Environmental Monitoring at Swedish Research Stations in Antarctica

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Abstract

The abstract of this thesis has been written in English, in Swedish and in French.

Abstract

Establishing and implementing a long-term environmental monitoring programme in Polar Regions is both a complex and multidisciplinary field which requires participation and involvement of a great number of specialists on diverse and varied topics.

The Swedish Polar Research Secretariat, responsible to promote and coordinate polar research, has always had the ambition to protect the Antarctic's environment and the associated and dependent ecosystems. In accordance with the Protocol on environmental protection in Antarctica, the secretariat has implemented an environmental monitoring programme since the beginning of the 1990's. However, the output is not fully comprehensive: on the one hand, it has provided necessary information on the understanding of the area and permitted to take mitigation measures, on the other hand, sporadic measures and inappropriate data management system has left gaps in the environmental knowledge of the area.

That is why, within the International Polar Year framework, the secretariat has decided to implement a complete long-term environmental monitoring programme to not only evaluate impacts from anthropogenic activities around the Swedish polar stations Wasa and Svea but also to estimate their trend.

The success of such programme depends on several key elements: feasible and clearly defined objectives, a standardized sampling programme and an efficient data management system. Moreover, this programme should be strongly linked with the decision-making process and international cooperation would make this programme even more valuable.

As science advancement continues, the need to protect the Antarctic's environment become more and more obvious, indeed, we know that this continent maybe keeps in its ice answers to tomorrow's environmental questions.

Sammanfatning

Att genomföra ett miljöövervakningsprogram i polarområdena är en komplex disciplin som behöver medverkan och engagemeng av ett stort antal specialister inom många ämnen.

Polarforskningssekretariatet är en myndighet som har till uppgift att främja och samordna svensk polarforskning. Sekretariatet har alltid haft en hög ambitionsnivå för att beskydda och bevara miljön i Antarktis och i dess sammanhängande ekosystem. I överensstämmelse med Madridprotokollet beträffande miljöskyddet i Antarktis, har sekretariatet infört ett miljöövervakningsprogram i början av 1990-talet. Emellertid är programmet som det är utformat idag inte helt opitmalt: å ena sidan har programmet försett miljöansvariga med nödvändig bakgrundsinformation för att förbättra förståelsen av området och gett möjlighet att vidta skyddande åtgärder för miljön de svenska polar stationerna Wasa och Svea. Å andra sidan har de tillfälliga provtagningarna i kombination med ett svagt system för att bearbeta tidigare data orsakat luckor i kunskaperna kring miljön i lokalområdet.

Det är darför sekretariatet har bestämt sig för att ta fram och införa ett mer omfattande miljöövervakningsprogram som kan användas till att både utvärdera effekterna från de mänskliga aktiviteterna runt omkring de svenska forskningsstationerna, och förutsäga tendenser kring miljötillståndet.

Förutsättningarna för att det nya miljöprogrammet ska få önskat utfall är att det har väldefinierade målsättningar, standardiserade provtagningsmetoder och ett effektivt databehandlingssystem. Dessutom behöver programmet införlivas i beslutsfattandesprocessen. Dessutom, internationellt samarbete med stationer i området kommer att göra programmet mer värdefullt.

Allteftersom forskningen gör framsteg och projekten i Antarktis blir fler och samtidgt mer avancerade, så blir behovet för att beskydda Antarktismiljö mer och mer påtagligt. Vi vet att i Antarktis is kan det finnas svar på flera av framtidens miljöfrågor.

Résumé

Établir un monitoring environnemental à long terme dans un environnement polaire est une discipline à la fois complexe et transversale qui demande la participation et l'implication d'un grand nombre de spécialistes dans des domaines divers et variés.

Le Secrétariat de Recherche Polaire Suédois, responsable de la promotion et de la coordination de la recherche dans les régions polaires a toujours eu la volonté de protéger l'environnement en Antarctique ainsi que les écosystèmes associés et dépendants. En accord avec le Protocole de Madrid relatif à la protection de l'environnement en Antarctique, le secrétariat a mis en œuvre un monitoring environnemental autour de ses stations de recherche Wasa et Svea dès le début des années 1990. Cependant, le bilan de ce programme est plutôt contrasté ; d'un coté, il a fourni les informations nécessaires à la compréhension du milieu et a permis de prendre les mesures indispensables à sa préservation. D'un autre coté, les échantillonnages et mesures sporadiques et un système de management des données inapproprié laissent subsister des inconnus dans la perception environnementale de la région.

C'est pourquoi, profitant de l'année polaire internationale, le secrétariat à décider d'établir un monitoring environnemental sur le long terme permettant non seulement d'évaluer concrètement les impacts d'origine anthropogénique autour des stations de recherche suédoise mais aussi d'en prévoir la tendance.

La réussite d'un tel programme repose sur quelques éléments clés : des objectifs réalisables et clairement définis, des méthodes d'échantillonnages standardisées et un système de management des données efficace. De plus, pour être efficace, le monitoring environnemental doit être en étroite relation avec le système de prise de décision dans l'organisme. Enfin, ce monitoring environnemental ne pourra qu'être valorisé par une collaboration internationale.

Au fur et à mesure des progrès de la science, il apparait de plus en plus évident de protéger l'Antarctique qui garde probablement dans ses glaces les réponses aux questions environnementales d'aujourd'hui et de demain.

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List of Acronyms and Chemical Symbols

Acronyms

ADDS Antarctic Data Directory System

AEON Antarctic Environmental Officers Network

AMD Antarctic Master Directory

ASMA Antarctic Specially Managed Area

ASPA Antarctic Specially Protected Area

BOD Biological Oxygen Demand

BTEX Benzene, Toluene, Ethylbenzene, and Xylene

COD Chemical Oxygen Demand

COMNAP Council of Managers of National Antarctic Programs

DO Dissolved Oxygen

EMP Environmental Monitoring Programme

EPA Environmental Protection Agency

GC-MS Gas Chromatography – Mass Spectroscopy

ICP Inductively Coupled Plasma

ICP-AES Inductively Coupled Plasma – Atomic Emission Spectrometry

ICP-MS Inductively Coupled Plasma- Mass Spectroscopy

IPY International Polar Year

JCADM Joint Committee on Antarctic Data Management

LAM Light Absorbing Material

NA Not Applicable

NADC National Antarctic Data Centre

PAH Polycyclic Aromatic Hydrocarbons

QA Quality Assurance

QC Quality Control

SCAR Scientific Committee on Antarctic Research

SOP Standard Operating Procedure

SWEDARP Swedish Antarctic Research Program

T Temperature

TC Total Carbon

TIC Total Inorganic Carbon

TOC Total Organic Carbon

TPH Total Petroleum Hydrocarbons

TSS Total of Suspended Solids

US United States

Chemical symbols

Al Aluminium

As Arsenic

B Boron

Ca Calcium

Ca^{2+} Calcium ion

Cd Cadmium

Cl^{-} Chloride ion

Co Cobalt

Cr Chromium

Cu Copper

F^{-} Fluoride

Fe Iron

Hg Mercury

K Potassium

K^{+} Potassium ion

Mg Magnesium

Mg^{2+} Magnesium ion

Mn Manganese

N Nitrogen

Na^{+} Sodium ion

NH_4^{+} Ammonium

Ni Nickel

NO_2^{-} Nitrite

NO_3^{-} Nitrate

P Phosphorus

Pb Lead

PO_4^{3-} Phosphate

S Sulphur

SO_4^{2-} Sulphate

Zn Zinc

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Part 1

*I*ntroduction

1. Introduction

1.1. Background

Antarctica's history goes back at least to Ancient Greece, well before its discovery. In these days, mankind was already fascinated by the speculations over this continent. The existence of southern lands was not established before the early 19th century, when the exploration of the Antarctic Peninsula region and other areas south of the Antarctic Circle began. However, due to its extreme environment, lack of resources and isolation, the continent remained disregarded for the rest of the 19th century.

Only later, after the World War II, scientific research intensified on the area. Since, the interest for this extreme continent has never ceased to increase. Many countries set up their own research station and some of them began to have terrestrial claims. In the light of this, an Antarctic Treaty was negotiated and finally signed in 1959 by twelve countries. This treaty defined Antarctica as a continent devoted to peace and science and froze the territorial claims. Nowadays, most of human activities in Antarctica are in connection with science and related logistic support.

It is now an accepted fact that Antarctica has unique and priceless scientific and environmental values. What is unique about Antarctica is, among other, that it encloses information about history of the earth evolution for million years. This could turn out to be very useful knowledge to understand tomorrow's environmental problems.

In the last few years, the environmental awareness has significantly developed within the scientific community; more and more actions have been carried out in order to preserve Antarctica's environment. As a consequence, the Protocol on Environmental Protection to the Antarctic Treaty, also known as the Antarctic Environmental Protocol, entered into force on 1998. It provides Antarctica with a general framework for environmental conservation. All signatory nations have agreed to improve the protection of Antarctica's environment and the associated ecosystems. Particularly, the article 3.2 (d) states that "*regular and effective monitoring shall take place to all assessment of the impacts of ongoing activities, including the verification of predicted impacts*". So, Sweden, as a signatory of the Environmental Protocol has to assess all the environmental impacts from anthropogenic activities of its two polar research stations in Antarctica: Wasa and Svea.

1.2. Problem

Since the construction of its two research stations Svea (SWEDARP 87/88) and Wasa (SWEDARP 88/89), the Swedish Polar Research Secretariat has always had the willingness to manage all environmental impacts from its scientific activities in Antarctica and related logistic support in order to preserve the area of interest. Since the beginning, monitoring activities have been carried out on various media: soil, vegetation, snow and ice, etc.

A lot of environmental information have been gathered. However, a complete monitoring programme including e.g. standard operating procedures and efficient data management system has never been implemented. As a result, some information has never been analysed or synthesized, some are presented in different format, and some conclusions have just been drafted. Thus information is not easily usable and explicable. That is why there may be gaps in the environmental knowledge of the surrounding area.

As a consequence, the Swedish Polar Research Secretariat would like to establish a long-term monitoring programme in order to assess the environmental impacts from anthropogenic activities of the two Swedish stations in Antarctica, with a particular attention to the design of the operating procedure and the data management system. The results of this monitoring programme could be used in the decision making process so as to protect efficiently Antarctica's environment and the associated ecosystems.

1.3. Aims and Objectives

1.3.1. Aims

The main aim of this thesis is to propose a long-term environmental monitoring programme of the Swedish polar stations located in Antarctica. This project will focus on providing a suitable watching system for the assessment of ecosystems integrity and changes due to anthropogenic activities around polar stations.

1.3.2. Objectives

So as to fulfil the aims, some objectives were first set up.
First, studies related to environmental monitoring that have been performed at Swedish stations in Antarctica should be listed; known environmental impacts should be summarized. It can be useful to know which kind of data have been collected and which methods have been used.
Then, after clearly defining objectives of the environmental monitoring, sampling methods and data handling (that is to say data collection, storage and analysis) should be organized and standardized in order to improve data comparison and knowledge sharing.
It could be also interesting to contact other research groups in Antarctic (e.g. Finnish, Norwegian, French, Belgian … polar stations) in order to know if they have an environmental monitoring and if they have one, how they perform it.

1.4. Delimitations

The work will be divided into two parts: the design of the monitoring programme and the analyses and conclusions of the master thesis. The monitoring design includes scoping, defining and implementing the environmental monitoring programme.

2. Frame of Reference

2.1. Antarctica

Antarctica is the southernmost continent of the earth, overlying the South Pole. Many superlatives can describe this extreme land: coldest, windiest, highest or even driest place on earth. With its 14 million km^2, Antarctica is the fifth largest continent in the world, larger than Europe or Australia and represents 10% of the world's total area. Harsh weather conditions are daily life in Antarctica, the yearly average temperature is -40˚C and the continent is regularly subject to snow storm and violent blizzard. (Australian Antarctic Division, 2006)

Figure 1: Map of Antarctica

Source: United States Central Intelligence Agency's World Factbook

Antarctica is the biggest snow covered desert in the world, 98% of its surface is permanently covered with an ice cap which averages at least 1600 meters in thickness. The remaining 2% constitutes the most suitable habitat for flora and fauna. Flora consists predominantly of lichens, mosses, algae and fungi. Fauna consists mainly of seals, seabirds and microfauna. (British Antarctic Survey, 2007)

Antarctica is an important component in the Earth's ecology: it encloses 90% of the world's ice and 70% of the fresh water. It also plays a major role in global processes such as the circulation of ocean currents and atmospheric wind.

There is no permanent resident in Antarctica but explorers and scientist constitute the major part of the temporary inhabitants. Since the continent has been devoted to peace and science through the Antarctic Treaty, their number has dramatically increased. Nowadays, there are more than 70 permanent research stations in Antarctica, where several thousand scientists of many nationalities conduct diversified ongoing research. Global processes such as climate change and ozone depletion take up a large place in the present scientific research. (Australian Antarctic Division, 2006)

2.2. The Antarctic Treaty System

The Antarctic Treaty System, constituted by the Antarctic Treaty and five related agreements including the Protocol on Environmental Protection, aims at regulate international relations in Antarctica. Everything south of the southern 60th parallel is concerned by the treaty. (British Antarctic Survey, 2007)

2.2.1. The Antarctic Treaty

At the end of the 19th century, expeditions to Antarctica intensified and the first terrestrial claims began to emerge. In 1908, Great Britain was the first country to claim an area in Antarctica, soon followed by number of other nations. However, United States and Soviet Union refused to recognize these claims. That is why an agreement should be found to settle growing rivalries and conflicts about Antarctica.

During the International Geophysical Year of 1957-58, the twelve countries involved in a common research programme accepted that their terrestrial claims would be put aside on behalf of scientific cooperation. This laid the foundations of the future Antarctic Treaty which can be considered as the diplomatic expression of the existing cooperation. These countries were: Argentina, Australia, Belgium, Chile, France, Japan, India, New Zealand, Norway, South Africa, the USSR, the United Kingdom and the United States. The Antarctic Treaty was signed on 1969 by these twelve countries and officially came into force on June 23rd 1961. Currently, there are 46 treaty member nations. 28 of these countries are Consultative Parties and 18 Acceding States. Sweden is a Consultative Party since 1988.

The three main objectives of the treaty are to ban all military activities in Antarctica, to promote and encourage scientific cooperation and last but not least to set aside claims for terrestrial sovereignty.
At present, a Protocol on Environmental Protection to the Antarctic Treaty and four other agreements complete the legal system of Antarctica (Australian Antarctic Division, 2006 and British Antarctic Survey, 2007)

2.2.2. The protocol on Environmental Protection

The protocol on Environmental Protection to the Antarctic Treaty deals with all issues related to environmental protection of Antarctica. It provides legal system for the comprehensive protection of Antarctica's environment and related ecosystems. It also defines Antarctica as *"a natural reserve, devoted to peace and science"*. The main objective of this protocol is to make assessment of environmental impacts from ongoing and planned activities compulsory.
The protocol opened for signature in 1991 and came into force on January 14th 1998. Currently, the treaty has been ratified by 27 countries; a further 16 have signed it but not yet ratified it. (Australian Antarctic Division, 2006 and British Antarctic Survey, 2007)
This protocol and the Article 3 in particular should provide the general and legal framework for this master thesis:

"The protection of the Antarctic environment and dependent and associated systems and the intrinsic values of Antarctica, including its wilderness and aesthetic value [...] shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area. […] Activities in the Antarctic Treaty area shall be planned and conducted on the basis of, information sufficient to allow prior assessments of and informed judgments about, the possible impacts on the Antarctic environment."

(Protocol on Environmental Protection to the Antarctic Treaty, Article III)

2.3. Swedish Research

Being a country with a long polar tradition, Sweden has been involved in research both in Arctic and Antarctic regions for many years.

2.3.1. Swedish Research in Antarctica

Swedish history in Antarctica began at the end of the 19th century. At the beginning of the 20th century, the first Swedish expedition to Antarctica marks a turning point in the Swedish Polar History. This expedition was conducted by Otto Nordenskjöld (1869-1928), a Swedish geologist and geographer, in 1901-1903. Then, Swedish research in Antarctica intensified and few years later, in 1949-1952, Sweden participated in an important expedition to Dronning Maud Land together with Norway and Great Britain. (Liljequist, 1993)

The first Swedish Antarctic Research Programme (SWEDARP) was implemented in 1987-1988, the year of the construction of the small research station Svea. In 1988-1989, a bigger research station, called Wasa, was built. Since, expeditions have been organised regularly to Antarctica.

2.3.2. Swedish Polar Research Secretariat

The Swedish Polar Research Secretariat was founded in 1984. It is a government authority under the Ministry of Education and research which has the responsibility to promote and coordinate Swedish polar research by among other organising and leading expeditions to the Arctic and Antarctica. (Swedish Polar Research Secretariat, 2006)

The secretariat works also hard to protect environment in the Polar Regions and is responsible for the implementation of environmental monitoring programme to assess the impacts from Swedish activities around the research stations Wasa and Svea. (Swedish Polar Research Secretariat, 2006)

Currently 18 persons work at the Secretariat within various units: Management and Administration, Expeditions and Logistics, Information and Documentation and Environment. Since 1994, the Secretariat is the administrative authority able to deliver permits for visits or activities in Polar Regions in accordance with the Swedish Act on Antarctica. (Swedish Polar Research Secretariat, 2006)

2.3.3. The Swedish Research Stations in Antarctica

Sweden has two research stations in Antarctica, Svea and Wasa. They are situated in Dronning Maud Land.

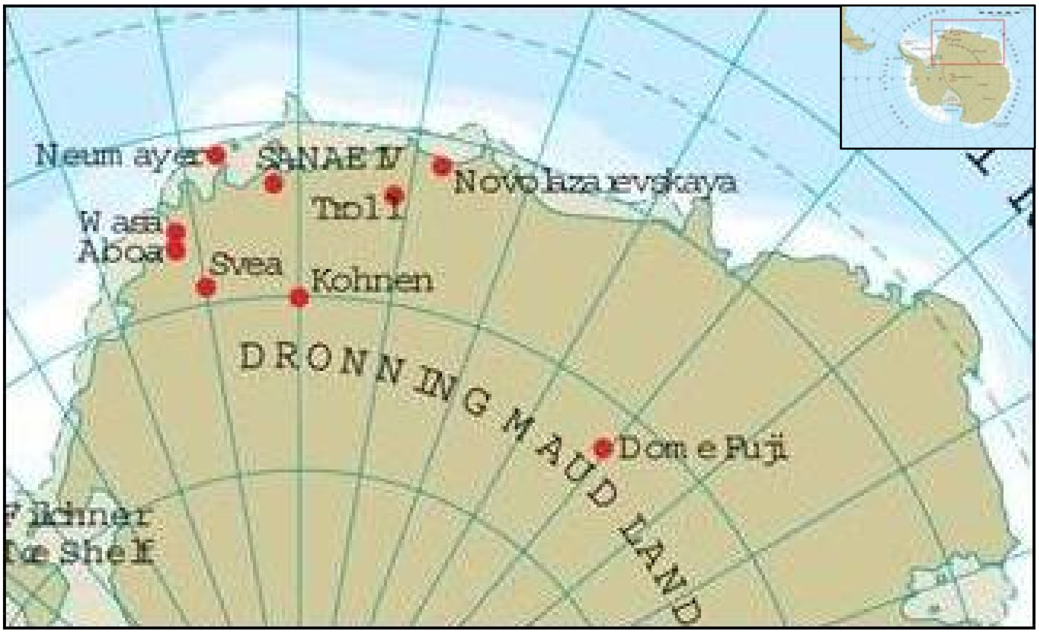

Figure 2: Map of Dronning Maud Land
Source: Swedish Polar Research Secretariat

Svea was built in 1987-1988 in the Heimefront Range (74˚35'S, 11˚13'W). It is a small station (4 people), used periodically as a field station for specific studies during the austral summer season.

Figure 3: Svea station
Source: Swedish Polar Research Secretariat

Wasa was built in 1988-1989, one year later. It is located at the nunatakk Basen (73˚03'S, 13˚25'W). It is a medium research station (12-16 people) used as a base camp by Swedish expeditioners. Since their building, the stations have been visited regularly during the southern summer.

Figure 4: Wasa station
Source: Swedish polar Research Secretariat

Research activities in these two stations require a range of capability including housing, energy generation, freshwater production, transportation, etc. These anthropogenic activities have potentially important and long-term effects on Antarctica's environment. So, this has lead to recognize the need for a long-term environmental monitoring in order to provide useful information for minimizing human impacts and preserving resources around polar stations. (Swedish Polar Research Secretariat, 2006)

The description of the Swedish stations will be set out in detail further (c.f. *Site Description* Part 2 Chapter 1.3)

2.4. Environmental Monitoring

2.4.1. Definition

Monitoring can be defined as a standardized and systematic measurements and observations of key variables related to an activity or a process. This should allow to determine how the state of the environment changes over the time and whether it is functioning as expected. Thus the monitoring programme should provide sufficient information to determine whether management actions (e.g. modifying the activity or the process, implementing mitigation measures) are required.

The main objectives of a monitoring programme are to assess impact prediction and to detect at an early stage any unforeseen effect. The determination of the key variables to be monitored should be based on the specificity of the area of interest, the nature of the activity, and the result from previous monitoring programme. (SCAR/COMNAP, 1996 and Arctic Environment Protection Strategy, 1997)

The general scheme of Environmental Monitoring Programme can be sum up as follows (Figure 5). We can see that environmental monitoring programmes progress can be seen as a virtuous circle and should lead to a continuous improvement in understanding, protecting and restoring ecosystems.

