An environmental impact assessment of a proposed emergency landing facility on Marion Island – 1987

SOUTH AFRICAN NATIONAL SCIENTIFIC PROGRAMMES REPORT NO 140 – 1987

Report to the Minister of Environment Affairs

on

an environmental impact assessment of a proposed emergency landing facility on Marion Island – 1987

by

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Issued by the Foundation for Research Development of the CSIR, Pretoria
at the request of the Department of Environment Affairs

Written requests for the full report can be made to:

The Director General: Environment Affairs
Private Bag X447
Pretoria 0001.

ISBN 07988 4114 1

Printed in the Republic of South Africa
by the Graphic Arts Division of the CSIR
on behalf of the Department of Environment Affairs

<u>Cover Photograph</u>: Fjaeldmark vegetation on a grey lava moraine at the western end of the proposed Emergency Landing Strip. The three scoria fissure cones, known as Tom, Dick and Harry lie to the north-west of the runway. Junior's Kop in the background.

ABSTRACT

The report contains background on the Prince Edward Islands, the status of environmental protection on them and a description of the proposed emergency landing strip. The viability of this proposed facility is assessed, the environmental components of the Islands, with emphasis on the area of Marion Island which would be most seriously influenced, are described in some detail and mitigating measures discussed. The report concludes that the facility should not be constructed and so recommends. This recommendation was formally accepted by the Minister of Environment Affairs in May 1987.

SAMEVATTING

Die verslag bevat inligting oor die Prins Edward-eilande, die huidige stand van omgewingsbeskerming daar en 'n beskrywing van die voorgestelde noodlandingstrook. Die lewensvatbaarheid van die voorgestelde fasiliteit word ondersoek, die omgewingskomponente van die eilande, veral dié gebied van Marion-eiland wat die meeste beïnvloed sou word, word in besonderhede beskryf en verligtende maatreëls word bespreek. Die verslag eindig met die gevolgtrekking dat die fasiliteit nie opgerig behoort te word nie en beveel ook so aan. Dié aanbeveling is in Mei 1987 formeel deur die Minister van Omgewingsake aanvaar.

ACKNOWLEDGEMENTS

The Panel which conducted this environmental impact assessment acknowledges the cooperation it received from the following sources:

- The Department of Environment Affairs for organizing the visit to Marion Island by the Panel and its advisors, the expedition team on the Island for their assistance and hospitality, and the Officers, Crew and Helicopter Complement of S.A.S. Protea for their support during this visit.

- The many persons invited by the Panel to submit to it their comments, opinions and suggestions on the proposal and its potential environmental impact.

- The consulting engineers retained on the project by the Department of Environment Affairs, for their ready provision of detailed information on the design and engineering aspects of the proposal.

- The many other individuals and groups which in one way or another assisted the Panel with its task.

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GLOSSARY OF ACRONYMS

ATCM	Antarctic Treaty Consultative Meeting
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environment Affairs
DOT	Department of Transport
ELS	Emergency landing strip
FRD	Foundation for Research Development of the CSIR
H.M.S.	Her Majesty's Ship (naval)
H.M.S.A.S.	His Majesty's South African Ship (naval)
ICSU	International Council of Scientific Unions
IUCN	International Union for the Conservation of Nature and Natural Resources
MOES	Marion Offshore Ecological Study
SANARP	South African National Antarctic Research Programme
S.A.S.	South African Ship (naval)
SASCAR	South African Scientific Committee for Antarctic Research
SCAR	Scientific Committee on Antarctic Research of the International Council of Scientific Unions

AUTHORS' NOTE

This report was submitted to the Department of Environment Affairs on 29 April 1987.

On 12 May 1987 Mr G J Kotzé, MP, Minister of Environment Affairs and of Water Affairs, released the following press statement.

"The investigation into the possibility of constructing a landing facility on Marion Island has received wide publicity. I am pleased to be able to announce that a report entitled 'An Environmental Impact Assessment of a Proposed Emergency Landing Facility on Marion Island - 1987' has been handed to me. This investigation was undertaken at the request of my predecessor and is the combined work of a panel of specialists under the leadership of Dr G Heymann, Deputy President of the CSIR.

I wish to express my very sincere thanks and appreciation for the thorough work done by the Panel and particularly for their enthusiasm and their willingness to give of their time and of themselves to undertake this very important study.

It is my strong conviction that when development is being considered in an environmentally sensitive area, the prospective developer, be it a government or private agency, must take the necessary steps to ensure that all relevant environmental impacts are thoroughly understood and given full weight before reaching a final decision.

The effects on the environment of building a landing facility on Marion Island are adequately covered in the Report. After studying the findings and recommendation of the Panel, I have decided that although a need does exist for a landing strip on Marion Island, to provide such facility is not desirable because of the impact it will have on that fragile environment, particularly during the construction stage.

A limited number of copies of the Report are to be published and will be made available to recognised scientific, academic and environmental organizations by the end of June 1987. An executive summary, extracted from the report is, however, available at present.

Written requests for the full report can be made to; The Director General: Environment Affairs, Private Bag X447, Pretoria 0001.

Copies of the executive summary are available from the Department offices in Pretoria (tel: 324-1740 ext. 3823) and Cape Town (tel: 45-7394)."

EXECUTIVE SUMMARY

BACKGROUND AND TERMS OF REFERENCE

Late in 1986 the Department of Environment Affairs (DEA) made known its intention to investigate further the construction, on Marion Island, of an emergency landing strip (ELS) facility for aircraft. A provisional feasibility study by a firm of consulting engineers had already been completed. The advantages foreseen were that the ELS would:

- Provide rapid access to the Island to attend to or evacuate sick or injured personnel.
- Provide surveillance and rescue aircraft with an alternative landing site.
- Enable better control of territorial waters and the fishing zone.
- Enable provisioning of the Base Station with emergency supplies.

The Minister of Environment Affairs approved that an impact assessment be undertaken by a Panel led by the Chairman of the South African Scientific Committee for Antarctic Research (SASCAR). He emphasized that the findings of the Panel would be decisive in the decision making process on whether or not a landing facility would be provided on the Island.

From the original request and subsequent consultations, the Panel interpreted its terms of reference to be:

- To obtain an understanding of the reasons for and background to the proposal.
- To obtain detailed knowledge of the design specifications for the facility including its infrastructure, the complete range of methods including alternative sites, logistics and time schedule to be used, and the type and extent of its subsequent use.
- To examine and describe the nature of environmental components which could be sensitive to disturbance by man's activities on the Island.

- To assess the type and extent of all impacts on the environment that the construction and operation of the facility could be expected to, or will, have over both the short and long term.

- To conclude whether these impacts are acceptable or not when judged against;

  - the stated reasons for the facility,

  - the sensitivity of the natural environment,

  - the importance and advantages (both national and international) of maintaining the Island's environment in as undisturbed a condition as possible, and

  - the *de facto* uses to which the Island is put or which it serves.

- To report to the Minister of Environment Affairs accordingly in April 1987.

PREPARATORY WORK

The Panel's first task was to obtain comments from groups and individuals with expert knowledge about, or with a specific interest in, Marion Island. Twenty-six submissions by experts, representing the opinions of 43 persons, were invited and received. An information sheet on the proposal and the Panel's proposed procedures was prepared and distributed. A further 63 unsolicited submissions were received. All comments received were taken into account in the Panel's deliberations.

The Panel subsequently had to establish a baseline from which to proceed in terms of the policy on and long-term objectives for the use of the Island. Although the general impression exists among those involved with the Prince Edward Islands that the Islands enjoy statutory nature reserve status, the Panel established that this was not the case. Apart from protection afforded to seabirds and seals and control over fishing matters, no other statutory form of environmental protection exists for the Prince Edward Islands. The voluntary inclusion by South Africa of the Islands in the area of interest of the Scientific Committee on Antarctic Research (SCAR) with the environmental protection this implies, the inclusion of the sea around the Islands in the area of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), and the provisions of some other international instruments afford a measure of environmental protection to certain components of the Island's ecosystem.

The Panel established that the DEA was drafting proposals for new environmental legislation, for submission to Parliament in 1988, in which the conservation status of the Prince Edward Islands was being addressed. In addition, the DEA was in the process of finalizing a Code of Conduct on Environmental Protection for these Islands as an interim measure. The latest draft of this Code was used to establish a clear indication of official policy on the Islands.

VISIT TO MARION ISLAND

With all the above as background, the Panel paid a 10-day visit to Marion Island in February 1987. To advise it on technical aspects of the proposal, the Panel was accompanied by experts from the DEA, the consulting engineers who were undertaking the feasibility study, and the South African Air Force.

In addition to providing fresh, first hand knowledge about and experience of the Island's environmental components, particularly those most sensitive to man's impact, the visit provided the opportunity for the Panel to discuss in detail all aspects of the proposed facility with the proposer, the consulting engineers, aviation experts and scientists presently working on the Island. The fact that these five groups were present together on the Island made a very valuable contribution towards the Panel's investigation. It provided all parties with clarity on the objects and detail of the proposal, on sensitivities of the environment in general and specifically the areas that would be influenced by the proposed facility, and perhaps most significantly of all, the opportunity to jointly examine all aspects (environmental, engineering and usability of the finished facility) of possible alternatives.

THE PROPOSAL

According to the proposal as finalized by the consulting engineers after the return of the Panel from Marion Island, the facility would contain the following elements:

- A runway 1 400 m long and 30 m wide with turning areas at both ends and a 50 m x 80 m parking area to one side, suitable for occasional use by an aircraft of the size and weight of a Hercules C130.
- An access road from Transvaal Cove to the emergency landing strip (ELS) of 2,8 km long and 4 to 6 m wide, required mainly during construction but subsequently also, with slight modifications, for travel between the Base Station and the ELS.

- An accommodation camp at the Base Station for a construction team of about 50 or 60 persons for a period of two to three years.
- A landing facility on the boulder beach in Transvaal Cove, suitable for use by a shallow draught, self-propelled landing craft.

With the exception of 4 300 t of cement (for a concrete runway pavement) or 350 t of bitumen (for an asphalt pavement), all other materials for construction of the facility would be found on the Island in proximity to the ELS.

The ELS would be for emergency use only. It would not be equipped with permanent navigational facilities. A portable, non-directional beacon would be kept at the Base Station. Runway lights, landing or take-off aids, fuel storage facilities, an electrical supply and accommodation for aircraft or personnel would not be provided. Expected use would not be more than six times per year and permanent operations staff on the Island would not be required.

THE ENVIRONMENT

In common with five other groups of sub-Antarctic islands, Marion and Prince Edward Islands are extremely isolated specks of land in the vast Southern Ocean. They, as well as other sub-Antarctic islands, experience cold, wet and windy climates and are clothed by a treeless, tundra-like vegetation. Very few species of animals and plants occur on them and those that do are extremely sensitive to man-induced influences. The most serious threat to the survival of the indigenous plants and animals on Marion and Prince Edward Islands is the impact that aggressive alien species, such as cats and certain weeds, have on their populations. The water-logged peaty soils are very vulnerable to erosion, while the extremely pure waters of lakes and streams are easily polluted.

The expected impacts of the proposed project were analysed in detail in terms of direct or indirect influences, immediate or long-term effects and whether these will be of a local or widespread nature.

CONCLUSIONS AND RECOMMENDATIONS

The Panel analysed the stated reasons for the facility and its economic viability, examined all environmental components on the Island which would be influenced and identified all those upon which in its view impact would be significant.

The Panel recommended unanimously that construction of the facility not be undertaken for the following reasons:

- The paramount importance of maintaining the Prince Edward Islands in their present near pristine condition.
- The importance of the Island in the sub-Antarctic context.
- Serious impact on sensitive environmental components.
- Danger of the introduction of further invasive alien species.
- Economic non-viability.
- Interference with scientific activities.
- Availability of cheaper and environmentally less damaging alternative solutions to the problems posed by the proposers.
- Aesthetic considerations.
- Danger of unforeseen secondary impacts.

The Panel further recommended that:

- Its report be publicly released.
- Its report be submitted to SCAR through SASCAR.
- Consideration be given to the upgrading of medical facilities at the Base Station.
- The feasibility and acceptability of other solutions to emergency situations be investigated.

The Panel recommended, however, that should the decision nevertheless be taken to proceed with construction:

- The Code of Conduct for Environmental Protection at the Prince Edward Islands be implemented immediately and strictly adhered to.
- Environmental Officers, approved by SASCAR, be appointed such that at least one be present continuously on the Island throughout the whole construction operation.
- Should the extent of the facility or its use be increased by 10 % or more, a further impact assessment be undertaken beforehand.

- Detailed mitigating measures, which could already be foreseen, be applied and that these be reviewed as construction proceeded.

- Key environmental components be monitored according to a programme approved by SASCAR.

- Under no circumstances should Prince Edward Island be visited, other than for strictly limited scientific projects, during the entire period of the ELS construction.

CHAPTER 1

INTRODUCTION

1.1 THE PRINCE EDWARD ISLANDS

The Prince Edward Islands, comprising Marion Island (46° 54' S, 37° 45' E; approx 290 km² in area) and Prince Edward Island (46° 35' S, 37° 56' E; approx 45 km² in area and 19 km north of Marion Island) lie in the Indian Ocean sector of the Southern Ocean, approximately 2 180 km SE of Cape Town, about 1 770 km SSE of Port Elizabeth, and some 2 300 km north of Lutzow-Holm Bay, Antarctica. The nearest land is Isle aux Cochons of the Crozet Islands group, a French possession, 950 km to the east (see Figure 1.1).

The Prince Edward Islands were apparently discovered by Barent Barentz Ham in the _Maerseveen_ in March 1663. However, in January 1772 two ships, _Mascarin_ and _Marquis de Castries_, under Marion-Dufresne of France sighted the Islands. Thinking these were promontories of a vast southern continent, Dufresne named the larger Island (i.e. Marion Island) "Terre d'Espérance" and the smaller one (i.e. Prince Edward Island) "Ile de la Caverne". Attempts to land were unsuccessful and the explorers sailed on. Dufresne and many of his ship's company subsequently perished at the hands of the Maoris in New Zealand. During early 1775, Cook tried unsuccessfully to locate these Islands using Ham's reports. Upon his return to Cape Town he met Crozet, one of the few survivors of Dufresne's expedition, who described to Cook the discoveries the French expedition had made. In December 1776 Cook eventually sighted the Islands, but not realizing at the time that these were the Islands seen earlier by Dufresne, named them the "Prince Edward Islands" after the fourth son of Britain's reigning king. Later on, realizing his error, Cook named the larger of the two Islands "Marion", after Marion-Dufresne (Van Zinderen Bakker _et al_., 1971).

Exploitation of seals (fur from Fur Seals and oil from Elephant Seals) commenced in the 19th Century, many if not most of the visits for this purpose being unrecorded. The last known sealing expedition to the Prince Edward Islands occurred in Oct - Nov 1930. In October 1940 a British expedition with H.M.S. _Neptune_ visited the Islands in search of World War II prisoners, but no landing was made (Cooper & Avery, 1986). This is the last known visit before the South African annexation of the Islands.

On 29 December 1947 a South African expedition with H.M.S.A.S. _Transvaal_, under Commander John Fairburn, annexed Marion Island. This was followed by the annexation of Prince Edward Island on 4 January 1948 by the same expedition (Marsh, 1948). According to the official record (see South African Parliament Assembly Debates, 22 September 1948, pp. 3 040 - 3 046) these annexations were carried out following consultations between the British and South African governments. A small monument, the "Fairburn Monument", erected in 1982 at the present Base Station on Marion Island, commemorates the annexations.

Marion Island (see Figure 1.2) has been occupied continuously since annexation by South African expedition teams. The site (Transvaal Cove) currently occupied by the Base Station has always been the site of the South African station on the Island (see Figure 1.2). Initially, the main activity of these expedition teams was the acquisition of synoptic meteorological data. From the mid-1960s the Base Station has gradually developed into what is today a well equipped scientific facility, capable of accommodating up to 34 persons over winter and nearly double that number for shorter periods of time, such as during the two annual ship-based relief exercises (April/May and August/September) of up to about six weeks each. The Station covers an area of about 1 ha abutting the coast at Transvaal Cove. The main living complex, power plant and store rooms constitute the central complex. Laboratories and the launching hut for meteorological balloons are situated further away. All buildings are interconnected by wooden or metal catwalks above the ground surface (see Figure 1.3)

The main scientific activity on the Islands, concentrated primarily on Marion Island, is in the fields of biological sciences (entomology, limnology, littoral biology, mammalogy, microbiology, ornithology, plant ecology, palynology) and earth sciences (geology, glaciology, volcanology). Through the 1970s there were ongoing activities in the physical sciences (ionospherics, geomagnetism) but, with the exception of continued routine biennial geomagnetic observations, these activities have ceased. Routine surface and upper air meteorological observations continue. In 1985 a new programme of offshore research, focusing on the chemical, physical and biological structure and the ecological dynamics of the sea around the Islands, was initiated. This programme of research is known as the Marion Offshore Ecological Study (MOES), and falls under the oceanographic sciences component (see below) of the South African National Antarctic Research Programme.

Some details on the biological and earth sciences programmes at the Prince Edward Islands, for the financial years 1982/83 to 1987/88 inclusive, are given in Table 1.1.

Scientific research at the Islands is directed by the South African Council for Scientific and Industrial Research (CSIR), through the South African Scientific Committee for Antarctic Research (SASCAR). This Committee is also the South African National Committee for SCAR (Scientific Committee on Antarctic Research, of the International Council of Scientific Unions), and is responsible for directing all scientific research in the South African National Antarctic Research Programme (SANARP). The research is funded by the Department of

TABLE 1.1 Some details on the SASCAR biological and earth sciences research programmes carried out at the Prince Edward Islands, from the financial years 1982/83 to 1987/88 inclusive.

DETAIL	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	*TOTALS
1. <u>Biological Sciences</u>							
- Number of projects funded	10	15	11	6	11	11	(31)
- Number of scientific publications on the Prince Edward Islands	15	21	27	32	10	10	105
- Number of persons employed	18	22	18	12	17	15	(66)
- Number of institutions involved	4	5	5	4	5	6	(7)
- Funds made available	R308 850	R326 700	R283 500	R287 971	R403 809	R388 500	R1 999 330
2. <u>Earth Sciences</u>							
- Number of projects funded	2	2	2	1	3	3	(5)
- Number of scientific publications on the Prince Edward Islands	2	5	10	4	4	10	15
- Number of persons employed	3	3	2	1	4	5	(12)
- Number of institutions involved	2	2	2	1	3	4	(3)
- Funds made available	R 41 034	R 45 500	R 43 000	R 26 662	R122 100	R136 500	R414 796

*= Figures in brackets represent numbers of separate projects/persons/institutions involved

Environment Affairs (DEA) on the advice of SASCAR. The scientific research is organized into four main programmes, namely biological sciences (focused mainly on Marion Island), earth sciences (focused on western Queen Maud Land, Antarctica and the fracture zones and volcanic islands of the South Indian and South Atlantic Oceans), oceanographic sciences (focused on the Southern Ocean south of southern Africa), and physical sciences (focused mainly at the South African Antarctic Station "Sanae" in western Queen Maud Land). The overall administration of SANARP, and the provision of logistic and financial support for it, is the responsibility of the DEA. The South African stations on Marion and Gough Islands, and the "Sanae" and "Sarie Marais" stations in western Queen Maud Land, Antarctica, are SANARP facilities. The supply/research ship S.A. Agulhas is used primarily for the logistic support of SANARP, and it and the fisheries research vessel Africana are used to support the Southern Ocean oceanographic sciences programme of SANARP. Both these vessels are members of a fleet of research vessels owned and operated by the DEA.

1.2 THE LEGAL STATUS OF THE PRINCE EDWARD ISLANDS AND ENVIRONMENTAL PROTECTION AT THEM

1.2.1 National

The Prince Edward Islands Act, 1948 (Act No. 43 of 1948), declared the Islands to have been formally annexed to, and to form part of, the Union (now Republic) of South Africa.

The responsibility for the administration of the Islands now resides with the DEA. For the purpose of the administration of justice and in general for the application of the laws of the Republic of South Africa, the Islands are deemed to be part of the Cape Town magisterial district. In terms of the Act, the Roman Dutch law as applied in the Cape Province is the common law of the Islands.

The Act provides that a number of laws enumerated in the schedule thereto shall be in force on the Islands in so far as they are applicable, and provides further that the State President may, by proclamation in the Government Gazette, declare any law in force in the Cape Province to be in force at the Prince Edward Islands. Although impressions exist that the Islands enjoy provincial nature reserve status, it was established that this is not the case.

The Sea Birds and Seals Protection Act, 1973 (Act No. 46 of 1973) provides for the protection, and the control of the capture and killing, of most species of seabirds and seals occurring at the Prince Edward Islands. Originally the Act placed the responsibility of its execution, with respect to the Prince Edward Islands, including the issue of permits for capture or killing of seals and seabirds, under the Minister of Transport. This responsibility has now also been transferred to the Minister of Environment Affairs. The Act [article 16.(2)] provides for exemption from the provisions of the Act in any area defined by notice of the Minister in the Gazette and declared to be a National Park under Section 2 of the National Parks Act, 1962 (Act No. 42 of 1962). Schedule 1 of the latter Act does not list either Marion or Prince Edward Island, and it is therefore assumed here that neither of the Islands are declared national parks.

It would appear that apart from the limited protection afforded most species of seabirds and seals occurring on the Islands through the Sea Birds and Seals Protection Act, 1973, no other statutory form of environmental protection exists for the land areas of the Prince Edward Islands. The Sea Fisheries Act (Act No. 58 of 1973) provides for the control and conservation of sea fisheries in the territorial waters (12 nautical miles) and fishing zone (200 nautical miles) of the Islands. The Fishing Industry Development Act (Act No. 86 of 1978), which provides for the development of the fishing industry and the marketing of fish and fish products, also applies to this area.

The Council for the Environment has advised the Minister of Environment Affairs on a possible plan for the protection of special features and systems in the South African coastal zone (Robinson, et al., 1985). The advice included proposals on the Prince Edward Islands. The DEA is at present drafting proposals for new environmental legislation, for submission to Parliament in 1988, in which the conservation status of the Prince Edward Islands will be addressed.

In the meantime, on the basis of a draft developed by SASCAR, the DEA has drafted a "Code of Conduct for Environmental Protection of the Prince Edward Islands" (Appendix A). This is to serve as an interim guideline for all organizations and their personnel operating at or in the vicinity of the Islands. In the absence of any form of statutory protected area status or measures for environmental protection, the Panel conducting this environmental impact assessment decided to use this Code of Conduct as a baseline from which to view the proposal for the emergency landing strip facility.

1.2.2 International

The CSIR on behalf of South Africa has been a member of SCAR since its founding in 1958. The Prince Edward Islands fall within the area of interest of SCAR, having been voluntarily so offered. Among the conditions for National membership of SCAR (SCAR Rules of Procedure, Section 1.2) is the following requirement:

> "When making application for membership of SCAR, the country concerned shall present a statement in writing of its proposed continuing programme of scientific research in the Antarctic

> and its agreement to comply with the principles of protection of the environment recommended by SCAR".

The principles of environmental protection referred to above are not specifically defined by SCAR, but are embodied in: (a) SCAR recommendations adopted by Antarctic Treaty Consultative Meetings (ATCMs) in the form of, for example, the "Agreed Measures for the Conservation of Antarctic Fauna and Flora" (see below), the "Convention on the Conservation of Antarctic Seals", etc.; (b) SCAR responses to ATCM recommendations concerning environmental issues (e.g. SCAR's response to Recommendation XII-3 of the 12th ATCM, 1983, later published by SCAR as the book entitled "Man's Impact on the Antarctic Environment" by Benninghoff & Bonner, 1985); and (c) SCAR recommendations to its members, of which recent examples from the 18th meeting of SCAR in 1984 are:

> *Rec. XVIII. BIOL.-1.* "SCAR recommends that Antarctic operating agencies and National Antarctic Committees either follow established national procedures for review (audit) of Environmental Impact Assessments and Statements, or establish an independent *ad hoc* committee for this purpose."
>
> *Rec. XVIII. BIOL.-2.* "SCAR, being aware of increasing human pressures on sub-Antarctic islands and of the urgent need for adequate and effective codes of conservation, recommends that appropriate National Committees request their governments to have regard to the principles of the Agreed Measures for the Conservation of Antarctic Fauna and Flora when drafting new or revised legislation affecting these islands."

It is recognized that SCAR recommendations do not have the status of recommended measures approved by Contracting Parties to the Antarctic Treaty, but rather that membership of SCAR implies compliance with SCAR's principles on environmental protection.

South Africa is one of 12 original signatories to the Antarctic Treaty, which came into force on 23 June 1961. The Prince Edward Islands lie outside the Antarctic Treaty Area (south of 60° S) and are, therefore, not subject to the provisions of the Antarctic Treaty. However, Section 5 (Protection and Conservation of Fauna and Flora) of the DEA's draft Code of Conduct states that activities at the Islands shall be conducted in accordance with the "Agreed Measures for the Conservation of Antarctic Fauna and Flora" of the Antarctic Treaty (see annexure to Appendix A). Article VII (Harmful Interference) of these Agreed Measures lists a number of specific interferences of a harmful nature, amongst which are notably:

- Flying helicopters or other aircraft in a manner which would unnecessarily disturb bird and seal concentrations, or landing close to such concentrations (e.g. within 200 m).

- Driving vehicles unnecessarily close to concentrations of birds and seals.

- Use of explosives close to concentrations of birds and seals.

- Any disturbance of bird and seal colonies during the breeding period by persistent attention from persons on foot.

and includes also the statement that:

> .... the above activities (i.e. those listed above amongst others) "may be permitted to the minimum extent necessary for the establishment, supply and operation of stations".

Concerning the introduction of alien species, Article IX of the Agreed Measures lists four provisions. Of these, the following have relevance here:

- The bringing in of any species of non-indigenous animal or plant, is prohibited, except in accordance with a permit.

- All reasonable precautions shall be taken to prevent the accidental introduction of parasites and diseases. (Some precautions, such as the inoculation of dogs against specified diseases and an outright ban on live poultry, are defined in Annexure D to the Agreed Measures.)

In view of the provisions of Section 5 of the DEA's draft Code of Conduct, the Panel accepts that it is morally incumbent upon South Africa to comply with the Agreed Measures at the Prince Edward Islands.

South Africa is a founder member of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), which came into force on 7 April 1982. The area to which the Convention applies is defined as south of the Antarctic Convergence (see Figure 1.1), which for the purposes of the Convention was defined in terms of a line joining points along parallels of latitude and meridians of longitude. Between 30°E and 80°E the line is at 45°S, which means that the marine living resources of the waters of the Prince Edward Islands are included in the Convention Area.

Article II of the Convention states that:

> "1. The objective of this Convention is the conservation of Antarctic marine living resources.
>
> 2. For the purposes of this Convention, the term "conservation" includes rational use.

3. Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with the provisions of this Convention and with the following principles of conservation;

   (a) prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment;

   (b) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in sub-paragraph (a) above;

   (c) prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, the effects of associated activities on the marine ecosystem and of the effects of environmental changes, with the aim of making possible the sustained conservation of Antarctic marine living resources."

Perhaps of most importance here are the "dependent" and "related populations" of sub-paragraph 3(b), and the fact that at the 1986 meeting of CCAMLR the Southern Elephant Seal was highlighted as a priority endangered species.

In addition there are other international environmental conventions to which South Africa is a party and which have relevance to this assessment. For example:

- Convention Relative to the Preservation of Fauna and Flora in their Natural State (London, 8 November 1938).

- International Plant Protection Convention (Rome, 6 December 1951).

1.3 POLICY ON AND LONG-TERM GOALS FOR MARION ISLAND

1.3.1 Environmental Protection

The afore-mentioned Code of Conduct represents the only document in which official short- and longer-term conservation goals for the Prince

Edward Islands are mentioned. The following statement from the Code provides the best overall description of these goals:

> Implementation of the Code of Conduct "is done in the desire to ensure that the day to day activities of man on the Islands be conducted in harmony with, and with respect for, the environment, and in the spirit of international recommendations to which South Africa has, in good faith, committed itself".

With respect to specific policy on and/or measures relating to environmental protection at the Islands, and of direct relevance to this study, the following statements in the draft Code of Conduct (see Appendix A) are noteworthy:

- No construction of any form of permanent installation shall be undertaken outside the site (i.e. a 1 km^2 area abutting the coast and centred about the present Base Station) without the specific authority of the DEA. Such authority may only be granted after consideration of an environmental impact assessment of the proposed construction.

- Activities at the Islands shall not lead to undue, unsightly or irreversible pollution or marring of the environment, nor to the build-up of waste and debris on the Islands.

- Activities at the Islands shall be conducted in accordance with the Agreed Measures for the Conservation of Antarctic Fauna and Flora of the Antarctic Treaty.

- No live alien fauna or flora (except fresh vegetables for human consumption) or their propagules shall be introduced onto the Islands.

- Landing sites, flight routes and flying altitudes shall at all times be chosen to minimize disturbance of or damage to native animal colonies, except in the case of emergencies.

- Anchor sites, landing sites and steaming routes around and between the Islands shall be chosen to minimize disturbance of or damage to all kelp beds and inshore areas off major animal breeding colonies, except in the case of emergencies.

These and other statements in the draft Code of Conduct were interpreted by the Panel as a desire by the DEA to protect, to the greatest extent possible, the environment of the Prince Edward Islands. This code thus provided the Panel with a primary point of reference on the goals for environmental protection at the Islands.

1.3.2 Scientific Research

The authorities responsible for the administration of the Prince Edward Islands have never issued any formal policy on the utilization of the Islands. It appears that since annexation all logistic activities at them have been specifically undertaken in support of, or to facilitate, scientific activities.

As has been described earlier, scientific and logistic activities at the Islands fall under the auspices of SANARP for which the DEA is responsible, with the CSIR being responsible through SASCAR for the direction, management and coordination of the scientific projects and programmes. SASCAR has described the goals of the scientific programmes in SANARP. For the biological sciences research programme these goals are described in the publication "South African Antarctic Biological Sciences Research Programme" (SASCAR, 1981). The rationale given in this document for biological research at the Prince Edward Islands includes the following pertinent statements:

- "In developing a case for biological research .... it is essential that the special or unique opportunities present, as well as the Islands' role in national and international biological research programmes, be assessed carefully".

- "The comparative youth of the Islands, almost complete glaciation during the last glacial maximum and the existence of several hundred small lakes of varying size, shape and altitude, offer unusual and varied opportunities for research. The extensive mires have already yielded important palynological information on the past climate of the Islands, the Southern Ocean and indeed the Southern Hemisphere. The isolated Islands are dependent entirely on long-distance dispersal mechanisms for the immigration of biota and are thus good field laboratories for studying dispersal, colonization, adaptation and competition in hostile environments".

- "The simple physiognomy and more particularly the extreme species paucity of vascular plants and the absence of trees and shrubs result in a relatively simple plant community structure, which lends itself to a systems analytical approach in studies of community functioning".

- "Another interesting feature of sub-Antarctic terrestrial ecosystems is their almost complete dependence on nutrient inputs from the marine environment - saltspray-laden winds reach every point on the Prince Edward Islands and the lowlands are heavily manured by seabirds and marine mammals. Thus the initiation of closely integrated studies on community and ecosystem structure and functioning at the Prince Edward Islands would clearly throw further light on fundamental ecological processes in the sub-Antarctic".

- "As much as special opportunities exist for studies at the community level, these opportunities also exist for autecological studies on plants, birds, mammals and invertebrates. Introductions of alien vascular plants and mammals to the Prince Edward Islands, especially to Marion Island, have created a series of novel research challenges. The absence of almost all these aliens on neighbouring Prince Edward Island provides a natural reference point for comparative studies".

- "Despite the severe local impact that man has had since the establishment of the Meteorological Station on Marion Island in 1948, the Prince Edward Islands are relatively undisturbed by man. This feature, combined with their isolation from sources of pollutants, accounts for their suitability as baseline monitoring sites for pesticide residues, heavy metals and other environmental pollutants".

- "The Prince Edward Islands also offer outstandingly good opportunities for studying freshwater ecosystems subjected to different degrees of biotic enrichment and having limited food chains. The freshwater bodies could also be ideal for chemical monitoring studies".

The goals for the SANARP earth sciences research programme are described in the publication "South African Antarctic Earth Science Research Programme " (SASCAR, 1984). The rationale given in this document for the programme includes the following pertinent statements concerning sub-Antarctic islands:

- South African geoscientists have two additional incentives for the study of sub-Antarctic islands situated above mantle 'hot spots' - "first, there is evidence of some kinship between 'hot spots' and kimberlites, and second, a combination of systematic intensive studies on the 'hot spot' islands and nearby dredged mid-ocean ridge basalt samples - especially closely spaced suites located near islands such as the Prince Edward group - are likely to constrain theories of the earth's evolution".

- "Oceanic islands remote from the continents enable the petrologist to study problems of magma genesis in isolation, uncomplicated by the effects of a sialic crust".

- "On Marion and Prince Edward Islands exposures exist that are likely to provide a more complete terrestrial record of Upper Pleistocene chronology than anywhere else in the southern hemisphere. The escarpments of Marion and Prince Edward Islands contain numerous datable lava flows interlayered with deposits of possible glacial and periglacial origin as well as recognizable plant remains. By combining geochronology with palaeomagnetism this stratigraphic succession could also contribute to refining the Pleistocene geomagnetic polarity time scale".

- "The renewal of volcanic activity on Marion Island in 1980 created a potential hazard to all forms of life including human habitation. Investigations aimed at predicting the time, location, magnitude and character of future eruptions have thus become of practical importance. In addition, South African scientists are afforded their only opportunity of studying and monitoring an active volcano on South African territory".

The Panel, therefore, recognizes that in the fields of biological and earth sciences research the Prince Edward Islands provide South African scientists with special, if not sometimes unique, opportunities. The utilization of these opportunities does not simply enable scientists to practice their profession, but in many cases is of fundamental importance in understanding the evolution, functioning and wealth of South African and/or Antarctic mainland ecosystems and features. For this reason the Panel has no difficulty in supporting the exclusive use of these Islands as natural scientific 'laboratories', as has been and is presently the case. However, the absence of officially stated policy in this regard is seen to be a serious omission in terms of the provision of guidelines for ongoing logistic and other activities (e.g. tourism, recreation, etc.) that might in time find reason for development at these Islands.

1.3.3 Tourism

Tourism is presently not an activity of any consequence at the Islands. No formal policy on this exists, though the DEA is currently working towards a policy, based partly upon relevant recommendations from the Antarctic Treaty and SCAR.

Various foreign companies now operate regular commercial tours to the Antarctic and sub-Antarctic regions. At least one tour itinerary by such an organization included a call at Marion Island, for which permission was not granted by the South African authorities. The ever-increasing expansion and sophistication of the tourist industry, and private expeditions, makes it likely that in the long term pressure for commercial and/or private tourism at the Prince Edward Islands could increase. There is no question that uncontrolled tourism in the sub-Antarctic can unnecessarily and seriously interfere with scientific research (e.g. souvenir collection, trampling, overcrowding of domestic facilities, etc.). If the long-term goals for and policy on the Prince Edward Islands is centred about their use as 'scientific reserves', as is assumed for reasons given in Section 1.3.2, the control of tourism there is likely to become not simply desirable, but essential.

1.3.4 Other Considerations

In the absence of clearly stated policy and long-term goals on the use of the Prince Edward Islands, the Panel found it necessary to examine the literature in order to further develop an insight into current national and international trends in sub-Antarcic island use and management. This also assisted the Panel in further developing reference criteria with which to assess the ELS proposal. Of particular relevance were the following observations:

- The Prince Edward Islands are considered to be managed as a nature reserve equivalent to the International Union for the Conservation of Nature and Natural Resources (IUCN) category I (= Scientific/Strict Nature Reserve). Overall, conservation prospects for Marion Island are regarded as good (Clark & Dingwall, 1985).

- The Islands are considered worthy of formal special protection by the South African Council for the Environment (Robinson et al., 1985).

- Environmental protection in the Antarctic region (i.e. including the sub-Antarctic) has two components - "one concerned with maintenance of the high productivity and ecological relationships in the Southern Ocean; the other with the maintenance of the unspoiled environment and of the fragile ecosystems of the terrestrial areas. The region's prime value is as a unique source of information that it continues to provide in areas of biology, geophysics, geology and oceanography useful to all of mankind. Its greatest value resides in the wealth of information it contains and yields about planet Earth. Attention to the protection of the environment, particularly of the biological components, needs to be intensified, if for no other reason than to keep the environment in the best possible condition for further scientific study" (Benninghoff & Bonner, 1985).

- "Sub-Antarctic islands are areas of outstanding scientific interest and great natural beauty. They support a diverse range of biological communities containing many endemic species of animals and plants, and provide the principal breeding areas for many millions of birds and seals. Many of them are still little modified by human activities. Their fragile ecosystems, dependent on nutrient transfer from the Southern Ocean, are vulnerable to change and easily destroyed, especially by introduced animals and plants. The principal objectives of conservation for these islands must be to maintain and protect their indigenous flora and fauna in natural associations, both by active management and by all necessary legal instruments. Policies, legislation and operational practices should be developed to constrain modification of the ecosystems, and encourage and promote a greater scientific understanding and public awareness of the importance of these unique islands" (Walton, 1987).

- The report on the joint SCAR/IUCN workshop on "The Biological Basis for Conservation of Subantarctic Islands" (12 - 14 September 1986, Paimpont, France) gives nine recommendations for the improvement of sub-Antarctic island conservation. Of these the following three have direct bearing on this study;

Rec 2. Recommends that "all islands be protected from any new accidental introductions by man and that all necessary inspection and quarantine procedures to ensure this be brought into use as soon as possible",

Rec 4. Recommends that "each national authority develops and implements conservation policies and plans, devised specifically for each island or island group, and incorporating a full consideration of the control of human impact on the natural ecosystem",

Rec 6. Recommends that "organization and control of stations, logistics and scientific programmes be exercised to ensure minimal impact on the natural ecosystem, and that station development be constrained within a designated area".

- "The Prince Edward Islands are, compared to many oceanic islands, relatively pristine. They do not support any farming or mining activities, and there is only one site of regular human habitation on Marion Island. The human population is small and nonbreeding, there is no surface vehicular transport and very few sources of human pollution. Away from the station and the immediate vicinity of field huts, man's disturbance of the environment is evident by little more than occasional footpaths and scientific markers. Human disturbance, in the absence

> of military, tourist, commercial fishing, farming or mining activities, is presently restricted mainly to that produced by scientific and support personnel. Despite the absence of legally institutionalized status and measures, the combination of the remoteness of the Islands and the voluntary practices adopted through the Code of Conduct mean that the de facto status of environmental protection is at the present time relatively healthy, though in terms of practice or application there is room for improvement" (Cooper & Condy, in press).

These observations reinforce the Panel's view that sub-Antarctic islands are particularly important preserves for nature and science, because of, rather than in spite of, their unusual degree of self-protection from man through their remoteness and inhospitability. If man must maintain a presence, the most responsible and sensitive form of this presence would be through a scientific research programme, the conduct of which is strictly designed to minimize its environmental impact.

1.4 BACKGROUND TO THE PRESENT STUDY

In November 1986 the DEA made known its intention to investigate the construction of a landing strip on Marion Island. The idea of such a facility on Marion Island was inherited by the DEA from the Department of Transport (DOT) when the responsibility for SANARP, and also for the administration and control of the Prince Edward Islands, was transferred in 1985 from the DOT to the DEA. A feasibility study by consulting civil engineers was commissioned around 1983/84. A visit to the Island for this purpose took place from 2 to 5 October 1984 and the initial feasibility report (Lötter, 1985) was submitted by the consultants in August 1985. All this activity was only made publicly known in November 1986.

In announcing the investigation late in 1986, the DEA gave the following four reasons for its interest in the provision of an emergency landing strip (ELS) on Marion Island:

- To provide rapid attention to or evacuation of injured or sick personnel.
- To provide surveillance and rescue aircraft with an alternative landing place.
- To enable better control of territorial waters and the fishing zone around the Islands.
- To enable provisioning of the station with emergency supplies.

At the same time the DEA invited the Chairman of SASCAR to establish and convene a Panel to conduct an environmental impact assessment (EIA), and the CSIR to provide the necessary support services for this. Consultations between representatives of the CSIR and the DEA led to the following agreements on this matter:

- A small Panel of experts be established to undertake the EIA. The membership of the Panel was to be decided upon by its Chairman, and it was to proceed with its task independent of the DEA.
- At least one overseas expert should either be a member of the Panel, or act as an independent external reviewer (auditor) of the Panel's report and report directly to the DEA.
- The EIA Panel's report, and that of the external auditor in the event this alternative procedure was followed, should be submitted to the DEA as early as possible in April 1987. These reports would play a decisive role (see annexure to Appendix B) in the decision whether or not to proceed with the ELS project.
- Arrangements would be made for the EIA Panel and its advisors (e.g. experts from the DEA to advise further on the need for the ELS, aviation experts to advise on the technical requirements and usability, consulting engineers to advise on design and construction aspects) to make a short visit (7 - 10 days) to Marion Island in February 1987.
- The Panel's report would be released by the DEA.
- The Antarctic Programme office of the CSIR's Foundation for Research Development (FRD) would provide the secretariat/ support service for the EIA Panel.
- The EIA Panel was free to develop and follow its own procedure, including consultative processes to obtain advice and opinions from outside its membership.

With this brief established, a five-member EIA Panel was set up by invitation during December 1986. Its members, each serving in their personal capacity, were:

Dr G Heymann, Deputy President of the CSIR, Pretoria, and Chairman of SASCAR (physicist and Panel Chairman).

Prof T Erasmus, Head of the Department of Zoology of the University of Port Elizabeth, and Chairman of the SASCAR Committee on Biological Sciences (zoologist).

Mr B J Huntley, Manager National Programme for Ecosystem Research, FRD, CSIR (ecologist, botanist at Marion Island in 1965/66).

Dr A C Liebenberg, Chief Executive Partner, Liebenberg and Stander; consulting civil and marine engineers, Cape Town (consulting civil engineer).

Prof G de F Retief, Head of the Ocean Engineering Research Group in the Department of Civil Engineering, University of Stellenbosch (coastal/environmental engineer).

Dr P R Condy, Mr O A van der Westhuysen and their staff at FRD, CSIR, provided the Panel with a secretariat and support services.

In addition, Mr W N Bonner (British Antarctic Survey) was initially able to accept an invitation to act in his personal capacity as the external reviewer (auditor) of the Panel's report, but subsequently had to withdraw. Following his withdrawal, insufficient time was available to obtain the services of an alternative reviewer, and the Panel decided to recommend that the DEA submit their report to SCAR through SASCAR.

During the initial consultations between the Panel's chairman and the DEA, and subsequently through consultation between the Panel and DEA representatives (e.g. during the visit to Marion Island), it became apparent to the Panel that background to the reasons for the proposal included the following considerations:

- During the four years up to and including 1985 it was necessary to conduct four evacuations of sick/injured persons by ship, and one parachute drop of emergency medical supplies.

- The Cape Sea Route is an important and busy one. While most passages around the Cape take place within about 100 nautical miles of the coast some vessels, especially yachts not calling at Cape Town, prefer a more southerly passage.

- Volcanic activity resumed on Marion Island in 1980, this being the first recorded activity since discovery of the Islands. Significant though not major outpourings of lava occurred in the central upper and western coastal regions of Marion Island. The Base Station is on the coast on the eastern side and was not in any way threatened by these outpourings. However, since the Islands lie on an active fracture zone in the ocean floor, it is reasonable to expect further activity sooner or later.

- An alternative emergency landing strip for surveillance, search and rescue aircraft has become desirable, mainly in view of the inability of the South African Air Force due to international embargoes to replace its now decommissioned, long-range Shackleton maritime surveillance aircraft with better or equally suited aircraft.

- The DEA, which is responsible for the administration of the Prince Edward Islands, for the administrative control of South African fishing zones, for administering South Africa's membership of and compliance with the Antarctic Treaty and the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), and for the overall administration of SANARP, has an interest in occasional surveillance overflights of the Prince Edward Islands.

- The death of a member of an expedition team on Marion Island would pose the question why the DEA had not already given serious attention to, and/or implemented, ways of conducting rapid deployment of such emergency facilities as might have prevented a death, or for rapid evacuation to prevent this.

1.5 TERMS OF REFERENCE OF THE PRESENT STUDY

From the original request and subsequent consultations, the Panel interpreted its terms of reference to be:

- To obtain an understanding of the reasons for and background to the proposal.

- To obtain detailed knowledge of the design specifications for the facility including its infrastructure, the complete range of methods including alternative sites, logistics and time schedule to be used, and the type and extent of its subsequent use.

- To examine and describe the nature of environmental components which could be sensitive to disturbance by man's activities on the Island.

- To assess the type and extent of all impacts on the environment that the construction and operation of the facility could be expected to, or will, have over both the short and long term.

- To conclude whether these impacts are acceptable or not when judged against: (a) the stated reasons for the facility; (b) the sensitivity of the natural environment; (c) the importance and advantages (both national and international) of maintaining the Island's environment in as undisturbed a condition as possible; and (c) the *de facto* uses to which the Island is put or which it serves.

- To report to the Minister of Environment Affairs accordingly in April 1987.

