Initial Environmental Evaluation

Scott Base and field support operations

2019-2023

Antarctica New Zealand

Contents

Executive Summary **1**
1. Introduction **2**
1.1. National requirements 2
1.2. Four-year outlook 3
1.3. Scope 4
2. Purpose **5**
2.1. Historic context 5
2.2. Antarctica New Zealand 5
2.3. Science Platform 6
2.4. Long-term science 7
3. Location **9**
4. Duration **13**
5. Nature and intensity of Scott Base and field support operations **14**
5.1. Power generation 15
5.2. Hazardous substances storage and use 16
5.2.1. Fuel 16
5.2.2. Other chemicals 16
5.3. Waste 17
5.3.1. Wastewater 18
5.4. Maintenance activities 18
5.4.1. Minor earthworks 18
5.4.2. Water intake and outfall structure replacement 19
5.4.3. Satellite dome replacement 19
5.4.4. Water tank replacement 19
5.4.5. Unforeseen maintenance 19
5.5. Transport 20
5.5.1. Intercontinental aircraft 20
5.5.2. Shipping 20
5.5.3. Surface transport 21
5.5.4. Intra-continental flights 23
5.5.5. Penguin census 24
5.5.6. Drones and Remotely Operated Vehicles 26
5.5.6.1. Season 2021/22 proposed RPAS operations 26
5.6. Field support 27
5.6.1. Camp equipment and set up 27
5.6.2. Installations 28
5.6.3. Field fuels 30
5.6.4. Sea ice thickness measurements 31
5.6.5. Search and Rescue training 32

5.6.6. Testing Battery/Solar Power supply setup 32
5.6.7. Foreshore preparation for heated plates experiment 33
5.7. Recreation and familiarisation 33
5.7.1. Observation and familiarisation 33
5.7.2. Independent recreation 33
5.7.3. Organised activities 33
5.7.4. Winter recreation 34
5.8. Community Engagement Programme 36
5.8.1. 2021/22 season Community Engagement Programme 36
5.9. Invited Visitors 36
5.10. Management of Antarctic Specially Protected Areas 37
5.11. Managing sites of past activity 38
5.11.1. Clean up 39
5.11.2. Historic sites and artefacts 39
5.12. Enabling works for the Scott Base Redevelopment 40
5.12.1. Season 2019/20 40
5.12.2. 2020/21 and 2021/22 Long-term science (LTS) location surveys and relocations 43
5.12.2.1. 2021/22 Arrival Heights proposed activities for geomagnetic huts installation 44
5.12.3. 2021/22 Civil engineering – Pile testing 51
5.12.3.1. Background 51
5.12.3.2. Proposed works 51
5.12.3.3. Equipment and materials 52
5.12.3.4. Removing the piles 52
5.12.4. Other SBR enabling works 55
5.12.4.1. 2021/22 Ground Contamination Investigations 55
5.12.4.2. Geotechnical Site Investigations 56
5.12.4.3. Test rig and test rope barrier 56
5.12.4.4. Shoreline survey 58
5.12.5. Operational area tidy-up and preparation 58
5.13. Monitoring programmes 60
5.13.1. **2021/22 CEE environmental baseline monitoring** 63
6. Summary of permit applications 65
6.1. Interfering with native plants and invertebrates 65
6.2. Importing non-native micro-organisms 65
6.3. ASPA entries 66
7. Alternatives 68
7.1. Do not proceed 68
7.2. Reduce period of operation 68
7.3. Reduce level of activity 69
7.4. Reduce the area of operations 69