Figure 5: General Scheme of Environmental Monitoring Programme

2.4.2. Environmental Monitoring in Antarctica

Monitoring programmes in Antarctica are very special compared with monitoring programmes in non-polar regions. The harsh weather conditions of this continent, the extreme sensitiveness of its ecosystems, the remoteness of the research stations, etc. increase significantly the cost and the difficulty of such programmes (Arctic Environment Protection Strategy, 1997).

However, as Antarctica remains relatively pristine, it is maybe the most important place on earth to monitor.

> *"Environmental monitoring is a fundamental element of basic research, environmental management, and conservation. The organized and systematic measurement of selected variables provides for the establishment of baseline data and the identification of both natural and human-induced change in the environment. Monitoring data are important in the development of models of environmental processes, which in turn facilitate progress towards a predictive capability to detect environmental impact or change. The collection and evaluation of monitoring data is essential for the detection of human perturbation within the natural variability of ecosystem processes."*
>
> (SCAR/COMNAP, Discussion Document, 1992)

Both global and localised environmental monitoring in Antarctica has a long history. Since the International Geophysical Year (1957), a lot of data about global phenomena have been gathered by scientific programmes. The parameters of interest include gaseous constituents of the Antarctic atmosphere, pollutants in snow and ice, greenhouse gases, heavy metals and acidification and ultraviolet radiation related to ozone depletion. This information can be used as baseline for localised monitoring programme in Antarctica. (SCAR/COMNAP, 1996)

Localised EMP are more recent. As it is required in the Environmental Protocol, most of national programmes have assessed environmental impacts from anthropogenic activities around research stations, most often based on a small number of specific compounds, organisms or activities. (SCAR/COMNAP, 1996)

At the beginning, there was little coordination and agreement on standardized methods between national programmes. The joint efforts of the COMNAP and SCAR led to the publication of two documents: *Antarctic Environmental Monitoring* Handbook (COMNAP/SCAR, 2000) and the *Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica* (COMNAP, 2005) to promote cooperation on localised monitoring programmes. Currently, a number of programmes are implementing their own monitoring programme based on these documents. However, there has been little coordination between nations. The reasons can be a lack of interest for the monitoring program, a lack of resources (financial, staff, etc) or the wrong impression that environmental impacts are negligible for little stations.

2.4.3. Monitoring Programme at Swedish Stations

Since its foundation, the Swedish Polar Research Secretariat has always had the ambition to minimise its environmental impacts on Antarctica. In 1988-1989, during the establishment of the Wasa station, environmental aspects of the surroundings have been carefully considered (Larsson, 1990). The first monitoring programme was implemented in 1991-1992 in accordance with the Environmental Protocol. The key environmental values included flora and fauna, soil, air, freshwater environment, wilderness and aesthetic values. The main focus was on pollution level in soil, snow and ice, lichen and microfauna studies and station footprint area (Swedish Polar Research Secretariat, 2003). Since, various parameters have been monitored on a more or less regularly basis. An overview of the parameters measured from 1991 is detailed further (C.f. *Historical Perspective* Part 2 Chapter 1.4)

However, this monitoring programme did not have a very efficient data management system thus there is some gaps in environmental knowledge at Wasa and Svea station.

3. Method

The method used to perform this project is described below.

3.1. Working Process

The main part of the project is to design and develop a long-term monitoring of the environmental impacts from human activities around the Swedish stations in Antarctica. This should provide a basis for future implementation of such programme. The project has been divided into three phases: planning the project, designing and developing the project and analysing the project.

In order to perform this work, the main method used in the first part of the project (planning the project) has been to search for literature and reports about existing environmental monitoring programmes from Swedish Polar Research Secretariat and other national research programmes.

A three-step approach has been chosen for the second phase: designing and developing the project. This approach is based on the document published by the COMNAP in 2005 "*Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica"*. The step 1 consists in scoping the monitoring programme including setting clear objectives. The step 2 consists in defining the project, in other words, in deciding what to monitor and designing the sampling methods. The step 3 consists in implementing the monitoring programme. During this phase, all environmental data that have been gathered in the first phase have been analysed to design the monitoring programme. Indicators and parameters to be monitored have been chosen and their prioritisation was established with regard to the requirements of the Swedish Polar Research Secretariat. Contacts with laboratories have been established to ensure the feasibility of the suggested programme.

The last phase of the project, analysing the project, consists mainly in evaluating the project and identifying the critical points in order to suggest recommendations about further developments.

The project has finally resulted in a proposition of a monitoring programme that could be implemented during coming expedition at Swedish stations in Antarctica.

Figure 6 below set out in detail the working process for this project.

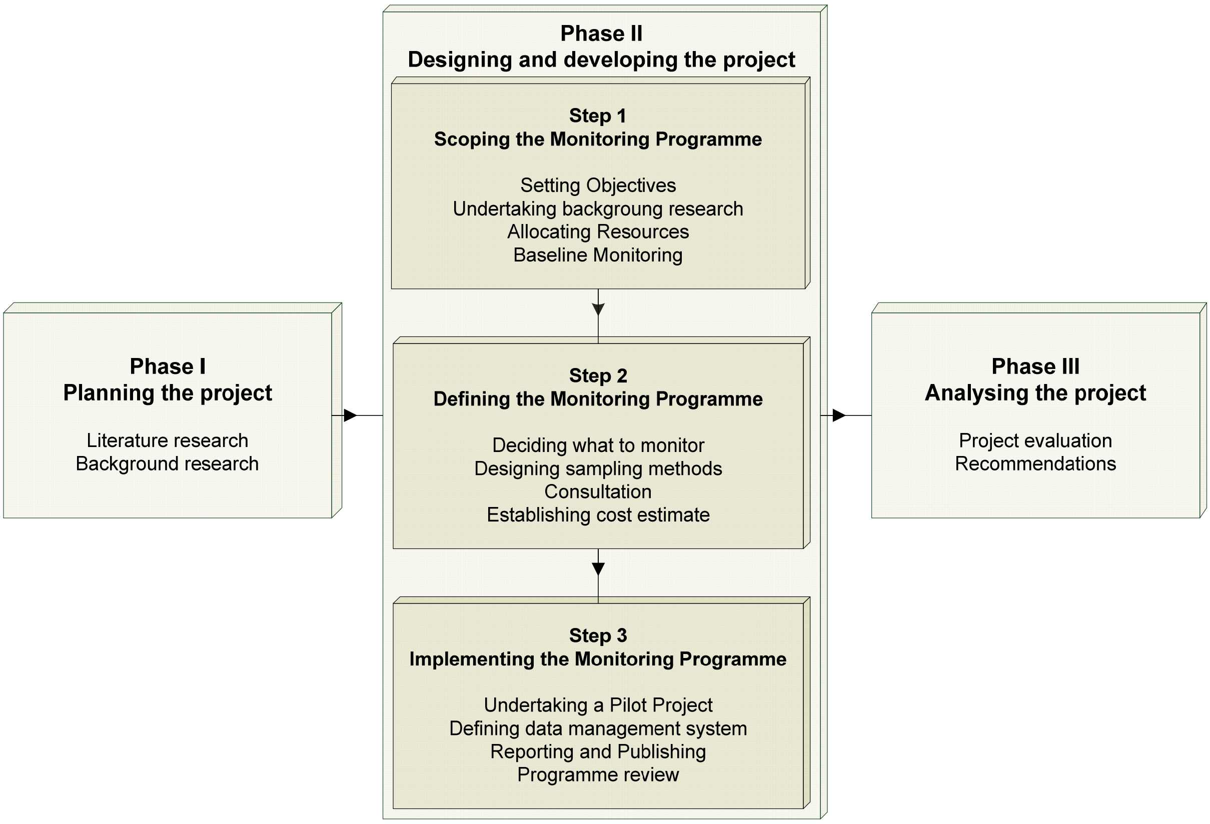

Figure 6: Three-step approach to designing a monitoring programme
Source: freely adapted from COMNAP 2005

3.2. Data Collection

Such a project involves the collection of different types of data about the topic of interest. Given that all the countries involved in scientific research in Antarctica have signed the Antarctic Treaty that promote knowledge sharing and cooperation, data collection about this subject should not be affected by any self-interest. However, as the suggested monitoring programme quality depends directly on the data reliability, a special attention has been paid to data sources.

Publications, reports, guidelines and handbooks from international organisations directly involved in environmental monitoring programmes in Antarctica (e.g. SCAR, COMNAP) have been used in priority. In particular, two documents: the "*Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica"* (COMNAP, 2005) and the "*Antarctic Environmental Monitoring Handbook*" (COMNAP/SCAR, 2000) constitutes the main sources of information for this project. Information from Swedish Polar Research Secretariat and other national polar research programmes have been used as a reliable data. Articles from scientific journals and books with special interest on the subject have constituted another source of information.
The Internet has also been used as a source of information. However, due to the quality discrepancy between websites, only information from official organisations has been considered. In order to improve reliability of the collected data, several sources have been compared when possible.

Part 2

Environmental Monitoring Programme

1. Step 1: Scoping the Monitoring Programme

Once the project has been planned in the first part, the second part of the project should consist in the actual design and the development of the project.
The first step should focus on the preparatory work of the environmental monitoring programme. It should provide the necessary information to provide a clear understanding about the site.

1.1. Setting Objectives

Considering the scientific value of Antarctica's ecosystems and its extreme sensitiveness, environmental monitoring of polar station activities has become unavoidable. However, it is not possible, of course, to monitor everything everywhere. So, setting clear and well-defined objectives for the monitoring program is an essential step.

The objectives of this environmental monitoring programme can be divided into two different groups: general objectives and objectives focused on one or several polar stations in particular and their activities.

1.1.1. General Objectives

According to SCAR/COMNAP (1996), there are three distinct general objectives for monitoring in Antarctica:

- To protect the Antarctic's scientific value
- To help in the continuous improvement of Antarctic environmental management
- To meet the legal requirements of the protocol and national legislation

These objectives are not specific to one polar station; they represent basic objectives that environmental manager of each station should keep in mind in order to establish the monitoring programme of human-induced impacts around the station, in accordance with the Environmental Protocol (Annex I, article II) of the Antarctic Treaty.

1.1.2. Objectives for Wasa and Svea Stations

The first objective of a long-term environmental monitoring program at Wasa and Svea stations is to provide systematic, regular and verifiable observations that allow to detect, measure and document any change and trend in the ecosystems by collecting data on selected variables. This program should be established in order to support a decision-making process that minimizes and controls impacts from anthropogenic activities. (Kennicut II et Al. 1999)
In other words, the main objective is to detect any unforeseen effects and verify actual impact and scope of those effects that are anticipated. (Swedish Polar Research secretariat, 2003)
The related objective is to be able to detect any environmental problem at the very beginning when corrective actions still can be effective.

In general, past monitoring programs were limited in time and geographically. So they were not able to provide a complete coverage of the potential area of impact.

This program does not claim to monitor all changes that occur in the area but only changes induced by human activities at the stations. That is why baseline data have to be collected very carefully to be able to differentiate natural or global variability from changes due to the presence of humans.

According to Walton and Shears (1994), the success of any monitoring programme will depend, in part, on the establishment of an effective system for handling the data. So a special attention will be paid to data management. Modern GIS techniques seem to be an interesting method to organize these diverse datasets into a coherent and coordinated framework.

Financial resources are often a curb on environmental monitoring programme. So, this program should be cost-effective and try to use existing resources (e.g. equipment, station personnel and scientists) as much as possible in order to minimise costs.

This programme should be undertaken during a defined period (e.g. a period of five years) before conducting a major review of the programme. Indeed, some parameters which appear essential to monitor now can become obsolete after five years due to global change in the environment or change in the station activities, area, etc.

To summarize, the monitoring programme will provide reliable assessments based on a solid foundation of data that are quality controlled, integrated into coherent and harmonized data sets, and analysed for their significance in an environmental strategy context. These processes altogether should build foundation of reliable environmental information from human impacts at Wasa and Svea. (Swedish Polar Research secretariat, 2003)

1.2. Hypothesis for the Environmental Monitoring Programme

Following the recommendation of the SCAR/COMNAP (1996) that any monitoring programme should be based on hypothesis, the following generic hypothesis will be used as a based for the whole EMP of the Swedish stations.

- The sphere of influence of the human-induced impacts due to the presence of a station is bounded and the boundary limits can be determined.

- Any significant change in operations and activities at the station will be reflected in changes in the selected indicators

1.3. Site Description

The site description should provide the necessary features of the site in order to design an appropriated monitoring programme.

1.3.1. Wasa (73°03′S, 13°25′W)

Wasa is the main Swedish station in Antarctica. It was built during the austral summer 1988/1989, and is situated partway up the nunatakk Nordenskiöldbasen, called “Basen”, 120 km inland. The Finnish station Aboa lies some 200 metres from Wasa. The stations lie in an area that is snow free in the summertime.

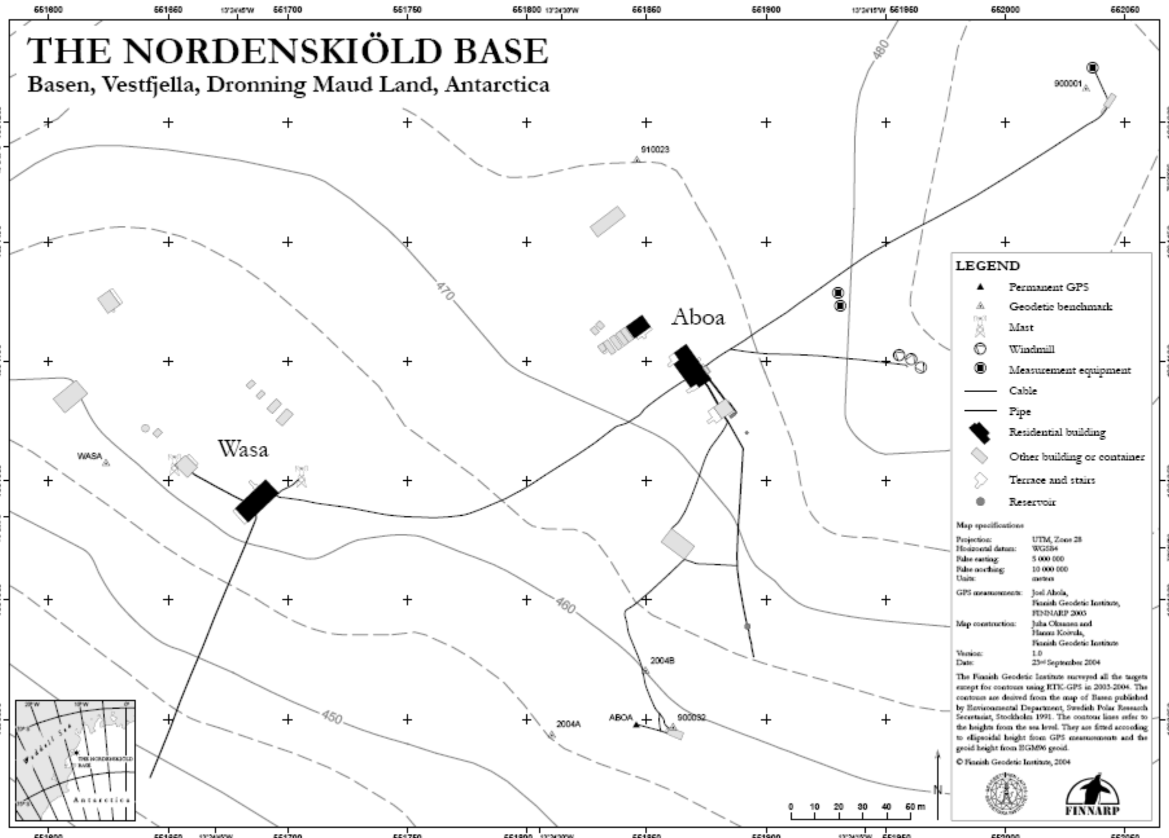

Figure 7: Map of the Nordenskjöld Base
Source: Swedish Polar Research Secretariat

Wasa consists of three buildings: the Radio House, the generator house and the workshop. These buildings surround an area of bare ground that is considered as the station yard. Most of the work at the station is done here. (Swedish Polar Research Secretariat *a*, 2004)

Figure 8: Wasa station
Source: Swedish Polar Research Secretariat

1.3.1.1. Building Design and Facilities

The main building (The Radio House) is 17.5 x 7.6 m, made of wood. The station has open metal foundations with a distance to the ground of 1.4 to 1.8 metres in order to avoid snow accumulation. (Larsson, 1990)
The station has been designed to accommodate 16 people: 12 in main building and 4 in a container designed as living quarters. The generator house, a building of 7.5 x 6 m, consists of three joined containers, contains generators, the water supply system, and a workshop.
Three 40-feet containers are used as winter storage for the tracked vehicles, and three other 20-feet containers (Workshops) are used for storage of food, chemicals, and scientific and logistic equipment. (Swedish Polar Research Secretariat *b*, 2004)
The station is equipped with showers, sauna, dry toilet, washing machine and modern kitchen.
The generator house is well insulated acoustically and the noise produced is negligible in the immediate neighbourhood of this building.
There is a thermal influence on the area immediately around the sewage system of the main building due to discharging grey-water with a temperature of 25-40 degrees. (Larsson, 1990)

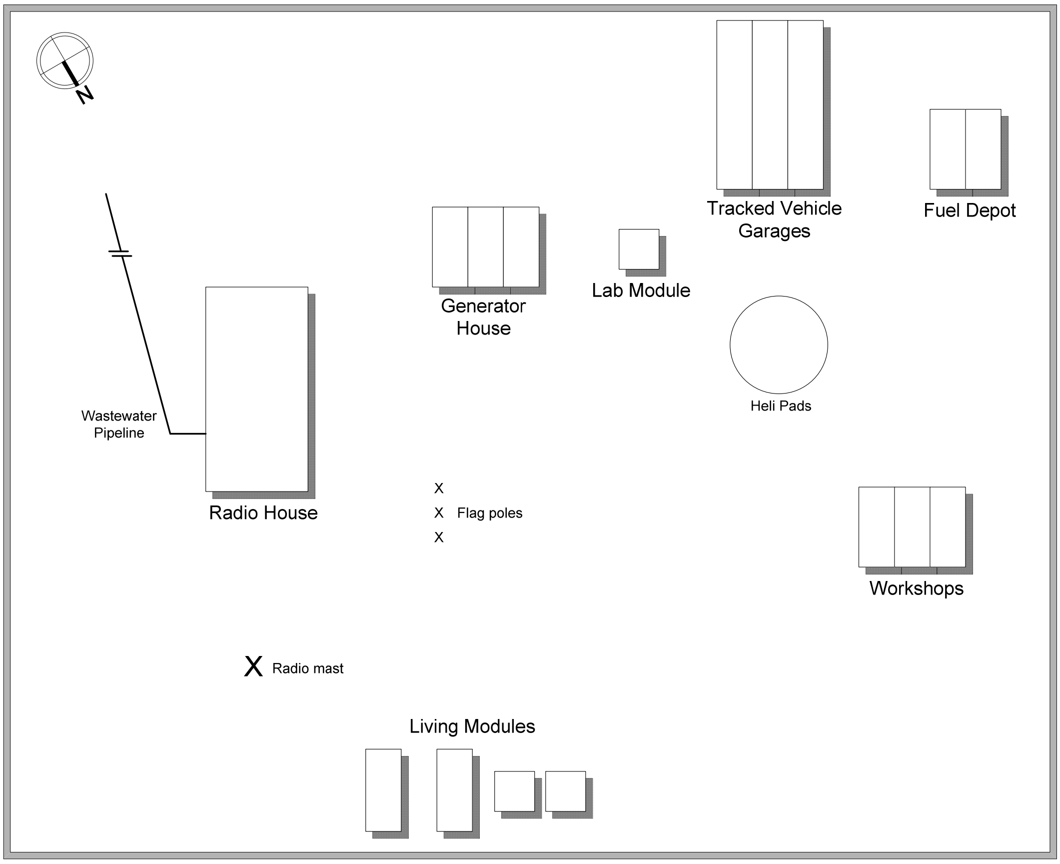

Figure 9: The Wasa Area
Source: Swedish Polar Research Secretariat

1.3.1.2. Power Generation

Solar panels (48 individual units that are 20.6 sq meters) mounted on the walls of the station provide energy for the station. This energy is stored in 80 1.2v nickel cadmium batteries located underneath the building. This provided 12, 24 and 220 volt power to the station through the use of a power inverter. When the weather is clear, solar panels can produce sufficient electricity to operate the station. There are also two diesel generators and two LPG generators as a back-up to the solar system. (Swedish Polar Research Secretariat *b*, 2004)

Figure 10: Solar panels at Wasa station
Source: Swedish Polar Research Secretariat

1.3.1.3. Energy Management

Thanks to a wide range of energy conservation measures, the main building is extremely energy efficient. 30 to 50 cm of rock wool insulation are used for the walls, floor and ceiling. The building is constructed of box plywood sections with an external cladding of timber vertical boards. Triple-glazed windows are located on the northern, eastern and western walls to have a maximum heat gain from the summer sun.
Moreover, a heat exchange system continuously circulates heat from one part of the building to the other. Heat generated from cooking meals, from use of the shower or sauna and produced by the occupants is used to keep the whole building at an even temperature.
For the expedition in 2001/2002, the total energy cost in fossil fuels for the operation of the station over the summer season was estimated at only 300 kg of LPG and 28 litres of petrol. (Papworth 2002)

1.3.1.4. Waste Management and Recycling

All wastes generated on the station are sorted into organics, burnable, glass, metals, batteries, hazardous waste and waste oil. Then, they are stored in used 200-litre drums for back-loading and subsequent disposal or recycling in Republic of South Africa.

