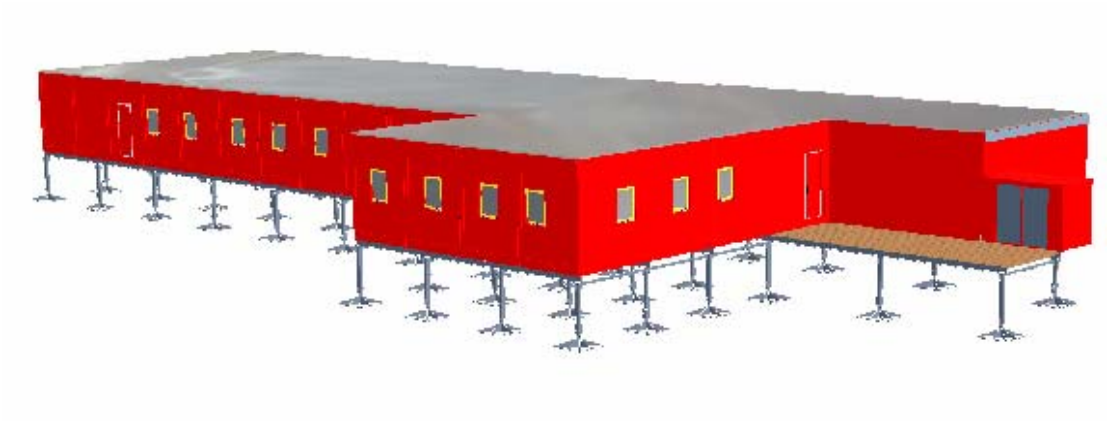
FINAL Comprehensive Environmental Evaluation (CEE) for the upgrading of the Norwegian summer station Troll in Dronning Maud Land, Antarctica, to permanent station.



The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in Norwegian polar regions. The institute also advises Norwegian authorities on matters concerning polar environmental management.

Norwegian Polar Institute 2004

Preface

The Norwegian Polar Institute (NPI) prepared a draft Comprehensive Environmental Evaluation (Draft CEE) for the upgrading of the Norwegian summer station Troll in Dronning Maud Land, Antarctica, to permanent station. The Draft CEE was submitted to the Ministry of Environment (MoE) in January 2004.

The Draft CEE was then made publicly available according to the provisions of the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol) as confirmed in the national regulations pertaining to the protection of the environment in Antarctica (Antarctic Regulations). The Draft CEE was made available on the NPI website (www.npolar.no) from February 2004.

The Parties to the Antarctic Treaty were notified about the Draft CEE and made aware of its website location through diplomatic notice (dated 23.01.04), satisfying the provisions of Article 3 (3) of Annex I of the Environmental Protocol. The NPI received comments on the Draft CEE from Australia and Germany. The comments are attached as Appendix 9 to this final version of the CEE (Final CEE). The suggestions and concerns raised in these comments are addressed in the present document. All modifications are in italics with corresponding footnotes on the originators of the particular comment.

The Draft CEE was furthermore submitted to the CEP Chair for CEP's consideration in accordance with Article 3 (4) of Annex I of the Environmental Protocol. The CEP considered the Draft CEE and reported to the Antarctic Treaty Consultative Meeting (ATCM XXVII) held at Cape Town, South Africa in May/June 2004. The ATCM consideration is provided at Appendix 10.

Since the drafting of the CEE in early 2004 and since the CEP/ATCM consideration in May/June 2004, many technical specifications for the station construction that were not in place earlier have been settled, and information on these have been incorporated into the Final CEE as appropriate. All additions/modifications that are considered significant have been marked with italics. Obvious spelling errors and language modifications (including deletions) have been corrected without special marking.

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1 Non-technical summary

1.1 Introduction

Norway has decided to upgrade its summer station Troll in Dronning Maud Land, Antarctica, to a permanent all-year station. The Norwegian Polar Institute, operator of the Norwegian Antarctic research program, is responsible for the upgrading.

The fact that the Troll station has summer operations only, has limited the Norwegian Antarctic research program thematically, geographically and seasonally. It has been considered desirable and necessary to give room for expansion of the scope of the program through the establishment of a permanent all-year station. Both scientific and operational aspects support this decision.

It was decided that a Comprehensive Environmental Evaluation (CEE) for the concept of upgrading the summer station to a permanent all-year station was to be prepared, seeing that the conceptual change at the station is quite significant.

The present document describes the proposed activity and the impacts associated with it. The document has been prepared in accordance with §§ 10, 11 and 12 of the *Regulations relating to protection of the environment in Antarctica*, reflecting the intentions of Article 3 of Annex I to the Protocol on Environmental Protection to the Antarctic Treaty.

1.2 Description of the activity (including alternatives)

The main activity is converting a summer-operated station into an all-year station. The conversion into a permanent station will require many minor and some major modifications to the physical appearance and technical installations at Troll. The largest changes will nonetheless be conceptual rather than physical, since an already existing station will constitute the core of the permanent station, and since the activity level during the summer season is expected to remain relatively unchanged compared to the current situation.

The following elements, described in more detail below, constitute the main changes envisioned as a result of the upgrading of Troll to an all-year station:

- Room for new research initiatives.
- Future expansion of the area affected by station operations due to e.g.:
    i. Construction of research and monitoring facilities (e.g. air-monitoring facilities) some distance away from the main station complex.
    ii. Establishment of antenna park in the vicinity of the station area.
- Some expansion of the building complex within the existing station area.
- All-year presence of personnel, and potentially an increase in presence during summer.
- Upgrading of technical systems at the station with an increased focus on green technology and solutions.

- Increased energy consumption due to all-year presence and research/monitoring activity, but nonetheless potentially over time a relative decrease in fuel consumption due to focus on energy conservation and alternative energy solutions.
- Potentially increased access to and pressure on the Jutulsessen area of Dronning Maud Land due to permanent presence at the Troll station.

In the process of deciding to establish an all-year station in Antarctica, other alternatives than expanding Troll has not been discussed in detailed. The only true alternative to establishing Troll as an all-year station at the existing site is to not establish an all-year Norwegian station in Antarctica at this point in time (**0-alternative**). Such an alternative would entail a *status quo* with regard to the summer operations at Troll, and the station installations and operations would remain much the same as today, although periodic and sporadic upgrading would likely be necessary.

The decision to upgrade Troll to permanent station was made in 2003. Preparation and initial structural improvements have been initiated in the 2003-04 season. The complete conversion, including necessary physical changes, is expected to be finalized in 2006. Troll will be officially opened as an all-year station in 2005, and the first winter team will stay at the station during the 2005 austral winter.

1.3 Description of initial environmental state

The Troll station is situated on permafrost ground consisting of scree blocks and frost weathering products. The mean temperature for the warmest month is below 0 ºC and winter temperatures may drop below – 50 ºC. The climate is little influenced by heat advected from the ocean, radiation from the sun and the atmosphere is the main energy source, and there is little precipitation. Predominant winds in the Troll station area seem to be east to west. The average wind speed is likely quite moderate, but extreme winds do occur. The precipitation level is not high, estimated to be around 200 mm/year.

The conditions at the nunataks of the nearby mountains represent one of the limits for plant life on earth. Some areas have sufficiently benign microclimate to support some patches of vegetation and associated microfauna. The vertebrate fauna consists of birds only: snow petrel (*Pagodroma nivea*), Antarctic petrel (*Thalassoica antarctica*) and south polar skua (*Catharacta maccormicki*). No unique species or assemblages of flora or fauna have been registered in the area.

1.4 Impact assessment

The environmental impacts of the proposed changes have been assessed in accordance with Article 3 of Annex I to the Protocol on Environmental Protection to the Antarctic Treaty and the steps stipulated in "Guidelines for Environmental Impact Assessment in Antarctica" (CEP 1999). Identified outputs from the activity include emission (to air and ground), wastes, noise, mechanical actions and obstructions. No environmental elements of high value were identified. Two elements were identified to have medium value due to operational and scientific concerns, and a number of elements of low value were also noted, such as flora, fauna, atmosphere, ice, geology and aesthetic values.

A number of unavoidable impacts have been identified through the assessment, mainly of low and medium intensity. Mitigative measures will be instituted to minimize these impacts. The following impacts with both high probability and high intensity have been identified, and merit prioritization in further mitigation efforts:

- Disturbance of micro-organisms (flora/fauna) due to discharge of wastewater. Local impact on low environmental value.
- Impacts on ice-free ground due to settling of combustion products. Local impact on low environmental value.
- Impacts on ice-free ground due to spills and discharge of substances to ground (wastewater, fuel spills, etc.). Local impact on low environmental value.

In association with the upgrading of the station it must be expected that the Jutulsessen area will experience a much higher intensity with respect to use of the area. Even so, the additional impact caused by the upgrading of Troll will 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 quite low, and a limited additional emission is not expected to have significant cumulative consequences.
- Stress for the seabirds in the Jutulsessen area may increase due to the increased operations, but impacts on fauna due to the upgrading are expected to be quite limited since the main change in activity will occur in the season of low or no biological activity. The cumulative stress caused by the addition of the planned activity is therefore expected to be low.
- With the upgrading of Troll to a permanent station, it is likely that atmospheric research and monitoring will be important elements of the research to come. This requires a clean environment (pollutants/noise), and efforts will therefore be made to ensure limited impact on the science, which also will have positive consequences with regard to environmental impacts. Reference is here made to experience from the research station in Ny-Ålesund on Svalbard, where major efforts have been instituted to ensure a clean environment.
- 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.

No negative effects are expected on ongoing scientific activities. A positive consequence for ongoing research is the improvements to operations at the station. Smoother operations, which are a likely consequence of the upgrading and the fact that there will be presence throughout the year at the station, will benefit the ongoing research activity.

1.5 Monitoring

The existing monitoring protocol for Troll station will constitute the basis for monitoring at the permanent Troll station. An updated practical monitoring plan will be developed in order to take into account the new operational framework as well as take advantage of the opportunities the all-year presence gives for more specific and analytic monitoring.

1.6 Gaps in knowledge and uncertainties

There is sparse written information regarding the environment for the Troll area, which contribute to uncertainties regarding the assessment. However, many years of operation at the station has given the operator a relative intimate understanding and knowledge of the area, which has provided basis for the assessment. *Further efforts will be initiated in order to increase the level of baseline information in the area.*

1.7 Conclusions and recommendations

It is the Norwegian Polar Institute's conclusion that the unavoidable environmental impacts of the upgrading of Troll and associated activities will be of no more than a minor or transitory character. The NPI therefore recommend that the proposed activity be implemented as described, under the condition that the activity is conducted in accordance with the given framework, that separate environmental impact assessments be conducted for the various components that will be instituted, that the mitigative measures described in this document are followed, and that an appropriate monitoring protocol is prescribed.

1.8 Preparers and advisors

This assessment and documentation has been prepared by the Norwegian Polar Institute.

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2 Introduction

The Norwegian research station Troll is located in Jutulsessen at 72º00'S, 2º32'E, in the Mühlig-Hofmanfjella, Dronning Maud Land, approximately 230 km from the ice edge.

Presently, the Troll station is normally occupied every summer season (early December to mid February), with a varying number of personnel. The activity at Troll is part of the Norwegian Antarctic Research Expeditions (NARE). Although Troll is the hub of the Norwegian Antarctic activities, the station has until now been mostly a logistical hub, while the research activity itself normally has taken place in areas outside the Jutulsessen area.

In 2003 Norwegian authorities decided to upgrade the Troll research station to a permanent all-year station, enabling research activity to take place both during the summer and winter seasons. The process of upgrading the station facilities is planned to take place in the 2004-2006 period, including the 2005 winter season. Changes will mainly be in the form of upgrading/expansion of the present station facilities, and will focus on "green" solutions. The formal switch to a permanent station is planned to occur early in 2005, and the first winter season will be in 2005.

The conversion into an all-year station will require many minor and some major modifications to the physical appearance and technical installations at Troll. The largest changes will nonetheless be conceptual rather than physical, since an already existing station will constitute the core of the permanent station, and since the activity level during the summer season is expected to remain relatively unchanged compared to the current situation.

Norwegian authorities decided to prepare a Comprehensive Environmental Evaluation (CEE) for the upgrading of the summer station to a permanent all-year station, seeing that the conceptual change may be considered quite significant. Furthermore, even though it is not a question of establishing a new station in a new location, Norwegian authorities are aware that the establishment of permanent research stations by other Antarctic Treaty Parties normally has undergone CEE processes since the Protocol on Environmental Protection to the Antarctic Treaty came into force.

The present document consequently describes and evaluates the impacts of the conversion of Troll to an all-year station[1]. The document has been prepared in accordance with §§ 10, 11 and 12 of the *Regulations relating to protection of the environment in Antarctica*, reflecting the intentions of Article 3 of Annex I to the Protocol on Environmental Protection to the Antarctic Treaty.

[1] *Germany has commented that by evaluating the impacts of the conversion of Troll to an all-year station separately from eg. the establishment and operation of Troll Runway, a comprehensive evaluation based on an overall consideration of the impact of the planned activities on the site has not been achieved. It should in this context be noted that international cooperative work on the Troll Runway was initiated before the decision was taken to upgrade the station. A separate IEE was conducted for the preparation and operation of Troll Runway. The assessment showed that no impacts associated with the establishment of the runway would have a high or medium degree of intensity, and it was concluded that no outputs from the operations were likely to have more than a minor or transitory impact on the environment. In considering the impacts of all-year operations at Troll, the effects of having and operating the Runway in the vicinity have been taken into account as part of the overall picture. A fuller description of this situation has been included where considered appropriate.*

A separate environmental evaluation was conducted at the time of the establishment of the Troll station in 1990 (NPI, 1990). An Initial Environmental Evaluation was also prepared for the operational aspects of the Norwegian Antarctic Research Expeditions (Njåstad, 2000). In 2002 an IEE for the construction and operation of Troll Runway (NPI, 2002) was prepared. Together, these three documents give a description of the environment and today's activity. Background information in the present document originates to a large degree from these documents.

2.1 Background

Research activities have taken place in Dronning Maud Land for more than half a century. Combined whaling, mapping and research expeditions were conducted already early in the 20th century, but it was the 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 research stations in Dronning Maud Land. Currently eight nations operate stations, while a number of additional nations are involved in the on-going research activities in the area.

To establish the Norwegian summer station Troll was considered essential for continuation by Norway of modern scientific research in Antarctica. Jutulessen was selected as the location for Troll because (NPI, 1990):

1. It was centrally located in relation to Norwegian science priorities.
2. It appeared to have relatively sparse biological activity and therefore environmental impacts would be minimized.
3. It had logistical advantages in terms of no difficult crevasse areas in the vicinity, and there seemed to be possibilities for creating future airstrip.
4. It appeared to have a relatively benign climate.

Since the establishment of the station in 1990, the station and its operations has continuously undergone modifications, although these have mostly been minor in character and must be considered normal development of a station of this kind. The most substantial changes were described and evaluated in the IEE for upgrading of the Norwegian research station Troll (NPI, 1999).

The station has since its establishment served the Norwegian Antarctic research activity satisfactorily. However, the type and length of research projects that could take place in the area have been limited, because of logistics constraints. These include short shipping season caused by sea ice prevalence.

In 2000 a new era was initiated in Norwegian Antarctic research history with flight operations to Troll. This change in operational modus has made it possible to expand the research season significantly and the research potential has become wider. It has lead to less travel time and a potential for longer and more flexible research seasons (possibility of shorter field periods and exchange of personnel in the course of the season, for example).

In July 2003 Norway took a further step and announced that Troll is to be upgraded to a permanent all-year station. The Minister of the Environment emphasized Norway's

commitment in protecting this untouched continent for generations to come. The Minister noted that through a continuous presence at Troll it would be possible for Norway to get an even stronger platform for its research and monitoring efforts in Antarctica.

2.2 Purpose and need

The fact that the Troll station has summer operation only limits the Norwegian Antarctic science program thematically, geographically and seasonally. It has been considered desirable and necessary to give room for expansion of the scope of the program through the establishment of a permanent all-year station.

2.2.1 Science

The following scientific arguments have given rise to the need to establish Troll as a permanent station[2]:

1. By establishing all-year operations it will be possible to establish continuous research and monitoring tasks at and in the vicinity of the station, and thereby get a fundamentally better understanding of the environment in an area of Antarctica that otherwise is explored minimally.

2. Year-round operations will make it possible to maintain special emphasis on atmospheric sciences *such as studies of UV-radiation and greenhouse gases and southern lights*. Operating air-monitoring programs at Troll may generate valuable data that can be compared with the atmospheric monitoring programs at the research station in Ny-Ålesund, Svalbard (cf. http://www.nilu.no/niluweb/services/zeppelin/).

3. All-year operations will make it possible to expand significantly ongoing science programs *by extending summer season activities in time and space,* such as the ornithological research at Svarthamaren and the geoscience field programs.

4. A permanent occupation at Troll will give a solid foundation for the Norwegian scientific contribution to the planned International Polar Year 2007/08, *e.g. in support of demanding logistical operations such as inland traverses.*

5. Upgrading Troll to an all-year station fills in a gap in the Antarctic network of existing all-year stations with a wide range of scientific projects. The nearest, SANAE (South Africa) lies 200 km to the northwest. More distant stations are Maitri (India) and Novolazarevskaya (Russia) 300 km to the east-northeast and Neumayer (Germany), 400 km to the west. *Comparative studies with other station's monitoring data will be prioritized.*

6. Permanent occupation will also render it possible to collect detailed meteorological *and climatological* data on a continuous basis, and thereby provide essential

[2] *Australia noted that although the draft CEE argues that the establishment of a permanent winter station will allow for enhanced research programs, many of the research examples cited did not appear to be dependent on the existence of such a station. Although most of the existing programs do not depend on winter operations, they may be enhanced by such operations and new opportunities are provided as described in the revised text.*

background information for many scientific projects, and provide input to research that aim to get a better understanding of global climate issues. *In addition, Norway plans to establish monitoring of bird colonies and glacier mass balance in the vicinity of Troll.*

Norwegian polar activity is mainly focused on the Arctic. A wide variety of scientific issues relevant to the Arctic are also relevant to the Antarctic and *vice versa*. A positive side effect of establishing all-year monitoring and research programs in Antarctica will be the potential to carry out bipolar comparative studies between the Arctic and the Antarctic.

The Norwegian Research Council will shortly adopt a policy platform document on "Norwegian research in the Antarctic: Priorities for the period 2005-2009", which focuses on the opportunities presented by all-year operations at Troll. The following assessment of future Norwegian research in Antarctica is promoted in the strategy document:

> *In the Antarctic, Norway will concentrate research efforts in fields where Norwegian researchers can make a significant contribution to progress in Antarctic science and provide reliable knowledge for the management of Dronning Maud Land, Peter I Øy and Bouvetøya. Interdisciplinary research in a bipolar context is particularly important for Norway.*
>
> *On this basis, scientific priorities for the period 2005-2009 will focus on research on climate dynamics (past, present and future), marine ecosystems, and the human dimension. Climate studies will focus on the paleoclimate, the Antarctic ice sheet, the ocean circulation and climate modelling. To understand climatic processes and explain the role of the Antarctic in the global climate system, an interdisciplinary approach is needed that uses both field observations and modelling.*
>
> *In marine ecosystem studies, special priority will be given to process studies and modelling, and to studies of biological resources and human impacts. An interdisciplinary approach involving both the physical sciences and ecosystem studies is also needed to enhance our understanding of climate and ecosystem processes.*
>
> *Studies of the human dimension in the Antarctic will focus on problems related to governance, tourism and other human impacts, and the historical heritage.*
>
> *There will be more emphasis on environmental surveys and long-term monitoring. These activities include topographic mapping and geological mapping and surveying. It is in Norway's national interest to establish long-term environmental monitoring and research programmes at the Troll Station.*
>
> *The International Polar Year 2007-2008 is likely to offer an excellent opportunity to achieve key objectives set out in this document. Norway should aim to play an active role in IPY 2007-2008.*

The draft strategy document (presently under adoption) is attached in full in Appendix 11.

2.2.2 Support

The following operational arguments have given the rise to the need to establish Troll as a permanent station:

1. Through the Dronning Maud Land Air Network (DROMLAN-project) the various national operators in Dronning Maud Land aims 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 is establishing and will be operating a blue ice runway (Troll Runway) in the vicinity of Troll (cf. NPI, 2002). The establishment of the Troll Runway will likely entail that the Troll station will be more in focus as a communication basis and logistical hub also for other programs than the Norwegian program. All-year operations at Troll will enable longer flying season and safer operations of the Troll Runway.

2. Norwegian Antarctic research activity in the coming years is expected to continue to emphasize research activities for which Jutulsessen is the best geographic position as support base (see 2.1 and 2.2.1). All-year operations will make it possible to start summer activities earlier and end later. During winter, a permanent staff at Troll will be able to prepare for the next year's scientific expedition, specifically with regard to planned field activities outside the Jutulsessen area. This will increase efficiency for the scientific personnel, and thereby increase the value of the research conducted in the area.

3 Description of activity (including alternatives)

3.1 The concept

3.1.1 The activity

The main activity discussed in this document is converting a summer-operated station into an all-year station. The conversion into a permanent station will require many minor and some major modifications to the physical appearance and technical installations at Troll. The largest changes will nonetheless be conceptual rather than physical, since an already existing station will constitute the core of the permanent station, and since the activity level during the summer season is expected to remain relatively unchanged compared to the current situation. *The activity and its impacts must, however, also be considered in the context of other ongoing activities in the area (cf. footnote 1).*

In the 1999 austral winter season the Norwegian Polar Institute gave permit to a private expedition to spend the winter at Troll in order to prepare for a ski expedition the following austral summer. This gave the operators of the Norwegian Antarctic program the opportunity to consider the functionality of the Troll station for winter operation purposes. The experience gained during this expedition has been important in the further consideration of the upgrading of Troll to a permanent station.

The following elements, described in more detail below, constitute the main changes envisioned as a result of the upgrading of Troll to an all-year station:

- Room for new research initiatives.
- Future expansion of the area affected by station operations due to e.g.:
    i. *Potential* construction of *research and monitoring facilities (e.g. air-monitoring facilities)* some distance away from the main station complex.
    ii. *Likely* establishment of antenna park/*satellite readers* in the vicinity of the station area.
- Expansion of the building complex within the existing station area.
- All-year presence of personnel, and potentially an increase in presence during summer.
- Upgrading of technical systems at the station with an increased focus on green technology and solutions.
- Increased energy consumption due to all-year presence and research/monitoring activity, but nonetheless potentially over time a relative decrease in fuel consumption due to focus on energy conservation and alternative energy solutions.
- Potentially increased access to and pressure on the Jutulsessen area of Dronning Maud Land due to permanent presence at the Troll station.

3.1.2 Alternatives

In the process of deciding to establish an all-year station in Antarctica, other alternatives than expanding Troll has not been discussed. The reasons for this has been:

- Use of the existing facilities as a core in the "new" station instead of building from scratch makes sense both economically and practically.
- Use of the existing location for the "new" station makes sense with regard to minimizing impacts, and operations will take place in a disturbed area instead of opening a pristine, undisturbed area.
- Proximity to the Troll Runway (currently under construction).
- The factors that were decisive for location for the original Troll station (see Chapter 2.1 above) are still valid as location factors for the new station.
- There are no other permanent research stations in the immediate vicinity of the Troll location, and for scientific purposes it therefore makes sense to maintain a station in this area.

The potential of utilizing capacity at existing permanent stations run by other countries has been superficially considered, but have been discarded as this would entail that Norway would have to change focus regarding research priorities, both with regard to topic and geographic location.