1.6 PROCEDURES ADOPTED

The procedure and schedule adopted by the Panel were as follows:

November/December 1986. Panel established. Invitations to submit non-confidential commentary on the ELS proposal and initial feasibility report sent to persons/groups with experience in scientific or logistic activities at Marion Island over the past 10 to 15 years (see list of submissions in Appendix C).

January 1987. Study of submissions, consultations with the DEA, preparations for visit to Marion Island.

February 1987. Visit to Marion Island and on-the-spot consultations with consulting engineers (ELS design, construction, infrastructure, logistics, costs, etc.), aviation experts (infrastructure, usability), DEA representative (background to and reasons for the ELS), expedition team members (general comments; specific inputs by expedition biologists).

March/April 1987. Consultations, examination of additional new invited/unsolicited submissions (see Appendix C), drafting and finalization of report.

The Panel had five formal meetings excluding those held during the visit to Marion Island. In accordance with a SCAR recommendation (Rec. XVIII. BIOL.-1.) the Panel produced and invited SCAR to distribute an "Information Sheet" (Appendix B) in February 1987, describing the background to, reasons for and details of the proposal, the membership of the Panel, and the procedure it intended to follow.

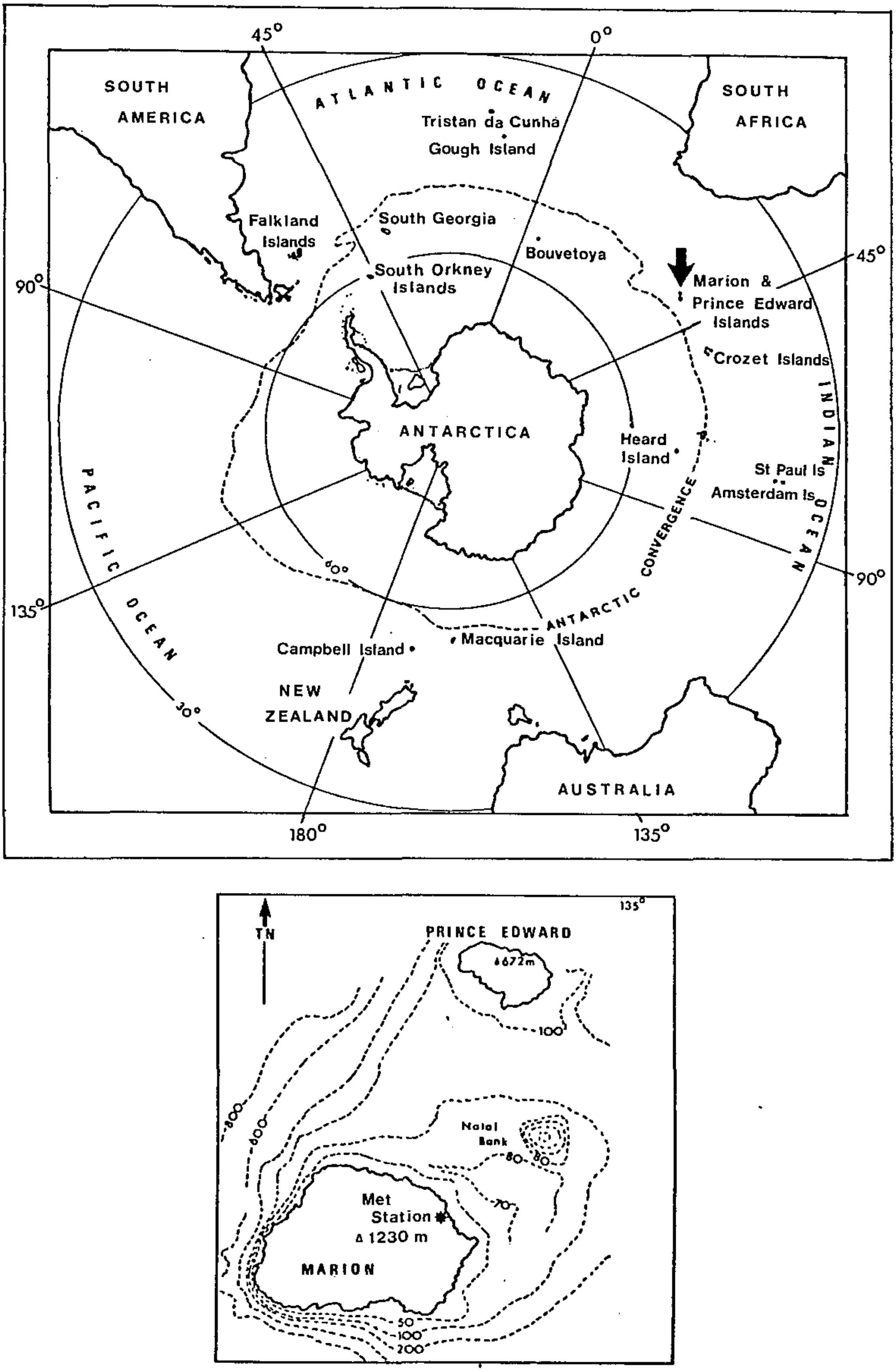


FIGURE 1.1 Southern polar projection of the earth showing the Southern Ocean, Antarctic Continent, and sub-Antarctic islands. The smaller map shows the sizes and positions of Marion and Prince Edward Islands relative to each other.

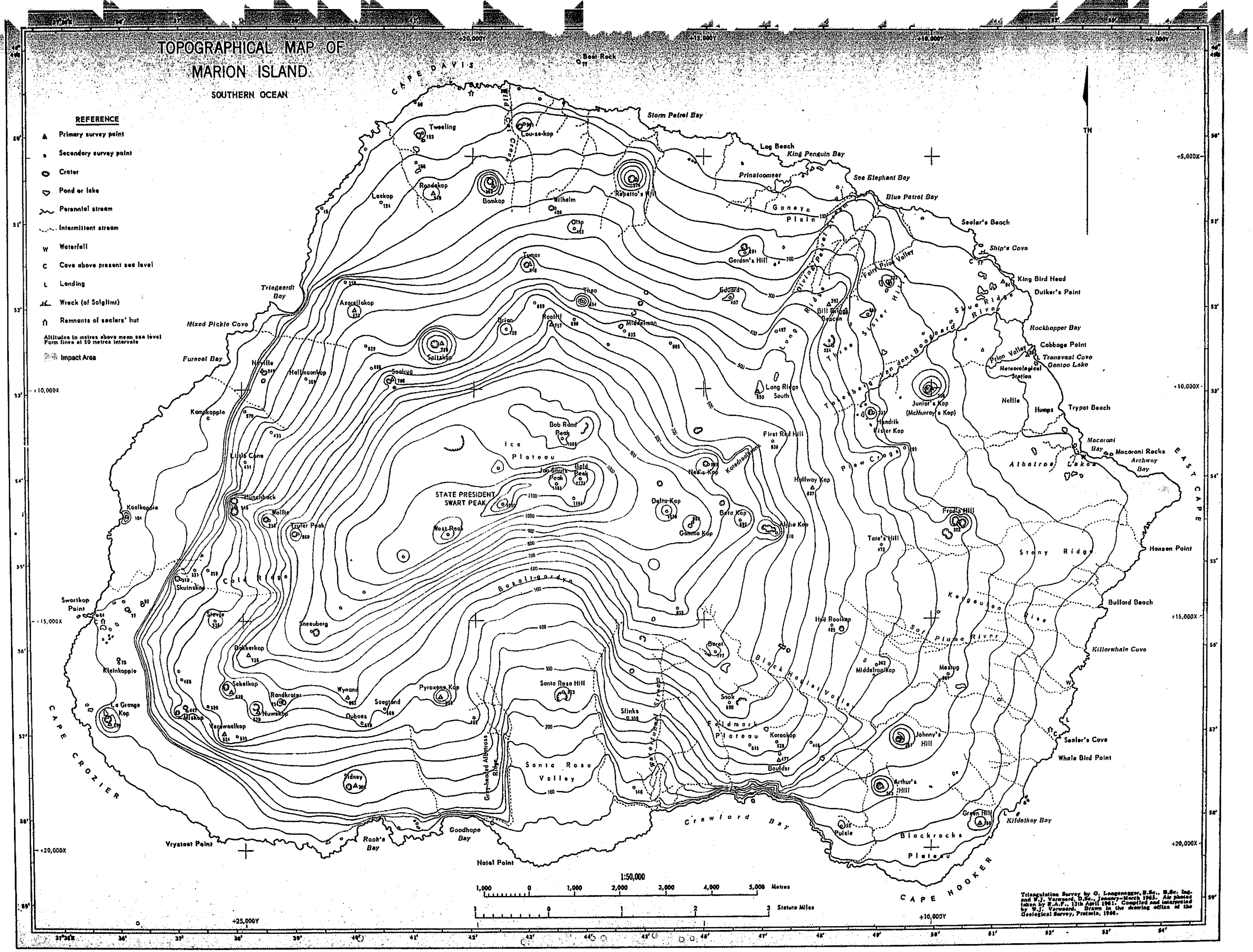


FIGURE 1.2   Topographic map of Marion Island

FIGURE 1.3 Aerial view of the Base Station on Marion Island. The central complex comprises living quarters, power plant and store rooms. In the middle background are helicopter landing pads and the radiosonde balloon release and tracking hut. Boulder Beach of Transvaal Cove in the centre foreground, Gentoo Lake in the left foreground, and Gunners' Point with the cargo hoist centre right.

CHAPTER 2

DESCRIPTION OF THE PROPOSED FACILITY

2.1 GENERAL

According to the latest report of the consulting engineers (Lötter, 1987), the completed facility will essentially consist of the ELS and parking area for Hercules C130-type aircraft, situated as close as possible to the Marion Island Base Station, and connected to the Base Station by a light vehicle access road for the transport of emergency provisions, equipment and personnel. No provision has been made for any permanent ground support facilities such as runway lighting, instrumented landing systems, additional fuel storage, weather forecasting, flight crew accommodation, etc. A non-directional beacon (NDB), supported by a mobile power generator, will be stored at the Base Station and used at the ELS under emergency circumstances. An essential requirement for the construction of the ELS, as well as for possible future maintenance operations, is a beach landing facility and access road for the transportation of construction equipment and materials to the ELS site.

A number of alternative landing sites and access route combinations were considered by the consulting engineers, in an attempt to marry the requirements of the construction phase of the project with those of the completed facility, thereby minimizing both financial costs and the potential environmental impact. These alternative combinations are discussed under various sub-headings in this Chapter, and summarized in Section 2.4.

The development plan most favoured by the consulting engineers, and which is analysed in detail in this report, consists of the following components:

- A permanent 1 400 m x 30 m wide bitumen or concrete surfaced runway, designed to cater for Hercules C130-type aircraft, with a 25 m widened turning circle at each end and a 50 m x 80 m parking apron. The runway is to be located at an elevation of 44 m above sea level running exactly in an east/west direction on a grey lava ridge, due west of East Cape (see Figure 2.1).

- A permanent 2,8 km long, gravel surfaced access road connecting the runway site to a beach landing facility on Boulder Beach in Transvaal Cove, with a short catwalk connector section between this access road and the adjacent Base Station. The provisional route chosen for this road, which will vary in width from 4 m to 6 m, is shown in Figure 2.1.

- A beach landing facility at Boulder Beach in Transvaal Cove, comprising a graded ramp (which can receive a 550 t landing craft) and a level stacking area.

- A contractor's accommodation camp sited alongside the Base Station, which will be designed as a permanent facility to replace the entire or older sections of the existing Station which will be demolished in time.

- A temporary construction yard sited at the western end of the proposed ELS, a temporary asphalt or concrete mixing plant located next to the aircraft parking area, and a temporary crushing plant at a quarry site immediately south of the runway in an area of black lava outcrop.

- A fill material quarry site amongst the series of small scoria cones known as Tom, Dick and Harry to the north-west of the ELS site, or at Fred's Hill 1,5 km to the south-west. Scoria, as a fill material, is considered essential to project implementation. The use of crushed black lava as an alternative fill material would require a quarrying and crushing programme lasting up to two years and involving prohibitive cost escalations. (This problem is discussed further in Section 2.2.2.5.)

2.2 CONSTRUCTION PHASING AND COSTS

The implementation programme envisaged by the consulting engineers can be considered in four phases (see Figure 2.2 for detailed schedule):

Pre-construction Phase (weeks 1 - 52 = 13 months). During this phase a 36-week period is required between the decision to proceed and the date of contract award, with a further 16 weeks thereafter for mobilization.

Site Establishment Phase (weeks 52 - 68 = 4 months). During this phase an advance team using helicopter support will prepare the beach landing, and then proceed with erection of the accommodation camp, construction of the access road, establishment of the construction yard and preparation of the ELS site.

Construction Phase (weeks 68 - 132 = 16 months). During this phase the ELS will be constructed. On completion, all temporary works will be dismantled and prepared for return shipment.

Demobilization Phase (weeks 132 - 136 = 1 month). All contractor's plant and removable products of construction will be removed and the site cleared and restored where possible.

The total contract period is expected to be around 34 months, of which 21 months will involve on-site construction. It has not been possible at this stage to identify a probable calender month scheduling of the above programme.

Preliminary cost estimates indicate a total contract price ranging from R15,8m to R16,3m. The higher price includes the construction of an access road to the quarry at Fred's Hill. The lower price assumes use of the Tom, Dick and Harry scoria cones for fill material. However, due to the uncertainties attached to the manner in which the contractors may evaluate risks and competition, a budget figure of at least R20m is recommended by the consulting engineers. If, for environmental reasons, fill material cannot be obtained from either Fred's Hill or the small scoria cones (Tom, Dick and Harry) near the runway, an extra R3m in cost and a time extension of one year is anticipated by the consultants. Each of the above implementation phases is dealt with in detail below.

2.2.1 Pre-construction Phase (weeks 1 - 52 = 13 months)

The only engineering activity during this period which might have an environmental impact is a proposed pre-tender site visit, ideally scheduled for week 12, but which will probably take place during a scheduled relief visit by the S.A. Agulhas. This site visit will not only be an orientation study by potential contractors, but will also provide the consulting engineers with an opportunity for further detailed field studies (e.g. test drilling) prior to design finalization. Over and above the contractors' representatives present, a survey team of about 12 to 15 technicians will require about three weeks to carry out the following tasks using helicopter support for equipment transfer:

- A runway centreline materials survey, requiring 2 m deep test holes at maximum intervals of 200 m (i.e. at least eight holes).
- Surface sampling and augered test holes to be made in the Fred's Hill and Tom, Dick and Harry scoria formations.
- Test cores to be drilled in the black lava formation south of the ELS site, to approximately 10 m depth.
- Collection of surface samples of grey lava at the ELS site.
- Installation of recording anemometers at the ELS site.
- Detailed survey of the beaching and stacking area in Transvaal Cove to identify the availability of rock, the most suitable site for the temporary stacking area, and the probable fate of Gentoo Lake resulting from construction activities.

- detailed survey and limited materials investigations along the route of the access road between Transvaal Cove and the ELS site.

2.2.2 Site establishment Phase (weeks 52 - 68 = 4 months)

2.2.2.1 Transport to and from Marion Island

During the 21 months of construction, up to 6 000 t of plant and materials will need to be transported to the Island. A personnel shuttle service between Island and mainland will also be required throughout the contract, and during demobilization most of the plant and equipment used in the project will have to be returned to the mainland. The possible items of plant involved are listed in Appendix D.

Possible solutions to the problem of transporting and deploying heavy equipment, which were considered, include:

- Parachute dropping. As it was considered highly unlikely that the need for a beaching facility could be avoided (e.g. because of the need to demobilize plant), no cost saving or reduction in environmental impact would be achieved and the option was not pursued further by the consulting engineers.

- Airlift from a ship by heavy-duty chartered helicopter. As no such aircraft are apparently available in South Africa, this option was also not pursued further.

- Charter of a cargo vessel and landing craft for a one time delivery and removal of plant. This option was found to cost R850 000 more than the recommended option below, and was also thought to be insufficiently flexible.

- Charter of a self-powered landing craft. For reasons of both economy and flexibility the recommended transportation system is the charter of a self-powered landing craft for the duration of the contract, which would then also act as a regular (e.g. monthly) shuttle carrying up to 550 t of cargo and 12 passengers at a time. This type of vessel will, however, require a prepared landing beach. Thus the first task in the establishment phase (i.e. in week 52) would be to deploy by helicopter a small, mobile crane onto Boulder Beach in Transvaal Cove to prepare the beach for the first arrival of the landing craft. The preparation of the beach is described in detail in the following Section.

2.2.2.2 Beach landing facility

As there does not appear to be a viable alternative to the need for a beach landing facility, the available sites between Transvaal Cove and East Cape were evaluated in terms of logistic feasibility and potential environmental impact.

The alternatives considered were the beaches at Archway Bay, Macaroni Bay, Trypot Beach and Transvaal Cove. Whereas at all these the provision of a beach landing site and temporary stacking area were considered feasible (minor boulder removal and kelp clearing would be required at all beaches except Transvaal Cove), the construction of an access road to the ELS site presented a much greater problem. Although Macaroni Bay lies less than 1 km from the ELS site, the access route would traverse a highly unstable area of saturated peaty slopes which render road construction, within the scale of engineering considered, virtually impossible. The potential routes from Archway Bay and Trypot Beach to the ELS site were also considered unsuitable by virtue of the rough and/or hilly terrain interspersed with saturated mires. Macaroni Bay, Archway Bay and Trypot Beach also all support considerable penguin and important Elephant Seal breeding and/or moulting colonies.

The remaining site, at Transvaal Cove, not only offers the most acceptable option from an engineering viewpoint, but is situated immediately adjacent to the Base Station and thus falls in an area already impacted by man, and does not support important penguin or seal breeding or moulting colonies.

The landing ramp on Boulder Beach will probably consist of a metal mat rolled out over a prepared section of the beach, immediately below the cliff face on the northern edge of Transvaal Cove. The mat would probably extend out to a depth of about 2 m below mean sea level (normal tide range is about 0,70 m). As Transvaal Cove has been used ever since annexation of the Island for the off loading of supplies (by means of a 2,5 t crane installed on the cliff top), a narrow approach channel through the kelp already exists. The kelp bed is approximately 100 m wide and lies 200 m to 300 m offshore. Prior to the arrival of the landing craft a wider channel would have to be cut through the kelp. Apart from this, no other underwater clearing work or boulder removal would have to be done in the channel approaches.

Boulder Beach, which consists of a grading of rounded lava boulders (250 - 750 mm diameter) set at a slope angle of about 20°, has a slope width of about 20 m at the proposed landing site. Preparation of the beach to receive the metal mat will probably entail the relocation of certain boulders followed by the placement of a blinding layer.

The temporary beach stacking area will probably be located between the landing ramp and adjacent Gentoo Lake, and will entail the stacking of boulders and levelling of the site. No blasting of rock is envisaged.

2.2.2.3 Access road to ELS site

The route selected for the 2,8 km long access road between Transvaal Cove and the ELS site, is shown in Figure 2.1.

Road width will vary, from 4 m along level sections to 6 m where sight distance is inadequate (e.g. short crest vertical curves). Passing bays will be provided at approximately 0,5 km intervals. As a durable gravel surface is required for the road, the construction methods recommended by the consulting engineers involve:

> Peaty areas. No clearing of vegetation is contemplated. Crushed rock will be placed directly onto the natural surface and compressed until a firm working platform has been established. This will be followed by a final wearing surface in the form of a prefabricated mesh panel, or a layer of geofabric covered by a well draining aggregate such as scoria. (The final choice will vary with road gradient.) Where necessary, batteries of small-diameter PVC pipes will be installed in the compaction layers to maintain surface or sub-surface water seepage. Crushed rock for the working platform will initially be obtained from Boulder Beach (i.e. for the first 400 m of road) and later from rocky outcrops along the line of the road. The final scoria wearing surface will be brought in from the scoria quarry near the ELS site as soon as the rudimentary road (up to working platform level) has been completed.
>
> Fern covered, rocky and hummocky terrain. Projecting rocky outcrops will be levelled and the resulting material used to fill intervening gullies. The wearing surface will be a 150 mm to 200 mm thick layer of scoria. It is estimated that approximately 3 000 m^3 of scoria will be required for the road works.
>
> Drainage lines. There is one stream bed (Trypot Stream) on the route. Large-diameter culverts will be used to facilitate normal water flow.

Apart from the transportation of plant and materials to the ELS site along this road, a further five to six trips per day by a light (e.g. two ton) truck can also be expected (e.g. personnel transport). Approximately 30 large items of plant will traverse this route twice (i.e. on the way in at project initiation and out on its completion), while the transportation of materials during the contract period could result in as many as 500 trips of a two-ton truck. Thus, including personnel movement, a total of 3 500 trips along the access road can be expected during the 21-month contract period, and the road will require ongoing maintenance. On completion of the contract the road will resort to a pedestrian/light vehicle access road between the Base Station and the ELS. A reduced maintenance programme would still be required, and those sections of the road which are most costly to maintain might be replaced by short lengths of metal catwalk.

The area directly impacted by the road will, on average, be a ribbon approximately 8 m to 10 m wide (i.e. allowing for minor cut and fill, material dumps, etc.) and approximately 2,8 km long, totalling about 3 ha in area.

Specific design details are briefly summarized below with reference to the three main sections of the road:

> <u>From 0 m to 400 m (i.e. from beach to vegetated black lava hummocks)</u>. Average gradient will be 5 % with short, steeper sections of 10 % to 12 %. This section is typified by a 1 m thick layer of saturated peat overlying harder lava formations. It is possible that minor peat slips could occur during road construction over this section. Road fill material will be obtained by crushing boulders from Boulder Beach to a < 300 mm product. A single-stage jaw crusher, set up on the beach, will perform this task. Boulders and crushed rock fill will also be required to form a short causeway across Gentoo Lake where the road leaves the beach. The final extent of boulder removal from the beach has not yet been determined. It is, however, very likely that a large portion of the beach will disappear in the process, causing Gentoo Lake to drain and exposing the shoreline to slightly increased wave attack under heavy surf conditions.
>
> <u>From 400 m to 1 700 m</u>. This 1 300 m section follows a route over hummocky, vegetated or rocky terrain, interspersed with short lengths (5 m - 15 m) of mire totalling about 10 % of the section length. Normal road construction procedures, as described above, will be followed along this section. A 20 m wide stream bed (Trypot Stream) crossing, encountered towards the end of this section, will be effected by means of large-diameter culverts.
>
> <u>From 1 700 m to 2 700 m (ELS site)</u>. This secton traverses the northern slopes of the grey lava ridge on which the ELS site is located. The area is covered by grey lava slabs and offers a relatively stable foundation for the roadworks, which will involve little more than boulder removal.

2.2.2.4 Accommodation camp

The contractor's accommodation camp is to be located alongside the existing Base Station, and is to be planned as a permanent replacement of the entire or older sections of the existing Station, which will be demolished in time.

Accommodation will be provided for about 45 labourers, 10 plant operators and 6 to 7 senior personnel (the latter being possibly accompanied by wives). About 1 000 m² of building area, covering a ground area of about 3 000 m², will be required. The sewerage system of the proposed camp will be linked to the existing Base Station system. All other support facilities, such as power generation, radio communication, etc. will be provided independently of the existing systems.

Buildings will be of modular construction, brought in by helicopter airlift, and erected on light piles. Waste disposal and general camp management will follow the codes and practices already adopted for the present Base Station.

2.2.2.5 Construction yard and quarry sites

The yard for the contractor's plant, workshop and offices will probably be located at the western end of the ELS site. An asphalt or concrete mixing plant for preparation of the runway surface material is likely to be located next to the proposed aircraft parking area. The total area required for the camp and mixing plant is not likely to exceed 1 ha. These and all other construction site areas will be clearly demarcated to limit movement of site personnel.

A quarry and crushing plant will be set up immediately south of the ELS site in an area of black lava outcrops. Approximately 15 000 m³ of this material will be quarried and crushed for use as base and sub-base material on the runway. If the concrete pavement option is pursued a further 10 000 m³ of this material will be required for concrete aggregate and sand. The use of this material as concrete aggregate will, however, depend on quality tests carried out in the pre-construction phase. The quarry will leave a hole up to 3 m deep and between 1 ha and 2 ha in area. Together with the crushing plant and stockpile, a denuded area of about 3 ha to 4 ha can be expected.

If insufficient aggregate-quality material is available from this black lava quarry site a possible, but highly impractical, alternate source of material would be the grey lava formations at the Fault between Trypot Beach and the Albatross Lakes. This fault line is surrounded by mires and thick peat formations, and would involve considerable effort, cost and environmental disturbance to utilize. The fault line also lies in the drainage path of a large catchment area, and quarrying may well prove to be virtually impossible. At this stage this site is not considered feasible.

A second quarry site will also be established in either the small scoria cones known as Tom, Dick and Harry, 0,5 km to the west of the ELS site, or at Fred's Hill 1,5 km to the south-west. At Tom, Dick and Harry two of the larger, 30 m high cones and one smaller cone would be removed during the course of the contract, involving a plan area of about 3 ha. At Fred's Hill, which is approximately 80 m high, quarrying will remove a portion of one side of the hill, leaving a slip face extending from the base to the truncated crest. Construction of the access road to Fred's Hill would follow the same procedures described in Section 2.2.2.3. Approximately 200 000 m^3 of scoria will be required.

If for environmental reasons the scoria at either of the above-mentioned sites cannot be quarried, and all crushed rock is to be obtained from the black lava aggregate quarry south of the ELS, a larger quarry and crusher installation would be required. The area quarried would then increase to about 12 ha, and this alternative would increase costs by about R3m and require a time extension to the contract of one year.

2.2.2.6 Site preparation

Site preparation, before commencement of the ELS construction phase, would include the removal and stockpiling of approximately 1 500 m^3 of the larger, surface boulders from the runway site and surrounding ridges (within a distance of ± 1 km), for later use as crushed aggregate if the asphalt pavement alternative is adopted. If the concrete pavement option is pursued all aggregate requirements would come from the black lava quarry site, and surface boulder collection would not be needed. Boulder collection would involve minor surface disturbance of the area, mainly in the form of localized scars and tyre tracks caused by a front-end loader and trucks ferrying the rock to the aggregate stockpile.

Along the ELS site itself, peaty topsoil and loose grey lava slates will be removed from the surface of future cut and fill areas, and stockpiled on the south edge of the site for later use as an erosion protection layer on finished cut and fill slopes. Fine material leached from these stockpiles will drain into the black lava outcrops on the southern side of the ELS site.

2.2.3 Construction Phase (weeks 68 - 132 = 16 months)

The final ELS layout and recommended typical construction cross-sections are shown in Figures 2.3 and 2.4.

2.2.3.1 Alternative siting

The recommended site at East Cape was chosen by the consulting engineers after consideration of all alternative sites along Marion Island's eastern coastal plain. Three alternative sites were identified, all of which are located on grey lava ridges. These sites were Kerguelen Rise and Stony Ridge to the south of the recommended East Cape site, and Skua Ridge to the north of the Base Station and East Cape site. The two alternate southern sites were discarded because of unacceptably steep gradients and greater distances from the Base Station. The Skua Ridge site was not considered acceptable from an engineering and aviation point of view because of local topographical, drainage and orientation problems.

Although the East Cape site is considered the most feasible site, it does not fully comply with the necessary clearances for take-off in a westerly direction, and landing in an easterly direction. According to the consulting engineers' analysis, for 90 % of the time winds blow from the westerly sector, thus allowing the approach for landings from the east over the sea but necessitating take-offs in a westerly direction towards the Island's central mountains. Other risk factors associated with use of the ELS, and an analysis of its probable utilization are presented in Chapter 3 (Section 3.2).

2.2.3.2 Alternative pavement designs

Four alternative pavement designs were considered by the consulting engineers:

- Metal netting on suitable crushed stone base courses.
- Penetration macadam on suitable crushed stone base courses.
- Premixed asphalt pavement on suitable crushed stone base courses.
- Concrete pavement on crushed stone sub-base and concrete base courses.

Metal netting was discarded because of relatively high transport and materials costs, unpredictable performance and maintenance characteristics, while yet requiring similar earth works and foundations to the other options.

Penetration macadam would appear to be the most economical option. However, serious doubt exists as to whether the bitumen spray process is feasible under the climatic conditions prevailing at the site.

Premix asphalt pavement, with special attention being given to the mix design and construction procedures, which will require 350 t of bitumen, is considered feasible and is one of the two options favoured by the consulting engineers. Details of the process are given in Section 2.2.3.3.

Concrete pavement offers the most durable and easily worked alternative, but will require five times more high quality aggregate than the asphalt option and the importation of

4 300 t of cement (as opposed to the 350 t of bitumen). The feasibility of this option will depend solely on the availability of sufficient, high quality aggregate from the black lava quarry site to the south of the ELS. The alternative source of aggregate from the grey lava formations along the fault line between Trypot Beach and the Albatross Lakes area is not considered a feasible option by the engineers (see Section 2.2.2.5).

2.2.3.3 Recommended construction procedure

The ELS site is covered by a scattering of pyroclastic boulders and grey lava plates, resting on about 200 mm to 500 mm of soft marshy material, in turn underlaid by volcanic ash which can be described as a well graded gravel (0,075 mm - 75 mm). Unfortunately the high water content of the ash and surrounding formations precludes effective compaction of this material as a base course, thus necessitating its partial replacement by a well drained fill material such as crushed basalt or scoria.

After completion of the site preparation phase (as described in Section 2.2.2.6), cut and fill operations along the ELS site will commence. Where fills exceed 600 mm the existing surface will be left intact and course, compactable, rocky material (e.g. scoria) will be dumped directly on top. Approximately 200 000 m^3 of such material will be required (see Section 2.2.2.5). Adequate drainage of the landing strip is of critical importance to avoid subsidence and slip formations. To prevent erosion, the slope of cut and fill side faces will not exceed 25 %.

During fill operations a 20 m wide section of a lake (Albatross Lake X, see Chapter 4) lying on the line of the runway will be filled in, reducing the size of the lake by approximately 300 m^2. At this point the runway is expected to be elevated above natural ground level by a fill of about 5 m.

The 0,9 m deep lake (Albatross Lake IX, see Chapter 4) at the north-eastern end of the ELS will be used as a source of water for construction, after which it will be drained to avoid permanently saturated ground conditions in the area.

Compaction and fill cycles will continue up to within 800 mm of the finished surface. In cuts the volcanic ash layer will be exposed to a depth of at least 600 mm below finished surface. Surplus material from the cuts will be used for fill in the runway shoulders and overruns, where ground compaction is less important.

For the asphalt pavement option, base and sub-base courses will comprise 150 mm thick layers of graded crushed rock. The fill material beneath the pavement layers will be scoria. Crushed rock will be obtained from the black lava quarry south of the ELS. The 40 mm thick asphalt layer will comprise a graded aggregate of the crushed grey lava boulders collected from the ELS site and surrounding ridges. This will be followed by a surface seal treatment using 6,7 mm or 9 mm aggregate as an antiskid friction course.

For the concrete pavement option 300 mm of graded base courses will be followed by a 250 mm thick concrete pavement, finished with an anti-skid surface. Aggregate and sand for the concrete will be obtained from the black lava quarry site.

General construction activities throughout this 21-month period will include frequent vehicular traffic along the access road from the Base Station, blasting and rock crushing at the black lava quarry site, the presence of the construction team on the site, noise from crushers, bulldozers, generators, dewatering pumps at the black lava quarry site, etc. and limited air pollution from engine exhausts, asphalt plant or concrete mixers (modern asphalt plant design has greatly removed previous air pollution problems). Domestic waste from the construction site will be contained and returned to the Base Station for disposal.

Throughout both the site establishment and construction phases of the project, unforeseen or unplanned contamination of the environment can occur due to accidents, localized fuel leakage, bitumen or cement spillage, vehicles running off a prepared surface into a mire, etc.

The consulting engineers propose that an Environmental Officer be appointed for the duration of the contract, to advise the resident engineer on environmental aspects and to monitor adherence to impact reducing measures such as the restriction of personnel movement, waste management, etc. (see Chapter 5).

2.2.4 Demobilization Phase (weeks 132 - 136 = 1 month)

During this period the contractor's plant, unused materials (e.g. bitumen, cement, etc.) and products of the construction will be dismantled and returned, via the access road to Transvaal Cove, for shipment back to the mainland.

Restoration of the construction site will include the replacement of topsoil and grey lava slabs on the cut and fill slopes, and restoration of the construction yard site to present levels and appearance. If scoria from nearby sources is to be used as a fill material and road gravel, an attempt will be made to restore the removal site(s) to as natural an appearance as possible (scoria would be removed only down to ground level, so that no holes would be left). The black lava quarry site will be allowed to fill naturally with water and is expected eventually to become a small lake.

After completion of the contract the ELS, including parking and turning areas, will cover an area of about 19 ha. Viewed from the air, one could expect to see 4,6 ha of black asphalt or grey concrete pavement surface, a 3 m wide gravel strip bordering the pavement, while the remaining 13,4 ha will hopefully in time resemble the present appearance of the surrounding basalt strewn ridges. Immediately to the south will be the lake in the black lava quarry site, and to the north running from the ELS to the Base Station will be the 8 m to 10 m wide access road. The small lake at the eastern end of the runway and Gentoo Lake at Transvaal Cove will probably have been drained, while Boulder Beach will have been radically modified. The Base Station would also have taken on a new appearance.

2.3 ELS OPERATIONS AND MAINTENANCE

As the proposed landing strip is intended as an emergency facility its probable frequency of use cannot be deterministically defined. A probability analysis of possible use is presented in Chapter 3 (Section 3.2). For the purposes of environmental impact evaluation, a probable frequency of use of zero to two, but never exceeding six emergency landings per year, has been proposed by the DEA.

The largest and most probable type of aircraft which would use the ELS is the Hercules C130. This has an all-up mass of 61 364 kg at a Load Classification Number (LCN) of 37.

If it is assumed that landings will only take place under normal visual approach conditions (i.e. without instrumented landing systems or even a non-directional beacon), it is highly likely that an initial low altitude inspection flight would be made over the runway from east to west, followed by either a left or right hand 180° turn into a leg heading seaward and following a line parallel to and approximately 2 to 3 km away from the landing strip. A final 180° turn would then be made out at sea before final approach and landing. If wind speed and direction at the ELS surface are previously radioed to the pilot, the inspection loop could be omitted and the final approach and landing would be immediately undertaken using radio altimeter and radar.

Depending on circumstances, the aircraft undertaking the emergency landing might then need to await a second aircraft to assist in whatever repair/recovery actions may be required. If the initial landing were made to assist in an emergency situation on the Island, the aircraft would carry sufficient fuel and support equipment for subsequent take-off. Depending on wind conditions, take-off may have to be rocket assisted. Temporary accommodation and support for flight crews would be provided at the Base Station. While grounded, the aircraft will be exposed to the frequent gales and storms encountered on the Island. Suitable anchorage and continuous vigilance will be required during such events.

The possibility of a crash landing or aborted take-off should also be considered. Apart from the obvious disturbance which would occur in the immediate area of any crash site, the impact may extend further through groundwater pollution, habitat destruction, etc. It seems unlikely that fire damage would extend beyond the immediate Impact Area because of the saturated nature of the ground.

Maintenance of the facility would probably entail periodic inspections by Base Station personnel, the possible translocation of birds breeding on or near the ELS, removal of any foreign material on the pavement surface, and in the case of the asphalt surface minor repairs to the pavement after about a five to ten year period, depending on the durability of the surface under local conditions. Access road maintenance would entail minor surface gravelling which could be carried out manually from time to time, erosion control, and over particularly troublesome areas a more permanent, metal catwalk would probably be installed.

If in time the ELS were abandoned for any number of reasons, the runway would remain intact for many years, while the access road would probably gradually become overgrown with vegetation, provided good erosion control was maintained.

Alternatively, if the ELS were found to be unsafe for reasons of length, bird strike, or lack of instrumentation, etc. it is conceivable that improvements might be introduced at a later stage. The prime motivation for such upgrading actions would be the already committed expenditure, and these actions might include extension of the ELS through contract works similar to those described in this report, the installation of instrumentation and associated support such as power supply, the introduction of bird deterrent measures during landings, etc. Such an upgrading would imply other secondary effects, and would again have to be considered afresh in terms of environmental implications.

2.4 SUMMARY OF ENGINEERING ALTERNATIVES

2.4.1 ELS Siting

Four landing strip sites, each within reasonable range of the Base Station, were investigated (see Section 2.2.3.1). The Skua Ridge site was not considered viable from an engineering viewpoint and the two sites south of East Cape presented unacceptable gradients, would involve longer access roads, and are further removed from the general area already impacted by the Station. It was, therefore, concluded that no environmental or financial advantages could be gained by further consideration of alternative sites.

2.4.2 Construction Methods

Alternative access road routing and transportation methods have been discussed in Sections 2.2.2.2 and 2.2.2.3. The recommended option is considered to offer the least damaging solution from an environmental point of view. Only two runway pavement designs are considered feasible, viz. asphalt or concrete (see Section 2.2.3.2). A concrete pavement will require more high-grade aggregate (hence a larger quarry) and imported raw material (4 300 t cement) than the asphalt option (350 t bitumen). Concrete will, however, produce a more durable and maintenance-free surface. From a construction viewpoint neither option displays any distinct environmental advantages over the alternative.

Apart from the problems associated with the higher quality aggregate materials, the alternative options for sources of fill material (200 000 m^3) have to be addressed. According to the consulting engineers "the feasibility of the project largely, if not entirely, depends on the use of the scoria". The only feasible sources of scoria available are the 30 m high cones Tom, Dick and Harry immediately west of the runway, or the 80 m high Fred's Hill 1,5 km south-west of the ELS site (see Section 2.2.2.5). Access to the Tom, Dick and Harry source site will pass through the construction yard area, which will already be impacted by construction activities. The alternative Fred's Hill access road will pass through relatively difficult terrain, at the additional cost of R0,5m.

2.4.3 Alternative Time Schedules

Date of implementation of the proposed project is particularly sensitive to the following three considerations: (i) timing of the site visit during the pre-constrution phase, which will depend on the availability of either the S.A. Agulhas or other chartered vessel; (ii) phasing of the construction into any specific financial cycle; and (iii) delays in project approval. The preliminary schedule would indicate contract award and mobilization by the end of 1987. For the reasons given by the DEA for initiating this project, it would seem likely that if this date is not met every effort will be made to proceed with implementation as soon as possible thereafter.

Deviations from the proposed construction schedule will probably be limited to the re-scheduling of specific tasks, in order to avoid particularly sensitive periods in the annual cycles of Island fauna. Any consequent delay in critical path activities will naturally result in an extension to the contract period, which in turn might constitute an unacceptable environmental impact. Short of increasing the scale of the proposed construction programme considerably in order to shorten the contract period (but at both increased financial and environmental cost), there does not appear to be any feasible alternative to the schedule as proposed.

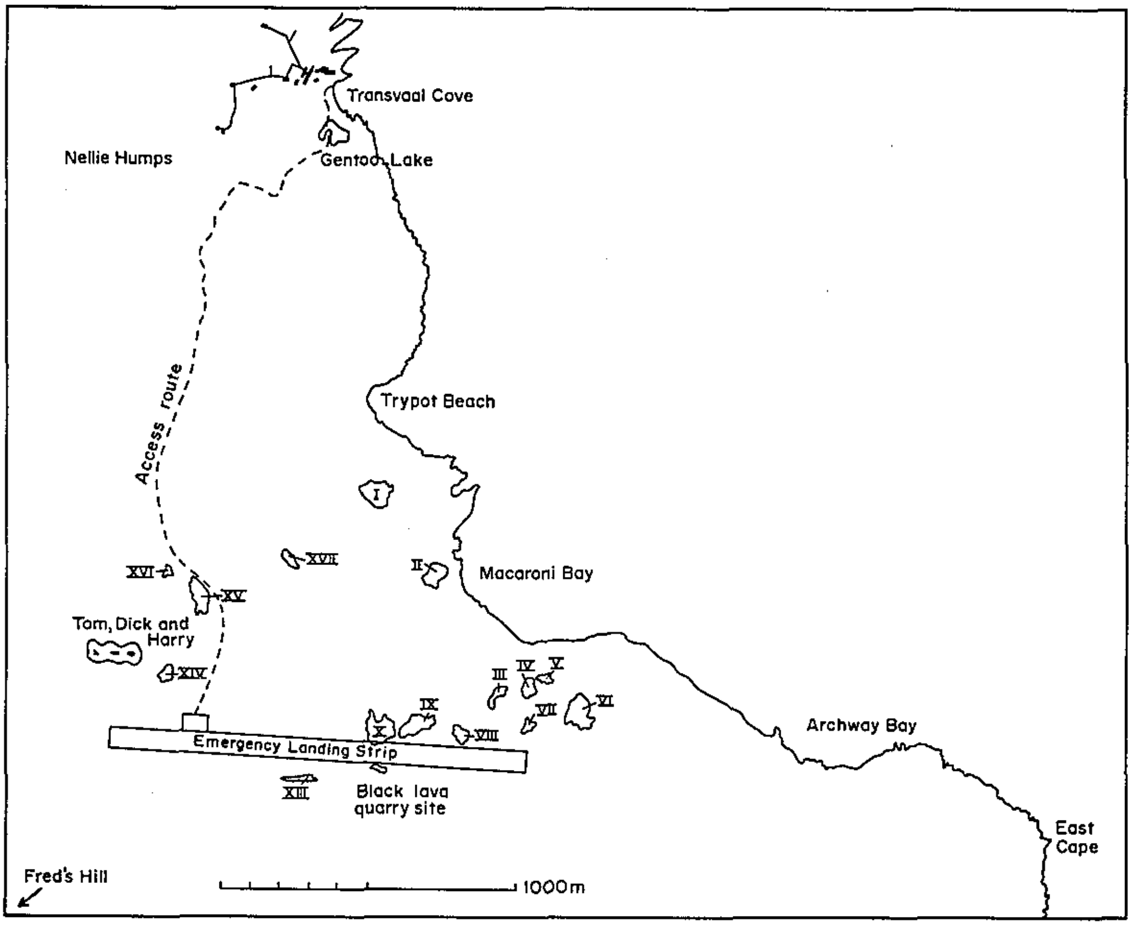


FIGURE 2.1 Sketch map of the proposed emergency landing strip and access route (from Lötter, 1987).

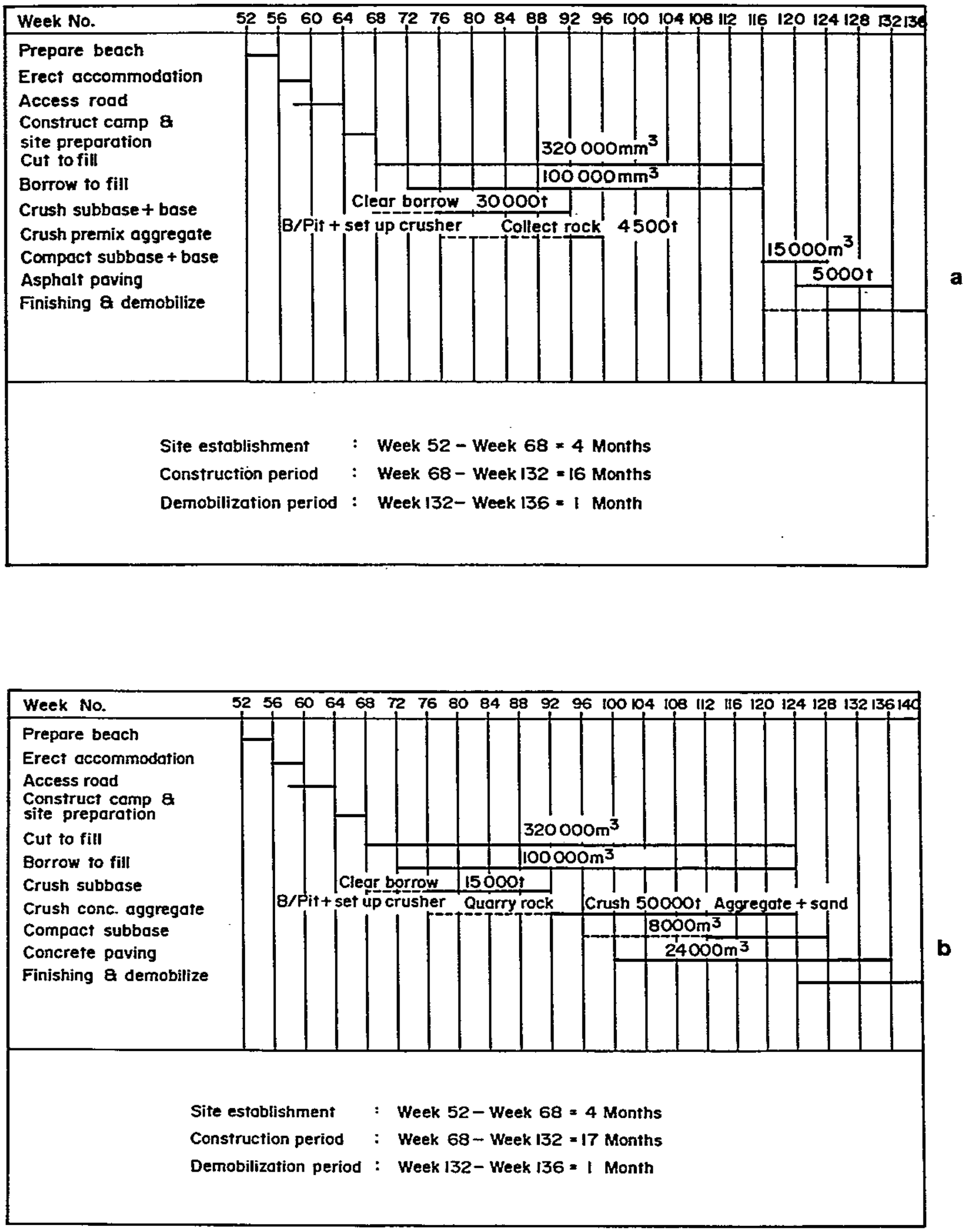


FIGURE 2.2 Schedule of construction phases: (a) Asphalt pavement option; (b) Concrete pavement option (from Lötter, 1987).