7.5. Reduce the size of Scott Base ... 69
7.6. Change energy sources ... 70
7.7. Change location ... 70
7.8. Summary ... 70
8. Initial environmental state ... 71
8.1. Scott Base and Pram Point ... 71
8.1.1. Soils ... 72
8.1.2. Biota ... 72
8.1.3. Air ... 74
8.1.4. Sea ... 74
8.2. Ross Island and McMurdo Sound surrounds ... 76
8.3. Arrival Heights ASPA 122 ... 77
8.4. McMurdo Dry Valleys (ASMA) ... 79
8.5. Cape Adare ... 79
8.6. Cape Hallett ... 80
8.7. Terra Nova Bay ... 81
8.8. Cape Colbeck ... 83
8.9. Rockefeller Mountains ... 83
8.10. Ross Ice Shelf ... 84
8.10.1. Crary Ice Rise ... 85
8.10.2. Siple Coast and Siple Dome ... 85
9. Interaction of activities with the environment ... 86
10. Mitigation measures ... 90
10.1. Antarctica New Zealand's Environmental Management Policy ... 90
10.2. Environmental Management System ... 90
10.3. Atmospheric emissions ... 92
10.4. Noise and wildlife disturbance ... 92
10.5. Waste management ... 93
10.6. Light, heat and electromagnetic radiation ... 93
10.7. Mechanical action ... 93
10.8. Fuel spills ... 94
10.9. Discharge to sea ... 94
10.10. Introduced species ... 95
10.11. Presence ... 95
11. Identification of impacts ... 96
11.1. Atmospheric emissions ... 99
11.2. Noise and vibration ... 102
11.3. Light and heat ... 105
11.4. Electromagnetic radiation ... 106
11.5. Mechanical Action ... 107

11.6. Spills ... 109
11.7. Discharge to Sea ... 111
11.8. Species transfer ... 113
11.9. Presence ... 115
12. Significance of impacts ... 116
13. Monitoring Programmes ... 120
14. Conclusions ... 121
15. References ... 123
16. Glossary ... 126
17. Appendices ... 127
Appendix 1: Environmental Code of Conduct ... 128
Appendix 2: Chemicals stored at Scott Base and remote facilities, as of winter 2019 ... 130
Appendix 3: Long-Term Science relocation – Site plans – supplied as pdf files ... 136
Appendix 4: Summary of SBR monitoring plots biodiversity value ... 137
Appendix 5: VLF Radio Noise Survey at the Eyrewell ... 140
Intermagnet Observatory (provided separately) ... 140

List of figures

Figure 1: Levels of Antarctic Environmental Impact Evaluation....2
Figure 2: McMurdo Station and Scott Base, Hut Point Peninsula, Ross Island 9
Figure 3: Map of planned field activities....10
Figure 4: Stations and facilities. Yellow dots indicate year-round stations, red summer-only (Source: COMNAP) 12
Figure 5: Breakdown of Antarctica New Zealand supported personnel travelling to Antarctica annually 14
Figure 6: Scott Base bed nights, 13/14 – 18/19....15
Figure 7: Field bed nights, 13/14 – 18/19 15
Figure 8: Bulk JP8 fuel tank, Scott Base....16
Figure 9: Annual quantities of waste between the 2008/09 and 2018/19 seasons 17
Figure 10: USAF C-17 landing © Antarctica New Zealand Pictorial Collection 20
Figure 11: RNZAF B-757 taxiing in after landing on Pegasus Airfield. © Antarctica New Zealand Pictorial Collection....20
Figure 12: Polaris ranger electric vehicle in Christchurch cargo yard before shipping to Scott Base for trial....21
Figure 13: Southern Lakes Helicopter with Twin Otter DHC6 aircraft in the background. © Antarctica New Zealand Pictorial Collection 23
Figure 14: Basler DC3 aircraft operated by Ken Borek Air in Antarctica 24
Figure 15: Fixed Wing and Helicopter hours 2015/16 to 2018/19 (Source: 2018/19 End of Season Review) 24
Figure 16: Tents supplied by Antarctica New Zealand for field use (clockwise from top left: Polar Haven, Rac Tent, Polar Tent, Endura) 28
Figure 17: Clearing snow to open Cape Bird hut. © Antarctica New Zealand Pictorial Collection 28
Figure 18: Proposed sea ice thickness measurement sites 32
Figure 19: Ross Island Trail System. Source: Brad Herried, Polar Geospatial Centre (PGC) and Joe Heil, Antarctic Support Contract (ASC) November 2012 35
Figure 20: Drilling during Hillary Field Centre Site investigations. 40
Figure 21: Indicative locations of site investigation work 42
Figure 22: Proposed location for geomagnetic huts 47
Figure 23: 3D view of the new huts....48
Figure 24: Options for accessing the proposed geomag huts location....49
Figure 25: Area of proposed activities in relation to visible sand-wedge polygons 50
Figure 26: Proposed excavator with excavating tool 52
Figure 27: Vibro-hammer used to install piles....52
Figure 28: Primary and secondary locations for the pile tests 54
Figure 29: Wire rope barrier (main barrier and terminal ends) 56
Figure 30: X marks the sampling spot - Scott Base ground contamination survey 57
Figure 31: Soil microplastics transects on Pram Point 61
Figure 32: Soil and biology monitoring plots on Pram Point 62
Figure 33: Crater Hill area of interest to install 2x cameras....64
Figure 34: Turtle Rock circled in red, Erebus Glacier Tongue above 64
Figure 35: Vegetation density and SBR monitoring plots (SM01-25) 73
Figure 36: Lichen close to Scott Base © Antarctica New Zealand Pictorial Collection 74
Figure 37: Four species of anemones and for sponges compete for space in the marine environment near Scott Base. The large predator nudibranch Tritonia challengeriana is centre right. Photograph: Ian Hawes 75
Figure 38: Large volcano sponge at about 50m depth outside Scott Base: Image from video by Ben King 75
Figure 39: Map of ASPA 122 (Source: USAP)....78
Figure 40: Bull Pass in the McMurdo Dry Valleys. Image: Josh Landis, USAP Photo Library....79
Figure 41: Cape Adare, Northern Victoria Land....80
Figure 42: Aerial view of Seabee Hook at Cape Hallett. Image: Kevin Pettway, USAP Photo Library ...81
Figure 43: Mario Zucchelli Station, Terra Nova Bay. © Antarctica New Zealand Pictorial Collection 82
Figure 44: The Republic of Korea's Jang Bogo Station. Image from The Korea Times....83
Figure 45: Ross Ice Shelf....84