The only true alternative to establishing Troll as an all-year station at the existing site is to not establish an all-year Norwegian station in Antarctica at this point in time (**0-alternative**). Such an alternative would entail a *status quo* with regard to the summer operations at Troll, and the station installations and operations would remain much the same as today, although periodic and sporadic upgrading would likely be necessary. Consideration of this alternative is included in the environmental impact assessment (see chapter 5), but in general it is noted that the upgrading of the stations enables a holistic consideration and installment of more efficient technology and procedures that in fact may contribute to a decrease in outputs and exposure (and thereby impacts), something that will not be so easily achieved by maintaining the *status quo* at the station.

3.2 The details

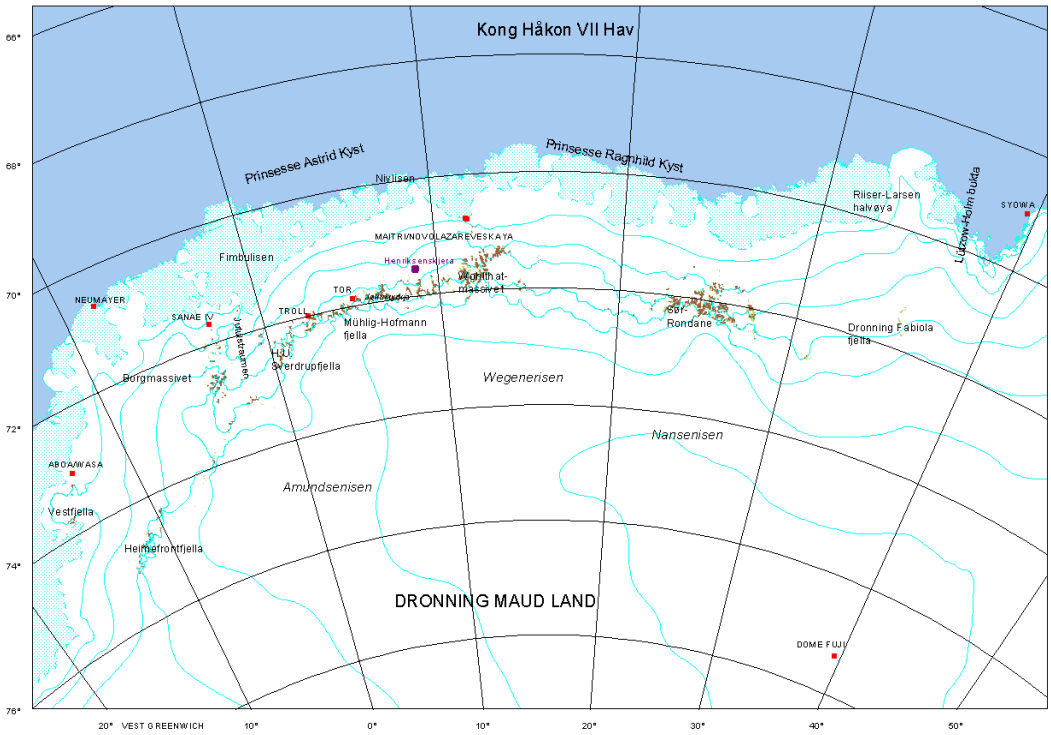
In this chapter the proposed and envisaged changes to the existing research station Troll is described in some detail, both with respect to physical installations and operational procedures. Where activities during the construction phase are expected to differ from today's activity or the proposed all-year activity, these are described separately. Alternatives are discussed to the degree this is relevant and feasible.

3.2.1 Location

The present summer station Troll is located in Dronning Maud Land in Jutulsessen at 72º00'S, 2º32'E, in the Mühlig-Hofmanfjella, approximately 200 km from the ice edge (see Figure 1 and Figure 2). The station is located in a north-facing amphitheatre-shaped ice-free area covering approx. 15 x 20 km^2, enclosing an extensive blue-ice area. The ice-free area extends from 1100 to 2400 meters in elevation. Generally expansion in connection with the conversion to a permanent station will take place in the area already occupied by the existing station operations (an area with a radius of approximately 250m from the station core, thus covering approximately 0.20 km^2). Future research and monitoring programs may, however, require installment of facilities in areas not affected by station operations, and an enlargement of the station area is therefore not unlikely (see 3.2.3.1). A separate antenna park may also be

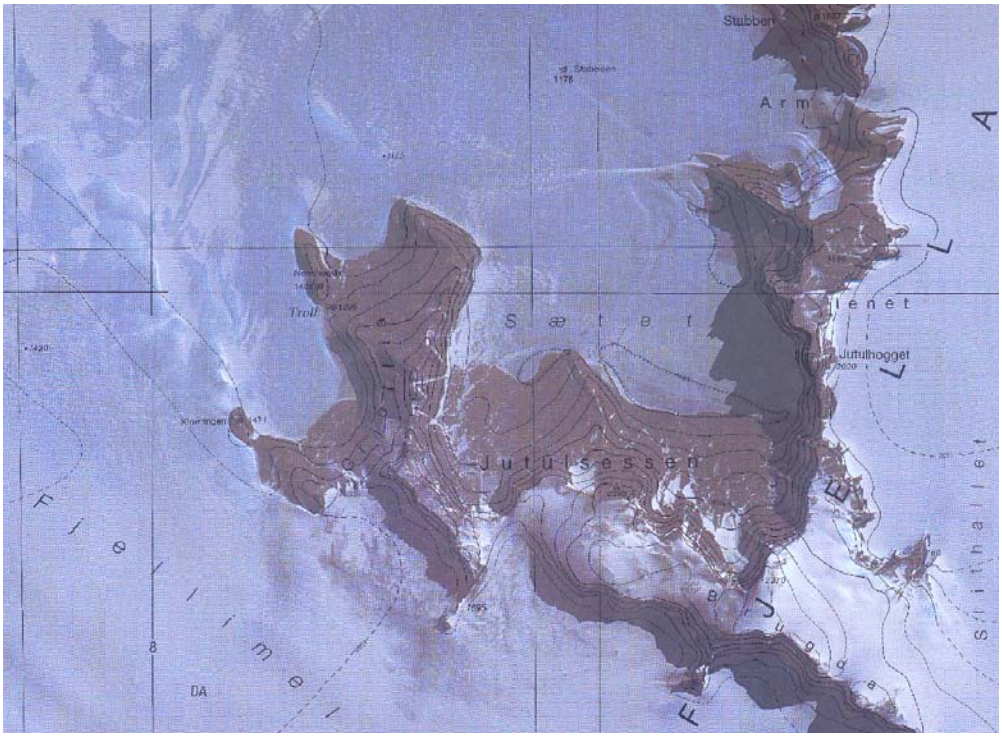
necessary to provide required communication equipment for monitoring and research programs.

Figure 1: Map of Dronning Maud Land with location of present research stations



Source: Norwegian Polar Institute (1999)

Figure 2: Jutulsessen and the location of Troll

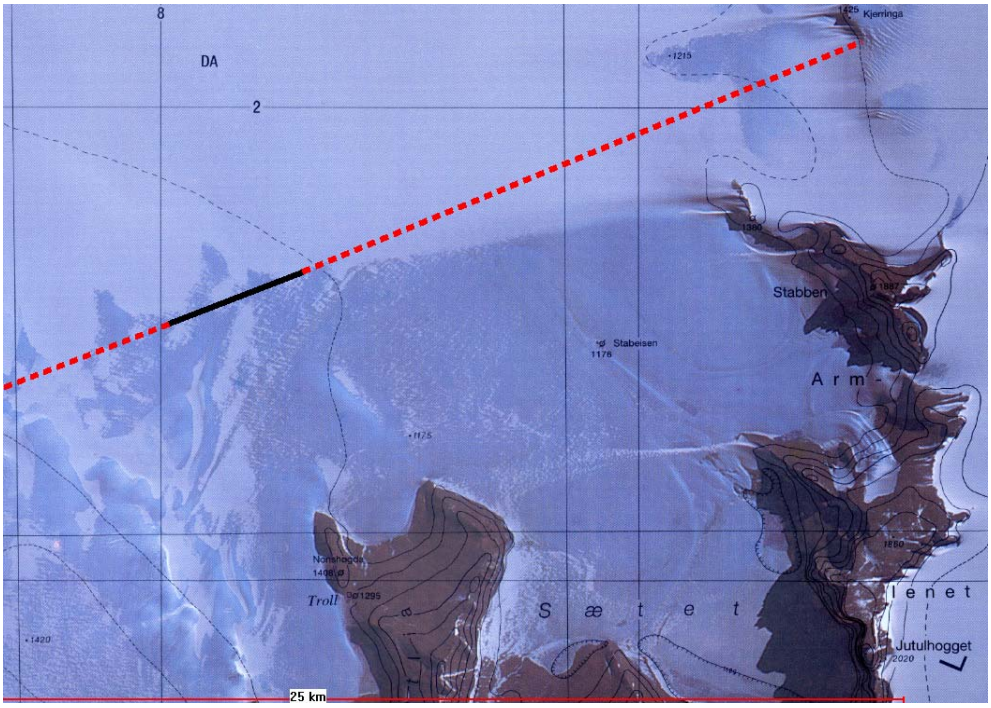


Source: Norwegian Polar Institute (1992)

Supply transport to Troll station is normally conducted with tracked vehicles from Troll losseplass (Troll unloading port) at the edge of the ice-shelf. The overland route to Jutulessen is about 280 km. This route will be used during the construction phase, and will continue to serve as the main supply route to Troll also in the future.

Approximately 6 km from Troll is the location of the Troll Runway (see Figure 3), which will mainly be used for transport of personnel and lighter cargo. The runway may be used somewhat during the construction phase, but will first be in full operation after the conversion of the Troll station to an all-year facility (cf. NPI, 2002 for further information regarding construction and operations of the Troll Runway). *The fact that Troll is being upgraded to an all-year station is not expected to influence the use of the Troll Runway to any significant degree*[3]*. No additional flights will be required to serve the winter operations at the station, and the upgrading of the station to an all-year station is therefore to a large degree independent of the air operations. However, it is clear that the combination of winter operations and air operations may make it possible to extend the operating season in time, opening for increase in air traffic to support increased summer science activities.*

Figure 3: Troll Runway



Source: Norwegian Polar Institute (2002)

3.2.2 Duration

The decision to upgrade Troll to permanent station was made in 2003. Preparations were initiated in the 2003-04 season. The main art of the construction work will take place in the 2004-05 season. The complete conversion, including necessary physical changes, is expected to be finalized in 2006. Troll will be officially opened as an all-year station in February 2005, and the first over-wintering team will stay at the station during the 2005 winter season.

[3] *It has been suggested by both Germany, Australia and ATCM XXVII that the upgrading of the Troll station to an all-year station be considered more comprehensively in the context of the establishment of the Troll Runway.*

2003-2004:	Preparatory work at station (survey, storage deck[4], etc.)
2004 (1. half):	Project preparations/planning
2004 (2. half):	Project preparations/planning/procurement and shipping of material/equipment
2004-2005:	Construction of additional units (accommodation, *emergency unit, generator unit and initial work on* garage/workshop unit). Official opening of all-year station in mid-February 2005.
2005 (all year):	Indoors work in new station units *and completion of garage/workshop unit*.
2005 (1. half):	Continued project preparations/planning
2005 (2. half):	Procurement and shipping of material/equipment
2005-2006:	Technical work *and finalization of project*.
2006- :	*Open for construction of relevant structures/installments (eg. monitoring facilities, communication facilities, etc.) after appropriate environmental consideration.*

The life expectancy for the permanent all-year station Troll is in principle indefinite, although continuous maintenance and periodic upgrading of structures will be necessary.

3.2.3 Nature and intensity

3.2.3.1 Physical station expansion

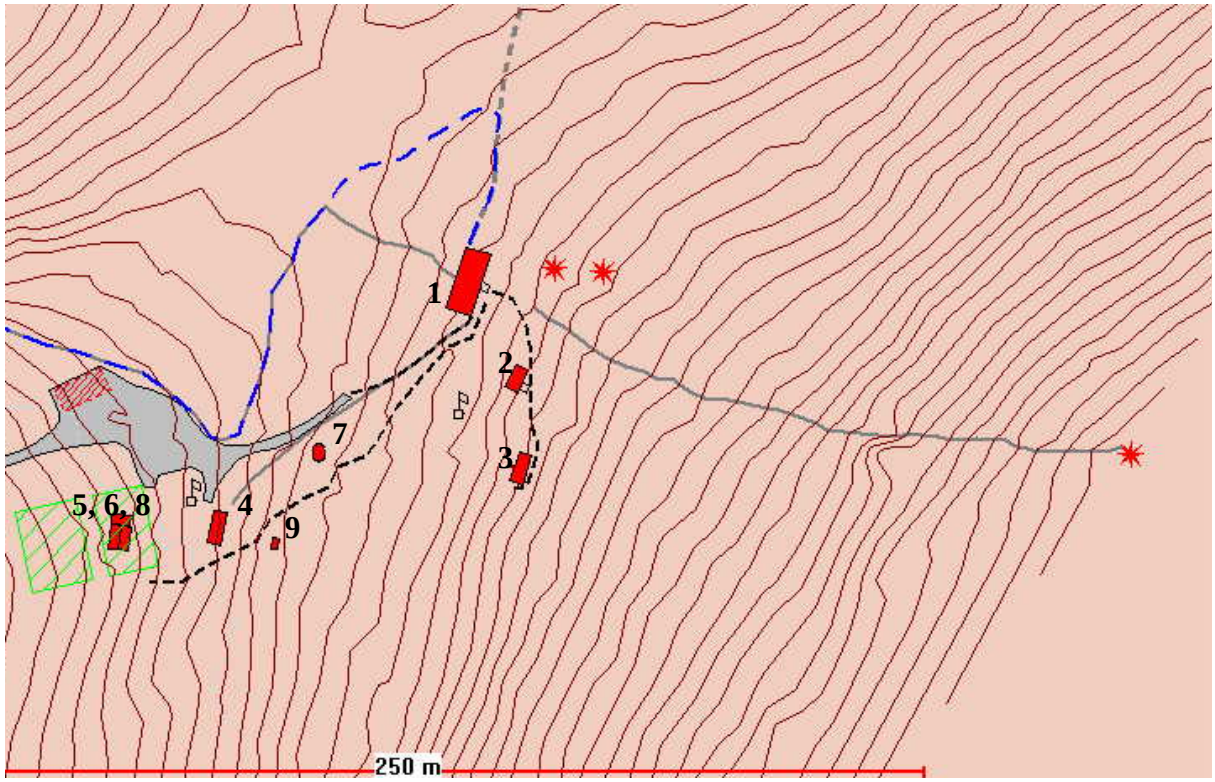
Present state
Table 1 gives an overview of the present building mass at the Troll station. There is extensive storage of equipment, fuel, waste and vehicles outdoors in addition to the permanent structures listed in the table. Figure 4 and Figure 5 also illustrate the station complex, indicating also the extent of the area affected physically by the station elements.

Table 1: Present building mass at Troll station (2004)

Building	~ Area (m^2)	Type	Function
1. Station building	99	Insulated steel	Accommodation
2. Old generator building	22	Insulated steel container	Back-up generator, workshop
3. New generator building	16	Insulated steel container	Generator, melting pan
4. Garage container	26	Insulated steel container	Emergency quarters, food storage
5. Storage container	15	Non- insulated steel container	Food storage
6. Storage container	15	Non- insulated steel container	Equipment storage
7. Fiber igloo	13	Non-isolated fiber glass	Emergency quarters, storage
8. Hut	10	Lightly isolated aluminum coated	Equipment storage
9. Vehicle cabin	6	Non-isolated steel	Equipment storage

[4] *Germany expressed concerns regarding the fact that upgrading started before the CEE was completed and appropriate evaluation of the project was conducted. Note, however, that the storage deck has throughout been considered as an improvement/upgrading of the summer station and would have been implemented also if the station were not to be upgraded to an all-year station. The storage deck is an element in an effort to tidy up the station area and minimizing visual impact, a problem that was identified during an international inspection conducted at Troll in 2001 (MFA, 2001).*

Figure 4: Arial map of the Troll station area (numbers on map refers to Table 1)



Source: Norwegian Polar Institute (2003)

Water pipes

Permanent structures (numbers refer to Table 1)

Paths

Cables

Road/vehicle area

Communcation equipment (antennas, etc.)

Figure 5: The Troll station in 2003 (numbers on picture is reference to Table 1)

Photo: John Guldahl (NPI)

Proposed changes

The upgrading of Troll to a permanent station will be based on the existing station complex with the following changes and additional structures to ensure sufficient safety, practical operation and low environmental impact[5]:

- A new addition to the main accommodation building to accommodate the winter personnel and expanded research needs. The structure will be built as an extension of the existing station.
- A simple emergency unit, to ensure safe accommodation in case of mishaps to the main accommodation units during the winter season. *The emergency unit may serve as summer accommodation.*
- A new combined workshop and garage unit. This unit is also envisioned as an emergency accommodation unit for the Troll Runway (in case of long-lasting layover in bad weather).
- A new container deck is already under construction *(see footnote 4),* and in the future storage containers will be placed on this deck. This latter initiative will ensure a more aesthetically and clean station area and provide for safer and more practical operations. Associated with this it is planned that some of the present storage units present today at the station either will be moved onto the storage deck or removed all together. *Furthermore, laboratory and food storage facilities will be located on this storage deck.*
- Finally, a new generator unit will be set up next to the new garage/workshop unit and the storage deck.

[5] *Germany notes that the expansion of the station will lead to a fourfold increase in developed land in the area. NPI would emphasize the fact that none of the proposed new structures lie beyond the perimeter of the area already considered affected by station activities although the building mass will be expanded fourfold (ie. all new structures lie well within a radius of 250 m from the mid-point of the station area and in fact to a large degree are simply expansions of existing buildings).*

It is not unlikely that associated research/monitoring facilities will be proposed in the future. Some potential facilities (e.g. an air-monitoring facility) may be some distance away from the main station complex, to ensure that research can take place in an area unaffected by station operations (clean environment).

Likewise it is likely that the upgrading of the station will require a larger amount of antennas and satellite readers to accommodate new research and communication needs. An antenna park will also be located in a suitable location nearby the station. Some likely location for outlying facilities is Nonshøgda (Site 1), 500 horizontal and 100 vertical meters north of the current station area, or Site 2 some 1000 meters south of the station (see Figure 6). These are areas currently used by station personnel for recreational walks. Separate environmental impact assessments will be conducted for the location and design of outlying facilities. *A survey will be conducted for this purpose in November 2004, providing basis for the development of a land-use management plan.* The assessment in the present document takes into account the concept of an enlarged station area.

Figure 6: Some potential areas for facilities outside the exposed station area (seen from the north-east)

Source: Norwegian Polar Institute (2004)

Table 2 shows the proposed additional larger structures to be installed in the process of converting the station to an all-year operation. Figure 7 shows the conceptual layout of the upgraded station. Some of the existing structures (container units) will be removed from the station area.

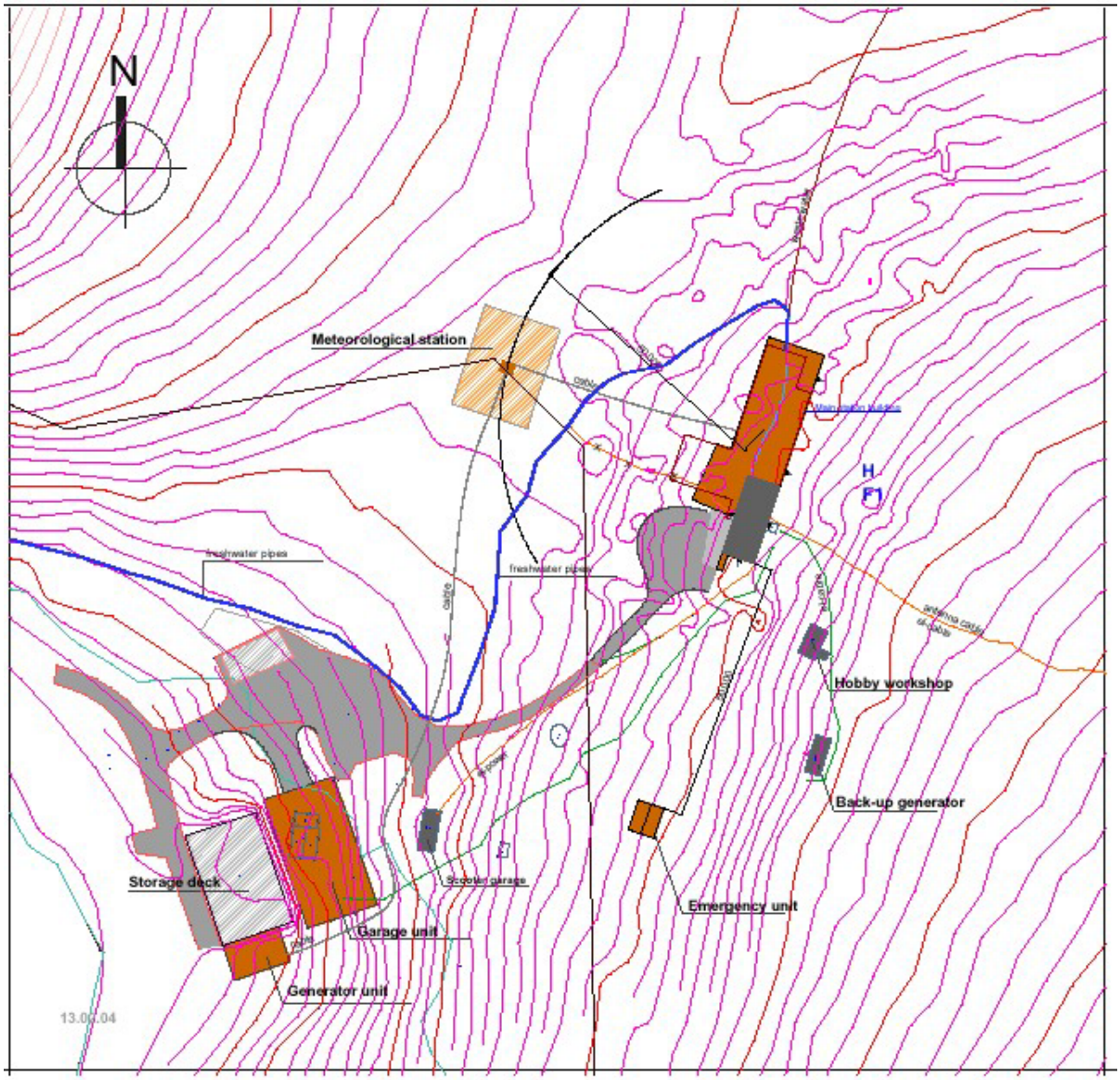
Table 2: Building mass at the upgraded station

Building	**~Area (m^2)**	**Function**
New elements		
1 Station building	*+200 (total 360)*	Accommodation, offices, *hospital*, water, heat and waste. *Note that the "old station" which is incorporated into the new station, in essence will be closed down during winter.*
2 Garage and workshop unit	300	Garage, workshop and emergency accommodation
3 Emergency accommodation	*30*	Accommodation for winter personnel in case of mishap to main accommodation units
4 Energy unit	*115*	Building for *el*-power generation, *heat distribution plant* and ice/snow melting
5. Outdoor food storage	*45*	*Container units for freezer goods, fresh goods and dry goods. Placed on storage deck.*
6. Outdoor laboratories	*12*	*Container units for wet and dry laboratories. Placed on storage deck.*

Table 2 cont.