Figure 11: Waste management system at Wasa station
Source: Swedish Polar Research Secretariat

1.3.1.5. Water Conservation and Use

Constructional efforts have been done to minimize the daily specific water demand. Water saving taps at all wash sink, two standard thermostatic showers with water saving showerheads, a dishwasher machine with low water consumption and a washing machine with low water consumption has been installed in the station. According to Larsson (1990), between 40 and 50 litres of water per person and day are necessary.
The water supply of the station is provided by a melt ice area approximately 1.5 km from Wasa. About 1 litre of petrol is necessary to produce 300 litres of water

1.3.1.6. Sewage and Waste Water Treatment

The sewage system produces only grey-water thanks to dry toilet integrated in the main building. The grey-water generated is not treated by any means but discharged through a pipeline to an ice-cover area in the vicinity of the station from where it ultimately drains to the sea. Grey-water contains remains of soap, detergent from laundry and washing but also organic matter (food particles).

Figure 12: Wastewater pipeline at Wasa station
Source: Swedish Polar Research Secretariat

1.3.1.7. Chemical Management

Storage and monitoring arrangements of hazardous chemicals are done at the Wasa station. In total 55 different chemicals are stored (e.g. lubricants, anti-freezers, motor oil, transmission oil, absorption materials …).
A database for monitoring the use of chemicals is currently under develoment and the general policy applied at the station is to systematically substitute hazardous substances with less hazardous ones. (Swedish Polar Research Secretariat *b*, 2004)

Figure 13: Chemical storage at Wasa station
Source: Swedish Polar Research Secretariat

1.3.2. Svea (74°35′S, 11°13′W)

The Svea Research Station was built during the Antarctic Expedition of 1987/88 and was the first Swedish research station in Antarctica (since Maudheim in 1949 and Snow Hill Station in 1901). Svea is located on a nunatak in the Heimefront Range about 300 km inland, in the niche valley of Scharffenbergbotnen. The station is used periodically during the field seasons and was the main base during the 1992/93 expedition when Svea was expanded with a living module and a workshop and storage container.

Figure 14: Svea station
Source: Swedish Polar Research Secretariat

1.3.2.1. Building Design and Facilities

The station consists of two joined glass fibre modules. Svea is about 12 m2, has four beds and one pantry. It is equipped with a LPG heater and a stove.

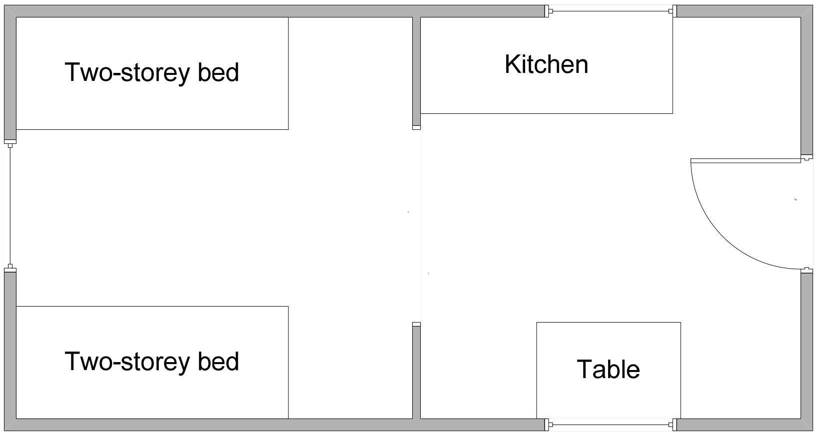

Figure 15: Svea's plan
Source: Swedish Polar Research Secretariat

1.3.2.2. Waste and Sewage Management

Waste from Svea has to be brought back to Wasa. Sewage is collected and transported to Wasa, or in case of small quantities, untreated grey-water is discharged onto a glacier close to the station. (Swedish Polar Research Secretariat *b*, 2004)

1.4. Historical Perspective

After defining the objectives for environmental monitoring, gathering historical environmental monitoring data at Swedish and Finnish polar stations is an essential step.

1.4.1. Existing Data and Research

In the past, a number of studies have been performed at Wasa and Svea stations. In accordance with the Environmental Protocol of the Antarctic Treaty, an environmental monitoring programme was established during the season 1991/1992. The main focus for this programme was pollution levels in snow, ice and soil, lichen and microfauna's studies and station footprint area. Then, some studies have been performed over short time periods and focused on specific management concerns.

A review of all historical monitoring data that have been collected since 1988 at the Swedish polar stations is provided in the **Appendix 1**

As the table in **Appendix 1** shows, a lot of different parameters and key environmental values have been monitored at different places around the Swedish polar stations. However, due to differences in sampling methods, sporadic measurements and inappropriate data handling (that is to say non-standardized data collection, storage and analysis), these information seem difficult to use within the context of a long-time monitoring strategy.

Moreover, some parameters (such as air pollution, erosion, etc) have never been monitored around the station. Some others (such as snow cover thanks to aerial photography) have been monitored only once and never again which does not allow to detect any change in environmental features of the site.

1.4.2. Environmental Features within the Monitoring Area

Background information about the polar stations allows us to build up a picture of key environmental features that are found in the area of interest. Known impacts in the Wasa and Svea stations can be summarized as following:

Atmospheric, freshwater, marine or terrestrial environments including ice-shelves and ice-free ground:

- Small and well-defined areas show a significant impact
- Wasa station is located on a nunatak which is a **particularly sensitive area** in Antarctica
- Contamination of petroleum hydrocarbons and heavy metals have been found in **grey-water** and **soil** mainly from fuel spillage, in helicopter landing site and near the generator house
- Pollution levels in **snow and ice** indicate that pressure from human activities at the research station is very local
- **Station footprint** area has increased due to more facilities at Wasa
- The environment is not protected as part of an Antarctic Specially Protected area (ASPA) or Antarctic Specially Managed Area (ASMA)

Flora and Fauna:

- There seems to be **no species** or species assemblages that are **rare or unique** in the considered area
- As they provide life support for a lot of different species, nunatak are considered as special areas in Antarctica
- Human activities seems to have very local influence on **ecosystems** surrounding the stations (birds, microfauna, lichens and mosses, etc)

Heritage:

- There is **no historic site** listed on the Historic Site and Monument list in the considered area
- As everywhere in Antarctica, the unique natural environment keeps the **historical record of the evolution of the Earth's climate** in a particularly good condition

1.5. Resources Available and Responsibilities

1.5.1. Resources Available

According to COMNAP (2005), sufficient resources are instrumental to the success of the monitoring programme. Allocated resources depend on many parameters (station size, type of monitoring programme, collaboration with other nations, etc.) For the Swedish polar stations Wasa and Svea, resources could be defined as follows:

- The **dedicated budget** should be well defined before each expedition. This total could vary each year in accordance with other activities of the Swedish

Polar Research Secretariat and depends on financing from government and European Union.

- The environmental officer of the Swedish Polar Research Secretariat could be the **programme manager**. He could oversee the implementation of the monitoring programme.

- **Expert scientists** who will take responsibility for sample collection and analysis and **trained staff** who will assist them have to be recruited for next expeditions

- **Specialist equipment** such as field, laboratory and data management equipment have to be available.

- Given that Finnish station and Swedish station share the same area, collaboration between the two nations could be a good opportunity. **Collaborative opportunities** with other nation which have research station in Arctic and in Antarctic could be useful.

1.5.2. Roles and Responsibilities

Roles and responsibilities for the environmental monitoring programme have to be clearly defined:

- According to the Environmental Protocol (Annex I, article II) of the Antarctic Treaty, **Swedish Polar Research Secretariat** has to monitor environmental impacts due to anthropogenic activities around Wasa and Svea stations in Antarctica.

- The **Director General** of the Swedish Polar Research Secretariat is responsible for allocating sufficient resources for the environmental monitoring programme. It is also responsible for recruiting competent staff for establishing, implementing and reviewing the monitoring programme.

- The **Environmental Officer** is responsible for the technical part of the programme. He has to establish, implement, and review a long-term environmental monitoring programme of the human impacts at the Swedish stations in Antarctica.

1.6. Baseline Monitoring

Baseline monitoring can be defined as a data set describing the environmental features around the stations before any anthropogenic activities. Then, any subsequent observed modification can be measured and compared with this basic information.
Baseline information can be quantitative (e.g. concentration of heavy metals in organisms) but also qualitative (e.g. general features of landscapes)

1.6.1. Baseline Information at Swedish Stations

Baseline data can be classified in two categories:

- Baseline data from previous investigation. This information can be found in documents and data banks from the Swedish Polar Research Secretariat, international Antarctic programs, scientific organisations and non-governmental organisations.

- Baseline data from reference plots farthest away from the stations similar to those near the station but not influenced by human activities. This reference data have to be collected during the expedition, in parallel with other samples.

These two types of baseline data are essential to intend to identify and distinguish local human environmental impacts from global and regional human environmental impacts (e.g. climate change, increased UV-B radiation, global contamination caused by the application of technology elsewhere in the world) as well as from random change. (Thor, 1997) It is worth noting that, at present, baseline information from Antarctica is minimal and that is why long term databases are essentials to establish change related to human impacts.

1.6.1.1. Baseline Data from Previous Investigations

This data can mainly be found in documents published by the Swedish Polar Research Secretariat. The yearbook published each year is useful to find such data. The table in **Appendix 1** can give a general idea of what have been previously monitored in order to find baseline data about a specific subject.

1.6.1.2. Baseline Data from Reference Plots

According to previous expeditions, some reference plots have been identified. They have been summarised in the Table 1 below.

Table 1: Summary of the known reference plots

Matrix	Year	Number of reference plots	Location	Coordinates	References
Soil contamination	2003	3	North Basen 1	73°01.236 S 13°23.765 W	[20]
			North Basen 2	73°01.236 S 13°23.765 W	[20]
			Cape Petrel	73°01.848 S 13°26.100W	[20]
Snow and Ice	1992	1	Plogbreen 1.5km upwind from the station	73°02'11.93'' S 13°22'43.12'' W	[6]
Lichen and mosses	1997	n.a.	The plots farthest away from the station		[16]
Grey water	2003	2	Drinking water		[20]
			Tank water		[20]

Source: Swedish Polar Research Secretariat

1.7. Scales of the Environmental Monitoring Programme

According to Mahlon et al. (1998), all environmental impacts should be defined within a spatial and temporal framework. It is really important to carefully consider theses scales before implementing the monitoring programme. Indeed, data collected at the improper scale might diminish the use and value of environmental monitoring programmes (Kennicutt et al. 1998). That is why the following considerations should be taken into account to determine the temporal and spatial framework of this monitoring programme.

First, aims and objectives of the monitoring programme propose a general framework. It has been defined that the monitoring programme should allow to detect any environmental problem at an early stage when corrective actions can still be effective. So this suggests that monitoring programme should be implemented every expedition or second expedition to have enough data to follow environmental trends. Spatial framework is more dependent of the parameter of interest so it is not precisely define in the aims and objectives. However, we know that the sphere of influence of contaminants is restricted to areas close to the pollution source.

As the monitoring programme should be closely related to management decisions, the scales of the monitoring programme should also be fitted to those of the decision-making process to be useful. Indeed, if the scales of data collection are well designed, this could provide suitable information about the effect of environmental management decisions including documentation of recovery when mitigation measures have been implemented. (Mahlon et al. 1998) At the Swedish Polar Research Secretariat, the decision-making process is based on the expedition framework, so the monitoring programme should be implemented every field season or second field season in a limited area around Swedish stations.

This monitoring programme is highly localised. This requires a high spatial and temporal resolution and areas identified as “high impacts” areas require a higher temporal and spatial scale. However, physical, technical, logistical or cost considerations may influence the scales of the monitoring programme. So a compromise between these two aspects should give an accurate framework for the monitoring programme.

To conclude, sampling at Swedish station should be performed every field season or second field season in a restricted area around the stations (depending on each parameter). Where and when possible, sampling at the beginning and end of each expedition should provide more accurate results about contaminants accumulation due to human activities.
Due to resource constraints, sampling that requires a specialist scientist on site could have appropriated timescale (every third expedition for example). Hot spots should also have adapted scales.

A detailed study of the sphere of influence for each contaminant should provide a basis for determining the intensity and the frequency of data collection in both time and space. Temporal and spatial scales for each parameters of this monitoring programme will be set out in the program design.

The spatial and temporal framework accuracy will be tested in the field during the pilot study.

2. Step 2: Defining the Programme

All the environmental and technical features of the area are now well known. The second step should focus on the definition of the boundaries for the monitoring programme.

2.1. Deciding What to Monitor

The first step in defining the monitoring programme is deciding what to monitor. This is an essential stage in the process in order to meet the stated objectives. Deciding what to monitor is a complex process due to the number of factors with a potential influence. To determine these factors, several questions can be helpful:

- Which components of the ecosystem may be affected?
- Which activities may have unacceptable effects?
- Which key indicator variables need to be monitored?

2.1.1. Key Environmental Features of the Area

Considering the first step of the monitoring programme, some key environmental features have been identified. The main components of the ecosystem that could be affected by human impacts around Swedish stations can be sum up as follows:

- Atmosphere
- Terrestrial environment
  - Soil
  - Ice
  - Snow
  - Freshwater environment
- Biodiversity
  - Birds
  - Microfauna
  - Lichens
  - Mosses
  - Algae
- Wilderness
- Aesthetic value

2.1.2. Activities, Outputs and Impacts

Activities which can have an effect on the environment and which may occur at Swedish polar stations are mainly transport, station activity (that is to say all the activities related to human settlements), construction and science. The following table (Table 2) summarizes all these activities, their outputs and their potential impacts on the surrounding environment. According to SCAR/COMNAP workshops, an output can be defined as a physical change or an entity imposed on or released to the environment and an impact can be defined as a change in values or resources attributable to a human activity. Impact is the consequence of an agent of change not the agent itself.

Table 2: Activities, Outputs and Impacts

Activity		Output	Impact
Transport	. Helicopter landing . Vehicles traffic . Foot traffic	. Air/exhaust emissions . Dust . Contaminants . Fuel/hazardous material spills . Noise . Heat . Mechanical actions (terrain disturbance)	. Landscape alteration . Habitat destruction . Biological introduction . Disturbance of biological communities and individuals
Station activities	. Power generation . Heating . Water production . Liquid/solid waste disposal . Fuel storage . Snow removal . Runoff management . Facility and equipment maintenance	. Exhaust emissions . Contaminants . Liquid/solid disposal . Fuel/hazardous material spills . Noise . Mechanical disturbance . Heat . Biological introductions	. Landscape alteration . Habitat destruction . Disturbances of biological communities and individuals
Construction	. Building (including demolition) . Excavation/fill . Airfields . Roads . Pier/wharf . Explosives	. Exhaust emissions . Contaminants . Liquid/solid disposal . Fuel/hazardous material spills . Noise . Mechanical disturbance . Heat . Biological introductions	. Landscape alteration . Habitat destruction . Impacts on biological communities and individuals
Science	. Sample collection . Explosives . Balloons . Etc	. Exhaust emissions . Contaminants . Liquid/solid disposal . Fuel/hazardous material spills . Noise . Mechanical disturbance . Heat . Biological introductions	. Landscape alteration . Habitat destruction . Impacts on biological communities and individuals

Source: SCAR, COMNAP (1996)

2.1.3. Activities Which Can Have Unacceptable Effects on the Environment

Considering the previous table (Table 2), we are now able to determine which activities can have unacceptable effects on the environment around the stations. According to Swedish Environmental Impact Assessments and Post-activity reports from earlier expeditions, outputs as a result from disposal of liquid waste water and fuel storage are the main sources of human impacts in the area.

2.1.3.1. Liquid Waste Disposal

As we already seen, the sewage system at Wasa station produces grey-water. The grey-water is not treated by any means but discharged through a pipeline to an ice-covered area in the vicinity of the station from. Grey-water contains remains of soap, detergent from laundry and washing but also organic matter (food particles). At Svea station, sewage is collected and transported to Wasa, or in case of small quantities, untreated grey-water is discharged onto a glacier close to the station.

Direct impact of human sewage water in Antarctica is predominantly on a local scale. Releasing untreated waste water can have several effects on the surrounding environment.

One risk is that fresh water for Wasa comes from a nearby blue-ice area, approximately 1.5 km from the station, where ice in the summertime melts to water. By releasing untreated grey-water in the crevasse, this might lead to contamination of the melted blue-ice area in the future, as the ice moves.

Another risk is about the discharge of toxic chemicals at potentially dangerous levels. This could affect local biodiversity. Moreover, the presence of micro-organisms in grey-water is also a problem: it represents a health and pollution concern for humans and local biodiversity. According to Hughes K.A. (2005), infection via sewage of local species may be possible. So the persistence of these micro-organisms in Antarctic environment and their interaction with endemic species should be studied.

2.1.3.2. Fuel Storage

Fuel remains the most important pollutant brought to Antarctica during expedition, hence, correct fuel handling is important.
Fuel usage is limited at Wasa and Svea stations thanks to a wide range of energy conservation measures (e.g. solar panel, good insulation, heat exchange system). Fuel is essentially used for vehicles and generators (two diesel generators and two LPG generators).
The system for fuel handling was improved during the expedition 1999/2000. All storage of fuel drums is now on flat racks and all fuel handling was in line with the Nordic Environmental Handbook.
Usage of fuel can have several hazardous effects on surrounding environment. The first one is related to oil spills. These spills generate the release of highly toxic chemicals into the terrestrial environment. This can have great effect on the local biodiversity. The second one is related to depositions from combusting engines used around the station.

2.1.3.3. Other Activities

Other activities that can also have unacceptable effects include waste production, vehicles and foot traffic, etc. This will be set out in detail later.

2.2. Indicators and Parameters

2.2.1. Indicators

According to the COMNAP (2005), an environmental indicator is defined as "*signs or symptoms of change due to numerous factors in an environmental feature or features*".

Based on the objectives of the programme, the environmental setting, and the activities which can have unacceptable effects (previously defined) at Swedish stations, a set of indicators at the Swedish stations have been proposed for the monitoring programme on the **Appendix 2** (Overview of Some Potential indicators and Parameters for Use in Monitoring Programmes in Antarctica). Indicators are specific for each theme areas and have been classified as follows:

- Atmosphere
- Terrestrial environment
- Coasts and oceans
- Biodiversity
- Human settlements and activities

2.2.2. Parameters

Once the most appropriate indicators have been defined, parameters to measure should be determined. There exists a lot of different parameters for each indicator so it is important to pay particular attention to the choice of parameters. The Australian Antarctic Data Centre has developed a number of functions that a parameter should have. Environmental parameters should:

1. Serve as a robust indicator of environmental change;
2. Reflect a fundamental or highly-valued aspect of the environment or an important environmental issue;
3. Be either national in scope or applicable to regional environmental issues of national significance;
4. Provide an early warning of potential problems;
5. Be capable of being monitored to provide statistically verifiable and reproducible data that shows trends over time and, preferably, apply to a broad range of environmental regions;
6. Be scientifically credible;
7. Be easy to understand;
8. Be monitored with relative ease;
9. Be cost-effective;
10. Have relevance to policy and management needs;
11. Contribute to monitoring of progress towards implementing commitments in nationally important environmental policies;
12. Where possible and appropriate, facilitate community involvement;
13. Contribute to the fulfilment of reporting obligations under international agreements;
14. Where possible and appropriate, use existing commercial and managerial indicators; and
15. Where possible and appropriate, be consistent and comparable with other countries and State and territory indicators.

This set of indicators' functions has been tested for several years by the Australian Antarctic Division and seems to be effective. So, the parameters for the monitoring programme of the Swedish Polar Research Secretariat will be inspired by these functions.
The criteria defining by the COMNAP (2005) will also be used to define indicators and parameters for the programme.

2.3. Prioritisation

In accordance with the criteria established before for indicators and parameters, a list of possible monitoring indicators and parameters from local environmental values and possible impacts has been initially developed. (C.f. **Appendix 2**: Overview of some potential indicators and parameters for use in monitoring programmes in Antarctica)

However, values and impacts are too large to be adequately monitored within available resources. So undertaking a prioritisation of values and impacts that are most critical could be helpful to decide what to monitor. Prioritisation will be based on the work carried out in Step 1. It will also be based on the likelihood and the consequences of the considered impacts. According to Mahlon et Al. (1998), the choice of the parameters should consider practical constraints. Indeed, the extreme conditions in Antarctica imply particular set of criteria.
First, parameters should be measurable on samples that can be measured on site or that can tolerate transport from Swedish stations to laboratories in Sweden. Then, the monitoring

activities should not disturb or ruin the area of concern, especially when the parameters are related to biological organisms.
Of course, all of the above criteria can not be met but they should be taken into account as much as possible to prioritise the indicators and parameters of the monitoring programme. The highest priority should be given to those values that are the most sensitive, those most likely to be significantly impacted, and those that are more important to protect, or a combination of these factors. (COMNAP 2005)

Based on all the above considerations, prioritisation of the parameters can be established. High, medium or low priority can be assigned to each parameter. In order to meet Environmental Protocol requirements and ensure minimisation of environmental impacts, it has been decided that only the parameters with high or medium prioritisation will be assessed. This should give enough environmental information to detect any change in the environmental features at an early stage and to adequately monitor values and impacts in the considered area within available resource. The availability and effectiveness of these indicators and parameters should be assessed during the pilot study.

