Initial Environmental Evaluation

Construction and operation of Troll Runway

Norwegian Polar Institute
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Appendices

1 Summary

As part of the international DROMLAN project the Norwegian Polar Institute proposes to establish and operate a blue ice runway (Troll Runway) in the vicinity of the Norwegian research station Troll in the Jutulsessen Mountains in Dronning Maud Land.

The present document describes the proposed activity and the impacts associated with it. The document has been prepared in accordance with § 10 of the *Regulations relating to protection of the environment in Antarctica*, reflecting the intentions of Article 2 of Annex I to the Protocol on Environmental Protection to the Antarctic Treaty.

The activity has been planned as to minimize environmental impacts. Provided the activity is conducted in accordance with the plans, it is expected that environmental impacts stemming from the activity will be minimal. The analysis has, however revealed a number of potential impacts that may more significant than the direct impacts associated with the activity:

- The establishment of the Troll Runway may make this area of Dronning Maud Land much more accessible and thereby increase associated activities both in the Norwegian program, other nearby programs and non-governmental activities. An increase in activity in the area would exaggerate all the impacts that have been identified and furthermore could potentially lead to further consequences not possible to foresee at this point in time. Potentially the access to the Jutulsessen area as a staging area could lead to an increase in activities in surrounding areas, and thereby further decrease the area of Dronning Maud Land that today are relatively untouched by human activities.
- A major incident due to failure in takeoff or landing of aircraft is not considered an integral part of the planned activity. There is, however, always a risk for an aircraft incident associated with flight operations, and the risk will increase with the number of flights. The overall incident rate compared to number of takeoffs is very low (on an average less than 2 hull losses per 1 million takeoffs), although likely to be higher in Antarctica due to difficult flying conditions. The consequence of a major incident in the vicinity of the Troll Runway is assessed to be larger and more intense than the direct impacts associated with the planned activity itself, although not expected to irreversibly impact natural functions or processes.

If the activity were not carried out (the 0-alternative) the impacts on the environment would be smaller, but it should be noted that flight operations will take place in the area, and that impacts must be expected in the area regardless.

Having conducted the required analysis of the activity the Norwegian Polar Institute has come to the conclusion that the impacts associated with the activity should be considered acceptable, and that they likely will constitute no more than minor or transitory impacts on the environment. On this basis the Norwegian Polar Institute does not believe the activity merits the preparation of a Comprehensive Environmental Evaluation.

2 Introduction

2.1 Background

Research activities have taken place in Dronning Maud Land over a number of decades. Combined whaling, mapping and research expeditions were conducted already early in the 20th century, but it was Norwegian -British-Swedish Maudheim Expedition (1949-52) and the activities associated with the International Geophysical Year in 1957-58 that really boosted the level of research effort in this part of Antarctica. During that time period and the following decades a number of nations have established and operated a number of research stations in Dronning Maud Land. Currently eight nations are operating research stations, while a number of additional nations are involved in the on-going research activities in the area.

Traditionally, transport of personnel and cargo to the stations and operations in Dronning Maud Land has been by sea. However, the Soviet Antarctic program constructed two runways in in the early 1980s, one near Novolazarevskaya station in Dronning Maud Land and one near Molodezhnaya station just outside Dronning Maud Land. These runways were used during the period 1981-1991. The runway at Novolazarevskaya is now under re-establishment, to be used in connection with transport of personnel and cargo for national operators in the area[1]. Since the 1996-97 season the private operator Polar Logistics has also intermittently used a blue ice runway by Henriksenskjera at 71º31'S, 08º48'E (called Blue 1) to transport private expeditions as well as national operator personnel to Dronning Maud Land.

There is currently a general increase in use of aircraft for transport of personnel and cargo amongst the national operators in Dronning Maud Land. For all operators the reason is likely to be concurrent with the Norwegian arguments for increasing air transport (Njåstad 2000):

1) Efficient transport to/from the continent; personnel does not have to spend non-efficient time at sea.
2) Efficient transport within the continent – less time and resources spent on ground transport of personnel to/from place of arrival/departure
3) Flexibility as to when to get personnel to the continent; can better accommodate needs of research project
4) Efficient time on the continent; personnel does not have to spend unreasonably more time than necessary on the continent.

The desire to increase the use of air transport is thus rooted in the ever-increasing demand for efficiency. Researchers prefer to spend only such time and resources in the field as are required for the research itself. Transport time and waiting time, which both are common in Antarctic operations and which often becomes the main component of an expedition, are not desirable with respect to efficiency. All actions that are initiated with the aim to reduce non-efficient aspects of the expeditions are considered to be of overall gain to the operations.

The various national operators in Dronning Maud Land have therefore initiated a cooperative effort with respect to air services in the region, the so-called DROMLAN-project. The main

[1] For further information refer to the IEE prepared for the ice runway at Novolazarevskaya Station (Russia 2001).

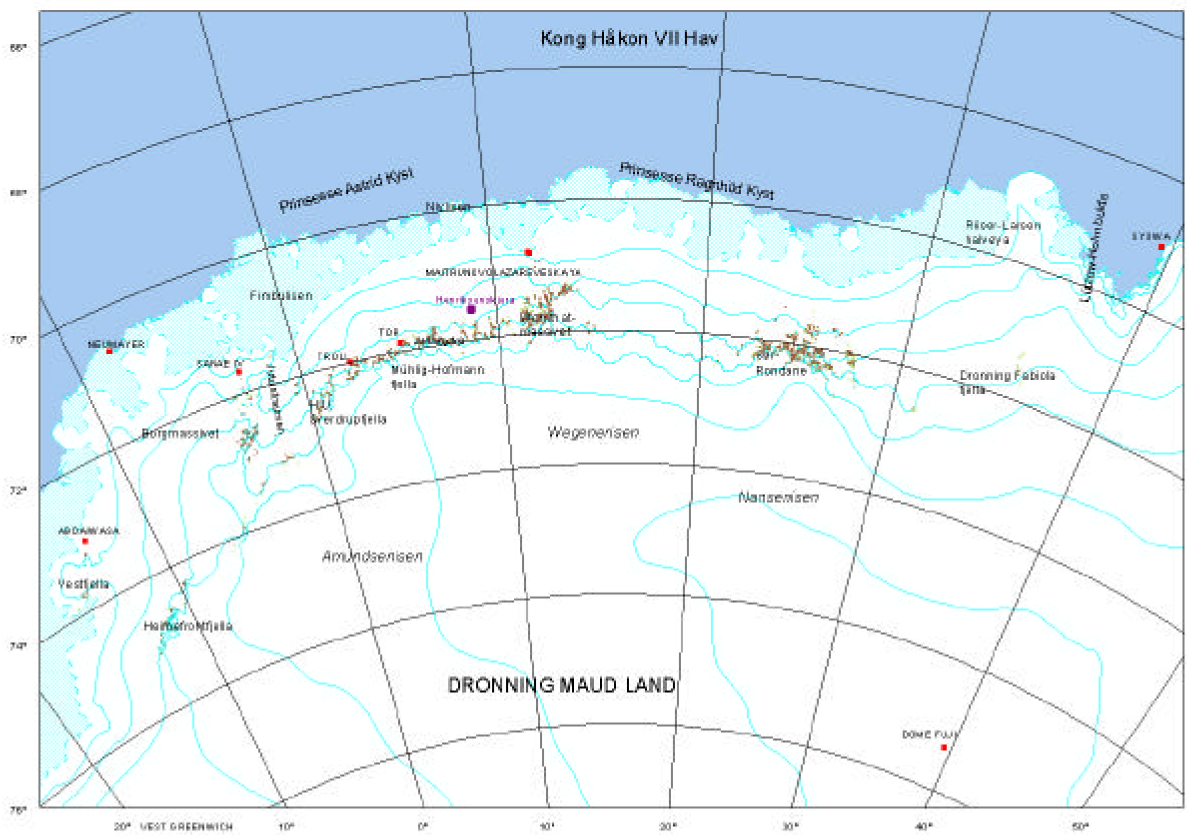
purpose of this project is to coordinate and promote better air services for the national operators in the Dronning Maud Land region.

As part of the DROMLAN package the Norwegian Polar Institute proposes to establish and operate a blue ice runway (Troll Runway) in the vicinity of the Norwegian research station Troll (72º00'S, 2º32'E), in the Jutulsessen Mountains, Dronning Maud Land.

2.2 Purpose and need

The two runways (Henriksenskjera and Novolazarevskaya) which up to now have been used as landing site for trans-continental aircraft in Dronning Maud Land are relatively far away from the working areas for most of the westerly located stations in DML (see Figure 1). During an international inspection/survey conducted in the 2000-2001 season it was observed that "a second ice runway for large aircraft in this part of DML would be of great advantage for several reasons. Most of the permanent occupied stations and summer bases of countries involved are located in the westerly part of DML." It was furthermore noted that "the availability of an alternative air runway for intended landings at Blue 1 is another important point of consideration, e.g. for safety of flight operations in this area. (…) Thus flights can be planned much more precisely when an alternate air runway will be maintained in the area of destination" (Haugland 2001).

Figure 1: Dronning Maud Land



The purpose of establishing and operating a runway near the Troll station is consequently to provide better and safer transport service for national operators in Dronning Maud Land, especially those who have research operations in the western part of DML. Currently a number of national operators have interest in the establishment of a runway in western Dronning Maud Land, e.g. Germany, South Africa, Sweden, Finland, United Kingdom and Norway. Furthermore, national operators operating in the eastern part of Dronning Maud Land (e.g. Russia and Japan) have a strong interest in the establishment of the runway due to the increased safety that will be ensured by having two operative runways in the region.