Building	~Area (m^2)	Function
Existing elements incorporated into upgraded station		
7. Old generator building	*22*	*Will be converted into hobby workshop*
8. New generator building	*16*	*Will function as back-up/emergency generator*
9. Old garage container	*26*	*Snow mobile and equipment storage*
10. Storage deck	*350*	*Deck for storage containers*
Total building mass (excl. storage deck)	*926*	

Figure 7: Concept sketch of upgraded Troll station



Note: Orange denotes new structures, dark grey old structures and light grey current transportation and work areas
Source: The Directorate of Public Construction and Property (2004)

Alternatives
Table 3 shows some options to the proposed plan, and arguments for and against these.

Table 3: Alternative construction options

Alternative	Pros'	Cons'
Using existing building mass	- No need for further construction/impact except "normal" maintenance/upgrading due to wear/tear.	- Health and safety standards for long-term occupation not satisfactory (fire hazard, indoor air quality, etc.). - Reduced opportunity to make significant improvements with regard to "green technology", aesthetics, etc. - No possibility for year-round research/monitoring
Remove all existing building mass and start from scratch	- Design station for long-term occupation and operation (potentially more efficiency can be gained). - Full utilization of opportunity to consider new and green technology.	- Cost and impacts of removing existing building mass. - Cost and impacts of building from scratch.

3.2.3.2 Personnel

Present state
Today the main building houses up to 9 people, while additional personnel sleep in the glass fiber igloo, garage unit or in tents. Normally permanent summer personnel are accommodated in the main building, while transit personnel (field party personnel) use the alternative lodgings.

The number of people at the station during summer operations varies significantly. At peak periods 30 persons have been associated with the station and its operations. However, this far exceeds what the facilities at Troll can adequately accommodate.

Proposed changes
After the conversion of Troll to a permanent station it will be possible to accommodate approximately 20 persons comfortably at the station. This will enable better handling of the peak presence that is experienced at the station already today, as well as overlap between winter teams[6]. It is, however, not envisioned that the size of the team staying at Troll during

[6] *Australia notes that there was no persuasive explanation provided in the draft CEE as to why the station's accommodation needed to double to accommodate a smaller wintering population. The following should be noted in this regard:*

i) The bed capacity at the station should accommodate an overlap of succeeding winter teams. Field parties will still utilize emergency accommodation and tents during their stay at Troll.

ii) *The accommodation at the current station is in four double rooms. It is considered essential that the winter team members have separate rooms. New rooms are built, as the old rooms do not meet standards for long-term occupation. The current rooms will be maintained so that a total of 12 bedrooms will be available at the upgraded station (will also enable somewhat larger winter teams during special events such as e.g. IPY 2007/08). Several of the rooms will be equipped to serve as double rooms in the summer season. The four bedrooms in the old station will normally be closed down during the winter season.*

the summer season will change significantly after the conversion to an all-year station, as it is likely that field parties will constitute the core of the Norwegian Antarctic summer research program also in the future. Due to easier access by plane, a larger turnover of people at the station during a season may be expected, ie. a larger number of people visiting the station during a season, but no major increase in number of person days.

The plan is to accommodate 6-8 persons at Troll during the winter season, which is sufficient to run the station and the envisioned monitoring and research programs. Additional research personnel for specific short-term projects can also be accommodated within this capacity framework.

Emergency accommodation capacity for personnel landing at Troll Runway on their way to other stations in case of long-lasting layover in bad weather will be simple, and will utilize the capacity of the new garage/workshop unit.

The capacity at Troll is summarized in Table 4.

Table 4: Present and planned personnel capacity at Troll

Description	Present	After upgrading
Summer operations	9 staying permanent at the station. Visitors/transit personnel stay in temporary lodging (tents). Facilities (water, toilet, kitchen, etc.) have a capacity for around 10 persons.	16-20 staying permanent at the station (accommodating both winter personnel and summer personnel). Facilities will have a capacity to handle approx. 20 persons.
Winter operations	None	6-8 persons
Runway operations	None	Emergency accommodation in case of long-lasting bad weather. Simple facilities so that such accommodation does not need to interfere with normal station operations. *NOTE! Temporary passenger facilities will be available at the runway. The facilities at Troll will only be for emergency/extreme situations.*

During construction
During the construction period, ie. the 2004-2005 and 2005-2006 season it is expected that the size of the construction team will be around 20 persons (including winter personnel), *in addition to a transportation team of ~3 persons and a runway preparation crew of ~ 6 persons*. During the 2005 winter season it is planned that a team of *7* persons will stay at the station to finalize indoor construction work.

Alternatives
Table 5 shows some options to the proposed plan, and arguments for and against these.

Table 5: Alternative options regarding capacity at Troll

Alternative	Pros'	Cons'
Build for a larger winter capacity	- More flexibility with regard to potential future research needs.	- The planned capacity is adequate for the present and envisioned future need. - Higher cost
Build for a smaller winter capacity	- Less construction - Lower cost	- For health and safety reasons it is not desirable to build for a smaller group.
Build for a larger summer capacity	- More flexibility with regard to potential future needs	- The planned capacity is adequate for the present and envisioned future need. - Higher cost
Build for a smaller summer capacity	- Less construction - Lower cost	- Troll is already today too small to accommodate a normal sized Norwegian Antarctic expedition. Pressure on the existing facilities may lead to costly breakdowns.

3.2.3.3 Water supply

Present state
The main water source during the summer season is melt water from a reservoir underneath the blue-ice in the immediate vicinity of the station complex. A network of water pipes has been laid out, from the water reservoir to the generator building, from the generator building to the station unit, and from the station unit to the discharge point (see Figure 4). The pipes are partly covered by gravel. Alternatively water is supplied by melting of snow or ice. Melt pans have been installed in both generator buildings, utilizing surplus heat from the generators in the melting process.

Proposed changes
The two systems for water supply that presently are used at the station in principle work satisfactory. Although little is known about the quantity and longevity of the fresh water reservoir under the blue-ice, it is nevertheless clear that the reservoir is not a source that can be used during the winter operations due to freeze-up. Melting of snow and ice will therefore constitute the main source during the winter season.

Technical upgrading will be instituted to improve the supply system for the use of the fresh water reservoir. A new water pipe system *will be installed* to avoid problems with freezing of pipes and in order to reduce energy requirement.

A new and improved system for snow/ice melting will be installed in association with the new generator building. The principal concept remains the same as the present system, but *the new system is a significant improvement with regard to utilization of surplus energy from the*

generators (see further description in 3.2.3.6). The water melt container and storage containers are both kept in a room separate from the generators in order to ensure hygienic control.

Alternatives
No alternatives have been considered. The present systems are relatively simple, satisfy the needs and require limited resources (energy, labor, competence, etc.).

3.2.3.4 Water conservation

Present state
No water conservation measures are in place today, although the small capacity at the station has naturally limited the amount of water used. No measurement or registration of quantity of use has been conducted.

Proposed changes
Water consumption will increase due to increased activity at the station. This will have consequences for operations and wastewater disposal (see 3.2.3.5). With the upgrading of the station measurement of water consumption will be conducted. Technology and procedures will be instituted to ensure water conservation because of the uncertain capacity of the freshwater reservoir and the relative labor-intensive snow melting system. Consideration will be given to everything from limitations to personal hygiene (e.g. shower time) to reuse of treated wastewater. *These are issues that will be dealt with further in the first year of operations, at which time one will have a greater understanding of potentials, limitations and technical challenges.*

3.2.3.5 Waste management

Present state
There are no structural installments for waste storage. Waste management at the stations is in accordance with the *Antarctic Waste Management Handbook for Nordic Antarctic Operations.* In short, this entails that all waste, except wastewater, is separated, collected in empty fuel drums and brought out of Antarctica for appropriate disposal or recycling. The following waste management aspects should be noted:

- Waste compressor: A waste compressor has been installed at Troll. The compressor reduces waste volume significantly and also enables compression of empty fuel drums to 20% of full size. The compressor is located outdoors.

- Toilet: At present one electrical incinerator toilet is in use. The collected waste in the holding area is subjected to heat temperatures up to 600ºC for a pre-selected run time up to maximum 2 hours (1-2 kW). The heat and smoke within the incineration chamber is filtered through an odor control catalyst and the exhaust is ventilated out. The system contains an exhaust blower that continues to extract heat after the heating coil has shut down to about room temperature. Five users generate about one cup debris in a week. *Analysis of the solid waste residues has shown that the values for some metals are somewhat higher than that which is recommended for material to be used for cultivation purposes. The residue from the toilets is collected and transported out for proper disposal, and further use of the material has not been considered appropriate.*

- Wastewater: A system for purifying/treating wastewater has been installed at Troll. Wastewater is discharged through a heated piping in an ice-free area system behind the station. The treatment system has proved to function in principle, but is not satisfactory with regard to maintenance (user friendliness) and capacity.

- Waste storage: Waste is stored outdoors in empty fuel drums. The area selected is suitable with respect to access and snow accumulation, but adds to the somewhat untidy appearance of the station area.

- Waste production: Since the size of the Norwegian Antarctic Research Expedition varies from year to year, the amount of waste generated each year varies accordingly. Table 6 gives an overview of the some of the NARE expeditions the last years, giving an indication of waste production at Troll.

- Disposal of waste: Today, arrangement for disposal of waste in South Africa is made in advance of an expedition. Agreements are made with relevant recycling companies and waste management companies. The companies are required to confirm in writing what amount of waste has been received and that it has been treated in accordance with the agreement.

Table 6: Waste production (# 200 liter drums) at Troll the last seasons

	Metal	**Glass**	**Mixed**	**Spill oil**	**Wastewater**	**Hazardous waste**
00-01	1 drum	1 drum	4 drums	2 drums	4 drums	2 drums
01-02	2 drums	1 drum	11 drums	1 drums	2 drums	0
02-03	2 drums	2 drums	49 drums	7 drums	26* drums	0
03-04	3 drums	0	12 drums	3 drums	0	0

* Note that wastewater treatment system was not in use this season and most wastewater was collected as for disposal outside Antarctica.

Proposed changes

The general strategy for waste management will remain as it is today at the upgraded Troll station, although in time consideration may be given to installment of a new incinerator. Clear guidance as to the requirements of the Environmental Protocol (cf. Article 3 (1) of Annex III) will in this case be sought. The following should be noted:

- Waste compressor: The waste compressor will be moved indoors and waste handling will be carried out in protected environment. This should simplify handling procedures, prolong the life expectancy of the compressor, and reduce chances of spillage/littering to the environment.

- Toilet: With the upgrading of the station and increased summer capacity *two* additional incinerator toilets will be installed in the station proper (*a total of three*) so that the capacity matches that of the personnel capacity at the station. This will ensure proper combustion and likely reduce handling problems. *One incinerator toilet will be installed in the emergency unit.*

  Toilets will also be used in association with any emergency accommodation provided for the runway. However, since this facility will be operated as an exception rather than a rule, field standard toilets are likely to be used here. Waste from these toilets will be treated as normal waste and brought out of Antarctica for proper disposal according to the waste management plan.

- *Wastewater: A new and improved wastewater treatment system delivered by HACO AS will be installed. The new system will ensure simple handling and monitoring of discharge and have sufficient capacity to handle the normal personnel load during summer season. The treated water can in principle be reused for non-consumption purposes, and in this manner it is possible to reduce water production, thus saving both energy and labor associated with the melting procedures. The treatment capability of the HACO treatment system is provided in Table 7. Discharge is presently planned to take place in same area as today (see Figure 7).* No build up of ice residues has been evident in the discharge area until now (due to ablation) and changes to the topography have not been evident.

Table 7: Treatment capability for biological treatment system for wastewater[7]

	Suggested min. treatment efficiency (%)	***Suggested max. discharge concentrations***	***Measured average concentrations in HACO system***
BOD_5	*>90*	*<20 mg/l*	*3.7 mg/l*
COD	*60-90*	*<30 mg/l*	*---*
Total nitrogene	*>25*	*<10 mg/l*	*5.5 mg/l*
Ammonium nitrogene	*>50*	*-*	*-*
Total phosphorus	*>75*	*<0.5 mg/l*	*0.3 mg/l*
E. coli	*>99*	*>1000 E.coli/100ml*	
Thermo tolerant bacteria			*280 TKB/100 ml*

- Waste storage: Considerations will continue to be given as to how storage can be implemented with less aesthetic consequences.

- Waste production: Waste production during summer season is not expected to change significantly. However, the all-year occupation of the station will increase the amount of waste that will require transport out of the continent during a year. *The expected amount of waste production calculated based on the max production per person day over the last few seasons, and estimating a presence of 3500 person days[8], is presented in Table 8. The numbers indicate an average waste volume roughly ten times the volume of today.*

  Waste is today transported by tracked vehicles to the ice shelf in connection with arrival of supply vessels. In this manner free transport capacity is utilized in an efficient manner. Such return capacity will also be utilized in the future. *An estimated 40 drums can be pulled by each vehicle, which indicates that all waste can be transported utilizing such free return capacity (ie. no separate trip to handle waste, and consequently no additional combustion output).* Intercontinental airplanes landing at the Troll Runway may also have free return capacity to transport non-hazardous waste. The overriding principle will be to transport waste out every summer season, utilizing free return capacity on vehicles,

[7] *ATCM XXVII suggested that a fuller description of wastewater disposal procedures would be useful to demonstrate that there is a low risk of the escape of bioactive substances into the environment. A fuller description has been provided in the above. It should be noted that the HACO system meets the requirement that are currently under consideration as Norwegian minimum requirements for discharge of wastewater from small treatment systems into vulnerable areas:*

- *90% reduction of phosphorus calculated as annual average value compared to what is fed into the treatment plant*
- *1 mg total phosphorus per liter discharge calculated as annual average, or*
- *1 mg/l total phosphorus and 25 mg/l BOF_5 calculated as annual average.*

[8] *7 persons over 12 months and 13 persons over 2.5 months = 3500 person days.*

vessels or aircraft as far as possible. Waste that cannot be brought out during a summer season will be stored appropriately at Troll.

Table 8: Theoretical estimation of annual waste production at Troll in the future (3500 person days)

	Metal	*Glass*	*Mixed*	*Spill oil*
Estimated production	*35 drums*	*35 drums*	*135 drums*	*20 drums*

During construction
The station elements have been pre-fabricated and the modules are ready for installment, thereby reducing the amount of construction waste significantly. Some construction waste is nevertheless expected. Such waste will be sorted into appropriate categories and stored appropriately in containers until the end of the construction period at which time the waste will be transported out of Antarctica for appropriate disposal.

During the construction period accommodation will be in an advanced tent based field camp. Due to the work at the station the water treatment system will not be available for use. It is planned that wastewater (grey water) in this period will be collected and disposed of in appropriate ice pits in the vicinity of Troll. Such disposal will adhere to the provisions of Article 4 of Annex III to the Environmental Protocol.

Alternatives
Table 9 shows some options to the proposed waste management procedures, and arguments for and against these.

Table 9: Alternative options regarding waste management procedures at the upgraded Troll

Alternative	**Pros'**	**Cons'**
Install incinerator	- Smaller volume to be transported out - Reduced storage requirements - Potentially easier handling.	- Combustion emission - No agreed standards for incineration (cf. Article 3 (1) of Annex III in the Environmental Protocol). - Potential for technical break-down.
Remove wastewater for disposal outside Antarctica	- No discharge in station area, and thereby reduced pollution potential. - Increased transport need ensures appropriate consideration of water conservation.	- Larger volume to be transported out. Associated transport and pollution issues.
Discharge wastewater in other area	- In accordance with requirements of Article 4, Annex III of the Environmental Protocol	- No areas that satisfy the requirements of the Protocol are available in the vicinity of the station. Only option is to bring out for disposal outside Antarctica. See above.
Alternative toilet solutions	- No combustion emission from incinerator toilets.	- Larger volume to be transported out. Associated transport and pollution issues.

3.2.3.6 Energy

Present state
Power supply at the stations is mainly based on generators and Jet A-1 consumption. The station is equipped with a 46.4 kW (4 stroke) generator and a 15 kW (4 stroke) back-up generator. The former consumes approx. 150 liters, the latter approx. 50 liter fuel per day at a much lower effect. There is also a 4.5 kW emergency generator at the station. The following aspects regarding the energy system should be noted:

- Alternative energy: Propane is utilized for heating, water heating and for the kitchen stove in addition to traditional fuel. 190 kg gas bottles are stored outside the station, and some 11 kg bottles are available inside. At current level approximately 100-150 kg is used per season.

- Fuel consumption for energy: Assuming that only the 46.6 kW generator is utilized during a season, the maximum fuel consumption for a normal summer season (75 days) is estimated at 24000 liters of Jet A-1 fuel at Troll. The used amount during the last seasons is considerably lower than this, recorded at around 6500 liters.

- Energy conservation: At Troll surplus heat from the generators is utilized for melting snow/ice. Melting pans have been installed in the generator buildings for this purpose.

Proposed changes
Electric energy will remain the main source of energy at Troll station also after the upgrading, although alternative energy sources will be considered further. The following should also be noted:

- Energy production: *Two diesel generators of type SDMO (model JS80UC) with a capacity of 73 kW each will be installed at the station. Emission data for the generator is provided in Table 10. The generators are automatic coupled, providing flexibility as to variations in energy use*, and thereby also contribute to reducing fuel consumption and combustion emission. *The generator presently at the station will serve as a back-up/emergency generator.*

Table 10: Emission data for the SDMO (JS80UC) 73 kW generator

Combustion product	***Quantity***
HC	*0.30 g/bhp/h (0.40 g/kWh)*
CO	*0.45 g/bhp/h (0.60 g/kWh)*
NO_x	*6.06 g/bhp/h (8.08 g/kWh)*
PM	*0.16 g/bhp/h (0.21 g/kWh)*

- *Energy conservation: The energy system will utilize the surplus energy released in the process of producing electric energy efficiently. Surplus energy will consequently be used for i) freshwater production (by melting of ice/snow in a 5400 liter melting container) and maintenance of a 3500 liter freshwater reservoir, and for ii) the heat distribution plant (see below). Surplus energy is in this manner utilized to the fullest degree possible. Another energy conserving effort involves the winter "closure" of parts of the station unit. The station is furthermore designed in such a manner that heat loss from the station is minimized.*

- *Heating: Heating of the station will be through a heat distribution plant located in the generator building. A pipe system will carry a glycol/water mix heated by the surplus energy from the generators to the station buildings. As heating fluid DOWCAL 20 heat transfer fluid has been selected. It is an economical, high quality fluid designed for a temperature range of –45ºC to +120ºC. DOWCAL 20 consists of propylene glycol with a low acute oral toxicity that makes it particularly suitable for applications where toxicity is a concern. Some other characteristics that make DOWCAL 20 particularly suitable for the purposes at Troll are:*
    - *Freeze protection*
    - *Corrosion protection in hot and cold systems*
    - *Confirmed biogradability*
    - *Long fluid life*
    - *Low maintenance cost*
    - *Heat transfer efficiency*
    - *Cost-effectiveness*
    - *Protection against bacterial growth*

  Table 11 gives some further information on the key features of DOWCAL 20. Approximately 240 liters of DOWCAL 20 is required by the heating system at Troll (mixed with 40% water).

Table 11: Key features of DOWCAL 20

Feature	***DOWCAL 20***
Composition, wt%	
Propylene glycol	*94*
Ethylene glycol	*---*
Inhibitors and water	*6*
Boiling range at 1013 mbar, ºC	*±170*
*Viscosity at 20ºC dynamic, mPa*s*	*73-78*
Viscosity at 20ºC kinematic, mm2/s	*69-74*
Refractive index n_D 20ºC	*1.434*
*Specific heat at 20ºC, kJ/kg*K*	*2.33*
*Thermal conductivity at 20C, W/m*K*	*0.21*
Pour point, approx. ºC	*± -50*
Specific electrical conductivity at 20ºC (33% vol. in demin. water), mS/cm	*3.1*

- *Energy budget: Table 12 gives an overview of estimated energy requirement throughout the year at the upgraded station. A total energy requirement of approx. 340,000 kWh is estimated.*

Table 12: Estimated energy budget for the upgraded Troll

Month	***Electric energy requirement (kWh)***	***Thermal energy requirement (kWh)***	***Total energy requirement (kWh)***
January	*6,159*	*17,143*	*23,302*
February	*5,565*	*16,535*	*22,100*
March	*6,311*	*20,991*	*27,302*
April	*6,404*	*22,555*	*28,959*
May	*7,148*	*25,568*	*32,716*
June	*7,081*	*25,991*	*33,072*
July	*7,313*	*26,821*	*34,134*
August	*7,148*	*25,777*	*32,925*
September	*6,404*	*23,305*	*29,709*
October	*6,311*	*22,126*	*28,437*
November	*5,965*	*18,790*	*24,755*
December	*6,159*	*17,145*	*23,304*
TOTAL	***77,968***	***262,747***	***340,715***

- Alternative energy: New technologies will be considered further in the future. However, two fundamental parameters need to be sorted out before final decision will be taken with regard to any installment: i) baseline information at Troll on physical factors affecting energy production (eg. wind situation and solar radiation) and ii) safety and reliability of new technologies in an isolated environment. The first operating years at the permanent Troll station will give opportunity to establishing baseline information regarding the two parameters mentioned above. In addition to considering new technologies, the use of propane will continue/expand. The kitchen facilities will be upgraded with regard to propane use. This reduces the pressure on the generator system. An ultimate long-term goal is to enable summer operations running as far as possible on alternative energy sources.

- Research needs: With a potential establishment of additional research and monitoring facilities or other station facilities, the energy requirements at the station will increase. *Presently it is not possible for the Norwegian Polar Institute to assess what dimensions such operations may have and the consequent future increase in fuel consumption*[9].

Alternatives

Table 13 shows options to the proposed fuel system, and some arguments for and against these.

[9] *Australia noted the lack of explanation regarding the former statement estimating a 'doubling' in energy usage for the station because of the needs of air-monitoring facilities. Establishment of additional research and monitoring facilities are part of a second phase of the upgrading of Troll station. Details about energy requirements are therefore not available at this time. As an initial estimate it is considered realistic to estimate an additional constant energy requirement of 60 kW, equalling an annual fuel requirement around 150,000 liters (750 drums).*

Table 13: Alternative options regarding fuel and fuel consumption at the upgraded Troll

Alternative	Pros'	Cons'
Install wind generators	- Less fuel consumption and thereby less emission. - Less fuel transport.	- Existing knowledge regarding wind situation at Troll indicate that low wind speeds are common. - Operational challenges in case of breakdowns.
Install solar panels	- Less fuel consumption and thereby less emission. - Less fuel transport.	- No sun during winter season - Operational challenges in case of breakdowns.
Other alternative technologies	- Less fuel consumption and thereby less emission. - Less fuel transport.	- Technology development still limited. Need reliable systems at the station. - Operational challenges in case of breakdowns.

3.2.3.7 Transport

Njåstad (2000) outline the operational framework of today's transport in Dronning Maud Land. The below contains only a short summary with regard to the present situation.

Terrestrial

Present state

- Use of ground transport has three primary purposes:
  1) Transport of equipment to/from the stations/ice-edge (vessel)
  2) Transport of personnel for field operations
  3) Operations in the station area

- The ground transport has the following vehicles: Three tracked BV 206 Hägglunds that utilize Jet A-1 fuel, approx. 1.3 liters/km with no cargo, and 2 liters/km with cargo, and *two BV TL6 Hägglund.* Two Prinoth Everest are also used for transport of equipment as well as work on the Troll Runway. *The TL-6 consumes approx 1400 liters pr. roundtrip to the ice-shelf and the Prinoth approx. 2000 liters.* An excavator is being used at Troll for operations in the station area.

- Snow machines are used during normal operations, running on gasoline (95 unleaded) with some oil mixed in, approx 0.25 liters/km.