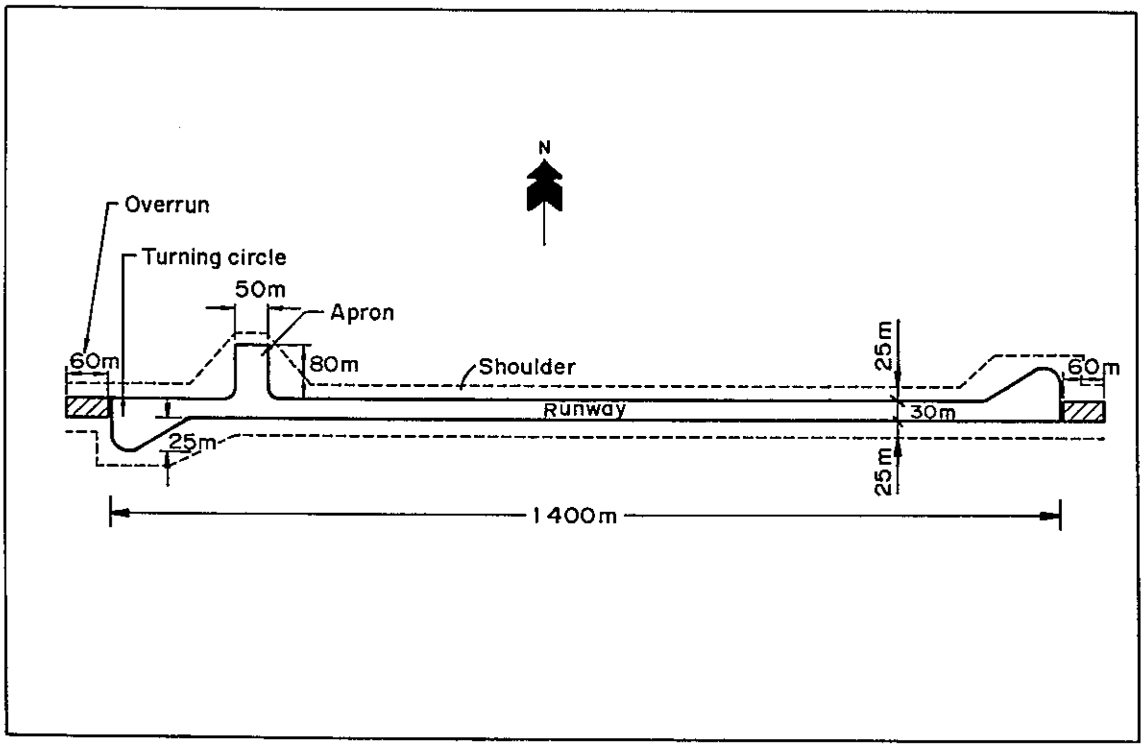


FIGURE 2.3 Plan of the emergency landing strip (from Lötter, 1987).

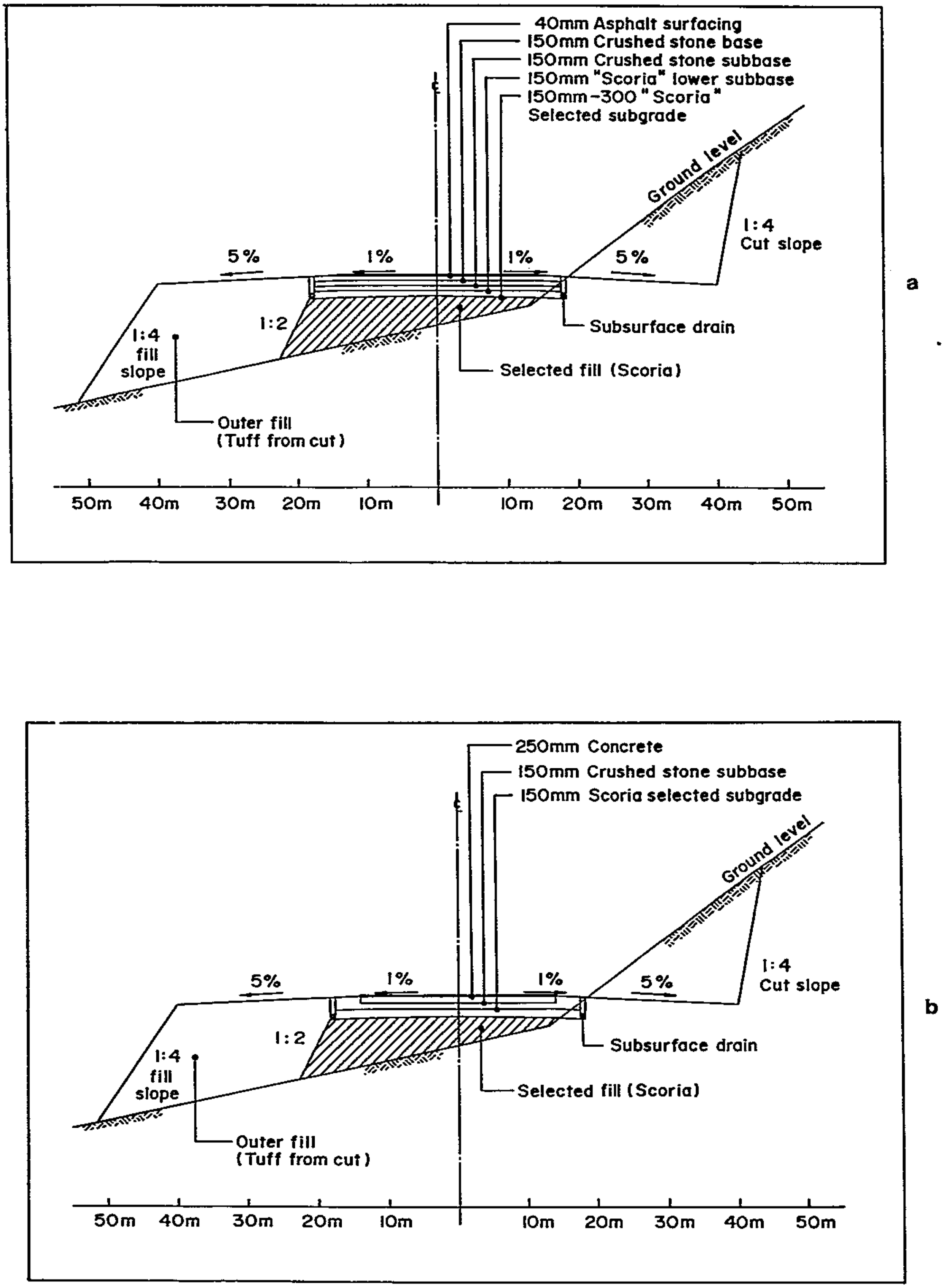


FIGURE 2.4 Emergency landing strip cross-section detail: (a) Asphalt pavement option; (b) Concrete pavement option (from Lötter, 1987).

CHAPTER 3

VIABILITY ASSESSMENT OF THE PROPOSED FACILITY

Before proceeding in Chapters 4 and 5 with the assessment of the probable environmental impact of the proposed facility, an evaluation is made in this Chapter of the probable economic viability and technical usability of the proposal, measured against possible alternative steps which can be taken to meet the stated needs of the DEA presented in Chapter 1 (Section 1.4).

3.1 ASSESSMENT OF REASONS GIVEN FOR THE PROPOSED FACILITY AND EVALUATION OF ALTERNATIVE SOLUTIONS

The stated reasons for the proposed facility, which are presented in Chapter 1, are dealt with below in terms of suggested alternative solutions:

3.1.1 To Provide Rapid Attention To or Evacuation Of Injured or Sick Personnel

During the four years up to and including 1985 it was necessary to mount four separate voyages to evacuate injured persons. Until now, evacuations for medical reasons have taken place by ship. Apart from the four incidents referred to above, it appears that only one other special evacuation voyage (suspected appendicitis during the 1960s) has been recorded during the preceding 33 years. Of the five cases three of the evacuees have fully recovered. In the other two cases it seems that rapid evacuation (i.e. by air) would not have resulted in a different prognosis. At least two of the injuries that necessitated rescue voyages could probably have been avoided through stricter adherence to Station rules, a third through more rigorous pre-expedition medical screening.

A ship takes about four days to reach the Island, whereupon attention from a medical doctor is possible. Air evacuation could take about 24 hours, weather permitting. However, even after a successful landing, it is highly unlikely that the aircraft would be able to take off immediately because of the low occurrence of favourable easterly winds. It may be that, in really urgent cases, 24 hours might still be too long a period. Therefore, it would appear that there is a strong case for a qualified medical doctor, as at the South African Antarctic Station "Sanae", to be part of the Marion Island team. The benefits of such an appointment (including the upgrading of medical facilities at Marion Island) are analysed in Section 3.2.3.

In 1980 lava outpourings occurred in the central and western regions of Marion Island. In the highly unpredictable case of seismic or volcanic activity threatening the eastern seaboard of the Island, the runway would stand an equal chance of being damaged. For such an eventuality, consideration should be given to inflatable lifeboats to reach unaffected parts of the Island if overland routes are blocked. Emergency sub-stations could be established at suitable beaching sites and these stocked with the necessary equipment and supplies.

The use of a sea plane, or amphibious fixed-wing aircraft, has been suggested as a possible alternative to the need for an ELS for rapid evacuation of Station personnel. The aircraft would land as near as possible to the Base Station on the relatively calm sea in the lee of the Island. The type of aircraft that could be considered is the highly adaptable utility craft developed for fire fighting, aerial spraying and maritime surveillance, search and rescue. It would appear that such craft could normally reach the Island with a payload of approximately 1 000 kg, but would require refuelling at the Island before returning to the mainland. At 24 hours notice, however, fuel tanks could be fitted in lieu of the fire fighting water tanks, thus obviating the need to refuel at the Island. Although this option appears possible in principle, a further study would be required to establish the viability of landing, mooring and taking off in the prevailing weather and sea conditions. Such planes have been known to land, or carry out water-scoop operations for fire fighting, in average wave height conditions of up to 2,0 m. In Section 3.2 of this Chapter the reliability of landing on the ELS during day time is estimated to be 0,29 and raised to 0,4 (in line with the philosophy of weighting probabilities in favour of positive utility). It can be expected that the reliability of landing on the sea surface will be lower than that for the ELS by an amount which can only be determined after a suitable period of wave observation off the Island's lee shore. These wave data will also determine the feasibility of mooring the aircraft in a protected bay for short periods. On the other hand, the reliability of take-off is likely to be higher than that at the ELS due to fewer directional and topographic constraints.

The installation of a permanent seismometer, possibly as an extension to the existing mainland network of seismic monitoring stations, along with improved communications with the mainland such that seismometer data can be transmitted daily to the mainland for interpretation by experts, would be an additional step that could be taken to deal with the threat of volcanic eruption.

3.1.2 To Provide Surveillance and Rescue Aircraft with an Alternative Landing Place

The Cape Sea Route is an important and busy one. While most passages around the Cape take place within about 100 nautical miles of the coast some, especially yachts not calling at Cape Town, prefer a more southerly passage.

There would not appear to be a ready alternative solution for this need, except replacement of existing aircraft with more reliable, long-range aircraft (amphibious aircraft included), or using ship-based activities for surveillance. However, the proposed ELS can only offer a safe landing and take-off under a limited set of environmental conditions (see Section 3.2). The probable usability and cost effectiveness of the ELS is also analysed in Section 3.2 and Appendix E.

3.1.3 To Enable Better Control of Territorial Waters and the Fishing Zone Around the Islands.

Expert evidence to the Panel indicates that there are no known commercial fishing activities presently taking place within 200 nautical miles (i.e. within the fishing zone) of the Prince Edward Islands. The absence of a large, shallow-water plateau (as around Kerguelen) means that demersal trawling is never likely to be a commercial proposition. At present, territorial waters are 12 nautical miles and, in the absence of any threatening intrusions into these waters in the past, there seems to be little need to patrol territorial waters.

The high percentage cloud cover in the region probably makes aircraft unsuitable for patrolling either the fishing zone or territorial waters. An alternative that would seem more effective would be a patrol ship, in that it could request vessels to stop and be inspected and could operate independently of cloud cover.

3.1.4 To Enable Provisioning of the Station with Emergency Supplies

It has only been necessary to supply the Base Station with emergency provisions by air on one, or possibly two, occasions in the past. Medical supplies were air-dropped on one of these occasions. It would seem perfectly feasible to stock the Base Station with adequate supplies (as is already done). If needed, additional supplies could be air-dropped.

Evidence to the Panel indicates that air-drops are often used at the sub-Antarctic Macquarie Island (Australian possession) without any apparent problems.

The occurrence of circumstances requiring emergency provisioning of the Base Station with critical, non-medical supplies, so rapidly that a ship taking four to five days to reach the Island would be too slow, is unlikely and has not to the Panel's knowledge ever occurred. Steps, if not already taken, to ensure an 18-month supply of basic requirements (e.g. food and fuel), with air-drops as a last resort, would seem to satisfy the whole range of circumstances so far experienced. It is pertinent to observe here that, in the past, sealers and shipwreck survivors have survived for many months, even years, living mainly off naturally occurring resources (e.g. food and shelter).

3.2 ANALYSIS OF THE ECONOMIC VIABILITY OF THE PROPOSED FACILITY

3.2.1 Nature of Analysis

An approximate analysis of important costs and benefits, but excluding those due to environmental disturbance, has been done by evaluating an objective function of the utility U_n of the ELS, in order to establish whether the project is economically viable in terms of the needs defined in Chapter 1 (Section 1.4) of this report.

Construction costs have been based on estimates prepared by the consulting engineers. Other probable costs (or losses) and benefits have been based on somewhat arbitrary, but not unreasonable, assumptions. Where available, published statistics have been used. The risk assessments have been derived in consultation with experts in the relevant fields. Throughout the analysis, the value assessments of the various terms of the utility function have been heavily weighted in favour of positive utility as it became clear, at an early stage of the investigation, that the objective function was likely to be largely negative even if any negative environmental impacts, the quantitification of which would admittedly be highly subjective, were omitted. The effect of possible singular, but very unlikely catastrophic, events are noted in order to assess the equivalent values of extreme benefits as well as extreme costs (or losses).

The risk of events (i.e. the probability of an event x consequential costs) that have to be assumed in order to evaluate the terms of the function are the following:

- The risk of a member of the Marion Island personnel requiring urgent medical care, not available on the Island, to prevent death or permanent incapacity of a serious nature.

- The risk of a member of the Marion Island personnel requiring urgent medical care, not available on the Island, to prevent temporary or partial incapacity.

- The risk of a surveillance aircraft of the Hercules C130 or equivalent requiring the emergency landing facility on Marion Island.

- The risk of a surveillance aircraft of the Hercules C130 or equivalent crashing at an attempted landing on the airstrip on Marion Island.

- The risk of volcanic activity.

3.2.2 The Objective Function of Utility U_n

Details of the assumptions made and of the method of analysis are given in Appendix E. For the purposes of this exercise the objective function has been considered for a useful period of 20 years, but the effects of shortening or extending this period have also been investigated. All value assessments of expected benefits and costs (or expectations of losses) are capitalized at present value in equivalent rand.

Utility U_{20} = Benefits - Costs (or losses) - Environmental Impacts
= B - C - EI

where: B = a + b + c + d + e + f + g + h

a = equivalent value of the prevention of death or permanent incapacity of any of m members of the Marion Island personnel requiring urgent medical care, by the use of the proposed ELS.

b = equivalent value of the prevention of temporary or partial incapacity of any of m members of the Marion Island personnel requiring urgent medical care, by the use of the ELS.

c = equivalent value of saving the crew of surveillance aircraft by emergency landings on Marion Island.

d = value of saving aircraft by emergency landings on Marion Island.

e = value of improved supply of any other emergency needs of the Marion Island personnel.

f = value of improved supply of the general needs of the Marion Island personnel.

g = saving in costs of rescue missions otherwise carried out by ship, and the avoidance thereby of consequential losses due to the non-employment of the ship elsewhere.

h = equivalent value of evacuation by air of personnel endangered by volcanic activity.

thus: The value of B has been evaluated as described in Appendix E (Section 2) in equivalent rand as follows:

B < R6.9 x 10^6 (for $n = 20$ years, where the probability of B exceeding the value is not accurately calculable but is small).

and: $C = x + y + z$

x = cost of all items related to the complete construction of the ELS.

y = cost of all items related to the maintenance of the ELS.

z = cost of operations related to rescue flights, including the risk of the loss of an aircraft and crew on attempting a landing.

thus: The costs or losses under C have been evaluated in Appendix E (Section 3) in equivalent rand as follows:

C > R24,9 x 10^6 (for $n = 20$ years, where the probability of C being less than the value is not accurately calculable but is small).

The environmental impacts EI can only have a negative effect on the equation, but even if we assume that it is very small and therefore ignored, then the utility for $n = 20$ years is:

$$\begin{aligned} U_{20} &< B - C \\ &< R(6,9 - 24,9)10^6 \\ &< -R18,0 \times 10^6 \end{aligned}$$

and the benefit/cost ratio;

$$\frac{B}{C} < \frac{6,9}{24,9} < 0,28 \text{ (should be} > 1,0\text{)}$$

It is interesting to note that:

if $n = 10$; then $B/C < 0,15$ (see Appendix E, Section 5)
if $n = 30$; then $B/C < 0,38$
if $n = 40$; then $B/C < 0,46$

The effects of possible singular, but very unlikely catastrophic, events on the Cost-Benefit equation are discussed in Appendix E (Section 4).

3.2.3 The Cost/Benefit Implications of Alternative Emergency Measures

The alternative emergency measures discussed in Section 3.1 of this Chapter can be analysed approximately, in terms of probable costs or losses and benefits, in similar manner as for the proposed ELS. Accurate assessments are difficult, so the costs have been estimated conservatively in the procedure of formulating the utility function in order to weight the relevant terms towards negative utility, contrary to the procedure adopted for the ELS.

The same beneficial terms, a to b of the utility function enumerated in Section 3.2.2 above, have been applied, except that the use of the alternative emergency measures replaced that of the ELS and that the terms were weighted towards negative utility as follows (see Appendix E, Section 6 and compare with Appendix E, Section 2):

a > R1,25 x 10^6
b > R0,05 x 10^6
c = 0
d = 0
e = 0
f = 0
g > R0,75 x 10^6
h > R0,13 x 10^6

therefore:

B > R2,18 x 10^6

Likewise, the costs (or losses) have been weighted towards negative utility. The cost items used in the case of the ELS are not applicable, but the following apply (refer to Section 3.1 and Appendix E, Section 7):

j = cost at present value of additional medical facilities on Marion Island including operating theatre and full-time medical doctor and assistant over a period of 20 years.
< R2,0 x 10^6
k = cost of evacuating patients by ship where further medical care is necessary.
< R0,45 x 10^6
l = cost of providing emergency substation, equipment, supplies, tents and life boats for evacuation in the event of seismic or volcanic activity.
< R0,5 x 10^6
m = loss of surveillance aircraft due to lack of ELS
< R2,2 x 10^6
n = loss of aircrew due to lack of ELS
< R0,23 x 10^6

therefore:

$$\begin{aligned} C &= j + k + l + m + n \\ &< R5,38 \times 10^{6} \end{aligned}$$

No attempt has been made to evaluate the alternative costs and benefits in connection with the control of territorial waters and the fishing zone around the Islands.

Therefore:

$$\begin{aligned} \text{Utility } (U_{20}) &> B - C \\ &> R(2,18 - 5,38) \times 10^{6} \\ &> -R(3,2) \times 10^{6} \end{aligned}$$

$$\text{and: } \frac{B}{C} > \frac{2,18}{5,38} > 0,41$$

Compared with the utility of the ELS which is less than $-R18,0 \times 10^{6}$ and the B/C ratio of the ELS which is less than 0,28, the utility of the alternative emergency measures is much less negative and they would not have the same order of negative environmental impact.

3.3 CONCLUSION

On the basis of the above analyses, which have not included any possible damages due to environmental impacts, the costs greatly exceed the benefits and the DEA's proposal cannot be considered to be viable on economic grounds. Alternative solutions are much less costly and would not have the same order of negative environmental impact.

CHAPTER 4

ENVIRONMENTAL COMPONENTS

4.1 INTRODUCTION: ELEMENTS OF SUB-ANTARCTIC ECOLOGY

Marion and Prince Edward Islands comprise composite volcanic peaks rising to over 1 200 m above sea level from the south Indian Ocean. In common with five other island groups, termed the sub-Antarctic islands, Marion and Prince Edward are extremely isolated from other land masses (see Figure 1.1). The Prince Edward Islands are of comparatively recent geologic age and have cold, wet and windy climates.

A feature which immediately strikes the visitor to Marion Island is its bleak and barren appearance. Trees and shrubs are absent from the tundra-like vegetation. The few plants that clothe the Island's rugged, windswept slopes have arrived by means of the long-distance dispersal of their seeds or spores, transported by birds, wind or sea drift. During the approximately 500 000 years since the Island's origin, only 24 species of ferns and flowering plants have established on the Island by natural means. Since sailors, sealers and scientists started visiting Marion Island in the nineteenth century, at least 15 species of weeds have been introduced. Some 72 species of mosses, 35 species of liverworts and over 100 species of lichen are also found on the Island.

The Island's harsh climate, with an average of 308 days on which precipitation occurs, 107 days with gale force winds and 82 days with snowfall per year at the Base Station, results in very slow growth rates in almost all plant species. Many of the dominant plants and birds are slow breeding and long-lived, with very low rates of recruitment, making their populations unusually susceptible to any increase in mortality rates. As a consequence, the impact of disturbance on one generation might take a decade or more to become obvious.

Climatic and geologic factors account for the absence of well developed mineral soils on the Island. The windswept plateaux and ridges are covered in loose stones and broken lavas - a desolate 'wind desert' or fjaeldmark, with shallow soils of poorly weathered volcanic ash. The densely vegetated slopes of protected valleys and the waterlogged lowland mires have a deep organic peat. Peat slips are common features on slopes disturbed by burrowing birds, seals or man. Whatever the cause of soil scarring, re-vegetation is extremely slow.

Unlike continental ecosystems, where the impact of the surrounding oceans is principally through major atmospheric and climatic processes, the terrestrial ecology of oceanic islands is also strongly influenced by their very close interaction with the marine system. Thus, on Marion Island, the deposition of salt-spray blown in from the ocean and from waves pounding the rugged coastline, dominates the water chemistry of its inland waters and strongly determines the plant community patterns of the coastal lowlands. Furthermore, the hundreds of thousands, indeed millions of penguins, albatrosses, petrels and seals that feed at sea and deposit thousands of tons of guano on the Island strongly influence plant growth and vegetation and nutrient cycling patterns, especially on the coast.

The most significant ecological features of sub-Antarctic islands are their extreme biological simplicity and their sensitivity to man-induced disturbances. Most indigenous species recover extremely slowly following disturbance, whereas some introduced plants and animals spread rapidly and aggressively out-compete the islands' natural fauna and flora.

Any evaluation of the environmental impacts of man's activities in the sub-Antarctic must give consideration to the above characteristics of these oceanic islands. This Chapter will illustrate the concepts in the context of Marion Island, more specifically that area of the east coast falling between Transvaal Cove, Fred's Hill and East Cape, hereafter referred to as the Impact Area - i.e. that area most likely to be affected by the proposed facility (see Figure 1.2).

4.2 ECOLOGICAL SYSTEMS AND PROCESSES

Although the negative influences of disturbance might be most dramatically described in terms of the death of individuals or the extinction of populations or species, the broader consequences of man-induced impacts occur at the level of ecological systems and processes. These will be described before examining the nature and distribution of habitats and species in the Impact Area. In preparing this outline, information has been drawn freely from the extensive bibliography of scientific research conducted on the Prince Edward Islands. Some of the key sources of information are noted in the List of References and Selected Bibliography towards the end of this report.

4.2.1 Geology, Soils and Surface Cover

Three differently coloured geological formations are readily recognized on Marion Island (Figure 4.1). Grey lavas, of 100 000 to 500 000 years old spread radially from the central highlands. These were planed down to a series of smooth plateaux and ridges by glaciers which developed and receded with the global glacial events of the Pleistocene Ice Age.

The last major glaciation occurred from 50 000 to 15 000 years ago. With the retreat of the glaciers, extensive deposits of conglomerate-like tills (moraines) formed from the mass of broken lava rubble that the glaciers had carried. The site of the proposed ELS cuts across several of these moraines (Figure 4.2). Black lavas, which have poured forth since the end of the last glaciation and still continue at sporadic intervals, form extremely ragged flows between and over the older grey lavas. Red conical hills of volcanic cinder (scoria) form the third conspicuous geological formation. The sequence of these lavas and moraines in the area of the ELS is illustrated in Figures 4.2 and 4.3.

None of these rock types have decomposed adequately to form the rich, loamy soils found on more ancient or tropical volcanic islands. What soil exists is composed almost entirely of the slowly decomposing organic remains of plants (peat) and fine volcanic ash from volcanic eruptions. Profiles of the peat soils of the major vegetation types are illustrated in Figure 4.4.

These peats are unstable and susceptible to erosion, especially on slopes and where subjected to increases in pH as can occur at sites heavily manured by burrowing birds. Smith (pers. comm.) has suggested that with increased pH a gelatinous layer of colloidal material accumulates at the surface of iron pans in the peat profile and peat slips can then occur along this lubricated layer (Figure 4.5).

On the lowlands, a fairly continuous mat of mosses, ferns, herbs and grasses covers peat and rocky substrata. Where this mat is broken, or where excessive waterlogging develops on steep slopes, fairly large peat slumps and slips occur. These are most prevalent on inland slopes occupied by dense burrowing petrel populations, or on coastal cliff faces eroded by penguins.

Despite the very slow growth rate of Marion Island plants, they are adequately robust to survive light levels of trampling. Despite more than 20 years of scientific survey on the Island, few of the main routes radiating from the Base Station have cut deep scars into the vegetation cover. Boot impressions can remain visible in cushion plants or moss carpets for a year or more, but most species return to their former profile. Once the vegetation mantle over peat has been incised, however, further erosion and peat slipping can be both rapid and extensive.

Slip scars resulting from human activities are relatively rare, but that caused by the water pipeline for the hydro-electric scheme below the Van den Boogaard River dam is extensive and shows no signs of recovery even four years after its formation. An estimated 1 500 m^3 of peat has been eroded from the slopes below the dam (Figure 4.6).

The areas deemed to be most susceptible to slip scarring and erosion in the Impact Area are indicated in Figure 4.7.

4.2.2 Weather and Climate

The climate of Marion and other sub-Antarctic islands may be summarized as cold, wet and windy. Marion Island lies approximately 200 km north of the Antarctic Convergence, where the cold Antarctic waters sink below the slightly warmer sub-Antarctic waters. The mean monthly air temperature of the Island closely tracks that of the ocean, and ranges from 3,6°C in August to 7,9°C in February. Sunshine duration averages only 3,6 hours per day, or 29 % of that possible (Table 4.1).

While the Island is never warm, it also does not experience the bitter cold of continental tundras, and the absolute minimum screen temperature is only -6,8°C. This feature, and the absence of strong diurnal temperature ranges, is a consequence of the moderating influence of the ocean on the Island's climate.

Marion Island lies in the middle of the proverbially tempestuous 'Roaring Forties' within the belt of west winds between 40° and 50°S. These westerlies are interrupted by numerous depressions or extra-tropical cyclones, which originated in the South Atlantic Ocean and pass to the west of, or directly over, Marion Island. The anticyclones, following depressions, pass north of the Island in an easterly direction. The predominance of winds from the WNW to NNW sectors is illustrated in Figure 4.8.

As indicated in Table 4.1, Marion Island experiences an average of 107 gale days per year. Such days are defined as those on which the mean wind speed exceeds 55 km h^{-1} for at least an hour. Gales usually greatly exceed this speed and gusts of over 160 km h^{-1} are frequently recorded, while gales with mean speeds exceeding 70 km h^{-1} often rage for over 24 hours without a break. A wind trace from a 24-hour period during the Panel's visit to the Island is presented in Figure 4.9.

A factor of considerable importance to the use of a landing strip on Marion Island is the occurrence of 'false winds'. Expert opinion submitted to the panel indicated that under some weather conditions, especially when a temperature inversion exists within the first 1 000 m above sea level, the presence of the Island causes distortion to the wind pattern. Under these conditions, strong westerly or north-westerly winds over the open ocean, or at a few hundred metres above sea level, will appear as very erratic easterly winds at the Base Station. At unpredictable intervals the vortices change pattern or break up and then the true wind suddenly manifests itself at the surface. Changes of direction of 180° and in speed of 30 m s^{-1} can occur within a few seconds. These are frequent and unpredictable occurrences. Furthermore, it has been observed that on many occasions radiosonde balloons have been subjected to down-drafts in the order of 10 m s^{-1}, a phenomenon recorded close to the Base Station, but probably of general occurrence in the disturbed wind flow to the lee of the Island's mountains.

TABLE 4.1 Mean climatic data for the Base Station, Transvaal Cove, Marion Island (from Schulze, 1971 and Weather Bureau, pers. comm.).

	Recording period in years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Sunshine duration, % of possible	17	32	34	30	24	24	21	22	24	26	33	34	32	29
Sea temperature, °C	15	5.7	6.1	6.1	5.7	5.0	4.7	4.3	4.0	4.0	4.2	4.7	5.1	5.0
Air temperature, °C	34	7.4	7.9	7.7	6.3	5.3	4.6	3.9	3.6	3.8	4.8	5.7	6.5	5.6
Days with moderate gales	10	8.7	6.2	6.5	8.0	8.6	9.5	10.7	10.3	11.4	8.4	8.4	10.1	107
Maximum gusts, km h^{-1}	10	130	148	143	134	126	142	198	161	145	150	163	148	198
Precipitation, mm	34	218	198	218	224	233	212	203	185	184	172	189	218	2454
Days with precipitation	34	25.6	22.1	24.0	25.4	27.3	27.0	27.6	27.4	26.1	24.5	25.0	26.0	308.0
Days with snowfall	34	2.7	1.7	2.4	4.4	6.9	8.2	10.9	12.0	11.8	8.5	7.4	5.2	82.1
% Relative humidity	12	81	83	83	84	83	83	84	83	83	81	81	81	83

Marion Island has a mean annual rainfall of 2 454 mm. Precipitation of one form or another is recorded on 308 days per year and no month receives less than 172 mm. Relative humidity averages 83 %.

As might be expected from the above statistics, cloud cover is high - the monthly mean being 6,9 oktas, while clouds with a base below 300 m above sea level are recorded on 150 days per year. At the Base Station snow occurs on 82 days per year, fog on 43 days per year and freezing conditions, at the coast, on 56 days per year.

The above weather conditions make the Island wholly unsuitable for normal use and development by man. Even scientific studies can only be conducted with considerable discomfort and commitment. Engineering activities (e.g. the Base Station) take considerably longer and require more expensive materials compared with similar projects on the South African mainland.

4.2.3 Hydrology: Ground Water and Drainage Patterns

As a consequence of the very high and seasonally uniform moisture regime on Marion Island and the deep and highly organic composition of its peat soils, information on the nature and distribution of drainage patterns is extremely important to the planning and implementation of any of man's activities on the Island.

Marion Island has a poorly developed, radial drainage pattern with only two perennial streams and some 30 intermittent water courses. Subsurface drainage through the younger porous black lavas is rapid. Small bogs and ponds are abundant in the older black lavas, while extensive, poorly drained areas of swamplands (mires) and large lakes are characteristic of the impermeable grey lavas (Figure 4.10).

The distribution of all plant communities is strongly influenced by subtle changes in hydrological conditions. Slight changes in soil-water relations will transform communities from one type to another, either through changes in the growth response of individual species, or through the death of existing species and their replacement by species better adapted to the new conditions. The most frequent changes in community structure relate to changes in physical hydrology, but more dramatic changes may occur where the water chemistry of a site is altered through manuring by animals or pollution from man's activities.

The proposed ELS runs over several glacial moraines and will cut catchments draining into extensive mires and lakes. The drainage patterns in the Impact Area are indicated in Figure 4.11.

4.2.4 Species Interactions: Predation, Competition and Alien Invasives

Individual species within biological communities display several possible forms of interaction with other species occupying the same area. The most important of these are predation (where one species benefits while the other suffers), competition (where two species are disadvantaged through their joint use of a limited resource) and mutualism (where two species benefit from each other's activities).

On Marion Island, predation of one bird species by another, or of squid, krill or fish by seals, albatrosses or penguins, is a common and expected phenomenon. The marine and terrestrial fauna have evolved and maintain their population equilibria principally in response to the interactions of predators and prey. The situation changes very rapidly when a new predator, such as a whaling vessel or a feral domestic cat, appears on the scene. The dramatic decrease in world whale stocks and, on Marion Island, of small burrowing petrels, consequent upon the appearance of these new and alien predators, is well documented. This aspect will be detailed in Section 4.4.2.

Where two species require similar resources, such as soil nutrients, light or water, the species that is better equipped to rapidly exploit the resource is usually able to exert dominance over the other. On Marion Island, the few plant species that have reached it by long-distance dispersal of their seeds have been able to exploit the available resources with very little competition from the few species that arrived before them.

Only 24 species of ferns and flowering plants appear to have established themselves on Marion Island in the 500 000 years since the Island's formation (Table 4.2). Yet, in the less than 200 years since man first visited Marion Island, 15 species of weeds have been recorded, the majority of these in the last 50 years (Table 4.3). Several of these species are clearly more efficient at using the Island's resources and are rapidly invading and out-competing native species. Their success seems to be highest in sites where the indigenous plants and/or soil cover have been disturbed by man's activities. The spread of alien plants and animals is the greatest single threat to the Island's native flora and fauna, an aspect which will be discussed in detail later in this report.

4.2.5 Corridors and Pathways

For the vast majority of the birds, and all seal species found on Marion Island, the Island is a terrestrial base to a life style that includes a major portion of the year at sea. The route from seashore to land base is often maintained from generation to generation and, in a few sites, deep scars have been worn into the black basalt by pathways developed

TABLE 4.2 Checklist of the indigenous vascular flora of Marion Island (after Huntley, 1971).

PTERIDOPHYTA

- Lycopodiaceae
  - *Lycopodium magellanicum* Sw
  - *L saururus* Lam
- Hymenophyllaceae
  - *Hymenophyllum peltatum* (Poir) Desv
- Polypodiaceae
  - *Blechnum penna-marina* (Poir) Kuhn
  - *Polystichum marionense* Alston & Schelpe
  - *Grammitis kerguelensis* Tard
  - *Elaphoglossum randii* Alston & Schelpe

SPERMATOPHYTA - ANGIOSPERMAE

- Potamogetonaceae
  - *Potamogeton* sp.
- Gramineae
  - *Agrostis magellanica* Lam
  - *Poa cookii* Hook f
- Cyperaceae
  - *Uncinia compacta* R Br
- Juncaceae
  - *Juncus scheuchzerioides* Gaud
  - *J effusus* L
- Portulacaceae
  - *Montia fontana* L
- Caryophyllaceae
  - *Colobanthus kerguelensis* Hook f
- Ranunculaceae
  - *Ranunculus biternatus* Sm
  - *R moseleyi* Hook f
- Cruciferae
  - *Pringlea antiscorbutica* R Br
- Crassulaceae
  - *Crassula moschata* Forst f
- Rosaceae
  - *Acaena magellanica* Lam
- Callitrichaceae
  - *Callitriche antarctica* Engelm ex Hegelmeyer
- Umbelliferae
  - *Azorella selago* Hook f
- Scrophulariaceae
  - *Limosella australis* R Br
- Compositae
  - *Cotula plumosa* Hook f

TABLE 4.3 Alien plants recorded on Marion Island (from Watkins & Cooper, 1986).

Species	Date first recorded, locality, present status
TRANSIENT ALIENS	
Avena sativa	1965-66, Base Station
Holcus lanatus	1953, April 1965, Base Station
Hypochoeris radicata	1953, 1965-66 chicken run at Base Station
Plantago lanceolata	1965-66, chicken run, Base Station All the above species have not been recorded since 1966. Presumably none has survived
Unidentified thistle	1984, Van den Boogaard River and Base Station
RESTRICTED NATURALIZED ALIENS	
Rumex acetosella	1953, no locality, 1965-66, Sealer's Cave, Base Station, Gentoo Lake
Alopecurus australis	Dec 1965, Feb 1975, Mixed Pickle Cove
Elytrigia repens	1966, Ship's Cove
Festuca rubra	1966, 1973-75, sealer's camp at Ship's Cove. North Van den Boogard River. Cliff near Base Station
WIDESPREAD NATURALIZED ALIENS	
Cerastium fontanum	1965-66, Base Station, Ship's Cove, Sea Elephant Bay, Mixed Pickle Cove, Kaalkoppie, Bullard Beach. 1973-75 at least 30 sites, perhaps as many as several hundred between Cape Davis and Archway Bay areas, Mixed Pickle Cove, Kaalkoppie, Swartkop Point
Poa annua	1948 no locality. 1965-66, 13 localities at old sealing bases or shipwrecks. 1973-75, 83 localities around perimeter of Island
Stellaria media	1873, north-east coast, Marion Island. 1965-66, 12 localities at old sealing bases or shipwrecks. 1973-75, 45 localities around perimeter of Island, perhaps as many as several hundred
Sagina apetala	1965-66, Base Station. 1973-75, abundant from south of Gentoo Lake to Cabbage Point. 200 to 300 individuals mouth Van den Boogard River. May 1975 single plant between Base Station and Trypot Beach
Agrostis stolonifera	April 1965, Feb 1966, Jan 1975, Ship's Cove and Base Station. 1981, north-eastern lowland from Ship's Cove to Archway Bay
Poa pratensis	1965-66, Base Station, Ship's Cove. 1973-75, seven localities between Archway Bay and Ship's Cove, occupying areas 10 to 30 m^2 in area. In 1981 two new stands were found

over thousands of years by the passage of millions of penguins. The topography of traditional, inland Elephant Seal moulting areas has also been developed over generations.

Any disturbance to the use of these traditional routes could severely disrupt the breeding, moulting or loafing behaviour of the animal population concerned.

4.3 HABITATS AND COMMUNITIES

The natural environment of Marion Island can be divided into three major habitat types - marine, terrestrial and freshwater - within which a wide range of subsidiary habitats and animal and plant communities may be recognized. Each of these communities has been shaped by the individual resource needs and interactive responses of their constituent species. The degree to which man's activities exert a positive or negative influence on the communities differs widely from one community to the next. A brief outline of the major features of those communities found in the Impact Area and illustrated in Figure 4.12 is, therefore, essential background to the discussion of environmental impacts in Chapter 5.

4.3.1 Marine Communities

Marion Island is a mere speck of land in the vast Southern Ocean. The coastline comprises rugged, vertical cliffs of 10 to 100 m, with a few isolated boulder beaches of 10 to 50 m width. The sea is very cold (4° - 6°C) and tempestuous, and the windward west coast is heavily pounded by waves.

In the protected coves of the leeward east coast, fairly wide beds of the offshore giant kelp, *Macrocystis pyrifera* grow in water of 10 to 20 m depth. The fronds of this kelp grow extremely rapidly in summer. After storms, vast amounts of this alga are washed up on the shores. Many animal species grow and live on the fronds and the bristly growths of hydroids are noticeable on washed-up wrack. The fragile pink mussel, *Gaimardia trapesina* also occurs in great numbers on the living fronds. These mussels provide a large proportion of the Kelp Gulls' diet and gulls spend much time foraging for mussels amongst the offshore *Macrocystis* canopy. On the cliffs between Transvaal Cove and Trypot Beach many patches of crushed pink mussel shells can be seen. These are regurgitated by the Kelp Gulls in dense, egg-shaped masses after the mussels have been crushed and digested.

The tidal range is only about 70 cm. The upper range of the intertidal zone is clearly marked by the upper limit of the bright pink, encrusting alga *Lithothamnion* sp. Most of the marine animals are very small, cryptic species. There are three different kinds of minute mussels hidden beneath boulders and in crevices in the intertidal zone. The only common large animals are the limpet, *Nacella delesserti* and the starfish, *Anasterias rupicola*. In the gaps between large boulders near the water's edge there are large clusters of this limpet, which is the main diet of the starfish.

A small (4 - 7 cm) plunder fish, *Harpagifer bispinis* also inhabits the intertidal and shallow subtidal zones, where it is usually found hiding beneath rocks. It is an important prey of the Imperial Cormorant.

Most of the shore around the Island consists of sheer cliffs with bull kelp, *Durvillaea antarctica* growing on them. In places where the spray shoots up the cliff faces, the kelp has an extended range and grows quite high above normal tidal level. The bull kelp grows much more slowly than does *Macrocystis* and it is also washed up onto the shore in fairly large quantities after storms. Kelp wrack is quickly broken down by amphipods and bacterial action. Vast swarms of amphipods (or sand-hoppers) often occur in rotting kelp wrack.

Scattered tufts of light green *Porphyra* sp. grow on the tops and sides of boulders in the spray zone. This alga is a favourite food of Lesser Sheathbills. These birds do not have webbed feet and cannot swim, but are very active foragers along the shoreline. They eat a wide variety of marine organisms, including limpets and starfish, and are regular foragers in the gullies and intertidal pools.

The coastal rock pools are not very active when compared with those in mainland South Africa. A few red and pink anemones and also the large isopod, *Exosphaeroma gigas* are the most conspicuous animals found here.

The close interaction and interdependence of the marine communities and several species of shore-based birds is clear from the above brief synopsis. Damage to the kelp beds and boulder beaches will thus have impacts far beyond the marine environment.

Figure 4.13 illustrates some features of the marine communities at Trypot Beach.

4.3.2 Terrestrial Communities

4.3.2.1 Vegetation and soil patterns

The natural communities of the Impact Area include all the main vegetation types and the majority of the bird and mammal species breeding on the Island. For purposes of simplicity, these communities will be described in terms of their vegetation rather than their animal constituents.

Due to the small number of ferns and flowering plants on the Island, most of the plant communities are characterized by single species. Furthermore, the very rapidly changing spatial patterns of geological and topographic substrata results in a very high turnover of species dominance from one site to the next. The consequence of these features is reflected in the dense patchwork or mosaic patterning, of plant communities and related soil types over the Island (Figure 4.14).

These mosaics are extremely intricate on younger (5 000 to 15 000 yr) black lava flows, where bogs, mires, fern slopes and fjaeldmark replace and repeat themselves over distances of from one to 10 metres (see Figure 4.14). It is thus difficult and pointless to map the individual components of these mosaics at the scale used in this report.

On the older (15 000 to 50 000 yr) grey lava flows and moraines, more gently undulating topography and greater age has permitted the development of more extensive stands of the various communities - sometimes of up to tens of hectares. These communities are mappable at the scale used in this report and are indicated in some detail (see Figure 4.12).

Only the basic plant community units will be described in the following account of the vegetation of the Impact Area. These 'primary communities' form the basic components, which merge and overlap with one another over rapidly changing environmental conditions, and thus form the continua and mosaics that characterize the Island's vegetation.

4.3.2.2 Salt-spray communities

The vegetation lining the boulder beaches and steep cliff faces of Marion Island forms a conspicuous, bright green ribbon of from 10 to 250 m width. The plants growing here must contend with very high levels of salt-spray and, frequently, very high levels of nutrient enrichment from the penguins, gulls and seals using the coastline. Two plants, *Cotula plumosa* and *Crassula moschata*, are dominant here.

Vegetation Unit 1. *Crassula moschata* halophytic herbfield. *Crassula moschata* is a small succulent herb, found only within a few hundred metres of the sea, and which can tolerate daily inundation by sea spray. It does not tolerate high levels of trampling or manuring by animals. Imperial Cormorants and Kelp Gulls usually nest in this community.

Vegetation Unit 2. *Cotula plumosa* herbfield. *Cotula plumosa* is a feathery leafed herb which cannot tolerate poor drainage, but forms luxuriant stands where it occurs in heavily manured sites within the salt-spray zone. This community is best developed in Gentoo Penguin, Elephant Seal and Fur Seal resting or moulting areas.

Changes in soil drainage, manuring or salt-spray deposition will, therefore, clearly influence the state of these two species and the other plants and animals which constitute their communities. Further details of these two communities are provided in Tables 4.4 and 4.5 and Figures 4.15 and 4.16.

4.3.2.3 Tussock grasslands

The high cliff faces around Macaroni Bay in the Impact Area are covered by a mosaic of the tussock-forming grass, *Poa cookii* and the dense, stoloniferous, invasive alien grass, *Agrostis stolonifera*.

Vegetation Unit 3. *Poa cookii* tussock grassland. *Poa cookii* dominated the steep slopes of Macaroni Bay until the last decade, and shared the habitat with a half dozen other herb species and with a variety of burrowing petrels and Sooty Albatrosses. In the last 10 years, however, *Agrostis stolonifera* has spread rapidly over the shorter plants and bare ground between *Poa cookii* tussocks, cutting off the light source to the smaller plants and leading to their disappearance from the community.

