post-closure Phase all remaining process plant activities, including the water treatment plant, are shut down and removed.

During the Post-closure phase, no active care will be required except the occasional maintenance of the gravel roads to the mine site and tailings facilities at Taseq to permit inspections and monitoring activities.

This chapter is divided into three sections:

- Section 10.1 evaluates the potential impact of tailings water to Taseq River – Narsaq River on the **water environment** in the Post-Closure Phase;
- Section 10.2 describes and assesses the potential **radiological impact** in the freshwater environment of Taseq River – Narsaq River; and
- Section 10.3 describes the marine discharge in the Closure Phase.

10.1. Water quality in Tailings Ponds and downstream water environment

The design and the operations procedure of the two tailings ponds are detailed in Section 5.11. Water quality issues related to the deposition of tailings in the entire lifespan of the mining have been modelled and detailed in a comprehensive technical report covering the entire Operations Phase (year 1-37), the Closure Phase (year 38 - 43), and the Post-closure Phase (year 44 and onwards) The findings are summarized below based on /Orbicon 2015b/.

It shall be recalled that no effluents to Taseq River will take place in the Operations Phase nor in the Closure Phase. When acceptable water quality criteria for effluents to the freshwater environment are met, the Post-closure Phase commences. This is the rationale for describing the water quality associated with tailings management in this section.

10.1.1 Settings and assumptions in water quality assessments

The majority of the tailings produced in the Operations Phase originate from the physical extraction of zinc, uranium and REE (~90 % of total tailings) and is deposited subaqueously in the FTSF (Flotation Tailings Storage Facility). The minor part of tailings (~10 % of total tailings) is the residue remaining following the refining of REEs and uranium and is deposited subaqueously in the CRFS (Chemical Residue Storage Facility).

The FTSF and CRSF utilize the natural depression of the valley of the Taseq basin. Two embankments will be constructed, one for the FTSF and one for the CRSF, with the height of each increased in the Operations Phase to cater for the increasing requirements of storage capacity throughout the Operations Phase

Unnecessary inflow from the catchment area to FTSF and CRSF will be reduced by constructing diversion channels before the Operations Phase starts. The channels will partly divert the run off away to Taseq River downstream of the FTSF embankment. In the Closure and Post-closure Phase the functioning will gradually level out deliberately because the channels will not be maintained.

At the beginning of the Closure Phase, a barren rock layer of 1- 1½ meters in thickness will be distributed on top of the solid tailings to cap the tailings and prevent re-suspension. The liquor above the barren rock layer will still be decanted in the six year Closure Phase and pumped to the process plant. The decanting reduces the depth of the liquor in the FTSF and CRSF to 0.25 m above the barren rock layer. This strategy ensures a faster return to an acceptable water quality in the FTSF and CRSF required in the Post-closure Phase.

Due to precipitation and natural run-off to CRSF and FTSF, the water level will increase in the beginning of the Post-closure Phase and a few years later the overflow of the embankments of CRSF and FTSF downstream to Taseq River will start. At that time, the water quality in the tailings facilities shall be sufficient to comply with water quality requirements at a control point downstream.

A control point for future water quality monitoring has been proposed downstream the junction between Taseq River and Narsaq River. The Greenlandic Water Quality Criteria are specified as ambient water quality criteria. This means that the water quality criteria shall be met downstream of a defined mixing zone of a river or outside a confined area in marine waters. The geographical size of the mixing zone will be determined by the Greenlandic Authorities (MRA) on a case-by-case basis taking physical, chemical and biological conditions into account. From a practical point of view, the control point in a river shall be easily accessible in order to carry out future monitoring.

Three alternative control points have been considered as indicated in Figure 10-1.

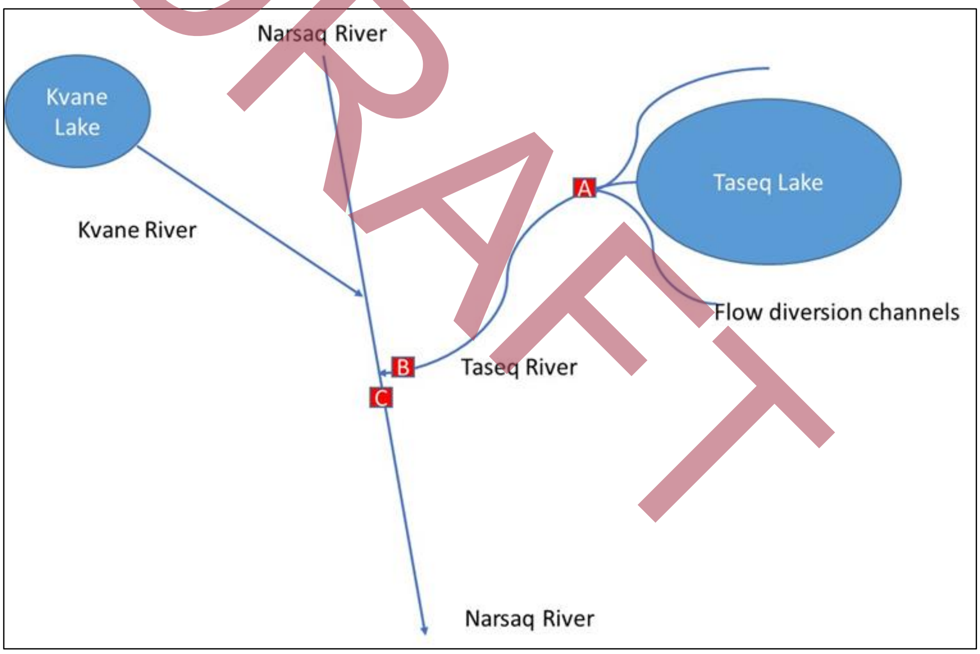

Figure 10-1: Sketch with three positions for control points for compliance with water quality criteria

If the natural baseline concentration of a given element is negligible, the concentration at locations A, B and C is the concentration in the outlet from Taseq Lake divided by the dilution. For elements that have significant baseline concentrations (e.g. fluoride) the existing concentrations at each location shall be taken into account.

In the data evaluation, the Control Point C is used for the assessment since this point integrates the differences in the composition of the baseline chemical conditions from the various sub-catchments. This is in particular relevant considering the noticeable variations in background levels of fluoride from specific sub-catchments. Natural levels of fluoride are significant higher in Narsaq River compared to Taseq River. Control points for future ambient water quality compliance in Taseq River (A or B) is therefore not adequate because the natural higher levels in Narsaq River might increase the levels after the confluence. The natural variations shall therefore be integrated in the control point assessments.

The objectives of assessing the water quality in the FTSF and CRSF are to get a clear understanding of:

- the concentration and flows in the tailings facilities and their interactions with the process plant throughout the lifespan of the mining project; and
- the concentration and flows of the eventual discharge to the freshwater bodies of Taseq River and Narsaq River from the FTSF and CRSF during the Post-closure Phase.

A comprehensive dynamic process simulation model has been developed for this purpose using an industry-leading process simulation software package, IDEAS®, simulating the three distinct project phases through almost a 100 year lifespan. The sequences and milestones in the phases are summarized in Table 10-1.

Specific information from geochemical assays of the tailings slurry, chemical processes in the process plant, hydrological development of the tailings ponds and a number of robust assumptions have been applied to develop the process model /Orbicon 2015b/.

Phase	**Year no. (in mining)**	**Year (calendar)**	**Remarks**
Operations Phase **(37 Years)**	1	2021	Start of mining
	1 – 37	2012 - 2057	Tailings stored continuously in FTSF and CRSF. Excess water (supernatants) decanted and re-used in process plant. No effluents to Taseq River Tailings volume capacity and height of embankments increased several times in the period
	37	2057	End of Operations Phase (Tailings production stopped)
Closure Phase **(6 Years)**	38	2058	Start of Closure Phase
	38 - 43	2058 - 2063	Water in the ponds decanted to process plant and used for fluorspar production and discharged to Nordre Sermilik following treatment. No effluents to Taseq River Water level in ponds gradually lowered. Precipi-

			tation and run off will partly compensate decanted water volume. Water quality gradually improved.
	43	2063	End of Closure Phase
Post – closure Phase **(50 Years and beyond)**	44	2064	Start of Post-closure Phase
	44 - 48	2064 - 2068	Precipitation and run-off to the ponds will increase the water level. Maintenance of diversion channels has been stopped and gradually increased the run off to the ponds (effect of diversion channels in model has been terminated in 2073)
	48	2068	Water from CRSF starts overflow the rim of the embankment to FTSF. No effluents to Taseq River
	49	2069	Water from FTSF starts overflow the rim of the embankment to Taseq River. The Post-closure Phase is fully implemented.
	59	2079	Water quality results presented 10 year after commencement of the discharge to Taseq River
	93	2113	Time horizon for model runs of IDEAS®

Table 10-1: Timeline and milestones in the tailings ponds management

The process model predicts the behaviour of over 400 different chemical species and elements through the flotation and refinery processes, including the REEs, uranium, thorium, reagents and impurities.

Specific attention has been devoted to the elements included in the list of ambient Water Quality Criteria in Greenland, in addition to elements in Kvanefjeld having significant quantities above the continental crustal average and identified as elements of ‘environmental concern’. In total 46 elements from the periodic table are included.

Furthermore, a full list of 32 reagents and consumables used in the processes has been prepared. Based on the inventory and knowledge about the fate of the reagents, eco-tox properties, bio-accumulating properties and quantities, fifteen reagents have been included in the model.

Modelled concentrations of elements have been compared to the Greenlandic Water Quality Criteria and international criteria (Canadian) where Greenlandic values are absent. Eco-toxicological values expressed as ‘predicted no-effect concentration’ (PNEC) were applied as benchmark for the content of reagents. As a conservative approximation, reagents in the supernatants are calculated without any further degradation, despite long retention times of 2 - 4 years and 0.5 – 1.5 years in the FTSF and CRSF respectively.

Finally, baseline concentrations from the rivers and lakes was included in the model. Measured baseline concentrations obtained from Narsaq River, Taseq River, Kvane River, and Kvane and Taseq Lakes since 2007 indicate persistent high levels of fluoride (F) exceeding international ambient water quality guidelines by up to two orders of magnitude (factor 100). From time to time arsenic, zinc, and phosphorus concentrations also exceed the Greenlandic WQ criteria. The heterogenic geological features in the area are the likely reasons for the variation meaning that the origin of the run-off (surface near run-off or groundwater) and the geological variation within the individual sub-catchments are determining the baseline water quality. Existing baseline water quality shall be taken into account as off-set when model output of the future water quality is assessed.

10.1.2 Results of IDEAS® modelling

The concentration of certain elements and reagents present in the tailings ponds during the Operations Phase exceed ambient water quality criteria. However, during the Operations Phase none of the water from the tailings ponds is discharged to the natural environment, instead it is re-used as process water in the processing facility, with any excess water pumped to the water treatment facility for treatment prior to being discharged to Nordre Sermilik.

During the Closure Phase the concentrations of all elements and reagents in the tailings pond supernatants will be significantly reduced by continued pumping of water for treatment, and by dilution via precipitation and runoff to the ponds. This will effectively reduce the concentrations of almost all elements and reagents to below ambient water quality criteria or PNEC values when the outflow from the tailings ponds to Taseq River starts at the beginning of the Post-closure Phase.