- Table 14 shows vehicle use the last three NARE-seasons. *Note that the steep increase from the 2001/02 season to the 2003/04 season is due to the preparatory work on the Troll Runway (cf. NPI, 2002) and the level of use is not expected to remain this high after the completion of the runway.*

Table 14: Vehicle use the last two seasons during operations at Troll (incl. transport)

	01-02	02-03	03-04
BV 206 Hägglund (3 vehicles)	2260 km	5300 km	5700 km
Prinoth (1-2 vehicles)	---	490 operating hours	680 operating hours[1]
Snow machine (operations)	600 km	2400 km	2800 km
BV TL6 Hägglund			420 operating hours

[1] Two machines from the 03-04 season

Planned changes
Use of terrestrial vehicles at the all-year station is expected to remain relatively unchanged. However, the following should be noted:

- The old Hägglunds BV 206 will mainly be used to local work at the station as they are about to go out of commission, while the TL-6 and Prinoth Everest will be the main components of the overland transport vehicle park. The snow machine park will over the next few years be upgraded and more cost-effective machines that require less fuel (approx. half the amount) will replace the existing machines.

- Use of vehicles will likely increase somewhat after the upgrading of the station to an all-year station. A somewhat higher need with regard to transport of supplies/equipment from the ice-shelf[10], and some higher activity at the station itself. The season will also be prolonged, but due to conditions (light, snow, etc.) it is not expected that winter transportation will be very high. *Use during a normal operational year is estimated at maximum 5 roundtrips with three vehicles (compared to approx. 1 roundtrip with three vehicles presently). In addition the operations of the Troll Runway will require some annual maintenance work, estimated at 300 operating hours (5,100 liters fuel), with intermittent high maintenance seasons with an estimated requirement of 1000 operating hours (17,000 liters fuel).*

During construction
- Use of vehicles during the construction phase will be higher than during normal operations, both in the station area itself (construction work) and for transport purposes. *It is estimated that a total of 13 roundtrips (utilizing three vehicles) to the ice shelf will be necessary during the 04/05-season.*

<u>*Seaborne*</u>

Present state
The Norwegian Antarctic program uses vessels to transport heavy equipment, and also some personnel. The Norwegian program cooperates in the Nordic joint program, and the vessels used vary from season to season. Space may be chartered on vessels run by other national Antarctic research programs, but the Norwegian activities also include operation of separate vessel to provide a platform for marine research. Further description of vessel activity can be found in Njåstad (2000).

Planned changes
The upgrading of Troll to an all-year station in combination with the increased flight operations in the area, may have consequences for the use of vessels in the Norwegian program. The large-scale supply operations may take place more irregularly, as small-scale supply operations can be conducted by air operations instead. The frequency in use of vessel

[10] *Australia noted the need to consider possible indirect or second order impacts of the proposed activity, in particular the potential for greater use of the Troll losseplass. There are no permanent instalments at the Troll losseplass, which is simply a low spot at the edge of the ice-shelf, and it serves only as a temporary storage depot during the transportation phase. Due to increased energy requirements at the station, a larger amount of fuel will be temporarily stored at Troll losseplass during the transportation phase. This will increase the risk of fuel spills and contamination in this area. Normal procedures for fuel storage will continue to be implemented to minimize such risk. Fuel is currently stored in 200-liter drums, limiting the size of any spill.*

in order to support operations at Troll may therefore decrease in the future. In such a case also the extent of vehicle operations may decrease somewhat.

During construction
No changes to vessel operations during construction period are anticipated. The Norwegian program will charter space on vessels already operating in the area to transport construction material.

Airborne

Present state
There is currently a general increase in use of aircraft for transport of personnel and cargo amongst the national operators in Dronning Maud Land.

Some of the reasons behind this are (NPI, 2002):

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.

Presently intercontinental flights land at the runway near Novolazarevskaya (Russia), and personnel and equipment is transported to Troll by feeder link operations (small aircraft or helicopters).

Planned changes
The Norwegian program is constructing a runway (Troll Runway) approximately 6 km from the Troll station (cf. NPI, 2002). This eases the access and use of Troll.

The Troll Runway will only be operated in the austral summer season, i.e. currently assessed to last from mid-November to mid-February. Possibly ice melting will prevent its use for about 3-4 weeks in mid-summer (mid-December/mid-January). It is envisioned that the operating season may be extended in time in the future as more experience with the flight operations at the runway are gained.

It is at this stage difficult to be certain about the type of aircraft and the number of flights that will land and take off from Troll Runway during a normal operating season, although an indication of potential aircraft types are summarized in Table 15. An estimate of the potential operational intensity is given in Table 16. 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.

At present it is not planned with separate flights to the Troll Runway to support the winter operations (ie. winter personnel will transported in and out on flights that serve the summer

field season), and the upgrading of the station to an all-year operation does therefore not affect the use of the runway[11].

Table 15: Potential aircraft types at Troll Runway

Type	Operation type
Ilyushin 76	Intercontinental
Hercules C-130	Intercontinental
Boeing 737-747	Intercontinental
Falcon 7 Ex	Intercontinental
Antonov-2	Intracontinental
Twin Otter	Intracontinental
Basler 67 (DC-3)	Intracontinental
Helicopters (various types)	Intracontinental

Table 16: 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

During construction
The Troll Runway will not be open for traffic until the end of the 2004-05 summer season at the earliest. It is not expected that air traffic will increase or be excessively high during the construction period.

3.2.3.8 Fuel consumption and management

Present state
There are no structural installments for fuel storage except for one double-walled fuel tank (1900 liters) designed for the generator. The following aspects with respect to fuel consumption and pollution management should be noted:

- Fuel consumption: Current level of fuel consumption is summarized in Table 17. Note that due to variations in expedition size, the fuel consumption varies extensively from season to season. Fuel consumption has been higher the last seasons due to construction work on the Troll Runway.

- Fuel depot: The fuel depot at Troll is currently located on the ice-free ground between the ice and the garage unit. Containment mats, on which fuel can be stored, are available at Troll. Such mats are meant to retain any small spills that may occur during storage. These mats have proved to function according to purpose. Furthermore, safety drums are available for immediate protection for damaged drums. Empty fuel drums are compacted to reduce volume of waste. There will always be a few liters of fuel left

[11] *Australia noted the need to consider possible indirect or second order impacts of the proposed activity, in particular the potential for greater use of the Troll Runway. The above suggests that this is not an issue. It should be noted, however, that the combination of winter operations and air operations may make it possible to extend the summer season in time, opening for some increase in air traffic to support summer science activities. It is not possible to quantify such potential increase on the basis of today's plans.*

in all fuel drums, and consequently a containment system has been constructed for the compacting operations, so that no waste fuel contaminates the environment. Such leftover fuel is treated as spill oil.

- Helicopter pads: Containment mats for helicopters are available. At Troll all helicopter landings, re-fueling, maintenance, etc. takes place on such containment mats in order to reduce pollution into the environment.

Table 17: Fuel consumption at Troll the last three seasons *and estimated future use*[12]

Used for	**01-02**	**02-03**	**03-04**	***Future***
Generator (Jet A1)	6,700 liters	6,100 liters	10,800 liters	*100,000 liters* *83 tonnes*
Snow machines (JP 8)	450 liters	600 liters	800 liters	*1,000 liters*
Vehicles (Jet A1)	4,900 liters	17,900 liters	33,200 liters	*30,000 liters*[a] *25 tonnes*
Helicopter	2,400 liters.	4,200 liters	---	---[b]
Aircraft	3,200 liters	---	---	*60,000 liters*[c] *50 tonnes*
Total Jet A1 JP 8	 17,200 liters 450 liters	 28,200 liters 600 liters	 44,000 liters 800 liters	 *190,000 liters* *1,000 liters*

[a] *May during intermittent seasons with high level of maintenance work increase to 42,000 liters.*
[b] *Helicopters may intermittently be used for research programs, but level of use is not possible to estimate as it will vary from season to season as has been the situation also in the past.*
[c] *An estimated fuelling requirement of approx. 100 drums per flight leaving Troll.*

Proposed changes
The general strategy for fuel management will remain as it is today at the Troll permanent station. The following should however be noted:

- Fuel consumption: Due to all-year operations the amount of fuel required for energy generation will increase. Fuel consumption for transport purposes (vehicles and aircraft) likewise. Due to cost of fuel (transport) it is in the interest of the Norwegian Antarctic program to reduce fuel consumption as much as possible. Initiatives regarding alternative energy, fuel conservation, etc. have therefore both environmental and operational advantages. *However, it should be noted that an approximate tenfold increase in total fuel consumption compared to the 2001-2002 season can be expected.*

- Fuel consumption for energy: Fuel consumption is expected to remain stable during summer operations compared to today, but additional fuel will of course be required during winter operations. *An annual fuel consumption of approx. 100,000 liters (500 drums) is estimated.*

- *Fuel consumption for vehicle transport: The expected overland transport intensity is noted in 3.2.3.7. With this transportation requirement fuel consumption is expected to level off at approximately (maximum) 24,000 liters. In addition maintenance work at the Troll Runway will require approximately 60,000 liters of fuel per season.*

[12] *Australia noted that there was no estimate of energy consumption changes. Since the Draft was prepared calculations have been conducted and are included here.*

- *Fuel consumption for aircraft operations: The expected aircraft operation intensity is noted in Table 16. A consumption rate of approx. 20,000 liters fuelling per return flight (large aircraft) is estimated.*

- Emission: There will be an increase in emission levels corresponding to the increase in fuel consumption. *Table 18 gives an indication of emission levels from the upgraded operations. Flight operations are not included due to the degree of uncertainty regarding intensity. Compared to the emission from energy production and transport the local aircraft emissions will be relative limited.*

Table 18: Estimated annual emission levels from operations at upgraded station

	HC	***CO***	***NOx***	***PM***
Energy production	*0.14 tonnes*	*0.20 tonnes*	*2.75 tonnes*	*0.07 tonnes*
Transport	*0.13 tonnes*	*0.43 tonnes*	*1.28 tonnes*	*0.15 tonnes*

- Fuel depot: Considerations will be given to how storage can be implemented to further reduce the risk of spills and contamination and give aesthetic benefits. Today's system with fuel stored in 200-liter drums on containment mats in principle gives a relatively limited chance of large spills to the environment. With continuous monitoring, possible with all-year occupation, the chance of mishaps should be even further reduced. *This system will be maintained for the time being. In addition, double bottom day tanks (satisfying Norwegian Standards (NS)) holding 1200 liters each will be installed inside the generator unit for the two generators. Filling of the day tanks will be directly from fuel drums (placed on a protected fuel deck outside the building) by electric pump (installed inside the building) with check valve (non return). The day tanks will be monitored for leaks through inspection and manometer-control.*

During construction
During construction the transport requirement will be higher than normal (see 3.2.3.7). The estimated 13 roundtrips with three vehicles will require approximately 60,000 liters Jet A-1.

Alternatives
Table 19 shows some options to the proposed fuel management procedures, and some arguments for and against these.

Table 19: Alternative options regarding waste management procedures at the upgraded Troll

Alternative	**Pros'**	**Cons'**
Install fuel tanks	- Opportunity to install automatic monitoring system	- Larger spill in case of mishap - Vulnerability due to several levels of transfer.

3.2.3.9 Science

Present state
The location of Troll is a support base for a wide variety of research studies already going on in the area, including:

1. The Jutulstraumen/Fimbulisen ice stream/ice shelf system, the largest ice stream in Dronning Maud Land. The investigation is concerned with understanding the ice shelf/ocean interaction and the response of the system to climatic change.
2. Glaciological studies on the Antarctic plateau south of Troll in connection with the European Program on Ice Coring in Antarctica (EPICA).
3. The interrelationship across the geologic boundary between East and West Antarctica, probably marked by a large geological break along the Jutulstraumen – Pencksøkket glacier system. This discontinuity is the most important key structure for the reconstruction of the Gondwana continent.
4. Studies of the colony of more than 200 000 breeding pairs of Antarctic petrels at Svarthamaren, and the energy flow and behavior of this population located 200 km from the ocean. Svarthamaren is a Site of Special Scientific Interest (SSSI) and is located 90 km east of Troll.

Proposed changes
The Norwegian Research Council will shortly adopt a policy platform document on "Norwegian research in the Antarctic: Priorities for the period 2005-2009", which focuses on the opportunities presented by all-year operations at Troll. The latest draft of the strategy document(presently under adoption) is attached in Appendix 11.

An all-year station offers a great potential for establishing atmospheric monitoring programs. It will be possible to monitor persistent organic pollutants such as mercury and other heavy metals, conduct measurements of climate related gases such as CFCs, its substitutes, SF_6, as well as ozone and UV-radiation and climate related measurements (see 2.2). To enable such studies there are plans to establish air-monitoring facilities some distance away from the main station complex (see 3.2.3.1).

Troll is particularly well located as a starting point for glaciological studies on the Antarctic ice plateau, and all-year operations will support such efforts even further. Such opportunities may be particularly interesting in the context of the IPY 2007/08.

In general it is expected that summer research activity to a large degree still will remain field based, although research activity at Troll itself may increase somewhat as room is given for all-year monitoring programs based out of the station facilities.

For future research projects the plan is to install required laboratories as container units according to need (for the specific projects) in addition to the two basic laboratories on the storage ramp. The container laboratories would remain at the station for the duration of the particular research project.

3.2.4 Mitigation measures in place

Present state
All current activities/operations at Troll have been assessed and are in compliance with the requirements of the Norwegian Regulations pertaining to the protection of the environment in Antarctica (1995), the Norwegian legal instrument for implementing the Environmental Protocol to the Antarctic Treaty.

The NP has, in co-operation with its Finnish and Swedish counterparts developed environmental guidelines that have relevance for station operations. These guidelines are collated in the Nordic Environmental Handbook for Antarctic operations. Operations at the Troll station are carried out in accordance with these guidelines. Currently the following guidelines have been developed:

- Procedures for fuel storage transfer and transport (Appendix 1).
- Oil Spill Contingency Plan (with Fuel spill response guidelines, attached here as Appendix 2)
- Nordic environmental guidelines for operations of aircraft and helicopter in Antarctica. A short version of the guidelines is attached as Appendix 3
- Waste Management Handbook including waste management strategy (short version of Waste Management Guidelines are attached in Appendix 4).
- Environmental Guidelines: flora, fauna and the natural environment (Appendix 5).

Other mitigative measures in place:
- Troll is equipped with spill response equipment.
- Personnel and expedition members are instructed both in advance of expedition and during expedition in relevant provisions of the legal frameworks and any guidelines developed for the purpose.
- *Monitoring program that will give "early warning" as to any unforeseen impacts. The current monitoring program will be revised to take into account the changes in operations in the area.*

Proposed changes
Guidelines and operating procedures will be updated to reflect the changes in the station facilities and operations. Training and education procedures will be reviewed to take into account the new operations. In principle, the basic framework described above will still constitute the core of the mitigative efforts.

4 Description of initial environment state

4.1 Ground conditions

The mountains of Gjelsvikfjella (including the Jutulsessen area) are built of an Archean basement complex of gneiss and charnockite. The metamorphism ranges from amphibolite facies in the west to mainly granulite facies in the east. The lithology varies from granitic to gabbroid.

The texture and weathering of rocks vary in a way significant to vegetation. Charnockites yield a rugged surface of protruding feldspars, whereas the gneiss have smoother surface more suitable for lichen growth.

The ground is permafrost consisting of scree blocks and frost weathering products. Some areas thaw during favorable weather conditions in summer, and melting ponds are characterized by growth of the green algae *Prasiola crispa*.

4.2 Climate

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 20 to give an indication of climate characteristics.

Table 20: 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)

The sun is under the horizon for 2.5 months during mid-winter, and above the horizon from 15 November to 27 January during austral summer. Being so far inland, the area is seldom affected by cyclonic weather activity. The climate is therefore little influenced by heat advected from the ocean, radiation from the sun and the atmosphere is the main energy source, and there is little precipitation. The inland mountains hinder snowdrift.

There is sparse information regarding the wind situation. Predominant winds in the Troll station area seem to be east to west. The average wind speed is likely quite moderate, but extreme winds do occur. The original station complex has been built to endure winds up to 60 m/s.

The precipitation level is not high. No measurement data from Troll exists, but is estimated to be around 200 mm/year. Annual accumulation along a surveying traverse in the area between 70º, 5ºE and 75ºS, 15ºE has shown a variation from 271 mm at Fimbulisen to 24 mm at 2840

m.a.s.l. (Van den Broeke et al., 1999). Snow accumulates in the station area mostly due to wind, and the snow cover in the station area normally melts during the summer season.

At the time of the construction of the original Troll station (1989/90) a study was implemented looking at chlorinated components in snow samples near the station to determine impact from the camp activities on the surroundings. Samples were collected at arrival and at departure 200 meters from the base camp (current location of station) and 2 km from base camp (Greibrokk et al., 1992). The samples and results of the analyses of the initial state of the snow quality may serve as baseline documentation for future studies on impact on snow.

4.3 Flora and fauna[13]

4.3.1 Description

The conditions at the nunataks of the nearby mountains represent one of the limits for plant life on earth. The mean temperature for the warmest month is below 0 ºC and winter temperatures may drop below – 50 ºC. 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 micro-fauna. The vegetation, however, is very susceptible to desiccation.

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 21). The terrestrial vegetation is very restricted in species diversity and abundance compared to other areas. No rare species have been observed. *Samples of lichens were collected in the Troll area at the time of the construction of the original Troll station (1989/90) and were analyzed for metal contents. The samples and analyses of the initial state of the lichens may serve as baseline documentation for future studies on impact on lichens. A study of the occurrence of algae was conducted in the 1989/90. The samples collected had a varied occurrence of algae. Further information on the analysis of the samples is found in NIVA (1991).*

Invertebrate fauna is found in association with the vegetated areas. *During the construction of Troll station in 1989/90 a study was carried out in the area to map the invertebrate species and density. Invertebrates were observed generally in the whole area. Particularly large numbers of* Cryptopygus sverdrupi *(collembola) was found in a nunatak northwest of Stabben in the western part of Jutulsessen, particularly large numbers of* Maudheimia wilsoni *was found in the proximity of the location of Troll and large numbers of* Tydeus erebus *at the base of Grjotlia, approx. 2.5 km south of Troll.* Maudheimia wilsoni *was studies in greater detail. It was found to be numerous on the underside of stones at Jutulsessen. Daily temperature fluctuations of the microhabitat from as high as 19ºC and to as low as -17º-C were observed during the austral summer (NPI, 1990).*

[13] *ATCM XXVII advised that further details on the biodiversity of the area be provided. Records of earlier registrations have been studied in detail and some additional information has been added to the description. However, no detailed geographic information (mapping) of biota in the area is available. Efforts will be initiated to remedy this situation.*

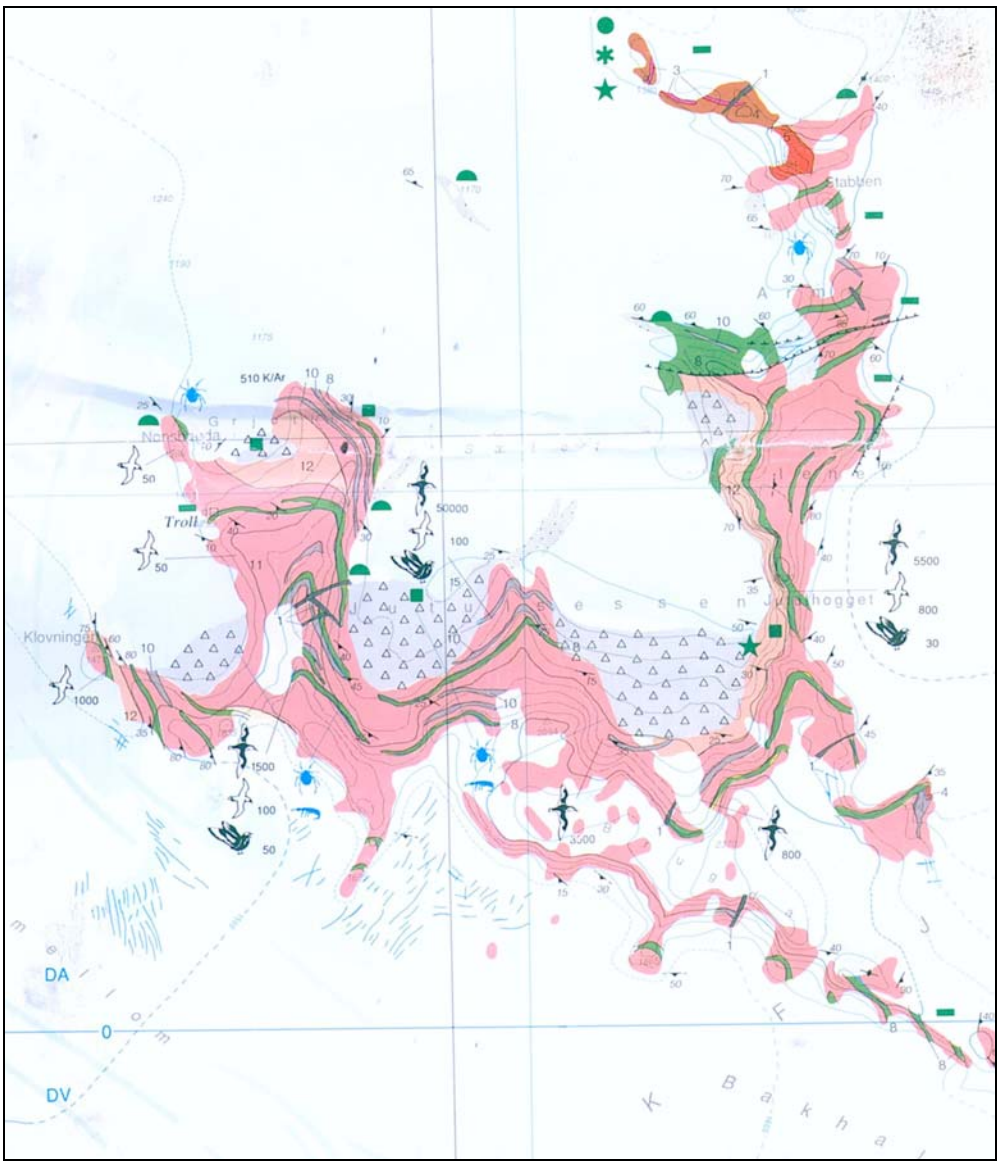
Table 21: Flora and Fauna registered in the Jutulsessen area

Flora	
Lichens	*Acarospora buellia* *Candelariella hallettensis* *Lecanora expectans*
Green algae	*Prasiola crispa* *"Pleurococcus"* *Ulothrix*
Blue-green bacteria	
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 consists 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 9. *Røv (1991) registered one large colony of Antarctic petrels in the "bottom" of Jutulsessen (Sætet), consisting of one sub-colony approx. 10 km air distance from Troll and one sub-colony approx. 6 km air distance from Troll. It is estimated that there are 20-50,000 pairs in this colony.* In the vicinity of the Troll station are two small colonies (~50 pairs) of snow petrel, one just north of the station in the Nonshøgda area and one just south of the station area. Breeding south polar skuas are registered in the Jutulsessen (approx. 10 pairs estimated), and non-breeding young skuas are observed in the vicinity of the petrel colonies.

A more detailed mapping of the vertebrate fauna in the surrounding area is to be implemented during a planned survey in the 2004/05 season, at which time also further observations regarding micro-fauna and vegetation occurrences will be initiated.