3 Description of activity (including alternatives)

Below a description of the plans related to the establishment and operation of a runway for heavy wheeled aircraft at a selected location near the Jutulsessen Mountains and the Norwegian research station Troll is provided. Alternatives that have been considered are discussed where appropriate.

3.1 Location and layout of runway

3.1.1 Location

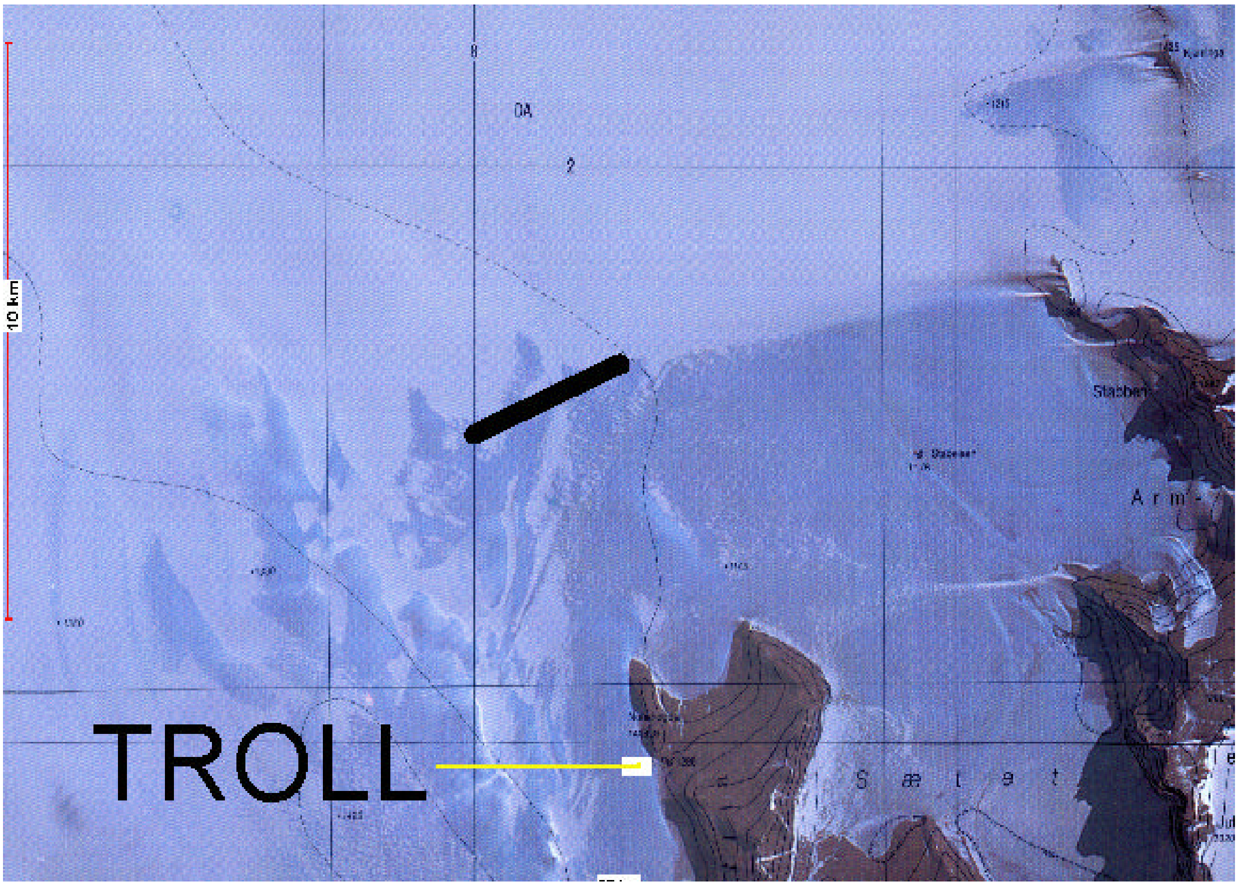
A vast blue ice field near the Troll station at the northern end of the Jutulsessen Mountains has been surveyed and found suitable (with respect to operations and safety) as a landing site for heavy wheeled aircraft (Haugland and Klokov 2002). The site spans a 500 m corridor from 71º57’37”S, 225’37”E in the western end to 71º57’03”S, 2º30’29”E in the eastern end. The location is shown in Figure 2. The closest ice-free areas (the Grjotlia area of the Jutulsessen Mountains) are located approximately 6 km from the planned runway.

The selected site has been pinpointed as an optimal location due to a number of factors:

- The size of the blue ice area is suitable for the purpose, ie. safe aircraft landings and takeoffs.
- The prevailing winds (east to west) is likely to ensure that the selected area will be snow free most of the year, a factor of importance for maintenance considerations.
- There are no biotic occurrences of significance in the immediate vicinity of the site or the potential flight path, which indicated that it could be possible to construct and operate a runway at this location with minimal consequences to the surrounding environment.
- There is free sight in both directions from the runway, an important factor with respect to safety of operations.
- The surface of the blue ice area is relatively smooth, making it suitable for landing and takeoff of wheeled aircraft.
- The altitude of the location is such that it is expected that minimal melting will occur, and thus will render the runway suitable for operations during a relatively large part of the operating season.
- The distance to Troll is short enough that the station is easily accessible (and thus minimizing the need for facilities at the runway site), but at the same time long enough to ensure that flight operations will not negatively impact the station operations.

A number of in-situ measurements are still required to find the maximum optimal placement where the properties of the blue ice are most suitable for the planned activity, ie. with respect to ablation rate, firn layers, lateral movement, etc.

Figure 2: Location of planned runway



Source: NPI (1992)

Alternatives: An extensive aerial survey of suitable areas for a runway was conducted during an international evaluation flight in January 2001. No alternative locations that satisfied operational and safety concerns were identified during this survey.

In assessing the impacts of establishing a runway at the selected site it is assumed that if the environmental impacts of the activity conducted at the given site proves to be no more than minor or transitory, then it would in effect not make a significant difference whether an alternative site is chosen or not. If, however, the assessment indicates that larger impacts may be expected, then consideration should be given to continue to assess alternative sites.

The only true alternative to establishing the Troll Runway is to continue to use Novolazarevskaya and/or Henriksenskjera as the main landing sites in DML and not establish an additional runway in western DML (**0-alternative**). This alternative will still entail the need to maintain and operate a small runway for feeder link operations (from Novolazarevskaya or Henriksenskjera) in the vicinity of Troll to support the NARE operations. A small runway on the blue ice just off the Troll station site has formerly been established for this purpose (Figure 3). With the establishment of the new Troll Runway the use of this runway will cease. It is noted that this small runway is located much closer to the nunataks and associated seabird colonies. The layout of this runway is such that it is normally required that the approaching and departing aircraft must fly over or close to the nunatak area and seabird colonies nearby the Troll station.

Figure 3: Present small-scale runway at Troll

Photo: Bertran Kiil (NPI)