Figure 46: The USA Siple Station, situated on Siple Dome....85
Figure 47: Overview of Antarctica New Zealand’s Environmental Management System....91
Figure 48: Carbon emissions from Antarctica New Zealand operations, 2015/16 to 2017/18, excluding one off projects. Source: CEMARS inventory....101
Figure 49: Aurora viewed from Scott Base. © Antarctica New Zealand Pictorial Collection....105
Figure 50: Ground disturbance levels at Scott Base 2018/19....108
Figure 51: Twenty years of spills, Scott Base and Antarctica New Zealand field operations....109
Figure 52: Twenty years of spills by type, Scott Base and Antarctica New Zealand field operations....110
Figure 53: Introduced species intercepted at Scott Base, 2007/08 – 2017/18....114
Figure 54: A= depiction of active Nostoc found at site SM24. B= Bryum spp. moss found at site SM25. C= example of Caloplaca spp. lichen at site SM09....137

List of Tables

Table 1: Anticipated areas of Antarctica New Zealand operations 2019-2023....11
Table 2: Fuel storage at Scott Base....17
Table 3: Scott Base vehicle fleet 2019-2023....22
Table 4: Adelie penguin aerial census colonies....25
Table 5: Proposed RPAS operation locations....26
Table 6: Remote facilities owned and operated by Antarctica New Zealand....29
Table 7: Antarctica New Zealand field installations....29
Table 8: Fuels stored in the field (winter 2019)....31
Table 9: New Zealand ASPA and ASMA Management Plan Reviews 2019-2023....37
Table 10: Summary of SBR - LTS activities 2020/21-22/23....44
Table 11: Summary of feedback from members of the Arrival Heights Working Group....46
Table 12: Sampling activities in season 2021/22....63
Table 13: Plant and invertebrate samples 2019/20....65
Table 14: Annual entries to Antarctic Specially Protected Areas....66
Table 15: Definition of environmental aspects....86
Table 16: Actions which occur as part of Antarctica New Zealand operations and the aspects in which they interact with the environment....87
Table 17: Aspects and environmental receptors....89
Table 18: Summary of aspects, actions and potential impacts....97
Table 19: Carbon emissions from Antarctic New Zealand’s Antarctic operations 2017/18....101
Table 20: Audibility of noise sources to Weddell seals underwater....103
Table 21: Audibility of noise sources to Weddell seals at surface....103
Table 22: Definition of impact extent, intensity, duration and probability....116
Table 23: Scoring of impact significance....117
Table 24: Significance of impacts....118

Executive Summary

This Initial Environmental Evaluation for Antarctica New Zealand's operations at Scott Base and in support of fieldwork has been prepared in accordance with the requirements of the Protocol on Environmental Protection to the Antarctic Treaty and the Antarctica (Environmental Protection) Act 1994.