Tussock grasslands can tolerate high levels of salt-spray, but seem more dependent on good drainage and moderate to high levels of manuring by birds. Should the latter be disturbed to the extent that they leave an area, particularly burrowing petrels, it is probable that the tussock would die out. Table 4.6 and Figure 4.17 illustrate aspects of tussock grassland.

4.3.2.4 Mixed herbfields and fern slopes

Vegetation Unit 4. *Poa cookii* - *Acaena magellanica* mixed herbfield. Although tussock grasslands are most conspicuous and extensive on the high coastal cliffs, small patches of *Poa cookii* tussock are found on inland slopes, such as those on the grey lava moraines on which the ELS is proposed. *Poa cookii* occurs on these well drained slopes with *Blechnum penna-marina*, *Acaena magellanica* and *Azorella selago*.

Vegetation Unit 5. *Blechnum penna-marina* fern slopes. Nearly all the slopes just inland from the salt-spray zone are dominated by an almost pure carpet of the short-leaved, dark olive-green fern *Blechnum penna-marina*. This fern is sensitive to high levels of manuring and salt-spray, and prefers well drained slopes protected from high winds. Scattered about within the *Blechnum penna-marina* carpet are individual plants of species such as *Poa cookii*, *Azorella selago* and *Acaena magellanica*. Changes to drainage patterns and to the pH or nutrient status of slope soils (through effluents or other pollution sources) would induce rapid change in the dominance of *Blechnum penna - marina*.

TABLE 4.4 Phytosociological characters of vascular plants recorded in *Crassula moschata* halophytic herbfield (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Crassula moschata	5	4	3	4
Azorella selago	5	3	3	2
Poa cookii	5	+	1	2
Cotula plumosa	3	+	2	3
Ranunculus biternatus	2	+	2	1
Callitriche antarctica	2	+	2	1
Juncus scheuchzerioides	1	+	2	1
Agrostis magellanica	1	+	1	2
Poa annua	1	+	2	2
Montia fontana	1	+	3	2
Acaena magellanica	1	+	2	1
Blechnum penna-marina	1	+	2	1

TABLE 4.5 Phytosociological characters of vascular plants recorded in *Cotula plumosa* herbfield (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Cotula plumosa	5	5	5	4
Poa cookii	5	1	2	3
Ranunculus biternatus	4	+	3	3
Callitriche antarctica	3	+	3	3
Crassula moschata	3	1	3	3
Poa annua	2	+	3	3
Montia fontana	2	+	4	3
Azorella selago	2	+	3	3
Acaena magellanica	2	+	3	2
Juncus scheuchzerioides	1	+	1	2
Stellaria media	1	+	3	3
Uncinia compacta	1	+	1	2
Blechnum penna-marina	1	+	3	1

TABLE 4.6 Phytosociological characters of vascular plants recorded in *Poa cookii* tussock grassland (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Poa cookii	5	3	2	4
Montia fontana	5	+	3	3
Acaena magellanica	4	2	4	2
Ranunculus biternatus	4	+	3	3
Poa annua	3	2	4	3
Callitriche antarctica	2	+	3	3
Azorella selago	2	+	3	3
Agrostis magellanica	2	+	2	2
Cotula plumosa	2	+	3	3
Stellaria media	2	+	3	3
Blechnum penna-marina	1	+	3	2
Crassula moschata	1	+	3	2
Pringlea antiscorbutica	1	+	1	3
Cerastium holosteoides	1	+	3	3
Uncinia compacta	1	+	1	2

TABLE 4.7 Phytosociological characters of vascular plants recorded in *Poa/Acaena* mixed herbfield (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Acaena magellanica	5	5	5	4
Azorella selago	4	3	3	3
Blechnum penna-marina	4	3	4	3
Poa cookii	4	+	2	3
Montia fontana	4	+	3	3
Agrostis magellanica	3	+	2	3
Ranunculus biternatus	3	+	3	3
Stellaria media	2	+	3	3
Pringlea antiscorbutica	1	+	1	3
Cerastium holosteoides	1	+	3	3
Lycopodium saururus	1	+	2	3
Poa annua	1	+	2	3

TABLE 4.8 Phytosociological characters of vascular plants recorded in *Blechnum penna-marina* fern slopes (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Blechnum penna-marina	5	5	5	4
Azorella selago	5	3	3	3
Acaena magellanica	5	3	5	3
Agrostis magellanica	5	+	2	3
Poa cookii	3	+	2	3
Uncinia compacta	3	+	2	3
Montia fontana	3	+	3	3
Ranunculus biternatus	2	+	2	3
Juncus scheuchzerioides	1	+	2	3
Grammitis kerguelensis	1	+	3	3
Lycopodium magellanicum	1	+	2	2
Pringlea antiscorbutica	1	+	1	3
Stellaria media	1	+	2	3

TABLE 4.9 Phytosociological characters of vascular plants recorded in *Juncus scheuchzerioides* bog (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Agrostis magellanica	5	1	2	3
Montia fontana	4	+	2	2
Juncus scheuchzerioides	3	+	2	2
Ranunculus biternatus	3	+	2	2
Azorella selago	2	+	3	1
Uncinia compacta	2	+	2	2
Blechnum penna-marina	2	+	2	1
Callitriche antarctica	2	+	2	1
Poa cookii	1	+	1	1

Tables 4.7 and 4.8 and Figures 4.18 and 4.19 give further details on the floristic and habitat characteristics of mixed herbfield and fern slope.

4.3.2.5 Swamp communities

Marion Island's cold, wet climate and the absence of major herbivores or detritivores account for the very slow rate of decomposition of plant material, for the continuous accumulation of organic material and, ultimately, for the formation of deep, waterlogged peats. These peats are acidic and contain very few nutrients in a form available for plant growth.

Vegetation Unit 6. *Juncus scheuchzerioides* bog. Bogs are stagnant, anaerobic peats with little lateral drainage. They are most typically found in small basins within the rolling hummocks of black lava flows. Bog surfaces are usually covered by the liverwort, *Blepharidophyllum densifolium* and a sparse cover of the rush, *Juncus scheuchzerioides*. Most bogs are too wet and unstable to permit one to cross on foot, which is usually possible over the somewhat drier and better drained mires.

Vegetation Unit 7. *Agrostis magellanica* mire. Mires occupy deep, waterlogged peats which have some lateral waterflow and often cover gently sloping ground. The grass, *Agrostis magellanica* is the dominant flowering plant of mire, but species such as *Blechnum penna-marina*, *Azorella selago*, *Uncinia compacta* and *Ranunculus biternatus* are also important in this community. Mosses and liverworts often form an almost continuous carpet under the herbaceous plants. These moss carpets support high densities of worms and caterpillars, and these provide an important food source for Kelp Gulls and Sheathbills, especially during winter.

Most of Marion Island's 24 fern and flowering plant species are intolerant of the waterlogged, highly acidic and nutrient poor conditions found in bogs and mires. However, many species, otherwise absent from the swamps, establish themselves where Wandering Albatrosses or Giant Petrels nest on mires and create small areas of heavily manured peat around their nests. Thus, changes in nutrient and/or drainage conditions will initiate significant changes in the community structure of mires and bogs. Tables 4.9 and 4.10 and Figures 4.20 and 4.21 illustrate these swamp communities.

4.3.2.6 Fjaeldmark communities

Vegetation Unit 8. *Azorella selago* fjaeldmark. The barren, windswept ridges and plateaux of Marion Island are almost devoid of vegetation. Between the loose rocks and boulders, scattered individuals of low, hemispherical cushions of *Azorella selago* are found. The cushions often form a substratum for the establishment of other species in this inhospitable fjaeldmark or 'wind desert'. Up to 13 species, including

TABLE 4.10 Phytosociological characters of vascular plants recorded in *Agrostis magellanica* mire (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Agrostis magellanica	5	3	2	3
Uncinia compacta	5	2	2	3
Juncus scheuchzerioides	4	+	1	3
Azorella selago	4	1	3	2
Montia fontana	3	+	2	3
Ranunculus biternatus	3	+	2	3
Blechnum penna-marina	3	1	1	1
Acaena magellanica	2	+	2	1
Callitriche antarctica	1	+	1	2
Lycopodium magellanicum	1	+	1	4
Poa cookii	1	+	1	1
Poa annua	1	+	1	1

TABLE 4.11 Phytosociological characters of vascular plants recorded in *Azorella selago* fjaeldmark (from Huntley, 1971).

Species	Constancy	Cover	Sociability	Vitality
Azorella selago	5	2	3	3
Agrostis magellanica	5	1	1	2
Ranunculus biternatus	3	+	2	2
Acaena magellanica	2	+	2	2
Lycopodium saururus	1	+	1	3
Blechnum penna-marina	1	+	2	1
Montia fontana	1	+	1	2
Grammitis kerguelensis	1	+	3	2
Hymenophyllum peltatum	1	+	2	2
Poa cookii	1	+	1	2
Uncinia compacta	1	+	1	2
Lycopodium magellanicum	1	+	2	2
Pringlea antiscorbutica	1	+	1	1

Agrostis magellanica, *Acaena magellanica*, *Blechnum penna-marina* and *Poa cookii* make use of this microhabitat. Between the rocks and *Azorella* cushions, mosses and lichens are common. The mosses frequently form spherical 'mossballs' where they are constantly rolled about by wind and frost heaving.

The soils of fjaeldmark comprise organic material and fine volcanic ash and debris. These soils are usually fairly shallow (less than 1 m) and moderately well drained. *Azorella* cushions appear to grow to a great age in fjaeldmark (at least 100 years in plants of less than 25 cm height) and the recruitment of seedlings is very slow. The physical removal of *Azorella* and other plant species from fjaeldmark would require many decades, if not centuries, of protection to permit the community to return to its former state. Table 4.11 and Figure 4.22 illustrate the fjaeldmark community.

4.3.3 Freshwater Communities

4.3.3.1 Standing (lentic) waters

A variety of freshwater bodies occur on Marion Island. The standing (lentic) waters have been classified into lakes, crater lakes, lava-lakelets and wallows. Most lakes occur in kettles, or against moraines on the old grey lavas, have a mean surface area of about 4 000 m^2 and an average depth of about one metre. They are usually flat-bottomed and steep-sided, where encroaching vegetation may form springing mats or rafts. The lakes of the Macaroni Bay area have been numbered from I to XVII for reference purposes (see Figure 4.11).

Within the porous black lava flows, numerous small lava-lakelets are found, occurring from sea level to approximately 500 m a.s.l. They range in surface area from 10 to 1 000 m^2 and are seldom deeper than 1,5 m. Within the central depressions of some of the many scoria cones which occur on the Island, crater lakes are found. These lakes contain crystal-clear waters, but are often exposed to violent weather conditions when winds can transform the water into a foaming, churning mass. The standing waterbodies are all subject to various degrees of biotic enrichment caused by the animal life on the Island. An extreme condition of biotic fertilization is found in the wallows, which form in depressions made by moulting Elephant Seals.

The vegetation of standing waters includes three flowering plant species which occur nowhere else on the Island. The endemic dwarf buttercup, *Ranunculus moseleyi* and the small water plant, *Limosella australis* form small mats on the floors of lakes and lakelets. The pond weed, *Potamogeton* spp. is a large aquatic plant with leaves forming a floating mat on the surface of Albatross Lake I. It is not known from any other lake on Marion Island, nor from any other sub-Antarctic island.

Nine species of Entomostraca have been identified from standing waters on Marion Island. *Pseudoboeckella volucris* and *Daphinopsus studeri* dominate the zooplankton in most waters. Oligochaetes have been found in the sediments of one lake. In general, the diversity of species is limited and as no freshwater fish (except the very few surviving trout introduced into the Van den Boogaard River in the 1960s, see Section 4.4.2) occur, zooplankton occupy the top of the foodchain.

The close proximity to the ocean and the prevailing winds also influence these waters. Masses of sea salts are transported onto the Island through windswept spray and precipitation. Several factors influence the salt deposition (e.g. wind strength and direction, sea condition), which in turn controls the chemical composition of the freshwaters. Table 4.12 provides some data on the chemical properties of Marion Island's lakes and streams.

4.3.3.2 Running (lotic) waters

The running waters on Marion Island are mere rivulets or streams. No large, permanent waterways occur. Most of the rain water reaches the sea via underground drainage. The alien grasses, *Poa annua* and *Agrostis stolonifera* often dominate the fringing vegetation of streams, and are usually covered with dense growths of filamentous algae.

Brown Trout, *Salmo trutta* and Rainbow Trout, *S. gairdneri* were, unfortunately, introduced to the Van den Boogaard River in the early 1960s. A small dam wall was built across this stream in the mid-1970s. More recently, an attempt to develop a hydroelectric scheme on this river has resulted in substantial erosion and visual marring of this once beautiful stream valley (see Figure 4.6).

The lotic waters are generally acidic and vary widely in ionic content. The chemical composition is dominated by NaCl (sodium chloride) and the ionic dominance is the same as for seawater. The high rainfall and small volumes of the water bodies ensure short retention time. Geochemical modification is minimal, so that the general composition of the water is maintained, with less influence from animals and leached humic compounds than the lentic waters.

The very pure, nutrient poor (oligotrophic) and acidic nature of Marion Island's freshwater systems make them very sensitive to pollution by effluents, in particular by increases in pH from alkaline or calcareous sources.

TABLE 4.12 Chemical characteristics of water samples collected from lakes and streams on Marion Island. Results in mg l^{-1} except for conductivity (umho.cm^{-1}) and alkalinity (meq l^{-1}) (from Grobbelaar, 1974).

Parameter	Lakes	Streams
pH	5,99	6,63
conductivity	139,0	62,65
alkalinity	0,024	0,117
Na	19,7	9,24
K	0,79	0,53
Ca	0,89	0,62
Mg	2,58	1,37
Fe	0,11	0,01
Cl	45,9	17,33
SO_4	4,46	1,91
NO_3-N	0,04	0,0
NH_3-N	0,01	0,0
Tot-P_{diss}	0,0	0,0
Total major ions	74,38	31,00
Na/Na + Ca	0,95	0,94
O.O.N.	102,6	83,4

4.4 SPECIES OF SPECIAL INTEREST

4.4.1 Rare and/or Endemic Plant Species

Seven species of ferns and 17 species of flowering plants are considered to be indigenous to the Prince Edward Islands (Table 4.2). Only one of these, the small fern *Elaphoglossum randii*, is known only from the Prince Edward Islands. Several species occur only on the islands of the Kerguelen phytogeographical province (i.e. Prince Edwards, Crozets, Heard, Kerguelen). Two species are known only from Marion Island in the sub-Antarctic, but occur elsewhere in the Southern Hemisphere.

Elaphoglossum randii is rare but sporadically distributed on the lowland *Blechnum penna - marina* fern slopes of black lava flows. It occurs occasionally in Nellie Humps. Few populations were noted along the route of the proposed road in the Impact Area, but the fern is common on the slopes of the Tom, Dick and Harry scoria cones.

Polystichum marionense, endemic to the Prince Edward and Crozet Islands, occurs in isolated and rare populations in sinkholes and similar well protected sites in the lowlands. A few populations occur in Nellie Humps (Figure 4.23).

Colobanthus kerguelensis is known only from the Prince Edward Islands, the Crozet Islands and Kerguelen. This small, button plant is fairly widespread and common on the lowlands, especially as an epiphyte on *Azorella selago* cushions. It is possibly being reduced by aggressive competition from *Sagina apetala*, an alien weed of similar growth form.

Ranunculus moseleyi is a minute water plant, also known only from the Prince Edward Islands, the Crozet Islands and Kerguelen. It occurs in many of the Albatross Lakes and in small lakelets of the Nellie Humps black lava flow.

Pringlea antiscorbutica is restricted to the Kerguelen province. It occurs sporadically and widely over Marion Island, being common in sheltered, well drained sites in Nellie Humps and in the salt-spray zone. Unfortunately, it is presently under attack from the recently introduced Cabbage Moth *Plutella xylostella* (see Section 4.4.2).

Juncus effusus is known from only three isolated populations on Marion Island and nowhere else in the sub-Antarctic. It was first discovered on Marion Island at Trypot Beach (Figure 4.24) and later from two other sites - at Long Ridge and the Van den Boogaard River mouth. It is probable that this is an example of a species that arrived by natural means and is now slowly establishing itself on Marion Island.

Potamogeton sp. was discovered on Albatross Lake I in 1965 and despite thorough searches in all other water bodies, has not been found elsewhere on Marion Island. It is not known elsewhere in the sub-Antarctic and, in common with *Juncus effusus*, is possibly a recent natural immigrant. The distribution of these two species in the Impact Area is indicated in Figure 4.25.

Although a number of rare and endemic mosses, liverworts and lichens have been recorded on Marion Island, not enough is known about them to provide details of their distribution and rarity in the Impact Area.

The species listed above deserve special protection on Marion Island. Any disturbance of vegetation cover and/or hydrology, or the creation of pollution, should be sited away from populations of these species.

4.4.2 Alien Invasives

The problem of alien invasive plants and animals in isolated, species poor island ecosystems has been referred to in the introduction to this Chapter. On Marion Island, 15 species of weeds have been recorded (Table 4.3). Twelve of these were recorded within 100 m of the Base Station and of these, five have apparently not survived and are referred to as transient aliens.

In 1965 it was apparent that only three weeds were widespread on Marion - *Poa annua, Cerastuim fontanum* and *Stellaria media*. These species are still widespread, but do not appear to be competing with the indigenous vegetation. They occur sporadically in the Impact Area, usually on bare soil exposed either by burrowing birds, penguins or man. They are not considered a threat to the Island's natural communities.

Since 1965 three weeds, *Agrostis stolonifera, Sagina apetala* and *Poa pratensis* have spread widely from the vicinity of the Base Station and are aggressively competing with indigenous species.

- *Agrostis stolonifera* is a lax, stoloniferous grass of 20 to 30 cm height, which forms luxuriant swards on well drained lowland sites. It has spread most actively along the banks of the lower reaches of the Van den Boogaard River, along Trypot Stream and on the slopes of Macaroni Bay (Figure 4.26). It occurs in abundance on the margins of some of the Albatross Lakes. It has probably been dispersed by burrowing petrels and other birds, as well as by water transport along streams. Its ability to rapidly establish on bare surfaces, and to form a dense blanket over other slower growing species, accounts for its success. Although it serves to cover bare areas and probably reduces soil erosion and peat slipping, it is a potential threat to the survival of slower growing native species with similar resource requirements.

- *Sagina apetala* is a small, low growing cushion and mat forming herb with minute leaves (Figure 4.27). It is easily mistaken for *Azorella selago* by casual observers. In 1965 it was known only from a few small populations near the Base Station. In the 22 years since, it has spread over the moist peat surfaces of the wide area of disturbed land around the Base Station, along the salt-spray zone to Macaroni Bay, and sporadically inland. It appears to favour moist disturbed sites, especially those receiving slight manuring by animals, but is currently found on a wide range of bare substrata on the lowlands of the Impact Area. Its rapid spread has probably been assisted by the movement of researchers and others around the Island from the source area of the Base Station. It is clearly visible along the main footpaths leading away from the Station, but it is also dispersed by penguins, albatrosses and petrels.

- *Poa pratensis* is a grass of 20 to 30 cm height which is currently spreading rapidly within the *Poa/Acaena* mixed herbfields within the Impact Area, particularly on the slopes of the Macaroni Bay glacial moraines.

In common with *A. stolonifera*, *S. apetala* and *P. pratensis* owe their success to rapid establishment and growth, covering plants in their path by the development of a blanket over the slow growing indigenous species, which are thus smothered and die. Any disturbance created by man will add to the rapid spread of these aggressive aliens.

In addition to the 15 species already recorded from the Island, any major new development involving the transport of material and personnel to the Island increases the threat of the introduction of new invasive plant species. It is significant that since 1965, only one further alien has been recorded - a thistle which appears to have been introduced with the building sand brought to the Island to construct a hydroelectric turbine hut beside the Van den Boogaard River.

In addition to the alien plants noted above, 31 species of alien terrestrial animals have been recorded on Marion Island (Watkins & Cooper, 1986). Most of these have been very short-lived on the Island. The presence of sheep and chickens has been responsible for the introduction of some of the alien plant species, which were imported with the food and fodder for these animals.

Of the 18 species of alien invertebrates recorded, 14 are considered naturalized (Table 4.13). Larvae of the Diamond-back Moth, *Plutella xylostella* were first recorded at Marion Island in May 1986, feeding on the leaves and growing points of the Kerguelen Cabbage, *Pringlea antiscorbutica* causing extensive damage and stunted growth. This species was probably introduced with fresh cabbage supplies, since its present distribution is downwind from the Base Station.

TABLE 4.13 Animal species known or thought to be aliens recorded from Marion Island (from Watkins & Cooper, 1986).

Species	Common name	Present status
INVERTEBRATES		
Myro kerguelensis	spider	widespread, naturalized
M. paucispinosus	spider	widespread, naturalized
Limnophyes pusillus	chironomid midge	widespread, naturalized
Fannia canicularis	Lesser house fly	widespread, naturalized
Telmatoscopus albipunctatus	winged dipteran	widespread, naturalized
Pericoma sp.	winged dipteran	widespread, naturalized
Macrosiphum euphorbiae	hemipteran	widespread, naturalized
Rhopalosiphum padi	hemipteran	widespread, naturalized
Neomyzus circumflexus	hemipteran	widespread, naturalized
Brachycaudus helichrysi	hemipteran	widespread, naturalized
Heliothis armigera	American bollworm	transient
Agrostis ipsilon	Cutworm	transient
Blatella germanica	German cockroach	transient
Psychoda sp.?	latrinefly?	?
Scaptomyza sp.	Fruitfly	naturalized
unnamed	thrip species	naturalized
Plutella xylostella	Diamond-back moth	naturalized
Dendrobaena rubida	Earthworm	widespread, naturalized
FISH		
Salmo gairdneri	Rainbow trout	transient
S. trutta	Brown trout	naturalized
MAMMALS		
Mus musculus	House mouse	widespread, naturalized
Felis catus	Domestic cat	widespread, naturalized

Both Rainbow Trout, *Salmo gairdneri* and Brown Trout, *S. trutta* were deliberately introduced to Marion Island but it is probable that none survive.

The most devastating impact on the Island's fauna has been due to the introduction, in 1949, of Domestic Cats, *Felis catus*. The progeny of the first few cats rapidly spread around the Island and by 1973 the total population was estimated to number 1 500. The breeding population was estimated at 2 100 at the height of the 1975 summer season, when it was believed that they were annually killing some 450 000 burrowing petrels of seven species (Van Aarde, 1980). Following an intensive campaign to reduce the cat population, it is probable that they now number *c*. 800. Even at this number they kill over 100 000 birds per year (see Section 4.4.4.5).

House mice, *Mus musculus* are widespread and numerous on the Island. They feed principally on the larvae of the endemic flightless moth *Pringleophaga marioni*. It has been suggested (Crafford & Scholtz, pers. comm.) that mice might have exterminated the closely related flightless moth *Pringleophaga kerguelensis* from Marion Island (see Section 4.4.4.6).

The danger of introducing microorganisms, especially disease viruses, to the Island in foodstuffs, timber or other media must be recognized and subject to suitable precautions.

4.4.3 Birds

4.4.3.1 Introduction

Marion Island is well known for its bird life. Table 4.14 provides a list of the species as well as an estimate of their respective numbers in the Impact Area, on the whole Island and in the world.

All the birds are dependent on the sea for food and, except for the Kelp Gull, Gentoo Penguin, Giant Petrel and Lesser Sheathbill, leave the Island during the phase of their lifecycle spent at sea. For these birds the Island serves as a breeding platform. For the penguins it is also a moulting platform.

The existence of the rich bird life depends on their ability to breed and moult successfully. Marine birds are long-lived (a Wandering Albatross may reach an age of 50 - 60 years) and slow breeders. It should, therefore, be realized that the total failure of a species to breed for a number of years may take several years to detect in the absence of an intensive monitoring programme. Recovery is similarly very slow.

4.4.3.2 King Penguin - Koningspikkewyn *Aptenodytes patagonicus*

King Penguins have a strange breeding strategy which is poorly known, but may involve breeding twice in every three years or in alternate years. They are rather asynchronous, with egg laying in mid-November through to March. Probably most late eggs fail. Incubation period is 55 days; chick period is 10 to 13 months.

Marion Island is the second most important breeding locality in the world for this species, containing *c.* 30 % of the world population. Within the Impact Area a colony of about 1 500 pairs breed at Archway Bay. As with all penguins, moult occurs on land. However, it is spread through an extended period from September to March, with each bird taking about a month to moult. In addition to the Archway Bay colony (Figure 4.28), birds moult at Transvaal Cove (10's), Trypot Beach (1000+) and Macaroni Bay (100's).

4.4.3.3 Gentoo Penguin - Gentoopikkewyn *Pygoscelis papua*

Gentoo Penguins breed annually, but are very asynchronous and frequently make second attempts to rear a brood if the first fails. Laying commences in June with some clutches occurring as late as November. Incubation period is 37 days; chick period is 2 to 3 months.

The Marion Island population is insignificant in world terms (less than 1 %) and possibly rather marginal. Within the Impact Area about 25 % of the Island population is found. Breeding groups tend to move around to quite an extent from year to year and are rather vulnerable to disturbance. Normally, the breeding colonies are away from beaches, perhaps up to a kilometre inland (Figure 4.29). Moulting occurs in groups on beaches or near breeding sites. The birds are resident throughout the year.

4.4.3.4 Rockhopper Penguin - Geelkuifpikkewyn *Eudyptes chrysocome*

Egg laying occurs in early December. Incubation period is 33 days; chick period is 65 to 75 days.

The Marion Island population is about 4 % of the world total for this species (or subspecies by some authorities), and the Impact Area contains only a small fraction of the birds on the Island. They breed at colonies of 50 to 500 birds along the whole coast, from Cabbage Point (Transvaal Cove) to Hansen Point (East Cape), wherever suitable rocky areas occur. They moult after breeding and leave the Island for the period late May to early November.

TABLE 4.14 Number of breeding pairs of birds in the Impact Area compared to the total Island and world populations (from Hunter, pers. comm.).

Species	Number in Impact Area	% of MI Pop	Number in Island Pop	% of World Pop	Number in World Pop
King Penguin	1 500*	0,7	228 000*	30	750 000*
Gentoo Penguin	250	25	1 000	0,5	275 000
Rockhopper Penguin	*c.* 5 000	5	100 000	3,6	2 750 000
Macaroni Penguin	2 150	0,5	405 000	7,4	5 500 000
Wandering Albatross	122*	6,6	1 852*	9,0	20 600*
Sooty Albatross	103*	5,1	2 030*	10,2	*c.* 20 000*
Light-mantled Sooty Albatross	5*	2,8	176*	1,1	*c.* 16 000*
Northern Giant Petrel	60	18,8	320	3,7	8 600
Southern Giant Petrel	272	10,2	2 655	7,0	38 000
Salvin's Prion	est 1 000's	1,0	100 000's	10,0	1 000 000's
Blue Petrel	est 100's	1,0	10 000's	1,0	1 000 000's
Kerguelen Petrel	est 10's	1,0	1 000's	1,0	100 000's
Soft-plumaged Petrel	est 10's	1,0	1 000's	1,0	100 000's
Great-winged Petrel	est 100's	10,0	1 000's	1,0	100 000's
Grey Petrel	est 10's	10,0	100's	0,1	10 000's
White-chinned Petrel	est 100's	1,0	10 000's	1,0	1 000 000's
Imperial Cormorant	73	25,6	285+	1,1	25 000+
Kelp Gull	*c.* 25	12,5	200	2,0	10 000's
Sub-Antarctic (Brown) Skua	70	10.0	700	14,0	5 000+
Antarctic Tern	2	40,0	*c.* 5	0	50 000+
Kerguelen Tern	0	0	*c.* 20	4,0	maybe 500
Lesser Sheathbill	20	2,0	980	20,0	1 000's

*This represents the number of breeding pairs in one season though the species breeds in alternate years. The total number of pairs breeding in an area is approximately the annual total multiplied by 1,8.

4.4.3.5 Macaroni Penguin - Macaronipikkewyn *Eudyptes chrysolophys*

Breeding cycle: Incubation period is 35 days; chick period is 65 days.

Marion Island has 7,5 % of the world population, though this may be a slight underestimate. Less than 1 % of the Island population occurs in the Impact Area, mainly at Macaroni Bay. Moult occurs after breeding and the birds then leave the Island between May and October.

4.4.3.6 Wandering Albatross - Grootmalmok *Diomedia exulans*

Wandering Albatrosses are biennial breeders, with about 20 % of each demi-population breeding in consecutive years due to early failure. Egg laying occurs in late December and the first half of January. Incubation period is 78 days; chick period is 8 to 12 months.

Marion Island is the third most important breeding locality in the world for this species, with about 9 % of the world population occurring here. Of the Island population *c.* 7 % occurs within the Impact Area, spread out through the more open sites near the coast, particularly in the vicinity of the proposed ELS at Macaroni Bay, Albatross Lakes and East Cape (*c.* 85 pairs). The overall world population (including both demi-populations) is about 37 000 pairs and is thought to be declining at all major sites including Marion Island, though exact information on long-term trends is difficult to obtain because of the longevity and slow breeding of this species. Breeding birds leave the Island during their off-breeding year.

4.4.3.7 Sooty Albatross - Bruinmalmok *Phoebetria fusca*

Breeding cycle: Laying occurs in late October. They are probably biennial when breeding successfully. Incubation period is 70 days; chick period is 140 to 150 days.

About 10 % of the world population breeds on Marion Island and 5 % of the Island population breeds on the Macaroni Bay cliffs in the Impact Area. Birds are away from the Island from June to August.

4.4.3.8 Light-mantled Sooty Albatross - Swartkopmalmok *Phoebetria palpebrata*

Breeding cycle: Laying is in late October. Successful birds are probably biennial. Incubation period is 67 days; chick period is 135 to 150 days.

An insignificant proportion of the world population occurs at Marion Island, with only five pairs in the Impact Area. Birds leave the Island from June to September.

4.4.3.9 Northern Giant Petrel - Grootnellie *Macronectes halli*

Breeding cycle: Laying occurs in August. Incubation period is 60 days; chick period is males 114 days, females 110 days.

Nearly 4 % of the world population occurs on Marion Island, with about 20 % of the Island population being within the Impact Area. They tend to breed in small groups in amongst rocky outcrops providing nest shelter. There are concentrations in Nellie Humps, just north-west of the Fault, at Tom, Dick and Harry and throughout the Archway/East Cape region. The species is resident and feeds at seal beaches and penguin colonies. It may be declining along with the Elephant Seal population, but there is not yet enough long-term data to substantiate this.

4.4.3.10 Southern Giant Petrel - Reuse Nellie *Macronectes giganteus*

Breeding cycle: Egg laying occurs through September and early October. Incubation period is 61 days; chick period is males 123 days, females 117 days.

Seven percent of the world population occurs on Marion Island, 10 % of which are in the Impact Area. They breed in larger, more organized colonies than *M. halli* and generally in the open. Colonies occur in Nellie Humps, at the Fault, and through the Archway/East Cape region. Both species tend to move nesting sites from year to year, but generally no more than about 0,5 km. The species is resident all year and predominantly feeds off penguins.

4.4.3.11 Burrowing petrels

The following species of burrowing petrels are found within the Impact Area:
Salvin's Prion - Breëbekwalvisvoël *Pachyptila salvini*
Blue Petrel - Bloustormvoël *Halobaena caerulae*
Kerguelen Petrel - Kerguelense Stormvoël *Pterodroma brevirostris*
Soft-plumaged Petrel - Donsveerstormvoël *Pterodroma mollis*
Great-winged Petrel - Langvlerkstormvoël *Pterodroma macroptera*
Grey Petrel - Pediunker *Procellaria cinerea*
White-chinned Petrel - Bassiaan *Procellaria aequinoctialis*

All these species are dealt with together here. The breeding cycle parameters are shown in Table 4.15.

With the possible exception of the White-chinned Petrel, these burrowing petrels have suffered massive predation of feral cats and population decline as a result. The *Pterodroma* species and Grey Petrels are now reduced to remnant populations on Marion Island, none of which are of world importance. Insignificant numbers are likely to occur within the Impact Area, though exact counts are unavailable.

TABLE 4.15 Details of the breeding cycles of the species of burrowing petrel occurring in the Impact Area (from Hunter, pers. comm.).

Species	Laying Period	Incubation Period	Chick Period
Sàlvin's Prion	21 November	49 days	52 to 63 days
Blue Petrel	23 ± 2 October	49 ± 2 days	53 ± 2 days
Kerguelen Petrel	early October	49 days	61 days
Soft-plumaged Petrel	mid-December	50 days	91 days
Great-winged Petrel	late May	56 days	118 days
Grey Petrel	April	55 days	93 days
White-chinned Petrel	November	58 days	94 days

Salvin's Prions occur throughout Marion Island and the Impact Area at a reasonable density, but the population is now not important in world terms. Likewise, White-chinned Petrels are distributed through much of the coastal plain areas of Marion Island and the Impact Area contains a reasonable, but not significant, number.

Blue Petrels occur on the slopes above Macaroni Bay in two colonies, both of which are now reduced in numbers and not important in Island or world terms.

All these petrels leave the Island during the non-breeding season, though Salvin's Prions tend to visit the Island in large numbers on very misty days during the winter months.

If the present cat eradication programme is successful, then populations of these species would be expected to increase at a relatively slow but consistent rate. Marion Island might then become an important world station for some of these species, but there is no reason to think that the Impact Area will be of any particular significance out of proportion to its size.

4.4.3.12 Imperial Cormorant - Duiker *Phalacrocorax atriceps*

Breeding cycle: Laying is very variable and poorly documented. Birds with eggs can be found from June through to December. Some pairs possibly lay replacement clutches and without further data double brooding cannot be ruled out. Incubation period is 29 days; chick period is 75 to 80 days.

The estimate for Marion Island is almost certainly too low and is probably nearer 500 pairs, or about 2 % of the world population, though this depends on the exact taxonomic position of the Marion Island birds in the *P. atriceps* - *P. albiventer* species complex. Even taking the higher estimate of 500 pairs, a significant proportion (*c.* 15 %) of the Island population occurs in the Impact Area. Although the species is colonial, actual breeding sites vary from year to year between a number of traditional localities.

Certainly, in some years the number of breeding pairs in the Impact Area is higher than the 73 pairs counted in the 1986/87 breeding season. The birds are resident and, in addition to breeding colonies, a number of loafing sites for non-breeders occur within the Impact Area.

4.4.3.13 Kelp Gull - Swartrugmeeu *Larus dominicanus*

Breeding cycle: Laying occurs in late November and December. Incubation period is 28 days; chick period is 56 days.

The Marion Island population represents about 2 % of the world population, though this is almost certainly an overestimate of their significance. The Impact Area contains about 12 % of the Island population, made up of one colony of about 8 pairs at the Fault and single breeding pairs distributed all along the coast between the Base Station and East Cape. The species is regarded as non-migratory and is the only one for which there are good estimates of the overall (not just breeding) population from winter censuses carried out in the last three years. This shows that the total population is 600 to 800 birds, of which 25 % occur within the Impact Area. A considerable number of non-breeding gulls also live in the Impact Area, where they predominantly feed on terrestrial invertebrates. A night roost of *c.* 100 birds occurs at Albatross Lakes.

4.4.3.14 Sub-Antarctic (Brown) Skua - Bruinroofmeeu *Catharacta lonnbergi*

Breeding cycle: Laying occurs between late October and mid-December with occasional replacement clutches. Actual laying date is closely related to the laying dates of the nearest penguin colonies. Incubation period is 29 days; chick period is 50 to 65 days.

The world population total is not known, but is probably of the order of 5 000 pairs and the Marion population would be 15 % of this total, 10 % of which occur within the Impact Area. In addition to breeding pairs, there is a non-breeding 'club' at Albatross Lakes containing 80 to 100 birds. The Impact Area contains three trios - about 20 % of those found on the Island. The composition and significance of these co-operative breeding units, or trios, is unknown, as is any long-term trend in their numbers.

4.4.3.15 Antarctic Tern - Grysborssterretjie *Sterna vittata*

Breeding cycle: Laying probably occurs in December to January. Incubation period is unknown, possibly 30 days; chick period is unknown, possibly 25 days.

The Marion Island breeding population seems close to extinction, possibly due to cat predation and is of no importance in a world context. The Impact Area is one of only two areas where the species now definitely breeds on the Island. They are summer visitors.

4.4.3.16 Kerguelen Tern - Kerguelensesterretjie *Sterna virgata*

Breeding cycle: Laying probably occurs in October/November. Incubation period is unknown, possibly 30 days; chick period is unknown, possibly 25 days.

The Marion Island breeding population seems close to extinction, possibly due to cat predation. World population total is unknown, but probably of the order of hundreds of pairs rather than thousands. This is one of the world's rarest terns. Probably no pairs nest in the Impact Area, but actual nest sites on the Island are not known. This species is resident.

4.4.3.17 Lesser Sheathbill - *Chionis minor*

Breeding cycle: Laying occurs during December. Incubation period is 28 to 33 days; chick period is 50 to 60 days.

Marion Island is one of the main breeding stations for this species. They mainly occur territorially in penguin colonies. The Impact Area contains relatively few, and they are resident all year round. Unlike all other species of birds on the Island, the Lesser Sheathbill does not have webbed feet indicating that it is a truly terrestrial (land) bird rather than a seabird. For this reason its protection from introduced land predators (e.g. cats) is even more important.

4.4.4 Mammals

4.4.4.1 Introduction

The marine mammal fauna of Marion Island comprises one species of elephant seal, two species of fur seals and the killer whale. Baleen whales (eg the Southern Right Whale, *Eubalaena australis*) and other species of Antarctic seals (eg the Leopard Seal, *Hydrurga leptonyx*) have occasionally been sighted.

The terrestrial mammal fauna presently comprises only two species, the House Mouse, *Mus musculus* and the feral Domestic Cat, *Felis catus*, both of which have been introduced by man. Other man-introduced terrestrial mammals present at one time or another since 1948 include domestic sheep, dogs, pigs, goats and donkeys.

The marine mammals are dependent on the sea for food. The Island serves basically as a platform in the ocean upon which they breed, suckle their young, mate, moult and rest. With the exception of certain segments of the population they leave the Island for periodic, pelagic feeding phases in their life cycles, with the result that during the winter season the numbers present are greatly reduced compared with the summer season. As in the case of the birds, the marine mammals are most sensitive to disturbance by man during the main terrestrial phases (ie breeding and moulting) of their life cycles, mainly because they are unable to leave the Island during these critical phases without endangering themselves or their suckling offspring.

4.4.4.2 Southern Elephant Seal - Suidelike Olifantrob *Mirounga leonina*

The Marion Island Elephant Seal population has been in a state of decline since about the mid-1960s. The reasons for this decline, a trend also being displayed at other sub-Antarctic islands, are unknown. The total Marion Island population calculated from pup production for the 1986/87 season is approximately 2 500, down from an estimated 12 000 in the late 1950s to mid-1960s.

Current breeding and moulting season data relating to the Impact Area were only available for the months September 1986 to February 1987, and comments will be limited to these months. The whole Marion Island population has, in fact, been monitored constantly since the early 1970s, thus making it possible to accurately extrapolate from the current season's data for the Impact Area only.

The Elephant Seals, due to their shape, size and anatomy, tend to be confined to the leeward side of Marion Island where the beaches are comprised of small, rounded pebbles and stones, and slope gently upwards from the sea. On the windward side of the Island, continually pounded by heavy seas, the coastline is very much more broken and rugged and is impossible for elephant seals to negotiate.

Five Elephant Seal beaches occur in the Impact Area. These are Boulder Beach in Transvaal Cove, Trypot Beach, the beaches at the northern and southern ends of Macaroni Bay, and the beach at Archway Bay. Figure 4.30 illustrates the number of animals seen on each of these beaches during the months September 1986 to February 1987 as a percentage of the total population hauled out on Marion Island during these months. Figure 4.31 illustrates the approximate percentage of total numbers frequenting the Impact Area, and which are hauled out each month of this period on each of the five beaches in the Impact Area, thus also indicating the relative importance of each beach to the Impact Area population during this period.

The annual cycle of various segments of the Elephant Seal population, with specific reference to the Impact Area, is shown in Figure 4.32. This indicates that there are Elephant Seals on these beaches all year round. The breeding season is from mid-August to late November (adult males and females), and the moulting season is from November to early March for younger animals (sub-adults and yearlings) and from mid-December to early April for the adults. There is an important difference in the nature of beach use between the breeding and moulting season - during the breeding season the adults and their young are congregated in closely packed aggregations (harems) on the actual beaches from just above the surf zone, whereas in the moulting season the adults and sub-adults tend to scatter further inland into the vegetated, peaty moulting areas, using the beaches as the principal access zones, or 'corridors', between the sea and these moulting areas. During the autumn and winter seasons those animals present tend to remain on the beaches.

During the 1986 breeding season a total of 706 pups were born on Marion Island, of which 135 (19,2 %) were born in the Impact Area. Trypot and Archway Bay beaches were the two most important breeding beaches in this area, each having 59 pups (8,4 % of total Island pup production) born on them, with Macaroni Bay south beach having 17 pups (2,4 % of total production) born on it. Trypot and Archway Bay beaches are the two most important Elephant Seal breeding beaches on the entire Island. These two, plus the other three beaches in the Impact Area, along with the beach at Ship's Cove to the north of the Base Station and outside the Impact Area, comprise the main Prince Edward Islands Elephant Seal monitoring area. Monitoring and tagging of the population in this area commenced in 1973 and has been continued uninterrupted since then.

Of the five beaches in the Impact Area, Transvaal Cove is now the only one on which regular breeding no longer occurs, probably on account of disturbance from the nearby Base Station. It is, however, still used as a corridor to a reasonably important inland moulting site, used by adults and sub-adults from about November to March (see Figure 4.31). On the other hand, the north and south beaches of Macaroni Bay are important breeding beaches but, due to the high, steep cliffs immediately at the back of the beaches, do not provide access to inland moulting areas and are, therefore, not important moulting season corridors.

4.4.4.3 Southern Fur Seals - Pelsrob *Arctocephalus* spp.

Two species of Southern Fur Seal occur on the Island, the Subantarctic Fur Seal, *Arctocephalus tropicalis* and the Antarctic Fur Seal, *Arctocephalus gazella*. The former is very much more abundant than the latter, but the fact that they both breed and moult regularly on both Marion and Prince Edward Islands, and also even interbreed, is unique since this situation is not known to occur anywhere else in the world with respect to these two species.

The shape, size and anatomy of fur seals enables them to walk, climb and leap between or over large obstacles such as boulders and rough terrain in general. For this and possibly other reasons (e.g. thermoregulatory physiology), the fur seals at the Prince Edward Islands occur mainly on the more broken and rugged windward coasts of both Islands. However, the population of *A. tropicalis* is increasing rapidly at both Islands, with the result that in recent years more and more are starting to inhabit the leeward coastlines where they occur together with the Elephant Seals, and it is likely that this trend will continue. Presently most new fur seal rookeries on the leeward coast of Marion

Island are small and non-breeding, being mainly loafing and moulting rookeries comprised primarily of sub-adults and juveniles. However, as these individuals mature they may commence to breed at these sites.

Small rookeries as described above now regularly occur at four of the five Impact Area beaches, the exception being Transvaal Cove. A total of seven *A. tropicalis* pups were born in the Impact Area in the 1986 breeding season (Nov/Dec), this representing considerably less than 1 % of the total Island pup crop.

Fur seals in these new Impact Area rookeries tend to occupy the vegetated slopes behind and to the sides of beaches. Loafing animals of the sub-adult and juvenile age classes are present all year round, though fewer in number during the winter season.

4.4.4.4 Killer Whale - Moordwalvis *Orcinus orca*

Killer Whales are regular summer visitors to the Island, occurring most frequently in the months of November, December and February. They tend to cruise back and forth along the Island's coastline, particularly the calmer leeward coast, from a few metres to a few kilometres offshore. The band of Kelp, *Macrocystis pyrifera* that occurs prominently along the leeward coastline is no barrier to these animals. They have been seen taking King and Macaroni Penguins and it is likely that they take Elephant Seals and possibly also Fur Seals. A few small sheltered coves to the north and south of the Base Station are known to be frequently used as resting or loafing places, where it is possible to observe them from a range of a few metres.

During the regular annual relief of the Base Station in April/May, when cargo is transferred between ship and Base Station across about 1,5 km of water immediately off Transvaal Cove by towed, inflatable rafts, Killer Whales have been known to surface or swim alongside the raft or motor boat. On occasion they have even rubbed against the cargo raft when it is tied-up against the coastal cliff (Gunners' Point) beneath the cargo hoist on the Island. No damage to or interference with man or equipment has yet been recorded.

4.4.4.5 Feral Cat - Wilde Huiskat *Felis catus*

This species of terrestrial mammal has already been mentioned in Section 4.4.2 of this Chapter. The first few cats taken to the Island were taken there as pets and as an anti-mice measure. By August 1949 there were five Domestic Cats at the Base Station. Offspring of this founder group turned wild, and by 1951 the first feral (wild) cat was observed about 12 km west of the Base Station. By 1973 the population comprised about 1 500 free-ranging cats. In 1975 the breeding population was estimated to be about 2 100, with a population density of 13,8 cats/km² in the coastal regions of the Island. In 1977, when the breeding population was estimated at about 3 400, the first control measure was taken. This entailed introducing the infectious viral disease feline panleucopaenia, following two years of intensive research on this approach to cat control. This action resulted in a decline in the cat population to around 650 cats by 1982.