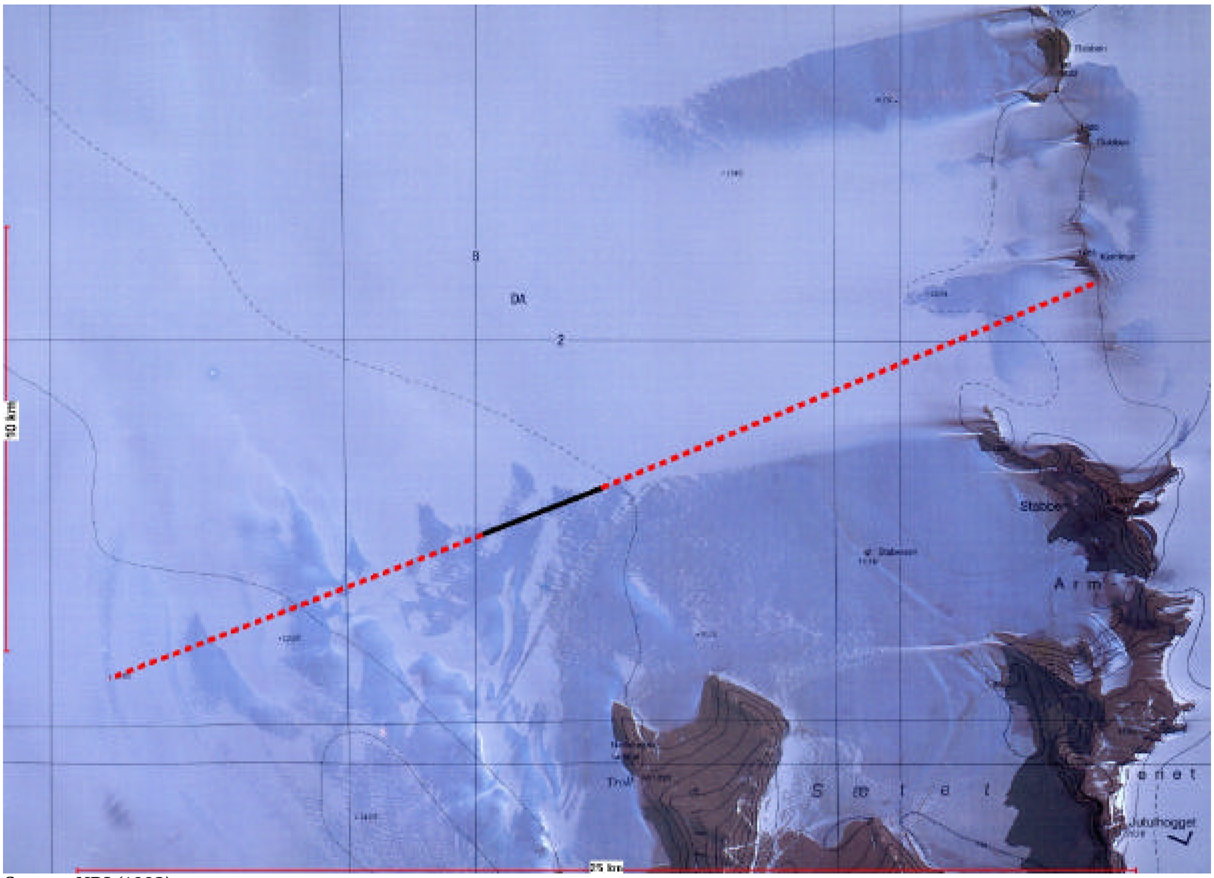
3.1.2 Layout

A 3 km long runway will be prepared. The direction of the runway will be in the prevailing wind-direction, east to west with true bearings of 067°/247° (east-west). The runway slope is 1.06%. Approach and departure sectors are almost free from obstructions, except that the terrain/ice rise to the west with approximately 1.5% within 9 km from the threshold, and 1.7% to the east within 12.5 km from the threshold (Kjerringa). Figure 4 shows the configuration of the planned runway, and its location relative to the nearby nunataks of the Jutulsessen Mountains.

Alternatives: Layout (direction, etc.) has been chosen on basis of safety standards and physical constraints. No alternatives exist at the site. The chosen direction is also one that ensures that landings and takeoffs are as removed from the nunatak area as possible and that the flight paths will avoid the mountains. This reduces the potential impacts on biota in the Jutulsessen area. However, note that some adjustments with respect to the exact location of the runway may be necessary based on measurements of the properties of the blue ice in the selected area. A glaciological program will be carried out in the 2002-03 season to ensure optimal placing of the runway.

It is planned that the entire length of the runway will be marked with black aluminium marker-boards, approximately 0.6*1.0 m^2 (0.6 cm thick). In addition to the runway itself, wing-bars of 150 meters length will be made on both sides of each threshold (see Figure 5), as well as shorter wing-bars at 300 and 600 m from threshold. The marker boards will be mounted on aluminium poles that will be drilled approximately 75 cm into the ice. Approximately 100 marker-boards will be needed to mark the runway. The marker-boards will remain in-situ between seasons, but will be removed when operations at the runway cease (or at an earlier stage should there be reasons for this).

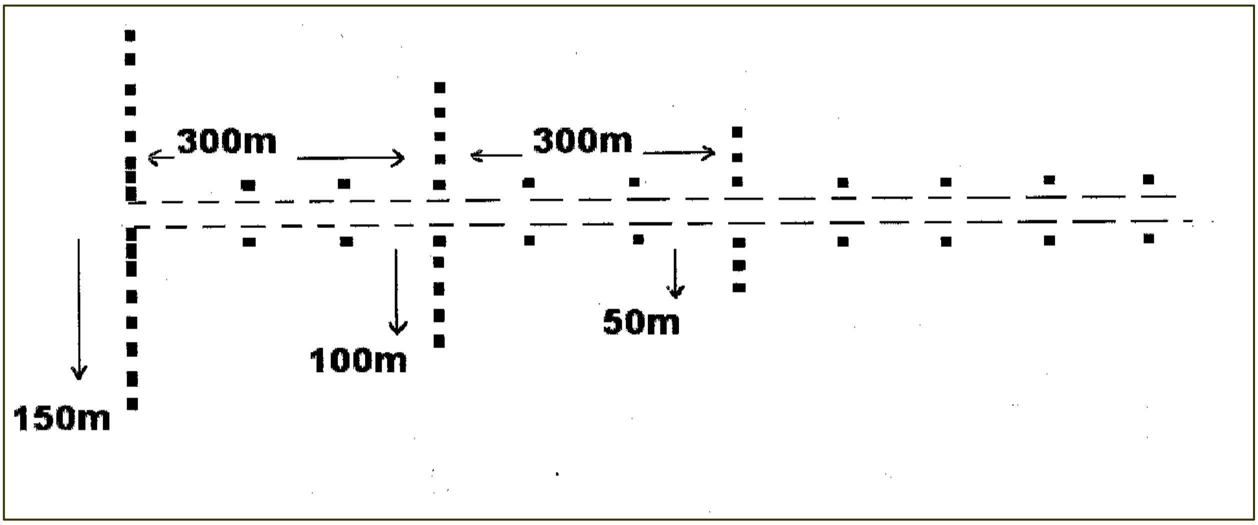
Figure 4: Layout of planned runway



Source: NPI (1992)

Alternatives: The marking system has proven useful at other sites in Antarctica (e.g. Novolazarevskaya). Due to the marking system's non-obtrusive and non-toxic nature the NPI has not seen the need to consider alternative markings. Consideration has been given to removing the markers at the end of each season. There is no (or little) environmental gain in removing the markers, with the possible exception that a few markers could break away and be lost as waste (due to severe winds). The amount of work and resources required versus the potential environmental gain is considered to be such that removal of the markers is not considered essential.

Figure 5: Runway marking at Troll Runway



3.2 Preparation and maintenance of the Runway

3.2.1 Grooming

Regular grooming of the runway surface by a scarifying heavy snow and ice grinder/blower is the only required treatment in period when the site is not affected by melting. Snow patches and ice bumps will be scraped away from the runway site, and the ice and snow will be deposited on the leeside of the runway.

Frozen melt cavities (see description in Section 4.1) found throughout the area could be an obstacle to safe landing/take-off. Experiments will be conducted during the preparatory seasons in order to clean and even out the cavities. Initially hot water steamers and vacuum cleaners will be utilized in this context. Should these non-obtrusive methods prove to be non-efficient and other methods be required, then a separate evaluation will be conducted if the methods considered may have more than minor or transitory environmental impacts.

During the first season it is estimated that approximately 1000 h work is needed to prepare the runway. After this initial preparatory work it is estimated that approximately 100 h of snow removal work is sufficient during a season, although it is recognized that experience may prove otherwise. At regular intervals a more labour intensive grooming may be necessary. It is expected that preparation of the runway will require 4-6 persons in the most intensive phases.

Alternatives: Snow and ice removal has been considered the only alternative if a runway is to be prepared at the site due to safety reasons. The use of snow/ice blower ensures an even distribution of the removed masses, thereby likely avoiding build-up of masses that may affect snowdrift patterns.

3.2.2 Vehicles and equipment

For the preparation and maintenance work the operator will utilize a Prinoth T4S snowgroomer[2]. The vehicle will run on JET A-1. Additional equipment used will be a MERI crusher (MJ-2.5)[3] and a regular snow blade. Additional equipment may be found necessary as one gains experience with operations and maintenance at the site.

The Prinoth T4S consumes on average 17 l/h. Table 1 gives an overview of expected fuel consumption during preparatory, high-peak[4] and normal operating seasons. It is assumed that the vehicle conforms to Euro 2 regulations with respect to exhaust emission levels. The permissible exhaust emission levels for heavy motor vehicles conforming to Euro 2 regulations are shown in Table 2 along with theoretical calculations for emissions related to runway grooming operations.

Table 1: Fuel consumption associated with preparatory work and grooming at Troll Runway

Season	Hours work	Fuel consumption (Jet-A1)

[2] For details see http://www.prinoth.it/eng/t4s/index.html
[3] For further specifications see http://www.hud-son.com/crusher.htm
[4] High-peak seasons indicate seasons when extensive maintenance of the runway might be necessary. It is expected that such maintenance will only be necessary every 5 years or so.

Preparatory season	1000 h	17.000 litres (13600 kg)
Normal season	100 h	1.700 litres (1360 kg)
High-peak season	1000 h	17.000 litres (13600 kg)

Table 2: Calculated exhaust emission levels associated with preparatory work and grooming at Troll Runway

	Methane	NM-VOC	CO	NO_x	N_2O	NH_3	PM_{10}	$PM_{2,5}$	PAH	CO_2
Euro 2[5]	0.29 g/kg	6.9 g/kg	12.6 g/kg	48 g/kg	0.02 g/kg	0.003 g/kg	1.0 g/kg	1.0 g/kg	0.3 mg/kg	3.17 kg/kg
Preparatory season	3944 g	93.84 kg	171.36 kg	652.8 kg	272 g	40.8g	13.6 kg	13.6 kg	4080 mg	43.112 tonnes
Normal season	394.4 g	9384 g	17.136 kg	65.28 kg	27.2 g	4.08 g	1360 g	1360 g	408 mg	43.11.2 tonnes

Alternatives: If a runway is to be established some level of preparatory work will be necessary. Some machinery and equipment will be required. Potential alternatives to the Prinoth T4S snowgroomer have been considered, e.g. bulldozer, tractor, etc. However, although these do not necessarily induce higher fuel consumption (and thereby emission), they would require more resource intensive transport into the area (including higher level of fuel consumption during transport) and have therefore been disregarded.