New Zealand has operated Scott Base continuously since 1957 and supported fieldwork in the Ross Sea region. The continuation of these operations implements New Zealand Government's strategy to:

- support science that contributes to understanding the role of Antarctica and the Southern Ocean in global systems and the impact of global environmental changes on Antarctica;
- be a leader in Antarctic environmental protection;
- tell the story of New Zealand's connection to Antarctica and the Southern Ocean through science, environmental protection, conservation, heritage and logistical support; and
- provide high-quality services to and collaboration with other nations.

The activities undertaken to achieve this include power generation, storage and use of hazardous substances, waste management including discharge of treated wastewater to the sea, maintenance activities, surface and air transport, field support. These activities take place primarily to support scientific research, but also for the purposes of education and staff recreation and wellbeing. Environmental management, including review of Antarctic Specially Protected Areas and Antarctic Specially Managed Areas and environmental monitoring is also undertaken. Permits are sought for entry to Antarctic Specially Protected Areas, and for sampling of soil, vegetation and invertebrates for monitoring purposes and the import of non-native species (e.g. bacteria to ensure high quality wastewater treatment can be achieved).

The existing environment is a pristine wilderness at the regional scale, but highly impacted at the local scale, particularly at Scott Base. The ongoing operation of Scott Base and support of field operations interacts with the environment in a number of ways and causes direct, indirect, and cumulative impacts. The impacts are mitigated wherever practicable, but some are unavoidable if operations are to continue, such as emissions to the atmosphere from fossil fuel burning (given currently available technology), or the diminishment of wilderness values by human presence.

The impacts have been evaluated in terms of their extent, intensity, duration and probability and are considered to be not more than minor or transitory.

1. Introduction

This document has been prepared in accordance with The Protocol on Environmental Protection to the Antarctic Treaty, and its New Zealand enabling legislation, the Antarctica (Environmental Protection) Act 1994.

Article 3 of the Protocol requires that activities in the Antarctic Treaty area are planned and conducted so as to limit adverse impacts on the Antarctic environment, and that those activities are planned and conducted on the basis of sufficient information to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment.

> *"The protection of the Antarctic environment and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area."*
> *Article 3, Protocol on Environmental Protection to the Antarctic Treaty*

Accordingly, Article 8 of the Protocol requires an environmental impact assessment (EIA) to be prepared in advance of any activity taking place in the Antarctic Treaty Area. Three levels of EIA are provided for, appropriate to the scale of activities and impacts (Figure 1).