Downstream of the confluence of Taseq River with Narsaq River all elements and reagents will be below the ambient water quality criteria and predicted no effect concentrations (PNEC) except fluoride. The Canadian ambient water quality guideline of fluoride is 0.12 mg/L and cannot be fulfilled due to the high baseline fluoride concentrations in Narsaq River (ranging between 1 and 28 mg/L depending on time of year).

Examples of the concentration patterns of uranium, fluoride and a reagent (SIBX - amine) are presented in Figure 10-2- Figure 10-4.

The example of uranium, the Figure 10-2 exhibit the concentration pattern in the CRSF with fluctuations in the first five years due the low volume in the CRSF combined with the quarterly values that are used for the hydrological input in the first 5 modelling years.

In the Operations Phase there is a slow increase in concentration levels in the CRSF, caused by constant input of tailings slurry. In the FTSF, concentrations are lower than the CRSF but still at significant levels.

In the Closure Phase there is a significant decrease in the concentrations in the CRSF, because the supply of water soluble metal from the tailings slurry stops, and pumping of water to the treatment plant reduces the supernatant volume and increases the impact of the dilution from run-off and precipitation.

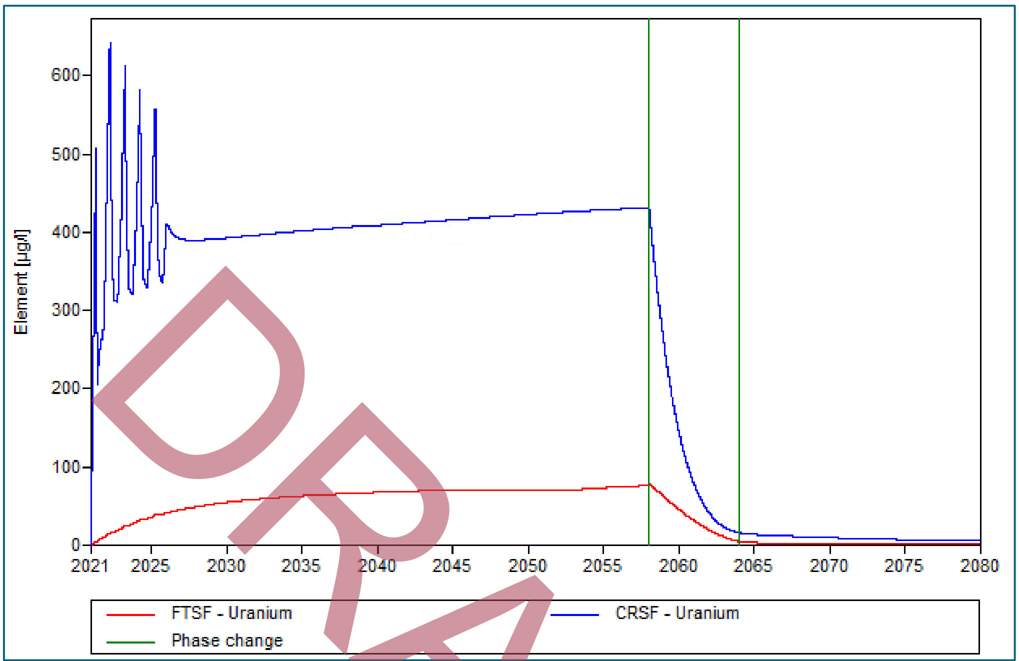

Figure 10-2: Uranium (U). No GWQG identified. Baseline WQ level is 0.1 – 2.8 $\mu g/l$ in the area. Canadian ambient water quality guidelines for freshwater is 15 $\mu g/l$

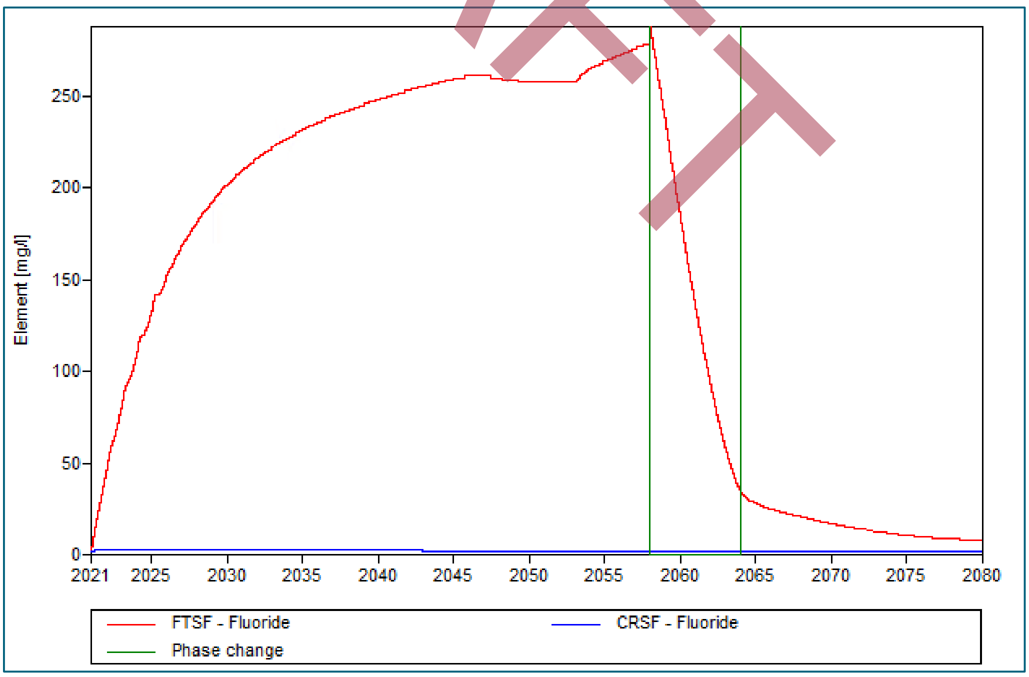

Figure 10-3: Fluoride. No GWQG identified. Baseline WQ level is 1 - 28 mg/L in the area and median values in Narsaq River 15 mg/L. WHO drinking water guidelines are 1.5 mg/L. Canadian ambient water quality guidelines for freshwater is 0.12 mg/L

Flotation reagents used in the flotation process are not present in the CRSF. During the Operations Phase, the concentration of flotation reagents in the FTSF increase sharply initially, and then gradually level out over time. During the Closure period there is a sharp decrease in the concentrations of these reagents, with the decrease in concentrations continuing in the post closure period.

The Figure 10-4 shows an example of the concentration pattern for a reagent (SIBX) used in the flotation process and thus only reporting to the FTSF.

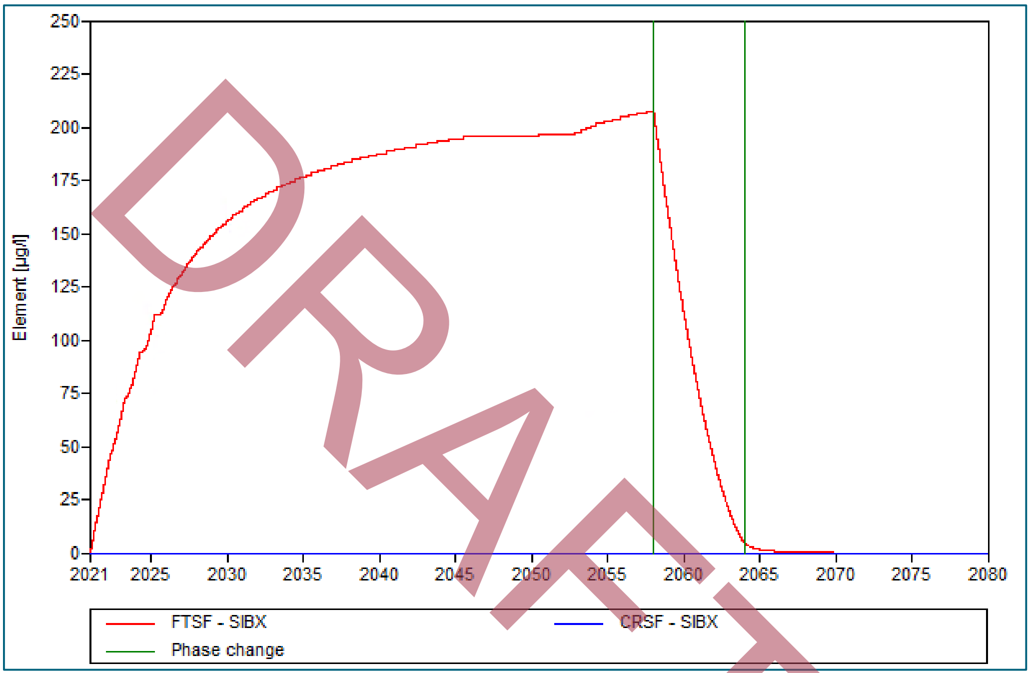

Figure 10-4: Concentration of SIBX - amine in for a 60 year period after mining start in the three phases separated by the green vertical lines.

Table 10-2 summarizes the results of the IDEAS® modelling of concentrations of metals and elements downstream of the Narsaq River and Taseq River confluence. The modelling results are shown alongside the criteria and the baseline values used in the modelling.

Table 10-3 summarizes the results of the IDEAS® modelling for reagents.

The criteria included in the tables is the Greenlandic Water Quality Guidelines (GWQG) if available - and where absent, the Canadian Guidelines (Canada, 2015). In addition to the elements of environmental concern, concentrations of other parameters are also included to give an overview of the impact on the chemical composition of the river water. For reagents a PNEC criteria is used (Predicted No Effect Concentration – see Chapter 9).

The columns ‘Year 49’, ‘Year 59’ and ‘Year 93’ are included in the Table 10-2 and Table 10-3 to illustrate the expected impact on concentration in Narsaq River (at Control Point C); at the start of outflow from Taseq Lake (Year 49), in the short term (Year 59) and in the long term (Year 93).

Elements River Narsaq	Criteria	Baseline (used in model)	Year 49 outlet from FTSF starts	Year 59 - 10 year after outlet from FTSF starts	Year 93
Arsenic (µg/L)	4	0,52	0,47	0,47	0,48
Cadmium (µg/L)	0,1	0	0,001	0,002	0,001
Chromium (µg/L)	3	0	0	0	0
Copper (µg/L)	2	0	0,002	0,003	0,002
Iron (µg/L)	300	22,18	17,39	17,39	17,40
Lead (µg/L)	1	0	0,000003	0,000006	0,000004
Mercury (µg/L)	0,05	0	0	0	0
Nickel (µg/L)	5	0	0,003	0,006	0,004
Zinc (µg/L)	10	3,1	3,0	3,0	3,1
Phosporous (µg/L)	20	2,3	5,5	5,8	4,3
Solids (ppm)		0,0	1,0	1,3	1,3
Fluoride (mg/L)	0.12*	2,7	5,6	4,7	3,8
Potassium (mg/L)		0,3	0,3	0,3	0,3
Sulphur (mg/L)		1,0	1,9	2,8	2,2
Chloride (mg/L)	120*	4,3	7,0	9,8	8,2
Sodium (mg/L)		5,2	12,0	13,7	10,6
Sulphate (mg/L)		3,1	5,6	8,3	6,5
Calcium (mg/L)		1,5	1,5	1,7	1,6
Uranium (µg/L)	15*	0,4	0,9	0,9	0,7
Thorium (µg/L)		0,0E+00	2,6E-05	5,2E-05	3,5E-05
Manganese (µg/L)		0	15,24	30,93	20,67
Molybdenum (µg/L)	73*	0	0,35	0,32	0,19
Lithium (µg/L)		0	9,85	7,39	4,17
Thalium (µg/L)	0.8*	0	0,00	0,01	0,00
Radium-226 (Bq/L)	0.5**	0	6,8E-05	1,3E-04	1,0E-04

Table 10-2: Model results from IDEAS® at characteristic dates at downstream the Taseq River confluence in Narsaq River. Criteria from Greenlandic Guidelines. Values marked with * and ** are Canadian Guidelines (Canada 2015) and (Canada Health, 2009). From /Orbicon 2015b/.