3.3 Operation of the Runway

3.3.1 Fuel

The plan is to establish Troll Runway as one point in a triangular flight pattern between Cape Town, Novolazarevskaya and Troll. In this system all fuelling of the heavy wheeled aircraft will occur at Novolazarevskaya and only feeder link operations will need fuelling at Troll Runway. Consequently, only a limited amount of fuel will be necessary at the site. It is estimated that approximately 25 drums will be stored at site throughout the operating season, while any additional fuel will be transported from Troll at need. No fuel will be stored at the site between seasons. Bringing excess fuel back to Troll will alleviate the risk associated with fuel drums melting into and subsequently freezing into the ice surface, and thereby risking cracks and spills.

Alternatives: Instead of storing fuel at the site it could be possible to transport fuel from/to Troll in connection with each flight through the Troll Runway. However, the highest risk with regard to fuel handling is likely associated with the transport phase. Therefore, the higher the number of times fuel is transported to/from the site, the higher the risk for fuel spills will be. The alternative is therefore not considered the most viable one.

3.3.2 Aircraft

A variation of aircraft types can be expected at the Troll Runway. No specific decisions or contracts on the flying operations themselves have been established at this time. It is important to note that the runway is established to accommodate aircraft operated by all

[5] Vehicle above 7.5 tonnes, speed lower than 30 km/h. Source: SFT (1999)

national programs active in DML, and that choices these programs make with respect to aircraft types may vary significantly. The assumption must therefore be that a number of different types of aircraft will utilize the Troll Runway. Table 3 gives an overview of potential aircraft types and Table 4 some values for average emission levels for different types of aircraft.

Table 3: Potential aircraft types at Troll Runway

Type	Operation type	Fuelling at TR
Ilyushin 76	Intercontinental	No
Hercules C-130	Intercontinental	No
Boeing 737-747	Intercontinental	No
Falcon 7 Ex	Intercontinental	No
Twin Otter	Intracontinental	Yes
Basler 67 (DC-3)	Intracontinental	Yes
Helicopters (various types)	Intracontinental	Yes

Table 4: Some emission values for selected aircraft

Aircraft/Product	NO_x	HC	CO	CO_2
Hercules C-130	7.7 kg/LTO*	3.9 kg/LTO	6.0 kg/LTO	3.15 tonnes/tonnes fuel
Boeing 737-600-800	4.95 kg/LTO	0.67 kg/LTO	11.83 kg/LTO	3.15 tonnes/tonnes fuel
Twin Otter	0.5 kg/LTO	0.22 kg/LTO	0.43 kg/LTO	3.15 tonnes/tonnes fuel
Helicopters	6.67 kg/tonne fuel	32 kg/tonne fuel	36.6 kg/tonne fuel	3.15 tonnes/tonnes fuel

* LTO: Landing and TakeOff cycle

Source: SSB (1997) and SSB (2002)

3.3.3 Season

The Troll Runway will only be operated in the austral summer season, i.e. mid-November to mid-February. Possibly ice melting will prevent its use for about 3-4 weeks in mid-summer (mid-December/mid-January).

3.3.4 Intensity

It is at this stage difficult to be certain about the number of flights that will land and take off from Troll Runway during a normal operating season. An estimate of the potential operational intensity is given in Table 5. These should, however, only be taken as indications, as it would be somewhat speculative to provide solid numbers at this time. The number of flights may increase with time as experience with operations advance.

Table 5: Estimated use of Troll Runway during a normal operating season

Type	Number of flights
Intercontinental landings	Min. 3
Intracontinental landings (feeder link operations)	Min. 9

It is expected that two to four persons will be needed at the site during landing and take-off operations. Due to the limited number of landings and take-offs runway personnel will be stationed at Troll, using snow machines and bandwagons for transport to and from the runway.

3.4 Runway facilities

Due to the close proximity of Troll station only a minimal number of ground facilities will be required at the Troll Runway. Services that are considered necessary to operate the runway include weather and communication services, as well as medical services for emergency situations. These services will mainly be provided out of Troll station.

A container unit (standard 20' container) for communication equipment and services will be set up at the site on an elevated platform with steel supports. A 5 kW generator will be installed to support the activities in the communication unit. The container will remain in-situ and will not be removed before operations at the Troll Runway are discontinued. The steel supports may be left in the ice when the unit is removed from the site.

A second container (standard 20' container) for storage of rescue and fire-fighting equipment, as well as contingency equipment, will also be set up at the site in the same manner as the communication unit. Rescue and fire-fighting equipment will be held adjacent to the landing site during flight operations and stored in the container between flights and off-season. The fire-fighting equipment will consist of a number of AB fire extinguishers (50 kg containers and 250 kg containers). In addition a number of oil spill kits will be made available for operations.

Two Automatic Weather Stations (AWS) will be installed at the site, and will remain in operation throughout the year. The AWS is pertinent in the context of weather forecasting for the flight operations to take place at Troll Runway.

A collapsible tent will be erected on the site during operating season. The tent will be used to shelter personnel who are waiting for flights (either intercontinental or intracontinental). Simple cooking and heating facilities will be installed. Such facilities will most likely be gas based.

The grooming machinery will be stored at Troll between operating seasons.

Alternatives: If a runway is to be established it will be necessary to maintain some level of ground facilities to support the operations of the runway. This is in order to maintain safety for flight crew and passengers, as well as ground crew. Not having any facilities at the site is therefore not considered an option. However, as an alternative to establishing permanent facilities at the site consideration has been given to arrange for such storage at the Troll station. This would entail that the container units used for communication and storage of equipment could be located on sleds that could be removed from the area (to Troll station) at the end of the season (**facilities-alternative**). At Troll the sleds would have to be stored on the ice (access to suitable ice-free areas is limited) and a possible difficulty associated with this alternative is that the sleds/containers could melt and subsequently freeze into the ice. Extensive resources could be needed to work loose the sleds/containers. Leaving the facilities at the site will increase build-up of snow around the facilities and will entail that some components (the steel supports) remain in the environment after the runway no longer is in use.

3.5 Associated Activities

With the establishment and operation of a runway near Troll station a number of associated activities may be expected. These are explored in brief in the below.

3.5.1 Transport to/from Troll

Associated with the activity at Troll Runway will be an increased traffic between the Troll station and the runway site. This transport will mainly be by snow machine and bandwagons. The traffic will be most intense in the preparatory season in which several trips per day can be expected. In a normal operating season an increase in traffic will be associated with arrival and departure of aircraft. In some instances the weather situation (or other circumstances) may require longer layovers for the incoming/outgoing passengers. In such circumstances it may become necessary to utilize Troll as a layover facility, which also would entail an increase in the traffic between the runway and the station for transport of passengers.

3.5.2 Transport to/from SANAE IV

One option for runway operations is that pre-season preparations and runway operations may be conducted with assistance of the over wintering team at SANAE IV. This would ensure a head start of the season at the runway. SANAE IV may become a transportation hub in the western Dronning Maud Land air operation system. With such an arrangement ground transport between SANAE IV and Troll is likely to increase. A safe route between the two stations will be surveyed. The entire route will be on snow or ice-covered ground.

3.5.3 Consequences for Troll station

The location of the runway will clearly have consequences for the operations at Troll. Due to its proximity to the landing site it will have to serve as a layover base for crew and passengers when the situation requires it (delays due to weather conditions, mechanical failures, emergencies, etc.). Troll is currently equipped to house approximately 12 persons and can accommodate many more in tents. This is likely not sufficient in the case of a larger influx of people from the Troll Runway. Considerations will therefore have to be done with respect to how to prepare Troll as an emergency base, including equipping the station with one or more portable and/or collapsible housing systems. Any permanent installations will be considered in a separate environmental impact evaluation.

3.5.4 Non-governmental activity

By opening a runway in the western part of Dronning Maud Land there is a potential of opening the area to non-governmental visitors and a higher level of private expeditions. This will raise issues that need to be considered closer, as this is an area that has been largely inaccessible to tourists earlier. These considerations will have to be done separately from the evaluation presented in this document.

3.5.5 Consequences for overall activity in the area

The Jutulsessen area is a relatively pristine and untouched area, with the exception of the impact created by the Norwegian station facilities at Troll. Although some research has taken place in the local area, most activities that use Troll as logistical hub has in fact been conducted in more remote areas. The Jutulsessen area has consequently mostly been visited only for recreational purposes by the core personnel at Troll station.

The increase in air traffic, the related influx of national program personnel and the potential increase in non-governmental activities will have bearings on the level of activity in the area of the planned activity. It must be expected that the Jutulsessen area will experience a much higher intensity with respect to use of the area, be it recreational activities, expansion of existing facilities, establishment of new facilities, etc. This situation has as far as possible been taken into account in the following impact assessment under the consideration of cumulative impacts.

3.6 Timeframe

The following timeframe is planned for the establishment and operation of the Troll Runway:

2002-2003 season: Preparations (grooming, etc.)
2003-2004 season: Further preparations and test flight
2004-2005 season: Normal operations with pre-season preparations and regular intercontinental and intracontinental flight.
Onward: As for the 2004-2005 season.