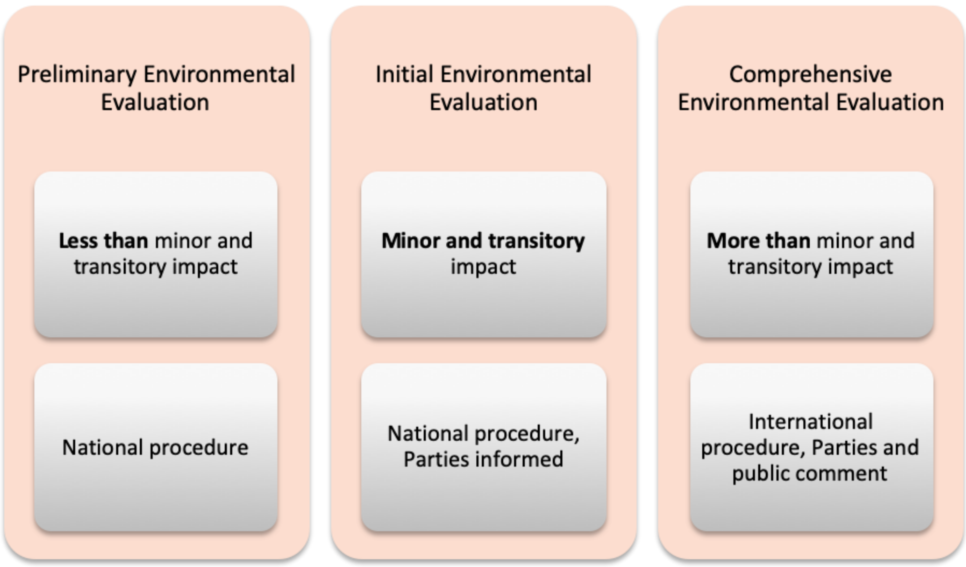


Figure 1: Levels of Antarctic Environmental Impact Evaluation

The detailed procedures for preparing and processing environmental impact assessments are set out in Annex I to the Protocol and further described in guidance material prepared by the Committee for Environmental Protection to assist those preparing EIAs. The most recent version of these guidelines was adopted by the 28th ATCM. These guidelines have been consulted in the preparation of this EIA.

1.1. National requirements

The EIA provisions of the Protocol are enacted in New Zealand law through the Antarctica (Environmental Protection) Act 1994. The Act applies to any New Zealand citizen or resident and to any member of an expedition that is organised in or departs from New Zealand.

The Act is administered by the Ministry of Foreign Affairs and Trade (MFAT) and the Minister of Foreign Affairs makes the final determination on whether an activity may proceed. It is an offence under the Act to carry out an activity in Antarctica without completing and submitting an EIA to MFAT.

The Minister has discretion under the Act to set conditions and make directions regarding the proposed activity. Such conditions may relate to, for example, managing compliance, undertaking environmental monitoring, and post-activity reporting. Under the provisions of the Act, non-compliance is an offence carrying a penalty of up to one year's imprisonment or a fine of up to $100,000 (Sections 10(2) and (3)).

The Act also prohibits the following unless a permit is obtained:

- entering or carrying out any activity in an Antarctic Specially Protected Area (ASPA)
- taking any native bird or mammal in Antarctica
- removing or damaging native plants so their local distribution or abundance is significantly affected
- harmfully interfering with native plants, mammals, birds or invertebrates
- introducing any species of non-native animal, plant or micro-organism
- importing any non-sterile soil into Antarctica
- removing any part of or the contents of any historic site or monument

A permit application can be considered at the same time as submitting an EIA if any of the above activities are identified in the EIA document. Permits are issued at the time of approval of the EIA and often carry additional conditions. Permit applications associated with this Initial Environmental Evaluation are summarised in Section 6.

International and national obligations have been fully considered in the preparation of this environmental impact assessment.

Following an assessment at the preliminary environmental evaluation level, it is considered that Antarctica New Zealand's planned activities are likely to have no more than 'a minor or transitory impact' on the Antarctic environment, provided proposed mitigation and monitoring measures are implemented. An environmental impact assessment at the Initial Environmental Evaluation (IEE) level is therefore considered appropriate for the activities proposed to be undertaken by Antarctica New Zealand over the next four-year period. This IEE provides relevant information in sufficient detail with respect to the requirements outlined in Section 18(2) of the New Zealand Antarctica (Environmental Protection) Act (1994) and Article 2(1) of Annex I of the Protocol.

1.2. Four-year outlook

This document is the third four-year IEE prepared for Antarctica New Zealand's support operations. A number of factors led to preparation of a four-year IEE, as opposed to a single year IEE, or multiple PEEs. The New Zealand Government is committed to an ongoing presence in the Ross Sea region so operations can be expected to continue long term. While operations do change over time to meet the needs of science support, the nature and scope of activities are not expected to significantly change over a four-year period and logistical planning is in progress for events within this time frame.

Individually, many of the support activities undertaken by Antarctica New Zealand in a single season are likely to have less than a minor or transitory impact on the environment. However, considering them together over multiple years allows a more appropriate assessment of the cumulative impacts of the operations collectively.