In the 1986/87 season a further control measure, in the form of a 16-man team of hunters, was introduced as part of a campaign over three consecutive seasons to eliminate or greatly reduce the population. This campaign is due to continue, during the summer months only, through the 1987/88 and 1988/89 seasons.

Recent studies on the cat population have indicated that the diet of cats has changed between 1975 and 1982, with the incidence of mice remains in cat stomach contents increasing and the incidence of petrel remains decreasing. It is thought that this change reflects a change in the relative abundance of petrels, and that the decreased abundance of petrels has, in turn, led to increased predation on penguins by Skuas.

4.4.4.6 House Mouse - Huismuis *Mus musculus*

The House Mouse appears to have been introduced onto Marion Island by sealers and/or shipwrecks, sometime in the 1800s. It is thought that they were already present in 1873 (Moseley, 1879). Several separate introductions may have taken place. Berry et al. (1978) found that the mice on Marion Island possessed certain genetic traits also found in *M. musculus* from the Faroe Islands and the Scandinavian countries, while Robinson (1978) found that female Marion Island mice possessed a genetic trait previously only found in *M. musculus* from southern Europe. Whatever the source populations, the species is well established on Marion Island below 450 m a.s.l.

Their density varies according to habitat, highest densities being found along the coast at places that are biotically influenced by penguins and seals. They are opportunistic omnivores, tending to feed mainly on invertebrates but also on plant material in the summer months.

The proposed ELS facility is unlikely to have any effect on the mice. However, their long period of presence on the Island (100 to 150 years) will have enabled evolutionary adaption to the local environment. This has two important implications, as follows:

- The population is likely to be scientifically interesting in terms of its genetic make up, as well as in terms of the behaviour and physiology of growth, reproduction, respiration and thermoregulation. Introductions of new genetic material from the mainland should, therefore, be avoided.

- Because of its adaption to the environment on Marion Island, mice from this Island would be equally well adapted to the environment on neighbouring Prince Edward Island, where mice have not yet been found. Thus, it is essential that they are not transferred to Prince Edward Island, where they would be able to easily and quickly colonize.

4.4.5 Invertebrates

Within the terrestrial invertebrates, only the insects have been studied in any detail, although preliminary surveys have been conducted on the spiders, earthworms and molluscs. Marine invertebrates have received more detailed study, at both community and population levels.

The insect fauna comprises 26 species, six of these are endemic to the Prince Edward Islands and 11 to the sub-Antarctic. The remainder are of cosmopolitan distribution and are possibly naturalized aliens. The insect larva are important agents in the decomposition of plant material and the release of nutrients in the highly oligotrophic peats and soils of Marion Island. They also form an important winter food source for Gulls, Skuas and Sheathbills, and are important in the diet of the alien House Mouse. It has been suggested (Crafford & Scholtz, in press) that the absence of the flightless moth, *Pringleophaga kerguelensis* from Marion Island could be due to size-selective predation of the larvae of this species by mice.

4.5 SITES OF SPECIAL SCIENTIFIC INTEREST

4.5.1 Rare or Sensitive Communities

The Impact Area includes examples of all the major lowland plant communities of Marion Island. Insufficient detailed information is available on the distribution of minor bryophyte communities to determine whether any unique moss or hepatic associations are restricted to the area.

The grey lavas of the Impact Area include a group of large lakes which are only replicated by those at Skua Ridge. The lake fauna and flora, and the lake-shore communities which are occupied by Skua and Kelp Gulls which forage for invertebrates in the moss mats, are of special interest.

4.5.2 Rare or Sensitive Species Distributions

The Antarctic Tern, *Sterna vittata* is known to breed at only two localities on Marion Island, one of these (of perhaps two pairs) being the grey lava fjaeldmark immediately east of Tom, Dick and Harry. The site will be crossed by the access road to the ELS and is within 100 m of the proposed parking area (See Figure 4.25).

Approximately 15 % of the Island's breeding population of the Imperial Cormorant, *Phalacrocorax atriceps* nest along the rocky cliff faces of the Impact Area. The species is very sensitive to human disturbance and any increase in the number of people visiting the colonies could cause a rapid decline in breeding success.

The Gentoo Penguin, *Pygoscelis papua* is very easily frightened by humans, even at a distance of several dozen metres. The colony at Gentoo Lake vacated the area soon after the establishment of the Base Station. The colonies inland of Trypot Beach and Archway Bay should be left totally undisturbed.

Juncus effusus is known only from three localities on Marion Island. It was first discovered at Trypot Beach.

Potamogeton sp. is known only from Albatross Lake I. It is considered a recent, natural immigrant to the Island.

Elaphoglossum randii is a very rare endemic. The best population of this fern, within the Impact Area, occurs on the northern slopes of Tom, Dick and Harry.

The Southern Elephant Seal, *Mirounga leonina* population on Marion and Prince Edward Islands has declined rapidly since the late 1960s. The beaches at Trypot Beach and Archway Bay are now the two most important breeding beaches on Marion Island.

4.5.3 Geological Features

Tom, Dick and Harry are a radial series of six small volcanic cinder vents, or scoria cones, which form a prominent landmark in the Impact Area. Although there are about 200 scoria cones on the Island, the Tom, Dick and Harry sequence is unique both in size and disposition (Figure 4.33).

They constitute the best example of a fissure eruption on Marion Island. They clearly show that fire-fountaining along a newly opened fissure is restricted to discrete vents and may end without accompanying lava flows. The nature of the volcanic ejecta at this particular locality shows the effects of water/magma interaction, leading to the conclusion that a marsh existed here during the eruption. Although it is probably not unique in the world, it may be doubted whether an equally instructive example of this particular type of volcanic activity exists on any other island within such easy access to scientists. It should, therefore, be protected as a natural volcanological entity.

The Trypot Fault, a sharply incised grey lava fault between the Albatross horst and Trypot graben, forms a prominent feature on the east coast (Figure 4.34). The deep peats of Albatross Lake I drain across the Fault, and quarrying of this Fault could lead to severe peat-slipping and erosion.

4.5.4 Palaeo-Ecological Features

The first peat cores for the palynological analysis of the Island's palaeo-history were collected in the Impact Area. These sites provide the best evidence of vegetation change on the Island over the past 15 000 years.

The peat core from Nellie Humps provided a profile of 4 500 years and demonstrated the nature of vegetation succession and change in these relatively young black lavas. The Macaroni Bay peat coring sites provided a longer time series of pollen samples, of at least 10 000 years and possibly 15 000 years duration. Debate over the interpretation of the deeper samples is unresolved and further samples need to be collected from the deepest peats in the Macaroni Bay mires.

Controversy exists over the origin and age of certain deposits (Macaroni Bay Palaeosols) in the Macaroni Bay sediment profile. The further analysis and interpretation of these deposits can lead to an improved understanding of the Island's evolution and of climatic change in the Southern Hemisphere over the past 15 000 years.

4.5.5 Historical Features

Marion Island is not richly endowed with historic artefacts, but those recorded from the Impact Area and described in a review paper by Cooper & Avery (1986), are noted here.

Marsh (1948) records sealers' remains from Transvaal Cove, but all traces have now been masked by the Base Station which occupies the site. The brass Marion Island annexation plaque, bearing the inscription "H.M.S.A.S. Transvaal, 29.12.1947" has been recently remounted on a concrete plinth next to the Base Station. The Deed of Sovereignty was placed in a brass cylinder made from a 40 mm Bofors cartridge-case and buried in "a disused penguin burrow" at the foot of the original cairn on Cabbage Point, on which the plaque was placed (Marsh, 1948). The entrance to the burrow (presumably that of a burrowing petrel) was sealed with heavy stones (Marsh, 1948). It is uncertain what became of this cylinder and its contents.

Approximately 0,5 km south of the Base Station a wooden cross marks the grave of Joseph Daniels, a seaman of the S.S. Gamtoos, who drowned on 29 January 1948 while off-loading material for the construction of the Base Station (Marsh, 1948; Crawford, 1982). Apparently this cross has been blown out and replaced several times. A second cross, without inscription, is situated *c.* 50 m south of the Base Station and dates from after annexation. It could possibly commemorate a man who drowned in Transvaal Bay on 13 April 1963 (Roets, 1963).

Somewhere inland from Transvaal Cove at least four cartridges of German manufacture were found in early 1948. At least one was of .45 calibre and bore the inscription "H Utendoerffer, Nurnburg" (Marsh 1948).

Trypot Beach is one of the best known sealers' sites on Marion Island. Uncertainty exists as to whether the trypot now found here is the original trypot or the one recently removed from the cave in Cave Bay on Prince Edward Island. Hut foundations and sealers' artefacts are to be found at the back of the beach.

4.5.6 Long-Term Research and Monitoring Sites

Scientific research programmes have been conducted on Marion Island since 1965, while detailed meteorological observations go back to 1948. Most of these scientific activities have been undertaken close to the Base Station and the majority of sites of ongoing long-term research and monitoring projects fall within the Impact Area. The position of such activities is indicated in Figure 4.35.

Avifaunal studies: Within the Impact Area a number of study colonies are being used for long-term monitoring. These include a Wandering Albatross colony above Macaroni Bay, two Macaroni Penguin colonies sited at Macaroni and Archway Bays, two Rockhopper Penguin colonies at Trypot Beach and just north of the Fault. Work at these colonies involves the monitoring of laying, hatching and fledging success and, in the case of the Wandering Albatross, a detailed study of breeding pairs and nest site variation. Variation in feeding and growth parameters in some or all of these species will be studied from 1988. On a less formalized basis, studies of both species of Giant Petrels between the Fault and Skua Ridge, and annual chick counts at the Archway Bay King Penguin colony, are being undertaken. Future projects might include detailed studies on King and Gentoo Penguins, Wandering Albatrosses, Kelp Gulls and Imperial Cormorants, with the colonies accessible from the Base Station being used. Loss or disturbance of such colonies within the Impact Area would obviously affect the feasibility of these projects. In the past, laboratory studies have often relied on using birds from close to the Base Station, and future physiological and energetics work will be dependent on these populations.

Elephant Seal studies: All beaches along the north-east coast of the Island (from Ship's Cove to Archway Bay) are included in the long-term monitoring of the trend in number of Elephant Seals. Annual counts of Elephant and Fur Seals have been made in this area for the past 14 years and are planned to continue indefinitely. Trypot Beach currently serves as the site for a three year (1986 to 1989) project on reproductive success and effort in Elephant Seals. Fieldwork on this project focuses on monitoring the effect of mating (timing, order and sequence) on reproductive success. Cows specially marked during the 1986 breeding season will thus be monitored in detail until 1989 and, hopefully, in the longer term to determine lifetime production.

Geomagnetic observations: From 1972 to 1982 geomagnetic variations were recorded continuously on Marion Island. Since 1982 geomagnetic observations have been made biennially during the relief cruises of the SA Agulhas. These observations were made at a specially selected geomagnetic observation site, situated on a ridge approximately 450 m south-west of the main Base Station buildings, where two non-magnetic huts were erected in 1972. It is likely that continuous recording of geomagnetic variations will again be made on Marion Island in the future, during international cooperative projects. Such observations will be for a limited duration (up to two years) and would most likely be made in the vicinity of the present non-magnetic huts.

Meteorological observations: The wide diversity of synoptic meteorological observations made at Marion Island continuously since 1948 are conducted from a number of sites in the immediate vicinity of the Base Station. These will continue indefinitely, and already represent a very valuable data set.

4.6 REFERENCES AND SELECTED BIBLIOGRAPHY

Research on the Prince Edward Islands has resulted in the publication of over 200 scientific papers in the open literature. Some of the more important information sources used in compiling this Chapter are listed in the List of References and Selected Bibliography later in this report.

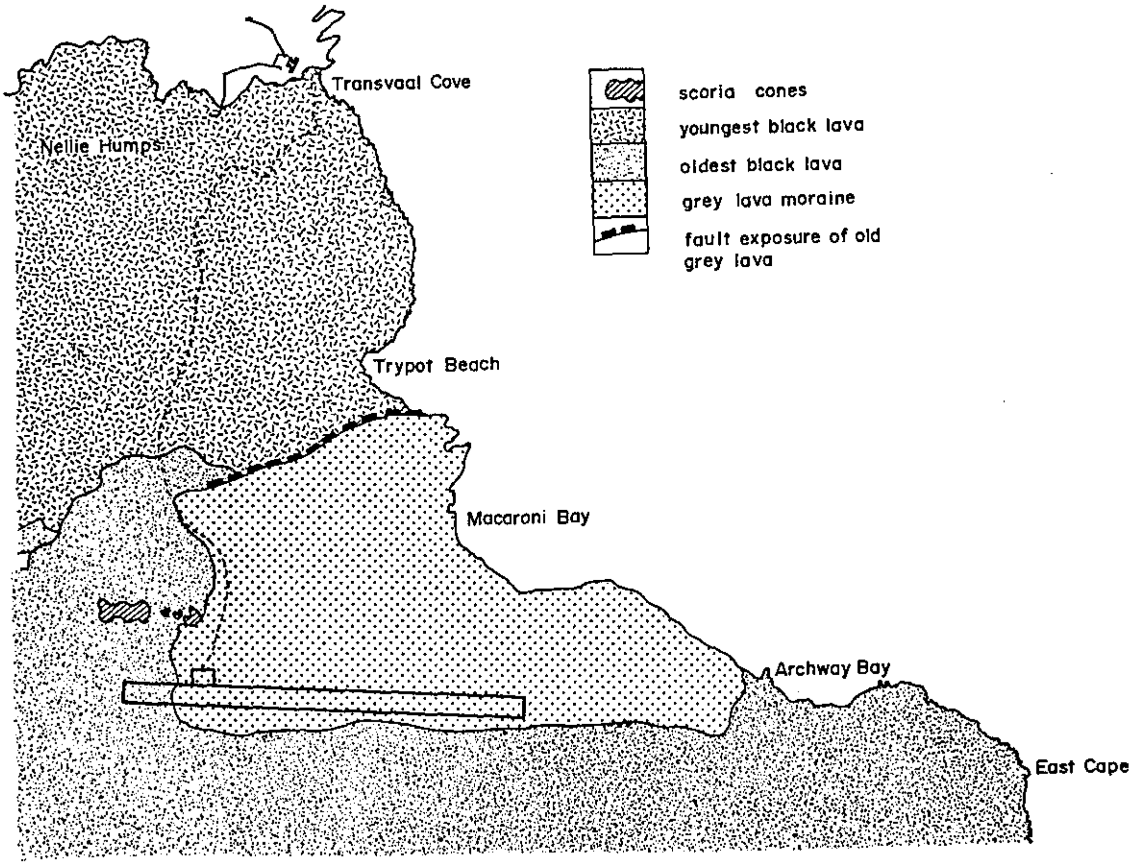


FIGURE 4.1 Simplified geological map of the Impact Area.

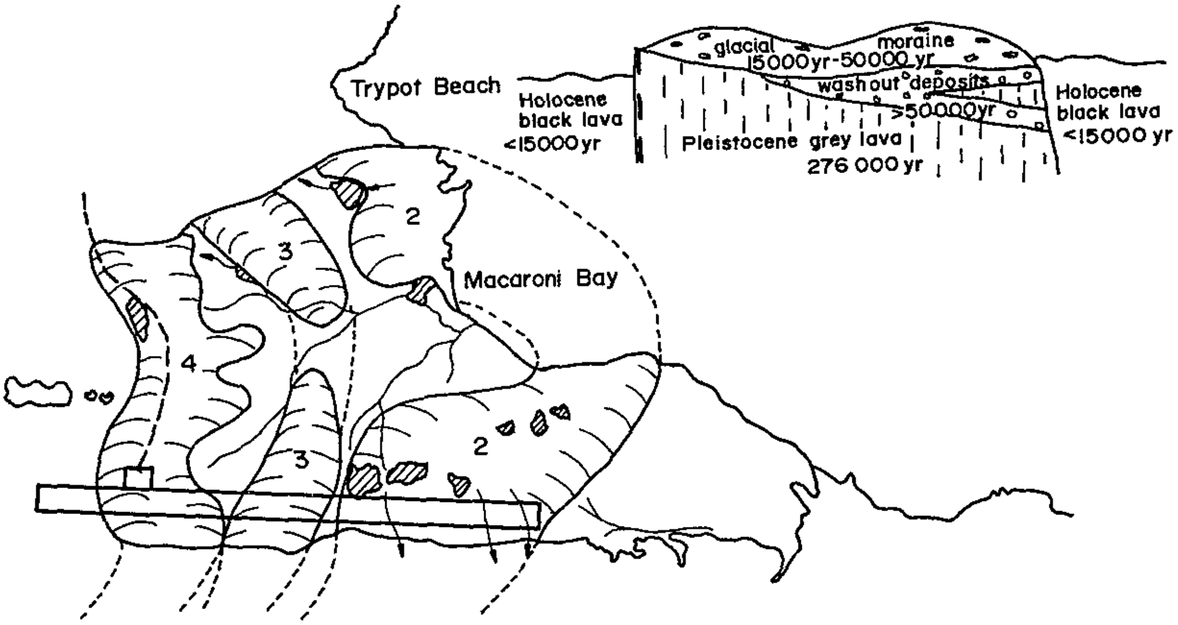


FIGURE 4.2 Sketch map of the Albatross Lakes area indicating the position of moraines 2, 3 and 4 (after Hall, 1978) and the stratigraphic sequence of lava flows and moraines (Chevallier, pers. comm.).

FIGURE 4.3 Coastline south of Trypot Beach. The Fault exposes 276 000 yr Pleistocene grey lavas, capped by grey lava glacial moraines of 15 000 to 50 000 yr. To the north of the Fault, black lavas of the post-glacial (Holocene) period are crossed by Trypot Stream. Note slip scars on slopes inland of Albatross Lake I.

FIGURE 4.5 Contact zone between roots of *Blechnum* fern slope peat and an iron pan. A gelatinous layer forming on this surface provides a lubricated surface conducive to peat slipping.

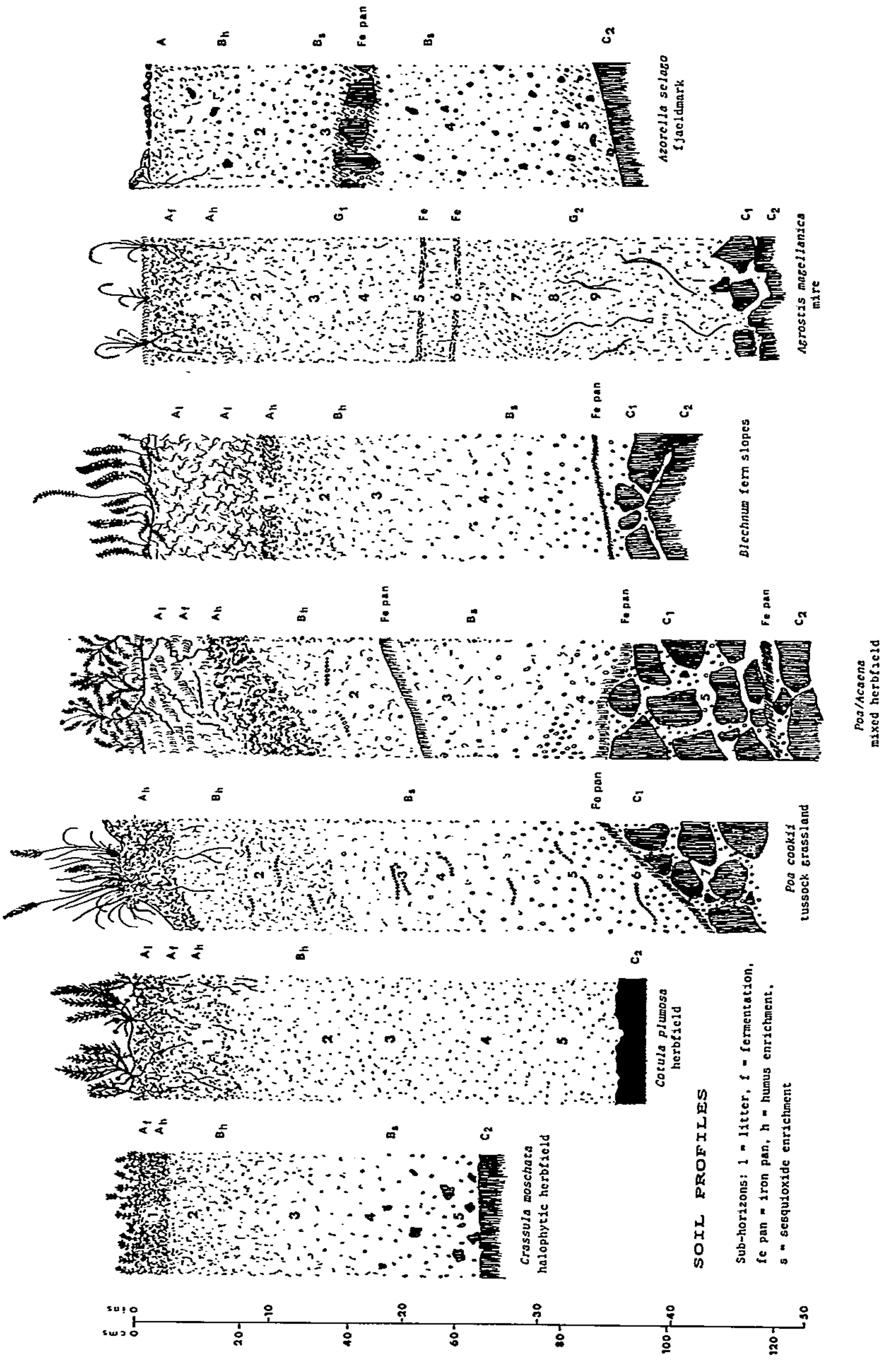


FIGURE 4.4 Soil profiles of the main vegetation types of the Impact Area (from Huntley, 1971).

FIGURE 4.6 Peat and soil slip in *Poa-Acaena* mixed herbfield below the hydroelectric dam on the Van den Boogaard River.

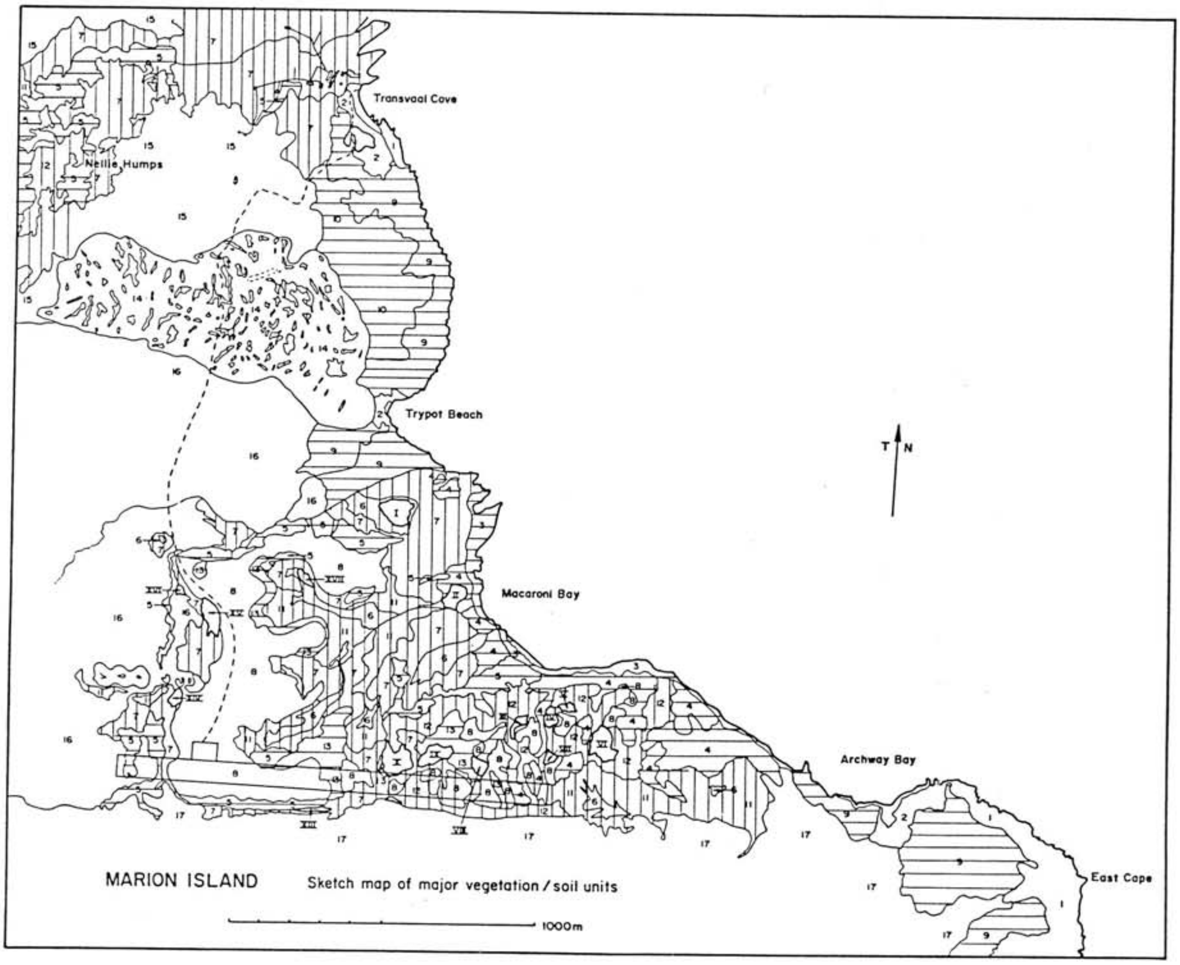


FIGURE 4.7 Distribution of soil slip risk classes in the Impact Area. Horizontal bars = high risk; vertical bars = low risk

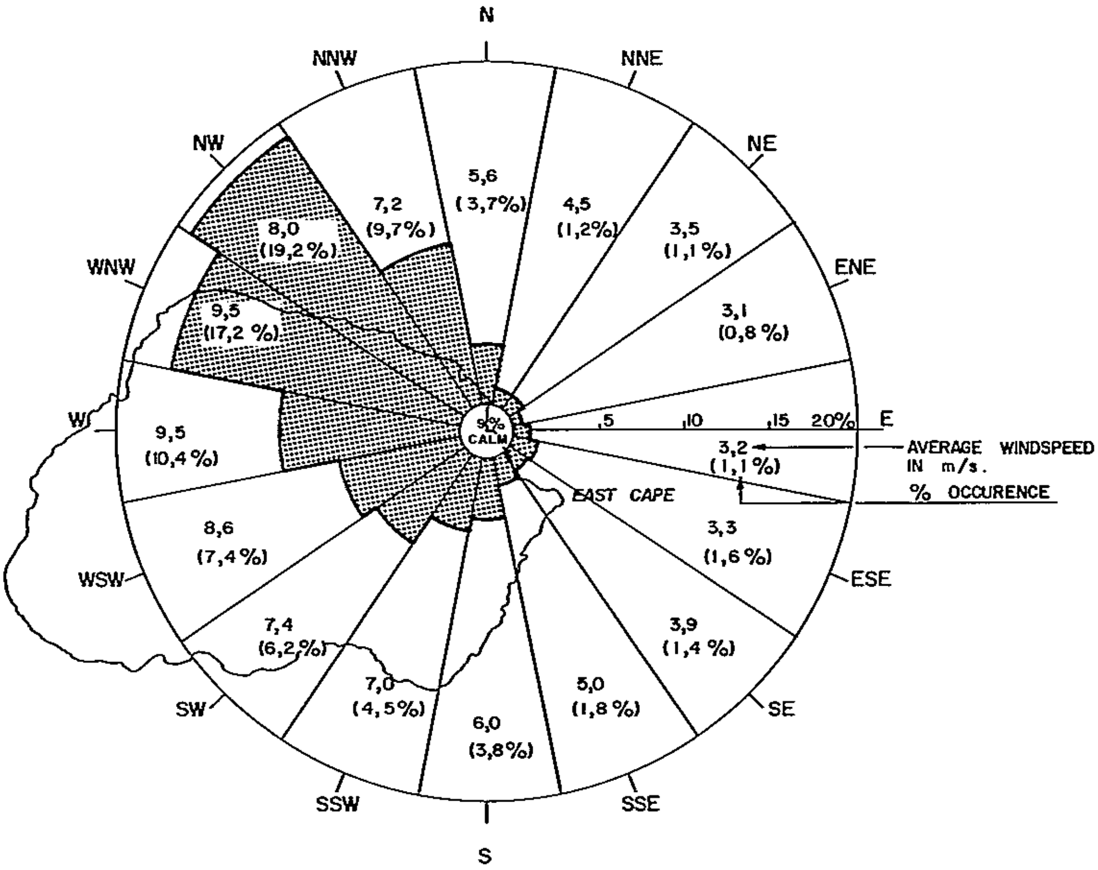


FIGURE 4.8 Wind direction frequency at the Base Station, Marion Island (data from SA Weather Bureau).

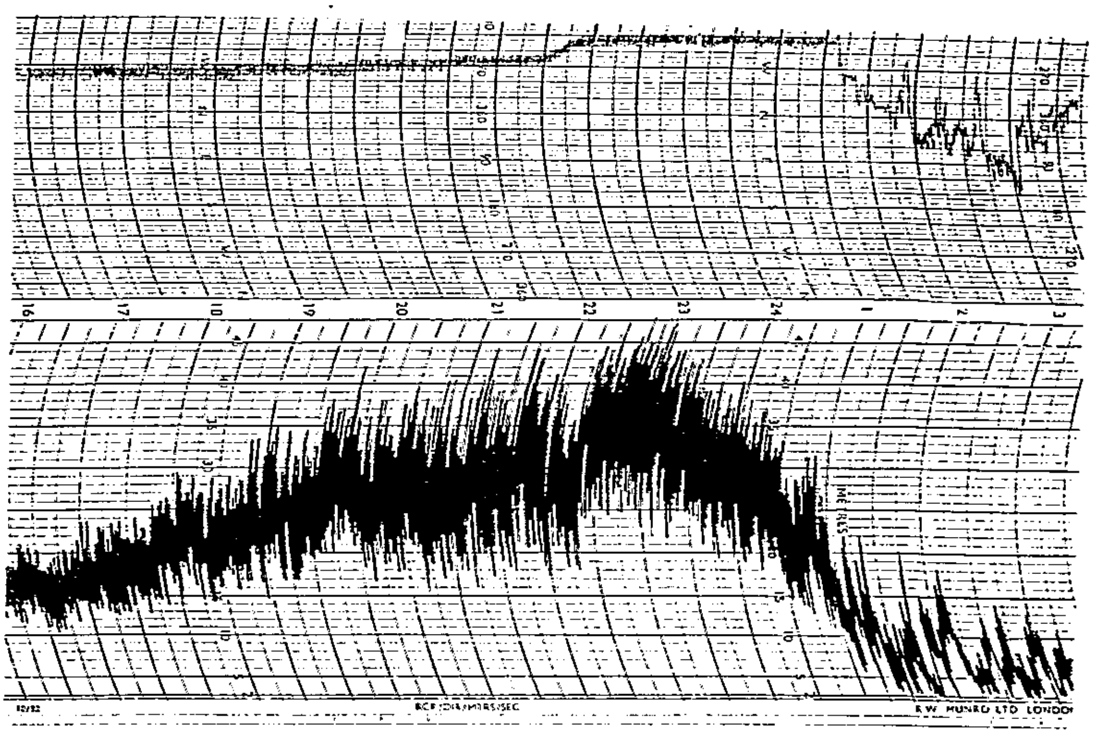


FIGURE 4.9 Wind trace recorded at the Base Station, Marion Island, 13/14 February 1987. Note gusts of up to 170 km h^{-1} and rapid directional change with gale-force gusting after passage of front.

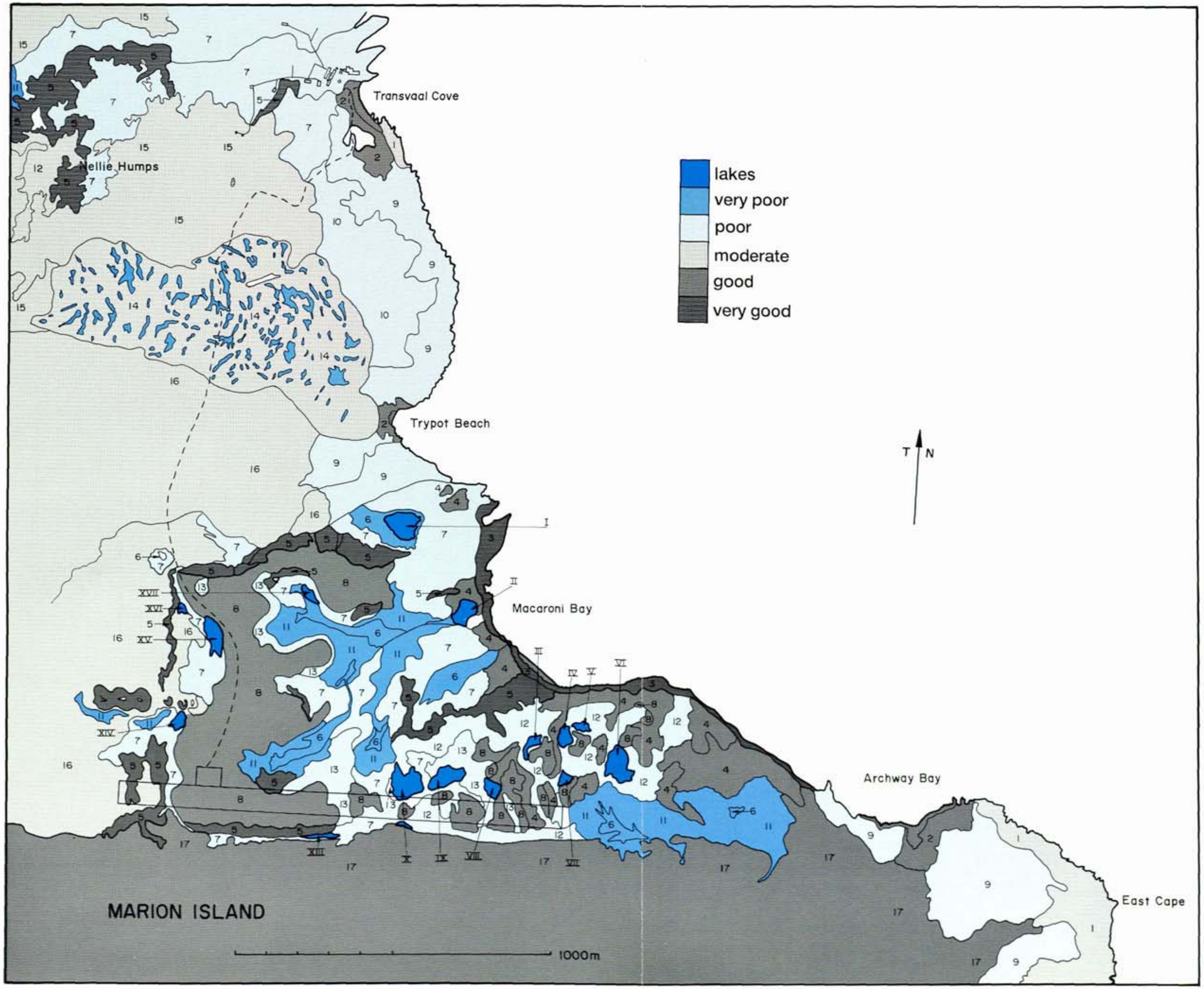


FIGURE 4.10 Soil drainage classes in the Impact Area (Numbers refer to the vegetation units given in Section 4.3.2.1 and Figure 4.12).

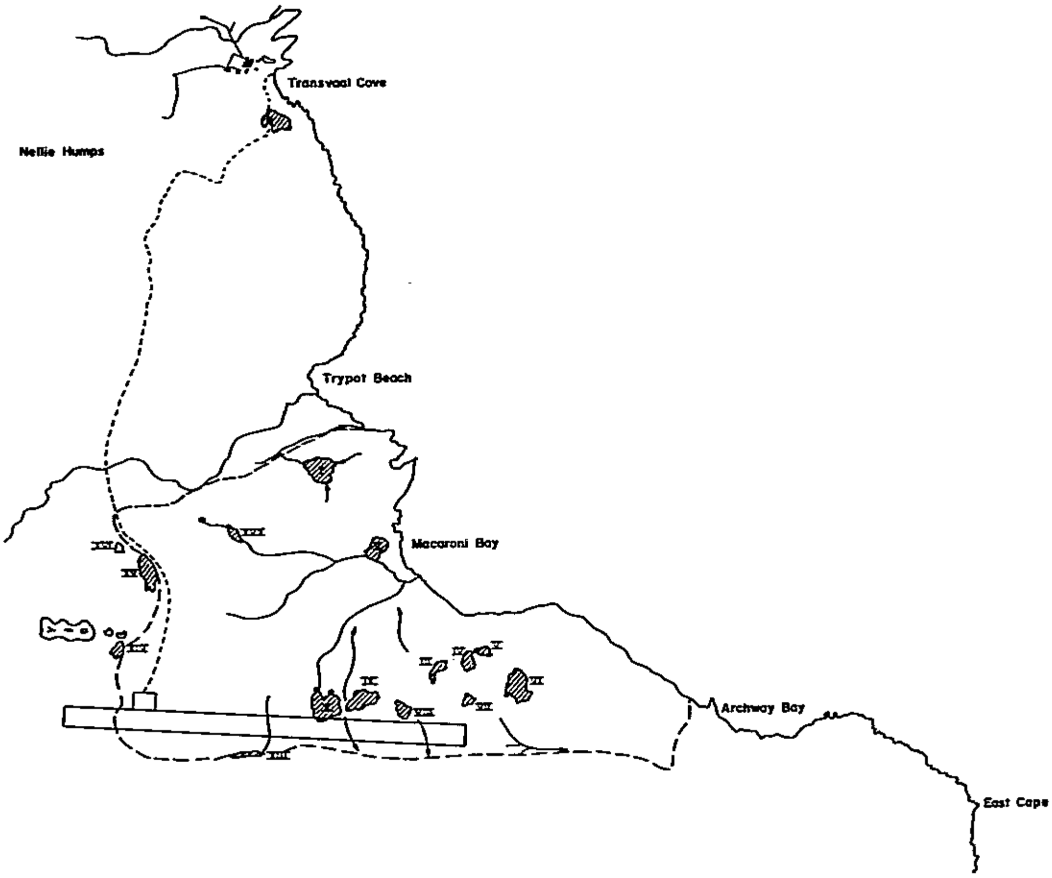
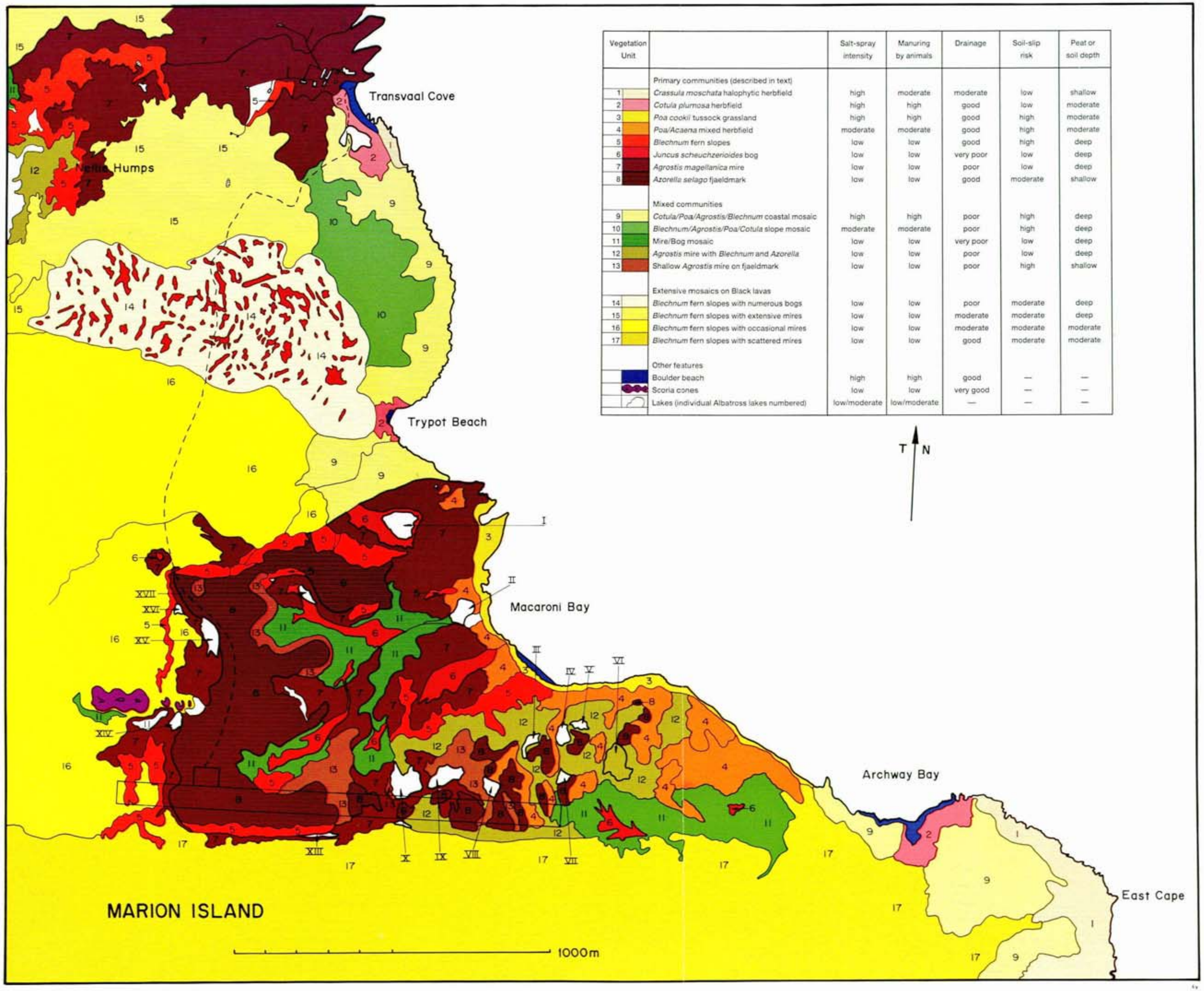


FIGURE 4.11 The stream and surface flow drainage patterns and lakes in the Impact Area on Marion Island.



Vegetation Unit			Salt-spray intensity	Manuring by animals	Drainage	Soil-slip risk	Peat or soil depth
		Primary communities (described in text)					
1	⬜	*Crassula moschata* halophytic herbfield	high	moderate	moderate	low	shallow
2	🟥	*Cotula plumosa* herbfield	high	high	good	low	moderate
3	🟨	*Poa cookii* tussock grassland	high	high	good	high	moderate
4	🟧	*Poa/Acaena* mixed herbfield	moderate	moderate	good	high	moderate
5	🟥	*Blechnum* fern slopes	low	low	good	high	deep
6	🟥	*Juncus scheuchzerioides* bog	low	low	very poor	low	deep
7	🟫	*Agrostis magellanica* mire	low	low	poor	low	deep
8	🟫	*Azorella selago* fjaeldmark	low	low	good	moderate	shallow
		Mixed communities					
9	🟨	*Cotula/Poa/Agrostis/Blechnum* coastal mosaic	high	high	poor	high	deep
10	🟩	*Blechnum/Agrostis/Poa/Cotula* slope mosaic	moderate	moderate	poor	high	deep
11	🟩	Mire/Bog mosaic	low	low	very poor	low	deep
12	🟫	*Agrostis* mire with *Blechnum* and *Azorella*	low	low	poor	low	deep
13	🟥	Shallow *Agrostis* mire on fjaeldmark	low	low	poor	high	shallow
		Extensive mosaics on Black lavas					
14	⬜	*Blechnum* fern slopes with numerous bogs	low	low	poor	moderate	deep
15	🟨	*Blechnum* fern slopes with extensive mires	low	low	moderate	moderate	deep
16	🟨	*Blechnum* fern slopes with occasional mires	low	low	moderate	moderate	moderate
17	🟨	*Blechnum* fern slopes with scattered mires	low	low	good	moderate	moderate
		Other features					
	🟦	Boulder beach	high	high	good	—	—
	🟪	Scoria cones	low	low	very good	—	—
	◯	Lakes (individual Albatross lakes numbered)	low/moderate	low/moderate	—	—	—

FIGURE 4.12 Major Vegetation Units of the Impact Area. Mapped from aerial photographs taken on 12 February 1987.

FIGURE 4.13 Bull kelp, *Durvillea antarctica* in the intertidal zone of Trypot Beach, with beds of *Macrocystis pyrifera* further offshore in deeper water.

FIGURE 4.14 Mosaic of fern slope, herbfield, mire, bog and fjaeldmark communities on young black lavas between Nellie Humps and Trypot Beach, Marion Island. The photograph covers an area of *c.* 100 ha.

FIGURE 4.15 *Crassula moschata* halophytic herbfield (orange) and *Cotula plumosa* herbfield (yellow green) on black lavas near East Cape. Cushions of *Azorella selago* visible in distance.

FIGURE 4.16 *Cotula plumosa* herbfield on well drained slopes south of Trypot, with moulting Elephant Seals and scattered tussocks of *Poa cookii*.