Figure 8: Known seabird colonies in the Jutulsessen area (Source: NPI, 1993)



Source: NPI (1993)

4.4 Conservation of flora and fauna

The following aspects with respect to conservation of flora and fauna should be noted:

- Currently no activity at the Troll station directly interferes with the flora or fauna in the Jutulsessen area. Further impact assessments will be conducted before reaching conclusions with regard to location of facilities (e.g. air monitoring facilities, antenna park) outside the currently exposed station area.

- Vegetation: The areas immediately surrounding the station (radius of approx. 500 m) are considered as disturbed areas and pedestrian activity is not restricted in these areas. No rare occurrences have been registered close to Troll, and consequently such disturbance has not been considered significant. Vehicle traffic on ice-free ground is kept to a minimum, but is necessary for supply and construction purposes.

- Bird colonies: The bird colonies close to the stations are not visited unless in connection with approved research. When utilizing motorized vehicles personnel are instructed keep a distance of at least 200 meters from bird colonies. Aircraft and helicopter traffic to the station is kept to a minimum, and care is taken to keep a distance to the nearby bird colonies.

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 upgrading of Troll to an all-year station.

The process used in assessing the activity has in principle 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 interaction 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 upgrading 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 6. 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 upgrading 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 7. No environmental elements of high value were identified. Two elements of

medium value were identified, and a number of elements of low value were however noted, such as flora, fauna, atmosphere, ice, geology 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 8. It is important to note that the exposure level is relatively low for most outputs identified in relation to the planned activity.

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 22 and Table 23 below. These are impacts that can be expected assuming that the activity is conducted in accordance with the framework defined in this document. The following terms have been defined in assessing the impacts:

	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. In Table 22 and Table 23 these are marked with grey shading. Prioritization will be given to efforts minimizing these impacts.

5.6.1 Impacts on Environmental Elements of High Value

No environmental elements of high value have been identified (cf. Appendix 7).

5.6.2 Impacts on Environmental Elements of Medium Value

Two environmental elements of medium value have been identified (cf. Appendix 7). In Table 22 these have been listed in accordance with the level of exposure to outputs (cf. Appendix 8).

5.6.3 Impacts on Environmental Elements of Low Value

A number of environmental elements of low value have been identified (cf. Appendix 7). In Table 23 these have been listed in accordance with the level of exposure to outputs (cf. Appendix 8).

Table 22: Potential Environmental Impacts from station operations

	Output	Description of potential impact	Evaluation of impact	Mitigation	Alternatives
Medium Exposure	**Atmosphere**				
	Emission to air	Combustion 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[14] 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. Since atmospheric research is planned as one of the main elements of the all-year activity at the station, such emission may have undesirable effects.	Extent: H Duration: L Intensity: L Probability: H	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts	All alternatives will entail use of fuel. The associated emission impacts are expected for all alternatives. In the 0-alternative emission is expected to be lower and the associated impacts thereby also somewhat lower, although not absent.
Low Exposure	**Freshwater**			-	
	Emission to ground	Fuel spills in station area may migrate in direction of freshwater reservoir under the blue-ice. Effects are mainly operational in the sense that drinking water will be exposed and potentially made unusable. Earlier measurements have indicated PAH-remains (very low quantities) in the drinking water (NIVA, 2000), which may stem from ground pollution, but which might also come from the equipment used to install water pump and pipes. Contamination will remain in reservoir over a long period due to a likely lack of water exchange in the reservoir.	Extent: L Duration: M Intensity: L Probability: L	- Fuel management procedures to ensure minimal spills. - Procedures for handling of water system.	All alternatives will entail handling of fuel. The associated impacts are expected for all alternatives.

[14] *An annual consumption of 190,000 liters estimated for Troll (including all transport, but excluding any future outlying research or monitoring facilities). For comparison the following examples are given: Expected fuel consumption at South Pole Station after reconstruction is 1,200,000 liters (NSF, 1998), estimated annual consumption is 230,000 liters at Maitri (MFA, 2001); 350,000 liters at Novolazarevskaya (MFA, 2001); 180,000 liters at Neumayer (MFA-Finland, 2004) and 260 tons at SANAE IV (MFA-Finland).*

Table 23: Potential Environmental Impacts from station operations

	Output	Description of potential impact	Evaluation of impact	Mitigation	Alternatives
High Exposure	**Flora**				
	Mechanical actions and obstructions	Construction of new station elements and associated use of vehicles may disturb small vegetation patches in the station areas. Increased pedestrian traffic in the station area (radius 500 meters) will likewise have such effect (Komarkova, 1983). Re-growth in damaged areas will be slow. Vegetation patches occur only sporadically in the area, and no unique assemblages have been recorded.	Extent: L Duration: H Intensity: L Probability: M	No mitigative measures identified.	All alternatives will entail some construction and vehicle use and thereby the associated impacts.
	Fauna				
	Mechanical actions and obstructions	Construction of new station elements and associated use of vehicles may disturb areas with micro-fauna in the station area. Such areas have not been identified, but likely occur throughout the area. No unique assemblages or species have been recorded.	Extent: L Duration: H Intensity: L Probability: H	No mitigative measures identified.	All alternatives will entail some construction and vehicle use and thereby the associated impacts.
	Ice-free ground				
	Mechanical actions and obstructions	Construction of new station elements and associated use of vehicles will disturb the ground in the station area.	Extent: L Duration: H Intensity: L Probability: H	Permanent tracks will be established and thereby reduce random vehicle use.	All alternatives will entail some construction and vehicle use and thereby the associated impacts.
	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	Efforts will be taken in the planning phase to consider aesthetic issues with regard to the expansion of the station complex.	All alternatives will entail some surface grooming and thereby the associated impacts on aesthetics.

Medium Exposure	**Fauna**				
	Emission to air	Combustion compounds may reach the seabird colonies in the vicinity of the station, but will be limited due to distance and prevailing wind direction. Although combustion products can affect birds (habitat and health), the exposure is limited due to relatively low emission levels from Troll. 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)).	Extent: L Duration: L Intensity: L Probability: H	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts	All alternatives will entail use of fuel. The associated emission impacts are expected for all alternatives. In the 0-alternative emission is expected to be lower and the associated impacts thereby also somewhat lower, although not absent. Alternative solutions such as wind generation power poses other dangers, such as death by collision.
	Emission to ground	Some micro-fauna and micro-flora and their habitat may be exposed to pollution, limited to the area of wastewater discharge and fuel handling. Exposure will likely destroy individuals and local habitat. No unique assemblages recorded, and affected area will be limited. Elements are not important aspects of a wider food web.	Extent: L Duration: H Intensity: H Probability: H	- Water treatment system that ensures discharge of clean water. - Water conservation efforts. - Fuel management procedures to ensure minimal spills.	All alternatives will entail use of fuel. Spills to ground will be likely. Retrograding of wastewater would reduce impact due to discharge of water, but increase emission to air.
Medium Exposure	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 and Riddle (1999)). It is expected that the limited exposure to output will be too low for any significant impact. Note also that exposure doe not change from current situation, where generators are operated throughout the summer season, the time that the birds are present.	Extent: L Duration: L Intensity: L Probability: H	- Efforts to minimize generator need during summer season by focus on alternative energy. - Construction of generator building as to ensure minimal noise exposure.	All alternatives will entail use of generators and equipment. The associated impacts are expected for all alternatives. Alternative energy sources may reduce reliance on generator and thereby reduce exposure.

	Ice-free ground				
	Emission to air	Combustion gases released into the atmosphere will settle in the area surrounding the station, although areas further away is less affected due to distance and prevailing wind direction. Fall-out remains and builds up in the environment due to slow break down and limited wash-out. Ground quality is affected over time, thereby changing the environmental quality of the micro-habitats.	Extent: L Duration: H Intensity: H Probability: H	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts	All alternatives will entail use of fuel. The associated emission impacts are expected for all alternatives. In the 0-alternative emission is expected to be lower and the associated impacts thereby also somewhat lower, although not absent.
	Emission to ground	Ground cover may be exposed to pollution, limited to wastewater discharge area and fuel handling area. Fuel pollution will remain in ground for a long time due to slow natural breakdown processes (Gore et al., 1999). Wastewater is likely to ablate (cf. experience from the area) to a large degree, although ice build-up may be expected during winter season. Wastewater treatment system will ensure minimal pollution in discharged water and thereby exposure to pollution.	Extent: L Duration: H Intensity: H Probability: H	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts - Wastewater treatment. - Water conservation efforts.	All alternatives will entail use of fuel. The associated emission impacts are expected for all alternatives. Retrograding of wastewater would reduce impact due to discharge of water, but increase emission to air.
	Wastes	Littering from station operations is likely. The effects will mostly be of aesthetic character, although some litter may pose a threat to individual birds in the area (Wang and Norman, 1993).	Extent: L Duration: M Intensity: L Probability: M	- Waste handling procedures	All alternatives are likely to entail some risk of littering. All-year operations will ensure facilities and human resources to keep risk to a minimum.

Medium Exposure	**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. Worren and Clarke (1990), 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: M	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts	All alternatives will entail use of fuel. The associated impacts are expected for all alternatives. Use of alternative energy sources will reduce the exposure.
Low Exposure	**Flora**			-	
	Emission to air	Uptake of combustion products may in the long run inhibit growth and reproduction in plants (Poblet et al. 1997). 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	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts	All alternatives will entail use of fuel. The associated impacts are expected for all alternatives. Use of alternative energy sources will reduce the exposure.

Low Exposure	Emission to ground	Habitat may be exposed to pollution, limited to wastewater discharge area and fuel handling area. Few vegetated areas around station, and no unique assemblages recorded. Fuel remains in ground for a long time due to slow natural breakdown processes, and thereby destroys habitat. Wastewater likely to ablate (cf. experience from the area), although ice build-up may be expected during winter season. Wastewater treatment system will ensure minimal pollution and thereby reduce exposure to pollution, although habitat may be destroyed by ice. Fertilizing in the area may produce new habitats for vegetation and micro-flora.	Extent: L Duration: H Intensity: L Probability: H	- Use of "clean" fuels as far as possible - Develop alternative energy solutions - Energy conservation efforts - Wastewater treatment. - Water conservation efforts.	All alternatives will entail use of fuel. The associated emission impacts are expected for all alternatives. Retrograding of wastewater would reduce impact due to discharge of water, but increase emission to air.
	Non-native organisms and disease	There are well-known examples of experimental and accidental introductions of non-native organisms in Antarctica. It is, however, considered likely that most non-native organisms will not find suitable environment to thrive in the Troll area (due to climatic and other environmental factors). Non-native organisms can displace existing vegetation and micro-flora/fauna (Smith, 1996).	Extent: L Duration: H Intensity: H Probability: L	- Procedures to discourage introduction (cleaning of equipment, checks on fresh food supplies, etc.) - Wastewater treatment	All alternatives are likely to entail some risk. Winter operations should not increase risk significantly as this is period of low biological activity.
	Fauna			-	
	Wastes	Littering from station operations is likely. Some litter may pose a threat to individual birds in the area (visiting skuas or birds in the nearby colonies). Some waste can become "traps" (straps, bands, sharp objects, etc.) and could cause death or injury to individual birds.	Extent: L Duration: M Intensity: L Probability: M	- Waste handling procedures	All alternatives are likely to entail some risk of littering. All-year operations will ensure facilities and human resources to keep risk to a minimum.

	Non-native organisms and disease	There are well-known examples of experimental and accidental introductions of non-native organisms in Antarctica. It is, however, considered likely that most non-native organisms will not find suitable environment to thrive in the Troll area (due to climatic and other environmental factors). Human activity can be the cause of disease outbreaks, bringing pathogens unintentionally into Antarctica. So far few, if any, disease outbreaks are however known to have been introduced to Antarctica as a result of human activity. Disease could be detrimental to populations (Knowles et al., 1999 and Gardner et al., 1997).	Extent: L Duration: H Intensity: M Probability: L	- Procedures to discourage introduction (cleaning of equipment, checks on fresh food supplies, etc.) - Wastewater treatment	All alternatives are likely to entail some risk. Winter operations should not increase risk significantly as this is period of low biological activity.
	Ice			-	
	Emission to ground	Some fuel spills may be expected with activity in the blue-ice area near the station. 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	- Fuel management procedures to ensure minimal spills.	All alternatives will entail handling of fuel. The associated impacts are expected for all alternatives.
	Waste	Some littering in the station area may be expected to reach the nearby blue-ice area. Associated impacts are mainly of an aesthetic nature. Break-down of litter is slow, and litter will remain. Contributes to overall contamination of environment.	Extent: L Duration: M Intensity: L Probability: M	- Waste handling procedures	All alternatives are likely to entail some risk of littering. All-year operations will ensure facilities and human resources to keep risk to a minimum.
	Mechanical action and obstruction	Due to traffic on the ice to and from the station, some abration must be expected. Due to general ablation in the area, the impacts are not likely to have any further impacts on environment.	Extent: L Duration: M Intensity: L Probability: L		All alternatives will entail transportation and traffic in the area. Associated impacts are expected for all alternatives.

Low Exposure	**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: H Intensity: L Probability: H	- Fuel management procedures to ensure minimal spills.	All alternatives will entail handling of fuel. The associated impacts are expected for all alternatives.
	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: H Intensity: H Probability: H	No mitigative measures identified.	All alternatives will entail noise. The associated impacts are expected for all alternatives. Use of alternative energy may reduce need for generator and reduce associated noise.

5.7 Identification of unavoidable impacts

Impacts identified to have a medium or high probability are considered to be unavoidable (cf. Chapter 5.6). Efforts to minimize these impacts will be instituted in accordance with mitigative measures. The following impacts with both high probability and high intensity have been identified, and merit prioritization in further mitigation efforts:

- Disturbance of micro-organisms (flora/fauna) due to discharge of wastewater. Local impact on low environmental value.
- Impacts on ice-free ground due to settling of combustion products. Local impact on low environmental value.
- Impacts on ice-free ground due to spills and discharge of substances to ground (wastewater, fuel spills, etc.). Local impact on low environmental value.

5.8 Indirect impacts

Potentially the opening of the Troll station as an all-year station *in addition to opening the Troll Runway* would add to the pressure on the Jutulsessen area as a staging area and 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. *It should be noted that Troll Runway is established by DROMLAN, an international consortium consisting of 11 operators of national Antarctic programs, with the purpose to provide air transport to/from and within Dronning Maud Land (DML) to any member country of COMNAP in science related activities (ATCM, 2004).*

Larger quantities of supplies may lead to some additional pressure on the Troll losseplass due to storage over longer periods of larger quantities of fuel (see footnote 10). It should be noted, however, that fuel is currently stored in 200-liter drums, limiting the volume of any spills. Fuel is also secured appropriately to withstand the pressures of the environment.

5.9 Cumulative impacts

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 relatively major changes occurring in the area, ie. increase in air traffic and upgrading of Troll to an all-year station, the related influx of national program personnel and the potential increase in non-governmental activities, will all 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 higher intensity with respect to use of the area, be it recreational activities, expansion of existing facilities, establishment of new facilities, etc. Even so, the additional impact caused by the upgrading of Troll will still be relatively non-obtrusive. The following may be noted in this respect:

- The planned activity will lead to additional fuel combustion and thereby a higher level of emission to air *(see Table 24)*. The total level of emission is still relatively low, *compared both to global values and to comparable operations in Antarctica (see footnote 14), and relative to levels considered harmful to the environment.* The cumulative consequences for the local environment are therefore not considered significant.
- Stress for the seabirds in the Jutulsessen area may increase due to the increased operations, but impacts on fauna due to the upgrading are expected to be quite limited since the main change in activity will occur in the season of low or no biological activity. The cumulative stress caused by the addition of the planned activity is therefore expected to be low.
- *The ice-free areas in the interior of Antarctica are relatively rare, and are as such vulnerable. All the on-going activity in the Troll area adds pressure on the land use. Although the station building mass will expand with the upgrading to an all-year station, the area affected by the building mass will remain relatively constant, as expansion will occur within the perimeters of the already affected station area (cf. 3.2.3.1). The Troll Runway is prepared on the blue-ice, and does not as such directly affect the ice-free areas. An unknown, and somewhat unpredictable factor, is the future potential addition of research and monitoring facilities associated with the station. Stipulating that a total area of 3.5 km^2 would be impacted directly by station and facility operations in the future[15], less than 2% of the ice-free ground in the Jutulsessen area would be affected.*
- With the upgrading of Troll to a permanent station, it is likely that atmospheric research and monitoring will be important elements of the research to come. This requires a clean environment (pollutants/noise), and efforts will therefore be made to ensure limited impact on the science, which also will have positive consequences with regard to environmental impacts. Reference is here made to experience from the research station in Ny-Ålesund on Svalbard (www.kingsbay.no), where major efforts have been instituted to ensure a clean environment.
- 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.

[15] S*tipulated by assuming that Site 2 (cf. figure 6) will be utilized for outlying facilities, noting however that the area directly impacted by the operations of the upgraded station will be approx. 0.5 km*^{2}.

Table 24: Annual fuel consumption and emission from the operations at Troll

		Summer operations only	***Summer operations and operation of TR***	***All-year operations and operation of TR***	***All-year operations (incl. outlying facilities) and operation of TR***
Transport and energy production	*Generator*	*6,700 liters*	*6,700 liters*	*100,000 liters*	*100,000 liters*
	Transport local	*1,000 liters*	*1,000 liters*	*2,000 liters*	*2,000 liters*
	Transport regional	*5,000 liters*	*5,000 liters*	*24,000 liters*	*24,000 liters*
	Grooming Troll Runway[a]	*NA*	*5,100 liters (17000 liters)*	*5,100 liters (17000 liters)*	*5,100 liters (17,000 liters)*
	Outlying facilities	*NA*	*NA*	*NA*	*150,000 liters*
	TOTAL	*12,700 liters*	*17,800 liters (29,700 liters)*	*131,100 liters (143,000 liters)*	*281,100 liters (293,000 liters)*
CO_2 emission (high values)		***33 tonnes***	***47 tonnes (78 tonnes)***	***345 tonnes (375 tonnes)***	***740 tonnes (770 tonnes)***
Aircraft operation[b]		*7,000 liters*	*130,000 liters*	*130,000 liters*	
CO_2 emission (high values) aircraft		*18 tonnes*	*340 tonnes*	*340 tonnes*	
Total CO_2 emissions (incl. aircraft)		*51 tonnes*	*387 tonnes (418 tonnes)*	*685 tonnes (715 tonnes)*	

[a] *Number in brackets suggests intermittent seasons with high maintenance intensity.*
[b] *Level of fuel consumption for aircraft operations is estimated on a **total** roundtrip basis (ie. currently estimated to 3 roundtrips from/to Cape Town), noting however that a number of flights to Troll are likely to serve other operators as well, and may not necessarily reflect activity originated by the Troll station.*

5.10 Evaluation of impacts on ongoing activities

5.10.1 Science

No negative effects are expected on ongoing scientific activities. A positive consequence for ongoing research is the improvements to operations at the station. Smoother operations, which are a likely consequence of the upgrading and the fact that there will be presence throughout the year at the station, will benefit the ongoing research activity. Preparation of equipment for fieldwork can be completed before arrival of research teams, facilities at Troll will provide better back-up capabilities, etc.

Furthermore, the all-year capabilities of the station will provide a new and improved platform for new research initiatives and thereby provide a more solid platform for Norwegian research in Antarctica.

5.10.2 Operations

The proposed changes and upgrading of the station are not expected to have negative consequences for the operations at Troll. On the contrary, the expectation is that new technology, new facilities and continuation in presence all will contribute to a smoother and better-implemented operation.

6 Monitoring

A separate monitoring protocol has been prepared for the NARE operation (NPI, 1999b). The aims of the monitoring program are to:

- assess whether the actual impacts from the activity are as anticipated
- establish the geographic extent of impact, and assess any changes to this "footprint"
- provide a basis on which to initiate processes to mitigate and minimize impacts
- assess changes in intensity of activity
- ensure that the activity is carried out in accordance with international agreements and national legislation

Currently the monitoring program bases itself mainly on registration of activity, ie. fuel consumption, fuel spills, presence at station (person days), waste produced, etc.

The goals of the monitoring program will remain the same at the upgraded station, but an updated practical monitoring plan will be developed in order to take into account the new operational framework as well as take advantage of the opportunities the all-year presence gives for more specific and analytic monitoring.

7 Gaps in knowledge and uncertainties

The following gaps and uncertainties have been identified with regard to the assessment of impacts stemming from the proposed project:

- Limited written information regarding the environment (especially with regard to flora and micro-organisms). However, many years of operation at the station has given the operator a relative intimate understanding and knowledge of the area, which has provided basis for this assessment.
- *A more detailed mapping of the vertebrate fauna in the surrounding area is to be implemented during a planned survey in the 2004/05 season, in which further details about the surrounding environment will be mapped.*

8 Conclusions and recommendations

It is the Norwegian Polar Institute's conclusion that the unavoidable environmental impacts of the upgrading of Troll and associated activities will be of no more than a minor or transitory character. The NPI therefore recommend that the proposed activity be implemented as described, under the condition that the activity is conducted in accordance with the given framework, that separate environmental impact assessments be conducted for the various components that will be instituted, that the

mitigative measures described in this document are followed, and that an appropriate monitoring protocol is prescribed.

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Appendix 1: Procedures for fuel storage, transfer and transport

Fuel spills in Antarctica can cause long-lasting environmental damage. The physical conditions in Antarctica retard the decomposition of the fuel products, and clean-up efforts are made difficult by the conditions as well.

The best strategy is to prevent spills from happening in the first place. This means that any person handling fuel in Antarctica has a certain responsibility to ensure that spills do not occur. All expedition members should therefore be aware of the guidelines outlined below and act accordingly.

Fuel Storage

- ✓ Fuel must not be stored in the vicinity of environmentally sensitive areas, i.e. vegetated areas, fresh water, bird colonies, etc.
- ✓ Store all containers, drums, etc. in such a way that any drips, leaks and spills will not enter into the environment. An accumulation of such minor releases can easily add up to unnecessary contamination.
- ✓ Fuel shall only be stored in containers specifically designed for the products being stored, and suitable for the prevailing climatic conditions.
- ✓ Containers must not leak, and must be sealed with a proper fitting lid or cap.
- ✓ Keep lids, valves, etc. tightly closed except during transfer of fuel.

Transport of fuel

- ✓ During transport all drums must be transported upright and properly secured to the vehicle to prevent shifting or swaying in any manner. All drums should be tied down with adjustable straps to restrict any shifting of the load.
- ✓ Containers of 20 liters or less should be stored in leak proof storage box during transport. This will keep the containers from bouncing out of the vehicle and will contain any spillage that may occur from small leaks.
- ✓ Maintain appropriate spill handling equipment with the transport vehicle. If leaks and spills are noticed, these should be stopped and contained immediately. Fuel from leaky or damaged containers should be transferred to un-damaged containers or to a safety drum.

Handling & Transfer of fuel

- ✓ Re-fuelling should as far as possible occur sheltered from the wind.
- ✓ During fuel transfer absorbent material should always be available. Fuel spills and leaks shall be removed with the aid of absorbents and disposed of in an approved manner.
- ✓ During fuel transfer operations absorbent mats should as far as practicable be used to avoid accidental spills to the ground.
- ✓ All spills and leaks must immediately be contained, cleaned and disposed of in an approved manner according to procedures described in the Oil Spill Contingency Plan (OSCP).
- ✓ Ensure that all spills are to be reported according to the procedures described in OSCP. Spills larger than 200 liters are to be reported to expedition leader immediately.
- ✓ All sources of ignition must be eliminated or removed while refueling.