2.3.1. Air

Previous considerations allow us to conclude that direct monitoring of air is not a high priority for the monitoring programme of Swedish stations. Indeed, there is no incinerator at Swedish stations and according to historical data, the concentration of contaminants in the atmosphere around the stations is at or below the detection level of usual measurement methods. To detect lower concentrations would not be cost-effective. Moreover, meteorological conditions of the site do not favour the concentration of the airborne contaminants in the vicinity of Swedish stations.
An indirect monitoring of air should be performed through the monitoring of local accumulators of air contaminants such as biota, snow, ice and water.

2.3.2. Marine System

Owing to the long distance from Swedish stations to the sea, the monitoring of marine system is not a high priority. Indeed, impacts on the marine ecosystem have a remote possibility to occur and will be really difficult to connect to human activities at Swedish stations. However wastewater generated by the station ultimately drained to the sea could be a source of pollution for the marine. That is why a monitoring programme of wastewater contamination should allow anticipating any contamination of the marine ecosystem.

2.3.3. Terrestrial Environment

According to the data collected previously, terrestrial monitoring should represent an important part of the monitoring programme. It will focus on soil, snow and ice environments and intends to observe any contamination from human activities. The monitoring programme of the terrestrial environments should be based on known historical areas of “high impact” (Swartling 2003), on local topography and on the expected movements of contaminants (downslope and downwind from the source).

2.3.3.1. Soil

Soils constitute the basis of the terrestrial environment. They are the support of biological communities but also accumulators of contaminants. That is why soil monitoring should provide useful information to determine precisely the extent of a contamination related to an activity.

Swedish station Wasa have been built on permanent snow-free area. Snow-free areas constitute only 1-2 % of the total area of Antarctica. These areas are also where most of its unique and sparse flora and microfauna is found. Due to the extreme conditions in Antarctica, plant growth is slow and the low rate of soil processes makes the snow-free ground especially sensitive to damage and erosion from vehicles and pollution. It is therefore vital to minimise the environmental impact in this sensitive ecosystem. (Swartling 2003)
Standard physical properties of soil that should be measured include grain size, pH, conductivity, moisture content, nutrients, Total Organic Carbon (TOC) and Total Inorganic Carbon (TIC). These parameters are required to assess natural variability in the monitored system. In general, these parameters are easy to measure thanks to standard and cost-effective methods. Due to low traffic around the station, the soil erosion should not be considered as a relevant indicator. Based on historical information (Swartling 2003), the following contaminants are also important: Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAH), Benzene, Toluene, Ethylbenzene and Xylene (BTEX) and a few relevant metals (e.g. Pb, Hg, Cd, Cu and Zn; Fe and Al are used to normalised metal data). These parameters are useful to control among others fuel and chemical spills impacts.

2.3.3.2. Snow and Ice

Snow and ice will be monitored as an accumulator of contaminants from human activities. Sites covered with more than a half meter of snow or ice should be sampled for measuring standard parameters: pH, salinity; and for some contaminants TPH, PAH, light absorbing materials, some ions and a few of relevant metals (e.g. Pb, Hg, Cd, Cu, Zn and S; Fe and Al). These parameters are useful to control among others depositions from e.g. combusting engines around the station and fuel or chemical spills impacts.
Although it could be interesting parameters, spatial extent using aerial photos implies very high costs so it should be only monitored when possible (that is to say when an airplane or a helicopter is available at the station).

Table 3: Prioritisation - Terrestrial Environment

Theme	Description	Indicator	Parameter	Priority
Terrestrial environment	Soil	Soil erosion (footpath)	Grain size	Medium
		Soil composition	pH	Medium
			Conductivity	Medium
			Moisture content	Medium
			Soil compaction	Low
			Nutrients (total amount and bioavailable concentration of P, N, Ca, K, Mg)	Medium
			Carbon Content (Total Carbon, Total Organic Carbon and Total Inorganic Carbon)	Medium
			Total Petroleum Hydrocarbons	Medium
			Polycyclic Aromatic Hydrocarbon	Medium
			Benzene, Toluene, Ethylbenzene and Xylene	Medium
			Metals (Pb, Hg, Cd, Cu, Zn, Fe and Al)	Medium
	Snow and ice	Snow coverage	Spatial extent	Low
		Snow analysis	pH	High
			Salinity	High
			Ions (Cations: Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+} and Anions: NO_3^-, SO_4^{2-}, Cl^-)	High
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al)	High
			Total Petroleum Hydrocarbons	High
			Polycyclic Aromatic Hydrocarbon	High
			Particulates / Light Absorbing Materials	High

2.3.4. Biodiversity

Given that biota interacts directly with its chemical and physical surrounding environment, it should represent a good indicator for the monitoring programme. It can also be useful to observe and measure any physical and chemical disturbances.
According to previous studies (Thor 2000), Swedish stations are not situated in the immediate vicinity of avian or mammalian habitat (including nesting area). So biological community is mainly composed of lichens, mosses, algae and microfauna.

2.3.4.1. Vegetation

Monitoring programme should focus on lichens and mosses. As we already know, Wasa station has been built on snow-free area which is the main support for lichens and mosses growth. This way, these biological communities should be important indicators to measure physical and chemical disturbance in the area. Indeed, lichens could be used as accumulators of contaminants (including metals); however, the growth rates of Antarctic lichens at continental localities have been measured to 0.1 mm per year (Johansson 2002). So any sample could adversely damage the lichen communities on the nunatak Basen. As previous studies (Thor 1997), the main objective of the lichens and mosses' monitoring should be to evaluate whether there are any changes in species richness and abundance and if so, whether these changes differ between the sites close to the research stations and the reference sites.

2.3.4.2. Higher Animals

Although higher animals such as birds or mammals are recognized as one of the most important values of Antarctica, indicators based on their observation should not have a high priority in this monitoring programme. Indeed, it is very difficult if not impossible to establish a clear link between change in the higher animals' community and human activities. Moreover such observations require specific resources (such as expert scientists or trained staff)
These higher animals are often on top of the food chain. So the objective of this monitoring programme is to have an efficient control of the first links in the food chain to prevent any contamination of higher animals.

2.3.4.3. Aliens

Aliens can be defined as non-native species introduced to an ecosystem as a result of human activities. Invertebrates (flies, aphids, beetles, etc.), vertebrates (mice, cats, rats, etc), and plants (grasses, pearlwort, rushes, etc.) can be brought, intentionally or not, to Antarctica via several vectors of spreading such as cargo, expeditioners (clothing, boots, equipment), fresh food, etc. Introduced species are closely related to intensity of Antarctic's activities. The likelihood that aliens succeed in adapting to Antarctic's extreme conditions is not negligible, all the more since aliens come from similar regions (Greenland, Svalbard, alpine regions, etc.). In some cases, aliens come to dominate local biodiversity in terrestrial, freshwater, and marine habitats. In Antarctica, more than elsewhere, alien species, are very undesirable because they constitute a threat to Antarctica's wilderness or intrinsic values.

As anthropogenic activities in Antarctica increased, introduction of non-native species becomes more and more a matter of concern for most of Antarctic's organisations (SCAR, COMNAP, AEON …). For example, AEON has launched a survey on existing procedures concerning introduction of non native species.
That is why introduced non-native species should be adequately monitored in this programme in order to give sufficient information to National and International programmes managers to

propose mitigation measures. Monitored parameters should be the number of species, the number or concentration of these species and their spatial extent.

Microorganisms can also be considered as aliens. They can be introduced in the Antarctica's environment through sewage water. At present very few studies cope with this subject. Their persistence in polar conditions and their interaction with endemic species is not well known at present and may require deeper studies.
Microorganisms should be monitored via wastewater monitoring programme.

Table 4: Prioritisation – Biodiversity

Theme	Description	Indicator	Parameter	Priority
Biodiversity	Wildlife	Population size of the four species of birds	Number of individuals	Low
		Breeding population of the four species of birds	Number of breeding pairs	Low
		Microfauna	Number of species	Low
			Concentration of individuals	Low
		Species and number species killed, taken or interfered with or disturbed for the purpose of scientific research	Number of individuals	Low
			Number of species	Low
	Vegetation	Vegetation quality (lichens, mosses and algae)	Number of species	Medium
			Spatial extent	Medium
			Total Organic Carbon	Low
			Colour	Low
		Pollution traces in the vegetation	Metals (Cd, Pb, Cu, Zn, Hg)	Low
	Introduced organisms	Introduced organisms	Number of species	Medium
			Concentration of individuals	Medium
			Spatial extent	Medium

2.3.5. Human Settlements and Activities

Disturbances in and around polar stations can only be understood within the context of human activities (Kennicutt et al. 1999). Their frequency, intensity and geographic location should be collected to support the interpretation of monitoring information and to determine the origin of the disruptions.
Human settlements and activities will be subdivided into several theme including station footprint, water, waste and fuel management.

2.3.5.1. Stations Footprint

Station footprint monitoring includes the total area of the stations, the stations person-days and the field activities (Number of person-days in field and location of field camps). The monitoring of heat and noise is not relevant for Swedish stations so it should not have a high or a medium priority in this monitoring programme. For the same reasons, measurements of electronic radiations used for communication should not be monitored.

Table 5: Prioritisation - Human Settlements and Activities - Footprint and Communication

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Footprint	Total area of the station	Station footprint	Medium
		Station person days	Person-days	Medium
		Medical consultations	Illness rate	Low
			Injury rate	Low
		Heat	Temperature	Low
			Thermal regime	Low
			Timing	Low
			Duration	Low
		Noise	Type	Low
			Quantity	Low
			Timing	Low
			Duration	Low
		Field activities	Number of person days in field	Medium
			Location of field camps	Medium
	Communication	Electromagnetic radiation	Frequency	Low
			Strength	Low
			Timing	Low
			Duration	Low

2.3.5.2. Water (including Freshwater and Wastewater)

Water remains one the most important medium in the transport and distribution of contaminant agents. So water monitoring should be an important part of this monitoring programme. As there is no wastewater treatment plant, wastewater should be monitored to control the amount of contaminants released from the station and freshwater should be monitored to detect at an early stage any contamination from sewage. Freshwater could also be used as a reference for wastewater analysis.

A lot of monitoring parameters for both freshwater and wastewater exists. The monitoring parameters of interest should include standard analyses such as the volume of wastewater discharged, pH, conductivity, temperature (T) and salinity. Hardness and turbidity should not give critical information for this monitoring programme so they should have a low priority. Total Suspended Solids (TSS) and Dissolved Oxygen (DO) could be interesting to measure but due to maximum holding time constraint (7 days), this analysis could not be used for this monitoring programme. Contaminants analysis should include measurements of some ions (NO_3^- and PO_4^{3-} but also NH_4^+, Ca^{2+}, SO_4^{2-}, Cl^- and F^-) and a few relevant metals (e.g. Pb, Hg, Cd, Cu and Zn; Fe and Al). NO_2^- cannot be analysed in this monitoring programme due to maximum holding time constraints. For the reasons already mentioned, coliform bacteria should be analysed both in freshwater and wastewater. In addition, biological (BOD) and chemical (COD) oxygen demand could well complete this set of parameters for water monitoring.

All these parameters have been used for a long time and most of them are described in the Antarctic Environmental Monitoring Handbook (COMNAP 2000). They have been chosen for their capacity to establish unambiguous link to anthropogenic activities.

Table 6: Prioritisation - Human Settlements and Activities – Water

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Wastewater	Volume of wastewater discharged from Swedish stations	Volume of discharge	High
		Composition of wastewater	pH	High
			Total Suspended Solids	Low
			Dissolved Oxygen	Low
			Temperature	High
			Conductivity	High
			Salinity	Medium
			Hardness	Low
			Turbidity	Low
			Biological Oxygen Demand	High
			Chemical Oxygen Demand	High
			Ions (Cations: NH_4^+, Ca^{2+} and Anions: NO_3^-, SO_4^{2-}, Cl^-, F^-, PO_4^{3-})	High
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al)	High
			Coliforms organisms	High
			Phytoplankton (chlorophylls)	Low
	Freshwater	Fresh water consumption	Total water consumption	Low
			Water consumption per person	Low
		Fresh water quality	pH	High
			Total Suspended Solids	Low
			Dissolved Oxygen	Low
			Temperature	High
			Conductivity	High
			Salinity	Medium
			Hardness	Low
			Turbidity	Low
			Biological Oxygen Demand	High
			Chemical Oxygen Demand	High
			Ions (Cations: NH_4^+, Ca^{2+} and Anions: NO_3^-, SO_4^{2-}, Cl^-, F^-, PO_4^{3-})	High
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al)	High
			Coliforms organisms	High
			Phytoplankton (chlorophylls)	Low

2.3.5.3. Waste

It is compulsory to report some data about waste to COMNAP. So the following parameters should be monitored: types and volume (or weight) of produced waste and types and volume (or weight) of waste returned to South Africa. Waste parameters should have only a medium priority because all waste should return to South Africa.

Table 7: Prioritisation - Human Settlements and Activities – Waste

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Waste	Solid waste	Waste types (including hazard)	Medium
			Volume/ Weight of discharge	Medium
		Waste returned to South Africa	Volume/ Weight of discharge	Medium
			Composition	Medium

2.3.5.4. Fuel Handling

Fuel handling has been previously identified as an activity which can have unacceptable effects on the environment. Fuel remains the principal pollutant brought to Antarctica. So the fuel imported and the fuel usage should be reported.

Table 8: Prioritisation - Human Settlements and Activities – Fuel Handling

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Fuel handling	Fuel imported at the stations	Fuel imported	High
		Amount of consumed fuel for stations	Fuel usage	High
		Amount of consumed fuel for vehicles/aircraft	Fuel usage	High

2.3.5.5. Environmental Incidents

In order to have an overall framework of the activities in and around the stations, information on chemical spills, fuel spills and fire should be collected. This includes their location and spatial extent.

Table 9: Prioritisation - Human Settlements and Activities – Environmental Incidents

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Environmental Incidents	Fuel spills	Number of spills	High
			Spatial extent	High
			Location of spills	High
		Chemical spills	Number of spills	Medium
			Spatial extent	Medium
			Location of spills	Medium
		Fire	Location of fire	Medium
			Spatial extent	Medium
		Others	Type	Medium
			Location	Medium
			Extent (m2)	Medium

2.3.5.6. Transport

Aircraft and vehicles operations should be reported to be able to connect these activities to human induced changes. Moreover, transport is in relation with fuel handling.

Table 10: Prioritisation - Human Settlements and Activities – Transport

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Transport	Aircraft operations	Distance travelled	Medium
			Number of landing	Medium
		Vehicles operations	Distance travelled	Medium

2.3.5.7. Logistic

Logistic refers mainly to the resources committed to environmental issues in the Swedish Polar Research Secretariat.

Table 11: Prioritisation - Human Settlements and Activities – Logistic

Theme	Description	Indicator	Parameter	Priority
Human Settlements and activities	Logistic	Resources committed to environmental issues	Allocated resources	Medium
		EIA/permit compliance	Number of breaches recorded	Low

It is important to note that the monitoring programme should essentially assess the impacts from Wasa station. Indeed, the impacts from Svea station are very limited both spatially and temporally.

2.4. Programme Design and Sampling Methods

Once Indicators and parameters have been clearly defined, the design of the programme has to be set out in detail. This step will consist on choosing the appropriated sampling methods, analytical techniques, temporal and geographical framework for each parameter in order to have an efficient monitoring programme.

According to COMNAP/SCAR (2000), the quality of any monitoring programme depends widely on the quality of sample collection, handling and conservation. Moreover, due to severe weather in Antarctica, sampling in support of environmental monitoring presents special challenges.
That is why, in order to simplify and standardize sampling methods in Antarctica, the Antarctic Environmental Monitoring Handbook (COMNAP/SCAR 2000) describes a lot of standard methods and analytical techniques that have been widely used in such regions for different matrix including wastewater/seawater/freshwater, snow and soil/sediments. These methods are well documented and are supposed to give accurate results for selected parameters. Moreover, if same methods are practiced all over Antarctica, this will improve share and comparison of data between national programmes. So these methods will be used as much as possible in this monitoring programme.

However, Swedish polar stations are not equipped to perform the analysis of samples themselves. Indeed, some methods described require a lot of materials on site and thus are more adapted to big stations. In our case, most of samples should be exported to an accredited laboratory in Sweden. In some cases, methods have to be adapted to specificities of Swedish stations (little research station, far from the coasts, etc.) and more appropriated standard methods should be used for some samples analyses. Moreover, in order to have some continuity in the monitoring programme at Swedish stations, analysis of the historical archive should provide guidance for selecting the sampling sites, methods and intervals.
More detail about sample collection, handling and preservation can be found in the Handbook published by COMNAP/SCAR (2000) (see section 4)

This programme claims to be a long-term monitoring programme; nevertheless, it is obvious that techniques, apparatus, materials and reagents will evolve in the course of the time. So for each analysis which should be performed at an accredited laboratory, the person in charge of sampling should imperatively contact directly the laboratory to know the currently used techniques, apparatus, materials, reagents, etc. and the related precautions for collecting, handling and preserving samples.

This programme design should be reviewed after the pilot study.

2.4.1. Terrestrial Environment

2.4.1.1. Soil

Soil has already been monitored at Wasa in 1999/00 and 2001/02. The following methods, material and descriptions are widely inspired from these previous studies (c.f. Swartling 2003)

Figure 16: Soil Samples
Source: Swedish Polar Research Secretariat

2.4.1.1.1. Material and Methods

The soil monitoring should be based on samples collection at different depths ranging from surface to 0.3 meters depth. Samples should be collected randomly and at historically known sites of high impacts, also called “hot spots”.
The technical analysis for each parameter will be set out in detail further.

Random Sampling

According to the secondary study performed during the 2001/02 season and reported by Swartling A. (2003), Wasa station should be divided into 21 squares of 20x20 meters (using e.g. a theodolite) and corners of the outer limits should be marked. This grid, based on two known GPS points can be found in Swartling (2003). Within every square, one surface sample should be taken randomly, only from snow-free patches.

Hot Spots Sampling

In addition to the random sampling, several samples should be collected from eight historically identified hot spots at different depths ranging from surface to 0.3 meters where possible. The hot spots are:

- The helicopter landing site (He): 6 samples points
- The battery storage (Ba): 1 samples point
- Under the generator house (Ge): 4 samples points
- At the fuel platform (Fu): 5 samples points
- The former fuel storage site (Bp): 2 samples points
- The former wastewater treatment site (Wt): 1 samples point
- At the leaking grey-water pipe (Pi): 1 samples point
- At the snow mobile parking site (Sp): 2 samples points

The soil sampling sites are indicated on the Figure 17.
If special contamination (e.g. oil) is obvious in a specific area, the number of samples should be increased.

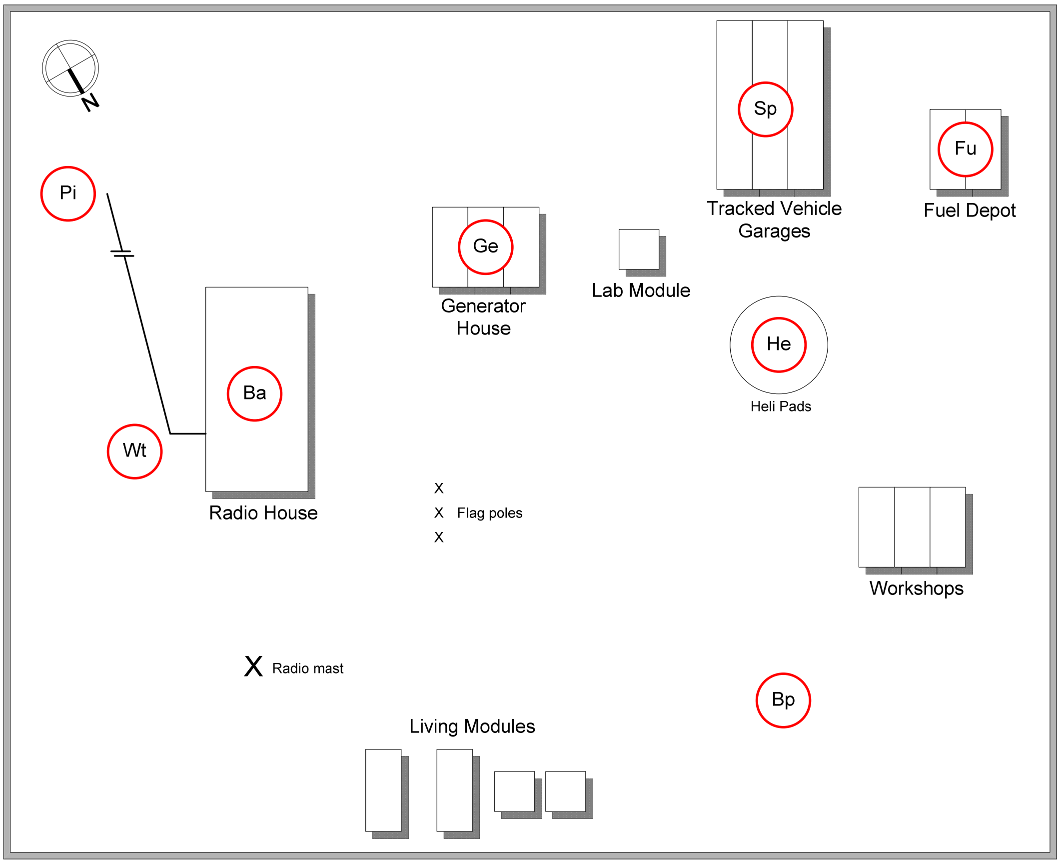

Figure 17: Soil sampling sites at Wasa Station
Source: Swedish Polar Research Secretariat

All samples sites should be photographed and geographical coordinates noted using a GPS.
To reduce analysis cost, composite samples can be made from the systematic random sampling at Wasa. Each composite sample can be prepared until three samples originating from three squares respectively. For the same reason, the surface samples should be analysed first and subsurface samples should be analysed if contamination is obvious in the surface sample.