It is noted the baseline values are defined for the control point C, i.e. after the confluence of Narsaq River and Taseq River. Some elements have higher values in baseline compared to the effluent from the FTSF due to differences in the water quality in Taseq River and Narsaq River.

Reagents River Narsaq	Criteria PNEC	Year 49 outlet from FTSF starts	Year 59 - 10 year after start of out-let	Year 93
Total Flocculant (µg/L)	10	0,00	0,00	0,00
SIBX (µg/L)	268	0,08	0,01	0,00
Copper Sulphate (µg/L)	0,1	0,00	0,01	0,01
Aero 6494 (µg/L)	0,33	0,03	0,00	0,00
Sodium Silicate (µg/L)	2470	774	396	324
Frother (µg/L)	0,24	0,06	0,01	0,00
Barium Chloride (µg/L)	220	0,00	0,00	0,00
NaHS (µg/L)	10	0,01	0,01	0,01
Alamine 336 (µg/L)	0,014	0,00004	0,00002	0,00001
Isodecanol (µg/L)	10	0,00	0,00	0,00
PC88A (µg/L)	4,2	0,01	0,00	0,00
Shellsol Diluent (µg/L)	2	0,01	0,00	0,00
CW Biocide (µg/L)	0,2	0,00	0,00	0,00

Table 10-3: Comparison of PNEC criteria for reagents and modelled concentrations. From /Orbicon 2015b/

In general, the modelled concentration patterns over time for reagents and elements at control point C downstream of the confluence of Taseq River and Narsaq River can be summarized as follows:

- Greenlandic Water Quality Guidelines (GWQC). Concentrations for all elements included in the GWQC at control point C are well below criteria values.

- Uranium is not included in the Greenlandic Guidelines. Instead the Canadian Guideline (Canada, 2015) of 15 µg/L is applied, and at control point C, the level is a factor of 16 times below this international water quality criterion.

- Fluoride. The concentration of fluoride exceeds the Canadian Guidelines of 0.12 mg/L by a factor of nearly 50. The geological features of the area however result in the fact that the baseline fluoride concentration already exceeds this guideline value by a factor of 22, hence the Canadian Guidelines are not applicable to the Kvanefjeld area. When compared to typical variations in the baseline fluoride concentration in Narsaq River upstream of control point C, between 1 and 28 mg/L, the expected peak fluoride level at control point C during Year 49 of 5.6 mg/L is well within baseline conditions, and therefore will have no noticeable impact on the existing environment.

- Reagent concentrations are well below PNEC values for all reagents.

Overall conclusion

Comprehensive water quality assessment of effluents associated with the tailings from the Kvanefjeld project to the freshwater environment points to the conclusion that Greenlandic criteria as well as international criteria - where Greenlandic criteria are absent - can be fulfilled for all parameters unless the existing water quality already exceeds these criteria in the baseline condition.

Very high baseline values of fluoride are observed in the Kvanefjeld area. The values exceed international ambient water quality criteria by a factor of up to 100 due to the geological characteristics of the project area. The assessment of effluents from the Kvanefjeld project to the freshwater environment has shown that the mining project will not significantly alter these baseline fluoride levels.

Impact during phases of the life of the mine				
Construction	Operation		Closure	Post-closure
Importance of impact without mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Very Low	Definite	Medium
Mitigation measures • None				
Importance of impact with mitigation				
Spatial extent	*Duration*	*Significance*	*Probability*	*Confidence*
Study area	Long term	Very Low	Definite	Medium

Table 10-4: Assessment summary of freshwater environment in Taseq – Narsaq River and the influence of effluent from the FTSF an CRSF in the Closure and Post-closure Phase. No effluent will take place in the Operations Phase

10.2. Radionuclides in Taseq River – Narsaq River

The level of radionuclides in tailings water released during Post-closure Phase have been thoroughly assessed. The conclusion is that concentrations of uranium, thorium and radium-226 in Narsaq River at the proposed control point are far below Canadian guideline values.

No radiological effects due to the discharge of radionuclides to the freshwater streams of Taseq River and Narsaq River are therefore expected to the freshwater ecosystems of the rivers /ARCADIS 2015a/.

ARCADIS /2015a/ has estimated the baseline and cumulative (baseline + project Increment) radiation dose for Arctic char in Narsaq River – see Table 10-5. This assessment shows that there is not expected to be any adverse effects on fish; the dose estimate is low and incremental dose from the project is negligible. It should be noted that this was a conservative assessment of the dose to fish as it assumes they reside in Narsaq River at the point of compliance. In reality, most adult char (3 years and older) migrate to the fjord to feed during summer and therefore are not in the river all year.

	Dose (mGy/d)	Screening Index (SI)
Baseline	5.7×10^{-2}	0.006
Cumulative (Baseline + Project Increment)	6.0×10^{-2}	0.006

Table 10-5: Dose and Screening Index Values for Arctic char in Narsaq River, Post-Closure. Screening Index (SI) is the dose compared to the selected benchmark of 9.6 mGy/d

10.3. Marine Environment in the Closure Phase

The wastewater treatment plant continues operating in the six year Closure Phase and the liquor in the two tailings ponds is pumped to the treatment plant in the same way as in the Operations Phase. The treated wastewater is released into the fjord at the TWP.

The content of fluoride in the liquor in the tailings ponds will be in the order of up to 250 mg/L. The concentration can be reduced significantly through a precipitation process in the treatment plant and the product of fluorspar can be reclaimed as a commercial product.

The concentrations of all elements and reagents in the outlet to the fjord will be less than the Operations Phase because the flotation and refining has been stopped in year 37. The potential impact in the marine environment in the six year Closure Phase will consequently be lower than concluded for the Operations Phase (Chapter 9).

In the Post-closure Phase, no wastewater from the tailings ponds or the treatment plant is placed in the fjord.

Precipitation and run off from the area of the waste rock stockpile will continue throughout the Closure and Post Closure Phase. The content in the run off will gradually reach levels similar to existing conditions.

11. ENVIRONMENTAL RISK ASSESSMENT

Identifying significant environmental risks is an important part of doing an overall environmental impact assessment for mining projects. This chapter deals with the risk and consequences of incidents in connection with the operation of the Kvanefjeld project.

This risk assessment involved all relevant components of the mine operation and range from the open pit, concentrator, refinery, tailings ponds, water and power supply services, and the truck transportation route from the mine site to the port.

A screening of potential significant environment risk events identified the following for priority evaluation:

1. Tailings embankment failure or overflow;
2. Discharge of untreated process water into the fjord;
3. Spill of oil and chemicals; and
4. Spill of uranium product (yellow cake).

Below, each of the identified risk events are discussed. The likelihood and the consequence of each risk event are determined. At the end of the section is a risk matrix that summarises the risk assessment

11.1.1 Potential accidents associated with the tailings ponds

Two types of events associated with the deposition of tailings were identified. These events can potentially have significant consequences for the environment. These are:

- Leak or collapse of tailings embankment(s); and
- Tailings pond overflow.

11.1.1.1. Leak or collapse of tailings embankments

Two tailings pond embankments will be constructed for the Kvanefjeld Project. One separates the CRSF from the FTSF while the other is positioned across the outlet of Taseq Lake. Both embankments will gradually be built higher as more and more tailings are deposited behind them. A water layer of at least 10 meters will be maintained over the tailings in both tailings ponds at all times. Both embankments will be designed with a 10 meter freeboard (height from water table to top of embankment). When tailings deposition ceases the solids will be covered by a layer of graded rock fill.

<u>Consequences of leak or collapse</u>
A leak or collapse of the embankment that separates the two tailings ponds will have no immediate environmental impact because the FTSF embankment is designed to accommodate the water (and tailings) of the CRSF.

A major leak or collapse of the FTSF embankment will cause some or all of the water that covers the tailings to flow out of the pond. This water will first flow to Taseq River, then the lower part of Narsaq Rivers before reaching the fjord at Narsap Ilua.

Only small amounts of tailings will be washed out of the FTSF with the water even in case of a total collapse of the FTSF embankment. This also applies to an embankment collapse after many years of production when tailings are stored behind the embankment. This is because the viscosity of the tailings is too high for them to flow like water.

If all the water leaves the FTSF the top layer of tailings will gradually become dry and friable. The exposed solids could be dispersed by strong winds. The dried tailings will also allow the slow release of radon gas which is otherwise absorbed by the water layer.

<u>Environmental impacts</u>
During the Operations Phase the supernatant of FTSF (the water on top of the tailings) will have elevated concentrations of some metals and reagents. If this water leaves the FTSF and runs through the Taseq River to Narsaq River and eventually Narsap Ilua it will affect the environment. There may be severe consequences for the aquatic life, in particular on the impacted section of Narsaq River. The impact on marine life in the fjord will be lower due to the dilution. The impact to Narsaq River (and Taseq River) will most likely be short term – that is a few days or weeks - but it will take much longer before the natural flora and fauna of the water courses are restored.

Radon released from tailings with the water cover lost will be a small contribution to the natural background and will probably not lead to a measurable increase in the radon concentration in the area (or in Narsaq).

A third potential impact is wind dispersal of tailings if no water cover is present. Dispersal of mildly radioactive tailings would potentially lead to a significant pollution of the impacted areas. Such a scenario is limited to summer months during the operational phase. In winter the tailings ponds are covered by thick ice and when the deposition of tailings ceases at mine closure the solids will be covered by a thick layer of rock fill. The solids consist of silt, with a particle size between 5 and 200 micrometers, would probably not be dispersed outside the Taseq basin if it was allowed to dry up.

Probability

Tailings embankment failures are very rare event and are typically caused by one or several of the following reasons:

- Sub-standard construction materials/techniques
- Geological instability
- Tailings pond overtopping due to inadequate freeboard allowance
- Poor maintenance
- Extreme inflow
- Human, computer or design error

The tailings embankments for the Kvanefjeld project will be constructed in accordance with best international practice. They are designed to be permanent installations. The design includes analysis of their stability both under static and pseudo-static (seismic) conditions. Rock fill and a conservative wall design will be used and the embankments will be equipped with a double liner to protect against seepage. Both embankments will be constructed to withstand extreme inflow of water, for example due to exceptional snow melting under føhn wind event. Furthermore, the probability for a seismic hazard for the Study area is considered very low (see section 6.2.1). For these reasons a major embankment leak or collapse is highly unlikely.

Mitigation

In the unlikely event of an embankment wall break or collapse repair work must be initiated immediately. Mobile equipment normally used to extract and move ore will be employed in the repair work. A rapid repair of the embankment is facilitated by the large amounts of natural rock and gravel that are available around the embankment.

To keep the surface of the tailings wet (to avoid wind dispersal of solids) water cannons will be used that shoot a high-velocity stream of water over long distances. As soon as possible the water cover will be restored.

11.1.1.2. Tailings pond overflow

Extreme weather and a landslide into the tailings pond can potentially cause water to overflow the embankments.

Consequences of overflow

An overflow of the CFSF embankment into the FTSF will have no immediate consequences because the FTSF embankment with its 10 meters free board can easily accommodate a major inflow of water from the CTSF.