Maintenance & Inspection

- ✓ Fuel containers should be superficially (visually) checked for leaks and spills by any person having errands in the fuel storage area.
- ✓ All fuel storage drums are to be thoroughly inspected on a weekly basis, and as soon as possible following adverse weather. The storage drums and storage area should be checked for leaks, spills, deformed drums, etc. Any leakage shall be repaired as quickly as possible.

Appendix 2: Fuel spill response guidelines

Initial assessment

The observer of the spill must carry out an initial assessment of the situation. He/she must check the:

1) Probable quantity of fuel spilled
2) Type of fuel
3) Location of the spill
4) Probable source and cause
5) Risk of fire or harm to human health

Initial notification

If spill is assessed to be larger than 200 liters the observer of the spill must notify expedition leader and communicate the information obtained in the initial assessment.

Response team

If spill is assessed to be less than 200 liters, observer initiates further response alone or with present personnel. Observer should request additional personnel if deemed necessary.

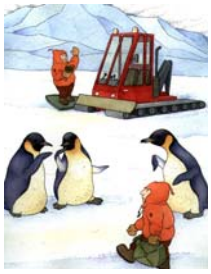
If spill is assessed to be larger than 200 liters, the Expedition Leader must decide on the most appropriate response strategy and ensure the presence of adequate personnel to take care of the spill. It is the duty of the selected personnel to protect:

1) Health and safety
2) Station facilities
3) Threatened resources

General clean-up procedures

Although each oil spill is different, general common procedures are outlined below:

- ✓ Ensure oil spill equipment is in a known and accessible location.
- ✓ If a spill occurs, stop or minimise any further spillage. Ensure safety of all personnel. Check for fire and explosion risk. Ensure safety equipment is worn.
- ✓ For all spills, deploy absorbents to contain fuel if possible. It may be possible to hold fuel in depressions by using absorbent materials, or by building small dams.
- ✓ If possible use pump to remove fuel from ground straight into 200 liter drums. Ensure that sufficient good quality empty drums are available near the spill site.
- ✓ Put absorbent pads on any remaining fuel or oil outside which cannot be pumped or manually removed. Oil soaked absorbents must be picked up and put into plastic bags and/or empty 200 liter drums.
- ✓ Contaminated snow can be stored in 200 liter drums which have had their tops removed. Allow the snow to melt and decant off fuel.
- ✓ Any waste drums containing a mixture of fuel and snow or water are likely to freeze. To prevent drums from splitting, use only those in good conditions. Do not fill completely.
- ✓ Drums of recovered fuel/water, oil soaked absorbents and contaminated clothing must be sent for disposal outside Antarctica. Follow the disposal instructions given in the Nordic Waste Management Handbook.



Appendix 3: Summary guidelines – Helicopter and aircraft operations

Wildlife

- ✓ Helicopters and small aircraft should not land or fly within 2000 meters horizontal and 2000 meter vertical separation of concentrations (20 or more animals) of birds and seals.
- ✓ When helicopters or aircraft are to be used closer to colonies/rookeries than the above stipulated 2000 meters, they should preferably not be used during incubation and weaning.

- ✓ All helicopters and aircraft should maintain a 300 meter vertical and horizontal separation limit above and around whales.
- ✓ If weather conditions make it impossible to maintain the minimum separations, then the flight should be postponed if possible.
- ✓ When approaching land, a flight path as low to the horizon as possible should be chosen. Seabirds are more alarmed by helicopter and aircraft above them than low to the horizon.
- ✓ Helicopters and small aircraft should always land downwind of wildlife concentrations to minimise disturbance due to noise, dust and exhaust fumes.
- ✓ In unfamiliar areas care should always be taken in order to avoid flying over concentrations of wildlife.

Lakes

- ✓ Helicopters and small aircraft should avoid flying over known lakes at altitudes of less than 500 meters or operate upwind of lakes, even when frozen, to prevent dust and exhaust fumes from settling on lake surfaces.

Vegetated areas

- ✓ Helicopters and aircraft should not land on, or immediately upwind of, vegetated areas, this in order to avoid physical damage to, or dust and exhaust fumes settling on vegetation.

Station Areas

- ✓ See the site specific guidelines pertaining to use of helicopters and aircraft at the Nordic stations

Protected Areas and Managed Areas

- ✓ Most Antarctic Protected and Managed Areas have strict regulations with respect to helicopters and aircraft. Before approaching, flying over or landing in a designated Protected or Managed Area, consult the management plan for the site in question.

Refueling and Maintenance

- ✓ Scheduled refueling and aircraft maintenance work should whenever possible be undertaken at fixed sites. At the Nordic stations these fixed sites are equipped with an absorptive mat or other foundation that will prevent large and small spills from reaching the ground.
- ✓ Refueling is not to occur in Protected Areas unless such action is permitted through the management plan.
- ✓ Refueling should not occur near concentrations of wildlife, lakes or vegetated areas unless helicopter or aircraft has been permitted to land near such areas in association with approved research.
- ✓ Fuel drums and other equipment must be removed from field sites at the conclusion of the refueling and maintenance operations.
- ✓ All helicopters and aircraft are to have the following equipment available in order to clean up spills from the refueling/maintenance operations:
    - ◊ absorption mats/pillows
    - ◊ plastic bags to dispose of soiled equipment

Appendix 4: Waste Management Guidelines

Waste Minimization

- ✓ Minimize purchase of products with plastic, glass or other bulky packaging material.
- ✓ Buy durable products instead of disposable products.
- ✓ Get rid of unnecessary packaging material (especially plastic) before leaving for Antarctica.
- ✓ Substitute shredded paper, polystyrene chips, beads and other similar loose packaging material with bubble wrap, cardboard or paper.
- ✓ Buy products that easily can be re-used for other purposes.
- ✓ Use packaging material that can be re-used.
- ✓ Re-use products/material whenever this is practicable.

Waste Removal

- ✓ No waste is to be disposed of in Antarctica unless special permission has been granted.
- ✓ No open burning of waste is allowed.

Environmentally harmful products

- ✓ Polychlorinated biphenyls (PCB), non-sterile soil, polystyrene chips/beads and similar forms of packaging material, pesticides (except that which is necessary for research or medical/hygienic reasons) are not to be brought to Antarctica.
- ✓ The use of polyvinylchloride (PVC) products is highly discouraged.
- ✓ The introduction of non-native (non-indigenous) species of animals and plants (including seeds) and any non-native microorganisms (including viruses, bacteria, parasites, fungi and yeast) requires a special permit.
- ✓ Products and substances that have a potential harmful environmental effect should be treated with special attention so that no emission and dispersal occur.

Separation of waste

- ✓ Waste is to be separated into the following categories:

BLUE	metal waste
GREEN	glass waste
ORANGE	mixed solid wastes
BLACK	sewage and food waste
BROWN	liquid kitchen waste/waste water

Sewage

- ❖ Discharge of sewage is prohibited under all circumstances unless the project has been granted exemption.
- ❖ Under no circumstances must sewage or domestic liquid waste be disposed of in vegetated areas or in areas with discharge to fresh water.

Hazardous waste

- ❖ Different categories of hazardous wastes should never be mixed together in the same drum or crate.
- ❖ Oil-contaminated soil/water/fabric is to be stored in separate containers (labeled oil polluted soil/water/fabric).

Solids to be combusted

- ❖ No burning is allowed

Radioactive waste

- ❖ For both liquid and solid radioactive waste it is essential that the correct information is provided in the labeling of the containers.

Appendix 5: Environmental Guidelines: Flora, fauna and the natural environment

Human activity can have a large impact on the vulnerable natural environment in Antarctica. Show respect, and do your utmost to ensure that your presence does not harm the environment unnecessarily.

Plants

- ✓ Plants in Antarctica are rare, fragile and grow slowly. Therefore you should avoid areas where mosses and lichens grow. Use established paths and trails where these exist.
- ✓ Establish camps in non-sensitive areas
- ✓ It is prohibited to collect plants without a special permit.
- ✓ It is prohibited to bring plants to Antarctica.

Animals

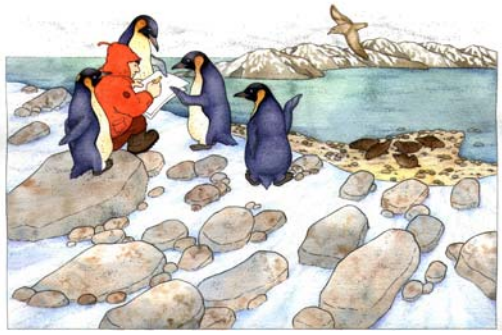
- ✓ Keep distance to animals, and be quiet and calm in their presence. Be especially alert in periods when animals breed. Do not walk through bird and seal colonies unless you are conducting approved research in the area. Avoid use of motorised vehicles closer than 200 meters from any animal.
- ✓ Do not feed, touch or handle birds or seals, or approach or photograph them in ways that cause them to alter their behaviour.
- ✓ It is prohibited to collect animals without a special permit
- ✓ It is prohibited to bring animals to Antarctica

Natural environment

- ✓ Do not paint on rocks or boulders, or in any other manner deface these.
- ✓ Avoid collecting or taking away geological specimens as a souvenir, including rocks, bones, fossils.
- ✓ When leaving a site it should be left in a natural state. Go thoroughly through the area before you leave, and remove waste and other left behind effects.

Protected areas and historic artefacts

- ✓ Always check whether there are Antarctic Specially Protected Areas (ASPA), Antarctic Specially Managed Areas (ASMA), Sites of Special Scientific Interest (SSSI) or registered historic sites and monuments in the areas you are staying in.
- ✓ Special permits are required for entering or engage in activity in ASPAs and SSSIs. The permit must be with you in the field.
- ✓ Most protected areas have management plans. It is your responsibility to familiarise yourself with and adhere to existing requirements and rules as they are articulated in the management plans.
- ✓ Cultural remains shall not be damaged, destroyed or removed.



Appendix 6: Outputs

Note! No outputs (x) that are not already present at the station were identified during the evaluation. In the table below outputs that are expected to increase in intensity are marked in grey shading, unless increased intensity is expected only during the construction phase.

	OUTPUTS							
ACTIONS	**Emission to air**	**Emission to ground**	**Wastes**	**Noise**	**Mechanical Action**	**Heat**	**Obstruction**	**Micro-organisms/ disease**
Vehicles & Machineries operations (incl. aircraft)	**C: X O: X** Exhaust emission. *All alternatives*	**C: X O: X** Exhaust emission. Fuel spills. *All alternatives*	**None**	**C: X O: X** Engine noise. *All alternatives*	**C: X O: X** Ground abrasion. Tracks. *All alternatives*	**C: X O: X** *All alternatives*	**None**	**None**
Facilities & station operations	**C: X O: X** Exhaust emission. *All alternatives*	**C: X O: X** Exhaust emission. Fuel spills. Wastewater disch. *All alternatives*	**C: X O: X** Operat. waste Fuel drums. *All alternatives*	**C: X O: X** Operational noise (generator, etc.) *All alternatives*	**C: X O: X** Snow drift around facilities. *All alternatives*	**C: X O: X** Generator heat. Station heat. *All alternatives*	**C: X O:X** Buildings. Storage areas. Equipment. *All alternatives*	**C: X O: X** Food supplies. Organic waste. *All alternatives*
Human activity	**None**	**None**	**C: X O: X** Littering. *All alternatives*	**C: X O: X** Human noise *All alternatives*	**C: X O: X** Ground abrasion. Tracks. *All alternatives*	**None**	**None**	**C: X O: X** Human carriers (incl. cloth/ equipment). *All alternatives*

C: Construction phase O: Operational phase

Appendix 7: 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 Troll station area and the immediate surrounding area.

Medium: The loss of the environmental elements could have bearings on the regional environment, in this instance Jutulsessen area, or could affect science or station operations.

High: The loss of the environmental elements could have significant bearings for the overall environment in Antarctica.

Environmental Element	Description	Value
Flora	Elements: - Limited flora is present on location. - Sparse occurrences in the Jutulsessen mountains (lichens and algae) Consideration of values: - No unique occurrences/assemblages have been registered in the local area. - Relatively undisturbed outside the local area Background information: - NPI (1990) - Ohta (1993) - NIVA (1991) - NILU	Low
Fauna	Elements: - Micro-fauna is present on location in limited amounts. - Two small snow petrel colonies in the vicinity of Troll – Nonshøgda to the north and an area just south of the station. Sporadic occurrences of skua in station area and Jutulsessen in general. - A number of larger seabird colonies are located in the more remote and inaccessible parts of Jutulsessen Consideration of values: - No unique occurrences registered. - Relatively undisturbed outside the local area. Background information: - NPI (1990) - Bye (1993) - Ohta (1993)	Low
Freshwater	Elements: - Freshwater reservoir in the blue ice in the station area Consideration of values: - Valuable to operations (as drinking water), but not considered environmentally unique. Background information: - NPI	Medium (loss/damage would affect operations)

Environmental Element	Description	Value
Sea water	Not present on location.	N/A
Soil	Elements: - Ground cover in station area Consideration of values: - Ground cover in station area affected by near 15 years of operations at Troll station. - No unique occurrence. Background information: - Ohta (1993)	Low
Air	Elements: - Air Consideration of values: - Air is relatively pristine as only affected by small scale operations at Troll - No atmospheric research currently on-going in area, but will be important in the context of the all-year station. Background information: - Njåstad (2000)	Medium (pollution will affect planned research)
Ice	Elements: - Blue ice area next to station. 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: - The Troll station is located in the Jutulsessen nunataks (description provided in chapter 4.1). 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

Environmental Element	Description	Value
Wilderness	Wilderness is associated with the concept of no physical human presence. As this is an area with station facilities and associated activities, it is considered that wilderness is not present in the station area.	N/A
Aesthetics and intrinsic values[16]	Elements: - Isolated and visually pleasing area, although obstructed by existing station facilities. 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 likely to be considered of higher aesthetic and intrinsic value.	Low
History	No HSM or historic remains in area.	N/A

[16] 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 8: Identification of Exposures

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

None No exposure has been identified
Low Exposure is irregular
Medium Exposure is regular, but not continuous
High Exposure is permanent

Note! No exposures that are not already present at the station were identified during the evaluation. In the table below exposures that are expected to increase in intensity are marked in grey shading, unless intensity is expected to increase only during the construction phase.

	ENVIRONMENTAL ELEMENTS/VALUES						
OUTPUTS	**Flora**	**Fauna**	**Ice-free ground**	**Air**	**Ice**	**Freshwater**	**Aesthetics and Intrinsic values**
Emission to air	**X (low)** Some pollutants may potentially reach vegetated areas in the surrounding areas, but limited due to distance and prevailing wind direction, as well as limited occurrences. *All alternatives*	**X (medium)** Some pollutants are likely to reach the seabird colonies in the vicinity of the station, but limited due to distance and prevailing wind direction. Seasonal due to migration of birds. *All alternatives*	**X (medium)** Fallout of pollutants in the area surrounding the station is certain, and will continue as long as the station is in operation. Ice-free areas further away is less affected due to distance and prevailing wind direction. Increases due to expanded season and higher intensity. *All alternatives*	**X (medium)** Air in local area around station will be exposed to exhaust emission. Increases due to expanded season (all-year) *All alternatives*	**X (medium)** Some combustion products may deposit in the ice surrounding the station. Increases due to expanded season (all-year). *All alternatives*	**None**	**None**

	ENVIRONMENTAL ELEMENTS/VALUES						
OUTPUTS	**Flora**	**Fauna**	**Ice-free ground**	**Air**	**Ice**	**Freshwater**	**Aesthetics and Intrinsic values**
Emission to ground	**X (low)** Some small patches of vegetation may be exposed to pollution. *All alternatives*	**X (medium)** Some micro-fauna may be exposed to pollution, limited to wastewater discharge area and around fuel handling area. *All alternatives*	**X (medium)** Ground cover may be exposed to pollution, but limited to wastewater discharge area and around fuel handling area. Increase due to expanded season and expected higher wastewater discharge. *All alternatives*	**None**	**X (low)** Some fuel spills may be expected with activity in the blue ice area. *All alternatives*	**X (low)** Fuel spills in station area may migrate in direction of freshwater reservoir. *All alternatives*	**X (low)** Spill remains visually affect aesthetic experience, but is limited to effect of station as a whole. *All alternatives*
Wastes	**X (low)** Wastewater may affect micro-flora potentially present in discharge area. Increase due to expanded season and expected higher wastewater discharge. *All alternatives*	**X (low)** Wastewater may affect micro-fauna potentially present in discharge area. Increase due to expanded season and expected higher wastewater discharge. *All alternatives*	**X (medium)** Littering from station operations may occur. *All alternatives.*	**None**	**X (low)** Littering from station operations may occur. *All alternatives*	**None**	**X (low)** Littering will visually affect aesthetic experience. *All alternatives*

	ENVIRONMENTAL ELEMENTS/VALUES						
OUTPUTS	**Flora**	**Fauna**	**Ice-free ground**	**Air**	**Ice**	**Freshwater**	**Aesthetics and Intrinsic values**
Noise	**None**	**X (medium)** Birds in the nearby colonies could be exposed to noise, but limited due to distance and prevailing wind direction. Seasonal due to migration. *All alternatives*	**None**	**None**	**None**	**None**	**X (low)** Noise will audibly affect aesthetic experience. *All alternatives*
Mechanical Action	**X (high)** New station elements and transport associated with construction may disturb vegetation patches in the station area. Pedestrian traffic may cause disturbance to vegetated areas. *All alternatives*	**X (high)** New station elements and transport associated with construction may disturb areas with micro-fauna in the station area. Pedestrian traffic may cause disturbance to areas with micro-fauna. *All alternatives*	**X (high)** Construction and station operations will require use of vehicles in station area and thereby expose the ground to abrasion. Pedestrian traffic may cause abrasion of groundcover in larger area than before due to increased activity/presence. *All alternatives.*	**None**	**X (low)** Some exposure of the blue ice area by the station to mechanical action due to station operations. *All alternatives*	**None**	**X (high)** Indication of mechanic actions may visually affect aesthetic experience. *All alternatives*

	ENVIRONMENTAL ELEMENTS/VALUES						
OUTPUTS	**Flora**	**Fauna**	**Ice-free ground**	**Air**	**Ice**	**Freshwater**	**Aesthetics and Intrinsic values**
Micro-organisms and disease	**X (low)** Human activity may potentially cause introduction of micro-organisms. Exposure to non-native species or diseases could occur. *All alternatives*	**X (low)** Human activity may potentially cause introduction of micro-organisms. Exposure to non-native species or diseases could occur. *All alternatives*	**X (low)** Human activity may potentially cause establishment of non-native flora/fauna. *All alternatives*	None	None	None	None

Appendix 9: Comments on the Draft CEE received from Antarctic Treaty Parties

Comments received from Australia (03.05.04)

Australia has sought input from interested stakeholders in Australia on the draft CEE for the concept of upgrading the Norwegian summer station, Troll, to a permanent 'wintering' station. I would like to pass on our initial comments, prior to formal consideration of the draft CEE at ATCM XXVII/CEP VII.

1. From the comments received, the proposal to upgrade the station does not appear to be of major environmental concern, however, the reasons given for upgrading from a summer to winter station, rather than simply upgrading the general standard of the station, are not clear.

2. Although the draft CEE argues that the establishment of a permanent winter station will allow for enhanced research programs, many of the research examples cited do not appear to be dependent on the existence of such a station:

- the [previous] ornithological work at Svarthamaren involved skuas and Wilson storm and snow petrels; species that are summer breeders and only present from mid-October to March, not during the winter;
- there do not appear to be any seasonal advantages in undertaking geoscience field programs in winter; and
- the option of automatic meteorological monitoring over winter is not fully considered in the draft CEE.

3. There is no persuasive explanation provided in the draft CEE as to why the station's accommodation needs to double (from 9 to 20) in size to accommodate a smaller wintering population (6-8 persons). Although the need for extra accommodation is explained on the basis of potential overlap of succeeding wintering teams, could this brief overlap be accommodated via current emergency accommodation, rather than needing to build a much larger station? Little mention is made of the potential need to accommodate additional people when field personnel are at the station (after arrival in Antarctica, or prior to departure from, Antarctica). It is not evident from the draft CEE whether the increase in accommodation capacity is in fact to house a larger summer population, to undertake an expanded research program.

4. There are no estimates of energy consumption changes due to the increase in station size/capacity, other than to note that it will increase due to winter operations, rather than to heat a larger station area. In addition, the predicted 'doubling' in energy usage for the station because of the needs of air-monitoring facilities is not explained.

5. The draft CEE does not contain environmental baseline data in areas such as local flora and micro-organisms, bird populations [throughout the year], and climate/meteorology. These data would assist in determining potential impacts of the proposal. The draft CEE notes that the operator has "… a relative intimate understanding and knowledge of the area, which has provided basis for this assessment", however, almost none of this knowledge is provided or analysed in the document.

6. There appears to be little consideration given to the possible indirect or second order impacts of the proposed activity, in particular the potential for greater use being made of the Troll *losseplass* (unloading port) and associated 280-km overland route to the station, or to the potential use of the proposed Troll runway. Consideration could have included estimates of increased usage of these facilities and the consequent predictions of environmental impacts.

Comments received from Germany (05.05.04)

Opinion on the Comprehensive Environmental Evaluation (CEE) for the concept of upgrading the Norwegian summer station Troll in Dronning Maud Land, Antarctica to a permanent station, submitted by the Norwegian Polar Institute

Current situation
Norway has decided to upgrade its summer station Troll in Dronning Maud Land, Antarctica, to a permanent station. To this end, a Draft CEE for the international cooperative process prescribed under Art. 8 and Annex I Art. 3 para. 3 of the Protocol on Environmental Protection to the Antarctic Treaty (PEP) was prepared.
The Federal Environmental Agency has made the evaluation accessible to the public as prescribed under Art. 16 para. 1 and para. 2 of the German Act Implementing the Environmental Protection Protocol (AUG) and is forwarding the following German opinion to the States Parties to the Protocol.

Evaluation
The CEE submitted is concerned with the concept for upgrading the Norwegian summer station Troll to a permanent station. On the basis of the CEE evaluation carried out the proposed activity will be permitted. The main work is due to begin next season; smaller-scale work on parts of the project has already begun ("A new container deck is already under construction, and in the future storage containers will be placed on this deck." - see p. 18, 4th indent). Impacts caused by the construction and operation of this station (and subsequent reinstatement) should be evaluated (at a later date) with a focus on individual aspects; a number of conditions should be imposed on the activity (including monitoring).
In the immediate vicinity of the station (6 km), preparations are underway for a runway scheduled to go into operation at the same time.

This approach which seems from our point of view not to be in line with the established standard for environmental impact assessments (methods and procedures) – as provided for under Annex I Art. 3 para. 3 of the Protocol on Environmental Protection (PEP) and as is common practise in the USA, for example– has not resulted in a comprehensive evaluation based on an overall consideration of the impact of the planned activities on the site.
The overall activity has been broken down into individual activities that make up the whole. Cumulative effects caused by

- upgrading the station, and
- the runway

were not considered, although the possibility of an improved air link is probably the most important cause of adverse effects on the environment in the future.

It is understood that the study submitted is only a conceptual study that is not intended to go into detail at this stage, and a decision has been taken for only a part of the project. Nevertheless, it should be possible and would be helpful to explore more of details in a study of this kind: the probable number of staff using the station (in summer and winter) and the sites for the additional/altered buildings are already known (possibly also further details). The question as to why work was begun during the drafting of the CEE (cf. Annex I Art. 3 para. 5 of the PEP)could also arise.