2.4.1.1.2. Tools

According to previous sampling collection at Wasa station (Swartling 2003), stainless steel trowels or spatulas for the organic analysis should be used. Samples should be put in double diffusion free plastic (layers of polyamide ethylene/ethyl vinyl alcohol/PE/ Polypropylene) sampling bags and properly sealed.
The tools should be cleaned with water, wiped with paper towel, rinsed with ethanol (analytical grade) and finally rinsed with acetone (analytical grade) between each sample. For the metal analysis, new plastic (PE) disposable spoons should be used for each sample. A spade and a crow bar should be used to dig pits when possible where samples should be taken by digging into the sides of the pit using the smaller tools. The larger tools should not be in direct contact with the soil being sampled and so they should be cleaned in snow or as described above for smaller tools if a fuel smell can be detected from the sample.
A battery driven, handheld, hollow stem drill should be used to retrieve samples from frozen ground when the surface layer is clearly contaminated.

2.4.1.1.3. Storage

Soil samples should be kept frozen stored in metal box at the station until analysis.
In order to improve accuracy of result, samples should be sent to the laboratory as soon as possible after the expedition.

2.4.1.1.4. Time Scale

This analysis should be performed every second expedition, alternately with snow monitoring. This time scale should be reduced if some unplanned event happens, such as large oil spill.

2.4.1.1.5. Baseline Data

According to Kennicutt et al. (1999), reference sites for the terrestrial monitoring should consist of equivalent grids of sampling locations, as similar as possible to the disturbed sites, in undisturbed locations. Common attributes between reference sites and disturbed sites should include as much as possible, slope, soil composition, altitude and coverage.
Historical baseline data for soil sampling at Swedish stations comprise three reference samples collected at two localities, referenced with GPS coordinates, two on the north part of the plateau Basen, the third on the south east part of the plateau.

North Basen 1:	73˚01.236 S	13˚23.765 W
North Basen 2:	73˚01.236 S	13˚23.765 W
Cape Petrel:	73˚01.848 S	13˚26.100W

These localities are situated approximately 100 meters higher than the station area, in an area where the influence from station activities is low, since vehicles are not used on the plateau and the prevailing wind direction is generally towards or parallel the station area.

2.4.1.1.6. Analysis

All analyses should be performed at an accredited laboratory in Sweden using standard methods.

Grain Size

The method described in the Antarctic Environmental Monitoring Handbook should be used for determining grain size of the samples (see section 8-1)

pH

There is no method described in the Handbook for this parameter. pH should be analysed with standard method (e.g. method ISO 10390:2005)

Conductivity

There is no method described in the Handbook for this parameter. Conductivity should be analysed with standard method (e.g. method ISO 11265:1994)

Moisture content

There is no method described in the Handbook for this parameter. Moisture content should be analysed with standard method (e.g. method ISO 11461). In the previous studies, moisture content was analysed by heating to 105˚C and weighing (method SS028113). The samples was then sieved and ground (method SS ISO 11464)

Nutrients (total amount and bioavailable concentration P, N, Ca, K, Mg)

There is no method described in the Handbook for this parameter. Different methods are used for different parameters:

- P_{TOT} and S should be analysed using inductively coupled plasma and atomic emission spectrometry (ICP-AES) according to the United States (US) Environmental Protection Agency (EPA) 200.7 method.
- N_{TOT} should be analysed according to SS-EN 25663
- P_{BIO}, Mg_{BIO}, Ca_{BIO} and K_{BIO} should be analysed using inductively coupled plasma (ICP)
- Other nutrients should be analysed using ICP-AES

Carbon Content (TC, TOC and TIC)

There is no method described in the Handbook for this parameter. TC and TOC should be analysed with standard method (ISO 10694:1995). In previous studies, carbon content was analysed according to ASTM D 3178-79 and TOC with SS-EN 25663. TIC can be found using the relation between TC, TOC and TIC. (TC = TOC + TIC)

Total Petroleum Hydrocarbons (TPH)

The method described in the Antarctic Environmental Monitoring Handbook should be used for analysing TPH (see section 8-4).

Polycyclic Aromatic Hydrocarbons (PAH)

The method described in the Antarctic Environmental Monitoring Handbook should be used for analysing PAH (see section 8-5). According to previous studies, the third method using Gas chromatography and Mass Spectrometry (GC-MS) should be used.

Benzene, Toluene, Ethylbenzene and Xylene (BTEX)

There is no method described in the Handbook for this parameter. BTEX should also be analysed using GC-MS, method used previously at Swedish stations.

Metals (e.g. Pb, Hg, Cd, As, Cu, Zn, Fe and Al)

The method described in the Antarctic Environmental Monitoring Handbook should be used for analysing metals content of the samples (see section 8-3). The third method using inductively coupled plasma method (ICP) should be used. Previous studies analysed trace metal using inductively coupled plasma and mass spectroscopy (ICP-MS) according to the modified United States (US) Environmental Protection Agency (EPA) 200.8 method for Cd, Co, Cr, Cu, Hg, Pb and As. Mn, Ni, V and Z were analysed using ICP-AES according to the modified EPA 200.7 method.

2.4.1.2. Snow and Ice

Snow has already been monitored at Wasa in 1991/92 and in 1993/94. The following methods, material and descriptions are widely inspired from these previous studies (C.f. Isaksson et al. 1992 and Stenberg et al. 1998).

Figure 18: Snow and Ice Sampling at Wasa station
Source: Swedish Polar Research Secretariat

2.4.1.2.1. Materials and Methods

Previous study (Stenberg et al. 1998) has shown that the influence of a little station could not be detected beyond 10 km. This indicates a suitable area for this snow sampling programme to study large-scale pollution pattern. According to the weather station at Aboa, the predominant wind direction is East-North-East.
In accordance with the previous studies, the surface snow samples should be taken from three different sites: one about 1.5 km upwind from the station (site 1), one immediately downwind (about 0.3 km from the station) (site 2) and one 3 km downwind (site 3). An area of about 10x10 meters should be delineated on the first sampling date (with e.g. bamboo stakes). At each site, ten evenly distributed samples of about 1 kg of snow should be taken in the uppermost 1-7 cm of the snow cover not closer than 50 cm from the square's sides.
Special precautions should be observed to keep the sampling area clean: snowmobile should be left about 100 m from the sampling site. Before entering the selected area, clean-room clothing should be put on, including shoes, gloves and mouth protections.
To reduce analysis cost, three of the surface snow samples can be randomly chosen from each site and analysed.

2.4.1.2.2. Tools

The snow samples should be collected in clean polyethylene bags, which should be sealed and kept in a frozen state. Sampling tools should be a plastic spade and pre-cleaned plastic tools.

2.4.1.2.3. Storage

The snow samples should be stored in boxes in a frozen state (about -15˚C) until the time of analysis at the laboratory.

2.4.1.2.4. Time Scale

During an expedition, the three sites should be samples twice: once as soon as possible after the expedition reached the station and again at the end of the field seasons. Snow monitoring programme should be performed at every second field season, alternately with soil monitoring.

2.4.1.2.5. Baseline Data

Historical baseline data for snow sampling at Swedish stations comprise two types of reference sample:
The site 1, situated 1.5 km upwind the station should be considered as reference site. During the field season 1991/92, its geographical coordinates was: 73˚02’11.93’’ S, 13˚22’43.12’’ W. A core (10 m) drilled about 2 km from the station Wasa have been chosen as reference to provide information back in time, before the establishment of the stations in 1988/89. Samples from two different depth intervals before 1988/89 were selected in accordance with known snow accumulation in this area. The first period covers about one year around 1985-87 and the second period covers about one year around 1978-1980 (Stenberg et al. 1998).

2.4.1.2.6. Analysis

All analyses should be performed at an accredited laboratory in Sweden using standard methods.

pH

There is no method described in the Handbook for this parameter. pH should be analysed with standard method (e.g. method ISO 10523:1994)

Salinity

There is no method described in the Handbook for this parameter. Salinity should be analysed with standard method (e.g. method IAPSO Standard Seawater)

Ions (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-})

There is no method described in the Handbook for this parameter. Cations and anions should be measured by ion chromatography using standard methods (e.g. cations: method ISO 14911:1998 and anions: method ISO 10304)

Metals (e.g. Pb, Hg, Cd, Cu, Zn and S; Fe and Al)

The method described in the Antarctic Environmental Monitoring Handbook should be used for analysing metals content of the samples (see section 7-1).

TPH

The method described in the Antarctic Environmental Monitoring Handbook should be used for analysing metals content of the samples (see section 7-2).

PAH

There is no method described in the Handbook for this parameter. PAH should be analysed with standard method (e.g. GC-MS method)

Particulates / Light Absorbing Materials

The method described in the Antarctic Environmental Monitoring Handbook should be used for analysing particulate matter in snow (see section 7-3). In the Handbook, the filter used is a Nucleopore 25 mm, 0.4 µm pore size; in previous study, the filter used was Nucleopore 37 mm, 0.2 µm pore size.

2.4.2. Biodiversity

2.4.2.1. Vegetation (Lichens, Mosses and Algae)

Vegetation and especially lichens, mosses and algae have already been monitored at Wasa in 1991/92, in 1993/94 and in 2001/02 The following methods, material and descriptions are widely inspired from these previous studies (Thor 1995, Thor 1997, Eriksson 1995, Johansson 2002)

Figure 19: Lichens at Wasa Station
Source: Swedish Polar Research Secretariat

2.4.2.1.1. Materials and Methods

The growth rates of Antarctic lichens at continental localities have been measured to 0.1 mm per year. This means that the development of lichen communities is a slow process, sensitive to human disturbance. As a consequence, a very special attention should be paid to lichens' monitoring. Due to extreme sensitiveness of vegetation, only non destructive analysis should be performed.

A method which establish permanent plots with lichens and mosses for monitoring local human impact around Swedish stations have been developed by Göran Thor (Thor 1997). This method should be repeated to have continuous data about the occurrence of lichens and mosses in this area. The following descriptions are from Thor (1997).

Eleven transects with permanent plots were established as close as possible to the three stations (i.e. at the nearest site supporting lichens), and also different distances from Svea and Wasa

Six transects (five 30 m in length and one 11.74 m) were established in Heimefrontfjella: one on the small rock mound on which Svea is situated, one on the north slope of the first hill south of Svea, one on a top of the second hill south of Svea, one on the south slope of the fourth hill south Svea and one on the moraine hill south of Svea. One reference transect was established near the north-western end of Steinnabben, a site rarely visited by Swedish participant.

Four transects (30 meters in length) were established at Basen: two in line close to the sewage water treatment works south of Wasa and two on the hill northeast of Aboa.

One transect was established at Fossilryggen circa 100m southeast of the small field station. The complete description of the site can be found in the article of Göran Thor: *"Establishment of Permanent Plots with Lichens and Mosses for Monitoring Human Impact on Environment in Heimefrontfjella and Vestfjella, Dronning Maud Land, Antarctica"*, 1997.

The start and end points of the transects have been permanently marked by aluminium stakes or by 20 mm diameters holes drill in the rock. So the transects should be found without difficulty. The start point should always be located at the northern end of the transect. Plots should be generally established at 1 m, 4 m, 7 m, 10 m, 13 m, 16 m, 19 m, 22 m, 25 m, and 28 m along the transect. There are some exceptions for some transects. Every second plot should be positioned on the right side ("R") and every second on the left side ("L"). In previous studies, the first plot was on the right site beside transect 4 where it was on the left side.

The plots, each 0.5x0.5 m, should be positioned along the transect. Usually 10 plots are positioned along each transect, with the exception of transect 1 (with 18 plots), transect 4 (with 11 plots), transect 5 (with 11 plots) and transect 11 (with 9 plots). Each plot was divided into 25 subplots, each 10x10 cm. About 250 subplots should be recorded along each transect apart from transect 1 (with 450 subplots), transect 4 (with 300 subplots), transect 5 (with 275 subplots) and transect 11 (with 225 subplots). Owing to irregularities in surface details the plots are usually not horizontal; indeed, some are almost vertical.
Each subplot should be investigated for occurrence of lichens and mosses.
The corners of all of the larger plots were marked with spray paint. The transect and plot markers should be regularly checked to ensure their continued existence in spite of the harsh climate, trampling or cryoturbation.
More detailed to record the plot can also be found in the article of Göran Thor: *"Establishment of Permanent Plots with Lichens and Mosses for Monitoring Human Impact on Environment in Heimefrontfjella and Vestfjella, Dronning Maud Land, Antarctica"*, 1997.

Each transect should be photographed and geographical coordinates noted using a GPS.

Lichens and mosses monitoring is dependent on weather. Indeed an extensive snow cover during the austral summer could imply the exclusion of some plots. So this monitoring should be done as soon as possible and repeated over the time at Wasa station. Investigation of the transects required about two weeks (Thor 1997).

2.4.2.1.2. Tools

A wooden frame 0.5x0.5 m should be used as a plot with a grid of wires forming the subplots (10x10 cm). Spray paint and aluminium stakes should be used to mark respectively the corners of all of the larger plots and the transects if markers have been damaged.
If need be, the length of the transects with plots should be measured with a metal measuring-type and should be oriented using an Antarctica improved 360˚ compass.

2.4.2.1.3. Time Scale

The vegetation monitoring requires a specialist scientist on site. So, this should be performed every second or third year.

2.4.2.1.4. Baseline Data

The plots farthest away from the stations are referred to as reference plots. Where possible, these were established in areas having species composition similar to those near the stations. The reference plots are intended to identify and distinguish local human environmental impacts from global human environment impacts (e.g. climate changes, increased UV-B radiations), as well as from random changes.

Reference transects in Heimefrontfjella are the transect established near the north-western end of Steinnabben, a site rarely visited by Swedish participant and the transect on the south slope of the fourth hill south of Svea.

2.4.2.1.5. Analysis

The analysis of lichens and mosses should be done exactly as Thor described (Thor 1997).

Number of species

Within each subplot, lichens or mosses presence or absence should be noted. If lichen is present in a subplot, the species should be determined and reported. Mosses are not determined to species; they are recorded only as “moss”. An identification key has been established for the lichens and lichenicolous fungi by the Swedish Polar Research Secretariat.

Spatial extent

The spatial extent of lichens and mosses should be monitored by determining the presence or not of each species of lichens and mosses in each subplot.

2.4.2.2. Introduced Organisms

Introduced organisms have never been monitored at the Swedish stations.

“IPY Aliens in Antarctica” is the name of an international project sponsored by SCAR (2007) that will help inform the Antarctic Treaty parties of the size and nature of the threat and possible mitigation methods. The study focus on the propagules which can be defined as a means of propagation for organisms e.g. seed, spore, egg, live insect.

The project will encompass five components directed at information attainment of logistic processes and propagule assessment:

- Component 1 - Travel history questionnaire
- Component 2 - Survey of organisations
- Component 3 - Human sampling program
- Component 4 - Cargo as a vector
- Component 5 - Data Management

Explanations on this programme can be found in SCAR (2007)

Introduced organisms are not easy to monitor for a little research station. The methods require specific analytical techniques, apparatus and materials. That is why a good way to monitor aliens could be to join the project and to share knowledge about this subject with other members of this project.

2.4.3. Human Settlements and Activities

2.4.3.1. Stations Footprint

Monitoring of station footprint should focus not only on stations (total area, number of person-days) but also on the field camps (location, number of person-days)

2.4.3.1.1. Materials and Methods

There is no particular material and method required to report the stations footprint. GPS receiver should be used to report coordinates of the station. Aerial photography, when possible, could be very helpful to determine the stations area (for aerial photos, see Malmberg C. 1997).

2.4.3.1.2. Time Scale

The station footprint should be reported every expedition.

2.4.3.1.3. Baseline Data

This type of data has to be recorded every year for the COMNAP so historical data about station footprint is available at Swedish Polar Research Secretariat.

2.4.3.1.4. Analysis

Total Area of the Stations

The total area of the station should be reported. This includes areas occupied by buildings, storage tanks, roads, landfills, snow disposal areas, pipelines, excavations, landing sites, etc.
If there has been no change since the previous expedition, just the total area should be report. If the area has been modified (construction or destruction), the modifications should be set out in detail. GPS coordinates of areas should be noted.

The Stations Person-days

The number of person-days at the station should be reported

Field Activities

The number of person-days in field and the location of the field camp should be reported using GPS coordinates. Any accident in the field should also be reported in the appropriated section (c.f. “Environmental Incidents” Part 2 Chapter **Erreur ! Source du renvoi introuvable.**)

2.4.3.2. Water

Water monitoring programme should focus on wastewater and freshwater.

2.4.3.2.1. Materials and Methods

Due to analysis constraints, some of the following parameters will be analysed on site and some other will be analysed after the expedition in an accredited laboratory in Sweden: temperature, pH and conductivity should be performed on site; other analyses should be performed in Sweden.

Water samples should be collected manually (using e.g. a grab sampler). A special attention should be pay in collecting samples in order to avoid any introduction of extraneous material.
Due to diurnal fluctuation in concentration and flow volume, it is quite difficult to get representative samples. So composite samples, consisting of several discrete samples collecting at different hours of the day should be constituted.

As water monitoring has never been performed at Swedish stations, the following method should be tested during pilot study and modified if necessary.
Samples collection should occur twice during the expedition. Due to samples storage constraints (1 month maximum), the analysis should be performed rather at the end of the expedition so as to samples can reach the laboratory as soon as possible and no later than one month after being collected (e.g. about 3 weeks and 1 week before going back to Sweden due to maximum holding time for samples). Each time, eight samples should be collected all day

long, from the morning to the evening, about every two hours and each collection time, two samples should be collected: one in plastic containers (about 500 mL) and one in an acid washed plastic bottle for the metal analysis (about 125 mL). The collection time for each sample should not exceed 15 minutes. In total, 2x8 discrete samples that should be brought together in 2 composite samples should be collected in one day for both freshwater and wastewater.

For wastewater monitoring, samples should be collected directly at the end of the wastewater pipe. For freshwater monitoring, samples should be collected on the tap of freshwater inside buildings.

A particular attention should be paid to water samples. They are really time-sensitive and they should be frozen as soon as possible after being collected. In order to have useful and readable results, it is important to contact the selected laboratory before the expedition to know which methods will be used, which containers are required, which amount of water should be collected, etc. because methods can change with time and laboratories are not all equipped with the same apparatus and material.

Temperature, pH and conductivity should be analysed directly on site. The analytical techniques are explained further.

2.4.3.2.2. Tools

Both plastic (PE) containers and acid washed plastic bottles should be used to perform these analyses. For discrete samples, 500 mL plastic (PE) containers and 125 mL acid washed plastic bottles should be used. Grab sampler should be used to collect water samples. Bigger containers should be used to store composite samples.
Temperature, pH and conductivity should be measured directly on site so some specific materials are needed. Handbook can be referred to have the complete list of apparatus, materials and reagents required for these analyses (see section 6-6, 6-7 and 6-10).

2.4.3.2.3. Storage

Samples should be kept at a frozen state until analysis. Analyses for the selecting parameters should be performed no more later than one month after samples collection.

2.4.3.2.4. Time Scale

Monitoring of water should be performed every expedition.

2.4.3.2.5. Baseline Data

Freshwater was studied in 1998 at Swedish station Wasa. So baseline data are available at Swedish Polar Research Secretariat. However sewage water has never been monitored. Moreover, freshwater could be used as a reference for sewage water.

2.4.3.2.6. Analysis

All analyses should be performed either at an accredited laboratory in Sweden or directly on site using as much as possible standard methods. For the technical analyses not described in the Handbook, information comes from Swedish laboratories.

Volume of Wastewater Discharged

This parameter should be measured installing a meter on the pipe of discharged water.

pH

The method described in the Antarctic Environmental Monitoring Handbook should be used to measure pH (see section 6-6). As pH samples should be analysed within 24h to give an accurate result, this parameter should be analysed directly on site.

Temperature (T)

The method described in the Antarctic Environmental Monitoring Handbook should be used for measuring temperature (see section 6-7). This parameter should be analysed on site. Such parameters depend on temperature (such as pH and conductivity)

Conductivity

The method described in the Antarctic Environmental Monitoring Handbook should be used for measuring conductivity (see section 6-7). As conductivity should be tested within 24h, this parameter should be analysed directly on site.

Salinity

There is no method described in the Handbook for this parameter. Salinity should be analysed with standard method (e.g. method IAPSO Standard Seawater)

Biological Oxygen Demand (BOD)

The method described in the Antarctic Environmental Monitoring Handbook implies a maximum holding time for the samples of 48 hours. A method with a maximum holding time of 1 month should be preferred, such as determination either by titration or by electrode.