The next four years, from 2019 to 2023, also represent the final phase of the current Scott Base facilities operation. From 2023/24, it is hoped that the Scott Base Redevelopment project will be under way, and operations can be expected to be different during construction.

The uncertain nature of operating in Antarctica means that activities may arise over a four-year period that were unforeseen. Should an activity that has a risk of environmental impact not included in this IEE be proposed, an amendment to this IEE (or, if appropriate, a separate environmental impact assessment) will be prepared and submitted to the Ministry of Foreign Affairs and Trade (MFAT) for consideration.

1.3. Scope

The activities covered by this environmental impact assessment include those undertaken by Antarctica New Zealand staff (both temporary and permanent) and non-science events supported by Antarctica New Zealand (e.g. the communication and education programme and other workers or visitors):

- The operation and maintenance of Scott Base (including power generation, fuel consumption and chemical use, transport, facility and ground maintenance and generation of waste);
- The operation and maintenance of field infrastructure (including field huts, field installations such as radio transmission antennae, and emergency and fuel caches); and
- Travel of science and non-science personnel outside the Scott Base area (including for health and safety reasons, search and rescue training, Antarctic field training, visitor programmes, general duties, activities at the invitation of other national Antarctic programmes, entry into Antarctic specially protected areas and environmental monitoring and management).

This IEE covers the operational activities which facilitate science, but not the scientific activities themselves[1]. Each science event undertakes their own EIA at the appropriate level, prior to travelling to Antarctica. Separate EIAs are also undertaken for some non-science activities led by other institutions, such as the University of Canterbury's Postgraduate Certificate in Antarctic Studies (PCAS), Land Information New Zealand (LINZ) and the Antarctic Heritage Trust (AHT). NIWA and Ministry of Primary Industries undertake toothfish surveys on fishing vessel. The science is approved by an Antarctic Marine Living Resources Act 1981 permit, but movements of the scientist between New Zealand and Antarctica are covered by this IEE.

A separate IEE has been completed for traverse operations to support the Ross Ice Shelf Project, as this was a new type of operation not covered by the 2016-2019 Antarctica New Zealand IEE. Activities covered by a separate IEE are not described or assessed in detail in this document, but will be noted where relevant.

A Comprehensive Environmental Evaluation is being undertaken for the Scott Base Redevelopment project, which will cover all construction and associated activities. However, some works are required prior to construction such as site investigations, setting up monitoring programmes, and possibly some staging of equipment of materials. These enabling works, during the 2019-2023 period, will be covered in this IEE.

It is anticipated that the activities covered by this environmental impact assessment will not significantly change over the next four years, however more specific details about proposed work will be provided to MFAT ahead of each season, at an agreed time.

1.4. Knowledge gaps

Where information is uncertain, incomplete or unavailable, this is noted in the text of the relevant section.

[1]Some long-term science equipment is monitored and maintained by Antarctica New Zealand staff at Scott Base and Arrival Heights on behalf of scientists, and occasionally data from field stations is downloaded for scientists, as part of the programme's activities

2. Purpose

Antarctica New Zealand manages Scott Base and operations throughout the Ross Sea region in order to:

- support nationally and globally relevant scientific research;
- protect the natural Antarctic environment;
- raise public awareness of the global significance of the Antarctic continent and surrounding Southern Ocean;
- maintain New Zealand's status as a Consultative Party to the Antarctic Treaty; and
- foster international cooperation with our Treaty partners.

2.1. Historic context

The New Zealand Government's interests in Antarctica date back to 1923, when the United Kingdom government passed an Order in Council under the British Settlements Act 1887, as follows:

> "*that part of His Majesty's Dominions in the Antarctic Seas, which comprises all the islands and territories between the 160th degree of East Longitude and the 150th degree of West Longitude which are situated south of the 60th degree of South Latitude shall be named the Ross Dependency*."

The Order in Council appointed the Governor-General of New Zealand as the Governor of the territory. New Zealand has maintained a permanent presence in the Ross Dependency since January 1957. Scott Base, which was built to support the New Zealand contingent of the joint United Kingdom / New Zealand Trans-Antarctic Expedition (TAE), opened on 20 January 1957. The expedition also set up scientific research as part of the International Geophysical Year, 1957/58. On completion of the TAE in 1959, the New Zealand Government established the Antarctic Division of the Department of Scientific and Industrial Research (DSIR), which continued to operate Scott Base and to support scientific research in the region.