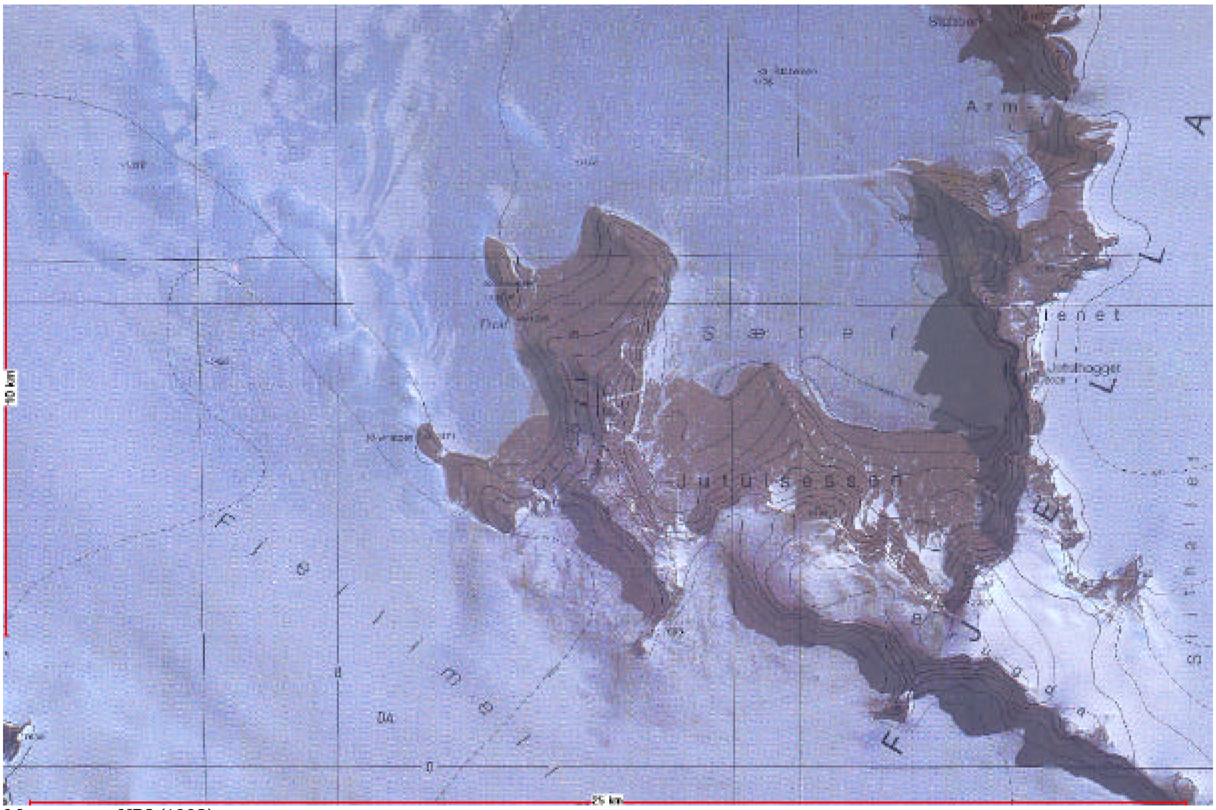
4 Description of the environment

4.1 The environment at the site

4.1.1 Physical environment

The preferred location for the runway is in the vast field of exposed bare glacial ice situated at the northern end of the Jutulsessen Mountains, about 200 km from the ice shelf. This is a relatively flat ice terrain that occupies more than 150 km^2 with an average altitude of 1250 meters above sea level (see Figure 6). It exists due to natural rock barriers that forms a deep bay opened to the north. The glacial ice flows to the bay from the northwest and ablates in Jutulsessen. The mass loss in the blue ice field is caused by evaporation and sublimation. A transition line ice-to-snow lies in a distance of 5 km to 10 km to the north and north-west of the Jutulsessen Mountains.

Figure 6: The Jutulsessen Mountains and surrounding blue ice fields



Map source: NPI (1992)

Frozen melt cavities are obvious evidence of melting occurring on the site. With air temperature in the area presumably below zero throughout the summer, ice does not melt at the surface. However, solar radiation in the peak of the summer provides enough energy to produce a subsurface melting. Melt takes place within the ice due to the absorption and trapping of solar energy in the blue ice, enhanced by the mineral particles blown down from the mountain surrounding the blue ice. These frozen melt cavities have round form and vertical walls (10-70 cm in cross-section and from 10-30 cm in depth).

The physical environment cannot be considered unique, although it should be noted that only approximately 1 % of the Antarctic surface is covered by blue ice as is this area (Bintanja, R, 1999, Winther et al., 2001).

4.1.2 Biota

No biological studies have been conducted at the site itself. However, biota is not commonly observed in association with the blue ice areas, and it is assumed that the biota of the ice environment of the site is relatively limited.

4.2 The environment of the nearby areas

4.2.1 Physical environment

The mountain area Jutulsessen is located nearby the selected runway site, the closest ice-free area being approximately 6 kilometers from the site.

4.2.2 Geology

The Jutulsessen area forms part of the Jutulsessen granitic gneiss regime and the Risemedet migmatite regime. Many gneiss lithologies in the eastern and southern ridges are transitional. Two younger intrusive bodies, the Stabben monozinite and the Stabben gabbro, cut the migmatites in the north-eastern continuation of the mountain area. A more in depth description of the geology of the area is found in Dallmann et al. (1990).

4.2.3 Meteorology

Meteorological data from the Jutulsessen area are sparse. An Automatic Weather Station (AWS) has been operated intermittently at the Troll station since 1990. Some basic data collected in 1993 is presented in Table 6 to give an indication of climate characteristics.

Table 6: Climate data from Troll (1993)

	Jan.	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Annual**
Monthly temp. (ºC)	-4.2	-9.8	-16.7	-20.9	-21.7	-21.9	-27.4	-24.8	-23.2	-15.0	-8.3	-4.6	-16.6
Air pressure (mb)	846.9	835.8	835.2	835.7	832.7	832.5	834.3	834.5	834.2	834.3	844.8	843.5	837.0

Source: Hanssen-Bauer (1995)

Being so far inland, the area is only slightly affected by the cyclones that buffet the coast. The climate is therefore little influenced by heat advected from the ocean.

4.2.4 Biota

Due to high intensity of solar radiation in summer, and low albedo, the surface temperature of the nunataks may be considerably higher than the air temperature, especially where protected from the wind. Such areas have sufficiently benign microclimate to support vegetation and associated microfauna.

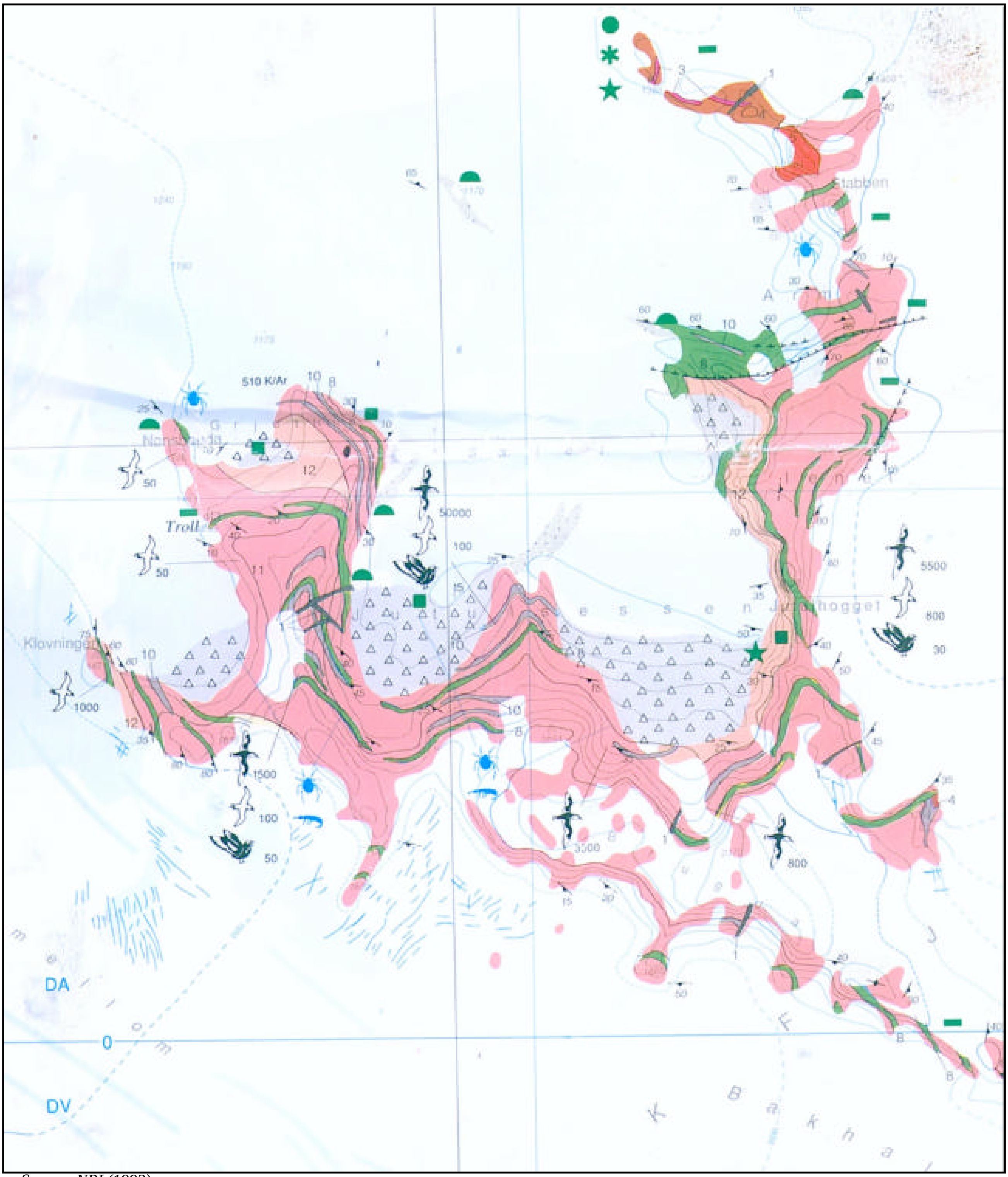
Biological studies conducted in the Jutulsessen area are limited in numbers and scope, and have mostly been conducted in the vicinity of the Troll station (see Table 7). The terrestrial vegetation is very restricted in species diversity and abundance compared to other areas. No rare species have been observed. Invertebrate fauna is found in association with the vegetated areas.