Supernatant water that overflows the FTSF embankment will first flow to the Taseq River, then the lower part of Narsaq Rivers before reaching the fjord at Narsap Ilua.

Environmental impacts
The impact on the freshwater biota and marine life will depend on the amount and quality of water that overflows the FTSF embankment. A worst case would be a major overflow during the production phase. This would cause tailings supernatant with high concentrations of several elements to enter water courses in Narsaq Valley and would have a severe impact on the aquatic life in the impacted sections. It should be noted though that if the overflow is caused by extreme rainfall or snow melting the supernatant will be much diluted and consequently the impact is probably significantly lower.

The impact to the Taseq and Narsaq Rivers will most likely be short term – a few days or weeks. The impact to marine life due to an overflow will probably be local only (limited to Narsap Ilua).

Probability
The design of the embankments has considered a range of extreme weather scenarios to avoid an overflow event, such as a 1/10 000 year rainfall event.

A conservative 10 meter freeboard has been chosen for both tailings ponds design. Large diversion channels will be constructed that captures water ingress to the Taseq basin and lead it away from the ponds. These channels significantly reduce the likelihood for an overflow of the tailings ponds.

The geology of the slopes that surrounds the tailings ponds has been studied carefully and the risk for a major landslide is assessed to be very low.

It can be concluded that the risk for an overflow during operations (and closure) is very low.

Mitigation
In order to minimizing the risk for an overflow it is essential that the diversion channels are kept well maintained during the operational and closure phases.

11.1.1.3. Assessment of embankment failure or overflow

A tailings embankment failure or a major overflow of supernatant during the operational phase would have serious implications for the impacted aquatic ecosystems in Narsaq Valley and for the marine life in Narsap Ilua. No serious impact would be expected for land animals and plants since all or nearly all tailings are expected to stay in the tailings ponds even in the event of an embankment collapse. It is also highly unlikely that solids would be dispersed outside the Taseq basin if allowed to dry up following a loss of water cover of the tailings ponds.

The likelihood of a major embankment leak, collapse or over flow is extremely low. But even if such an event did take place the environmental impacts would probably mostly affect the aquatic ecosystems of Taseq River and the lower section of Narsaq River.

11.1.2 Discharge of untreated process water into the fjord

During the Operations Phase excess water that cannot be recycled is treated before placement into Nordre Sermilik. During the Closure phase waters from the tailings ponds are pumped to the treatment plant before placement in Nordre Sermilik.

A malfunction or overflow of the treatment plant could potentially lead to a monor release of untreated water into the fjord.

<u>Environmental impacts</u>
The release of untreated water could potentially have a negative impact on marine life near the discharge point in Nordre Sermilik.

<u>Probability</u>
If the treatment plant fails during the Operation phase the production at the Refinery will be stopped immediately. This will prevent untreated water from being discharged to the fjord.

In case of a malfunction of the treatment plant during the Closure phase, the discharge of water will immediately be stopped, preventing untreated water from the tailings pond from being released to the fjord.

It is unlikely that significant quantities of untreated process water or water from the tailings ponds is discharged to the fjord.

<u>Mitigation</u>
No mitigation required.

<u>Assessment</u>
Since the discharge of water into Nordre Sermilik will be immediately stopped in case of a malfunction of the treatment plant pollution of the fjord with untreated water is unlikely.

11.1.3 Spill of oil and chemicals

During the Operational Phase large amounts of oil and chemicals are used in the production. These products will be shipped to the new mine port where they are stored. They are transported to the mine site by trucks and kept in smaller tanks and stores. The saleable mine products are transported by truck to the port where they are stored before shipped abroad.

During the Operational Phase the following activities/events are considered the most likely that could to lead to significant spills of oil and chemicals[2].

1. Shipping in the fjords;
2. Unloading from ships to land based storage;
3. Fuel storage tank ruptures or leaks;
4. Spills of chemicals and oily products during land transport;
5. Spills from pipelines; and
6. Spills from fuelling mobile equipment at tank farms.

11.1.3.1. Shipping in the fjords

About 56 000 m^3 of organic fuel will arrive to the port site each year in tankers. In addition about 270 000 tons of chemicals will arrive to the port annually and 71 000 tons of mine products will be exported. The chemicals and mine products will normally be transported in 65,000 DWT vessels.

<u>Consequences of spill</u>
A major shipping accident such as a collision or grounding could give rise to major spills of oil, chemical or mine products. In particular tankers involved in accidents could lead to significant spills. Spills of chemicals and mine products typically involve smaller quantities as these products are mostly packed in freight containers which provide further protection of the material in case of an accident.

<u>Environmental impacts</u>
Due to currents in the fjords, oil leaked to the marine environment will be transported over long distances quickly, and the narrow fjords will make shoreline contamination likely. Impacts have to be considered as potentially causing both marine and shoreline fouling.

[2] Note that transportation of the uranium product (yellow cake) is discussed separately in section 11.1.5.

The consequences of an oil spill to the marine life, including birds may be significant. In particular birds are extremely vulnerable to oil. Most fatalities are usually due to oiling of the plumage but many birds often also die from intoxication. Marine mammals are generally less sensitive to oiling.

Only a few rather small bird colonies are located near the shipping routes to the project port while quite large numbers of sea duck (eiders) winter in the fjords and thereby are vulnerable to oil spills.

Most of the fjords close to Narsaq have rocky shorelines and the intertidal organisms found here are commonly exposed to the scouring effects of sea ice. As wave action can clean away spill residue, wave-exposed shores are less sensitive to oil spills. However, sheltered rocky shores will be in contact with spills for longer, and effects on the invertebrate fauna can potentially affect the ecological balance of the shore.

Large spills of chemicals can also have adverse effects, depending on the toxicity and bioaccumulation of the spilled chemicals. However, the quantities released will likely be quite small, and the large volume of the fjords would mean that dilution and dispersal would likely mitigate the effects.

Probability
Shipping though the fjords to and from the project port has some potential hazards. These hazards are however not different from other shipping routes in Arctic coastal areas, including routes to a number of Greenlandic towns and settlements.
If all maritime regulations are followed, and shipping lanes are well placed, the likelihood of a full scale accident happening during operation is deemed to be very low.

Mitigation
To reduce the impact of operational spills of fuel and chemicals the following mitigating measures should be implemented:

- Proper procedures for loading and unloading of ships;
- At the port area: Properly dimensioned equipment for combating operational spills, including containment booms available for berthed ships, extra booms and skimmers;
- Contingency plans and procedures for detecting and combating operational spills, including procedures for operational spills in sea ice; and
- Incident - and season - related contingency plans and training.

In case of accidental spills of fuel and chemicals the following mitigating measures should be implemented:

- Conduct a navigational safety survey;
- Impose navigational speed restrictions;

- Compulsory pilotage;
- Separating shipping lanes;
- Prepare contingency plans with authorities to cope with large scale spills;
- Having contingency plans for spills the size possible in relation to the project; and
- Having sufficient materials for some response options, e.g. a helitorch for igniting oil spills, while other response options may require subsequent import of equipment, e.g. large scale deployment of skimmers.

11.1.3.2. Unloading from ships to land based storage

Fuel arriving to the project port will be pumped from the tankers through underground fuel pipelines to the storage tank farm at the port. The fuel storage in the port area s of two heavy fuel oil tanks (total capacity 10,417 m^3) and one 2,065 m^3 diesel oil tank.

Chemicals will also arrive by ships. Reagents transported in containers or ISO tanks will be unloaded by vessel cranes onto the wharf using spreaders and moved to the container storage yard, where they are stacked. Chemicals transported as bulk cargo (sodium chloride, limestone, sulphur and sodium carbonate) will be unloaded using clamshell bulk grabs and transferred to one of four bulk storage buildings.

<u>Consequences of spill</u>
Most spills from tankers result from routine operations in connection with loading, discharging and bunkering. The majority of this type of operational spill is small.
Loss of chemicals into the fjord can also occur through unloading accidents, by which discrete packaging will limit the amount spilled. Chemical spills at the port will typically consist of small quantities limited to one container or one ISO tank.

<u>Ecological impacts</u>
Since the amounts of oil and chemicals spilled in connection with unloading or loading accidents are mostly small the impact on marine life will be local and relatively small and usually well within the capacity range of the oil combat equipment available at the port.

<u>Probability</u>
In comparison to the likelihood of large shipping accidents, the likelihood of spills caused by operational events at the port is higher, but the consequences are much lower, as the quantities of spilled oil, chemicals or mine product in such an event are usually smaller.

Mitigation

Proper procedures for loading and unloading ships must be in place. Properly dimensioned equipment for combating operational spills must be available, including containment booms available for berthed ships, extra booms and skimmers. It is also essential to have contingency plans and procedures for detecting and combating operational spills in place, including procedures for operational spills in sea ice. Regular training will take place to ensure readiness for emergency responses. Planning will include winter and summer response procedures and training.

11.1.3.3. Fuel storage tank ruptures or leaks

Fuels for the project are initially stored at the port fuel farm. Smaller fuel storage tanks are also located at the Concentrator/Power plant, next to the Refinery and in the mine area.

Consequences of spill

All fuel storage tanks will have geotextile containment berms that can contain a full spill in case of total tank rupture. The containment beams eliminate the potential spread of an oil spill.

Environmental impacts

With all fuel storage tanks surrounded by geotextile containment berms a tank rupture will have no significant impacts on the environment.

Probability

Spills from fuel storage tanks with geotextile containment berms are very unlikely.

Mitigation

The geotextile containment berms must be inspected regularly to ensure that they are intact.

11.1.3.4. Spills of chemicals and oily products during land transport

Traffic accidents involving fuel tankers and flatbed trucks transporting containers with chemicals and mine product is a potential hazard. The minor volume of individual tank trucks and containers will limit the potential spills and hence the impacts of accidents during truck haulage.

Environmental impacts

Most chemicals and the mine products are transported in dry form, reducing the consequences of spills. Spills of fuel products and liquid chemicals will typically not affect large areas, unless seepage into nearby waterways occurs, or steep slopes at the spill site causes the spill to spread downhill.

Effects of oil spills on the Arctic vegetation will likely be localised, but as Arctic flora has very slow growth rates, effects can be long lasting, stretching into decades. As terrestrial spills likely only will affect relatively small areas, it will be relatively easy to prevent terrestrial mammals being exposed to the spills. It is also unlikely that terrestrial bird populations will be significantly impacted. Spills into freshwater ecosystems can cause an impact on diversity and abundance of invertebrates, plants and fish.

Probability
The likelihood of an accidental spill during land transport is low. In case of a spill it is most likely that it can be limited to impacting terrestrial habitats.

Mitigation
To reduce the risk of traffic accidents it is important to impose strict speed limits and avoid road transport when weather conditions are difficult (slippery roads).

11.1.3.5. Spills from pipelines

Tailings mixed with water will be transported as slurry through a pipeline from the processing plants to the tailings ponds. Process water will be (partly) sourced from the tailings ponds and transported through a pipeline. Excess process water will be transported from the Refinery though a pipeline to a treatment plant and subsequently to the fjord.

Consequences of spill
A pipeline rupture will lead to a spill of slurry containing tailings or process water. Since pressure sensors and block valves will be installed on all pipelines, a spill will be detected immediately. Emergency procedures and programmed interlocks will be activated to minimize the leak or rupture.

Environmental impacts
With a fast control system in place a spill from a pipeline will be small and the environmental impact local and small.