As part of a comprehensive evaluation, it seems useful to pay particular attention to the following points:
The Troll summer station is situated in continental Antarctica, approximately 230 km (144 miles) from the coast. The site is in Dronning Maud Land in the Jutulsessen area on the edge of the Muhlig-Hoffman mountain range on the slopes of the Gjelsvikfjella nunatak. The ground beneath the station site is ice-free permafrost soil consisting of debris and products of weathering. Ice-free areas of this kind occupy less than 2 % of Antarctica's land mass. For this reason, from our point of view, a habitat of this kind merits special protection and the remaining ice-free areas of this oasis that have not to date been used should be preserved as far as possible as a habitat and for scientific purposes.
In this respect the extension of the station could be counterproductive, involving a fourfold increase in developed land in this special area. The number of building projects and also the impact of the expected

increase in visitor numbers (additional scientists from other international research programmes, day-trippers from the camp site at the runway) could also cause further adverse effects.

The details provided on biodiversity in the oasis (cf. p. 36 of the CEE) could still be supplemented. Current microbiological, botanical and zoological inventories seem to be necessary to determine the effect on environmental assets in this area that are relevant from the point of view of nature conservation. A decision on whether the area is degraded or whether biota worthy of protection still exist would be difficult to take until the results of such an investigation are available.

We would also recommend ruling out any potential for commercial tourism to use the runway for intercontinental flights.

Appendix 10: Consideration of CEP VII/ATCM XXVII of the Draft CEE

4b) Consideration of Draft CEEs forwarded to the CEP in accordance with paragraph 4 of Article 3 of Annex I of the Protocol

The Committee considered four draft CEEs and provided advice to the ATCM.

i) Upgrading of the Summer Station at Troll

(20) Norway introduced their draft CEE ATCM XXVII/WP025 *The concept of upgrading the Norwegian summer station Troll in Dronning Maud Land to a permanent station*. Norway circulated the draft CEE to parties in January 2004.

(21) Norway delivered an audio-visual presentation on the project, recalling Norway's long history of Antarctic activity, and noting that the main focus of its current terrestrial research is on glaciology, geology and bird biology.

(22) Norway advised that the main reason for upgrading Troll is to enable support for year round science projects which will be based on a Scientific Strategic Plan 2005-2009 currently under development.

(23) The draft CEE concludes that the expanded operations at Troll will have some effect on the environment but that the impacts will be of no more than a minor or transitory nature.

(24) Comments received during the circulation period and at the meeting, and Norway's response to them included:

- The relationship between the Troll runway and the station.
    - Norway noted that the Troll runway is not a part of the station upgrading project, but an international project with eleven partners and had already been subject to an IEE prepared two years ago.
    - Planning for fuel storage at the Troll runway has not been completed, but the present planning aims at little aircraft re-fueling at Troll, and that therefore the need for significant aircraft fuel storage would be avoided.
    - The upgraded station would still be small and would have little impact on flights. Most of the passengers flown are expected to be summer personnel related to the activities of all the eleven nations sharing the Troll runway.
- The scientific rationale behind the plans;
    - This will be given in the new 2005-2009 Science Plan.
- Energy consumption;

    - Not all the information is yet available on energy consumption, but this will be dealt with in the final CEE.
- The limited baseline data on vegetation and biota;
    - Further information about micro-organisms will be included to the greatest extent possible in the final CEE. The environmental impact on micro-organisms is likely to be very limited.
- Norway's decision to start constructing the winter station before the CEE process had run its course;
    - Norway explained that station construction had not yet begun, but would start in the 2004/05 season. Norway had taken a decision in principle to establish the winter station, and the CEE contributed to developing the "how and where" of the project.
- The question of fuel handling, particularly in winter, when there may be a greater risk of spilling;
    - Norway advised that it is working on procedures for improved fuel storage and handling.
- The dispersal of waste, particularly liquid waste, onto ice-free areas;
    - Referring also to the discussion at CEP IV, Norway noted that liquid waste disposal is a challenge at inland bases. So far there has been no ice build-up noted from the disposal of liquid wastes at Troll. All liquid wastes at Troll pass through purification facilities before release.

(25) The UK congratulated Norway on the draft CEE, noting that Norway has an exceptional capability in air monitoring within its Arctic program at Ny-Alesund, and that similar research at Troll would be likely to have significant scientific value. The UK suggested that the issue of waste water management be referred to COMNAP for recommendations of best practice.

(26) COMNAP recalled that it had been tasked to investigate a related issue on a previous occasion, and had reached the conclusion that the proper treatment of waste water depended on the specific situation and that therefore there was no single "best" practice. COMNAP suggested that the issue was perhaps best addressed in the environmental impact assessment process according to the specific circumstances of a project.

(27) The Committee noted that the issue of liquid waste from inland bases may usefully be discussed further in the context of any future review of Annex III.

(28) Argentina congratulated Norway on its draft CEE, noting that the document followed the EIA guidelines agreed to by CEP II. Furthermore Argentina noted that Norway's compliance with the guidelines makes it easier to understand the text of the evaluation and aids comparison between different CEEs.

(29) Norway thanked the Committee for its comments and suggestions and undertook to address them in the final CEE.

(30) The Chair encouraged members to take note of the CEP Guidelines in preparing environmental impact assessments, and commended Norway's draft CEE as an excellent example of methodology and structure that could serve as a model for other CEEs.

(31) Appendix 1 contains the advice of the CEP to the ATCM on the Troll station draft CEE.

Appendix 1

CEP ADVICE TO ATCM XXVII ON THE DRAFT CEE CONTAINED IN ATCM XXVII/WP 25 (NORWAY)

The Committee for Environmental Protection,

With regard to the draft Comprehensive Environmental Evaluation for "The concept of upgrading the Norwegian summer station Troll in Dronning Maud land, to a permanent station",

Having fully considered the draft CEE circulated by Norway on 25 January 2004, as reported in paragraphs 20 to 31 of the CEP VII Final Report, and

Having noted the comments provided by the Parties to Norway, and Norway's response to those comments,

Provides the following advice to the ATCM:

In general, the draft CEE was well structured, comprehensive, and provided an appropriate assessment of the impacts of the proposed project.

The draft CEE follows the approach suggested by the CEP Environmental Impact Assessment guidelines, and appropriately assesses the impacts of the proposed project.

Ice-free areas such as the area on which the station is located are relatively rare and therefore merit special attention, but notes that although the area of buildings would increase significantly the upgrading would be kept within the general area of the existing station.

Where possible, fuller information and clarification be provided in the final CEE on the following:

1. A fuller description of waste water disposal procedures would be useful to demonstrate that there is a low risk of the escape of bioactive substances into the environment;

2. Further details on biodiversity of the area be provided;

3. The final CEE include further consideration of possible cumulative impacts, in particular in relation to the Troll runway;

Noting the conclusion reached by Norway in the draft CEE that the proposed activity will have no more than a minor or transitory impact on the environment,

Considered that the draft CEE was consistent with the requirements of Annex I of the Protocol and therefore recommends that the ATCM endorse these views.

Appendix 11: Strategy for Norwegian Antarctic Research

DRAFT 28.09.04
Policy platform document:

Norwegian research in the Antarctic: Priorities for the period 2005-2009

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Preface

This *Policy Platform Document for Norwegian Research in the Antarctic 2005-2009* was prepared by the Norwegian National Committee on Polar Research for the Research Council of Norway. It will replace the earlier Research Council document *Strategic Plan for Norwegian Research in the Antarctic (1997)*. During the preparation of the document, the Committee has consulted the Norwegian science community and experts in Antarctic science.

As an active Party to the Antarctic Treaty, Norway has a responsibility for ensuring scientifically based management of the natural resources of the continent. Thus, the Norwegian research and monitoring activities in Antarctica must both serve national obligations and address key questions relating to Antarctica on the international research agenda.

This policy platform is formulated on the basis of key challenges and opportunities specified for Norwegian Antarctic research, new trends in international research in the Antarctic and Norway's overall interests in this context. In keeping with the usual practice for Research Council policy documents, this platform has a five-year time-frame. However, it should be noted that a long-term approach to research efforts in the Antarctic is essential, for example in studies designed to improve our understanding of variability and processes of change in the natural environment.

The Executive Board of the Research Council adopted this policy document *on 13 October 2004*??. The Board would like to emphasise that document outlines general policy issues. This means that it can be used as a basis for further work, but that proposals for specific measures requiring separate funding must be evaluated and processed in the ordinary way, during the normal budgetary process.

Executive summary

Norway has long-standing polar traditions and is the only country with territories both in the Arctic and in Antarctica. In keeping with these traditions, Norway gives high priority to scientific research in the polar regions. Norway is entering a new era in Antarctica in terms of logistics with the establishment of a blue-ice runway at the Troll Station in Dronning Maud Land, and the upgrading of the station to winter-activity status from 2005. The new facilities will make it possible to decouple marine and terrestrial activities, which have until now been closely dependent on each other, resulting in rather strong logistic constraints on the scientific programmes.

In the Antarctic, Norway will concentrate research efforts in fields where Norwegian researchers can make a significant contribution to progress in Antarctic science and provide reliable knowledge for the management of Dronning Maud Land, Peter I Øy and Bouvetøya. Interdisciplinary research in a bipolar context is particularly important for Norway.

On this basis, scientific priorities for the period 2005-2009 will focus on research on climate dynamics (past, present and future), marine ecosystems, and the human dimension. Climate studies will focus on the paleoclimate, the Antarctic ice sheet, the ocean circulation and climate modelling. To understand climatic processes and explain the role of the Antarctic in the global climate system, an interdisciplinary approach is needed that uses both field observations and modelling.

In marine ecosystem studies, special priority will be given to process studies and modelling, and to studies of biological resources and human impacts. An interdisciplinary approach involving both the physical sciences and ecosystem studies is also needed to enhance our understanding of climate and ecosystem processes.

Studies of the human dimension in the Antarctic will focus on problems related to governance, tourism and other human impacts, and the historical heritage.

There will be more emphasis on environmental surveys and long-term monitoring. These activities include topographic mapping and geological mapping and surveying. It is in Norway's national interest to establish long-term environmental monitoring and research programmes at the Troll Station.

The International Polar Year 2007-2008 is likely to offer an excellent opportunity to achieve key objectives set out in this document. Norway should aim to play an active role in IPY 2007-2008.

The scale of the logistic and scientific challenges involved in Antarctic research makes close international cooperation essential, and the increased logistical flexibility both onshore and offshore will mean that stronger national coordination is needed to achieve the strategic goals. Norway should play a more active role in coordinating international research in Dronning Maud Land and adjacent sea areas.

There is a general need to recruit younger researchers to polar research. To ensure future recruitment at the highest levels, it is important to facilitate or encourage students to take masters and doctoral degrees in polar-related subjects. Further work is

needed to develop measurement technology for atmospheric, terrestrial and marine studies specially adapted to polar regions.

The funding for Antarctic research needs to be substantially increased to achieve the intended increase in the level of activity.

1 Introduction

Norway has a long history of whaling, exploration, scientific activity and surveying in the Antarctic. Its interests in these fields prompted the annexation of Bouvetøya in 1930, Peter I Øy in 1931 and Dronning Maud Land in 1939. Norway has also played an important role in Antarctic co-operation through long-term research and active participation in the development of the international legal framework for the management of Antarctica. Two of the post-war milestones in Norway's Antarctic research were the Maudheim expedition (1949-1951), a joint Norwegian-British-Swedish expedition that initiated international scientific cooperation in Antarctica and spent two winters in Dronning Maud Land, and the operation of Norway Station in Dronning Maud Land from 1956 to 1960 in connection with the International Geophysical Year (IGY).

A 15-year hiatus followed, during which Norwegian scientists only participated in expeditions organised by other nations, before the first Norwegian Antarctic Research Expedition (NARE) took place in the austral summer 1976-1977. Three more NAREs were organised in 1978-1979, 1984-1985 and 1989-1990. The Troll Station was erected at Jutulsessen in Gjelsvikfjella in Dronning Maud Land in the austral summer 1989-1990, and was the first Norwegian base established in Antarctica since Norway Station.

In 1991-1992, the first Nordic Antarctic Expedition was organised by Finland, under an agreement between Norway, Sweden and Finland under which each nation was to organise an expedition every third year. Nordic expeditions have subsequently been organised every year, with the exception of the austral summers 1994-1995 and 1998-1999. Norway was responsible for organising the expeditions in 1992-1993, 1996-1997 and 2000-2001. After this, the Nordic collaboration was reorganised to give each country the logistical responsibility for two consecutive seasons. The Nordic collaboration has also benefited from intercontinental flights between South Africa and Dronning Maud Land in the last few years.

In 1993, the Research Council of Norway established the Norwegian National Committee on Polar Research in direct response to a white paper on Norwegian polar research (Report No. 42 (1992-93) to the Storting). Under the auspices of the Research Council of Norway, the committee develops strategic plans for Norwegian polar research, both in the Arctic and in Antarctica. This policy platform document, which covers the five-year period 2005-2009, will replace the existing strategic plan for Norwegian Antarctic research.

In this document, Antarctic research is defined as research conducted on material and phenomena in the Antarctic or that has direct relevance to the Antarctic. Antarctic research is not a separate discipline, but forms part of the research effort in each scientific discipline. The Antarctic region is defined as lying between the South Pole and the Antarctic Convergence, including Dronning Maud Land, Bouvetøya and Peter I Øy.

This policy platform document retains several of the research priorities identified in the previous strategic plan for Norwegian Antarctic research. However, two major logistical developments that are taking place will have an impact on Norwegian

research in Antarctica. Firstly, upgrading of the Troll Station will make year-round research and monitoring possible at the station and in its vicinity. Secondly, regular intercontinental flights between South Africa and Dronning Maud Land will make terrestrial and marine research activities logistically independent of each other. This will give marine research greater geographical flexibility, while terrestrial research in Dronning Maud Land will be more flexible in terms of duration and timing.

2 Vision

Norway will make a significant contribution to Antarctic research in the period 2005-2009, with a special focus on advancing our understanding of the fundamental processes governing variability and change in the Antarctic environment and of the impact of human activity.

3 Rationale

Norway has played an important role in Antarctic co-operation through long-term research and active participation in the development of the international legal framework for the management of Antarctica. Norway is one of the consultative parties to the Antarctic Treaty, and a signatory to a series of agreements adopted under the Antarctic Treaty regime. Under the Treaty, which remains in force indefinitely, Antarctica in effect became a natural reserve devoted to peace and science from 1961. The 1991 Environmental Protocol under the Treaty is an instrument specifically designed to protect the Antarctic environment and dependent and associated ecosystems. Norway's obligations under the Antarctic Treaty system are an important framework for its scientific research in the region.

As an active Party to the Antarctic Treaty, Norway has a responsibility for ensuring scientifically based management of the natural resources of the continent. Norwegian research and monitoring activities will provide the basis for the management and conservation of the natural resources in Norwegian Antarctic territories. Sound management requires a basic knowledge of many areas of the natural and social sciences. Legal and political issues relating to Norwegian obligations under the Antarctic Treaty also require substantial contributions from the scientific community.

Norway is entering a new era in Antarctica in terms of logistics with the establishment of a blue-ice runway at the Troll Station in Dronning Maud Land, and the upgrading of the station to winter-activity status from 2005. The new facilities will make it possible to decouple marine and terrestrial activities, which have until now been closely dependent on each other, resulting in rather strong logistic constraints on the scientific programmes.

This will involve a number of advantages for terrestrial research, including shorter travel times, opportunities for longer and more flexible research seasons (possibility of shorter field periods and exchange of personnel in the course of the season) and lower costs. In the long term, the runway may function as a gateway to Antarctica, resulting in greater international activity and closer scientific collaboration in this part

of Dronning Maud Land. There will be opportunities for year-round research and monitoring, and scientists and students will be able to spend the austral winter in Antarctica for data collection and analysis.

The logistic decoupling will also provide much greater flexibility for marine activities. It will be possible for scientists to join the increasing number of major international expeditions or national and Nordic expeditions, or to make use of various types of commercial marine platforms (fishing and tourist vessels) in the region. There will be fewer geographical restrictions on the choice of research area and more vessel time available for marine scientists.

New generations of climate and ecosystem models and the development of advanced remote sensing techniques have opened the way for a new approach to Antarctic science that is less dependent on field activities. Models can be developed to integrate existing and new multi-disciplinary knowledge and data from a variety of fields, from physics to ecology, into a single system. This system can then be used to assess the current and future state of the marine ecosystem as a function of the main driving forces on the system. Thus, important studies of the Antarctic natural environment can be carried out remotely and Antarctic research does not necessarily involve regular field expeditions to the area.

Traditionally, most Norwegian research in the Antarctic has been oriented towards biology, geology, oceanography and glaciology. In future, an interdisciplinary approach will be needed to enhance our understanding of the Antarctic environment in a global context. Norway has several world-class interdisciplinary research groups in the Arctic. These groups can also make a significant contribution to Antarctic science. A bipolar approach, with a strong emphasis on studies in both the Arctic and the Antarctic, will thus benefit Norwegian Antarctic research. Research on biogeochemical cycles, habitats, biotic adaptations to extreme environments, thermohaline circulation, sea-ice variability, paleoclimatology, ozone/UV radiation and the historical heritage all are examples of fields where we can benefit from a transfer of knowledge between Arctic and Antarctic research. This policy platform document therefore recognises that Norwegian polar expertise can be more fully utilised by carrying out comparative bipolar studies.

4 Objectives and scientific priorities

The Antarctic is a challenging arena for research in a number of fields and many fundamental processes are poorly known. As a small nation, Norway cannot carry out research in all fields, but must concentrate on fields where it can make a significant contribution to progress in Antarctic science and provide reliable knowledge for the management of Dronning Maud Land, Peter I Øy and Bouvetøya.

On this basis, scientific priorities for the period 2005-2009 will focus on research on climate dynamics (past, present and future), marine ecosystems and the human dimension. Interdisciplinary research in a bipolar context is particularly important for Norway. In addition, there will be more emphasis on surveys and long-term monitoring.

4.1 Climate dynamics

The ocean, sea ice, land ice and atmosphere of Antarctica are believed to play a critical role in the global climate system. The specific role of each of these elements has changed through geological time. Basic information on each element of the system and on their interactions in geological time is stored in ice and sediment records. Climate models can be tested by analysing past records. In this field, research will focus on the paleoclimate, the Antarctic ice sheet, the ocean circulation and climate modelling. To understand climatic processes and explain the role of the Antarctic in the global climate system, an interdisciplinary approach is needed that uses both field observations and modelling. An interdisciplinary approach involving both the physical sciences and ecosystem studies is also needed to enhance our understanding of climate and ecosystem processes.

4.1.1 Paleoclimate

Important research areas will be:

- The long term variability of the Antarctic ice sheet
- Studies of synchrony and leads and lags between the Northern and Southern Hemispheres during glacial-interglacial transitions
- Climate variability during the Holocene

The Antarctic ice sheet has fluctuated considerably during the past ~35 million years and has been one of the major driving forces for changes in global sea levels and climate throughout the Cenozoic era. Determination of the scale and rapidity of the response of these large ice masses to climatic forcing is of vital importance, especially how fluctuations in the size and thickness of the ice sheet have affected sedimentation on the continental margin, the formation of Antarctic deep bottom water, and the circulation in the oceans. The thick sediment layers accumulated on the continental margin and in sediments around Antarctica hold important climatic records. Future Norwegian activity should focus on sampling (coring and drilling) and analysing this climatic archive, with special emphasis on the variability of the Antarctic ice sheet and other key factors in maintaining the circulation of Antarctic deep, intermediate and surface waters, and on their potential role in driving or amplifying high amplitude climate changes.

Important paleoclimatic information from the terrestrial environment is being provided by the European Project for Ice Coring in Antarctica (EPICA), while similar marine data is available from the IMAGES programme (International Marine Global Change Study) and IODP (International Ocean Drilling Programme). One crucial issue is to study possible inter-hemispheric coupling, for example determine whether Southern Ocean climate regimes have experienced the same type of rapid, frequent changes as the Northern Hemisphere. It is also essential to study synchrony and leads and lags between the Northern and Southern Hemispheres during periods of climate change. The EPICA ice core from Dronning Maud Land is an essential source of information for such studies. Additional important information about inter-hemispheric climatic coupling is to be found in the marine sedimentary archive. Future Norwegian research should primarily explore the combined information from

ice and marine sediment cores. It should focus on glacial/interglacial fluctuations and climate variability during the Holocene. An understanding of the paleoclimatic signals requires knowledge of marine sediments and deposition processes.

4.1.2 The Antarctic ice sheet

The overall research area will be:

- To understand how the ice sheet, ice streams and ice shelves respond to climate variability

Historically, research has focused largely on analysis of ice cores to explore past climate changes. This research should continue, but in addition studies of change in mass balance and ice dynamics are needed to predict the future evolution of the Antarctic ice sheet. Jutulstraumen in Dronning Maud Land is one of the largest Antarctic ice streams. Studies to improve our knowledge of basic glaciological parameters of Jutulstraumen, such as mass balance and velocity/dynamics, should therefore be given priority. Satellite remote sensing techniques are also a powerful tool for large-scale climatic studies in remote areas, and should be used to study glacier characteristics (e.g. surface properties, elevation, velocity).

Interdisciplinary research (glaciology and oceanography) should be conducted with a focus on melt/freeze processes underneath ice shelves. Understanding how the interactions between the ice shelf and the ocean modify water masses in the Antarctic Coastal Current is essential for an understanding of global change. In this context the freshwater flux beneath ice shelves and in the Coastal Current off Dronning Maud Land is very important.

It is generally accepted that the Antarctic ice sheet consists largely of accumulation zones, so that its mass balance is positive. In some areas near the margin, however, there are blue-ice areas that are characterised by negative mass balance and possible melt-related features. Recent changes on the Antarctic Peninsula demonstrate that melting at the surface can be an important trigger for larger changes, such as the disintegration of ice shelves. Recent research using in situ and satellite data as well as model simulations has demonstrated the importance of surface and sub-surface melting for the surface energy balance in Antarctica. This work should be continued to gain an understanding of the consequences of increased melting at both regional and continental scales in Antarctica. It could with advantage be expanded to include bipolar studies, e.g. Antarctica compared with Greenland.

4.1.3 Ocean circulation

Important research areas will be to:

- Understand the Meridional Overturning Circulation (MOC) and its role in the climate system
- Increase general knowledge of the Southern Ocean circulation and related processes

Thermohaline Circulation (THC) is the dominant component of the Meridional Overturning Circulation (MOC) and is driven by differences in the density of the sea water produced by temperature (thermal) and salinity (haline) effects. The driving force for the THC is water mass formation. Formation of sea ice over shallow continental shelves in the southern Weddell Sea releases high-salinity brine, and this cold, saline water contributes directly to deep-water formation. An important challenge for Antarctic science will be to understand the sub-ice-shelf circulation and the fate of the super-cooled and brine-enriched water masses. This is important, because it is uncertain how the Antarctic ice shelves will respond to the predicted climate warming. Thus, processes on the continental shelf as well as below ice shelves should be studied further, both by means of field measurements and by modelling. Monitoring of super-cooled water is particularly important.

The Antarctic Circumpolar Current is by far the world's largest current, and larger by a factor of 3-4 in terms of volume transport than the North Atlantic Current (the "Gulf Stream"). It effectively isolates the Southern Ocean from the rest of the world ocean. Being circumpolar, it provides the link between the deep basins of the Atlantic, Indian and Pacific Oceans. The establishment of transects for long-term monitoring of ocean properties should be considered. However, observations along such transects are very resource-demanding, and international co-operation will be necessary. The importance of long-term time-series is emphasised by climatologists working with global climate models. Atmospheric fallout and transport of radioactive isotopes in the Southern Ocean is believed to be limited, which means that it can provide baseline values for such isotopes. The distribution of these isotopes may also reveal water transport routes. Thus, it would be useful to establish studies of radioactive isotopes in the Southern Ocean.