Table 7: Flora and Fauna registered in the Jutulsessen area

Flora	
Lichens	*Acarospora buellia* *Candelariella hallettensis* *Lecanora expectans*
Green algae	*Prasiola crispa* *"Pleurococcus"* *Ulothrix*
Blue-green algaea	*Cyanobacteria*
4.2.4.1.1 Fauna	
Protozas	
Rotifers	
Nematods	
Tardigrads	
Mites	*Eupodes angardi* *Tydeus erebus* *Maudheimia wilsoni*
Insect	*Cryptopygus sverdrupi*
Seabirds	Snow petrel (*Pagodroma nivea*) Antarctic petrel (*Thalassoica antarctica*) South polar skua (*Catharacta maccormicki*)

The vertebrate fauna consiste of birds only: snow petrel (*Pagodroma nivea*), Antarctic petrel (*Thalassoica Antarctica*) and south polar skua (*Catharacta maccormicki*). The main locations of seabird colonies in Jutulsessen are indicated in Figure 7. Breeding south polar skuas are registered in Jutulsessen, and non-breeding young skuas are observed in the vicinity of the petrel colonies.

Figure 7: Known seabird colonies in the Jutulsessen area



Source: NPI (1993)

4.2.5 Human environment

The human activity in the Jutulsessen area is quite limited. With the exception of the activities associated with the Norwegian research station Troll (72º00'S, 2º32'E), there is no other current or planned activity in the area.

Troll presently consists of one main building, one station unit (combined garage and living quarters) and two combined generator and shop buildings, as well as a glass fibre igloo. The main building houses up to 10 people, while additional personnel stay in the glass fibre igloo, station unit or in tents. Troll is shown in Figure 8. The station is powered by two small generators (15 and 46,4 kW). There are no structural instalments for helicopter landing, fuel storage or waste storage.

The Troll station is normally occupied every summer season (early December to mid February), although the size of the group staying there varies widely. The activity at Troll is part of the Norwegian Antarctic Research Expeditions. Although Troll is the hub of the Norwegian Antarctic activities, the station is mostly a logistical hub, while the research activity in itself normally takes place in areas outside the Jutulsessen mountains.

Figure 8: The station Troll

Photo: Jan-Gunnar Winther (NPI)

5 Impact assessment

5.1 Introduction

In the below is documented the considerations that have been done in assessing the impacts of the planned activities associated with the establishment of the Troll Runway.

The process used in assessing the activity has to a large degree followed the steps stipulated in "Guidelines for Environmental Impact Assessment in Antarctica" (CEP 1999). A summary of each step of the process is given below.

5.2 Definition of terms

Cumulative impact:	the combined impact of past, present, and reasonably foreseeable activities. These activities may occur over time and space and can be additive or interactive/synergistics.
Direct impact:	a change in the environmental components that result from direct cause-effect consequences of interacation between the exposed environment and outputs.
Exposure:	the process of interaction between an identified potential output and an environmental element or value.
Impact:	a change in the value or resources attributable to a human activity. It is the consequence of an agent of change, not the agent itself.
Indirect impact:	a change in environmental components that results form interactions between the environment and other impacts (direct or indirect).
Mitigation:	the use of practices, procedure or technology to minimize or prevent impacts associated with proposed activities.
Output:	a physical change or an entity imposed on or released to the environment as the result of an action or activity.
Unavoidable impact:	an impact for which no further mitigation is possible.

5.3 Outputs

Before evaluating the impacts of the planned runway a number of activity outputs that were considered to have potential for environmental impact were identified. A summary of the activities and their outputs is presented in Appendix 1. Identified outputs include emission (to air and ground), wastes, noise, mechanical actions and obstructions.

5.4 Considering the environment

In order to assess the impacts of the planned runway the sensitivities and values of the surrounding environment have to be evaluated so that the identified outputs can be considered against the environment they take place in. A summary of this evaluation is presented in Appendix 2. No environmental elements of high or medium high value were identified. A number of elements of low value were however noted, such as flora, fauna, atmosphere, ice, geology, wilderness and aesthetic values.

5.5 Identification of exposures

It is essential to focus the environmental impact assessment on those impacts that in fact are likely to take place. To assist it is useful to consider the interaction between outputs of the activity and the environment present at the site. A summary of the exposure evaluation is presented in Appendix 3. It is important to note that the exposure level is relatively low for all outputs identified in relation to the planned activity, and only wilderness and aesthetic values seem to be affected by high exposure.

5.6 Identification and evaluation of impacts and proposed mitigative measures

The impact of the exposure of environmental elements to identified outputs have been considered and summarized in Table 8 below. These are impacts that can be expected assuming that the activity is conducted in accordance with the framework defined in this document. The issue of unforeseen events, such as a major air crash is considered in Section 5.6.4.

5.6.1 Impacts on Environmental Elements of High Value

No environmental elements of high value have been identified (cf. Appendix 2).

5.6.2 Impacts on Environmental Elements of Medium Value

No environmental elements of medium value have been identified (cf. Appendix 2)

5.6.3 Impacts on Environmental Elements of Low Value

A number of environmental elements of low value have been identified (cf. Appendix 2). In Table 8 these have been listed in accordance with the level of exposure to outputs (cf. Appendix 3). The following terms have been defined in assessing the impact:

	Low	**Medium**	**High**
Extent	Local, confined area	A certain part of Jutulsessen is affected, somewhat more extensive than the local, confined area	The entire area (Jutulsessen) is affected
Duration	Weeks to one season. Short in relation to natural processes	Several seasons, a number of years; impacts are reversible	Decades; impacts are reversible
Intensity	Natural functions and processes are not affected	Natural functions or processes are influenced for a short period, but are not changed over a long period or permanently	Natural functions or processes are influenced or changed over the long term
Probability	Unlikely	Likely	Certain

Any impact assessed to have a medium or high intensity is important to assess further as these are the impacts that in fact affect the natural processes in the area. Any impact assessed to have a low intensity is likely to have no more than a minor or transitory impact regardless of extent, duration and probability.

Table 8: Impact identification and evaluation

	Output	Description of potential impact	Evaluation of impact	Mitigation	Alternatives
High Exposure	**Ice**				
	Mechanical actions	Physical environment (surface) will be changed due to grooming. No indirect impacts are envisioned. After a period of no action the area is expected return to natural state.	Extent: L Duration: M Intensity: L Probability: H	No mitigative measures identified.	All alternatives will entail some surface grooming and thereby the associated impacts.
	Wilderness				
	Mechanical actions and Obstructions	Wilderness is no longer considered wilderness when human induced changes are introduced in the natural environment (see e.g. Overrein (2001)). Often a larger zone (e.g. 5 km) surrounding an impacted area is no longer defined wilderness. After a period of no action at the Troll Runway the area is expected to return to natural state.	Extent: M Duration: M Intensity: L Probability: H	No mitigative measures identified.	All alternatives will entail some surface grooming and thereby the associated impacts on wilderness. No facilities would be necessary in the 0-alternative and no new areas impacted. The probability of associated impacts on wilderness would therefore be lower.
	Aesthetic				
	Mechanical actions and Obstructions	Changes to physical environment by including human elements into natural landscape may change the emotional experience for visitors. Visitors in the area are normally associated with research expeditions and will normally expect presence of human elements in landscape.	Extent: L Duration: M Intensity: L Probability: L	No mitigative measures identified.	All alternatives will entail some surface grooming and thereby the associated impacts on aesthetics. No facilities would be necessary in the 0-alternative and no new areas impacted. The probability of associated impacts on aesthetics would therefore be lower.

Medium Exposure	**Atmosphere**				
	Emission to air	Gases released into the atmosphere can contribute to the greenhouse effect both directly and indirectly. However, in the overall emission picture (both in the Antarctic context and the global context) the contribution from the planned activity is expected to be miniscule. Air quality in general may be affected by releasing combustion compounds into the atmosphere. No atmospheric research in the area will be affected	Extent: H Duration: L Intensity: L Probability: H	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor. ??Use of “clean” fuels as far as possible	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Emission will be lower, and the associated impacts thereby also lower.
	Ice				
	Emission to air	Combustion products settling on snow/ice surfaces could potentially affect the albedo, which with time could lead to further alterations of the physical environment and ablation rates. Soot deposition has been shown to cause no measurable changes of snow albedo at the South Pole Station where there is higher and more constant emission (see e.g. Wolff (1992) and Suttie and Wolff (1993)). Ice quality in general may be affected by deposited combustion compounds. This could have bearings on ice related research (e.g. climate research). No ice related research is on-going or planned in the area.	Extent: L Duration: M Intensity: L Probability: H	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor. ??Use of “clean” fuels as far as possible	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Emission will be lower, and the associated impacts thereby also lower.
Low Exposure	**Flora**				
	Emission to air	Uptake of combustion products may in the long run inhibit growth and reproduction in plants. Sensitivity in plants may vary, and changes in species composition may occur. (see e.g. SFT (1992)). It is expected that the limited exposure to output will hinder any significant impact.	Extent: L Duration: H Intensity: L Probability: L	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor. ??Use of “clean” fuels as far as possible ??Flights over the Jutulsessen mountains to be avoided.	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Emission will be lower, but since vegetated areas are closer to area of operation exposure may be larger and the associated impacts could thereby also be higher.