FIGURE 4.17 *Poa cookii* tussock grassland on the slopes of Macaroni Bay. Note the peat slips and erosion on Macaroni Penguin footpaths up the slope in the foreground.

FIGURE 4.18 *Poa/Acaena* mixed herbfield on slopes of grey lava moraine. *Poa pratensis* covers much of the *Acaena magellanica*. Shallow mire on fjaeldmark in the foreground.

FIGURE 4.19 *Blechnum penna-marina* fern slopes in black lavas south of the Base Station. The small lakelet is surrounded by *Agrostis magellanica* mire. Peat cores collected in 1965 from the mire beyond the black lava lakelet provided a pollen sequence to 4 600 yrs BP.

FIGURE 4.20 *Juncus scheuchzerioides* bog surrounded by a carpet of *Blechnum penna-marina* and the moss *Racomitrium lanuginosum* in the foreground. Fern slopes in the background.

FIGURE 4.21 Extensive *Agrostis magellanica* mire on a glacial moraine draining into Albatross Lake II. *Blechnum penna-marina* carpet in the foreground. Note the deep green *Poa cookii* to the lee of the Wandering Albatross nest.

FIGURE 4.22 *Azorella selago - Ditrichum strictum* fjaeldmark on slaty grey lavas of the moraine on which the ELS is proposed.

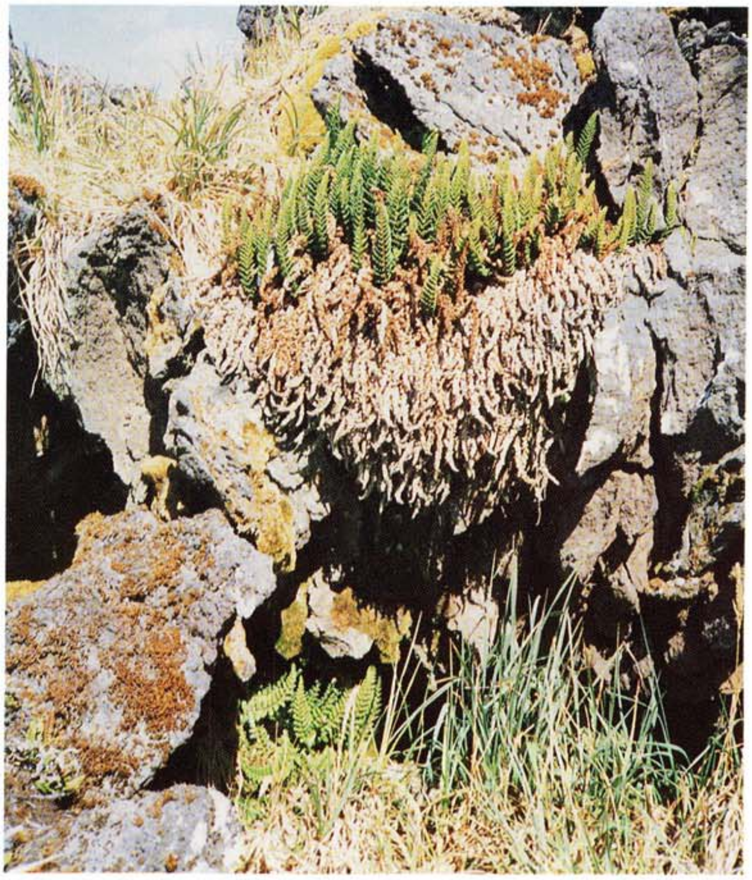


FIGURE 4.23 *Polystichum marionense*, the largest fern on Marion Island, endemic to the Prince Edward and Crozet Islands, seen here growing in a lava tunnel on the route of the proposed access road from Transvaal Cove to the ELS.

FIGURE 4.24 *Juncus effusus*, a large rush known in the sub-Antarctic only from this clump and two others on Marion Island. Trypot Fault in the background.

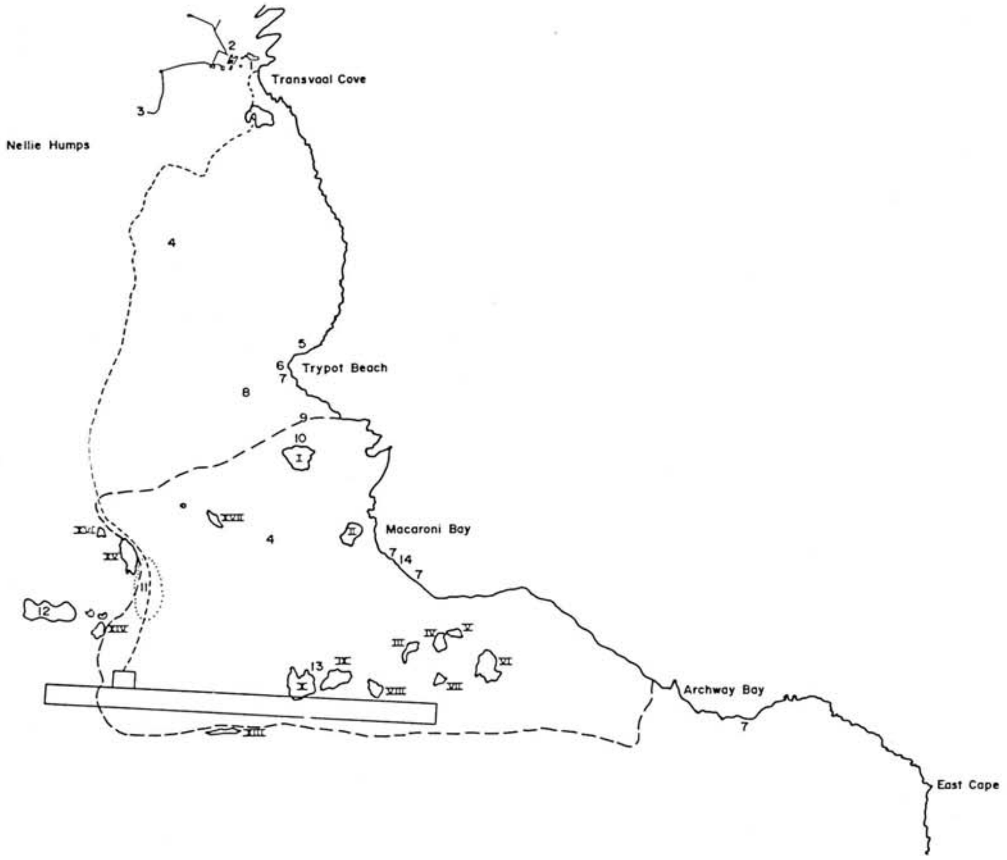


FIGURE 4.25 Distribution of sites of special scientific or historic interest in the Impact Area. 1 = Fairburn monument; 2 = meteorological recording site; 3 = geophysical recording station; 4 = palynological core site; 5 = *Juncus effusus* population; 6 = Trypot; 7 = Elephant Seal breeding beach; 8 = Gentoo Penguin moulting ground; 9 = Trypot Fault; 10 = Albatross Lake I with *Potamogeton* sp.; 11 = Antarctic Tern nesting area; 12 = Tom, Dick and Harry scoria cones; 13 = Skua and Kelp Gull resting area.

FIGURE 4.26 A dense sward of *Agrostis stolonifera* growing over *Poa cookii* tussock grassland on the slopes of Macaroni Bay, Marion Island.

FIGURE 4.27 *Sagina apetala* forming a dense mat over *Azorella selago*, *Agrostis magellanica* and *Montia fontana*.

FIGURE 4.28 Archway Bay, occupied by breeding King Penguins. This is one of the Island's most important Elephant Seal breeding beaches. *Cotula plumosa* and *Poa cookii* in the foreground.

FIGURE 4.29 Gentoo Penguins at a moulting site inland of Trypot Beach. Alpha, Beta, Gamma and Delta peaks in the distance rise above 1 000 m.

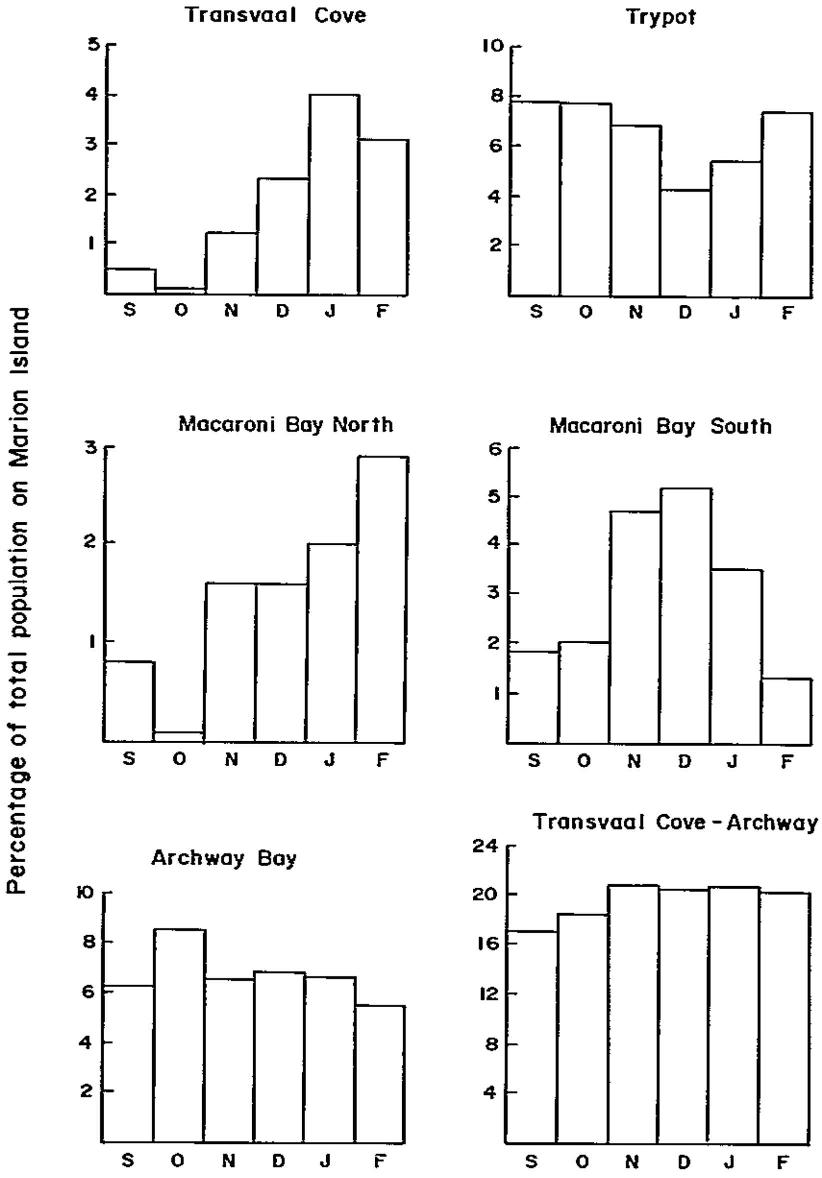


FIGURE 4.30 Distribution of the Elephant Seal population in the Impact Area during the period September 1986 to February 1987 as a percentage of total Island population numbers hauled out (Wilkinson, pers. comm.).

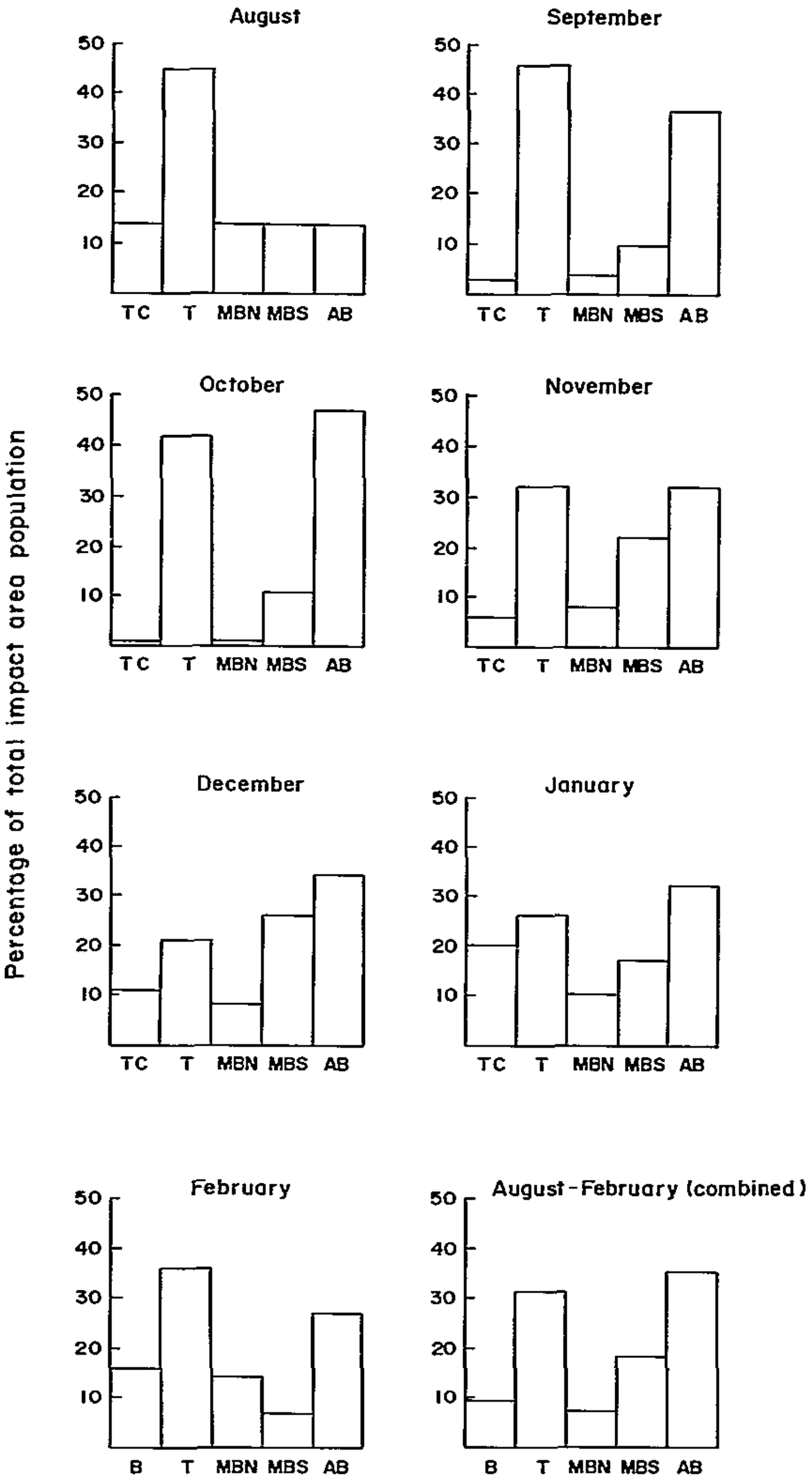


FIGURE 4.31 The seasonal distribution of Elephant Seals on the beaches of the Impact Area during the period August 1986 to February 1987. TC = Transvaal Cove; T = Trypot Beach; MBN = Macaroni Bay North; MBS = Macaroni Bay South; AB = Archway Bay (Wilkinson, pers. comm.).

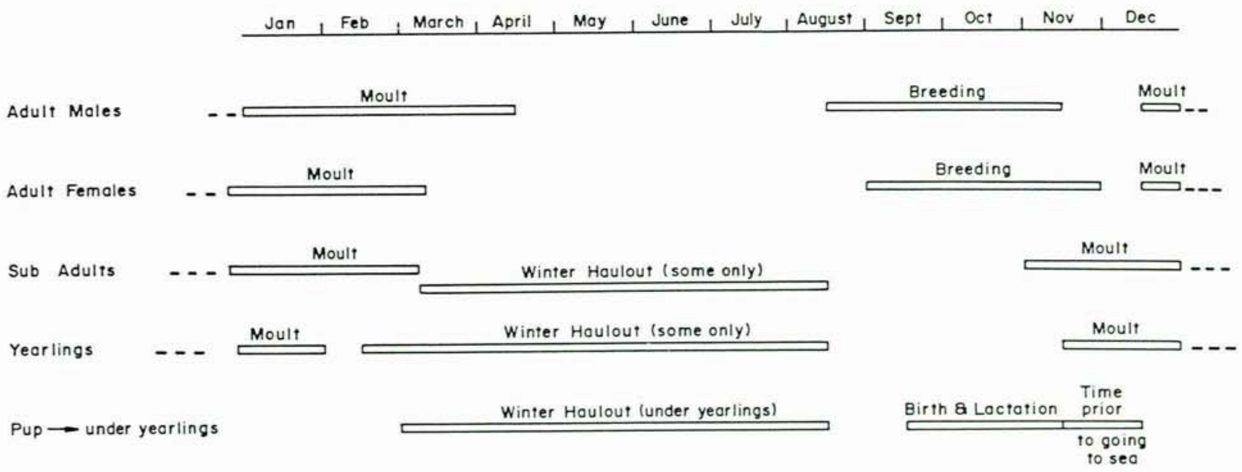


FIGURE 4.32 Annual cycle of Elephant Seals visiting the beaches of the Impact Area (Wilkinson, pers. comm.).

FIGURE 4.33 Tom, Dick and Harry - three small scoria cones at the inland margin of the Macaroni Bay moraines, and in the Impact Area. Junior's Kop is in the background.

FIGURE 4.34 The Trypot Fault, exposing grey lava of *c.* 276 000 yr age, overlain by Pleistocene moraine. Mixed mire, fern slope and herbfield communities are in the foreground.

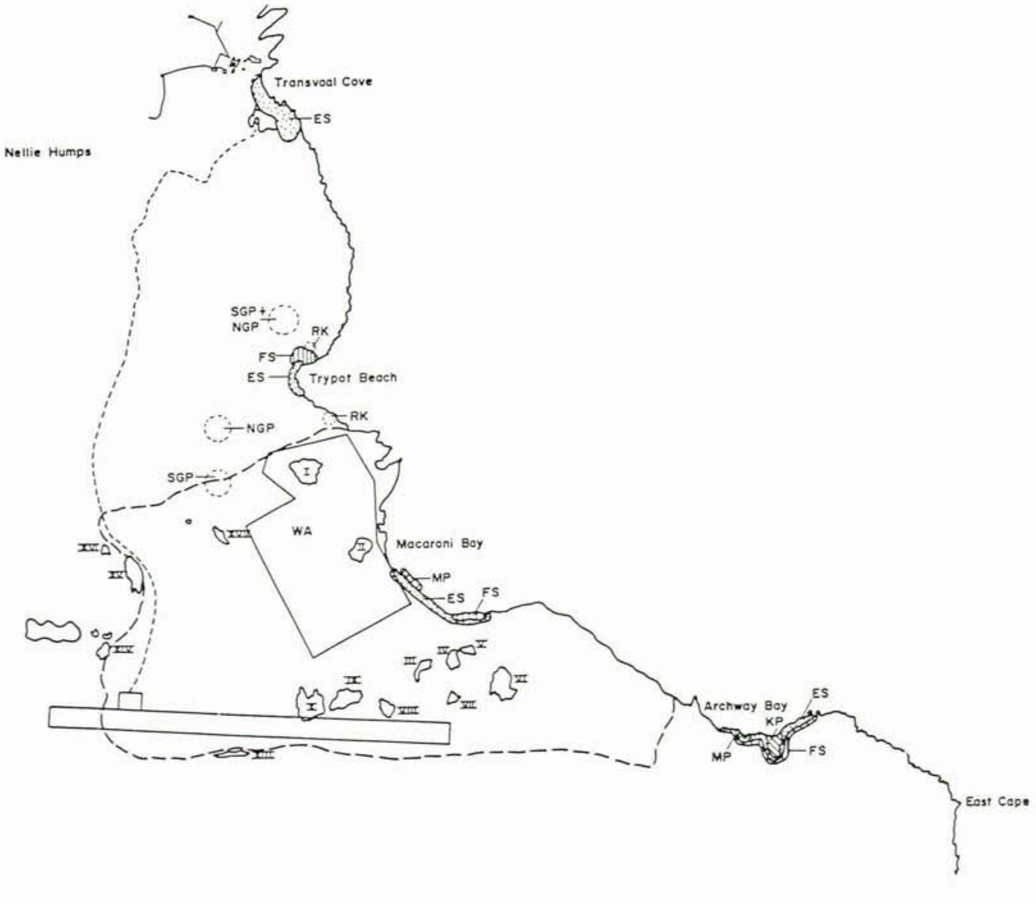


FIGURE 4.35 Distribution of long-term monitoring sites. ES = Elephant Seal; SGP = Southern Giant Petrel; NGP = Northern Giant Petrel; FS = Fur Seal; RK = Rockhopper Penguin; WA = Wandering Albatross; MP = Macaroni Penguin; KP = King Penguin.

CHAPTER 5

ENVIRONMENTAL IMPACTS AND THEIR MITIGATION

5.1 INTRODUCTION

This Chapter comprises four Sections. The first outlines the approach adopted in the environmental impact evaluation, the broad impacts of the proposal on aesthetics and on scientific research, and the increased vulnerability of the Island's ecosystems to invasion by alien biota. The second Section briefly describes the impacts to be expected along the access route and the ELS. Greater detail of possible impacts is given in the third Section, arranged in the same sequence of engineering phases described in Chapter 2. Finally, a brief synopsis of the major impacts of the execution of the proposal is provided.

5.1.1 Approach to the EIA

The analysis of the probable environmental impacts of the proposed ELS facility was conducted in four stages:

- The examination of comments on the proposal received from a wide range of scientists who had conducted research on Marion Island and who were familiar with the Impact Area. Relevant information in other, non-solicited, submissions was also considered.

- The field examination of each facet of the entire proposal and alternatives in the presence of the Consulting Engineers.

- The field examination of the site of the proposed beach landing ramp, access route and ELS with biologists stationed on the Island.

- Panel discussions using interaction matrices, cost/benefit analyses and further consultation with the sub-Antartic research community.

These discussions and field visits resulted in the identification of several potential impacts at differing spatial and temporal scales, and at different phases within the proposed project. In presenting an outline of these findings, possible approaches to reducing the negative impacts of the proposed facility are noted. Similarly, mention is made of topics on which current knowledge is wholly inadequate and on which further research is urgently required in order to assess the facility's likely impact with greater accuracy.

The *in situ* examination of alternative sites for the beach landing facilities, access routes and landing strip made possible the early rejection of many options which would have had serious environmental impacts. It was thus possible to avoid the important penguin and seal rookeries at Archway Bay, Macaroni Bay and Trypot Beach, the long-term research and monitoring sites along the coast, and specific sites of scientific or historical interest. Similarly, available knowledge on the distribution of sensitive plant communities, soils and geological features provided a basis on which both the engineers and the EIA Panel could reach consensus on the choice of options.

Although the proposed siting of facilities provides the least environmentally damaging course of action, the implementation of the proposal would nevertheless introduce serious impacts to the Island's ecosystems. These would constrain or negatively influence the current research programme at both national and international levels.

5.1.2 Aesthetic and Scientific Considerations

The immediate and overwhelming response of all parties consulted on the proposal (see Appendix C) was one of concern that the wilderness quality of the Island would be destroyed by the construction, maintenance and use of the ELS facility. The expansion of the anthropogenic zone, from the immediate surroundings of the Base Station to the Albatross Lakes area, plus the prospect of much larger and more frequent groups of visitors to the Island, was seen as an invasion of this pristine sanctuary. While these views are perhaps a little exaggerated, the prospect of extensive visual marring, peat slipping, disturbance of bird and seal colonies and major impacts on the hydrology of certain lakes will severely impair an otherwise relatively unspoilt environment, and will result in the disruption of research activities.

During the past 20 years South African scientists have made a major and internationally respected contribution to the knowledge of the geology, biology, meteorology and oceanology of the sub-Antarctic. This has been achieved through research programmes conducted at Marion Island and in the surrounding ocean. In addition to a major monograph (Van Zinderen Bakker *et al.*, 1971) over 200 scientific papers have been published on studies conducted on the Island.

The value of the Island as a centre for scientific research has been detailed in Section 1.3.2. Current and long-term research and monitoring sites are indicated in Figure 4.35. While the majority of these sites are several hundred metres from the ELS and access road, the visual disturbance and noise of engineering activities will undoubtedly influence the behaviour of the bird and seal communities being studied. These monitoring activities are part of South Africa's commitment to the international research aims of SCAR. The disruption of the programme would, therefore, have important implications for international cooperative research.

In addition to visual disturbance and noise, air- and water-borne pollutants could spread widely from the engineering works and might deleteriously influence scientific results. South Africa's current status as a leading contributor to research in the sub-Antarctic could be jeopardized as a consequence.

5.1.3 Invasive Biota

Perhaps the most serious threat to the Island's natural environment posed by the project is the danger of the introduction of aggressive alien plants or animals. The introduction of domestic cats in 1949 has resulted in the loss of several million birds, and the extinction of some species on Marion Island. Even small insects pose severe threats to plant life, while three weeds are currently spreading rapidly over the coastal lowlands. The problem of invasive alien organisms is discussed in detail in Section 4.4.2.

Some measures to reduce the danger of further introductions are presented here:

- Extremely stringent control of packaging and inspection of machinery and materials will be necessary to ensure that alien plants and animals are not transported to Marion Island. All machinery, especially earthmoving vehicles, crushing plant, etc., must be thoroughly steam-cleaned and, if possible, fumigated before landing on the Island.

- Personal clothing, especially shoes, of all personnel visiting the Island should be cleaned and inspected for seeds before being allowed on the Island.

- Extreme care should be taken to ensure that the unavoidable disturbance created by the project does not accelerate the spread of alien species already present on the Island. The distribution and demography of all alien species on Marion Island should be thoroughly investigated and monitored. This will require an expansion of the current SASCAR research programme.

- Throughout the duration of the project, Prince Edward Island, which is free of cats, mice and most invasive plants and invertebrates, should be declared a restricted area and all visits, whether by air or sea, prohibited. The total closure of this Island to all visitors (other than for strictly controlled scientific projects) is essential if accidental introductions of those alien species occurring on Marion Island are to be avoided.

- Strict precautions must be taken to prevent the movement of small mammals (e.g. rats, mice, cats, etc.) and insects (e.g. cockroaches, spiders, mites, etc.) from the quayside onto the ferry vessel in the home port. The berthing and loading sites that this vessel uses should be subjected to regular inspections by health and pest control authorities and stringent measures taken to reduce the presence of such species. The vessel should also be regularly fumigated.

5.2 THE ACCESS ROUTE AND THE ELS

5.2.1 Transvaal Cove and Gentoo Lake (from 0 to 100 m)

The proposed route to be used between Transvaal Cove and the ELS is indicated in Figure 5.1.

The proposal requires off-loading of plant and materials directly onto a landing ramp in Transvaal Cove. A channel will need to be cut through the kelp beds to the boulder beach (Figure 5.2). Although not presently planned, submarine blasting of submerged rocks may be necessary. If needed, this should be undertaken in winter, when such blasting should have only minor or no impacts on the very low number of penguins and seals on the Island at that time.

The proposal suggests the use of most of the boulders from the Transvaal Cove area for crushing and use as fill material for the landing ramp, stacking area and the access road. The beach, near shore and intertidal communities in Transvaal Cove will be severely damaged, if not destroyed, by this activity.

It is probable that Gentoo Lake will be drained and the boulder 'levee' between the lake and the sea removed for crushing. The breeching of the 'levee' will release thousands of kilolitres of organically rich water into Transvaal Cove, temporarily polluting the near shore communities but probably being dispersed relatively rapidly by wave action and ocean currents. The drainage of the lake will destroy the only highly eutrophic lake within at least three hours walk from the Base Station.

5.2.2 Gentoo Lake to Nellie Humps (from 100 to 400 m)

The access road will leave the beach via the peninsula bisecting Gentoo Lake, thereafter crossing deep waterlogged peats until the lava tunnel approximately 300 m inland of Transvaal Cove and 400 m from the landing ramp (Figure 5.3). This section of the road will be the most difficult to construct as it covers sloping waterlogged peats, which are therefore potentially highly unstable. These peats are occupied by a mixture of *Cotula*, *Blechnum*, *Agrostis* and *Poa cookii* communities, with an almost continuous carpet of mosses and liverworts (Vegetation Units 9 and 10. Several Wandering Albatrosses have their nests along the route (Figure 5.4). It would be advisable to attempt to move their nests to at least 50 m distant from the route, or to induce them to nest away from the route if time and seasons permit this to be done before road building commences. Peat slips and visual scarring in this area would be severe.

5.2.3 Nellie Humps (from 400 to 1 800 m)

The route rises rapidly over a distance of *c.* 40 m across the margin of a collapsed lava tunnel. This tunnel would provide a firm substrate for the rise up the *Blechnum* fern slope which leads into the mosaic of fern slopes and mires of Vegetation Unit 15 (Figure 5.5). This area is gently undulating with scattered and very small patches of fjaeldmark on the exposed ridges. The road would cut deeply into the *Blechnum* carpet and peat slips will undoubtedly occur. Suitable techniques for the stabilization and revegetation of the exposed peats must still be developed.

This area is occupied by reduced numbers of burrowing petrels (due to recent heavy cat predation) and occasional Giant Petrels. With careful preparation of the route during the winter preceding the initiation of road works, it should be possible to induce the Giant Petrels to nest away from the proposed route.

The route passes from Vegetation Unit 15 to Vegetation Unit 14. The latter differs from the former only in so far as it includes numerous bogs scattered through the fern slope/mire/fjaeldmark mosaic. The bogs occupy narrow depressions and their somewhat linear distribution is such that the route can be chosen to pass from one fern slope/fjaeldmark ridge to the next, with only narrow (*c.* 5m) stretches of bog to cross.

The route then passes through Vegetation Unit 16, comprising a mosaic of fern slopes, mires and fjaeldmark outcrops. The fairly extensive stretches of fjaeldmark and fern carpets on broken blocky lava (Figure 5.6) provide a solid substratum for the road. At approximately 1 800 m from the beach the route crosses Trypot Stream (Figure 5.7), passing on over an area of mire before reaching the north-east corner of the Albatross Lakes grey lava moraine.

5.2.4 Grey Lava Moraine (from 1 800 to 2 800 m)

Once on the fjaeldmark of the grey lavas, the road should be relatively easy to construct. The soils of the fjaeldmark (Vegetation Unit 8, Figure 5.8) become waterlogged rapidly during rain. If the cover of lava rubble and vegetation is removed, the fjaeldmark might erode and result in considerable siltation and organic pollution of Albatross Lake XV. The route passes through the Antarctic Tern nesting site on the grey lava above Albatross Lake XV. These extremely timid birds will almost certainly leave the site, one of only two known nesting sites of the species on Marion Island.

5.2.5 Emergency Landing Strip (ELS)

The route reaches the parking area of the ELS at *c.* 2 800 m from the landing ramp in Transvaal Cove. The ELS crosses a continuum of fjaeldmark to mire communities, varying from well drained fjaeldmark on shallow soils to permanently waterlogged mire on peat of up to *c.* 50 cm depth. A large extent of the ELS lies on a mixed mire/fjaeldmark with shallow, waterlogged soils and numerous scattered grey lava boulders (Vegetation Unit 13, Figure 5.9). Any disturbance of the vegetation or rock covering this shallow soil will result in extensive soil erosion, slip scar formation and siltation of the lakes into which the mires drain.

The ELS and its immediate surroundings are occupied by a few nesting Wandering Albatrosses, one or two Skua nests, and large numbers of Skuas and Kelp Gulls which loaf on the moss carpets of the mires and bogs adjoining Albatross Lakes IX and X. It is anticipated that a portion of Lake X will have to be filled and that Lake IX will have to be drained, resulting in major impacts on lakes, soils, drainage and vegetation (see Section 5.3.4.1). It is probable that these Skuas and Kelp Gulls will then move to and loaf on the runway.

The ELS is planned to extend beyond the margins of the grey lava moraines. To the west it will cover and totally modify drainage and community structure of *Blechnum* fern slopes. To the east a similar impact will be imposed on mixed herbfield and mire communities. Severe peat slipping and drainage problems can be anticipated in these areas.

5.3 ENGINEERING/ENVIRONMENTAL INTERACTIONS

5.3.1 Interaction Matrix and Impact Evaluation

The expected interactions between project activities and environmental components are summarized in Tables 5.1 to 5.5. Only major and minor impacts are distinguished. The interactions were initially analysed in terms of their spatial and temporal scales, whether they are expected to be reversible or irreversible, and whether direct or indirect. The matrix provides a useful checklist of potential interactions, of which the more significant are dealt with below within the framework of the project phases described in Chapter 2.

In evaluating the relative importance of individual impacts no attempt was made to rank them by means of Delphi or Analytical Hierarchy Process approaches. In many cases individual impacts were considered inconsequential on their own, but in combination with several other impacts, as would usually be the case, the total impact would be serious. Similarly, no attempt was made to quantify the environmental impacts in financial terms. Such assessments make use of a variety of indirect 'shadow pricing' approaches which are feasible where land, lakes, forests, wildlife or other environmental components have measurable real estate or commodity values. Marion Island comprises state land of no known commercial, agricultural or mineral potential. It is, therefore, difficult or impossible to allocate a realistic financial value to any environmental component.

5.3.2 Pre-Construction Phase

No major impacts are anticipated during this phase. Small and reversible impacts will result from sampling of materials from the ELS centre-line, scoria cones and black lavas. These excavations should be refilled and the surface micro-relief restored immediately after the required samples have been removed. A team of 12 to 15 technicians working in the area for a few weeks during this phase will unavoidably increase the risk of spreading alien species from the Base Station.

5.3.3 Establishment Phase

Many major impacts can be expected during this phase. Principal among these are spillage of materials during off-loading onto the Island, the development of the beach landing and stacking facilities, the construction of the access road, and the setting-up of the construction yard at the ELS site. These activities will have direct and often long-term irreversible impacts on the intertidal, beach, Gentoo Lake, coastal mosaic, slope, mire and fjaeldmark communities. Soil and vegetation cover, and hydrology, will be locally but severely changed.

Small numbers of Elephant Seals, Rockhopper Penguins, Wandering Albatrosses, Giant Petrels, Antarctic Terns, Skuas and burrowing petrels will be severely disturbed during this phase. It is possible that this disturbance will cause them to leave the activity area for the duration of the project, but many species might merely move off a short distance and become habituated to the activities.

5.3.3.1 Beach landing facilities

Only limited removal of kelp will be necessary to widen the existing channel to afford the landing craft access to the beach. The kelp beds provide feeding areas for small numbers of Kelp Gulls and Cormorants. Continual boat traffic through the beds may cause these birds to feed elsewhere, or may eventually break up and destroy the beds. Any fuel spills in or off Transvaal Cove would affect the local birds, probably directly oiling penguins, Giant Petrels and Gulls, as well as damaging or destroying localized feeding grounds.

TABLE 5.1 Impact matrix for pre-construction phase

KEY:

- • = Minor impact
- ■ = Major impact
- / = No impact at all
- RP = Rockhopper Penguin
- MP = Macaroni Penguin
- S = Sheathbill
- C = Cormorant
- SA = Sooty Albatross
- WA = Wandering Albatross
- GP = Giant Petrel
- SK = Skua
- AT = Antarctic Tern
- GN = Gentoo Penguin

ENGINEERING ELEMENTS

Site survey/site visit (5/87 15 people, 3 weeks, helicopter support)	Soil testing, runway centreline test holes	Scoria test holes	Black lava drill tests	Glacial moraine	Anemometer installation	Beach and road route surveys	**ENVIRONMENTAL ELEMENTS**
•	•	•	•	•	•	•	Landscape elements
							boulder beach
			•				black lava
	•			•	•		glacial moraine
		•					scoria cones
							stream bed (Trypot stream)
•	•	/	•	•	/	•	Ground cover
							vegetation/peat mat
							peats, waterlogged
							peats, free draining
							black lava volcanic debris
	•						grey lava slates
							rawmark soils
/	/	/	/	/	/	/	Hydrology
							catchment cohesion
							surface drainage
							groundwater drainage
							liquifaction, solifluction
							water quality/eutrophication/turbidity
/	/	/	/	/	/	/	Marine communities
							kelpbeds - Macrocystis
							sub-tidal boulders
							intertidal communities, incl. Durvillea
							boulder beaches, kelp fly associations
•	/	/	/	/	/	•	Terrestrial Communities
							Salt spray zone : Crassula herbfield (Unit 1)
							Cotula herbfield (Unit 2)
							Cotula/Poa/Agrostis coastal mosaic (Unit 9 & 10)
							Slope herbfields : Blechnum fern slopes (Unit 5)
							Blechnum/Agrostis slope mosaic (Units 14,15,16,17)
							Swamps : bogs (Unit 6 & 14)
							mires (Unit 7 & 16)
							Agrostis/Blechnum mire (Unit 12)
							Fjaeldmark : Azorella lowland/fjaeldmark (Unit 8)
							fjaeldmark/mire mosaic (Unit 13)
/	/	/	/	/	/	/	Freshwater communities
							Gentoo Lake
							Albatross Lakes
							streams
/	/	/	/	/	/	/	Birds
							coastal cliff surface nesters (RH, MP, S, C, SA, GN)
							coastal burrowing nesters
							inland surface/nesters (SK, WA. GP)
							inland burrowing nesters
							fjaeldmark nesters (AT)
/	/	/	/	/	/	/	Elephant Seals (breeding)
							(moulting)
•	•	•	•	•	/	•	Aliens
/	/	/	/	/	/	/	Research & Monitoring

TABLE 5.2 Impact matrix for establishment phase

KEY:

- • = Minor impact
- ■ = Major impact
- / = No impact at all
- RP = Rockhopper Penguin
- MP = Macaroni Penguin
- S = Sheathbill
- C = Cormorant
- SA = Sooty Albatross
- WA = Wandering Albatross
- GP = Giant Petrel
- SK = Skua
- AT = Antarctic Tern
- GN = Gentoo Penguin

ENGINEERING ELEMENTS

ENVIRONMENTAL ELEMENTS	Transport by sea	Offload equip by helicopter	Prepare approach channel (widen kelp channel)	Construct beach landing ramp & storage area	Crush boulders on beach	Construction access road - section 0-100m (Gentoo Lake)	100-400m (peaty slopes)	400-1800m (rocky terrain/stream crossing	1800-2800m (glacial moraine)	2800-3800m (Fred's Hill)	Erect accommodation camp at Base Station	Set up construction yard	Prepare quarry sites black lava	scoria (from Tom, Dick and Harry)	surface boulder collection	Clear vegetation and top soil along runway and store
Landscape elements	/	•	/	•	■	■	■	■	■	■	•	■	■	■	■	■
boulder beach		•		■	■	■										
black lava				•			■	■	/	■			■			■
glacial moraine		•			•	•			■			■	■		■	■
scoria cones			•							■				■		
stream bed (Trypot stream)								■								
Ground cover	/	•	/	■	■	■	■	■	■	■	•	■	■	■	■	■
vegetation/peat mat						■	■	■	■	■			■		■	■
peats, waterlogged							■	■		■					■	■
peats, free draining								■	■	■						■
black lava volcanic debris								■		■						
grey lava slates									■						■	■
rawmark soils									■						■	
Hydrology	/	/	/	•	•	■	■	■	•	■	/		■	/	■	■
catchment cohesion							•	•	•						•	■
surface drainage							■	■	■	■					•	■
groundwater drainage				•		■	■	■	■	■					•	■
liquifaction, solifluction							■	■	•	■					•	■
water quality/eutrophication/turbidity							■	•	■						■	■
Marine communities	•	/	•	•	•	•	/	/	/	/	/	/	/	/	/	/
kelpbeds - Macrocystis	•		•													
sub-tidal boulders	•			•												
intertidal communities, incl. Durvillea	•			•												
boulder beaches, kelp fly associations	•			■	■	■										
Terrestrial Communities	/	•	/	•	•	•	■	■	■	■	•	•	■		■	■
Salt spray zone : Crassula herbfield (Unit 1)																
Cotula herbfield (Unit 2)				■	■	■										
Cotula/Poa/Agrostis coastal mosaic (Unit 9 & 10)							■									
Slope herbfields :Blechnum fern slopes (Unit 5)								■		■			■	■		
Blechnum/Agrostis slope mosaic (Units 14,15,16,17)								■		■			■			
Swamps : bogs (Unit 6 & 14)								■		■			■			
mires (Unit 7 & 16)								■		■			■			
Agrostis/Blechnum mire (Unit 12)																■
Fjaeldmark : Azorella lowland/fjaeldmark (Unit 8)									■		■			■		■
fjaeldmark/mire mosaic (Unit 13)														■		■
Freshwater communities	/	/	/	•	•	•			•	/	•	/	/	/	/	■
Gentoo Lake				■	■	■										
Albatross Lakes									■							■
streams								•								
Birds	•	•	/	•	•	•		•	■	■	•	•	•	/		•
coastal cliff surface nesters (RH, MP, S, C, SA, GN)	•	•	•	•	•	•					•					
coastal burrowing nesters							•									
inland surface/nesters (SK, WA, GP)								•		■		•	•			•
inland burrowing nesters								•		■			•			
fjaeldmark nesters (AT)									■							■
Elephant Seals (breeding)	/	•	/	■	■	■	/	/	/	/	/	/	/	/		/
(moulting)																
Aliens	•	•	/	•	•	•	•	•	•	•	•	•	•			•
Research & Monitoring	/	/	/	•	•	•	•	/	■	/	•	/	/	■		

TABLE 5.3 Impact matrix for construction phase

KEY:

• = Minor impact
█ = Major impact
/ = No impact at all
RP = Rockhopper Penguin
MP = Macaroni Penguin
S = Sheathbill
C = Cormorant
SA = Sooty Albatross
WA = Wandering Albatross
GP = Giant Petrel
SK = Skua
AT = Antarctic Tern
GN = Gentoo Penguin

ENGINEERING ELEMENTS

Transport people/material/supplies by sea	Disembarcation of materials	Transport people/materials to site (4 300 t cement or 350 t bitumen)	Cut and fill (reduce lake by 20 m, utilize scoria)	Drilling, blasting and crushing	Lay asphalt or cast concrete	Water extraction and lake drainage	Labour force	ENVIRONMENTAL ELEMENTS
/	/	/	█	█	/	█	/	Landscape elements
								boulder beach
								black lava
			█			█		glacial moraine
								scoria cones
								stream bed (Trypot stream)
			█		•	/	•	Ground cover
					•			vegetation/peat mat
					•			peats, waterlogged
					•			peats, free draining
								black lava volcanic debris
					•			grey lava slates
					•			rawmark soils
			█		•	█	/	Hydrology
			█			█		catchment cohesion
			█			█		surface drainage
			█			█		groundwater drainage
			█			█		liquifaction, solifluction
			█		█	█		water quality/eutrophication/turbidity
•	•		/		/	/	/	Marine communities
•	•							kelpbeds - Macrocystis
								sub-tidal boulders
•	•							intertidal communities, incl. Durvillea
	•							boulder beaches, kelp fly associations
	•		█		•		•	Terrestrial Communities
	•							Salt spray zone : Crassula herbfield (Unit 1)
	•							Cotula herbfield (Unit 2)
								Cotula/Poa/Agrostis coastal mosaic (Unit 9 & 10)
							•	Slope herbfields : Blechnum fern slopes (Unit 5)
							•	Blechnum/Agrostis slope mosaic (Units 14,15,16,17)
			█		•	•	•	Swamps : bogs (Unit 6 & 14)
			█		•	•	•	mires (Unit 7 & 16)
			█		•	•	•	Agrostis/Blechnum mire (Unit 12)
			█		•	•		Fjaeldmark : Azorella lowland/fjaeldmark (Unit 8)
			█		•			fjaeldmark/mire mosaic (Unit 13)
			█		█	█		Freshwater communities
								Gentoo Lake
			█		█	█		Albatross Lakes
								streams
	•	•	•	•		•	█	Birds
	█						•	coastal cliff surface nesters (RH, MP, S, C, SA, GN)
							•	coastal burrowing nesters
			•	█		•	█	inland surface/nesters (SK, WA, GP)
				•			•	inland burrowing nesters
							█	fjaeldmark nesters (AT)
	•	•	/	/	/	/	█	Elephant Seals (breeding)
	█	•					█	(moulting)
█	█	•	•			•	█	Aliens
	█	█	•	•	•	•	█	Research & Monitoring

TABLE 5.4 Impact matrix for operations and maintenance phase

KEY:

- • = Minor impact
- ▮ = Major impact
- / = No impact at all
- RP = Rockhopper Penguin
- MP = Macaroni Penguin
- S = Sheathbill
- C = Cormorant
- SA = Sooty Albatross
- WA = Wandering Albatross
- GP = Giant Petrel
- SK = Skua
- AT = Antarctic Tern
- GN = Gentoo Penguin

ENGINEERING ELEMENTS

Presence of structures: runway	Access road	Beach facility	New accommodation at Base Station	Aircraft landing/take-off	Operational failure	Bird control	Abandonment	Increased use of runway	Upgrading of facilities	ENVIRONMENTAL ELEMENTS
▮	▮	▮	•	/	•	/	▮		Requires new impact assessment report if greater than 10 %	Landscape elements
		▮								boulder beach
										black lava
▮										glacial moraine
										scoria cones
										stream bed (Trypot stream)
▮	▮	•	•	/	•	/	▮			Ground cover
										vegetation/peat mat
										peats, waterlogged
										peats, free draining
										black lava volcanic debris
										grey lava slates
▮										rawmark soils
▮	▮	•	•	/	•	/	▮			Hydrology
										catchment cohesion
										surface drainage
										groundwater drainage
										liquifaction, solifluction
					•					water quality/eutrophication/turbidity
/	/	•	•	/	•	/	/			Marine communities
										kelpbeds - Macrocystis
										sub-tidal boulders
										intertidal communities, incl. Durvillea
										boulder beaches, kelp fly associations
▮	▮	•	•	/	•	/	•			Terrestrial Communities
		•								Salt spray zone : Crassula herbfield (Unit 1)
		•								Cotula herbfield (Unit 2)
	•									Cotula/Poa/Agrostis coastal mosaic (Unit 9 & 10)
	•									Slope herbfields : Blechnum fern slopes (Unit 5)
	•									Blechnum/Agrostis slope mosaic (Units 14,15,16,17)
	•									Swamps : bogs (Unit 6 & 14)
	•									mires (Unit 7 & 16)
	•									Agrostis/Blechnum mire (Unit 12)
▮	•									Fjaeldmark : Azorella lowland/fjaeldmark (Unit 8)
▮	•									fjaeldmark/mire mosaic (Unit 13)
•		•			•		/			Freshwater communities
		▮								Gentoo Lake
▮										Albatross Lakes
										streams
•				▮	•	▮	/	▮		Birds
				•		▮		▮		coastal cliff surface nesters (RH, MP, S, C, SA, GN)
				•		▮		▮		coastal burrowing nesters
•				▮		▮		▮		inland surface/nesters (SK, WA. GP)
						▮		▮		inland burrowing nesters
				▮		▮		▮		fjaeldmark nesters (AT)
							/			Elephant Seals (breeding)
										(moulting)
	•			•	•		•			Aliens
			▮		•		/			Research & Monitoring

TABLE 5.5 Impact matrix for demobilization phase

KEY:

• = Minor impact
■ = Major impact
/ = No impact at all
RP = Rockhopper Penguin
MP = Macaroni Penguin
S = Sheathbill
C = Cormorant
SA = Sooty Albatross
WA = Wandering Albatross
GP = Giant Petrel
SK = Skua
AT = Antarctic Tern
GN = Gentoo Penguin

ENGINEERING ELEMENTS

Clearing	Transport	Loading on ship	Restoration	Delay in scheduling	**ENVIRONMENTAL ELEMENTS**
•	/	•	■	/	Landscape elements
•	•				boulder beach
					black lava
•					glacial moraine
		•			scoria cones
					stream bed (Trypot stream)
•	/	•	■	/	Ground cover
•					vegetation/peat mat
•					peats, waterlogged
•					peats, free draining
•					black lava volcanic debris
•					grey lava slates
					rawmark soils
/	/	/	■	/	Hydrology
					catchment cohesion
					surface drainage
					groundwater drainage
					liquifaction, solifluction
					water quality/eutrophication/turbidity
/	•	/		■	Marine communities
	•				kelpbeds - *Macrocystis*
	•				sub-tidal boulders
	•				intertidal communities, incl. *Durvillea*
	•				boulder beaches, kelp fly associations
•	/	•	■	•	Terrestrial Communities
•			•		Salt spray zone : Crassula herbfield (Unit 1)
•			•		Cotula herbfield (Unit 2)
•			•		Cotula/Poa/Agrostis coastal mosaic (Unit 9 & 10)
•			•		Slope herbfields : Blechnum fern slopes (Unit 5)
•			•		Blechnum/Agrostis slope mosaic (Units 14,15,16,17)
•			•		Swamps : bogs (Unit 6 & 14)
•			•		mires (Unit 7 & 16)
•			•		Agrostis/Blechnum mire (Unit 12)
•			•		Fjaeldmark : Azorella lowland/fjaeldmark (Unit 8)
•			•		fjaeldmark/mire mosaic (Unit 13)
•	/	/			Freshwater communities
•					Gentoo Lake
•					Albatross Lakes
					streams
•	•	•	•	•	Birds
•	•	•			coastal cliff surface nesters (RH, MP, S, C, SA, GN)
•					coastal burrowing nesters
•			•		inland surface/nesters (SK, WA. GP)
•					inland burrowing nesters
•					fjaeldmark nesters (AT)
•	/	•		•	Elephant Seals (breeding)
•		•		•	(moulting)
	•	•		■	Aliens
	/	/		■	Research & Monitoring

In view of the Rockhopper Penguins' ability to continue to nest successfully within the Base Station environs, it is likely that the Transvaal Cove population will continue to do so, but may suffer a greater nesting mortality due to increased human activity on the beach. If human disturbance limits their access across the beach, it is possible that the penguins will abandon the Base Station area completely. Occasionally small numbers of King and Gentoo Penguins moult on the beach of Transvaal Cove. These will most likely go elsewhere if there is marked human activity on the beach.