Chemical Oxygen Demand (COD)

The method described in the Antarctic Environmental Monitoring Handbook should be used for measuring COD (see section 6-4). In previous studies, method SS 028118/1 was used.

Ions (NO_3^- and PO_4^{3-} but also NH_4^+, Ca^{2+}, SO_4^{2-}, Cl^- and F^-)

- Nitrate: The method described in the Antarctic Environmental Monitoring Handbook should be used for measuring nitrate and nitrite (see section 6-8). In previous studies, method SS 028132/1 has been used.
- Phosphate: The method described in the Antarctic Environmental Monitoring Handbook should be used for measuring phosphate (see section 6-9). In previous studies, method SS 028126/2 has been used.
- Other ions: There is no method described in the Handbook for other ions. Other ions should be analysed with standard methods. (e.g. cations: method ISO 14911:1998 anions: method ISO 10304)

Metals (e.g. Pb, Hg, Cd, Cu and Zn; Fe and Al)

The method described for the snow in the Handbook can be used for water samples (see section 7-1). In previous studies, method DIN 38406/22 (ICP) was used.

Coliform Bacteria

The analysis of Coliform bacteria presents some technicalities due to the maximum holding time of the samples. According to Björn Olsen, there is no quick method to analyse Coliform bacteria under field conditions. However, there are two possible alternatives: The samples can be frozen and analysed in a laboratory in Sweden after the expedition or the other option is to culture the samples on spot in a small portable incubator and to analyse the samples in Sweden after the expedition. In the laboratory, the method described in the Antarctic Environmental Monitoring Handbook should be used for analysing the Coliform bacteria (see section 6-11).

2.4.3.3. Waste

Waste monitoring should be based on the quantity and the composition of all wastes generated on the stations.

2.4.3.3.1. Materials and Methods

The composition of the waste generated should be assessed by sorting waste into different categories:

- **Organics** (without burnable waste): typically originating from plant or animal sources, which may be broken down by other living organisms a part burnable waste.
  Examples: green waste, food waste, paper waste, biodegradable plastics …
- **Burnable**: Burnable material free of any apparent or actual pathological/infectious, radioactive or hazardous chemical contamination
  Examples: paper, untreated wood …
- **Glass**
  Examples: bottles, broken glassware, jars …
- **Metals**
  Example: cans, metallic wrapping …
- **Hazardous waste**: waste with properties that make it dangerous or potentially harmful to human health or the environment.
  Example: batteries, solvents, chemicals …
- **Mixed solids**: All solids that do not belong to the previous categories

All this waste should be properly stored (c.f. *Storage and transport* Part 2 Chapter 2.4.3.3.3) and returned to Republic of South Africa where they should be disposed or recycled.
Special attention should be paid to medical waste. In some case, it can be considered as hazardous waste.

2.4.3.3.2. Tools

Used and cleaned 200-litre drums should be used to store most of generated wastes. Appropriated containers should be used to store batteries and hazardous waste.

2.4.3.3.3. Storage and transport

Metal, glass, organic, mixed solids, burnable waste and waste oil should be stored in used and cleaned 200-litre drums. Batteries and hazardous waste should be stored in adapted containers. At the end of the expedition, all the generated wastes should be back-load to Republic of South Africa. A subsequent disposal or recycling should occur there. Advice for treatment, storage, and disposal of hazardous waste has been published by the EPA (US) and should be followed.

2.4.3.3.4. Time Scale

Waste monitoring should be performed every year, at the end of the expedition.

2.4.3.3.5. Baseline Data

It is compulsory to report the amount of generated waste and its composition to COMNAP so historical data for waste monitoring are available at Swedish Polar Research Secretariat

2.4.3.3.6. Analysis

Type of produced waste

According to the categories described above, the type of the produced waste should be reported.

Volume (or Weight) of Produced Waste

Volume of produced waste should be reported as number of full drums. If a drum is not full, the fraction of the drum used should be reported.

Type of Waste Returned to South Africa

According to the categories described above, the type of the waste returned to South Africa should be reported.

Volume (or Weight) of Waste Returned to South Africa

Volume of waste returned to South Africa should be reported as number of full drums. If a drum is not full, the fraction of the drum used should be reported.

2.4.3.4. Fuel Handling

As we already said, fuel remains the most important pollutant brought to Antarctica, so it is really important to know its usage.

2.4.3.4.1. Materials and Methods

Fuel usage should be reported according to its type: Jet A1, diesel, gasoline, propane or lubricating oil. COMNAP (1992) advises that fuel storage tank should be visibly verified about once a week and as soon as possible after bad weather conditions to inspect the integrity of tanks. A detailed check of the content should be performed every month. These inspections (including internal tanks cleaning) should be recorded and maintained at the station.
More detail can be found on the COMNAP website.

Any accident with fuel should be reported (C.f. *Environmental Incidents* Part 2 Chapter **Erreur ! Source du renvoi introuvable.**).

2.4.3.4.2. Time Scale

Fuel handling monitoring has been performed regularly at Swedish stations. Fuel monitoring should be performed every field season.

2.4.3.4.3. Baseline Data

Baseline data about fuel handling is available at Swedish Polar Research Secretariat.

2.4.3.4.4. Analysis

Fuel imported

All fuel imported to Swedish polar stations should be reported. The type of fuel and the storage location should also be reported.

Amount of fuel consumed for stations

The amount of fuel consumed for station should be reported. The type of fuel should also be reported.

Amount of fuel consumed for vehicles/aircraft

The amount of fuel consumed for vehicles and aircraft should be reported. This parameter should be set out in detailed in the section *Transport* (C.f. Part 2 Chapter 2.4.3.6)

2.4.3.5. Environmental Incidents

Environmental incidents refer mainly to fires, chemical and fuel spills.

2.4.3.5.1. Materials and Methods

Each accident that occurs in and around the Swedish stations should be reported and well described. All accident sites should be photographed and GPS coordinates noted.
Moreover, any significant oil spill (generally more than 200 litres) should be reported to COMNAP. Practical guidelines to report any oil spill in a proper way is available on the COMNAP website (COMNAP, 1993)

2.4.3.5.2. Time Scale

Environmental incidents should be reported every time they occur

2.4.3.5.3. Baseline Data

Nor chemical spill neither fire have been reported at Swedish station from previous expeditions.
Fuel spills have already occurred at Swedish station but have not been properly report.

2.4.3.5.4. Analysis

Chemical Spills

The number of chemical spills, their spatial extent and location should be reported. The type of chemical product should also be set out in detail.

Oil Spills

The number of fuel spills, their spatial extent and location should be reported. The type of oil should also be set out in detail.

Fire

The location and the spatial extent of fire should be reported. The origin of the fire should also be set out in detail.

Other Environmental Incidents

Each accident which is not included in the previous categories should also be reported properly. The type of accident, its spatial extent and location, the potential consequences should be recorded.

2.4.3.6. Transport

Transport monitoring should focus on aircraft and vehicles operations.

2.4.3.6.1. Materials and Methods

All transport operation (including aircraft and vehicles operations) should be reported. The parameters of interest are the number of travelled kilometres, the fuel usage and the number of landing

2.4.3.6.2. Time Scale

Transport activity should be reported every expedition. The transport monitoring programme should be performed all along the expedition.

2.4.3.6.3. Baseline Data

Vehicles operations are reported every year, so baseline data is available at Swedish Polar Research Secretariat.

2.4.3.6.4. Analysis

Aircraft Operations

Aircraft operation is not very intensive at Swedish stations. The distance travelled and the number of landings on site should be reported

Vehicles Operations

The distance travelled for each vehicle should be reported. This should be related to the amount of fuel consumed for transport activities.

2.4.3.7. Logistic

This parameter refers to the resources allocated directly to environmental issues by the Swedish Polar Research Secretariat.

2.4.3.7.1. Time Scale

Resources committed to environmental issues at the Swedish Polar Research Secretariat should be reported every year. Any significant increase or decrease of the amount of money should be explained as much as possible.

2.4.3.7.2. Baseline Data

No baseline data is available.

2.4.3.7.3. Analysis

Resources Committed to Environmental Issues

The resource allocated directly to environmental issues by the Swedish Polar Research Secretariat and the detail of the use of these resources should be reported.

2.4.4. Summary of Monitoring Programme Design Elements

After having described in detail each element of the monitoring programme, the following table (Table 12) sums up each of them.

It is important to note that this monitoring programme focus essentially on Wasa station. Indeed, we have already seen that the predicted impacts from Svea station do not require a long-term monitoring programme. Moreover, in the objectives, collaboration between Finnish and Swedish programmes has been considered. However, this collaboration could not be developed, the reasons will be analysed on the Part 3 Chapter 1. In the future, if such collaboration could be established, it will not be so difficult to extend this monitoring programme to Aboa station.

Table 12: Summary of Monitoring Programme Design Elements

Theme	Description	Indicator	Parameter	Method
Terrestrial environment	Soil	Soil composition	Grain size	Handbook section 8.1.
			pH	ISO 10390:2005
			Conductivity	ISO 11265:1994
			Moisture content	ISO 11461
			Nutrients (total amount and bioavailable concentration of P, N, Ca, K, Mg)	ICP-AES
			Carbon Content (Total Carbon, Total Organic Carbon and Total Inorganic Carbon)	ISO 10694:1995
			Total Petroleum Hydrocarbons	Handbook section 8.4.
			Polycyclic Aromatic Hydrocarbon	Handbook section 8.5.
			Benzene, Toluene, Ethylbenzene and Xylene	GC-MS
			Metals (Pb, Hg, Cd, Cu, Zn, Fe and Al)	ICP-AES (method EPA 200.7 and 200.8
	Snow and ice	Snow analysis	pH	ISO 10523:1994
			Salinity	IAPSO Standard Seawater
			Ions (Cations: Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+} and Anions: NO_3^-, SO_4^{2-}, Cl^-)	cations: ISO 14911:1998 anions: ISO 10304
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al)	Handbook section 7.1.
			Total Petroleum Hydrocarbons	Handbook section 7.2.
			Polycyclic Aromatic Hydrocarbon	GC-MS
			Particulates / Light Absorbing Materials	Handbook section 7.3.
Biodiversity	Vegetation	Vegetation quality (lichens and mosses)	Number of species	NA
			Spatial extent	NA
	Introduced organisms	Introduced organisms	Number of species	NA
			Concentration of individuals	NA
			Spatial extent	NA
Human Settlements and activities	Footprint	Total area of the station	Station footprint	NA
		Station person days	Person-days	NA
		Field activities	Number of person days in field	NA
			Location of field camps	NA
	Waste water	Volume of wastewater discharged from Swedish stations	Volume of discharge	NA
		Composition of wastewater	pH	Handbook section 6.6.
			Temperature	NA
			Conductivity	Handbook section 6.7.
			Salinity	IAPSO Standard Seawater
			Biological Oxygen Demand	titration or electrode method
			Chemical Oxygen Demand	Handbook section 6.4.
			Ions (Cations: NH_4^+, Ca^{2+} and Anions: NO_3^-, NO_2^-, SO_4^{2-}, Cl^-, F^-, PO_4^{3-})	cations: ISO 14911:1998 anions: ISO 10304
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al)	Handbook section 7.1.
			Coliforms organisms	Handbook section 6.11.
	Fresh Water	Fresh water quality	pH	Handbook section 6.6.

			Temperature	NA
			Conductivity	Handbook section 6.7.
			Salinity	IAPSO Standard Seawater
			Biological Oxygen Demand	titration or electrode method
			Chemical Oxygen Demand	Handbook section 6.4.
			Ions (Cations: NH_4^+, Ca^{2+} and Anions: NO_3^-, NO_2^-, SO_4^{2-}, Cl^-, F^-, PO_4^{3-})	cations: ISO 14911:1998 anions: ISO 10304
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al)	Handbook section 7.1.
			Coliforms organisms	Handbook section 6.11.
	Waste	Solid waste	Waste types	NA
			Volume / Weight of discharge	NA
		Waste returned to South Africa	Volume / Weight of discharge	NA
			Composition	NA
	Fuel handling	Fuel imported at the stations	Fuel imported	NA
		Amount of consumed fuel for stations	Fuel usage	NA
		Amount of consumed fuel for vehicles/aircraft	Fuel usage	NA
	Environmental Incidents	Fuel spills	Number of spills	NA
			Spatial extent	NA
			Location of spills	NA
		Chemical spills	Number of spills	NA
			Spatial extent	NA
			Location of spills	NA
		Fire	Location of fire	NA
			Spatial extent	NA
		Others	Type	NA
			Location	NA
			Extent	NA
	Transport	Aircraft operations	Distance travelled	NA
			Number of landing	NA
		Vehicles operations	Distance travelled	NA
	Logistic	Resources committed to environmental issues	Allocated resources	NA

2.5. *Quality Assurance and Quality Control*

Quality assurance and quality control can be defined as follows in the Antarctic Environmental Monitoring Handbook (COMNAP, 2000):

> *"Quality assurance (QA) involves all of the planned and systematic actions necessary to provide confidence that the work performed conforms to the monitoring program's goals. Quality assurance encompasses quality control (QC) which involves the examination of work performed in the context of the standards agreed upon for measurements being made."*

Given that scientific research in Antarctica is based on sharing knowledge and data comparison principles, quality assurance seems to be very important to assure the intercomparisons with other relevant programmes results. Shampine (1993), in its article, defines the three main characteristics that data collected in a monitoring programme framework should have:

- Data quality should be known
- Data type and quality should be consistent and comparable
- Data should be available and accessible

These three characteristics should significantly improve the use and the value of the data.

For this monitoring programme, all technical analyses should be performed in an accredited laboratory in Sweden. So, the laboratory should provide the data quality and the analysis should be performed in order to obtain consistent and comparable data type and quality. Moreover, in order to avoid variance of data quality, Standard Operating Procedures (SOP) should be used in the field, in the laboratories and in data management area. The availability and accessibility of the data will be discussed later (C.f. Data handling Part 2 Chapter 3.2)

2.6. Consultation

Once the monitoring programme has been designed, a consultation with relevant stakeholders should be planned. The relevant stakeholders should be, among others, scientists, logistic staff, managers, etc.
This consultation should guarantee that the EMP will meet the aims and objectives stated in the first step. This should also guarantee that the monitoring programme will be effectively resourced and implemented.
As a result, the consultation board should give advice to the environmental manager about the environmental monitoring programme. This advice should be taken into account at the time of the programme review. (C.f. Part 2 Chapter 3.4)

2.7. Cost Estimate for the Environmental Monitoring Programme

The cost estimate should allow appreciating the feasibility of the environmental monitoring programme. It should also be useful to find the most cost effective alternatives to the programme if costs are too high.

A number of cost elements associated with monitoring programmes should be taken into account including:

- Programme design costs
- Field sampling programme costs
- Laboratory analyses costs
- Data management system costs
- Quantitative analysis and reporting costs

Administration, coordination and communication costs should also be taken into account.

Before implementing the pilot study, a complete cost estimate should be established. This report focuses only on the laboratory analysis costs. They are the easiest costs to estimate long time in advance and they should represent a significant part in the environmental monitoring programme budget. The cost estimate will be discuss in the Analysis (c.f. Part 3 Chapter 1)

2.7.1. Number of Samples

The first step consists in determining the number of samples to analyse. The term “site” in the Table 13 and Table 14 refers to the number of sites to be analysed, the term “Repetition” refers to the number of time that the samples collection should occur during the expedition.

2.7.1.1. Water Analysis

For the water analysis, the number of samples to be analysed should be divided into snow and ice analysis, wastewater analysis and freshwater analysis. The following table (Table 13) sums up the calculation to get the number of water samples for this EMP.

Table 13: Number of water samples

Snow and Ice	Total
Sites	3
Collected samples	30
Samples to analyse	9
Repetition	2
Base for the cost estimate	20
Time scale	Every second expedition
Samples to analyse per expedition	**10**

Wastewater	Total
Sites	1
Collected samples	8
Samples to analyse	1
Repetition	2
Base for the cost estimate	2
Time scale	Every expedition
Samples to analyse per expedition	**2**

Freshwater	Total
Sites	1
Collected samples	8
Samples to analyse	1
Repetition	2
Base for the cost estimate	2
Time scale	Every expedition
Samples to analyse per expedition	**2**

2.7.1.2. Soil Analysis

Soil samples should be collected through the random sampling, the hot spot sampling and the reference sites. The following table (Table 14) sums up the calculation to get the number of soil samples for this EMP.

Table 14: Number of Soil Samples

Soil	Random sampling	Hot spot sampling	Reference sites	Total
Sites	21	8	3	32
Collected samples	21	28	3	52
Samples to analyse	7	28	3	38
Repetition	1			
Base for the cost estimate	38			
Time scale	Every second expedition			
Samples to analyse per expedition	**19**			

2.7.2. Laboratory Analysis Costs Estimate

2.7.2.1. Water Analysis

The
Table 15 below sum up the calculation to find the water analysis costs. The document send by the laboratory can be found in **Appendix 3**.

Table 15: Cost estimate for water analysis

Analyse	Price per sample	Number of Samples	Total	Comments
Metals (V-3a)	670,00 SEK	2	1 340,00 SEK	Wastewater
Metals (V-2)	650,00 SEK	12	7 800,00 SEK	
PAH 16 (OV-1)	750,00 SEK	10	7 500,00 SEK	
TPH Oil Index (OV-20c)	500,00 SEK	10	5 000,00 SEK	
Suspended Particulates	300,00 SEK	10	3 000,00 SEK	
BOD 7	280,00 SEK	4	1 120,00 SEK	

COD (Cr)	170,00 SEK	4	680,00 SEK	
Nitrate	100,00 SEK	14	1 400,00 SEK	
Nitrite	90,00 SEK	4	360,00 SEK	
Sulphate	100,00 SEK	14	1 400,00 SEK	
Chloride + Salinity	140,00 SEK	14	1 960,00 SEK	
Fluoride	90,00 SEK	4	360,00 SEK	
Phosphate	90,00 SEK	4	360,00 SEK	
Ammoniumnitrogen	90,00 SEK	14	1 260,00 SEK	
Coliform Organisms	150,00 SEK	4	600,00 SEK	
Total for snow and ice	**2 630,00 SEK**	10	**26 300,00 SEK**	
Total for freshwater	**1 970,00 SEK**	2	**3 940,00 SEK**	
Total for wastewater	**1 950,00 SEK**	2	**3 900,00 SEK**	
Total			**34 140,00 SEK**	

2.7.2.2. Soil Analysis

The Table 16 below sums up the calculation to find the water analysis costs.

Table 16: Cost estimate for soil analysis

Analyse	Price per sample	Alternative Price	Number of Samples	Total	Comments
Grain size	735,00 SEK		19	13 965,00 SEK	Screen-curve
pH	104,00 SEK		19	1 976,00 SEK	Not necessary, include in the nutrient analysis
Moisture content	87,00 SEK	200,00 SEK	19	1 653,00 SEK	The price corresponds to the analysis of "dry-substance". The alternative price correspond to the analysis of "moisture" in a fuel-lab
Nutrients	446,00 SEK		19	8 474,00 SEK	Soil 2 (also including pH and Cu) + Mineralnitrogen
TOC	1 495,00 SEK		19	28 405,00 SEK	
TPH	900,00 SEK		19	17 100,00 SEK	
PAH	1 200,00 SEK		19	22 800,00 SEK	PAH 16
BTEX	1 000,00 SEK		19	19 000,00 SEK	
Metals	825,00 SEK		19	15 675,00 SEK	
Total	**6 688,00 SEK**		19	**127 072,00 SEK**	

These costs seem to be very high and absolutely not appropriated for this monitoring programme. This will be discussed later, in the analysis (c.f. Part 3 Chapter 1).

2.7.3. Laboratories Contact Information

2.7.3.1. Water Analysis

The Table 17 provides the contact information of the laboratory who has been asked for the water analysis.

Table 17: Contact information for the water analysis

Name and Function	Martin Stener Sales Representative		
Company	ALS Laboratory Group ALS Scandinavia AB		
Adress	Maskinvägen 2 Box 511		
Postal code	S-183 25	**City**	Täby
Country	Sweden		
Phone	0046 8 5277 5200	**Direct Phone**	0046 8 5277 5204
Cell	0046 73 048 5204		
Email	martin.stener@alsglobal.com	**Web**	www.alsglobal.com

2.7.3.2. Soil Analysis

The Table 18 provides the contact information of the laboratory who has been asked for the water analysis.

Table 18: Contact Information for the soil analysis

Name and Function	Sven-Åke Nilsson, Sales Representative		
Company	Lantmännen Analycen AB		
Adress	Gamla Tuvevägen 21		
Postal code	S-417 05	**City**	Göteborg
Country	Sweden		
Phone	0046 510 887 00	**Direct Phone**	0046 510 888 45
Cell	0046 70 624 79 08		
Email	sven-ake.nilsson@lantmannen.com	**Web**	www.analycen.se

3. Step 3: Implementing the Programme

The last step should focus on the programme implementation. This step should provide necessary information on how to implement concretely the environmental monitoring programme on Antarctica.

3.1. Pilot Project

Swedish Polar Research Secretariat should undertake the first year of its monitoring programme as a pilot study to ensure its effectiveness before fully committing and expending the monitoring programme. Selected indicators and parameters should be tested during this pilot study.