Probability
With modern control system in place the risk of a significant spill from a pipeline is considered very low.

Mitigation
It is essential to keep the pipelines and control system well maintained.

11.1.3.6. Spills from fuelling mobile equipment at tank farms

Fuelling of mobile equipment will take place at the fuel farm in the port area and the processing plant. Mobile equipment at the mine site (mine trucks, excavators, etc.) will be refuelled at the mine pit area.

Consequences of a spill
Fuelling mobile equipment can potentially lead to spills. However these spills will typically be small.

Environmental impacts
A spill associated with refuelling and handling of fuel in the mine area generally will be small and local the impact on the environment will be limited.

Probability
The risk of spills of oil products when refueling is larger than for example major shipping accidents, but the volume of oil spills are usually much smaller.

Mitigation
Strict procedures for handling of oil and equipment must be implemented to minimize any oil spill impact.

11.1.4 Assessment of oil and chemical spills

Marine spills of oil, chemicals and mine products
If all maritime regulations are followed, the likelihood of a full scale shipping accident happening during operation is deemed to be very low and phrased as ‘improbable’. With relevant mitigation in place, it is concluded that the likelihood of a full scale accident is deemed as low. Should such an accident occur, the consequences to the marine life, including birds may be significant.

In comparison to the likelihood of accident spills caused by ships, the likelihood of spills caused by operational events e.g. at the port is higher, but the consequences are much lower, as the quantities of spilled oil in such an event are usually smaller. The causes can be human failures, malfunctions of valves, rupture of hoses, etc.

In conclusion*:* Although the consequence of a major oil spill in the fjords at Narsaq during operation may be very severe, the likelihood of such event is considered very low. However, to minimize the impact of operational events and in particular accidental spills in the fjord it is essential to have effective contingency plans in place. With well-rehearsed contingency plans developed that can combat oil spills in all seasons, the potential impact on the marine life of the fjord from an chemical or oil spill accident is assessed as Low.

<u>Assessments of land spills of oil, chemicals and mine products</u>
The areas of the highest spill probability are considered to be at either end terminal, where immediate action can be taken to mitigate the effects.

Overall, the likelihood of a major accidental spill occurring on land or into local fresh water resources (such as Narsaq River) is low, but contingencies will be worked out. Lesser operational spills are more likely to occur, but the effects are likely to be localized, and relatively easy to combat.

In case of spills on land, the most obvious way of dealing with it will be mechanical removal, possibly in combination with either natural or accelerated *in situ* degradation (of oil). Chemicals and mine product should be mechanically removed to the extent possible.

<u>In conclusion</u>**.** The environmental impacts of chemical or fuel spills on land are assessed to be confined to the Study area or to a narrow corridor of a few km around the project activities (i.e. local scale). Spills affecting Narsaq River (or other water courses) in summer periods with high flows might spread downstream the spill location and reach the fjord, if no mitigating measures are in place.

11.1.5 Spill of uranium product (yellow cake)

At the Refinery, the uranium product (yellow cake), will be packed in sealed 200-litre steel drums which are loaded into standard containers before being transported to the port on flatbed trucks. The containers remain sealed throughout the journey from the mine to the final point of delivery at the port. The container is unloaded from the flatbed truck at the port and moved to a specified storage area. The storage area will have a gate and security that meets/exceeds the requirements of International Ship and Port Security Codes. The containers are moved around the port utilizing a reach stacker and then loaded into a vessel using a ship mounted crane.

The amount of uranium product transported will be 557 tons per year with about 13.8 tons per standard container. Therefore, 40 containers of drummed yellow cake is transported from the Refinery to the Port every year (about 1 every in 9 days).

A specific uranium transport assessment has been carried out for the Kvanefjeld project by Arcadis /2015b/ and the following is based on the findings in this study. Arcadis identified the following scenarios for transportation accidents involving uranium products:

1. Spill of yellow cake into rivers or harbour; and
2. Spill of yellow cake on land and gamma exposure.

While site clean-up is expected to occur within a short time following an accident, it is unlikely to recover 100% of the released material especially in the event of a spill into the harbour (e.g. residual uranium product will be present in sediment subsequent to remedial activities).

11.1.5.1. Spill of yellow cake into rivers or harbour

Consequences of spill

In case of a traffic accident (rollover or crash) containers could potentially be breached and their content of uranium oxide could be spilled into rivers. An accident in connection with the handling and loading of containers onto ships could lead to a spill into the marine environment.

Environmental impacts

Two comprehensive risk assessments of release into surface waters (rivers, lakes, and harbours) and land during transportation across arctic Canada were completed by ARCADIS-SENES Canada in 2014 /SENES 2014a,b/. The studies considered similar potential receptors as would occur in the Kvanefjeld area.

The potential impact on water quality (freshwater and marine environment) due to the release of yellow cake was assessed via fate and transport modelling of the released yellow cake as well as exposure pathway modelling and risk characterization for various receptors. The assessment assumed that a major clean-up effort will remove the majority (>90%) of the released materials. Both assessments included the release of yellow cake on sites that are similar to southern Greenland with respect to meteorology and winter conditions.

Two types of exceedances were identified; one where it is possible that populations of selected animals and plants would be affected and the less substantial impacts with only individuals being affected (but not population-level effects).

Based on the results of the assessment from Arctic Canada for similar radioactive material is can be inferred that a spill of yellow cake into the Narsaq River or Narsap Ilua may, when not frozen, have short-term as well as long-term implications. In the short-term the impacted water may be unsuitable for supporting aquatic life. The short-term period for water quality is defined as the time when the impacted water is diluted enough to meet the water quality guidelines for uranium. This period varies between water bodies, but is usually in the order of days or weeks. In the long term, the released material should be cleaned up and area remediated. Depending on the cleaning extent and efficiency, the long-term quality of sediment may be impacted resulting in undesirable exposure of biota which are exposed to contaminated water and sediments.

Probability

Based on experience from Arctic Canada the risk of a spill into water is calculated to be extremely low (less than $5x10^{-7}$ event per year).

11.1.5.2. Spill of yellow cake on land and gamma exposure

Consequences of a spill

In case of a traffic accident (rollover of crash) containers could potentially be breached and their content of uranium oxide could be spilled on land. The amount of spill depends on the amount of force applied to the container and the ability of the container and drums to withstand the forces. Part of the spilled product could become airborne due to the impact of the accident. If the accident is followed by fire, the buoyant effect of fire could contribute to the airborne release of the yellow cake particles.

Environmental impacts

In case of an accident involving the release of uranium products on land, both flora and fauna and member of the public (and workers) could be exposed to external gamma radiation as well as inhalation of airborne yellow cake particles.

Gamma radiation: Assuming an accident where half of the transported uranium oxide was spilled onto the ground and workers were exposed to gamma radiation from the spilled product during 10 hours of clean-up, the maximum dose received would be 0.026 mSv (Arcadis 2015b).

Dust inhalation: An accident can also potentially lead to yellow cake dust being suspended in air as an aerosol or gas. Assuming an accident where half of the transported uranium oxide was dispersed in a hemisphere with a radius of 10 m for 30 seconds, the immediate and very short duration concentration in the air near the accident area would be 63 mg/m^3. If a person exposed to this yellow cake dust concentration, the total inhalation dose will be 0.164 mSv. This dose is well below the recommended radiation dose limit of the public of 1mSv per years (over natural background level).

Probability

A review of road transportation accident statistics for Canada and the U.S. showed that the probability of an accident and release of product into the environment is extremely unlikely ($4.3x10^{-7}$ per year for probability of release of yellow cake and $2.5x 10^{-8}$ per year for probability of release and fire).

11.1.6 Assessment of spill of uranium product

Based on the results of the assessments from Arctic Canada for similar radioactive material it can be inferred that a spill of yellow cake into the Narsaq River or Narsap

Ilua may, when not frozen, have short-term as well as long-term implications. In the short-term the impacted water may be unsuitable for supporting aquatic life. This period varies between water bodies, but is usually in the order of days or weeks. In the long term, the released material needs to be cleaned up and area remediated. Depending on the cleaning extent and efficiency, the long-term quality of sediment may be impacted resulting in undesirable exposure of benthic invertebrates and other biota which are exposed to contaminated water and sediments.

In case on a land accident exposure to gamma radiation or inhalation of yellow cake dust will not have adverse health effects for workers taking part in the clean-up. The dose to local people, who are much further from the source, would be even lower. The same applies to wildlife and with an effective clean-up of spilled material no significant effects is expected to plants and animals.

Description of Event	Consequences	Potential environmental impact	Probability
Tailings embankment leak or collapse	Some or all water cover disappears and enters Taseq and Narsaq Rivers and ultimately the fjord Tailings will gradually dry up Small amounts of tailings enter the valley	Aquatic life in Taseq and Narsaq Rivers impacted by contaminated water Wind disperse radioactive dust dispersed	Major embankment leak or collapse is highly unlikely
Tailings pond overflow	Supernatant enters Taseq and Narsaq Rivers and eventually the fjord	Aquatic life Taseq and Narsaq Rivers impacted by contaminated water	The risk for an overflow during operation (and closure) is very low
Treatment plant overflow	Untreated water enters the fjord	Marine life around discharge point impacted by polluted water	It is unlikely that untreated process water or water from the tailings pond is discharged to the fjord because production will stop in the event of a treatment plant malfunction
Spills of oil in chemicals due to shipping accident	Significant marine oil pollution and shoreline fouling Spill of chemicals and mine products	Marine life, including birds impact by oil pollution Chemical spill can have adverse effects but dilution will reduce impact	The likelihood of a full scale accident happening during operation is very low
Spills of oil and chemical during unloading	Small amount of oil or chemicals are spilled into the fjord	Localized impacts on marine life	Compared to large shipping accidents, the likelihood of spills caused by operational events at the port is higher, but the consequences are much lower
Oil spill due to tank rupture	No spills as all fuel tanks will have geotextile containment berms that can contain the full tank content	No significant impact	Unlikely
Spills of chemicals and oily products during land transport	Spills of oil and chemicals along access road and seepage into nearby rivers	Limited impact if spilled material is dry and spill on land. Significant impact to aquatic ecosystem if spill enters river	Risk on spill on land is very low. Spill into freshwater even lower.
Spills from pipelines	Spill of slurry containing tailings or process water	Fast control system will ensure spill is small and local with limited environmental consequences.	With a fast control system in place the risk of significant spill from pipeline is very low

Spills from fuelling mobile equip-ment	Small oil spill at fueling stations	Limited environmental impact since spill will usually be small	Risk for spills is low.
Spill of uranium oxide into river or harbor	Uranium product released into surface water im-pacting water quality	Significant short-term consequences for freshwater ecosystem. Limited long terms implications with effec-tive clean-up	Extremely low
Spill of uranium oxide on land and gamma exposure	Exposure to gamma radiation and inhalation of uranium oxide dust	Gamma radiation and uranium oxide dust is unlikely to have adverse impact on ecosystem or local people	Extremely unlikely

Table 11-1: Summary table of risk assessment

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13. APPENDIX 1 – ENVIRONMENTAL MANAGEMENT PLAN

Environmental Management Plan for the Kvanefjeld Project

13.1. Introduction

The Environmental Management Plans (EMP) for a mine project describes how the mining company intends to manage the environmental issues identified in the EIA. The EMP also identifies who is responsible for each commitment.

13.2. Kvanefjeld Environmental Management Plan

The Kvanefjeld Environmental Management Plan (EMP) includes commitments and management measures that GMEL will implement to ensure the Kvanefjeld Project risks are managed to an acceptable level.