The release of brine that accompanies formation of sea ice is important with respect to deep-water production, deep-sea oxygenation, uptake of anthropogenic CO_2 by the ocean, and the impact of brine on seawater biogeochemistry in polar regions. Comparative bipolar studies are particularly important because freezing in the Southern Ocean and the arctic seas often occurs in different climatic regimes.

At times, polynyas develop in ice-covered areas; the Weddell Sea Polynya is a well-known example. It occurred in the 1970s near the Maud Rise, where it produced a major climate signal in Weddell Sea Deep Water. Such polynyas can be identified using remote sensing. Carefully designed experiments including both *in situ* measurements and modelling are required to describe the structure of polynyas and to understand the physics that underlies their formation.

4.1.4 Modelling

Modelling is an important tool for understanding interactions between the ocean, the sea ice, the Antarctic ice sheet and the atmosphere.

Important research areas will be:

- To improve parameterisation in regional and Global Circulation Models (GCMs) by process studies
- To develop physical models for a better understanding of key processes

Global circulation models (GCMs) are considered to be important tools for an assessment of the impact of anthropogenic release of CO_2 and other greenhouse gases and for predicting future climatic changes. Modelling of the Southern Ocean is one of the major tasks in this field. Understanding the variability of the Antarctic climate requires the synthesis of many observations of the atmosphere, ocean and sea ice. An understanding of the major physical processes and the coupling between the different components is essential to construct global and regional climate models. Because of the extremely low vertical stability of the water column, different models produce large differences in rates of vertical mixing and transport of nutrients and very different estimates of exchange of heat and gases such as CO_2 with the atmosphere.

Norwegian researchers should conduct process studies based on field observations of the Southern Ocean to improve the regional and global models. Their results should be used as the basis for improving model parameterisation. The energy transfer between the atmosphere and the ocean is critically dependent on the extent of the sea-ice cover. Satellite remote sensing is a valuable tool for energy transfer studies. Both the radiation balance and the transfer of heat and momentum are quite different in ice-covered regimes and in the open ocean.

Some of the largest errors in the results produced by GCMs are due to the treatment of sea ice albedo, clouds and aerosols and the corresponding feedbacks in the models. Processes that affect the sea-ice cover therefore need to be better understood. These include vertical mixing in the water column driven by surface cooling, freezing and wind energy, and interaction with the lower atmosphere in conditions with variable cloud cover. Ground truth measurements are essential for validation. Additionally, satellite radar and laser altimeter technology may prove to be useful tools for estimating sea-ice thickness. Bipolar studies can be particularly valuable in this field of research. In addition, better knowledge of the formation and radiative properties of mixed phase clouds and aerosols is important to obtain improved parameterisation schemes in climate models.

4.2 Marine ecosystems

Important research areas will be:

- To understand the physical, chemical and biological processes in the marine ecosystem, including the CO_2 cycle
- To quantify how natural and anthropogenic factors affect the marine ecosystem, including effects of UVB radiation and toxic substances
- To develop ecosystem modelling for better understanding of key processes
- To quantify the spatial and temporal distribution of marine species, their interactions, and limiting and regulating factors

The research should be based on the fact that marine organisms are excellent sentinels of environmental change in marine systems. Key ecosystem elements with a wide geographical distribution and that are logistically feasible to work with should be investigated to maximise the value of comparative studies around the Antarctic.

Carbon cycle research should be co-ordinated with studies of deep-water production and vertical export of carbon, and otherwise focus on the upward transport of nutrients and the regulation of primary production and production of micro-heterotrophs by physical factors, sea ice, nutrients and grazing. There are indications that the changes in atmospheric concentrations of CO_2 and methane during the last 700 000-800 000 years reflect the observed variation in processes in the Southern Ocean. It is a key challenge to find a definite answer to this fundamental question, which will involve studies of paleoclimatology and ecological and physical processes, including joint modelling efforts. Studies of the role of iron and other trace metals are essential for understanding interactions between dissolved organic carbon (DOC) and metals that make metals more readily bioavailable, while at the same time producing free radicals and superoxides that, in combination with natural UV radiation, can be harmful. The regulation of algae, zooplankton and micro-heterotrophs associated with sea ice and ice-filled water in the Southern Ocean and the high-arctic seas should be compared with the regulation of corresponding communities in HNLC waters (i.e. High-Nitrate Low-Chlorophyll waters). This will increase our understanding of "ordinary" nutrient limitation (nitrate, phosphate; silicate in the case of diatoms) in ice-filled waters as opposed to iron control in HNLC waters.

UVB levels have increased significantly at mid-latitudes in both the Northern and Southern Hemispheres. Even at current levels, UVB radiation is harmful to aquatic organisms and may reduce the productivity of marine ecosystems. Most UVB radiation research examines direct effects on specific organisms. The few studies that have investigated indirect effects demonstrate that UVB-induced changes in food-chain interactions can be far more significant than direct effects on individual organisms at any single trophic level. Norwegian research on UV radiation impacts in the Antarctic should focus on areas where our knowledge is inadequate, i.e. indirect (ecosystem-level) effects.

One goal of Antarctic ecosystem modelling should be to improve our understanding of ecosystem dynamics and to apply this in an ecosystem approach to management based on the precautionary principle. Through national and international cooperation, key species of the marine ecosystem should be quantified both in time and space. The data should be used as the input for models quantifying the abundance and interactions of key species in the ecosystem that are related to commercially exploitable stocks of krill and fish. This includes further development of methodology and technology to measure the state variables in the ecosystem and to estimate stock size and distribution and predict future developments.

Research on population dynamics, physiology and eco-toxicology should be continued to improve our understanding of how natural and anthropogenic changes in the environment affect the abundance and the spatial and temporal distribution of organisms. The levels of contaminants in Antarctic biota are generally low, but some substances are found in higher concentrations in Antarctic top predators than in the Arctic. The concentrations of different contaminants in an organism are often correlated, and it is difficult to determine which substances are most toxic. However, the concentrations of environmental contaminants are often different in Arctic and Antarctic biota, so that bipolar studies would be particularly useful in determining which components are most toxic.

Norway should focus on and participate in research where it can offer methodological expertise, for instance in acoustics and quantification of the interactions between important predator and prey stocks. State-of-the-art research can link and quantify changes in the distribution, life history strategy, demography, and population dynamics of key species of the Antarctic ecosystem and relate these changes to climate variability.

Our knowledge of the bottom-dwelling (benthic) animals inhabiting deep waters is limited. Whilst there seems to be some agreement that in the Northern Hemisphere species richness increases from the Arctic to the tropics, this is not the case in the Southern Hemisphere. Bipolar studies have therefore become an increasingly important means of understanding the key factors that determine species' distribution in time and space. The benthic animals of the Antarctic continental shelf exhibit many unusual features, including gigantism, longevity, a high degree of endemism, and the absence of taxa that are abundant in other geographical areas. The colonisation history of Antarctica and recent patterns of biodiversity in the region should be related to geographical, hydrographical and climatic conditions now and in the past.

As yet little is known about the krill and fish resources in the waters surrounding Bouvetøya and the sea off Dronning Maud Land. CCAMLR has encouraged investigations of these resources. Norwegian vessels participated in the fishery for toothfish for the first time in 2004, and an increasing interest in taking part in this highly profitable fishery is expected. The fishery should be managed on a scientific basis. The Norwegian research community should take part in studies to quantify the biomass of marine resources, understand the mechanisms that control populations, and increase knowledge of ecosystem interactions and species adaptations.

A number of Norwegian-South African expeditions have monitored and conducted research on fur seals, penguins and a variety of other seabird species resident on Bouvetøya. This sub-Antarctic island is interesting because it is distant from other land areas and is located just south of the Antarctic Convergence, and its fauna has recently undergone significant changes. Comparative studies of the marine ecosystem in the Southern Ocean and arctic marine ecosystems should be given priority.

4.3 Humans in the Antarctic

Important research areas will be:

- Research related to the governance of Norwegian Antarctic territories, Norway's international commitments, and opportunities in the Antarctic
- Tourism and other human impacts
- Historical heritage research
- Human biology

The principal legal and social science issues that concern Norway are related to the evolution of the Antarctic Treaty System. The Protocol on Environmental Protection (1991) is considered to be particularly important. Research related to the delimitation of the continental shelf associated with the Norwegian territories is needed. In addition, more research is needed with regard to multinational management of

resources and Norwegian history in Antarctica. Ownership of genetic resources may become an important issue in the future in relation to bioprospecting.

The Environmental Protocol sets strict standards for how activities in Antarctica, including scientific activities, are to be conducted. The growth in activity at Troll brings with it a risk of increasing impacts on the station area and its immediate surroundings. Further research and monitoring is needed to gain a better understanding of the effects of human activities in Antarctica on the environment. Research on relevant technologies that could reduce such impacts should also be considered.

The growth in tourism, which has recently involved Norwegian tour operators as well, means that it is important to analyse the environmental effects of increased tourist activity, the regulation of Antarctic tourism, the rules for liability in the event of environmental damage, and the methods that are used for environmental impact assessment, including the assessment of cumulative impacts

The most important elements of the Norwegian historical heritage in the Antarctic and sub-Antarctic are remains from whaling activities, but there are also cabins and other traces of early geographical exploration and scientific work. Most of the sites are outside the geographical area on which Norway is focusing. Thus, efforts to research and document sites and to establish effective protection and management regimes should primarily be based on international cooperation and support for Norwegian participation in expeditions organised by other countries.

Historical, ethnological and archaeological research on the Norwegian cultural heritage in the Antarctic and sub-Antarctic should continue, and the current studies at whaling sites should be expanded. Research may include the development of new methodology for surveying existing sites and multi-disciplinary research on degradation processes and conservation techniques. Historical heritage projects would benefit from using expertise from the Arctic, particularly from Svalbard.

Research on health-based selection of crew for long-term stays on the Antarctic continent is being conducted by several nations. The number of Norwegians over-wintering at Troll is too low to provide a sound statistical basis for behavioural or physiological analyses. Thus, any psychological research carried out by Norway should form part of already existing international research projects, and include follow-up of over-wintering personnel.

5 Surveys, thematic monitoring and prospecting

5.1 Surveying

There is still a lack of basic topographical and thematic data on Antarctica. Norway has a responsibility for surveying in Dronning Maud Land, Peter I Øy and Bouvetøya. In many cases, it will be an advantage to coordinate this work with surveys carried out by other nations.

5.1.1 Topographical surveying

Norway has an obligation to carry out both topographical and thematic surveys in Dronning Maud Land, Peter I Øy and Bouvetøya, and the Norwegian Polar Institute is the national mapping authority for this work. Topographical (and geological) mapping should continue in close collaboration with the other groups that are involved in research and monitoring activities in Dronning Maud Land.

5.1.2 Geological surveying

Basic geological surveying should focus on those areas of Dronning Maud Land that are not already being surveyed. In addition, basic geological investigations of the mountain range in Dronning Maud Land should be carried out to reveal its geological history. The geological and geophysical research in and around Dronning Maud Land should also focus on geochronology and on structural studies. The latter should include the sea-bed and subsoil of the submerged prolongation of the land mass, with the aim of interpreting its extent.

5.2 Monitoring

Antarctica is a pristine continent and therefore offers a unique opportunity to monitor levels of contaminants in the atmospheric, terrestrial and ocean compartments. Monitoring of climate variables is important in studies of the role of Antarctica in the global climate system.

The upgrading of Troll to an all-year station will open up opportunities for long-term monitoring programmes, for example in the atmospheric sciences, that could make comparative studies of Arctic and Antarctica possible. The upgrade should include a full synoptic surface station at Troll. Data should be disseminated via the Global Telecommunication System (GTS).

5.2.1 Contaminants

Persistent organic pollutants (POPs) and heavy metals in the atmosphere and ice are being monitored in Norwegian arctic areas, including Ny-Ålesund in Svalbard. Similar monitoring programmes for contaminants should be established at the Troll Station. In addition, measurements of climate-related gases and particles would be of interest. Measurements of ozone and UV radiation at Troll would provide a valuable supplement to measurements carried out at other stations. Any such Norwegian monitoring programmes should be co-ordinated with ongoing international programmes.

In the last few decades, there has been great concern about the accumulation of man-made harmful chemical compounds in virtually all ecosystems. An important group of pollutants in Antarctica are POPs, which because of their large affinity for lipids accumulate in the fatty tissue of living organisms and are concentrated upwards in the food web, reaching maximum concentrations in the fatty tissue of top predators.

However, levels of contaminants in Antarctic biota are generally low compared to those in other parts of the world.

5.2.2 Climate monitoring

When standard meteorological measurements are started at Troll, this will fill a gap in the network of sites for long-term meteorological observations in the Antarctic.

A number of long-term glaciological measurement programmes should be established in the Troll area, e.g. studies of glacier mass balance, superimposed ice formation, sub-surface melt water production, paleoclimatology, (ice coring), surface energy balance and glacier dynamics. These data should be related to information obtained by remote sensing.

A few key locations have been identified as extremely useful for assessing the long-term variability of ocean circulation under the ice shelf and the formation of bottom water and are considered to be suitable sites for continuous monitoring. Strategically placed hydrographic sections should be established for ocean climate monitoring. Good spatial coverage could be obtained by using drifting buoys (e.g. Argo floats).

Once Troll is permanently manned, it will also be possible to establish a High Resolution Picture Transmission (HRPT) station for reception of satellite data from meteorological polar-orbiting satellites. This would be expected to attract considerable international interest from the meteorological services and other relevant entities in South Africa and elsewhere. An HRPT station would also make it possible to carry out a wider range of research and experiments in Antarctica.

Since the station would receive all satellite images covering the area, local weather conditions could be monitored more closely. Monitoring and collection of data from research stations and platforms equipped with Argos transmitters would also be facilitated. An HRPT station would also allow the reception of Advanced TIROS Operational Vertical Sounder (ATOVS) data from the South Atlantic Ocean, which would be of interest for the international meteorological community. Finally, the establishment of advanced data communication facilities at Troll would make it possible to transmit relevant data to users in Norway and in other parts of the world.

5.2.3 Monitoring of marine living resources

Norway participates in the Environmental Monitoring Programme (CEMP) under the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) This programme focuses on identifying significant changes occurring in the Southern Ocean ecosystem and on distinguishing changes due to the harvesting of natural resources from those that can be ascribed to natural causes. The access of top predators to krill is of particular interest to CEMP, and several species of seabirds and marine mammals have been identified as indicator species and are being monitored in this context.

Norway monitors fur seal and penguin colonies at Bouvetøya as part of CEMP. The Bouvetøya station bridges a significant gap in the global research community's co-operative monitoring of the sub-Antarctic islands. Although the establishment of an

airstrip and the upgrade of the Troll Station in Dronning Maud Land will make it possible to monitor the avifauna there, research rather than monitoring should be given priority.

5.2.4 Human impact monitoring

Norway has obligations in this field under the Protocol on Environmental Protection to the Antarctic Treaty. The Protocol requires parties to put in place appropriate monitoring of key environmental indicators to assess and verify the level of impact of activities that may have a significant environmental impact. Research and the support activity associated with the operations at Troll (including flight operations) will be of such a magnitude that monitoring systems should be put in place. Relevant monitoring parameters must be identified and appropriate monitoring protocols should be developed and implemented. Issues that are relevant in this context include, but are not restricted to, impacts associated with flight operations (e.g. with respect to birds, combustion dispersal, fuel consumption (e.g. vegetation, birds, general dispersal of combustion products), vehicle and pedestrian traffic (e.g. vegetation, abrasion) and waste water discharge.

The growing number of Norwegian tour operators and the large number of trips ashore they are offering make it necessary to consider Norway's responsibility for monitoring the effects on the sites visited by tourists. It is an important task to achieve an overall understanding of the cumulative impacts of tourism on the sites they visit, and international cooperation is essential to develop and carry out responsible monitoring programmes in this field.

5.3 Bioprospecting

The Antarctic offers great potential for bioprospecting. Antarctic organisms are adapted to cold environments and possess genetic and biochemical features that could be exploited commercially to develop products such as industrial chemicals, drugs and genetic components. Considerable interest is already being shown internationally in surveying the genetic resources of polar organisms, but Norway has been less active than many other countries. However, Norway is now focusing much more on bioprospecting, and a concerted effort to identify valuable genetic resources in Antarctica could be highly profitable for Norwegian industry.

6. Troll as a research platform

The use of Troll as an all-year station combined with the establishment of the blue ice runway will make this part of Dronning Maud Land the obvious priority area for Norwegian terrestrial research in Antarctica. The runway will be one of very few gateways to Antarctica, and several other nations have already shown an interest in using this new Antarctic infrastructure for their national programmes. In addition to use for transit purposes, Troll may offer attractive opportunities for nations that do not have stations in Dronning Maud Land. It may be realistic to envisage the station as an international research platform similar to Ny-Ålesund, although on a smaller scale, at

some point in the future. In connection with the International Polar Year (IPY), Norway should take the initiative to ensure that this gateway to Antarctica and its proximity to the winter base at Troll Station are utilised.

Research at Troll must be carried out with due consideration for the vulnerability of the environment. Norway wishes to take the lead in environmentally sound operation of its research installations and activities in polar areas. It is therefore important to ensure that developments in the Troll area are in accordance with ambitious international standards and procedures for environmental protection, management and monitoring. When Troll opens as an all-year station in 2005, it will be in Norway's national interest to establish long-term monitoring and research programmes at the station.

7 Implementation

This chapter focuses on national and international cooperation, recruitment, the development of technology, funding and dissemination. The International Polar Year 2007-2008 is likely to offer an excellent opportunity to achieve key objectives set out in this document. Norway should aim to play an active role in IPY 2007-2008.

7.1 National coordination

The increased logistical flexibility both onshore and offshore will mean that stronger national coordination is needed to achieve the strategic goals. The Norwegian Polar Institute and the Research Council should be jointly responsible for coordination.

In order to realise the objectives of this document, integrated national research programmes must be developed. Improved logistic facilities open the way for more regular activities and long-term funding. An important aspect of national coordination is to ensure a good balance between data acquisition and data processing.

Norwegian scientific operations in the Antarctic provide opportunities for Norwegian companies providing technology, innovation and services. These opportunities should be exploited by strengthening cooperation between Norwegian businesses and research institutions.

7.2 International cooperation

The scale of the logistic and scientific challenges involved in Antarctic research makes close international cooperation essential. Norway should therefore cooperate more closely with other nations, and the successful Nordic logistic cooperation should be further developed. The Troll Station offers excellent opportunities for closer scientific collaboration with the Nordic countries and other nations. Research in the Arctic and Antarctica is an important area of future cooperation between South Africa and Norway, and will include the exchange of students and researchers as well as the

use of research facilities in Svalbard and Antarctica. Development cooperation funding may be used for some of these activities. Norway will also cooperate closely with South Africa on logistics

Norway should play a more active role in coordinating research in Dronning Maud Land and adjacent sea areas. Norway should also be more proactive in the development and steering of international Antarctic research programmes and should make greater contributions to research programmes that are relevant to Norwegian research priorities.

The Research Council recommends that:

- Norway should take part in and play an active role in the development of international research programmes
- Norwegian scientists should be encouraged to coordinate and play a leading role in international research activities

7.3 Recruitment

There is a general need to recruit younger researchers to polar research. Following a period during which soft money for young scientists working on Norwegian projects in Antarctica has dwindled, adequate funding must now be ensured. The expansion of research activities in Antarctica will require an increase in the number of qualified scientific personnel, and we know that many scientists will be retiring in the next few years. To cover both immediate and future research needs, project grants should therefore be allocated for both experienced and young scientists, in other words, grants to cover salaries and running expenses for fully-qualified scientists and post-doctoral and doctoral students. To ensure future recruitment at the highest levels, it is important to facilitate or encourage students to take masters and doctoral degrees in polar-related subjects. Recruitment can be ensured by requiring the establishment of dedicated scholarships for young scientists.

Thus, the Research Council will take steps to

- Increase recruitment of Antarctic scientists in both the short and the long term (from junior to senior levels)

7.4 Technological development

Satellite observations and observations from ocean- and ground-based instruments integrated into model systems are the basis for modern process studies and for environmental and climate monitoring. Further work is needed to develop measurement technology for atmospheric, terrestrial and marine studies specially adapted to polar regions, e.g. autonomous platforms and satellite remote sensing equipment. Greater use of satellite measurements in the polar regions and expertise to analyse them is essential for studying and monitoring the polar environment. Optimal use of the Troll station requires up-to-date infrastructure and communication solutions. Strengthening partnerships between Norwegian technology companies and research institutions will create an important potential for technological development and commercialisation of new technology.

The Research Council will:

- Encourage the development and application of new measurement and observation technology for use in Antarctica

7.5 Environmental monitoring

The upgrading of Troll to an all-year station will improve the infrastructure for monitoring programmes related to climate change and environmental pollution.

Long time series of data are important in studies of climate and environmental change, and for predicting future changes. It is often difficult to maintain long-term monitoring programmes, since funding for these activities has usually been given low priority in research programmes.

The Research Council will:

- Encourage the maintenance, establishment and funding of long time series of measurements of physical, chemical and biological environmental parameters as a basis for monitoring and studies of Antarctica

7.6 Financial implications

Some of the main conclusions that can be drawn from this document are that:

- Norway must ensure recruitment to the polar sciences
- The quality of Antarctic marine research should be improved by coordinating research activities on Norwegian cruises, thus maximising synergistic effects. Participation by other nations should be welcomed when scientifically appropriate
- Terrestrial research in Antarctica should become more efficient and its quality should improve as the new infrastructure is taken into use, since this will make the timing and duration of expeditionary work more flexible
- Year-round use of Troll Station will allow the establishment of long-term measurement programmes for crucial climate variables
- Surveying and long-term environmental and biological monitoring provide important background information for the management of Dronning Maud Land, Peter I Øy and Bouvetøya
- Bipolar research will significantly improve the cost/benefit ratio for Norwegian polar science
- Norway is now in a position to contribute significantly to international multidisciplinary projects and networks

To ensure that the full potential of Antarctic research is realised, it is therefore recommended that:

- Funding for research projects should not be limited to the funding from the Ministry of the Environment currently earmarked for NAREs. The

Research Council, for instance, will be prepared to fund Antarctic research through support from relevant ministries. The Research Council will also seek to gain more international financial support for Norwegian research

- Funding periods for research projects should be up to four years. Funding for post-expedition data analysis and modelling should be strengthened
- Funding for surveying and long-term monitoring activities should be secured and be separated from funding of research projects
- The annual budget for Norwegian Antarctic research, monitoring and logistics needs to be substantially increased to achieve the intended increase in the level of activity

7.7 Dissemination

One of the Research Council's core objectives is to ensure continuous dissemination of research results to the scientific community, the authorities and the general public. Research projects with public funding should therefore include plans for disseminating their results. One important task is to increase public awareness of Antarctica. Another is to implement scientific results in management decisions for this region.

The Research Council therefore recommends that:

- Research projects and monitoring programmes should publish scientific results in peer-reviewed journals. Projects that meet this criterion should be favoured in the next call for proposals
- Project results should be made available to all stakeholders. Results should be communicated through a wide variety of channels, including newspapers, popular-science journals, radio, television, the Internet, the educational system (from elementary to university level), exhibitions, newsletters etc.
- Relevant scientific results should be communicated to authorities in order to ensure appropriate science-based management of the Antarctic
- A centralised website and database should be established for all Norwegian Antarctic activities and could be maintained for instance by the Norwegian Polar Institute. Project managers should be required to provide updated information to the database regularly, following internationally agreed procedures prepared by the Scientific Committee on Antarctic Research (SCAR).