As noted in the introduction to this Chapter, field discussions with the consulting engineers added weight to the rejection of the most important Elephant Seal breeding beaches (Trypot, Macaroni, Archway) from consideration as possible landing sites for the proposed project. The decision to use Transvaal Cove thus considerably reduces the potential impact of the project on the Elephant Seal population, as no regular breeding occurs on the beach and only small numbers (less than 4 % of the Island population) come ashore at Transvaal Cove to moult. Fur Seals are seldom if ever seen at Transvaal Cove.

However, disturbance by construction personnel of the breeding harems of Elephant Seals on the other beaches in the Impact Area, from September to December, could have a major impact on the Marion Island population. It is therefore essential that the rigorous control of personnel and the presence of guides when they take to the field while off-duty, be exercised as recommended in Section 5.3.4.3.

The impact of project activities on Killer Whales is likely to be minimal, mainly because this species is highly mobile and able to move away from or avoid disturbed areas. The species is not known to use Transvaal Cove as a loafing area. Excessive disturbance of weaned and moulting Elephant Seals (in November to March), causing them to spend more time at sea in search of quieter beaches, might benefit the Killer Whales by making the seals easier prey. This, of course, would be to the definite disadvantage of the Elephant Seal population.

A potentially serious impact would result from storm seas breeching the lowered beach at Transvaal Cove, destroying or damaging both the landing ramp and stacking area and stored materials, and eroding the peat slopes inland of the drained Gentoo Lake. Such violent seas are not uncommon on the coast of Marion Island. If, on the other hand, the landing facility is well constructed, it would provide the Base Station with improved off-loading capabilities. The access road between Transvaal Cove and the ELS would also provide scientists with easier, all-weather access to the Albatross Lakes area.

5.3.3.2 Access road

The construction of the access road from Transvaal Cove will have serious impacts on the vegetation and soil cover along the route described in Section 5.2. Considerable expertise in road building on deep, unstable, waterlogged peats will have to be developed or imported if major erosion scars, peat slips and drainage problems are to be avoided in the construction of the access road. Despite the free-draining and stable appearance of the rawmark soils of the fjaeldmark on the glacial moraine (Vegetation Unit 8), it might be expected that these soils will erode or slip very rapidly during the almost daily heavy rains. The alignment of the road over this surface should be very carefully selected.

The construction of the access road will result in the direct destruction of a small number of burrowing petrel nests. The number involved is virtually impossible to estimate, but is probably of the order of a few score pairs, mainly Salvin's Prions and White-chinned Petrels. If construction proceeds through the breeding season, this will additionally cause the direct mortality of chicks and loss of eggs, and probably also desertion of surrounding nests by adults. Adults forced to leave during the day will stand a high chance of being preyed on by Skuas, especially as these predators will probably start congregating around work areas if they find extra prey becoming available. The effect of bulldozers on incubating burrowing petrels may well be that the adult birds will mainly "sit tight" and thus also be killed.

Construction will probably result in the destruction of two or three Wandering Albatross nests. If occupied by chicks, it is possible that they will still be fed by adults if they (and ideally the nest also) are moved a few metres away. On the other hand, incubating birds right next to the route will probably not desert but may fail to incubate eggs properly due to disturbance and thus fail to raise chicks. It is probable that not more than three pairs of Wandering Albatross would be affected. Birds returning to the Island to start breeding and finding their previous nest site destroyed can be expected to build another nest a short distance away.

The access road will possibly also affect a small group of about six Northern Giant Petrel pairs, which will probably behave in a manner similar to the Wandering Albatrosses.

The access road will go through about five Skua territories. These birds will continually leave eggs and very small chicks to harass human intruders, which will increase the chances of them failing to incubate eggs successfully. They should continue to feed larger chicks even close to construction activities, and may even be attracted to humans if food waste is left lying around. The same may apply in the case of juveniles and non-breeding adults.

The access road will go through two Antarctic Tern territories. These will probably harass construction workers by "dive-bombing" them if they have chicks or eggs. However, they will more likely desert the site but hopefully not the Island. They will almost certainly lose any eggs or chicks to predators (e.g. Skua) with any increased level of human activity.

The road will probably destroy three of four Kelp Gull nest sites around the boulder beach of Transvaal Cove. These breeding pairs may take up sites/territories nearby, or may just become non-breeding birds. Continuing disturbance of incubating or brooding birds will probably cause egg or chick loss, as this species readily leaves the nest.

5.3.4 Construction Phase

5.3.4.1 Specific impacts

A series of major impacts can be expected during this phase. Perhaps the greatest single threat to the Island's biota is that inherent in the transport to the Island of the seeds, spores or mature individuals of various invasive alien plants, animals or micro-organisms (see Sections 4.4.2 and 5.1.3).

The second most important potential impact of the construction phase would be the quarrying of the scoria cones known as Tom, Dick and Harry. The geological interest and value of these fissure cones is described in Section 4.5.3.

The third most important negative impact is that caused by the partial filling of Albatross Lake X and the draining of Albatross Lake IX. The landing strip will include the southern portion of Albatross Lake X, which will be filled in over an area of approximately 150 m^2. As the lake appears to drain northwards, the filling will not seriously affect the local hydrological situation, but the influence of the fill on the chemistry and biota of the lake cannot be predicted. In view of the highly oligotrophic nature of the Albatross Lakes, and the possibility of major physico-chemical changes being induced by the mixing and release of alkaline and clay-rich materials, it is recommended that crushed black lava, which is relatively inert and free of fine particulates, be used for this fill. Wind-blown cement might also modify the chemistry of the lakes adjacent to the ELS.

The proposed drainage of Albatross Lake IX will result in a considerable change to the local hydrology. This will lead to major soil erosion and peat slipping, unless draining is conducted with great care. A detailed study of the drainage patterns and probable impacts on the area must be undertaken prior to commencement of any work at this site.

The loss of the Albatross Lake IX due to drainage will affect the Skua "club" at present stationed there, but it is likely that they will take up station at one of the other nearby lakes, or on the finished runway. This might be hazardous to the actual use of the ELS. The large numbers of birds in the immediate vicinity of the ELS will also introduce an increased bird-strike risk.

The preparation of a black lava quarry site will have major, irreversible but localized impacts. The choice of quarry site must be based on a careful survey of terrain, to ensure that the excavation drains internally and that water can be pumped out of settlement ponds into subterranean drainage systems.

The sparse vegetation cover of the ELS is extremely slow growing and can be expected to die quite rapidly after removal and storage in dumps. It should not be expected that the fjaeldmark vegetation can be re-established after the ELS has been built. Some alien species will probably invade the surfaces laid bare by bulldozers. A decision will have to be taken as to whether alien plant cover is better than nothing, or whether costly and probably unsuccessful attempts should be made to re-vegetate with slow growing, indigenous species.

Both the runway and access road may cause erosion and/or hydrological problems that could affect bird breeding sites in their vicinity, after the completion of the construction phase. The run-off from the ELS runway, during the frequent heavy rainshowers, could cause severe erosion of the fjaeldmark on which the runway is to be built. The storm-water drainage system planned for the runway must be suitably designed to avoid such erosion hazards.

The possible pollution of soils and inland waters from spillage or wind dispersal of cement and other construction materials is also impossible to determine at this stage, but should be carefully monitored and, if time permits, investigated in a few disturbance experiments initiated during the pre-construction phase.

5.3.4.2 General impacts

The control of the labour force is discussed separately in Section 5.3.4.3. If adequate discipline is maintained, the presence of the labour force should not create major disturbances, but if discipline is allowed to slacken, very severe disturbance of bird, mammal and plant communities could result during this phase.

Artificial lighting used during the construction phase should be kept to a minimum. Structures such as fences, telephone lines, aerials, etc. should not be erected along the access route or at the construction yard. These structures are especially dangerous to night flying petrels.

The avifauna of Marion Island appears to be relatively insensitive to low to medium levels of noise (such as humans talking or even shouting), but it is probable that both ground-nesting and burrowing birds will leave the vicinity of blasting operations. Due to the severely reduced populations of most species of burrowing birds (due to predation by feral cats), it is probable that birds moving away from the blasting area will not encounter strong competition for nesting sites.

Blasting operations in the quarry and ELS areas will probably have to proceed throughout the year. It is nevertheless recommended that blasting be concentrated as far as is feasible during the period April to September, when bird breeding is at its lowest level.

Blasting operations in the vicinity of Albatross Lakes IX and X will probably cause the large groups of Skuas and Kelp Gulls to leave the shores of these lakes, but it is possible that they might become rapidly habituated to the disturbance or merely move to adjacent lakes.

The rock crushers at Transvaal Cove and at the quarries supplying the ELS and access road will create severe, but local, noise pollution in their immediate vicinity. The combined impacts of noise and dust, and human and vehicular movement, will undoubtedly cause birds to leave the vicinity of the quarries. It is unlikely that these movements will greatly disrupt the avifaunal population structure in the Impact Area.

The noise and visual disturbance of vehicular traffic, especially that of the light trucks moving materials from Transvaal Cove to the ELS, will be a constant and important source of disturbance to the bird population along the route. However, due to the low densities of birds along the route it is unlikely that this impact will be of major consequence.

Helicopter activity should, where possible, be restricted to the flight-limits indicated on Figure 5.1. Flights outside these lines should only be permitted for scientific or emergency purposes. Flights along the coastline should be avoided.

Should the entire construction phase be delayed and the duration of the activities extended, the re-scheduling will increase the risk of introducing alien biota, and will extend the period during which research activities are disturbed either directly or indirectly.

5.3.4.3 Personnel management

A potentially large, but at present unpredictable, impact is through the addition of considerable numbers of construction workers to the Island. Outside the actual worksite areas people could cause localized but significant impact by disturbing colonies of breeding seabirds (particularly penguins), and causing desertion of chicks or eggs.

Shooting, trapping and egging, whether for sport or food, would also have a detrimental effect, the magnitude of which would be dependent on the species involved and the extent of the disturbance.

It is therefore essential that all members of the workforce involved in every facet of the project be fully conversant with, and committed to, the DEA's draft Code of Conduct and with subsequent legislation should this become effective during or after 1988 (see Section 1.2).

All parties visiting the Island, inclusive of ship's crew, helicopter crew, senior personnel, observers, etc., should be obliged to agree in writing to the terms of the Code of Conduct and any detailed additions to the Code specifically designed to reduce the environmental impacts of this project. Any breach of the Code should result in severe penalty. The terms of the contract between the DEA, as client, and the construction company, as contractor, should make provision for the enforcement of such penalties.

It is furthermore recommended that a suitable video film be prepared, possibly from existing material, as a medium for briefing all visitors to the Island on the terms and restrictions provided for in the Code of Conduct.

Disturbance of animals, picking of plants, deliberate spread of alien species, removal of geological specimens and/or interference with scientific studies should be forbidden. In order to obviate any likelihood of such disturbance, all personnel including observers and others visiting the Island in connection with any phase of the project should be prohibited from entry to all but the facility area, as delineated in Figure 5.1. The boundary of this project area should be marked in the field. Any movement outside the area should only be allowed on permit from the Environmental Officer.

Recreational visits to places such as Ship's Cove, Bullard Beach, Long Ridge, etc. should be organized and supervised by the Environmental Officer, after consultation with the resident research team.

Control of littering should be rigorously enforced by the Site Engineer and monitored by the Environmental Officers.

5.3.5 Demobilization Phase

Upon completion of the facility, all plant, unused materials, rubble, litter, etc. should be removed from the Island. Great care and expertise will be needed to ensure the adequate rehabilitation of exposed sites.

The extremely slow growth rates of Marion Island's indigenous plants will be a major handicap to any attempt to re-vegetate sites exposed by project activities. In contrast, the aggressive and successful alien weeds grow extremely rapidly. They can be expected to invade all disturbed sites and prevent the establishment and growth of indigenous species at these sites. Many of the exposed peat or soil surfaces, such as those on cuttings through shallow mire on fjaeldmark (Vegetation Unit 13) or fjaeldmark (Vegetation Unit 8), are very unfavourable for the establishment even of alien weeds and it might not be feasible to re-vegetate these surfaces. Consultation with workers in other tundra regions would be necessary to determine suitable techniques.

Accelerated re-vegetation of some surfaces would be possible through the use of artificial fertilizers and substrata, but these conditions also favour alien species or short-lived, indigenous, coprophilous species such as *Montia fontana* and *Callitriche antarctica* which have limited soil-binding qualities.

5.3.6 Operations and Maintenance Phase

5.3.6.1 Impact of buildings and other structures

The physical presence of structures such as the runway, access road, buildings and catwalks will have a deleterious impact on aesthetic aspects of the environment. The wilderness quality of the Island and the atmosphere of pristine isolation will be severely affected by their presence. Equally important, however, is the impact on bird behaviour. Several species, such as Kelp Gull, Skua, Sheathbill and Giant Petrel, become habituated to human presence quite rapidly. This is particularly so if food resources are artificially increased, either from food waste or from the carcasses of night-flying burrowing petrels becoming available around the buildings into which they collide at night.

Catwalks should, whenever possible, be positioned flush with the surface contour. They should not be provided with guide-rails. The erection of fencelines, powerlines, or other isolated or raised structures should be avoided entirely or strictly limited. These structures are extremely hazardous to birds in flight, especially to nocturnal petrels. The boundaries of the facility construction area should be demarcated by means of short but conspicuous marker poles placed at intervals of 10 m, which should be removed at the conclusion of the project.

Lighting around work sites is likely to cause "night-bird attacks" during misty weather conditions. Burrowing petrels, particularly fledglings, are attracted to even weak lights on such nights and ground at or hit buildings and are killed by Skuas. At times the numbers involved can run to hundreds. These birds will not only be those from the Impact Area, but will include individuals from other parts of Marion Island and probably Prince Edward Island as well.

Scavenging species (Giant Petrels, Skuas, Gulls and Sheathbills) will be attracted to buildings and particularly organic wastes. At such sites these birds have an increased tendency to ingest items such as plastics. Human food wastes probably serve as poor substitutes for natural prey when fed to chicks. Reliance upon human food supplies can lead to mortality when these sources are suddenly removed, such as upon completion of the facility.

Birds can also be injured or killed by careless disposal of items such as plastic or wire packing bands, netting, string or fishing line/hooks in which they become entangled. Oil and fuel contaminants around work sites and buildings can be expected to cause fatalities amongst birds, particularly Skuas and Sheathbills.

In the event of the whole facility eventually being abandoned, it should be serviced until all possible sites of erosion or environmental disturbance have been fully rehabilitated, and until all existing structures that can be removed without increasing deleterious impacts have been removed from the Island.

5.3.6.2 Impact of aircraft

The potentially increased numbers of large birds around the ELS will aggrevate the serious hazard of aircraft bird-strikes. Should aircraft using the ELS require overflights in order to assess landing conditions, the noise and turbulence caused by such low-altitude flights could cause panic stampedes in penguin and seal rookeries with high casualty levels.

Should an aircraft crash on landing or take-off, the local impact will be especially severe if fuel spillage into an important stream or lake also occurs. Fire hazard is likely to be low due to the saturated nature of peat, soils and vegetation. The catastrophic impact of a crash into a major breeding seal or bird colony, such as those at Trypot Beach, Archway Bay, Bullard Beach or Kildalkey Bay, is considered too remote a probability to give cause for concern.

Expert opinion on the effect of helicopters flying near or over bird colonies suggests the following effects might occur:

- King Penguins that are not incubating eggs or brooding chicks will attempt to take to the sea by the quickest route. In addition, birds with eggs or small chicks will probably also try to leave if the aircraft is close. Giant Petrels, Skuas and Sheathbills move in and rapidly cause large-scale destruction of deserted chicks and eggs as they recover from the disturbance much more readily and rapidly than the penguins. Chicks are also likely to be trampled by the large-scale panic exodus of adults.

- Gentoo Penguins respond to overflights in a similar manner to King Penguins, but are more timid and the response may be even more extreme and take longer to overcome.

- Macaroni and Rockhopper Penguins are more aggressive birds and respond less dramatically to an overflight, though peripheral birds will take to the sea and some increased chick or egg predation may occur as a result. Imperial Cormorants probably also fall into this category.

- Incubating or brooding surface or cliff nesters such as Sooty Albatrosses and Giant Petrels continue to stay on the egg or chick, except for a few timid individuals. However, loafing or roosting birds usually take off immediately and fly around.

- Burrowing petrels are unlikely to leave burrows due to overflights during the daytime.

The worst-case scenario, assuming frequent use of the ELS over a single summer, is that the season's production of King and Gentoo Penguin chicks within the Impact Area may be severely reduced or eliminated.

5.4 SUMMARY OF MAJOR IMPACTS

The wide range of potential impacts that the proposed project might introduce to the Island's environment and research activities include both direct and indirect, and immediate and longer-term components.

Direct impacts which will be immediately apparent include the major transformation of the boulder beach at Transvaal Cove, the draining of Gentoo Lake, peat and soil slipping and erosion along the access route, the partial filling of Albatross Lake X and drainage of Albatross Lake IX, the removal of the Tom, Dick and Harry scoria cones, the presence of the ELS, and the excavation of an extensive quarry in the black lava flow south of the proposed ELS.

Some very important impacts might take several years or more to manifest themselves. These include the introduction to Marion Island of further species of alien plants, animals or micro-organisms, changes in the hydrology of soils, changes in the distribution, breeding and behavioural interactions of birds and seals, and most critical, the increased probability of invasion by alien biota of Prince Edward Island.

The indirect impacts of the execution of the proposal include an immediate national and international protest against the perceived threats to the Island's pristine quality, a probable negative impact on international cooperation in scientific research on Marion Island and, in the longer term, the dangers inherent in possible increased use of the landing strip and other facilities at Marion Island.

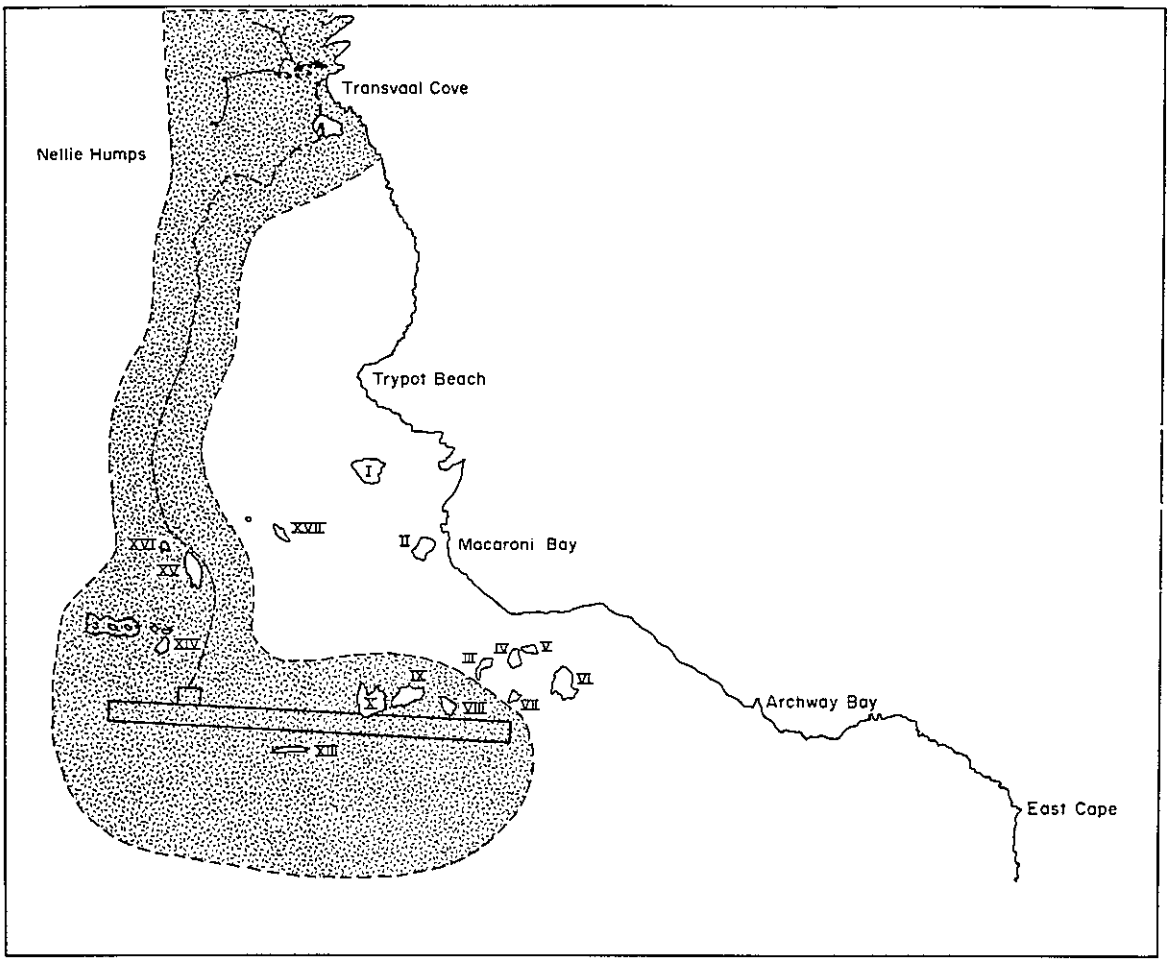


FIGURE 5.1 Map of the Impact Area indicating suggested limits to movement of ELS facility construction personnel.

FIGURE 5.2 Oblique aerial photograph of Transvaal Cove. The Base Station extends seawards along Gunners' Point, which provides a shelter to the northern end of the boulder beach. A channel will be cut through the kelp bed in the deeper waters of the Cove, to give access to a landing ramp to be built on the northern end of the beach. The road to the ELS follows the route marked in black.

FIGURE 5.3 Route from Transvaal Cove to Nellie Humps.

FIGURE 5.4 Wandering Albatross on its nest on the route of the proposed access road above Gentoo Lake. Deep waterlogged peat with *Agrostis magellanica* and moss carpet.

FIGURE 5.5 Gently undulating mosaic of *Blechnum* fern slopes, bogs and mires of Vegetation Unit 15. The access road will pass over shallow *Blechnum* peat on broken black lava.

FIGURE 5.6 Broken black lava covered by *Blechnum* carpet and shallow peat. The Albatross Lakes grey lava moraine forms the planed ridge on the horizon, with Tom, Dick and Harry in right background.

FIGURE 5.7 Trypot stream, immediately above the point at which the route of the access road crosses from Vegetation Units 16 to 8.

FIGURE 5.8 Position of the access route over *Azorella* fjaeldmark (Vegetation Unit 8) on shallow soil. Stony Ridge in distance, with one of the small scoria cones of Tom, Dick and Harry at right.

FIGURE 5.9 Shallow mire on fjaeldmark with Albatross Lakes X and IX in the distance. The approximate position of the ELS is indicated.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

In developing an assessment of the probable environmental impacts of the proposed ELS facility, the Panel considered all expected interactions between project activities and environmental components. The interactions were analysed in terms of their spatial and temporal scales, whether they might be expected to be reversible or irreversible, and whether the impacts would directly or indirectly influence the Island's environment and the attainment of environmental management goals for the Prince Edward Islands. From these considerations the following principal conclusions were drawn:

6.1.1 Direct Impacts on the Island's Environment

6.1.1.1 Physical disturbance

The most obvious impact of the project activities will be the physical disturbance and visual marring of landscape elements. These include:

- The complete replacement of the boulder beach in Transvaal Cove with a landing ramp and stacking area.
- The drainage and transformation of Gentoo Lake.
- Major scarring and probable peat slipping on the slopes to Nellie Humps.
- Removal and destruction of a set of volcanic scoria cones.
- Partial filling of one grey lava lake and drainage of another.
- The removal and replacement of fjaeldmark vegetation on the Albatross Lakes glacial moraine with a concrete or asphalt runway.
- The quarrying of an extensive black lava area.

6.1.1.2 Invasive species

The major increase in the number of people and quantity of material being brought to Marion Island, on a frequent basis and over an extended period, dramatically increases the risk of introducing further invasive alien plants, animals and micro-organisms to the Island. The extremely low species diversity of the Island's biota makes it unusually sensitive to competition from aggressive alien species.

The Island's lowland vegetation is already being substantially transformed due to the rapid expansion of three species of alien plants (see Section 4.4.2). The dispersal of these species would be greatly facilitated by increased numbers of people walking about the Island. The introduced Feral Cat population has dramatically transformed the Island's burrowing avifauna, being recorded as destroying up to 450 000 birds per year (see Sections 4.4.2 and 4.4.4.5). House mice appear to have brought about the extinction on Marion Island of a species of endemic sub-Antarctic moth, while the larvae of a recently introduced moth are inflicting severe damage on the endemic Kergeulen cabbage (see Section 4.4.2).

The risk of additional invasive species being introduced to Prince Edward Island, which is almost completely free of alien species, would also be heightened by changes in the dispersal patterns of alien species already on Marion Island.

6.1.1.3 Disturbance of animals

The continual presence, over a period of up to three years, of large numbers of construction workers, vehicles, blasting activities and noisy machinery, will have significant impacts on animal populations some of which are normally tolerant of short periods of low levels of human disturbance. Strict control of the movement of construction workers will have to be exercised.

The construction of the landing ramp, stacking area and access road will almost certainly cause the few Elephant Seals that still breed or moult in the vicinity of Transvaal Cove to permanently abandon the area. Similarly, continual disturbance on and in the vicinity of the boulder beach will probably cause the Rockhopper Penguins, currently resident among buildings of the Base Station, to abandon the area.

Burrowing petrels will be disturbed, if not killed, by the construction of the access road from Transvaal Cove to the ELS. The numbers affected, perhaps less than 100, are insignificant in terms of the total Island population. More important is the disturbance of several pairs, perhaps as many as a dozen, of Wandering Albatross, whose nests lie on or close to the road and ELS.

One of only two known nesting sites of Antarctic Tern on Marion Island will be destroyed by the road, but it is possible that these birds will move to other similar and apparently suitable nesting sites.

6.1.1.4 Research and monitoring activities.

During the past 20 years South African scientists have made a major and internationally respected contribution to the knowledge of the geology, biology, meteorology and oceanology of the sub-Antarctic.

The construction activities and personnel will unavoidably interrupt, damage or interfere with the Island's research and monitoring programmes. In some cases the presence of large numbers of construction workers and their equipment will disrupt long-term studies which form part of international scientific projects, while in others the need to move further away from the Base Station, beyond the disturbed area, will add considerably to the duration, costs and logistic needs of research projects.

6.1.2 Indirect and Secondary Impacts and Considerations

6.1.2.1 National and international public reaction

The announcement that the South African government is considering the feasibility of constructing an ELS on Marion Island elicited an immediate and overwhelmingly negative response in the media. Over 80 written submissions were received by the Panel from South African research groups involved in the Marion Island scientific programme, and from research or conservation groups throughout the world (see Appendix C). In all cases, the proposal was strongly condemned, while in the majority of cases the nature conservation and research record of the South African effort on Marion Island was applauded. Thus far, no formal representation has been made to the South African government by any other state but, should the project go ahead, it is highly probable that major international pressure will be brought to bear on the government.

6.1.2.2. Questions of aesthetics and of moral principle

The immediate and overwhelming response of all parties consulted on the proposal was one of concern that the wilderness quality of the Island would be destroyed by the construction, maintenance and use of the ELS facility. The expansion of the anthropogenic zone, from the immediate surroundings of the Base Station to the Albatross Lakes area, plus the prospect of much larger and more frequent groups of visitors to the Island, was seen as an invasion of this pristine sanctuary.

The remoteness of sub-Antarctic islands has served to keep them remarkably free of the effects of human disturbance. As such they are of very great scientific interest as 'living laboratories'. Despite this remoteness, however, many of the islands have been subjected to careless animal and plant introductions, the building and abandonment of whaling stations, research or other facilities, spillages of fuel or littering of waste materials. Marion Island is comparatively free of such disturbances, while Prince Edward Island is in an almost totally pristine state. This situation is almost unique for an island group anywhere in the world, and it places considerable responsibility on the South African government to safeguard the environmental quality of the Prince Edward Islands for both national and international scientific communities. This responsibility has been tacitly recognized since the Islands' annexation in 1949, and the construction of the ELS facility would be in conflict with the spirit of the DEA's proposed 'Code of Conduct' for environmental management on the Prince Edward Islands.

6.1.2.3 The financial viability of the proposed facility

The analysis of all costs and benefits resulting from the project, based on conservative estimates of the probabilities of all significant actions, indicates that over a 20 year period the costs will exceed the benefits by more than R18 million, with a benefit/cost ratio of 0,28. The cost estimate does not include the environmental costs described in section 6.1.1. If these costs could be quantified in monetary terms, the costs would exceed benefits by an even greater margin.

6.1.2.4 Soundness of project motivation

The Panel reviewed (see Section 3.1) each of the four reasons given for the construction of the ELS facility, but with only one exception, could find alternative solutions to each case, summarized as follows:

- The use of the ELS for the evacuation of sick or injured personnel could not be guaranteed due to the extremely unfavourable weather regime experienced on the Island. The provision of a medical doctor and adequate medical facilities would be more appropriate.

- Adequate planning in the provision of supplies and services to the Island would obviate the need for emergency provisioning of non-medical supplies.

- The lack of existing or potential marine fisheries within the fishing zone of the Island makes the use of surveillance aircraft to control or monitor fishing activities unnecessary. In the unlikely event of the development of a fisheries industry, patrol ships would be more appropriate.

- The need for an emergency landing site for surveillance aircraft experiencing difficulties in the vicinity of the Island cannot be met feasibly by any option other than the proposed ELS. However, the extremely low probability of a need for, and the risks involved in using, such a landing facility renders the proposal financially non-viable.

6.1.2.5 Increased use of the ELS and of the Island

Although the primary motivation for the ELS limits its use to emergency situations, the mere presence of the facility makes possible its use for other purposes. Even if the increased use was limited to visits by scientists, the risk of introduction of invasive alien species would be increased in proportion to the number of aircraft and visitors landing on the Island. Furthermore, increased frequency of use would result in demands for more conventional air safety facilities, greater permanence of aircraft or airstrip related personnel and, ultimately, the upgrading of the entire facility.

6.1.2.6 Possible additional advantages of the facility

The only additional benefits accruing from the proposed facility that could be identified are:

- The possibility for providing short-term access for senior scientists.
- An improved beach landing facility.
- An improved Base Station.
- Easier access to the Albatross Lakes area.
- Exposure of geological structures through quarrying activities.

None of these additional benefits are regarded significant relative to other considerations.

6.2 RECOMMENDATIONS

The Environmental Impact Assessment Panel, appointed by the Minister of Environment Affairs to consider the environmental implications of the development of an Emergency Landing Strip (ELS) on Marion Island, after full consideration of all aspects of the proposal, of the Island's environmental components, and of direct and indirect consequences of the implementation of the proposal, is of the unanimous opinion that the project should not proceed.

Should the relevant authorities conclude that the project must go ahead, the Panel recommends that:

- The DEA's draft 'Code of Conduct' should be implemented immediately and strictly.

- Environmental Officers approved by SASCAR and having the necessary training, experience and authority, should be appointed to monitor and advise on all environmentally sensitive aspects of project activities. At least one Environmental Officer should be resident on the Island.

- Should there be any deviation greater than 10% from the original specifications for the ELS (length and breadth of runway), for its construction (access road size or length, quarry size, etc), for its use (upgrading to include lights and navigation aids) or for its infrastructure (accommodation for air crew and aircraft), such deviation should be subject to further immediate environmental impact assessment by an independent panel before implementation.

- The judgment of whether a deviation from the project specifications represents more or less than 10% should be the responsibility of the resident Environmental Officer during the construction phase and of SASCAR thereafter. The mitigating action required for deviations judged to be less than 10% in extent should be established, and their implementation overseen, by the resident Environmental Officer.

- All mitigating measures recommended in this report should be implemented fully and properly and should be reviewed regularly as the project proceeds.

- A programme of intensive environmental monitoring in the Impact Area should be implemented immediately the announcement is made to proceed with the project. The monitoring programme should be developed and executed under the guidance of SASCAR. The programme should be continued so that knowledge of the environmental impact of such an action in the sub-Antarctic can be acquired.

- Under no circumstances should Prince Edward Island be visited, other than for strictly limited scientific projects, during the entire period of the ELS facility construction. The long-term protection of the pristine nature of Prince Edward Island should be a primary goal of any management plan for the Prince Edward Islands.

- Consideration be given to the upgrading of medical facilities at the Base Station.

- In conclusion, the Panel recommends that this report be publicly released and submitted to SCAR through SASCAR.

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APPENDIX A

DRAFT CODE OF CONDUCT FOR THE ENVIRONMENTAL PROTECTION OF THE PRINCE EDWARD ISLANDS

INTRODUCTION

The Prince Edward Islands, comprising Marion Island (46°53'S, 37°45'E) and Prince Edward Island (46°36'S, 37°57'E), lie about 2 300 km SE of Cape Town in the South Indian Ocean, only a few degrees of latitude north of the Antarctic Polar Front. South African sovereignty over these Islands was declared on 12 January 1948. The Prince Edward Islands Act No 43 of 1948 of the South African Government entered into force on 7 October 1948.

These Islands and the ocean immediately around them are host to many native species of animals, plants, and ecosystems found rarely or nowhere in the Republic of South Africa. Certain native species of plants and animals, or plant and animal communities and/or associations are either unique to one or both of these Islands, or are found at only a very few other sub-Antarctic islands. Furthermore, some native species, particularly seabirds, occur in greater abundance on one or both Islands than elsewhere in the world.

The presence and activities of man on these Islands, in the form of annual relief teams of scientists and technicians from different academic, scientific, technical and administrative institutions in South Africa, raises the question of the influence such presence and activities have on the environment, and how these can be controlled and minimized? The Sea Birds and Seals Protection Act No 46 of 1973 provides protection to most species of seabirds and seals found at these Islands. This Act, in the case of the Prince Edward Islands, is administered by the Minister of Environment Affairs and of Water Affairs. The Act does not, however, provide for the protection of the terrestrial or marine environments of these Islands. This does not mean that these environments are, therefore, totally unprotected. By virtue of South Africa's membership of the Antarctic Treaty, CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) and SCAR (Scientific Committee on Antarctic Research of the International Council of Scientific Unions) various Treaty, CCAMLR and SCAR sponsored conservation orientated agreements and recommendations therefore apply either directly or in spirit to these Islands.

Being aware of the special, in some cases unique, biological and geological features of these Islands and fragility of their terrestrial and marine environments, the Department of Environment Affairs agrees to implement of its own accord the following Code of Conduct in regard to the activities of man on these Islands. This is done in the desire to ensure that the day-to-day activities of man on the Islands be conducted in harmony with, and with respect for, the environment, and in the spirit of international recommendations to which South Africa has, in good faith, committed itself.

DRAFT CODE OF CONDUCT

1. AREA

The area to which this Code of Conduct is applicable shall comprise all the ground exposed above average mean sea level in the Prince Edward Islands Territory, as defined by the Prince Edward Islands Act No 43 of 1948, and the surrounding ocean within 200 nautical miles from the coastlines of both Islands.

2. CONSTRUCTION AND MAINTENANCE ACTIVITIES

(a) At the site, being a 1 km^2 area abutting the coast and centred about the main living complex known as Marion House, adjacent to Gunner's Point, Marion Island, occupied by the present base station on Marion Island, all essential construction, demolition and maintenance activities, including the erection of antennae etc., could proceed as required, on the understanding and on condition that;

(i) those responsible for any form of construction and maintenance at this site ensure that, prior to their departure, the whole site is cleaned of all debris arising from their activities; and

(ii) all debris be disposed of according to paragraph 3 below.

(b) No construction of any form of permanent installation shall be undertaken outside the site defined in 2(a) without the specific authority of the Department of Environment Affairs. Such authority may only be granted after consideration of an environmental impact assessment of the proposed construction, conducted by persons, nominated by the Department of Environment Affairs, who are competent to evaluate the need for, and the ecological impact of the proposed construction.

The persons responsible for the construction shall -

(i) abide by the conditions set out in such authorization by the Department of Environment Affairs;

(ii) take all reasonable steps to minimize damage to and general pollution of the local environment at the site during construction and subsequent maintenance, and on and alongside the access and supply routes to the site;

(iii) on completion of construction work remove all debris and restore the immediate environment around the installation and access/supply routes to as near natural conditions as is possible; and

(iv) abide by the judgement of the leader of the overwintering team in the event of dispute as to the meaning in practice of the conditions of the authorization.

(c) No temporary or movable installation, not related to 2(a) above, may be sited or erected except with the express and specific permission of the leader of the overwintering team, which permission shall only be granted after full consultation with those requesting or likely to use such facility for bona fide reasons in accordance with the official purpose of the expedition.

Such installation shall in any case not be placed in a position where it will damage, alter or disturb, or during its transport or placement cause undue disturbance or damage to -

(i) short- or long-term study sites of animal or plant communities, populations or associations;

(ii) designated protected areas as defined in 6 and 7 below;

(iii) the natural (actual or potential) flow of fresh or salt water;

(iv) bird flyways and walkways, and seal pathways.

Redundant installations (e.g. buildings, catwalks, fences, marker poles, hides, pipelines, cables, antennae, etc.) shall be removed and the site(s) or route(s) occupied by them shall be cleaned of all debris. Those responsible for original installation shall also be responsible for the clearance and restoration of the site(s) or route(s) concerned.

3. DISPOSAL OF WASTE MATERIAL AND PREVENTION OF POLLUTION

The South African activities at the Prince Edward Islands shall not lead to undue, unsightly or irreversible pollution or marring of the environment, nor to the build-up of waste and debris on the Islands.

Specifically:

(a) All general debris (e.g. from construction sites wherever these may be, the base station site, field huts, camp sites, study areas and sites, etc.) excluding plastics and rubber products, shall be collected and incinerated, or compacted or otherwise repackaged at the base station for transfer to the ship. Plastics and rubber products shall at all times be repackaged for transport back to the Republic.

If it is not possible to return burnable debris, except plastics and rubber products, to the base station or ship for incineration, on site incineration shall be done in such a way that there is no danger of grass or peat fires, or destruction of or disturbance to bird or seal colonies, or nearby SPA's or SSSI's.

(b) Kitchen slop and sewage from the base station shall be discharged directly into the ocean and such discharge shall take place at a site as indicated from time to time by the leader of the overwintering team.

(c) All radioactive waste and used batteries shall be suitably packaged and returned to the Republic for disposal through the user's home base disposal system for these wastes.

(d) All wastes containing high levels of heavy metals and/or harmful persistent organic compounds shall be repackaged for transport back to the Republic.

(e) Compacted or otherwise repackaged debris and wastes shall not be dumped into the ocean closer to the Islands than 50 nautical miles from their coastlines (see also 9(b) below) provided that repackaged plastics and rubber products as well as the waste and batteries referred to in paragraphs 3(c) and (d) above shall under no circumstances be dumped into the ocean.

4. TOURISM AT THE PRINCE EDWARD ISLANDS

Tourism at the Prince Edward Islands shall only be allowed under permit of the Department of Environment Affairs after consultation with the Interdepartmental Antarctic Committee, because -

(a) it is necessary to devote all available resources, including domestic facilities and search and rescue services, primarily to the conduct of official meteorological and research activities;

(b) the domestic facilities available at the base station are sufficient only for those engaged in official meteorological and research activities; and

(c) the fragility of the Island ecosystems necessitates a limitation upon the number of persons present on the Islands.

5. PROTECTION AND CONSERVATION OF FAUNA AND FLORA

The South African activities at the Prince Edward Islands shall be conducted in accordance with the Agreed Measures for the Conservation of Antarctic Fauna and Flora, (see Addendum A) in accordance with Rec. XVII-BIOL.-2 SCAR of the Seventeenth meeting of SCAR, Leningrad, 1982.

Furthermore:

(a) The killing or collecting of live birds and seals shall be prohibited, except by permit issued by the Minister of Environment Affairs and of Water Affairs, or the Director General: Environment Affairs or his delegate, in accordance with the Sea Birds and Seals Protection Act, 1973 (Act No 46, 1973).

(b) No fauna shall be killed or captured and removed from the Islands save under permit issued by the Department of Environment Affairs after consultation with the Antartic Management Committee.

(c) Reference material collected on the Islands for scientific studies, and which is no longer required by the collector, shall be deposited at institutions selected by SASCAR, for safekeeping. A list of the relevant institutions with which SASCAR has concluded suitable agreements for the housing of reference material is given in Addendum B.

(d) In the absence of a permit no person on the Prince Edward Islands or inside the 200 nautical mile marine area shall be allowed wilfully to destroy, harm, molest, interfere with or disrupt any native terrestrial or marine animal or plant, or native animal or plant community. The leader of the expedition team and/or leaders of groups of persons present on the Islands and/or the Masters of visiting ships shall be responsible for preventing this or for reporting such behaviour to the Department of Environment Affairs (through the leader of the expedition team where possible) for further action to be taken.