The EMP outlines the management objectives under each environmental aspect identified in the EIA, the potential impacts to the environment, the mitigation measures for each impact, who is responsible for each commitment as well as the applicable construction, operational or closure phase for which management is required. The commitments outlined in the EMP aim to provide a basis for which environmental performance and compliance can be measured throughout the Project.

The EMP and work procedures will be periodically reviewed and updated over the life of the mine. Environmental management commitments detailed in the EMP will be included in relevant contract documents and technical specifications prepared for the Project. All GMEL's employees, contractors and other personnel employed on the Project will be made aware of the EMP through the site induction process. During all phases of the Project, compliance with environmental management measures will be regularly monitored, any non-compliances addressed and improvement actions will be implemented.

The EMP presented below is a framework which consists of the following key elements:

- A management program that specifies the activities to be performed in order to minimize disturbance of the natural environment and prevent or minimize all forms of pollution;
- A definition of the roles, responsibilities and authority to implement the management program.

The EMP is tabulated in spreadsheets below, which are laid out with the following divisions:

- Project activity – the activity associated with the mining project which has been identified to possess a potential impact or risk to the environment. Each project activity has a reference number which correspond to the activity number in the Construction, Operational and Closure-Post Closure chapters of the EIA;

- Environmental impact – description of the negative impact of the activity (such as pollution or disturbance of natural environment);

- Action – the mitigating measure or actions identified to prevent or minimize the adverse environmental impact; and

- Responsibility – party/ies responsible for ensuring the action, measure, or principle is done.

Initial responsibility for meeting some of the management commitments in the tables will be transferred to GMEL's contractors. GMEL will commit the contractors to meeting the relevant management responsibilities. This will be done by developing a code of responsible environmental practice that will be included in tender documents and contracts. GMEL will fully recognize that it is not absolved from those management responsibilities. Ultimate responsibility for meeting all commitments in this section lies with GMEL. In most cases the person (or persons) assigned responsibility for a certain commitment is seen as the driver of the requirement. This will typically be the Resident Mine Manager and/or the company Environmental Manager.

13.3. GMEL's Environmental Management System

Before mine start GMEL is committed to also developing and implementing an Environmental Management System (EMS) consistent with the International Organization of Standardization's ISO 14001 guidelines for managing the EMS. The purpose is to formalize procedures for managing and reducing environmental impacts from the Kvanefjeld Project. The EMS will assist GMEL to maintain compliance with Greenland's environmental regulations, lower environmental impacts, reduce risks, develop indicators of impact and improve environmental performance. The ISO 14001 (2004) is based on the methodology known as Plan-Do-Check-Act (PDCA):

- **Plan**: establish the objectives and processes necessary to deliver results in accordance with the organization's environmental policy.
- **Do**: implement the processes.

- **Check**: monitor and measure processes against environmental policy, objectives, targets, legal and other requirements, and report the results.
- **Act**: take actions to continually improve performance of the environmental management system.

The GMEL's EMS will ensure that the environmental obligations associated with the Kvanefjeld Project are adequately managed in a manner that is planned, controlled, monitored, recorded and audited. Environmental incidents will be reported, investigated, analyzed and documented. Information gathered from the incident investigations will be analyzed to monitor trends and to develop prevention programs, which include corrective and preventative actions taken to eliminate the causes of incidents. All employees, contractors and sub-contractors will be required to adhere to the EMS and the non-conformance and corrective action system in place at Kvanefjeld.

EMP covering the Construction Phase

Ref. no.	Project activity	Environmental impact	Action	Responsibility
8.1.1	Stripping of the mine pit area	The mining activities can have aesthetic impact	Plan the pre-stripping to blend as far as practical with the surrounding land-scape	Project Manager
8.1.2	The use of Taseq and ad-jacent pond for tailings deposition	The mining activities can have aesthetic impact	Plan the tailings embankments to blend as far as practical with the sur-rounding landscape	Project Manager
8.1.3	Re-profiling of landscape for other mine facilities and infrastructure construction	Re-profiling of terrain for in-frastructure can have aes-thetic impact	Plan roads to blend as far as practicable with the surrounding landscape	Project Manager
8.1.4	Construction activities could cause erosion	Loss of soil, sand and gravel by the forces of water, ice or wind	Take erosion into account when selecting construction methods and routing of the alignments	Project Manager

8.1.5	Mobile equipment, drilling and blasting, land transport and shipping make noise	Increased noise load could disturb wildlife and people	Plan noise activities such as blasting to take place when noise impact is least	Project Manager
8.1.6	In dark periods the construction areas will be illuminated	"Ecological light pollution" can distract wildlife, in particular migrating birds	No action required since problem is negligible	Project Manager
8.2.1	Blasting, excavation and shipping in fjords generate dust and air emissions	Potential pollution of water and land	Plan construction works to minimize dust generation and air pollution	Project Manager
8.2.2	Mobile equipment such as excavators, bulldozers and trucks generate greenhouse gasses	Climate change	Limit the amount of fuel combusted as much as practical possible	Project Manager
8.3.1	Construction works will lead to changes of natural flow pattern and capacity of freshwater resources	Impact freshwater ecology including fish population	Limit mitigation possible except minimizing the impact as much as practically possible	Project Manager
8.4.1	Noise and visual disturbances from personnel	Disturbance of terrestrial mammals and birds	Restrict the movement of staff members outside the construction areas	Mine Manager
8.4.2	Construction works at port and shipping in fjords	Disturbance of marine mammals and birds	Low speed while in fjords and keep good distance to flocks of wintering sea birds (when possible)	Project Manager

8.4.3	Construction of bridges and embankments	Disturbance of freshwater organisms including fish	Minimise the disturbance of the water in when building new bridges and embankments by keeping the construction period as short as practically possible	Project Manager
8.4.4	Re-profiling to accommodate buildings	Loss of terrestrial habitat	Minimize the area to be disturbed by planning infrastructure to have as small a footprint as possible	Project Manager
8.4.5	Deposition of tailings in Taseq	Loss of freshwater habitat	No mitigating possible	Mine Manager
8.4.6	Re-profiling for shore to accommodate port	Loss of marine habitat	Minimize the area to be disturbed	Project Manager
8.4.7	Accidents can lead to spill of oil and chemicals on land	Impact on terrestrial habitats and biota	Prepare contingency plans for oil and chemical spills including efficient combat readiness training	Mine Manager
8.4.8	Accidents can lead to spill of oil and chemicals	Impact of freshwater and marine habitats and biota	Prepare contingency plans for oil and chemical spills including efficient combat readiness training	Mine Manager
8.5	Contamination of environment from domestic and industrial waste	Waste – and in particular hazardous waste - can lead to significant contamination of the environment	Handle waste according to procedure detailed in waste management manual and according to good environmental practice, with high degree of re-use and re-cycling	Mine Manager
8.5.1	Traffic along haul- and service roads	Road kills of animals	Ensure speed limits are enforced and that all staff are aware of animal hazards	Mine Manager
8.5.2	Shipping in the fjord	Introduction of invasive alien species with ballast water	Follow regulations of the International Convention for the Control and Management of Ships' ballast water and Sediments	Project Manager

8.6.1	Safety regulations at mine area	Hindrance of traditional land use	Keep the area closed to the public and the no-hunting zone as small as possible	Mine Manager
8.6.2	The new road between the port and the mine area will be closed for the public	Limit recreational use and tourism	No mitigation possible. Roads will be available for emergency use and planned special occasions.	Mine Manager
8.6.3	Construction work at port and Taseq	Disturbance of heritage site	Contact staff member of the Greenland National Museum and Ar-chives	Project Manager

EMP covering the Operational Phase

Ref. no.	Project activity	Environmental impact	Action	Responsibility
9.1.1	Landscape alterations at pit and embankments	Aesthetic impact	Plan the activities to blend as far as possible with surrounding land-scape	Project Manager
9.1.3	Noise from project opera-tions, blasting at pit	Disturbance of wildlife and people	Avoid blasting during evenings and at night	Mine Manager
9.2.1	Mine activities cause air emissions	Increased air emissions (concentration and deposi-tion of dust, NOx, SOx & Black carbon)	Minimize dust generation by implementing GMEL's Dust Control Plan Choose vehicles and other equipment based on energy efficiency tech-nologies to optimize emissions rates Maintain power plant, vehicles and other fuel powered equipment in ac-cordance with manufacture's specifications to minimize on emissions	Mine Manager
9.2.2	Mobile and stationary fuel combustion generates greenhouse gas emissions	Climate change	Choose vehicles and other equipment based on energy efficiency tech-nologies to optimize emissions rates Maintain power plant, vehicles and other fuel powered equipment in ac-cordance with manufacture's specifications to minimize on emissions	Mine Manager
9.3	Some mine activities cause release of radioac-tivity	Radiological emissions	Minimize dust generation (which can be radioactivity bearing) by imple-ment GMEL's Dust Control Plan	Project Manager
9.5.1	People and machines work at mine area	Visual (and noise) disturb-ance of terrestrial animals	Restrict the movement of staff members outside the Project area during spring and summer to minimize the general disturbance of wildlife	Project Manager

9.5.2	Discharge of water from mine operations to the fjord	Pollution of marine environ-ment	Optimization of diffusor outlet (possible engineering challenge as it shall be implemented 80 m below sea level)	Project Manager
9.5.3	Mine activities change hy-drology	Impact on fish population in Narsaq River	No mitigation needed	Project Manager
9.5.4	Accidents can lead to spill of oil and chemicals	Pollution of terrestrial, fresh-water and marine habitats	Prepare contingency plans for oil and chemical spills including efficient combat readiness training	Project Manager
9.5.5	Traffic along haul- and ser-vice roads	Increased mortality among terrestrial animals	Ensure speed limits are enforced and that all staff are aware of animal hazards	Project Manager
9.5.6	Shipping in the fjord	Introduction of invasive alien species with ballast water	Follow regulations of the International Convention for the Control and Management of Ships' ballast water and Sediments	Project manager
9.6	Many project activities generates waste	Contamination of environ-ment	Strict enforcement of waste handling procedures; and Continue updating waste management manual.	Project manager
9.7	Access to mine area not possible and no hunting security zone introduced	Restrict local peoples (and visitors) traditional use of area	Minimize no go and no hunting zones as much as possible	Project manager

EMP covering the Closure and Post Closure Phases

Ref. no.	Project activity	Environmental impact	Action	Responsibility
10.1.	Discharge of water from mine operations to the fjord	Pollution of marine environment	None, except continuous monitoring of effluent	Project Manager

14. APPENDIX 2 – CLOSURE AND DECOMMISSIONING PLAN

Conceptual Closure and Decommissioning Plan for Kvanefjeld Project

14.1. Introduction

The closure and the post-closure phases are integral parts of a mining project and the environmental management of the project. This part of the EIA summarizes the legal framework for project closure and describes broadly how each individual project component will be decommissioned. Since this conceptual plan is prepared before mine operations have started the plan will be expanded and refined during the operational phase.

14.2. Closure obligations

The Mineral Resources Act of 2009 (amended in 2012 and 2014) specifies that a Closure Plan shall be prepared and approved before exploitation begins (Part 10, section 43).

In the Act it is stipulated that: "*the licensee must submit a plan for steps to be taken on cessation of activities in respect of facilities, etc. established by the licensee, and how the affected areas will be left (closure plan). If the licensee plans to leave facilities, etc. in the area that for environmental, health or safety reasons will require maintenance or other measures after the closure, the closure plan must include plans for the maintenance or the measures and monitoring thereof*".