With the dissolution of the DSIR in 1992, the New Zealand Antarctic Research Programme was moved to the Ministry of Foreign Affairs and Trade.

2.2. Antarctica New Zealand

Antarctica New Zealand was established on 1 July 1996 by the New Zealand Antarctic Institute Act. Our principal functions under the Act are:

a) To develop, manage, and execute New Zealand activities in respect of Antarctica and the Southern Ocean, in particular in the Ross Dependency;
b) To maintain and enhance the quality of New Zealand Antarctic scientific research; and
c) To co-operate with other institutions and organisations both within and outside New Zealand having objectives similar to those of the Institute.

In performing our functions, the Act requires us to act in a manner that is consistent with:

a) The need to conserve the intrinsic values of Antarctica and the Southern Ocean;
b) Active and responsible stewardship of the Ross Dependency for the benefit of present and future generations of New Zealanders;
c) New Zealand's international obligations;
d) The provisions of the Antarctica Act 1960 and the Antarctica (Environmental Protection) Act 1994; and
e) The risks to personnel being minimised as far as is reasonable.

2.3. Science Platform

In 2017, the Government announced a $49 million dollar, seven-year investment in a new Strategic Science Investment Fund (SSIF) platform for Antarctic science.

The purpose of the Antarctic Science Platform is to conduct excellent science to understand Antarctica's impact on the global earth system, and how this might change in a +2°C (Paris Agreement) world.

The goals of the platform are to:

- improve scientific understanding of pressing issues such as climate change and ecosystem resilience;
- safeguard the strategic benefits of New Zealand's scientific activity in Antarctica; and
- optimise the value and impact of Antarctic science and Antarctic-related expenditure.

The Ministry of Business, Innovation and Employment has contracted Antarctica New Zealand to host and implement the platform. Its priorities are to understand:

- the stability of the West Antarctic Ice Sheet;
- the impacts of change in the Antarctic atmosphere and Southern Ocean;
- threats to ecosystem dynamics in the Ross Sea; and
- connections between terrestrial and nearshore Antarctic environments, including sea ice.

The Platform is expected to enable improved New Zealand Antarctic research and collaboration.

Two research programmes, with two major projects each, have been defined:

Programme 1: The Antarctic ice-ocean-atmosphere system in a warming world

- Project 1: Antarctic Ice Dynamics
  - How will marine-based ice sheets respond to a +2°C world?
  - What are the effects of this response?
  - What are the consequences of surpassing +2°C?

- Project 2: Antarctic Ocean-Atmosphere Coupling
  - How are oceanic and atmospheric heat transports changing?
  - When will we see the emergence of the anthropogenic signal from the natural variability?

Programme 2: Ross Sea Region ecosystem dynamics in a warming world

- Project 3: Ross Sea Region Ecosystem Dynamics (currently under review)

- Project 4: Sea Ice and Carbon Cycle Feedbacks
  - What are the drivers of sea ice variability and changes in Southern Ocean CO_2 uptake?
  - Are they related?
  - What are the consequences?

Information regard the Antarctic Science Platform is available on the Ministry of Business, Innovation and Employment website[2] and the Antarctic Science Platform website[3].

[2] https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/ssif-funded-programmes/antarctic-science-platform/
[3] https://www.antarcticscienceplatform.org.nz/

2.4. Long-term science

Several scientific measurements have been made continuously since Scott Base opened in 1957 and new long-term measurements have been added over the years.

Daily weather recordings have been made at Scott Base since its establishment, providing one of the longest climate records in Antarctica. The weather monitoring programme is overseen by the National Institute of Water and Atmospheric Research (NIWA) and data are used in climate models contributing to efforts under the United Nations Framework Convention of Climate Change to mitigate and adapt to climate change. In addition, a Landcare Research New Zealand soil climate station has been collecting data at Scott Base since 1999.