	Fauna				
	Emission to air	Ingestion through food not likely due to marine diet. Inhalation low due to distance from source. Exposure could in the long run affect respiratory system and other vital functions (see e.g. Maniero (1996)). It is expected that the limited exposure to output will hinder any significant impact.	Extent: L Duration: M Intensity: L Probability: L	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor. ??Use of "clean" fuels as far as possible ??Flights over the Jutulsessen mountains to be avoided.	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Emission will be lower, but since the seabird colonies will be closer to area of operation exposure may be larger and the associated impacts could thereby also be higher.
	Noise	Noise may disturb birds in a manner so that they leave their nests (and expose eggs/chicks to environment and predators), raise stress level and increase metabolism, all which could affect the fine tuned balance of energy intake and energy use (see e.g. CAFF (1998) and Giese (1999)). It is expected that the limited exposure to output will be too low for any significant impact.	Extent: L Duration: L Intensity: L Probability: M	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor. ??Flights over the Jutulsessen mountains to be avoided. ??Consider limiting grooming activity when wind direction would carry noise toward colonies.	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Noise will be lower, but since the seabird colonies will be closer to area of operation exposure may be larger and the associated impacts could thereby also be higher.
Low Exposure	Obstruction	Birds killed in aircraft encounters is relatively high in the more populated parts of the world (see e.g. www.birdstrike.org). In the case of Troll Runway the number of such incidents is expected to be very low (if any) due to the low number of flights and the observed flight patterns for the birds. Only a few individuals would be affected, and no ripple effect would be expected.	Extent: L Duration: L Intensity: L Probability: L	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor. ??Flights over the Jutulsessen mountains to be avoided.	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. In 0-alternative the seabird colonies will be closer to area of operation exposure may be larger and the associated impacts could thereby also be higher.

Low Exposure	**Ice**				
	Emission to ground	Jet A-1 is relatively volatile and a large portion of a spill is likely to evaporate instead of migrating into ice. Contaminants that migrate into the ice will be encapsulated and remain in the ice for an indefinite period. Impacts at release time depend on point of release, but could affect biota or quality of receiving environment. Contributes to overall contamination of environment and may have bearings on future ice related research. No ice related research is ongoing or planned in the area.	Extent: L Duration: H Intensity: L Probability: M	??Adherence to guidelines for handling and storage of fuel (Nordic Environmental Handbook) ??Maintain strict policy of no fuelling of intra-continental flights.	All alternatives will entail fuelling. The associated impacts are expected for all alternatives. Less through traffic is expected in association with the 0-alternative (ie. intracontinental traffic). Less handling of fuel will be necessary, and the associated impacts will be lower as well.
	Waste	Contributes to overall contamination of environment. Some types of waste, if spread into the Jutulsessen area, could become “traps” for seabirds (straps, bands, sharp objects, etc.) and could cause death or injury to individual birds.	Extent: L Duration: L Intensity: L Probability: M	??Adhere to waste management guidelines (Nordic Environmental Handbook) ??Institute operational practices that ensures that minimal waste is left in environment (chicken runs etc.)	All alternatives will likely lead to some waste escaping in association with operation. Due to less activity less waste would also be expected in association with the 0-alternative.
	Wilderness				
	Emission to ground and waste	Spills and waste will give visible evidence of human presence. After a period of no action the area is expected to return to natural state.	Extent: L Duration: L Intensity: L Probability: M	??Adhere to guidelines for handling and storage of fuel (Nordic Environmental Handbook) ??Maintain strict policy of no fuelling of intra-continental flights. ??Adhere to waste management guidelines (Nordic Environmental Handbook) ??Institute operational practices that ensures that minimal waste is left in environment (chicken runs etc.).	All alternatives will entail fuelling and likely also potential for escape of waste. The associated impacts are expected for all alternatives. Less intracontinental traffic is expected in association with the 0-alternative (through traffic). Less activity will lead to less waste and fuel handling, and the associated impacts will be lower as well.

Low Exposure	Noise	Noise will give audible evidence of human presence. When activity ceases a natural state is achieved.	Extent: L Duration: L Intensity: L Probability: H	??Coordination of flights to ensure that as few as possible flights are conducted. Due to cost restrictions this will always be a planning factor.	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Noise will be lower, and the impacts also lower.
	Aesthetic				
	Emission to ground and waste	Fuel spill remains and waste introduce visible human elements into natural landscape may change the emotional experience for visitors. Visitors in the area are normally associated with research expeditions and will normally expect human elements in environment	Extent: L Duration: L Intensity: L Probability: L	No mitigative measures identified.	All alternatives will entail fuelling and likely also potential for escape of waste. The associated impacts are expected for all alternatives. Less intracontinental traffic is expected in association with the 0-alternative (through traffic). Less activity will lead to less waste and fuel handling, and the associated impacts will be lower as well
	Noise	Noise introduce audible human elements into natural landscape may change the emotional experience for visitors. Visitors in the area are normally associated with research expeditions and will normally expect human elements in environment	Extent: L Duration: L Intensity: L Probability: L	No mitigative measures identified.	All alternatives will entail use of machinery and flights. The associated impacts are expected for all alternatives. No large wheeled aircraft will land in the area in the 0-alternative. Noise will be lower, and the impacts also lower.

5.6.4 Consequences of emergencies

A major incident due to failure in take-off or landing of aircraft is not considered an incident which is to be associated with the planned activity. The operational framework should ensure that the risk of such an incident occurring is minimal. Failure in aircraft operation is a rare incident in Antarctica, but has nonetheless happened, e.g. the Air New Zealand crash into Mt. Erebus in 1979. The risk for an aircraft accident increases with the number of flight hours. Furthermore, accidents statistically occur more often in relation to takeoffs or landings than related to cruising. It should also be taken into account that flying conditions in Antarctica may be difficult, and may increase the risk of incidents.

Consequences of a major accident in the vicinity of the Troll Runway or on the way to/from the runway are difficult to assess, but the following should be considered:

- Although there will be contingency facilities and equipment available at the Troll Runway (and at Troll) and the runway will be staffed when aircraft are expected, it is not likely that the resources available at the site will be adequate to carry out any significant rescue and contingency activity should a major aircraft accident occur during takeoff or landing.
- Aircraft flying into and taking off from Troll Runway may potentially carry as much as 30.000 litres of fuel. In the event of a major accident a major fuel spill would occur. However, biological elements are not likely to be affected, only if incidents occur over open water on the coast. Some of the fuel spilled will likely evaporate. Depending on where the incident takes place (and the movement of the ice) the encapsulated fuel will be released into the sea in the far future or in the nunatak areas in the nearer future. In the case of the latter, contamination of a sensitive ice-free area could result. Some response action on the spill could be taken if incident occurs near the runway, although the station and the runway are not equipped with sufficient contingency equipment to deal with such major amounts of spillage.
- The wreck should be considered waste. A major clean-up operation (with associated consequences) would likely be necessary.

5.6.5 Summary

The analysis of impacts laid out in Table 8 indicate that no impacts associated with the establishment of the Troll Runway have a high or medium degree of intensity, and it is therefore concluded that no outputs are likely to have more than a minor or transitory impact on the environment.

Impacts associated with an emergency situation (aircraft accident) may have a higher degree of intensity than those impacts expected from normal operations.

5.7 Cumulative impacts

The activity level is limited in the area of Dronning Maud Land where the planned activity will take place. Only Norway has any activity in the area, an activity that is a small scale and low impact activity. Thus, the additional impact caused by the establishment of a runway in the area may be relatively large, but still be relatively non-obtrusive. The following may be noted in this respect:

- ?? The planned activity will lead to increased emission to air. The existing level of emission is low, and a limited additional emission is not expected to have significant cumulative consequences.
- ?? Contamination of the ground due to fuel spills may increase due to the planned activity. The existing level of contamination is low, and a limited level of additional contamination is not expected to have significant cumulative consequences.
- ?? Stress for the seabirds in the Jutulsessen area may increase due to the increased air operation in the area, but the analysis above has shown that impacts on fauna due to the establishment of the runway are expected to be quite limited, and also in fact may lead to less impact in the immediate vicinity of the seabird colonies. The cumulative stress caused by the addition of the planned activity is therefore expected to be low.
- ?? Wilderness and aesthetic values will be affected by the new elements introduced into the environment. However, since this is an area that is already affected by ongoing activity, the cumulative impact is expected to be quite limited.

The establishment of the Troll Runway in this area may make the area much more accessible and thereby increase associated activities both in the Norwegian program, other nearby programs and non-governmental activities. Such increase in activity would lead to a corresponding increased impact, and furthermore potentially lead to further consequences not possible to foresee at this time. Potentially the access to the Jutulsessen area as a staging area could lead to an increase in activities in surrounding areas, and thereby further decrease the areas of Dronning Maud Land that today are relatively untouched by human activities. Realistically it is however believed that even with improved access the activity level in Dronning Maud Land will remain relative restricted simply due to costs of operation in the area. It is, however, realized that it is extremely important to follow closely the development and take appropriate action should the situation require it.