Pilot project should have several goals:

- To check that operating procedures are well described and appropriated to the parameters of interest
- To verify the accessibility of each sampling site and to inspect the markers (if needed) for existing ones
- To find an accredited laboratory in Sweden able to perform all the technical analyses for an acceptable cost and verify the data quality after analysis
- To verify that the real cost of the monitoring programme correspond with the cost estimate so that the programme could be implemented several years in a row
- To test the data management system

Given that all the analyses should be performed during the same expedition for the first year, the number of samples for the pilot project could be reduced in order to keep an acceptable cost, close to the cost estimation. This could be done either by making composite samples or by reducing the number of sampling sites.

The parameters which have already been tested with the same standard operation procedures as described in the program design should not be tested in the pilot project as new methods (e.g. soil, snow, lichens and mosses monitoring). They should be included in the pilot study in order to make a complete review of the entire monitoring programme.

A detailed report should be published after the pilot study with results and recommendation. As a result, the monitoring programme could be amended to ensure reliable and continuous monitoring programme quality in the future.

3.2. Data Management

Data management is a critical point of the environmental monitoring programme. The programme usefulness depends widely on how Antarctic scientific data are managed, in other words, on how they are disseminated and how they can be retrieved.
An efficient data management system should be able to receive, store, retrieve, manipulate and disseminate Antarctic scientific data.

3.2.1. Database Development and Management

3.2.1.1. Database

A web-accessible data-portal should be implemented to manage data, metadata and archives from this environmental monitoring programme. This system should allow scientists and

environmental managers to track changes in key Antarctic environmental factors and it could also be used as a powerful tool to use the monitoring programme system as a basis for the decision-making process.
The database could be added to the homepage of the Swedish Polar Research Secretariat, using a password access if needed. This database should take into account the specificities of the monitoring programme. It should promote efficient and effective use of data, as well as comparability and long term preservation of data. Integrity and security of data should also be guaranteed by the system. Free access and wide availability should also be considered. Flexibility should also be an important feature of the database in order to be able to cope with new types of data. This database should be able to generate graphs and statistics. In addition, it could be useful to have a database able to generate reports automatically.

The development of a database requires a database expert. This database could be inspired by an existing one in other National Programmes, for example, the Australia Antarctic Data Centre. As a major component of the monitoring programme, a sizeable part of the EMP budget should be allocated to the data management. The whole system should be operational before the implementation of the pilot study. Indeed, the database should be assessed during this phase as well as other components of the monitoring programme. Once the database has been implemented, a complete documentation about it should be established. This should promote the long term availability of the system.

3.2.1.2. Data Policy

In order to improve the data management system at the Swedish Polar Research Secretariat, a clear and well-defined data policy should be established. This data policy should include data administration, data control, data utilisation and data archiving. The timetable for analysing the data including the time limit from the end to the study to when the results should be handed back to the Secretariat should also be stated to avoid the data losses.

3.2.1.3. Interaction with Other Programmes

Following the recommendation of the Antarctic treaty about Antarctic scientific data: *"Scientific observations and results from Antarctica shall be exchanged and made freely available"* (section III.1.c), the Joint Committee on Antarctic Data Management has been created through a SCAR/COMNAP initiative to coordinate the development of the Antarctic Data Management System. JCADM deals with interaction and cooperation between national and international Antarctic programmes and works to promote the free access to and the wide availability of Antarctic scientific data. The main responsibility of the JCADM is to build and to manage the Antarctic Data Directory System (ADDS) which comprises an Antarctic Master Directory (AMD) containing descriptions of Antarctic scientific data (also called metadata) that have been generated and gathered by a network of National Antarctic Data Centres (NADC). The ADDS claims to be the most suitable starting point for a general Antarctic data management.

As 16 other countries with strong Antarctic research interests (Australia, Argentina, Belgium, Canada, Chile, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Russia, Spain, Switzerland, United Kingdom, United States), Swedish Polar Research Secretariat should set up its own NADC. All information about setting up a NADC can be retrieved on the JCADM webpage (www.jcadm.scar.org).

3.2.1.4. Metadata

Metadata can be defined as *"data about the data"* (COMNAP 2000), in other words, it is a description of the data of interest. Metadata can provide information on data collection (location, tool), on the sample content, on the quality, etc. They are essential in an efficient data management system.
A metadata file established in accordance with the guidelines edited by the JCADM should be associated with all data. See for example the simple form for metadata used by the New Zealand programme; http://www.antarcticanz.govt.nz/intl-connections/8041

3.2.2. Progress of the Data Flow

The progression of the data should be followed. The status of the samples should be regularly updated into the database in order to know the status and the location of the sample at anytime.
According to the SCAR/COMNAP Handbook (2000), the status could be:

1. Sample collection in the field
2. Sample transmittal and receipt by the laboratory
3. Processing status within the laboratory and completion of the analysis
4. Transmission of the analytical results to data management
5. Data entry
6. Data validation
7. Incorporation of validated data into the program database
8. Transmittal of the sample/data to the final repository
9. Archival

The specific tasks to do before, during and after the expedition so as to have an efficient data management system are described below.

3.2.2.1. Before the Expedition

A detailed summary of the planned sample collection for each matrix of concern should be established. For each sample, a unique designation also called sample ID should be assigned. The method to establish a sample ID can be seen on the **Appendix 4**.
Labels and Sample collection field form should be prepared in advance. They will be described later.

3.2.2.2. During the Expedition

During the sample collection, labels and sample collection field forms should be used to gather and report all information about collected samples. This should make easier the transition from the field into the database.

3.2.2.2.1. Label

Each sample should be referenced with a label containing several types of information: Project, Site, Date, Sample ID, Matrix, Name of the scientist and comments should be the minimal information contained on the label. It should form the basis for documenting the samples collection form in the field.
An example of a field sample collection label, inspired from the Antarctic Handbook (COMNAP, 2000) is shown on the Figure 20.

Project:	**Site:**	**Date:** / /
Sample ID:	**Matrix:**	**Scientist:**
Collection device:		
Comments:		

Figure 20: Field sample collection label example
Source: COMNAP, 2000

3.2.2.2.2. Sample Collection Form

The following step in the sample collection process should consist in establishing a sample collection field form. The basic information should include site, sample id, date, time, latitude, longitude, matrix, collection device, number of sample and remarks. This could also help to transcript the data from the field to the database. The Figure 21 shows an example of a sample collection field form example. It is inspired from the Antarctic Handbook (COMNAP 2000). These forms could be modified according to the specific needs on the field.

Sample Collection Data Sheet

Program: ______ **Scientist:** ______

Collection: ______ **Date:** ______ **Location:** ______

	Site	Sample ID	Date YY/MM/DD	Time Local HH:MM	Latitude 00.00.000 _	Longitude 00.00.000 _	Matrix	Collection device	# of Samples	Remarks
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Comments:

Page …/…

Figure 21: Sample collection field form example
Source: COMNAP, 2000

3.2.2.3. After the Expedition

Immediately after each field season, the sample collection field forms should be sent to the person in charge of the data management system. Data and metadata collected during the expedition should be put in the database as soon as possible.

Data should be controlled to minimize errors. This could be done using different tools in the database such as statistical calculations (e.g. minimum, maximum and mean values). Once the analyses have been done in the laboratories, data should be checked by the investigators and then put in the database. Data, once validated, should be made available. This could be done through the NADC and the AMD.

Data archival is also an essential point of the data management system. This should ensure the safe storage and easy retrieval of all accumulated data. Database programme should allow to do periodically backup of the data. Other media like photographs should be scanned to provide a digital copy and stored. Originals photographs should be kept in a safe storage area. In order to promote the maximum use of the photographs, they could be put in a Geographical Information System. This will be detailed further (C.f. Geographic Information System Part 2 Chapter 3.2.3) Samples that have not been analysed should be stored in a proper place for further control analyses or new analyses.

3.2.3. Geographic Information System (GIS)

A geographic information system (GIS) is a specialized computer-based tool for capturing, viewing, mapping and analyzing phenomena that are spatially situated (Malhon et al. 1999). In other words, GIS is a tool that allows users to analyze spatial information, edit data, maps and present the results of all these operation. The Figure 22 shows the GIS functioning through data layers

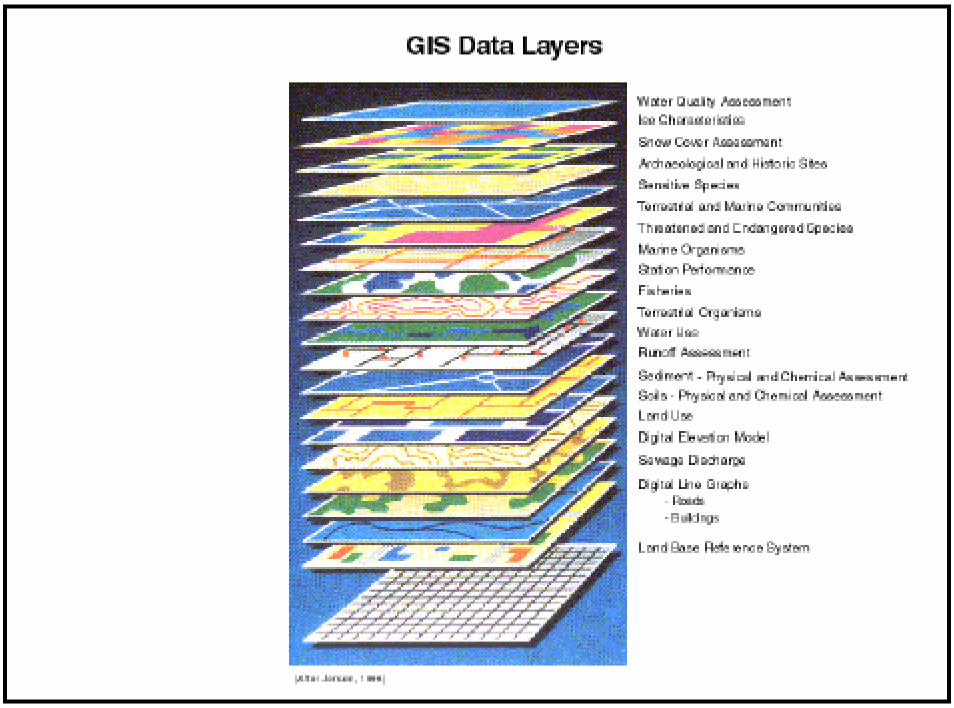

Figure 22: GIS Data layers
Source: COMNAP, SCAR (2000)

3.2.3.1. Geographical Information System as a Tool for Environmental Monitoring Programme in Antarctica

The major interest of GIS lies in its capability to complete or even replace the data management system for environmental monitoring programmes. Indeed, this powerful tool seems to have all the required qualities to manage efficiently a great number of data. GIS can be considered as a manifest improvement over a computerized database. Walton and Shears (1993) explain this as follows:

> *"Recently, attention has been drawn to the potential of using Geographical Information Systems (GIS) to store, integrate, visualize and analyze different environmental datasets for different variables within a specified area. Sequential datasets can also be handled and interrogated. GIS systems, therefore, are powerful tools which could help in the management of the environmental impacts of human activities in Antarctica."*
>
> (Walton and Shears, 1993)

A complete work named "GIS as a method for handling environmental data from Antarctica" was realised at the Swedish Polar Research Secretariat by Emilia Andersson. A lot of information concerning the relation between GIS and EMP can be found in her Master Thesis report.
For the moment, GIS has not been used successfully for the environmental monitoring programme at the SPRS. This will be analysed in the Part 3 Chapter 1 *Analysis*

3.3. Reporting and Publishing

Reporting is the next logical step in implementing the EMP. COMNAP (2005) recommends that the results of such programmes should be made widely available to other national programmes and scientists to promote the comparison and the sharing of data.

For the Swedish Polar Research Secretariat, the best solution seems to publish a yearly report containing the results of the monitoring programme on its internet site. The information could also be made available via the COMNAP website. The report should be provided in an electronic medium, using a standard format (PDF …). It should be provided in a limited time after each expedition.

The report should include among others an executive summary of the project, information on the project background, drawings about monitoring locations, monitoring result (including parameters monitored, monitoring methodology, locations and depth, date, time, frequency and duration but also name of the laboratory, types of equipment used and calibration detailed). Details that could influence the monitored parameters could also be described such as weather conditions, other activities carried out on the site during the monitoring programme, etc. The roles and responsibilities for the EMP should also be clearly stated (managers, scientists, logistic staff, etc.). Comments, recommendation and conclusion should complete the report.

A more detailed report should be published before to conduct the major review of the monitoring programme (e.g. every third year). In addition to the content described before, this report should include a detailed environmental status in the area of interest, the gaps in the collected information, plots showing trends for the monitored parameters and advices for the EMP review. These descriptions are non-exhaustive; any useful information should be added in the report.

3.4. Programme Review

A review of the environmental monitoring program in its entirety should be periodically implemented by the Swedish Polar Research Secretariat.

The monitoring programme review should be based on the objectives requirements and on the advice from the consultation (C.f. Part 2 Chapter 2.6). These requirements can be divided into 3 parts: protocol requirements, scientific requirements and practical requirements (including cost feasibility and utility of the environmental monitoring programme). In particular, the programme review should evaluate the usefulness of the monitoring programme and ensure that collected data are still pertinent and of maximum utility, that means to assess the capacity of the monitoring programme to generate information that can be used in the decision-making process to reduce impacts on the environment. (SCAR, COMNAP, 1996)
Its major goals are:

- To redefine the prioritisation of the EMP parameters in accordance with any change in the activity at the Swedish stations
- To identify any gaps in the monitoring programme knowledge
- To incorporate new scientific understandings into the monitoring program

The critical evaluation should mainly include data collection and data management reviews. Data collection should be reviewed in order to take into account new analytical methods, materials and/or costs operational difficulties. Data management should be reviewed to evaluate its efficiency in receiving, storing, retrieving, manipulating and disseminating Antarctic scientific data. Review should also provide information on how monitoring data are used in the decision-making process and if this has an observable effect (increase or decrease) in human impact around the Swedish polar stations. Resource allocation and use and reporting procedures should also be evaluated in the programme review.

A review is all the more objective and thus useful as it is conducted by someone who has no particular interest in the monitoring programme. However, for this monitoring programme, a review by an external staff is likely to cause high costs, so the EMP should probably be reviewed by the environmental manager of the Swedish Polar Research Secretariat. A good frequency could be every third expedition, in order to be able to observe some trends in the selected parameters measures. As this programme is new, a review should also be conducted after the pilot study.

However, an external point of view should be really valuable for such monitoring programme. So an external review on an exchange basis between polar stations on a regional scale could be arranged: a suggestion can be that each environmental manager from national programmes that have a research station in Dronning Maud Land (Belgium, Finland, Germany, India, Japan, Norway, Russia, South Africa and Sweden) could review the monitoring programme from another station every second review. In other words, one programme review should be an internal review and the next one should be an external review. The condition of this exchange remains to determine but it could be a solution to include an external point of view into the environmental monitoring programme.

As a result, the review should lead to additions, deletions or modifications in the different parts of the monitoring programme. The results of the review should be made available to the scientific community by publishing a report for example to the Antarctic Treaty Consultative Meetings and COMNAP (C.f. *Reporting and Publishing* Part 2 Chapter 3.3).

3.5. Implementation Plan

The plan for developing a long term monitoring programme at the Swedish stations can be depicted by the Figure 23. The planning and design phase is the first step of any long-term monitoring programme. Then, once the missing parts (e.g. data management system) have been completed, the pilot project should occur so as to test the proposed design and underlying assumptions. After this, a review of the monitoring programme should take place based on pilot study conclusions. As a result, the monitoring program could be amended.
The next phase consists in implementing the monitoring programme. After few years of implementation, the programme design should be reviewed again in order to adapt the program to natural or human induced variability in the area of interest and to meet at any time the stated objectives for the monitoring programme. This should lead to programme design modification and so on. This should create a virtuous circle that leads in principle to continuous improvement, on the one hand, of the monitoring programme and on the other hand, of the environment quality around Swedish stations.

This report belong to the first phase of the environmental monitoring programme: Program design phase

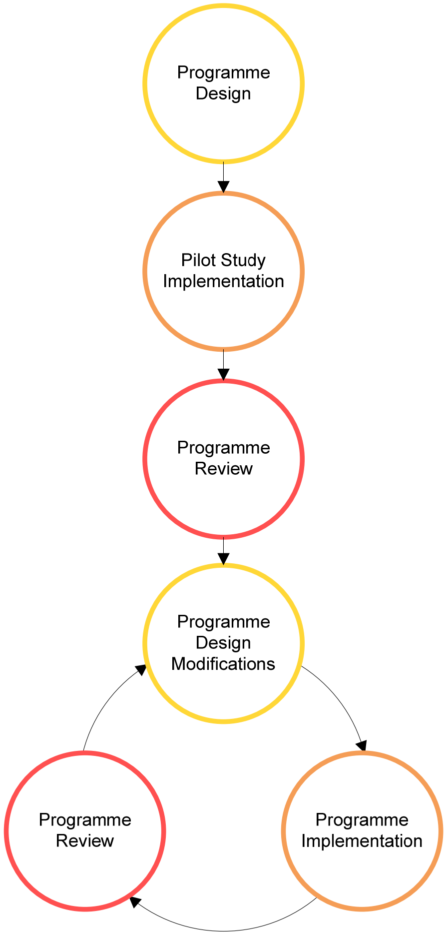

Figure 23: Implementation Plan
Source: Freely adapted from Malhon et al. (1999)

Part 3

Analysis and Conclusion

1. Analysis

In this part, project developments and difficulties should be analysed.

1.1. Initiate an Environmental Monitoring Programme

Monitoring the impacts from human activities at Swedish stations is not a new idea. Monitoring programmes have been implemented at Wasa and Svea stations since SWEDARP 1991-1992. They focused on one or several matrixes and, in some cases, have been repeated over time. Thus this project has not consisted in the design of a totally new programme. The main part of this project consists in collecting historical monitoring data, analysing and organising them in order to get a suitable programme design.

This report is only the very beginning of a complete long-term monitoring programme. According to the implementation plan, the pilot study should be the next step.

1.2. Project Analysis

Monitoring the impacts from human activities in Antarctica constitutes a fundamental aspect of the environmental management. It is the only way to assess the success of the undertaken mitigation measures. Such programmes should provide necessary information to plan and adapt the management actions based on the evaluation of the mitigation measures effectiveness.
Nevertheless, monitoring by itself is totally useless and accomplishes nothing. An environmental monitoring programme become a powerful tool only whether it is strongly tied to the decision making process. That is why, before monitoring it is indispensable to determine why there is a need for monitoring and how the results will directly influence the management decision. (SCAR, COMNAP, 1996)

This project has been though to provide enough information to both assess the mitigation measures undertaken at Swedish stations in Antarctica and to influence the environmental management to develop and adjust remediation measures as soon as it is required to protect and/or restore Antarctic's environment.
Indeed, the programme has been designed not only on the basis of the previous monitoring programmes implemented by the Swedish Polar Research Secretariat but also on the basis of concrete programmes from other national programmes. Given that the results of such programmes have been used for several years, this should guarantee that this programme will be able to assess the effectiveness of protection measures in Antarctica and to allow undertaking new one if it is necessary.

1.3. Encountered difficulties

During the working process, several difficulties have appeared.

1.3.1. Contacts with Other National Programmes

One of the difficulties has been to establish contacts with other national programmes: I got very few, if any, answers to my emails. I have tried to analyse the reasons of this. First, my master thesis occurred just before the beginning of the Antarctic's expeditions. All the managers are very busy at this time of the year and they cannot spend their time to answer email about non urgent questions. Then, the monitoring programme of a station in Antarctica is very specific to the geographical location of the station. So the other national programme could feel not very involved with this project. Lack of time, lack of interest from managers, the question remains unanswered… From my point of view, if the environmental manager of the Swedish Polar Research Secretariat continues this programme, he will probably find the necessary supports from other environmental managers.

1.3.2. Available Literature

At the beginning of the project, I spent much time to search literature about concrete monitoring programme in Antarctica from other national programmes. This was not so successful. Given that all the countries which have a research station in Antarctica have signed the Antarctic treaty, data should be made available for people with specific interest on this topic. This kind of data does not exist or has not been published.

1.3.3. Costs Associated with the Project

Another problem is the environmental monitoring programme costs and particularly the laboratory analysis costs. Costs associated with this monitoring programme can be high, the total cost estimate remain to do. Laboratory costs seem to be very high and so not adapted to this monitoring programme. Indeed, the environmental monitoring programme budget is limited and cannot reach such a cost. So, new alternatives have to be found. One option is to establish a cost estimate from other private laboratories in order to compare with the present cost estimate. Another option could be to ask the University of Stockholm to perform the analyses. They can be considered as a “public laboratory” so the analyses costs should be lower than those from private laboratories. Another option could be to cooperate with the Finnish station Aboa. This will be discussed later. At last, if any of these options allow to meet the budget requirements, monitoring programme modifications should be contemplated such as diminishing the number of samples or temporally spacing the sampling.

1.3.4. Historical Monitoring Data Retrieval

Finally, recovering the data from previous environmental monitoring programmes performed by the Swedish Polar Research Secretariat has also constituted one of the difficulties of this project. A lot of elements of environmental monitoring programme have been performed at Swedish polar stations. In some cases, data have been analysed and detailed reports with laboratory analysis have been published. However, in some other cases, data have never been compiled and/or presented.

This emphasises that the data management system is really one of the keys to success of any monitoring programme and that the development and implementation of such a system is essential for this monitoring programme.

1.4. Discussion

Some points need to be discussed further due to their importance in monitoring programmes.