14.3. The Kvanefjeld Project Closure and Reclamation Plan

The closure plan is based on the current open pit mine configuration and production rates and that the mining operations will cease in 2058, at which stage mine closure activities will commence. However, temporary suspension and possibly premature closure may be required if the operations are no longer viable due to a change in Project economics or other difficulties.

Since the plan is prepared before the mine is constructed it contains broadly identified tasks of the closure works and will be refined and expanded before the closure date for the mining and processing operations.

The plan covers the closure phase, which is estimated to take approximately six years. During this phase the decommissioning of equipment, buildings and other structures will take place. Throughout the closure phase the Treatment Water Placement (TWP) will continue during operating to treat water prior to fjord placement.

Post closure follows decommissioning and rehabilitation and is the phase during which monitoring continues. During this phase, no active care will be required except the occasional maintenance of the gravel roads to the mine site and tailings facilities in the Taseq Basin to permit inspections and monitoring activities. Post closure is managed through a monitoring plan and with liaison with the authorities. Towards the end of the life of the Project, the post closure objectives will be refined to accommodate the site conditions prevailing at the time.

14.4. Purpose and Scope of the Closure and Reclamation Plan

The overall closure and reclamation goal is to return the mine site and affected areas to viable and, wherever practicable, self-sustained ecosystems that are compatible with a healthy environment and with human activities.

In order to achieve this, the following core closure principles will be followed:

Physical Stability – All project components that remain after closure will be physically stable to humans and wildlife;

Chemical Stability – Any project components (including associated wastes) that remain after closure will be chemically stable and non-polluting or contaminating meaning that any deposits remaining on the surface or in lakes will not release substances at a concentration that would significantly harm the environment;

Minimized radiological impact - It will be ensured that the long-term radiation exposure of the public due to any radiological contamination of mine area is kept “as low as reasonably achievable” (ALARA); and

No Long-Term Active Care – Any project component that remains after closure will not require long-term active care and maintenance.

14.5. Closure implementation

The closure works e.g. how each individual project component will be decommissioned is broadly described below. As mentioned above, this conceptual plan is prepared before mine operations have started and the plan will be expanded and refined during the operational phase.

<u>Open pit mine workings</u>
The open pit will be fenced off to restrict access for humans, livestock and wildlife (for safety reasons) and allowed to fill naturally with water from groundwater inflows and direct snow- and rainfall. When full (after 50+ years) water will discharge to Nordre Sermilik.

<u>Waste rock pile</u>
During the operational phase, deposition of waste rock will take place in such a way that the pile will remain physically and geo-technically stable for human and wildlife in

the long-term. Any risk of erosion, thaw settlement, slope failure or collapse after mine closure is therefore negligible.

The geochemical test work that has already been undertaken shows that following the six-year closure phase, no significant acid rock drainage or metal leaching will take place from the waste rock pile and surface runoff. Seepage water quality from the pile will be safe for wildlife and humans.

Water management systems

This includes the embankments and diversion channels at the tailings storage facilities (FTSF & CRSF), embankment and diversion channel on Kvanefjeld, the Treatment Water Placement (TWP) pipelines and the Raw Water Dam at the Refinery.

The tailings storage embankments and diversion channels are left as constructed. When the six years closure phase ends, the return water pipelines are removed and the tailings storage facilities are left to fill naturally with water from groundwater inflows and direct snow- and rainfall. When full, water will overflow the CRSF into the FTSF as well as the FTSF embankment and discharge to the existing Taseq River. Water placement into Nordre Sermilik is concluded at this point.

The embankment of the Raw Water Dam is left as a bridge across Narsaq River, to permit future inspections and monitoring activities at Taseq, but the natural flow of the river is re-established.

Alternative deposition of tailings at mine closure

It has been considered as an option to move the tailings deposited in the Taseq basin back to the pit at mine closure. However, since the tailings can only be removed with water it would require that the solids are re-suspended into slurry and pumped through a pipeline to the pit. This option is not practically possible for the following reasons:

1. After 37 years of deposition the tailings have compacted considerably making their re-suspension very difficult. It is estimated that the tailings are 70%+ solids with high viscosity and are therefore not in a pumpable condition.

2. Even if the tailings at the bottom of the Taseq basin are able to be pumped it will take a long time and considerable cost to move it to the pit because of the massive volume. Not only must all the tailings be pumped to the pit – in order to keep the material suspended – all the water in Taseq will also have to be pumped to the pit.

3. Re-slurrying of the tailings will result in the release of salts trapped in the pores of the consolidated solids. This will release further contaminants such as uranium, Fluoride and Phosphate into the tailings water, which then will have to be contained in the pit.

4. It will not be practically possible to provide separation of the two tailings fractions if deposited in the pit. This will prevent future recovery of residues such as Zirconium, Thorium and Gallium and heavy Rare Earth metals, which could be economically recovered with future technologies and/or higher product prices.

Buildings and equipment
This includes the following main structures: crusher facility, concentrator plant, refinery, acid plant, power generation plant, fuel tanks, maintenance shops, offices, ware houses, accommodation village, processing reagent and explosive storage, mobile equipment and tailings and return water pipelines.

Except for the accommodation village at Narsaq, all buildings and major structures will be dismantled and removed. Foundations will be removed where possible, or covered by natural materials to blend into the natural surroundings.

The accommodation village will be left as constructed (if agreed with the Greenland authorities).

For aesthetic reasons and because a vegetation cover will help control erosion and dust dispersal, and provide food and shelter for wildlife, an active re-vegetation program will be considered once the buildings and mine facilities are removed. However, this will not be focused on the rapid establishment of a green cover on disturbed areas, for example by seeding grasses. These measures sometimes meet the short-term expectations for aesthetic improvement and sometimes erosion and dust control, but do not address the longer-sighted requirements for habitat restoration. Instead, the species selected for re-vegetation will reflect the site's ecological variables, as well as the nature of the mining-related disturbances and should follow the principle; "the best species for planting on a mine site are the ones that can be found growing nearby" /Withers 1999/.

Mine infrastructure
This includes the on-site roads, electrical power supply system (including power lines to the port), bridges, culverts and the port.

The haul roads will be reclaimed as soon as the mining operations no longer require them. The roads are ripped to encourage re-vegetation (see above).

The power line connecting the on-site plant with the port area is removed. Any culverts that could act as hydraulic conduits at closure are removed.

The roads connecting Narsaq and the mine port with the mine area (including the bridges across Narsaq River) as well as the track between the mine area and Taseq are left intact to facilitate future inspections and monitoring activities.

The mine port is left as constructed (if agreed with the Greenland authorities).

14.6. Identification and management of closure issues

To insure that the closure and post-closure phases of the Kvanefjeld project will meet the principles listed in section 13.3. each project domain has been analysed carefully to identify if there are issues for specific attention. This assessment identified the following:

Potential acid rock drainage and metal leaching from waste rock pile
Acid rock drainage and metal leaching from the weathering of undisturbed waste rock is a potential issue in connection with mine closure. Although the low temperatures in Greenland will slow the chemical weathering processes during a large part of the year, there is potentially a seasonal flush of accumulated contaminants during spring melt.

Static and kinetic acid rock drainage and metal leaching prediction tests have shown little metal leaching potential of the waste rock. However, during the first years of the closure phase some leaching of fluoride is expected. Field tests and monitoring on site will further characterize the mine waste water including the concentration of fluoride. To prevent Narsaq River exposure to seepages (mainly fluoride) from the waste rock water, the diches and berms constructed to divert the waste rock water into Nordre Sermilik during mine operations will be maintained.

Potential radiological contamination of mine area
It is an objective of the closure plan to ensure that there is no unacceptable radiological health risk to people, livestock (sheep) and wildlife after mine closure and in the future. This will be achieved by managing radiation in compliance with the “as low as reasonably achievable” or ALARA principle and the “Best practicable technology” principle.

The mine components potentially associated with elevated radiation following mine closure are identified as the pit area and the tailings ponds (Taseq).

From the mining area, there may still be releases of radon and dust (from any waste barren rock piles deposits that are uncovered) and mine openings and mineral waste facilities. These releases are expected to be very small and will not result in any measureable change in the receiving environment.

The tailings deposited in the tailings storage facilities (FTSF & CRSF) will contain uranium and thorium and their decay products and will emit radiation. To ensure that none of this radiation will be of any health risk to humans, livestock or wildlife the tailings will remain deposited under permanent water cover. This will ensure no radiation issue associated with tailings.

In the Post-closure there will be some small amount of radioactivity released to the freshwater environment; however the concentrations are low and thus the exposure is low, close to conditions at background levels. Overall, there are not expected to be any radiation issues associated with tailings.

Alteration of the hydrology and flow of surface water (Narsaq River)
All modifications to the hydrology of the Narsaq River and its tributaries, which are required during mining, will be removed at the end of the mine closure phase. This includes the control of the upper reaches of Narsaq River to supply water to the Raw Water Dam and the hindering of outflow from Lake Taseq during operations and closure phases. An exception is the water from rain- and snowfall on the Kvanefjeld which permanently will be directed to Nordre Sermilik. Also the water that overflows the pit 50 years after mine closure will be lead to Nordre Sermilik.

14.7. References

Withers, S.P. 1999. Natural Vegetation Succession and Sustainable Reclamation at Yukon Mine and Mineral Exploration Sites. Mining Environment Research Group (MERG). 67 pp.

15. APPENDIX 3 – ENVIRONMENTAL MONITORING PLAN

Conceptual
Environmental Monitoring Program
for the Kvanefjeld Project

15.1. Introduction

GMEL will develop and implement an Environmental Monitoring Program (EMP) in accordance with the Greenlandic guidelines to monitor the predicted residual effects of the Kvanefjeld Project and the effectiveness of implemented mitigation measures. The EMP will encompass all phases of the project (construction, operation, closure and post-closure) and identify any variances from predictions that occur and whether such variances require action, including any additional mitigation measures.

15.2. Content of GMEL's Environmental Monitoring Program

The Kvanefjeld EMP will be a best practice multiple lines of evidence approach comprising grab sampling of water, air, soil, lichens, plants, mussels, fish and seals from numerous locations in and around the mine site and tested to confirm that environmental protection systems are effective. The monitoring results will be submitted to regulatory authorities for review.

The EMP for the Kvanefjeld Project will comprise of the following key-elements:

1. Air Quality and Dust Monitoring;
2. Sea and Freshwater Monitoring;
3. Soil and Terrestrial Biota Monitoring;
4. Tailings Facility Monitoring; and
5. Meteorological Monitoring;

Each of the program elements will include:

- Description of design and objectives;
- Specific monitoring stations;
- Schedules for monitoring activities;
- Sampling procedures, sample preservation requirements, and analytical methods, as applicable;
- Procedures for comparison of monitoring results against baseline data, environmental standards and environmental quality objectives;
- Actions to be implemented when requirements set out in regulations or permits have not been met;
- Procedures for reporting results to Greenlandic authorities;
- Roles and responsibilities of key staff, for internal and external reporting of monitoring activities and results, as well as management of the EMP;
- Quality assurance and quality control processes; and
- Procedures for reviewing and updating the monitoring program.