(e) No live alien fauna or flora (except fresh vegetables for human consumption) or their propagules shall be introduced onto Marion and Prince Edward Island, and the following shall at all times receive priority attention:

(i) All supplies and equipment destined for Marion or Prince Edward Island shall be packed in an environment which is maintained free of alien fauna (e.g. rats) and flora or their propagules (e.g. seeds).

(ii) All containers shall be suitably sealed so that alien fauna or flora or their propagules are not able to enter them and thereby be transported to the Islands, or between the Islands.

(iii) All necessary precautions shall be taken to prevent the transfer of fauna and flora or their propagules from Marion Island to Prince Edward Island or vice versa (see 5(e)(i) and 5(e)(ii) above, and 8(c) below).

6. SPECIALLY PROTECTED AREAS (SPA's)

Selected areas within the whole area covered by this Code of Conduct may by proclamation be accorded full or partial protection from human activities. Traffic through, in or over these areas by foot or aircraft shall be confined to those activities permitted by the proclamation or necessitated by rescue activities only, and access routes (by air or land) between other parts of the Island and the base station shall not pass through or over selected areas except in cases of emergency. *Bona fide* activities within selected areas shall be conducted on foot only, and field huts may not be situated within such areas.

Furthermore:

(a) The proclamation and deproclamation of SPA's shall be authorized by the Department of Environment Affairs on the recommendation of the Interdepartmental Antarctic Committee (IAC) and the Antarctic Management Committee.

(b) Recommendations for proclamation or deproclamation shall be submitted to the Antarctic Management Committee by 31 July each year, and shall be accompanied by the following details:-

  (i) A precise description of the area and its boundaries including a map showing all salient features of the area.

  (ii) A precise description of the reason(s) why proclamation or deproclamation is being recommended.

  (iii) A recommendation as to what human activities, if any, should be allowed within the SPA.

  (iv) The full name(s) and signature(s) of the proposer(s) and the date of the proposal.

(c) An area may be proclaimed a SPA on either an all year round or a seasonal basis such that it enjoys the protection accorded to it permanently or seasonally, until deproclamation.

(d) Descriptions of all SPA's shall be kept at the base station for public inspection, incorporated into the Project Leaders Manual of the Department of Environment Affairs, and be freely available from the Department of Environment Affairs.

7. SITES OF SPECIAL SCIENTIFIC INTEREST (SSSI's)

The features (i.e. sites as opposed to areas) of special significance to scientists, conservationists or historians, shall by proclamation be protected against all forms of destructive human interference. Access to such sites will be confined only to those directly concerned with bona fide investigations within them. Such sites may be protected on a long- or short-term basis depending upon the reason(s) for which such protection is desirable.

Furthermore:

(a) The proclamation and deproclamation of such sites shall be authorized by the Department of Environment Affairs on the recommendation of the Interdepartmental Antarctic Committee (IAC) and the Antarctic Management Committee.

(b) Recommendations for proclamation or deproclamation shall be submitted to the Antarctic Management Committee by 31 July each year, and shall be accompanied by -

(i) a precise description of the feature and its site boundaries, including a map and if necessary a photographic illustration of the feature and/or site;

(ii) a precise description of the reason(s) why proclamation or deproclamation is being recommended;

(iii) a recommendation as to what human activities, if any, should be allowed within the SSSI; and

(iv) the full name(s) and signature(s) of the proposer(s), and the date of the proposal.

(c) Descriptions of all SSSI's shall be kept at the base station for public inspection, incorporated into the Project Leaders Manual of the Department of Environment Affairs, and be freely available from the Department of Environment Affairs on request.

8. AVIATION OPERATIONS AT THE PRINCE EDWARD ISLANDS

Landing sites, and flight routes and flying altitudes shall at all times be chosen to minimize disturbance of or damage to native animal colonies, except in the case of emergencies.

Furthermore:

(a) No landing at or in, or overflying of, SPA's or SSSI's shall occur, except in the case of emergencies.

(b) No flying about, around and between the Islands for 'sightseeing' purposes shall be permitted.

(c) Crew and passenger footwear and protective clothing and their equipment, cargo cabins and spaces, wheels and other under-carriage structures shall be clean and inspected for freedom of alien plants and animals and their propagules before landings on Prince Edward Island are made.

9. SHIP AND BOAT OPERATIONS AT THE PRINCE EDWARD ISLANDS

Anchor sites, landing sites and steaming routes around and between the Islands shall be chosen to minimize disturbance of or damage to all kelp beds, marine SPA's and SSSI's, and the inshore areas off major animal breeding colonies, except in the case of emergencies.

Furthermore:

(a) Adequate measures to prevent the spillage of fuel during fuel transfer from ship to shore by pipeline shall be implemented at all times; and spillages shall be immediately cleaned using tested methods known to cause minimal damage to the environment; and spillages in excess of 200 l shall be reported to the Department of Environment Affairs.

(b) No dumping overboard of waste material or debris, with the exception of kitchen slop and sewage, shall take place within 50 nautical miles of the Islands and waste material that is dumped beyond 50 nautical miles shall be packaged in a form that ensures it to sink immediately on being dumped.

(c) Kitchen slop and sewage shall be discharged overboard only between sunset and sunrise and not closer than three nautical miles from the Island's coastlines and to the lee of the Islands.

(d) All necessary measures shall be taken to ensure that the South African relief-ship is at all times free of rats, mice and insect pests (e.g. cockroaches); places where live animals are penned or caged be properly cleaned and disinfected upon the removal of the animals.

(e) All radioactive waste and batteries shall be suitably packaged and returned to the home port of the particular vessel for disposal through the user's home base disposal system for these wastes.

(f) All waste containing high levels of heavy metals and/or harmful persistent organic compounds shall be repackaged for transport back to the home port of the particular vessel.

(g) Plastics and rubber waste products shall not be dumped overboard, or incinerated unless the ship's incinerators are fitted with exhaust emmission quality control apparatus. Alternatively such waste products shall be repackaged and returned to the home port or next port of call.

10. CONTRAVENTIONS

Any contravention of the Agreed Measures in this Code of Conduct shall be reported in writing, within 24 hours of the contravention, to the leader of the expedition team, or the Senior Scientist, or the Departmental Co-ordinator of the take-over, or the Masters of visiting ships. In turn these persons shall report the matter to the Department of Environment Affairs (through the leader of the expedition team) at the first available opportunity for any further action necessary.

11. ACCEPTANCE

This Code of Conduct was accepted for immediate implementation by the Department of Environment Affairs on the recommendation of the Interdepartmental Antarctic Committee.

DIRECTOR GENERAL
DATE :

AGREED MEASURES FOR THE CONSERVATION OF ANTARCTIC FAUNA AND FLORA

III-VIII

AGREED MEASURES FOR THE CONSERVATION OF ANTARCTIC FAUNA AND FLORA

The Representatives, taking into consideration Article IX of the Antarctic Treaty, and recalling Recommendation I-VIII of the First Consultative Meeting and Recommendation II-II of the Second Consultative Meeting, recommend to their Governments that they approve as soon as possible and implement without delay the annexed "Agreed Measures for the Conservation of Antarctic Fauna and Flora."

AGREED MEASURES FOR THE CONSERVATION OF ANTARCTIC FAUNA AND FLORA

PREAMBLE

The Governments participating in the Third Consultative Meeting under Article IX of the Antarctic Treaty,

> Desiring to implement the principles and purposes of the Antarctic Treaty;
>
> Recognizing the scientific importance of the study of Antarctic fauna and flora, their adaptation to their rigorous environment, and their inter-relationship with that environment;
>
> Considering the unique nature of these fauna and flora, their circumpolar range, and particularly their defencelessness and susceptibility to extermination;
>
> Desiring by further international collaboration within the framework of the Antarctic Treaty to promote and achieve the objectives of protection, scientific study, and rational use of these fauna and flora; and
>
> Having particular regard to the conservation principles developed by the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions;

Hereby consider the Treaty Area as a Special Conservation Area and have agreed on the following measures:

ARTICLE I

(Area of application)

1. These Agreed Measures shall apply to the same area to which the Antarctic Treaty is applicable (hereinafter referred to as the Treaty Area) namely the area south of 60° South Latitude, including all ice shelves.

2. However, nothing in these Agreed Measures shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regard to the high seas within the Treaty Area, or restrict the implementation of the provisions of the Antarctic Treaty with respect to inspection.

3. The Annexes to these Agreed Measures shall form an integral part thereof, and all references to the Agreed Measures shall be considered to include the Annexes.

ARTICLE II

(Definitions)

For the purposes of these Agreed Measures:

(a) "Native mammal" means any member, at any stage of its life cycle, of any species belonging to the Class Mammalia indigenous to the Antarctic or occurring there through natural agencies of dispersal, excepting whales.

(b) "Native bird" means any member, at any stage of its life cycle (including eggs), of any species of the Class Aves indigenous to the Antarctic or occurring there through natural agencies of dispersal.

(c) "Native plant" means any kind of vegetation at any stage of its life cycle (including seeds), indigenous to the Antarctic or occurring there through natural agencies of dispersal.

(d) "Appropriate authority" means any person authorized by a Participating Government to issue permits under these Agreed Measures.

"The functions of an authorized person will be carried out within the framework of the Antarctic Treaty. They will be carried out exclusively in accordance with scientific principles and will have as their sole purpose the effective protection of Antarctic fauna and flora in accordance with these Agreed Measures."

(e) "Permit" means a formal permission in writing issued by an appropriate authority as defined at paragraph (d) above.

(f) "Participating Government" means any Government for which these Agreed Measures have become effective in accordance with Article XIII of these Agreed Measures.

ARTICLE III

(Implementation)

Each Participating Government shall take appropriate action to carry out these Agreed Measures.

ARTICLE IV

(Publicity)

The Participating Governments shall prepare and circulate to members of expeditions and stations information to ensure understanding and observance of the provisions of these Agreed Measures, setting forth in particular prohibited activities, and providing lists of specially protected species and specially protected areas.

ARTICLE V

(Cases of extreme emergency)

The provisions of these Agreed Measures shall not apply in cases of extreme emergency involving possible loss of human life or involving the safety of ships or aircraft.

ARTICLE VI

(Protection of native fauna)

1. Each Participating Government shall prohibit within the Treaty Area the killing, wounding, capturing or molesting of any native mammal or native bird, or any attempt at any such act, except in accordance with a permit.

2. Such permits shall be drawn in terms as specific as possible and issued only for the following purposes:

(a) to provide indispensable food for men or dogs in the Treaty Area in limited quantities, and in conformity with the purposes and principles of these agreed Measures;

(b) to provide specimens for scientific study or scientific information;

(c) to provide specimens for museums, zoological gardens, or other educational or cultural institutions or uses.

3. Permits for Specially Protected Areas shall be issued only in accordance with the provisions of Article VIII.

4. Participating Governments shall limit the issue of such permits so as to ensure as far as possible that:

(a) no more native mammals or birds are killed or taken in any year than can normally be replaced by natural reproduction in the following breeding season;

(b) the variety of species and the balance of the natural ecological systems existing within the Treaty Area are maintained.

5. The species of native mammals and birds listed in Annexure A of these Measures shall be designated "Specially Protected Species", and shall be accorded special protection by Participating Governments.

6. A Participating Government shall not authorize an appropriate authority to issue a permit with respect to a Specially Protected Species except in accordance with paragraph 7 of this Article.

7. A permit may be issued under this Article with respect to a Specially Protected Species, provided that:

(a) it is issued for a compelling scientific purpose, and

(b) the actions permitted thereunder will not jeopardize the existing natural ecological system or the survival of that species.

ARTICLE VII

(Harmful interference)

1. Each Participating Government shall take appropriate measures to minimize harmful interference within the Treaty Area with the

normal living conditions of any native mammal or bird, or any attempt at such harmful interference, except as permitted under Article VI.

2. The following acts and activities shall be considered harmful interference:

   (a) allowing dogs to run free,

   (b) flying helicopters or other aircraft in a manner which would unnecessarily disturb bird and seal concentrations, or landing close to such concentrations (e.g. within 200 m),

   (c) driving vehicles unnecessarily close to concentrations of birds and seals (e.g. within 200 m),

   (d) use of explosives close to concentrations of birds and seals,

   (e). discharge of firearms close to bird and seal concentrations (e.g. within 300 m).

   (f) any disturbance of bird and seal colonies during the breeding period by persistent attention from persons on foot.

   However, the above activities, with the exception of those mentioned in (a) and (e) may be permitted to the minimum extent necessary for the establishment, supply and operation of stations.

3. Each Participating Government shall take all reasonable steps towards the alleviation of pollution of the waters adjacent to the coast and ice shelves.

ARTICLE VIII

(Specially Protected Areas)

1. The areas of outstanding scientific interest listed in Annex B (which describes SPA's currently in existence and which is not included here for reasons of brevity) shall be designated "Specially Protected Areas" and shall be accorded special protection by the Participating Governments in order to preserve their unique natural ecological system.

2. In addition to the prohibitions and measures of protection dealt with in other Articles of these Agreed Measures, the Participating Governments shall in Specially Protected Areas further prohibit:

(a) the collection of any native plant, except in accordance with a permit;

(b) the driving of any vehicle;

(c) entry by their nationals, except in accordance with a permit issued under Article VI or under paragraph 2(a) of the present Article or in accordance with a permit issued for some other compelling scientific purpose.

3. A permit issued under Article VI shall not have effect within a Specially Protected Area except in accordance with paragraph 4 of the present Article.

4. A permit shall have effect within a Specially Protected Area provided that:

(a) it was issued for a compelling scientific purpose which cannot be served elsewhere; and

(b) the actions permitted thereunder will not jeopardize the natural ecological system existing in that Area.

ARTICLE IX

(Introduction of non-indigenous species, parasites and diseases)

1. Each Participating Government shall prohibit the bringing into the Treaty Area of any species of animal or plant not indigenous to that Area, except in accordance with a permit.

2. Permits under paragraph 1 of this Article shall be drawn in terms as specific as possible and shall be issued to allow the importation only of the animals and plants listed in Annex C. When any such animal or plant might cause harmful interference with the natural system if left unsupervised within the Treaty Area, such permits shall require that it be kept under controlled conditions and, after it has served its purpose, it shall be removed from the Treaty Area or destroyed.

3. Nothing in paragraphs 1 and 2 of this Article shall apply to the importation of food into the Treaty Area so long as animals and plants used for this purpose are kept under controlled conditions.

4. Each Participating Government undertakes to ensure that all reasonable precautions shall be taken to prevent the accidental introduction of parasites and diseases into the Treaty Area. In particular, the precautions listed in Annex D shall be taken.

ARTICLE X

(Activities contrary to the principles and purposes of these Measures)

Each Participating Government undertakes to exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity in the Treaty Area contrary to the principles or purposes of these Agreed Measures.

ARTICLE XI

(Ships' crews)

Each Participating Government whose expeditions use ships sailing under flags of nationalities other than its own shall, as far as feasible, arrange with the owners of such ships that the crews of these ships observe these Agreed Measures.

ARTICLE XII

(Exchange of information)

1. The Participating Governments may make such arrangements as may be necessary for the discussion of such matters as:

   (a) the collection and exchange of records (including records of permits) and statistics concerning the numbers of each species of native mammal and bird killed or captured annually in the Treaty Area;

   (b) the obtaining and exchange of information as to the status of native mammals and birds in the Treaty Area, and the extent to which any species needs protection;

   (c) the number of native mammals or birds which should be permitted to be harvested for food, scientific study, or other uses in the various regions;

   (d) the establishment of a common form in which this information shall be submitted by Participating Governments in accordance with paragraph 2 of this Article.

2. Each Participating Government shall inform the other Governments in writing before the end of November of each year of the steps taken and information collected in the preceding period of 1st July to 30th June relating to the implementation of these Agreed

Measures. Governments exchanging information under paragraph 5 of Article VII of the Antarctic Treaty may at the same time transmit the information relating to the implementation of these Agreed Measures.

ARTICLE XIII

(Formal Provisions)

1. After the receipt by the Government designated in Recommendation I-XIV (5) of notification of approval by all Governments whose representatives are entitled to participate in meetings provided for under Article IX of the Antarctic Treaty, these Agreed Measures shall become effective for those Governments.

2. Thereafter any other Contracting Party to the Antarctic Treaty may, in consonance with the purposes of Recommendation III-VII, accept these Agreed Measures by notifying the designated Government of its intention to apply the Agreed Measures and to be bound by them. The Agreed Measures shall become effective with regard to such Governments on the date of receipt of such notification.

3. The designated Government shall inform the Governments referred to in paragraph 1 of this Article of each notification of approval, the effective date of these Agreed Measures and of each notification of acceptance. The designated Government shall also inform any Government which has accepted these Agreed Measures of each subsequent notification of acceptance.

ARTICLE XIV

(Amendment)

1. These Agreed Measures may be amended at any time by unanimous agreement of the Governments whose Representatives are entitled to participate in meetings under Article IX of the Antarctic Treaty.

2. The Annexes, in particular, may be amended as necessary through diplomatic channels.

3. An amendment proposed through diplomatic channels shall be submitted in writing to the designated Government which shall communicate it to the Governments referred to in paragraph 1 of the present Article for approval; at the same time, it shall be communicated to the other Participating Governments.

4. Any amendment shall become effective on the date on which notifications of approval have been received by the designated Government and from all of the Governments referred to in paragraph 1 of this Article.

5. The designated Government shall notify those same Governments of the date of receipt of each approval communicated to it and the date on which the amendment will become effective for them.

6. Such amendment shall become effective on the same date for all other Participating Covernments, except those which before the expiry of two months after that date notify the designated Government that they do not accept it.

ANNEXES TO THESE AGREED MEASURES

ANNEX A

Specially Protected Species

All species of the genus *Arctocephalus*, Fur Seals.
Ommatophoca rossi, Ross Seal.

ANNEX C

Importation of animals and plants

The following animals and plants may be imported into the Treaty Area in accordance with permits issued under Article IX(2) of these Agreed Measures:

(a) sledge dogs,
(b) domestic animals and plants,
(c) laboratory animals and plants including viruses, bacteria, yeasts and fungi.

ANNEX D

Precautions to prevent accidental introduction of parasites and diseases into the Treaty Area

The following precautions shall be taken:

1. Dogs: All dogs imported into the Treaty Area shall be inoculated against the following diseases:

   (a) distemper;
   (b) contagious canine hepatitis;
   (c) rabies;
   (d) leptospirosis (*L. canicola* and *L. icterohaemorrhagicae*).

   Each dog shall be inoculated at least two months before the time of its arrival in the Treaty Area.

2. Poultry: Notwithstanding the provisions of Article IX(3) of these Agreed Measures, no living poultry shall be brought into the Treaty Area after 1st July, 1966.

CODE OF CONDUCT - ADDENDUM B

The following institutions in the Republic of South Africa have agreed to act as depositories for suitable reference material collected at the Prince Edward and Gough Islands, or in Antarctica:

Transvaal Museum	all major reference collections of mammals, birds and insects.
South African Museum	all major reference collections of fish and marine and terrestrial invertebrates (excluding the Insecta and Acarinae).
Albany Museum	all major reference collections of freshwater invertebrates.
National Herbarium	all major reference collections of plant material, including freshwater and marine phytoplankton, freshwater algae, Bryophyta, Pteridophyta, Phenerogams and Lichens.
Plant Protection Research Institute	all major reference collections of fungi.
Sea Fisheries Research Institute	all major reference collections of macrophytic marine algae.
National Museum	all major reference collections of Acarinae.

Suitable reference material being sent to the above institutions must be accompanied by the following basic supporting data:

- Higher Taxonomic Groups (Phylum to Family)
- Genus, Species and Author
- Type Status
- Number of Specimens Collected
- Name and Address of Collector
- Date of Collection
- Place of Collection (coordinates and locality name)
- Habitat Type and Altitude or Depth
- Name of Identifying Authority
- Nature of Specimen (e.g. skin, skull, whole organism etc.)
- Notes (e.g. sex, size, condition etc.)
- Publications arizing from studies on the collected material.

APPENDIX B

INFORMATION SHEET

THE PROPOSED LANDING STRIP ON MARION ISLAND

BACKGROUND

The Prince Edward Islands, comprising Marion Island (290 km²) and Prince Edward Island (44 km²) lie some 19 km apart at approximately 47°S, 38°E in the south Indian Ocean. They are part of the Republic of South Africa, sovereignty being declared through annexation in January 1948. A station, initially for meteorological observations, has been maintained on Marion Island since annexation. From the mid-1960s the station has developed gradually into what is today a well equipped scientific station capable of supporting up to 30 persons over-winter, and nearly double that number for shorter periods of time such as during the two annual relief periods lasting up to six weeks each. Scientific research on and around the Islands is organized and supported logistically under the auspices of the South African National Antarctic Research Programme (SANARP).

THE PROPOSAL

The Department of Environment Affairs (DEA), which is responsible for the administration of the Prince Edward Islands territory and whose Antarctic Division is responsible for the logistic support of the South African National Antarctic Research Progamme (SANARP), proposed the construction of a landing strip on Marion Island. The reasons that have been given for this by the DEA are:

1. To provide rapid attention to or evacuation of injured or sick personnel.

2. To provide surveillance and rescue aircraft with an alternative landing place.

3. To enable better control of territorial waters and the fishing zone around the Islands.

4. To enable provisioning of the station with emergency supplies.

and the motivations are the following;

- during the four years up to and including 1985 it was necessary to conduct four evacuations of sick/injured persons by ship, and one parachute drop of emergency medical supplies,
- the Cape Sea Route is an important and busy one. While most passages around the Cape take place within about 100 nautical miles of the coast some, especially yachts not calling at Cape Town, prefer a more southerly passage,
- volcanic activity resumed on Marion Island in 1980, this being the first known activity in living memory. Significant though not major outpourings of lava occurred in the central upper and western coastal regions of Marion Island. The base station is on the coast on the eastern side and was not in any way threatened by these outpourings. However, since the Islands lie on an active fracture zone in the ocean floor, hence their existence in the first place, it is reasonable to expect further activity sooner or later,
- an alternative landing place for search and rescue aircraft has been a long felt need.

A preliminary feasibility study by a firm of consulting civil engineers has been undertaken. A possible site for a runway (1 400 - 1 800 m long, 30 m wide) to cater for aircraft up to the size of a Hercules C130 transport plane, was identified on Marion Island. It lies a few kilometres south of the station atop a stony ridge south of and above the 'Albatross Lakes' area.

ENVIRONMENTAL IMPACT ASSESSMENT

The DEA has commissioned an independent environmental impact assessment, to be conducted prior to a decision being taken on whether to proceed or not with the proposal (see attached press statement by the Minister for Environment and Water Affairs, 29 December 1986).

A 5-member Panel has been formed to conduct this. Its members are Dr G Heymann (convenor of the Panel and Chairman of SA's SCAR National Committee), Prof T Erasmus (zoologist), Mr B J Huntley (ecologist), Prof G de F Retief (coastal and ocean engineer) and Dr A C Liebenberg (consulting marine and civil engineer). The Antarctic Programme office of the Foundation for Research Development (FRD) of the Council for Scientific and Industrial Research (CSIR) will provide the support services for the Panel, the persons responsible for this being Dr P R Condy and Mr O A van der Westhuysen.

The procedure being followed by the Panel is as follows:

1. Submissions to the Panel on the proposal have been invited from some 30 sources (individuals and groups) who are or have been engaged in activities (scientific or logistical) at the Islands over the past 10 - 15 years. These include biologists (botanists, entomologists, limnologists, mammalogists, marine biologists, ornithologists), engineers, geologists, volcanologists, geophysicists, logisticians and meteorologists.

2. The Panel and various other technical experts (aviation experts, design and construction engineers, etc.) will visit the Island for 7-10 days in February 1987 for on site inspections.

3. The Panel will hold discussions with members of current and past expeditions to the Island, and with other persons/parties as the need arises.

4. In the light of its findings through 1 to 3 above and its examination of the reasons given for the proposal, the Panel will submit its report to DEA in March 1987.

It is the intention that the Panel's report will be subjected to independent review ('audit') by an invited expert. His report will be submitted independently to DEA. This process is expected to take place in March/April 1987.

Thereafter, the DEA is expected to make a decision on whether or not to proceed with the proposal, and if so how and under what environmental controls.

The Panel's report, as well as that of the independent reviewer, will not be confidential though common courtesy requires that they be submitted to DEA before public release by the DEA.

G HEYMANN
Panel Chairman

IMPACT EVALUATION OF A POSSIBLE LANDING FACILITY ON MARION ISLAND

As a result of confusing reports which have appeared in the media, I consider it necessary to clarify the situation and place matters in perspective.

The responsibility for Marion Island and related functions were transferred to the Department of Environment Affairs during October 1985. An aspect which received the early attention of the new management was the high costs involved in servicing the Island in emergency situations. During the past 4 years it was necessary to mount four emergency voyages.

The Department is also responsible for the control of fishing in South African waters. The fishing zone around Marion Island, which is South African territory, receives very little attention at present and control in the zone must of necessity be upgraded to a considerable extent. It is also clear that much more information is required about the fishing potential of that region. It seems likely that people will in future pay more regular visits to the Island and that the need for better and more reliable contact will be of growing importance. Furthermore search and rescue operations necessitate that a thorough study be made of the possibility of providing a usable landing facility in the area

For some time now the idea of providing a landing strip of some sort on the Island has been bandied about, particularly with a view to facilitating the movement of personnel. Because I am aware of the sensitivity of the environment of Marion Island, I approved, as a first step, that a thorough ecological evaluation of the construction of a landing strip on Marion Island be undertaken.

Consequently I decided that an environmental impact evaluation should be done completely independent of the Department. To this end a Working Group of recognized scientists from various disciplines has been established, one of whom is from abroad. The Working Group is under the leadership of Dr G Heymann, Vice President of the CSIR and chairman of the South African Scientific Committee for Antarctic Research.

I wish to emphasize that the findings of the Working Group will be decisive in the decision-making process as to whether a landing facility will be provided or not on Marion Island.

ISSUED BY MINISTER J W E WILEY,
MINISTER OF ENVIRONMENT AFFAIRS AND OF WATER AFFAIRS
29 DECEMBER 1986

APPENDIX C

LIST OF SUBMISSIONS TO THE EIA PANEL

1. Submissions Invited by the Panel

SUBMISSION AUTHOR	ASSOCIATION OR CAPACITY
Prof J R Grindley	On behalf of the Habitat Council of South Africa.
Prof W J Verwoerd	Dept of Geology, Stellenbosch University.
Prof W R Siegfried, Messrs J Cooper, N J Adams, C R Brown & B P Watkins	Percy FitzPatrick Institute for African Ornithology, University of Cape Town.
Dr G A Robinson	National Parks Board.
Prof V R Smith	Dept of Botany, University of the Orange Free State, Bloemfontein.
Prof C H Scholtz & Mr J E Crafford	Dept of Entomology, University of Pretoria.
Prof G M Branch	Dept of Zoology, University of Cape Town.
Mr G H Stander	Sea Fisheries Research Institute, Dept of Environment Affairs, Cape Town.
Prof B R Allanson	Dept of Zoology and Entomology, Rhodes University, Grahamstown.
Prof J U Grobbelaar	Unit for Limnology, Dept of Botany, University of the Orange Free State, Bloemfontein.
Drs G J B Ross & N Klages	Port Elizabeth Museum.
Dr P R Sutcliffe	Magnetic Observatory of the CSIR, Hermanus.
Mr J G Nel	Personal, Pretoria.
Dr A E F Heydorn	On behalf of the South African Council for the Environment.

Prof J D Skinner	Mammal Research Institute, University of Pretoria.
Mr P S du Toit	South African Weather Bureau, Dept of Environment Affairs, Pretoria.
Messrs D M T Newham, K W Jacobs, A K Siebert & J K Thiart	Dept of Public Works and Land Affairs, Pretoria.
Mr R W Vice	National Institute for Telecommunications Research of the CSIR, Johannesburg.
Prof R Fuggle	Chairman, Environmental Evaluation Committee, South African Council for the Environment.
M Bennett and two colleagues	Marion 43 expedition team (1986).
Mr S L Chown	Entomologist, Marion 43 expedition team (1986).
Dr S Hunter	Ornithologist, Marion 43 expedition team (1986).
Dr M N Bester & Mr I S Wilkinson	Mammalogists, Marion 43 expedition team (1986).
Drs P Ashton, R D Robarts, R J Wicks & Messrs A C Jarvis & L M Sephton	National Institute for Water Research of the CSIR, Pretoria.
Prof W J Verwoerd & Dr L Chevallier	Dept of Geology, University of Stellenbosch.
The Director-General	Dept of Foreign Affairs, Pretoria.

2. Unsolicited Submissions Received by the Panel by 13 April 1987

Dr C Imboden	Director, International Council for Bird Preservation (ICBP), Cambridge, England.
Dr E A Zaloumis	President, Wildlife Society of Southern Africa, Johannesburg.
Dr J A Burton	Executive Secretary, Fauna & Flora Preservation Society, London.

Dr A E Burger	Ornithologist, Marion expedition teams 1974, 1976 and 1978.
Dr D Hey	Chairman, South African National Section, ICBP, Cape Town.
Dr J A Ledger	Director, Endangered Wildlife Trust, Johannesburg.
Dr V S Carruthers	Chairman, S A Ornithological Society (SAOS), Johannesburg.
W K Steele	Ornithologist, Marion 41 expedition team (1984).
Mr T Harris	Dept Birds, Transvaal Museum, Pretoria.
Dr P Jouventin	Director, Biological Studies Centre, C.N.R.S., France.
Dr R Schreiber	Chairman, Seabird Specialist Group, ICBP, Los Angeles.
Dr R W Furness	Dept of Zoology, University of Glasgow, Scotland.
Mr I P Newton	Ornithologist, Marion 39 expedition team (1982).
Ms C Hanel	Personal.
Dr R P Wilson	Dept of Zoology, University of Goteborg, Sweden.
Mrs N Rice	The Dolphin Action & Protection Group, Fish Hoek.
Prof W R Siegfried	Director, Percy FitzPatrick Institute, University of Cape Town.
Dr J C Coulson	Dept of Zoology, University of Durham, England.
Mr L du Plessis	Member, Marion 38 and 41 expedition teams (1982 and 1984).
Mr G Clarke	Member, Marion 41 expedition team (1984).
Mr D F French	Banchory, Scotland.

Mr S Fugler	Ornithologist, Marion 38 and 39 expedition teams (1981 and 1982).
Mr L Davies	Dept of Zoology, University of Durham, England.
Sir H F I Elliot	Oxford, England.
Mme M.-P Wilson	Paris, France.
Dr J.-F Voisin	Zoology Laboratory, Ecole Normale Superieure, Paris, France.
J B Nelson	Dept of Zoology, University of Aberdeen, Scotland.
Dr N W Pammenter	Dept of Biology, University of Natal, Durban.
Dr W Suter	Rüschlikon, Switzerland.
Messrs I Church, G R Springer, P Kitson & B W McDonell	Wanganui, New Zealand.
R I De Silva	Project Co-ordinator, Seabird Watch, Sri Lanka.
Dr W R P Bourne	Dept of Zoology, University of Aberdeen, Scotland.
Mr A B Crawford	Wadhurst, England.
Dr M E Richardson	Address unknown.
Dr R G B Brown	Dartmouth, Canada.
Dr G W Johnstone	Howden, Tasmania, Australia.
Mr S Russell	Botanist, Marion 37 expedition team (1981).
Dr F S Todd	Sea World Research Institute, Hubbs Marine Research Centre, San Diego, USA.
Mr D Pemberton & Ms R Gales	Dept of Zoology, University of Tasmania, Hobart, Australia.
W F Curtis	Ornithological Section, Yorkshire Naturalists' Union, Attwick, England.

Mrs N Rice	The Dolphin Action & Protection Group, Fish Hoek.
J R Jehl	Sea World Research Institute, San Diego, USA.
Dr Wm C Wakefield	Claremont, Cape Town.
N Brothers	Sandy Bay, Tasmania, Australia.
Dr R Bally	Chairman, Conservation Subcommittee, Western Cape Branch of Wildlife Society of South Africa.
G J Wilson	Lincoln College, Canterbury, New Zealand.
A D Hemmings	Zoology Dept, University of Auckland, New Zealand.
Mr E Woehler	Kingston, Tasmania, Australia.
Dr D C Duffy	Universidad Nacional, Heredia, Costa Rica.
Dr N Wace	Convenor, IUCN Working Group on Oceanic Islands, Canberra, Australia.
Mr G S Clark	S.R.V. Totorore Expedition, Kerikeri, New Zealand.
Miss V L Young	Coordinator, Focus on Antarctica, Auckland, New Zealand.
Mrs M Cameron	President, Royal Australasian Ornithologists Union, Victoria, Australia.
Dr E Dunn	Secretary, The Seabird Group, Sandy Beds, England.
Dr J F Monk	President, British Ornithologists Union, London, England.
Prof D F Parmelee	JFB Museum of Natural History, University of Minnesota, Minneapolis, USA.
Messrs C J R Robertson, B D Bell & P J Moors	Wildlife Service, Wellington, New Zealand.
Mr C J Grové	Member, Marion 32, 34 and 39 expedition teams (1975, 1977, 1982).

Mr J Hofmeyr	Chairman, Cape Bird Club, Cape Town.
Mr J G Kilian	Chairman, South African Antarctic Club, Pretoria.
Dr P J D Lloyd	President, Associated Scientific and Technical Societies of South Africa, Johannesburg.
Dr H Burton	Antarctic Division, Hobart, Tasmania, Australia.
Mr T Werner	National Audubon Society, Washington D.C., USA.

3. A Brief Summary of Submissions Received

A total of 89 organisations, societies and individuals submitted comments, opinions and information. Many of these made a very useful contribution to the work of the Panel.

The nature of a specific submission depended to a large extent on the information the author/s reacted on. Twenty-six invited respondents reacted on information contained in the information sheet and the preliminary engineering feasibility report. The majority of the submissions though, came from people responding to information gleaned from newspaper articles.

All invited respondents queried the validity of the reasons given for the need for a runway and most of them suggested alternatives. The general consensus was that the negative environmental effects of a runway far outweigh any advantages that may arise from it. It is interesting to note that of all the submissions, only three pointed out that a functional runway with regular landings from the mainland may facilitate research. All the others were of the opinion that a landing facility would jeopardize the very research that it is supposed to support.

The five respondents that commented on costs, indicated that the initial cost estimate of R8,5 x 10^6 was unrealistically low.

The majority of the remaining submissions that were based on information from newspaper articles came from overseas. Not one mentioned anything positive about the landing strip. Whereas they all opposed it on environmental grounds, some were convinced that the real motivation for the landing strip was for military use and also opposed it on these grounds. Some of the comments were rather emotional.

Two aspects which several of these unsolicited submissions highlighted, were; (a) the exemplary track record of South Africa in managing these Islands as nature reserves or wilderness areas, and (b) the quality of the science done on the Islands. In both cases South Africa was referred to as a leader in these fields. However, the submissions pointed out that these achievements, as well as South Africa's international standing, could suffer from the building of a landing strip.

APPENDIX D

POSSIBLE ITEMS OF PLANT TO BE USED IN THE CONSTRUCTION OF THE PROPOSED FACILITY ON MARION ISLAND

ITEM	NUMBER
Crusher set-up	1
D7-type Bulldozers	2
Type 619 Scrapers	2
Front-end Loader	1
Tracked Excavator	1
6 m^3 Tippers	6
Tractor/Digger/Loader	1
Rubber-tyred Tractor	1
Towed Vibratory Roller	1
Pneumatic Roller	1
Three-wheeled Roller	1
Grader	2
Concrete Dumper	1
Bitumen Distributor	1
Asphalt or Concrete Paver	1
Asphalt or Concrete Mixing Plant	1
Two-ton Trucks	3
Water Tanker	1

Details from Lötter(1987).

APPENDIX E

DETAILS OF ASSUMPTIONS AND ANALYSES USED IN THE COSTS/BENEFITS ANALYSIS OF THE PROPOSED FACILITY

1. Reliability in terms of landing opportunity for aircraft where environmental conditions are the restricting factors

The objective is to determine the probability of a possible landing on any given day in the year in order to determine the ELS reliability. It has been assumed that no landing is possible if the following environmental conditions are exceeded:

- Vortex formation behind the mountain (lee-side) has been assumed to exceed the safe limit, when wind speeds exceed the average wind speed for wind directions in the sector NW to SW. Transverse winds exceeding the average values have also been considered as unsafe.
- Low cloud condition has been assumed to exceed the safe limit, with cloud level below 200 m above sea level.
- Fog, snow, ice and hail have been assumed to be unsafe at occurrence.
- Birds on runway have been taken to be a certain hazard at night time, but have been disregarded in day time.

All the above conditions have been assumed to be independent in the reliability analysis, but intuitive (subjective) probabilities have been applied where a degree of joint occurrence seems likely.

Probability of no landing p(NL) = 1 - Reliability

$$\text{Reliability} = \pi \ (1 - p_{x})$$

where the p_{x} are the probabilities of safe environmental conditions being exceeded.

The following values for p_{x} have been based on data obtained from the South African Weather Bureau of the DEA:

Vortex and transverse wind occurrence: The wind occurrence in segment NW to SW is 64 % of total time, with average velocities in sub-segments therein varying from 7,4 to 10,0 m/s. Other unfavourable transverse winds have about 20 % occurrence. Assuming that 50 % have above average velocities that would make landing hazardous then:

p_{xw}(wind) = 0,50(0,64 + 0,20) = 0,42.

and:

p_{xc}(cloud) = 0,20
p_{xf}(fog) = 0,12
p_{xs}(snow) = 0,11 on the assumption that snow occurs independently of other environmental limiting conditions (all of it in the winter).
p_{xi}(ice) = 0,15 on the assumption that 50 % occurs independently.
p_{xh}(hail/ice rain) = 0,05
p_{xb}(birds) = 0,50 night-time occurrence, which can be neglected if only daytime is considered

Therefore, reliability during day time

= (1 - 0,42)(1 - 0,20)(1 - 0,12)(1 - 0,11)(1 - 0,15)(1 - 0,05)

= 0,29

In line with weighting the probabilities in favour of positive utility, the reliability of landing will be increased to 0,40.

2. <u>Probability coefficients of the benefits term B of the utility function (weighted positively)</u>

(i) a = equivalent value of the prevention of death of any of m members of the Marion Island personnel.

= p_a x n x m x (equivalent value of loss of one member in Rand) where p_a, the probability of death of one member in any year is taken as less than 0,01 and m = 25 members (i.e. < 5 occurrences in 20 years).

then:

a < 0,01 x 20 x 25 x R500 x 10^3
< R2,50 x 10^6

(ii) b = equivalent value of the prevention of temporary or partial incapacity of any of m members of the Marion Island personnel.

= p_b x n x m x (equivalent value of suffering in Rand) where p_b, the probability of partial incapacity of one member in any year is taken as less then 0,02.

then:

b < 0,02 x 20 x 25 x R10 x 10^3 (i.e. < 10 occurrences in 20 years)
< R0,10 x 10^6

(iii) c = value of saving the crew of surveillance aircraft by emergency landing

= p_c x n x r x (equivalent value of loss of crew in Rand)

where p_c, the probability of a surveillance aircraft being in the vicinity of Marion Island and able to land, is taken as less than p_1 x p_2 x p_3

where: p_1 = 0,001 is the probability of being in distress
p_2 = 0,30 is the probability of being in the vicinity of Marion Island
p_3 = 0,40 is the probability of being able to use landing facility (see Appendix E Section 1)
r = 24 surveillance flights per annum covering an area including the vicinity of Marion Island.

therefore:

c < 0,001 x 0,30 x 0,40 x 20 x 24 x R4 x 10^6
< R0,23 x 10^6

(iv) d = value of saving surveillance aircraft by emergency landing on Marion Island
= p_d x n x r x (equivalent value of aircraft in Rand)

By reference to c above

d < 0,001 x 0,30 x 0,4 x 20 x 24 x R38 x 10^6
< R2,2 x 10^6

(v) e = value of improved supply of any other emergency needs of the Marion Island personnel
= say R0,02 x 10^6

(vi) f = value of improved supply of the general needs of the Marion Island personnel
= say R0,10 x 10^6

(vii) g = saving in costs of rescue missions otherwise carried out by ship and allowing for consequential losses due to the non-employment of the ship elsewhere

= Σp x n x m x (equivalent costs and losses per case in Rand)

$\leq$ $\{[(p_a + p_b)n \times m]\}R100 \times 10^3$

$\leq$ $\{[(0{,}01 + 0{,}02)20 \times 25]\}R100 \times 10^3$

$\leq$ $15 \times R100 \times 10^3$

$\leq$ $R1{,}50 \times 10^6$

h = equivalent value of evacuation by air of personnel endangered by volcanic activity.

= P_h x n x m x (equivalent value of member of personnel in Rand).

where:

p_h = probability of occurrence of seismic or volcanic activity leading to the need for total evacuation of personnel.

= once in 1 000 years = 0,001.

therefore:

h < $0{,}001 \times 20 \times 25 \times R500 \times 10^3$

< $R0{,}25 \times 10^6$

therefore:

B = a + b + c + d + e + f + g + h

$R6{,}90 \times 10^6$

3. Determination of Costs (or Losses) C (weighted negatively)

C = x + y + z

where: x = cost of all items related to the complete construction of the emergency landing strip based on the estimate of the consulting engineers

$\geq$ $R20 \times 10^6$

y = cost of all items related to the maintenance of the landing strip for 20 years

$\geq$ $R4 \times 10^6$

z = cost of operations related to rescue flights including the risk of the loss of an aircraft and crew in attempting to land under adverse conditions

$\geq$ $(w \times R20 \times 10^3) + (p_z \times w \times 38 \times 10^6) + (p_z \times p_k \times w \times R4 \times 10^6)$

where: p_z = probability of crash > 0,001 say

p_k = probability of all crew being killed in crash = 0,3

w = number of landings in 20 years

= landings of a + b + (c or d)

= 5 + 10 + 0,06

say = 15

therefore:

z > $(15 \times R20 \times 10^3) + (0{,}001 \times 15 \times R38 \times 10^6) + (0{,}001 \times 0{,}3 \times 15 \times R4 \times 10^6)$

> $R0{,}30 \times 10^6 + R0{,}57 \times 10^6 + R0{,}02 \times 10^6$

> $R0{,}89 \times 10^6$

therefore:

$$C > R24,9 \times 10^6$$

4. The effect of possible singular, but very unlikely catastrophic, events on the cost/benefit equation

There are two possible events of approximately equal but low probability, that if either were to occur would have a significant effect on the cost/benefit equation, viz. the saving of one surveillance aircraft and crew i.e. $(c + d)$ at $R(4 + 38)10^6 = R42 \times 10^6$, and on the other hand the loss of one aircraft and crew on landing, i.e. z also at $R42 \times 10^6$. This implies that the cost/benefit equation (U_{20}) would in the first instance increase from $-R18,0 \times 10^6$ to $R21,6 \times 10^6$, and in the second instance would decrease to $-R59,4 \times 10^6$.

Although there is thus a possible benefit of considerable value (but at very low probability), the much greater risk of loss would confirm the conclusion of Section 3.3, Chapter 3.

5. The effect of changing the period of usefulness of the ELS

Shortening the period of usefulness of the ELS will increase the negative value of the utility, as the probable number of beneficial events reduce to pro rata the period, whereas the major cost item of construction is a determinate initial expenditure.

Extending the period will decrease the negative value but a break-even point will not be achieved. In 30 years the B/C ratio will still be less than 0,38 and in 40 years less than 0,46 if the assumptions remain valid.

6. Determination of benefits term B of the utility function (weighted negatively) for the alternative emergency measures

(See Appendix E, Section 2)

a = Pa x n x m x (equivalent value of loss of 1 member in Rand)

$> [(0,5 \times 0,01) \times 20 \times 25 \times R(500 \times 10^3)]$

$> R1,25 \times 10^6$

b $> [(0,5 \times 0,02) \times 20 \times 25 \times R(10 \times 10^3)]$

$> R0,05 \times 10^6$

g $> 0,5 \times R1,50 \times 10^6$

$> R0,75 \times 10^6$

h $> 0,5 \times R0,25 \times 10^6$

$> R0,125 \times 10^6$

7. Determination of cost and loss terms C of the utility function (weighted positively) for the alternative emergency measures

(See Section 3.2.3, Chapter 3)

j = cost of additional medical facilities + doctor + assistant

< R(400 x 10^3 + 20 x 80 x 10^3)

< R2,0 x 10^6

k = cost of evacuating patients by ship

< 0,3 x 1,50 x 10 ^{6} (See g in Appendix E, Section 2)

< 0,45 x 10^6

l = cost of emergency substation etc.

< R0,5 x 10^6

m = loss of surveillance aircraft

< R2,2 x 10^6 (See d in Appendix E, Section 2)

n = loss of aircrew

< R0,23 x 10^6 (See c in Appendix E, Section 2)

RECENT TITLES IN THIS SERIES

48. A bibliography of seabirds in the waters of southern Africa, the Prince Edward and Tristan Groups. J Cooper and R K Brooke. December 1981. 297 pp.

49 *National Geoscience Programme. The evolution of earth resource systems. SACUGS. June 1981. 42 pp.

50 South African Antarctic Biological Research Programme. SASCAR. July 1981. 54 pp.

51 South African Marine Pollution Monitoring Programme 1979-1982. R J Watling and C E Cloete (editors). July 1981. 52 pp.

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