1.4.1. International Cooperation

The first point to discuss is about international cooperation. International cooperation about environmental monitoring programme is very important in Antarctica and allows to maximise the return from invested resources. First this permits to have much more baseline information on a subject, allowing a better understanding of Antarctic’s environment both at a local and global scale. This allows also to save resources by avoiding to repeat analysis that has already been done and if some efficient methods are used by a national programme, these methods could be used for other national programme.

The development of an international data management system is also an important point. JCADM have implemented such a system for several years. It seems to be efficient and to grow rapidly. This kind of data management system can not replace national data management system but it can be added to the latter and allow to wide visibility of results that is to say a better use of resources.

1.4.2. Cooperation with Finland

In this programme, cooperation with Finland is even more important. Finnish station Aboa and Swedish station Wasa are situated one very close from the other (about 200 meters). Environmental impacts from the two stations mix together and thus it is not possible to know which impact come from which station.
That is why a complete collaboration between the Finnish and Swedish station concerning the environmental monitoring programme would offer a lot of advantages. Much time and effort should be saved and the costs should also be considerably reduced. Moreover, an external point of view always leads to more objectivity. This cooperation should lead to much more efficient monitoring programme for the two stations.

1.4.3. GIS Importance

As we already said, GIS as a data management system offers much more possibilities concerning the storage and the analysis of environmental data.
During this project, an attempt to use a GIS to store and present historical monitoring data has been done. However, this was not successful. The implementation and the maintenance of a complete GIS is really time consuming and requires specific knowledge.
GIS is quite new tool for environmental monitoring. From my point of view, Swedish Polar Research Secretariat should maybe wait that bigger national programmes begin to become familiar with the GIS utilisation and should keep being aware about the evolution of GIS in a near future.

1.4.4. Use of Standard Methods

In the programme design, the use of standard methods has been favoured. Standard methods from the *Antarctic Environmental Monitoring Handbook* (COMNAP 2000) have been chosen first. If there was no method available for a specific parameter, another standard method (e.g. ISO method) was chosen.
Their main advantage is to promote knowledge sharing and comparison. Their main drawback is their costs: approved standard methods are often very expensive, especially ISO methods.

2. Conclusion

2.1. General conclusion

Monitoring is a complex continuous process, involving a lot of different activities and knowledge.
Monitoring in Antarctica is a recent activity managed by the Protocol on environmental protection (1991). Due to Antarctica's specificity, monitoring there is maybe harder than anywhere else in the world but this continent remains certainly the most important to monitor. The first results of the undertaken mitigation measures begin to appear and can only encourage all the national programmes to continue and amplify the environmental monitoring efforts.

2.2. Recommendations

Due to severe conditions, natural ecosystems in Antarctica are extremely sensitive; a minor perturbation can affect them deeply and durably. Given that sampling programme in this monitoring programme should lead to work with these ecosystems, sampling should be performed very carefully. Indeed, the monitoring programme should not lead to any destruction as this first objective is to preserve and restore ecosystems. That is why destructive methods should be avoided in the program design.

2.3. Future Work

This report is the very beginning of the environmental monitoring programme at Swedish stations in Antarctica. A lot of work remains to do to get a useful and powerful tool for environmental management. In order to manage and concretise the results of this thesis, SWEDARP maybe should:

- Establish a contact with other environmental manager for future cooperation on environmental monitoring programme in Dronning Maud Land
- Establish an appropriated data management system, key to success for future monitoring programmes
- Implement the pilot study
- Collect and evaluate valuable information about environmental monitoring programme from other national programmes in a near future.

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Appendix

1. Appendix I - Historical Monitoring Data at Swedish Stations

The Appendix 1 sums up in a table all the historical monitoring data gathered during previous expeditions to Antarctica by the Swedish Polar Research Secretariat.
The table describes the matrix, the contaminants, the location and the principal investigators for each study. The reference number refers to the reference list and the availability of data indicates if the data gathered for the study and/or the complete study can be retrieved or not at the Swedish Polar Research Secretariat.

Matrix	Analysis (Contaminants)	Location	Principal Investigators	Contact Information	Reference	Data Available
Terrestrial	Soil analysis: - Temperature - pH - Carbon content	On the nunatak Basen	Eriksson C.	Swedish Antarctic Research Programme 1993/1994	Eriksson C. (1995)	No
	Soil contamination: - Heavy metals - Petroleum hydrocarbons (aliphates, aromates, benzene, toluene, ethyl benzene, xylene , PAH 16) - TC, N and P	30 sample sites near Wasa station	Modig A., Swartling A.	Swedish Polar Research Secretariat	Modig A., Swartling A. (2002)	Yes
	Soil contamination: - Content of heavy metals (Pb, Cu, Cd, Cr, Ni, Zn, Co, Hg) and content of Al, Fe, Mn, B and As - Organic substances (PAH, total non polar aliphatics, total extractable aliphatics, total extractable aromatics, TOC, TC) - Nutrients and cations (P, N, Ca, K, Mg) - pH, conductivity, particle size and moisture content	Wasa station: - under the generator house - at the battery storage - at the fuel storage site	Swartling A.	Swedish Polar Research Secretariat	Swartling A. (2002), Swartling A. (2003)	Yes
Biological	Lichens (45-50 species found) Moss (1 species found) Algae (2 macroalgae species found)	*Vestfjella:* - Basen (with Wasa and Aboa stations) - Fossilryggen *Heimerfrontfjella, Sivorgfjella:* - Haldorsentoppen (with Svea station)	Thor G.	Swedish Polar Research Secretariat	Thor G. (1992)	No
	Mosses (*Bryum pseudotriquetrum, Grimmia, Sarconeurum glaciale*)	Vestfjella and Heimefrontfjella	Thor G.	Section for Conservation Botany, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala	Thor G. (1995)	Yes

Matrix	Analysis (Contaminants)	Location	Principal investigators	Contact Information	Reference	Data Available
Biological (Cont.)	Lichens and Mosses	Several plots around Wasa, Svea and Gunnar Hoppe stations	Eriksson C.	Swedish Antarctic Research Programme 1993/1994	Eriksson C. (1995)	No
	Lichens and Mosses	120 plots around Wasa, Svea and Gunnar Hoppe stations	Thor G.	Section for Conservation Botany, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala	Thor G. (1997)	Yes
	Lichens and Mosses	81 plots around Wasa and Svea Station	Johansson P.	Department of Conservation Biology, Swedish University of Agricultural Sciences, Uppsala	Johansson P. (2002)	Yes
	Birds (number of nesting species and their nesting area): - Snow Petrel - South Polar Skua - Wilson's Storm-petrel - Antarctic Petrel	Wasa and Svea station	Thor G.	Swedish Antarctic Research Programme 1991/1992	Thor G. (1992)	No
	Birds: - Snow Petrel	Around Svea station	Thor G.	Department of Conservation Biology, Swedish University of Agricultural Sciences, Uppsala	Thor G. (2000)	Yes
	Birds - Snow Petrel - South Polar Skua - Wilson's Storm-petrel - Antarctic Petrel	*Vestfjella:* - Basen (with Wasa and Aboa stations) - Fossilryggen (with Gunnar Hoppe station) - The NW nunatak - The three small nunataks at the northernmost end of Fossilryggen	Thor G.	Section for Conservation Botany, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala	Thor G. (2000)	Yes

Matrix	Analysis (Contaminants)	Location	Principal investigators	Contact Information	Reference	Data Available
Biological (Cont.)	Microfauna: - Mites - Nematode - Tardigrade - Collembole	Around Wasa and Svea stations	Thor G.	Swedish Antarctic Research Programme 1991/1992	Thor G. (1992)	No
	Microfauna	On the Nunatak Basen	Eriksson C.	Swedish Antarctic Research Programme 1993/1994	Eriksson C. (1995)	No
	Microfauna (Nematode)	*Vestfjella:* - Basen (with Wasa and Aboa stations) - Fossilryggen *Heimerfrontfjella, Sivorgfjella:* - Haldorsentoppen (with Svea station) - Steinnabben - Egenhovet - Wrighthamaren	Boström S.	Zoo-tax, Swedish Museum of Natural History, Stockholm	Boström S. (1995)	Yes
	Microfauna (Nematode, Rotifer, Tardigrade)	*Vestfjella:* - Basen (with Wasa and Aboa stations) - Fossilryggen *Heimerfrontfjella, Sivorgfjella:* - Haldorsentoppen (with Svea station) - Moränryggen - Steinnabben - Okkenhaugrusta - Vardeklettane - Mannefallknausen	Boström S., Sohlenius B.	Section for Invertebrate Zoology, Swedish Museum of Natural History, Stockholm	Boström S., Sohlenius B. (1997)	Yes
	Algae: - Macroalgae - Edaphic, Endolithic, Epilithic, Epiphytic, Hypolithic Microalgae - Cyanobacteria	*Vestfjella:* - Basen (with Wasa and Aboa stations) - Fossilryggen - The NW nunatak west of the northernmost end of Fossilryggen	Thor G.	Section for Conservation Botany, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala	Thor G. (1995)	Yes
	Terrestrial bacteria	Basen (with Wasa and Aboa stations): 40 samples of soils, lichens and mosses along two transects	Eriksson C.	Swedish Antarctic Research Programme 1993/1994	Eriksson C. (1995)	No

Matrix	Analysis (Contaminants)	Location	Principal investigators	Contact Information	Reference	Data Available
Water	Water supply Sewage system (Organic Material (Cors), Phosphor (Ptot), Nitrogen (Ntot), Solid Particles (SS))	Wasa station	Larsson K.	Swedish Antarctic Research Programme 1988/1990	Larsson K. (1990)	No
	Water analysis: - Chlorophyll analysis	Wasa and Svea stations: samples from ponds and blue-ice areas	Thor G.	Swedish Antarctic Research Programme 1991/1992	Thor G. (1992)	No
	Water analysis: - Chlorophyll analysis - Light measurements - Oxygen production - Temperature - pH - Bacterioplankton analysis	Samples from two small and relatively nutrient-poor water pools on Basen	Eriksson C.	Swedish Antarctic Research Programme 1993/1994	Eriksson C. (1995)	No
	Water Conservation and Use Sewerage and Waste Water Treatment	Wasa station	Papworth W.	Australian Antarctic Division Tasmania, Australia	Papworth W. (2002)	Yes
Snow and Ice	Chemical Analysis (Carbon, Sulphate, Nitrate, Chloride, Ammonium, Sodium, Potassium)	Wasa station: - Two sites downwind - One site upwind	Isaksson E., Thor G.	Swedish Antarctic Research Programme 1991/1992	Isaksson E., Thor G. (1992)	No
	Chemical Analysis (Carbon, Sulphate, Nitrate, Chloride, Ammonium, Sodium, Potassium)	Wasa station: - Two sites downwind - One site upwind	Eriksson C.	Swedish Antarctic Research Programme 1993/1994	Eriksson C. (1995)	No
	Ions (Na^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}) Light-absorbing material	*Vestfjella:* Basen (with Wasa and Aboa stations)	Stenberg M., Eriksson C., Heintzenberg J.	Royal Swedish Academy of Sciences, Stockholm	Stenberg M., Eriksson C., Heintzenberg J. (1998)	Yes

Matrix	Analysis (Contaminants)	Location	Principal investigators	Contact Information	Reference	Data Available
Station Activities	Noise Thermal influence	Wasa station	Larsson K.	Swedish Antarctic Research Programme 1988/1990	Larsson K. (1990)	Yes
	Environmental issues Station performance	Wasa station	Modig A. Eriksson C. Eriksson C.	Swedish Polar Research Secretariat	Modig A. (2000) Eriksson C. (1995) Eriksson C.(1997)	Yes
	Power generation Energy conservation Recycling	Wasa station	Papworth W.	Australian Antarctic Division Tasmania, Australia	Papworth W. (2002)	Yes
Photography	1986 Basen		Institut für Angewandte Geodäsie, Germany	Malmberg C., University of Stockholm	Malmberg C. (1997)	No
	1992 Basen	Aerial photos	Thor G.	Swedish Polar Research Secretariat	Malmberg C. (1997)	Yes
	1993 Basen		Eriksson C.	Malmberg C., University of Stockholm	Malmberg C. (1997)	No
	1994 Basen	From the West	Karlqvist A.	Malmberg C., University of Stockholm	Malmberg C. (1997)	No
	1997 Basen	From the West, the North and the Northwest	Eriksson C.	Malmberg C., University of Stockholm	Malmberg C. (1997)	No

2. Appendix II - Overview of Some Potential indicators and Parameters for Use in Monitoring Programmes in Antarctica

This table summarizes some potential indicators and parameters that can be used for environmental monitoring programmes in Antarctica

Theme	Description	Indicator	Parameter
Atmosphere	Air emission	Atmospheric analysis	Atmospheric Carbon Dioxide - C13 isotope concentration (per mil)
			Atmospheric Carbon Dioxide concentration (ppm)
			Atmospheric Carbon Monoxide concentration (ppb)
			Atmospheric Hydrogen concentration (ppb)
			Atmospheric methane concentration (ppb)
			Atmospheric nitrous oxide concentration (ppb)
			Atmospheric Sulphur Dioxide (ppb)
		Dust	Particulates (µg/m3)
			Albedo
	Air temperature	Mean Air temperature	Temperature (˚C)
Terrestrial environment	Soil	Soil erosion (footpath)	Spatial extent (m2)
		Soil composition	Grain size
			pH
			Carbon Content (Total Carbon, Total Organic Carbon and Total Inorganic Carbon) (% carbon)
			Metals (Cd, Pb, Cu, Zn, Hg, Cr, Ni, Co, Al, Fe, Mn, B, As) (mg/kg)
			Total Petroleum Hydrocarbons (ng/g or µg/L)
			Polycyclic Aromatic Hydrocarbon (ng/g or µg/L)
			Benzene, Toluene, Ethylbenzene and Xylene (ng/g or µg/L)
			Total non polar aliphatic (ng/g or µg/L)
			Total extractable aliphatics (ng/g or µg/L)
			Total extractable aromatics (ng/g or µg/L)
			Nutrients (total amount and bioavailable concentration of P, N, Ca, K, Mg) (ng/g or µg/L)
			Conductivity (S/m)
			Moisture content
			Soil compaction
	Snow and ice	Snow coverage	Spatial extent (m2)
		Snow analysis	pH
			Total Suspended Solids (mg/L)
			Salinity
			Ions (Cations: Na^+, $NH4^+$, K^+, $Mg2^+$, $Ca2^+$ and Anions: NO_3^-, SO_4^{2-}, Cl^-) (ng/g)
			Metals (Cd, Pb, Cu, Zn, Hg, S, Fe and Al) (mg/kg)
			Total Petroleum Hydrocarbons (ng/g or µg/L)
			Polycyclic Aromatic Hydrocarbon (ng/g or µg/L)
			Particulates / Light Absorbing Materials (ng/g)
Biodiversity	Wildlife	Population size of the four species of birds	Number of individuals
		Breeding population of the four species of birds	Number of breeding pairs
		Microfauna	Number of species
			Concentration of individuals
		Species and number species killed, taken or interfered with or disturbed for the purpose of scientific research	Number of individuals
			Number of species
	Vegetation	Vegetation quality (lichens, mosses and algae)	Number of species
			Spatial extent (m2)
			Total Organic Carbon (% carbon)
			Colour
		Pollution traces in the vegetation	Metals (Cd, Pb, Cu, Zn, Hg) (mg/kg)

	Introduced organisms	Introduced organisms	Number of species Concentration of individuals Spatial extent (m2)
Coasts and Oceans	Sea water	Sea water quality	Total Suspended Solids (mg/L) Dissolved Oxygen (mg/L) Biological Oxygen Demand (mg/L) Chemical Oxygen Demand (mg/L) pH Nutrients (ng/g or µg/L) Coliforms organisms (per 100 mL) Metals (mg/kg) Total Petroleum Hydrocarbons (ng/g or µg/L) Salinity Temperature (˚C) Conductivity (S/m)
Human Settlements and activities	Footprint	Total area of the station	Station footprint (m2)
		Station person days	Person-days
		Medical consultations	Illness rate (consultations/person year) Injury rate (consultations/ person year)
		Heat	Temperature (˚C) Thermal regime Timing Duration (s)
		Noise	Type Quantity Timing Duration (s)
		Field activities	Number of person days in field Location of field camps
	Communication	Electromagnetic radiation	Frequency (Hz) Strength Timing Duration (s)
	Waste water	Volume of wastewater discharged from Swedish stations	Volume of discharge (m3)
		Composition of wastewater	pH Total Suspended Solids (mg/L) Dissolved Oxygen (mg/L) Biological Oxygen Demand (mg/L) Chemical Oxygen Demand (mg/L) Ions (Cations: NH4+, Ca2+ and Anions: NO3-, NO2-, SO42-, Cl-, F-, PO43-) (ng/g) Metals (Cu, Al, Mn, Fe, K, Na, Mg, Ca, Hg, Pb, Cd) Temperature (˚C) Conductivity (S/m) Salinity Hardness (˚dH) Turbidity (NTU) Coliforms organisms (per 100 mL) Phytoplankton (chlorophylls)
	Fresh Water	Fresh water consumption	Total water consumption (L) Water consumption per person (L/person/day)
		Fresh water quality	Total Suspended Solids (mg/L) Dissolved Oxygen (mg/L) Biological Oxygen Demand (mg/L) Chemical Oxygen Demand (mg/L) Acidity Alkalinity

			pH Ions (Cations: NH4+, Ca2+ and Anions: NO3-, NO2-, SO42-, Cl-, F-, PO43-) Metals (Cu, Al, Mn, Fe, K, Na, Mg, Ca, Hg) Temperature (˚C) Conductivity (S/m) Salinity Hardness (˚dH) Turbidity (NTU) Coliforms organisms (per 100 mL) Phytoplankton (chlorophylls)
	Waste	Solid waste	Waste types (including hazard) Volume (m3)/ Weight (kg) of discharge
		Waste returned to South Africa	Volume (m3)/ Weight (kg) of discharge Composition (kg or L)
	Fuel handling	Fuel imported at the stations	Fuel imported (L)
		Amount of consumed fuel for stations	Fuel usage (L)
		Amount of consumed fuel for vehicles/aircraft	Fuel usage (L)
	Environmental Incidents	Fuel spills	Number of spills Spatial extent (m2) Location of spills
		Chemical spills	Number of spills Spatial extent (m2) Location of spills
		Fire	Location of fire Spatial extent (m2)
		Others	Type Location Spatial extent (m2)
	Transport	Aircraft operations	Distance travelled (km) Number of landing
		Vehicles operations	Distance travelled (km)
	Logistic	Resources committed to environmental issues	Allocated resources (SEK and/or $)
		EIA/permit compliance	Number of breaches recorded

3. Appendix III – Cost Estimate for Water Analysis

The following document is the cost estimate for water analysis send by the laboratory ALS Laboratory Group

4. Appendix IV - Proposition for the Sample ID Construction

Unique sample ID for each sample seems to be an essential component of the data administration system. According to the handbook, the sample ID should incorporate information beyond simply a sequence number. A proposition of ID construction is detailed below.

4.1. General construction of the sample ID

[Matrix][Year][Site Reference][Specific Information]**-**[Sample number]

[Matrix]
Matrix refers to the sampling medium. In this monitoring programme, matrix can be Soil, Snow and Ice or Water.

- **S**: Soil
- **W**: Water
- **I**: Snow and Ice

[Year]
Year that should be indicated is the year when the expedition begins (ex: 2007)

[Site Reference]
Site reference refers to the site where the sample has been taken: The designation for each site reference will be set out in detail for each matrix.

[Specific information] (If available)
Specific information refers to further information that allows differentiating samples. It will be set out in detail for each matrix

[Sample number]
Sample number refers to the number of the sample in the matrix.

4.2. ID for Soil samples

S[Year][Site Reference][Specific Information]**-**[Sample number]

[Site Reference]:
Hot Spot Sampling: two letters after the site that they originate from

- He: The helicopter landing site
- Ba: The battery storage
- Ge: Under the generator house
- Fu: At the fuel platform
- Bp: The former fuel storage site
- Wt: The former wastewater treatment site
- Pi: At the leaking grey-water pipe
- Sp: At the snow mobile parking site

Random Sampling: one letter and one number after the square they originate from (ex: A1)

[Specific Information]
For Hot Spot Sampling, two numbers where the first denotes the sample number at a specific site and the second denotes the depth interval they are retrieved from.
No specific information for random sampling.

Example:
S2007A3-6 is the 6th soil sample during the expedition 2007; it is located in the square A3.
S2007He1:2-15 is the 15th soil sample during the expedition 2007; it is located at the Helicopter landing site sample no.1 at depth 2.

4.3. ID for Snow and Ice samples

I[Year][Site Reference][Specific Information]**-**[Sample number]

[Site Reference]: A letter after the site that they originate from
A: Site 1, about1.5 km upwind from the station
B: Site 2, immediately downwind (about 0.3 km from the station)
C: Site 3, 3 km downwind

[Specific Information]: the number of the sample within the square in site 1, 2 or 3. (From 1 to 10)

Example: I2007B7-17 is the 17th snow and ice sample, the 7th in the site 2 during the expedition 2007

4.4. ID for Water samples

W[Year][Site Reference]-[Sample number]

[Site Reference]: a letter after the site that they originate from
W: Sample of wastewater
F: Sample of Freshwater

[Specific Information]: no specific information

Example: W2007F-3 is the third water sample during the expedition 2007 and it is freshwater sample