Because uranium is one of the mine products the MSP will include radiological as well as non-radiological parameters. For this conceptual MSP, Arcadis has prepared a specific Radiation Monitoring Plan Outline /Arcadis 2015/, which proposes which environmental media to be measured or sampled. The Arcadis outline follows the principles defined by the Canadian Standards Association (CSA) /2010/ that the media to be monitored should provide information to assess the dose, be close to the receptor, consider the expected fate in the environment and recognize the variability of the media.

The EMP will be developed and updated throughout the mine life.

15.2.1 Conceptual Monitoring Program

Prior to project operations, a more detailed study design will be developed for each of the EMP's elements. This will be done in cooperation with the Greenland authorities. Below are descriptions of the proposed approach for each element of the EMP. In addition to the studies outlined below, supplementary studies may be conducted for specific, well-defined objectives and are not expected to continue throughout the program (e.g. indoor radon monitoring).

1. Air Quality and Dust Monitoring

Air quality and dust monitoring should continue at established stations in Narsaq and Narsaq Valley using High-Volume samplers and dustfall jars. The results will be compared to baseline values as well as applicable guidelines to determine if there is a change as a result of mine activities. The parameters to be monitored will be agreed with the Greenlandic authorities but are expected to include:

- Dust deposition recorded using dustfall jars. It is proposed to collect monthly samples at the baseline stations and along a gradient relatively close to the source. Depending on the deposition results, selected dustfall jars may be provided for analysis of radiological parameters;
- Concentration levels of Particulate Matter (PM_{10} and $PM_{2.5}$) collected using High-Volume dust samplers;
- Radionuclide content of dust collected in the High-Volume samplers. Samples should be collected from an area close to the operations as well as other locations such as the Narsaq townsite and a reference location. Quarterly composite samples should be sent for analysis of radionuclides. If sufficient mass for obtaining low detection limits is not available then chemical analysis will be conducted and secular equilibrium will be assumed.
- Radon and thoron monitoring (integrated semi-annual sampling) at locations near the mine area boundary and at other specific locations such as the Narsaq townsite, within the Narsaq Valley, Ipiutaq and a reference location.

- Gamma detectors should be deployed at the same locations as the radon and thoron monitors.
- Nitrogen oxides (NOx) from a selection of stations.

The sampling periods, the trace elements, major ions and radioisotopes to be analyzed and reporting requirements are to be agreed with the Greenlandic authorities.

2. Sea and Freshwater Monitoring

Water quality

Baseline water quality has been characterized from a large number of stations in the fjords at Narsaq and in watercourses, lakes and ponds on the Kvanefjeld plateau, Narsaq Valley, at Taseq Lake and a reference area. Sediment samples have also been collected and analyzed from the rivers and lakes in and around Narsaq Valley.

Monitoring of water quality and sediment should continue at the same sites during all phases of the mine project. The sampling frequency, reporting requirements, parameters to be monitored will be defined both for field monitoring activities and laboratory activities in cooperation with the Greenlandic authorities.

It is expected that the water and sediment sampling will include radiological as well as non-radiological parameters. Also the radionuclide content of supernatant of tailings pond water should be monitored to confirm modelled predictions.

When project operations commence effluent monitoring (chemistry) should be carried out at the discharge point into Nordre Sermilik. Monitoring of the mine water runoff from the waste rock deposit and pit that discharges to Nordre Sermilik will be performed.

Results of the monitoring will be compared to baseline values as well as applicable guidelines to determine if there is a change in water quality as a result of mine activities. Detailed quality assurance procedures will be provided, and will include calibration and validation of field measurement equipment as well as sampling measures. Data will be reviewed to update loading assumptions in the site water balance and verify water quality models.

Marine and freshwater biota

The marine and freshwater biota component of the EMP will provide detailed information regarding metal and radioisotope concentrations in selected key plant and animal species.

Since 2007 samples of indicator plant and animal species have been collected from a large number of stations to determine the background level of metals. This includes the fjords that surround Narsaq, Narsaq River and references areas. The target species were Ringed seal, Short-spined sea scorpion, Arctic char, Blue mussels and Bladder wrack seaweed.

It is proposed to continue monitoring of fish and seal samples on an annual basis and analyze for radionuclides. In addition, select or composite samples of blue mussels and seaweed should be provided for analysis on a periodic basis.

Monitoring of these species should continue at the same sites during all phases of the mine project and the metal loads are compared to baseline values to determine if there is a change as a result of mine activities.

Hydrology
Surface water flow monitoring will be continued at established stations in the Study area (Narsaq, Taseq and Kvane rivers) to monitor seasonal and annual flow patterns and support water management measures, refine the water balance, and inform water quality modeling. Water levels will be recorded continuously with a pressure transducer at automated stations, with calibration discharge measurements conducted at a range of flows during scheduled site visits.

3. Soil and Terrestrial Biota Monitoring

To establish background concentrations of metals and radioisotope in terrestrial habitats, samples of soil, lichens, grass and leaves of bushes have been collected since 2007 from stations at Kvanefjeld, Narsaq Valley and in a reference area.

Monitoring should continue at the locations identified in the baseline study and include soil, snow lichen, grass and leaves of Northern Willow (e.g. once every 3 years). This frequency is consistent with the approach adopted at uranium mining operations in Canada for these types of media where any changes would be expected to be gradual.

The results are compared to baseline values to determine if there is a change as a result of mine activities.

4. Tailings Facility Monitoring

The objective of the Tailings Facility monitoring is to provide on-going characterization of water quality in the Flotation Tailings Storage Facility (FTSF) and the Chemical

Residue Storage Facility (CRSF) during operation, closure and post-closure in order to confirm the predicted concentrations of metals in the two ponds.

The Tailings facility monitoring will include radiological as well as non-radiological parameters.

5. Meteorological Monitoring

Collection of meteorological data will continue at an established weather station on Kvanefjeld Plateau. Ongoing meteorological data collection is required to verify design assumptions for water management systems and dust dispersal modelling.

The Meteorological Monitoring reporting will include a summary of the measured parameters, including temperature, precipitation and wind.

The collected data will be compared with the predictions for extreme events or for performance predictions; results will be used to revise operational procedures as necessary. The results will also be used in the air quality monitoring.

References

Arcadis. 2015. Radiation Monitoring Plan Outline, Kvanefjeld Multi-Element Project, Narsaq Area, Greenland. 7 pp

Canadian Standards Association (CSA). 2010. *Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills.* N288.4-10.

The tables below show a framework for the monitoring parameters and sampling locations proposed. The suggested sampling frequency for each parameter should ensure validity of actual environmental conditions at the Project site and surroundings. Defined monitoring durations identify which phases of the mining project will generate the potential impact that requires sampling and monitoring. Where relevant the programme includes control sites where no expected Project impacts are likely to be experienced.

Monitoring aspect	Sites/activities to be monitored	Parameter to be monitored	Frequency	Duration	Assessment criteria[3]	Reporting
Dust deposition	High-Volume dust sampler stations and along a gradient relatively close to the source	Dustfall	Continual	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Concentration level of Particulate Matter	High-Volume dust sampler station locations	Concentration of PM_{10} and $PM_{2.5}$	Continual	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Radionuclide content of dust	High-Volume dust sampler station locations	Selection of relevant radionuclides	Continual	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Radon and thoron	Location near the mine area boundary and in Narsaq town, within the Narsaq Valley, Ipiutaq and a reference location	Radon and thorium gases	Semi-annual	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report

[3] The assessment criteria will be based on the water and air quality criterias for Greenland (and Canadian if no Greenland values are available)

Monitoring aspect	Sites/activities to be monitored	Parameter to be monitored	Frequency	Duration	Assessment criteria[4]	Reporting
Gamma radiation	Location near the mine area boundary and in Narsaq town, within the Narsaq Valley, Ipiutaq and a reference location	Gamma	Semi-annual	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Nitrogen oxides	High-Volume dust sampler stations	NOx concentration	Semi-annual	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Metal incl. radionuclide concentrations in rivers	Narsaq, Taseq and Kvane Rivers (at baseline stations)	Metals incl. radionuclides in water	Monthly Semi-annual in post closure	Construction, operational, closure and post closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Metal incl. radionuclide concentrations in rivers	Narsaq, Taseq and Kvane Rivers (at baseline stations)	Metals incl. radionuclides in sediment	Annually (August)	Construction, operational, closure and post closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report

[4] The assessment criteria will be based on the water and air quality criterias for Greenland (and Canadian if no Greenland values are available)

Monitoring aspect	Sites/activities to be monitored	Parameter to be monitored	Frequency	Duration	Assessment criteria[5]	Reporting
Supernatant of tailings ponds	Water of FTSF & CRSF	Relevant elements and radionuclide concentrations	Continual during operational and closure phases Semi-annual in post closure phase	Operational, closure phases and post-closure	To be defined in cooperation with MLSA	Weekly in operational and closure phases. Annual Monitoring Report in post-closure phase
Treatment Water Placement	TWP	Relevant elements and radionuclide concentrations	Continual	Operational and closure phases	To be defined in cooperation with MLSA	Weekly and annual Monitoring Report
Water stream to Nordre Sermilik from waste rock deposit and pit	Outflow to fjord	Relevant elements including radionuclides in water and sediment	Semi-annual in operational and closure phases Annual in post closure phase	Operational, closure and post-closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report

[5] The assessment criteria will be based on the water and air quality criterias for Greenland (and Canadian if no Greenland values are available)

Monitoring aspect	Sites/activities to be monitored	Parameter to be monitored	Frequency	Duration	Assessment criteria[6]	Reporting
Metal incl. radionuclide content in marine fish and mammals	Baseline stations in fjords and reference stations	Metals incl. radionuclides in Ringed seal, Short-spined sea scorpion and Arctic char	Annually (August)	Construction, operational, closure and post-closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Metal incl. radionuclide content in mussels	Baseline stations in fjords and reference stations	Metals incl. radionuclides in Blue mussels	Annually (August)	Construction, operational, closure and post-closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Metal incl. radionuclide content in seaweed	Baseline stations in fjords and reference stations	Metals incl. radionuclides in Bladder wrack seaweed	Annually (August)	Construction, operational, closure and post-closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report
Surface water flow	Narsaq, Taseq and Kvane Rivers	Seasonal and annual flow patterns	Continuously at automated stations Annual calibration discharge measurements	Construction, operational and closure phases	To be defined in cooperation with MLSA	Annual Monitoring Report

[6] The assessment criteria will be based on the water and air quality criterias for Greenland (and Canadian if no Greenland values are available)

Monitoring aspect	Sites/activities to be monitored	Parameter to be monitored	Frequency	Duration	Assessment criteria[7]	Reporting
Metal incl. radionu-clide contents in higher plants	Baseline stations and reference stations	Metal incl. radionu-clide content in snow lichen, grass and leaves of North-ern Willow	Annually (August) or once every 3 years	Construction, opera-tional and closure phases	To be defined in coop-eration with MLSA	Annual Monitoring Report
Metal incl. radionu-clide contents in soil	Baseline stations in and around mine area and reference stations	Metals in soil	Annually (August) or once every 3 years	Construction, opera-tional and closure phases	To be defined in coop-eration with MLSA	Annual Monitoring Report
Local climate	Weather station at Kvanefjeld	Temperature, pre-cipitation and wind speed and direction	Continual	Life of mine	-	Annual Monitoring Report
Higher fauna	Mine area and near surroundings	Ad hoc observations of birds and mam-mals in connection with other monitor-ing activities	Annually (August)	Life of mine	To be defined in coop-eration with MLSA	Annual Monitoring Report

[7] The assessment criteria will be based on the water and air quality criteria for Greenland (and Canadian if no Greenland values are available)