5.8 Monitoring

No specific monitoring protocol for the runway site has yet been established. But at a minimum the following monitoring will be conducted (part of NARE Monitoring Program):

- ?? Record of flights
- ?? Record of fuel consumption associated with runway activities (flights and associated activities)
- ?? Record of fuel spills

Consideration will be given to the need to monitor the following:

- ?? Effects of landings/take-offs on nearby seabird colonies
- ?? Deposition of emission products in ground
- ?? Deposition of emission products in vegetated areas
- ?? Record of number of people flying through as well as number of people using Troll Runway as starting point for research or adventures.

5.9 Conclusions and recommendations

It is concluded that the expected environmental impacts of the establishment and operation of the Troll runway will be of no more than a minor or transitory character (cf. Section 5.6.5). The NPI therefore recommends that the proposed activity may proceed, under the condition that the activity is conducted in accordance with the given framework, that the mitigative measures prescribed in the IEE are adhered to, and that an appropriate monitoring protocol is prescribed.

APPENDICES

Appendix 1: Outputs

	OUTPUTS						
ACTIONS	**Emission to air**	**Emission to ground**	**Wastes**	**Noise**	**Mechanical Action**	**Heat**	**Obstruction**
Vehicles & Machineries operations	**X** Exhaust emission *All alternatives* *< 0-alternative*	**X** Exhaust emission Spills from fuelling *All alternatives* *< 0-alternative*	**None**	**X** Engine noise *All alternatives* *< 0-alternative*	**X** Grooming Tracks to station *All alternatives* *< 0-alternative*	**X** *All alternatives* *< 0-alternative*	**None**
Fuel Storage	**None**	**X** Small spills/leaks *All alternatives*	**X** Empty fuel drums *All alternatives*	**None**	**X** Snow drift storage *All alternatives*	**None**	**X** Storage *All alternatives*
Facilities & associated activities	**X** Exhaust emission *? 0-alternative*	**X** Exhaust emission *? 0-alternative*	**X** Operational waste *All alternatives* *< 0-alternative*	**X** Human noise Generator noise *All alternatives* *< 0-alternative*	**X** Snow drift facilities Melting by markers *? 0-alternative* *< Facility-alt.*	**X** Generator heat *? 0-alternative*	**X** Facilities Runway marking *? 0-alternative*
Aircraft operations	**X** Exhaust emission *All alternatives* *< 0-alternative*	**X** Exhaust emission Spills from fuelling *All alternatives* *< 0-alternative*	**X** Cargo material *All alternatives*	**X** Engine noise *All alternatives* *< 0-alternative*	**None**	**X** *All alternatives* *< 0-alternative*	**X** Flights *All alternatives* *< 0-alternative*

? denotes that output is not likely if alternative is implemented
< denotes that output will be significantly smaller if alternative is implemented

Appendix 2: Considering the Environment

In considering the value of an environmental element the following terms have been used:

N/A: Values not present.
Low: The loss of the environmental elements would at the most have bearings on the local environment, in this instance the Jutulsessen area.
Medium: The loss of the environmental elements could have bearings on the regional environment, in this instance Gjelsvikfjella.
High: The loss of the environmental elements could have significant bearings for the overall environment in Antarctica.

Environmental Element	Description	Value
Flora	Elements: ?? No flora is present on location. ?? Nearest occurrences are in the Jutulsessen mountains (lichens, mosses and algae) Consideration of values: ?? No unique occurrences/assemblages have been registered. ?? Relatively undisturbed Background information: ?? NPI (1990) ?? Ohta (1993)	Low
Fauna	Elements: ?? No fauna is present on location. ?? Nearest occurrences in Jutulsessen mountains, approximately 6 km away. ?? Two small snow petrel colonies in the vicinity of Troll – the areas closest to the planned runway ?? A number of larger seabird colonies in the more remote and inaccessible parts of Jutulsessen Consideration of values: ?? No unique occurrences registered. ?? Relatively undisturbed Background information: ?? NPI (1990) ?? Ohta (1993)	Low
Freshwater	Not present on location.	N/A
Sea water	Not present on location.	N/A
Soil	Not present on location.	N/A

Environmental Element	Description	Value
Air	Elements: ?? Air Consideration of values: ?? Air is relatively pristine as only affected by small scale operations at Troll ?? No atmospheric research going on in area. Background information: ?? Njåstad (2000)	Low
Ice	Elements: ?? Blue ice area Consideration of values: ?? Not significantly affected by earlier activity. ?? No unique ice conditions registered in the area. ?? Blue ice covers only 1% of Antarctica – relatively rare type of surface. ?? Common surface condition in the region Background information: ?? Bintanja, R (1999) ?? Winther et al. (2001)	Low
Geology	Elements: ?? No geologic occurrences on location. ?? The Jutulsessen nunataks are located nearby (approximastely 6 km to nearest ice free area) Consideration of values: ?? No unique geologic elements registered in association with the Jutulsessen nunataks. ?? Area interesting for geological research due to good exposure of elements Background information: ?? Dallman et al. (1990) ?? Ohta (1993)	Low
Wilderness	Elements: ?? Large area void of technical installations and with limited human presence Consideration of values: ?? Technical installations within 10 km from site making the area somewhat affected by human activity ?? Part of an area in Antarctica that is rarely visited. Background information: ?? Njåstad (2000)	Low

Environmental Element	Description	Value
Aesthetics and intrinsic values [6]	Elements: ?? Isolated and visually pleasing area. Consideration of value: ?? The Jutulsessen mountains are not very high, steep or unique in any manner and other areas of the DML nunataks are more spectacular and are more likely to be considered of high aesthetic and intrinsic value. Background information:	Low
History	No HSM or historic remains in area.	N/A

[6] Aesthetic value can for example be defined as ”the response derived from the experience of the environment or particular natural and cultural attributes within it. This response can be to either visual or non-visual elements and can embrace emotional response, sense of place, sound, smell and any other factors having a strong impact on human thought, feelings and attitudes” (Australian Heritage Commission & Department of Conservation and Natural Resources 1994, p. 5).

Appendix 3: Identification of Exposures

In considering the level of exposure the following terms have been used:

None No exposure has been identified
Low Exposure is irregular
Medium Exposure is regular
High Exposure is permanent

	ENVIRONMENTAL ELEMENTS/VALUES					
OUTPUTS	**Flora**	**Fauna**	**Air**	**Ice**	**Wilderness**	**Aesthetics and Intrinsic values**
Emission to air	**X (low)** Some pollutants may potentially reach the vegetated areas of the Jutulsessen Mountains, but limited due to distance and prevailing wind direction. *All alternatives*	**X (low)** Some pollutants may potentially reach the seabird colonies in the Jutulsessen Mountains, but limited due to distance and prevailing wind direction *All alternatives*	**X (medium)** Air in local area around construction site will be exposed to exhaust emission. *All alternatives* *< 0-alternative*	**X (medium)** Some combustion products may deposit in the ice surrounding the runway. *All alternatives* *< 0-alternative*	**None**	**None**
Emission to ground	**None**	**None**	**None**	**X (low)** Some spills may be expected in association with refuelling of aircraft. *All alternatives*	**X (low)** Spill remains will indicate human presence, but it is expected that remains will become invisible with time. *All alternatives*	**X (low)** Spill remains will visually affect aesthetic experience, but it is expected that spills will become invisible with time. *All alternatives*

	ENVIRONMENTAL ELEMENTS/VALUES					
OUTPUTS	**Flora**	**Fauna**	**Air**	**Ice**	**Wilderness**	**Aesthetics and Intrinsic values**
Wastes	**None**	**None**	**None**	**X (low)** Some waste may be expected to litter the ground. *All alternatives* *< 0-alternative*	**X (low)** Wastes will indicate human presence. *All alternatives* *< 0-alternative*	**X (low)** Waste will visually affect aesthetic experience. *All alternatives* *< 0-alternative*
Noise	**None**	**X (low)** Birds in the Jutulsessen Mountains could be exposed to noise, but limited due to distance and prevailing wind direction. *All alternatives*	**None**	**None**	**X (low)** Noise will indicate human presence. *All alternatives* *< 0-alternative*	**X (low)** Noise will audibly affect aesthetic experience. *All alternatives* *< 0-alternative*
Mechanical Action	**None**	**None**	**None**	**X (high)** Snow and ice obstructions will be groomed on a relatively continous basis. Snow drift due to facilities. *All alternatives* *< 0-alternative* *< Facility-alternative*	**X (high)** Mechanical actions will indicate human presence. *All alternatives* *< 0-alternative* *< Facility-alternative*	**X (high)** Indication of mechanic actions may visually affect aesthetic experience. *All alternatives* *< 0-alternative*

	ENVIRONMENTAL ELEMENTS/VALUES					
OUTPUTS	**Flora**	**Fauna**	**Air**	**Ice**	**Wilderness**	**Aesthetics and Intrinsic values**
Obstruction	**None**	**X (low)** Aircraft can in rare instances obstruct flight path of foraging birds, but observations indicate other flight paths. *All alternatives*	**None**	**None**	**X (high)** Facilities will indicate human presence. *All alternatives* *< 0-alternative* *< Facility-alternative*	**X (high)** Facilities may visually affect aesthetic experience. *All alternatives* *< 0-alternative*

Appendix 4: References

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