The same two huts, H and G, have been used for magnetic observations since the International Geophysical Year (IGY). The instruments have changed significantly but the long-term dataset has proven invaluable, particularly as the magnetic pole is relatively close to Scott Base compared with most other permanent bases. The Institute of Geological and Nuclear Sciences (GNS) oversee the observations which are part of the INTERMAGNET programme, a global network of digital magnetic observatories using modern standard specifications for measuring and recording equipment for production of geomagnetic products in close to real time.

Gravity has also been measured since 1957, which contributes to the monitoring of global change by providing a benchmark for measuring the movement of the Earth.

Land Information New Zealand (LINZ) has maintained a tide gauge at Scott Base since 2001. The combined measurements of gravity and sea level assist with monitoring global sea level rise.

Medium-frequency radar and satellite measurements have been made by the University of Canterbury from Scott Base since 1982, developing the understanding of how middle atmosphere dynamics couple to different atmospheric regions and effects on ozone.

Otago University's study of 'space weather' since 2008 uses the upper atmosphere as a giant detector of energy coming from space into the polar atmosphere, allowing more to be learnt about processes in space and the relationship between space weather and Earth's climate. The Scott Base receiver contributes measurements to the World-Wide Lightning Location Network, which monitors real time global lightning discharges.

Since 1960, scientists and technical staff from Scott Base have also maintained a number of long-term experiments at the Arrival Heights laboratory, 2.7km northwest of Scott Base. It is a founding site of the Network for the Detection of Atmospheric Composition Change (NDACC) and a certified Global Atmosphere Watch (GAW) station. Arrival Heights is home to eight remote sensing instruments monitored by NIWA, as well as a LiDAR programme run by the United States' National Oceanic and Atmospheric Administration and University of Colorado.

International cooperation is integral to work conducted at Arrival Heights. The site is designated as Antarctic Specially Protected Area No. 122, to protect the ongoing research into extremely low and very low radio frequencies, auroral events, geomagnetic storms, meteorological phenomena, variations in trace gas levels, particularly ozone, ozone precursors, ozone destroying substances, biomass burning products and greenhouse gases.

Long running field research programmes are also in place at a number of field sites, supported out of Scott Base. Magnetic measurements have been made at Cape Evans since 1911 and Lake Vanda since 1974. Gravity has been measured at Cape Roberts since 2001. Adélie penguin colonies in the Ross Sea region have been surveyed using high-resolution aerial photographs since the early 1980s. The penguin monitoring seeks to distinguish between natural and human-induced changes and provide an indication of ecosystem health. Since 2012, NIWA has conducted an annual survey of Antarctic toothfish in the southern Ross Sea, which will play an important role in monitoring the Ross Sea Marine Protected Area.

Intensive study of the population ecology of Weddell seals in eastern McMurdo Sound, started during the 1960s by New Zealand scientists and continued by American researchers, is the longest-running study of any wild mammal with over 17,000 animals tagged (Eisert, et al., 2013). The colony on the sea ice in front of Scott Base is now being monitored using cameras as part of the Scott Base Redevelopment monitoring programme.

3. Location

The logistical hub of Antarctica New Zealand's operations in Antarctica is Scott Base, located on Hut Point Peninsula of Ross Island. The nearest neighbouring station is McMurdo Station, which is connected by road (Figure 2). Italy's Mario Zucchelli Station, Korea's Jang Bogo Station and Germany's summer-only Gondwana Station are located in the Terra Nova Bay area (Figure 3, Figure 4). New Zealand has scientific and logistical collaborations with these countries and personnel may visit or transit through the stations.

Historically much of New Zealand's scientific work has been within approximately a 200km radius of Scott Base, around Ross Island, McMurdo Sound and the McMurdo Dry Valleys. Antarctica New Zealand maintains a number of field huts in this area (as shown in Figure 3).

Increasingly, there is a need to work at "deep field" sites further away from Scott Base, in response to the current science priorities. Notably in the next four years, work is planned in several non-traditional locations (Table 1, Figure 3).

From time to time Antarctica New Zealand personnel may make visits to, or transit through, other National Antarctic Programme facilities such as South Pole Station or Concordia (Figure 4).

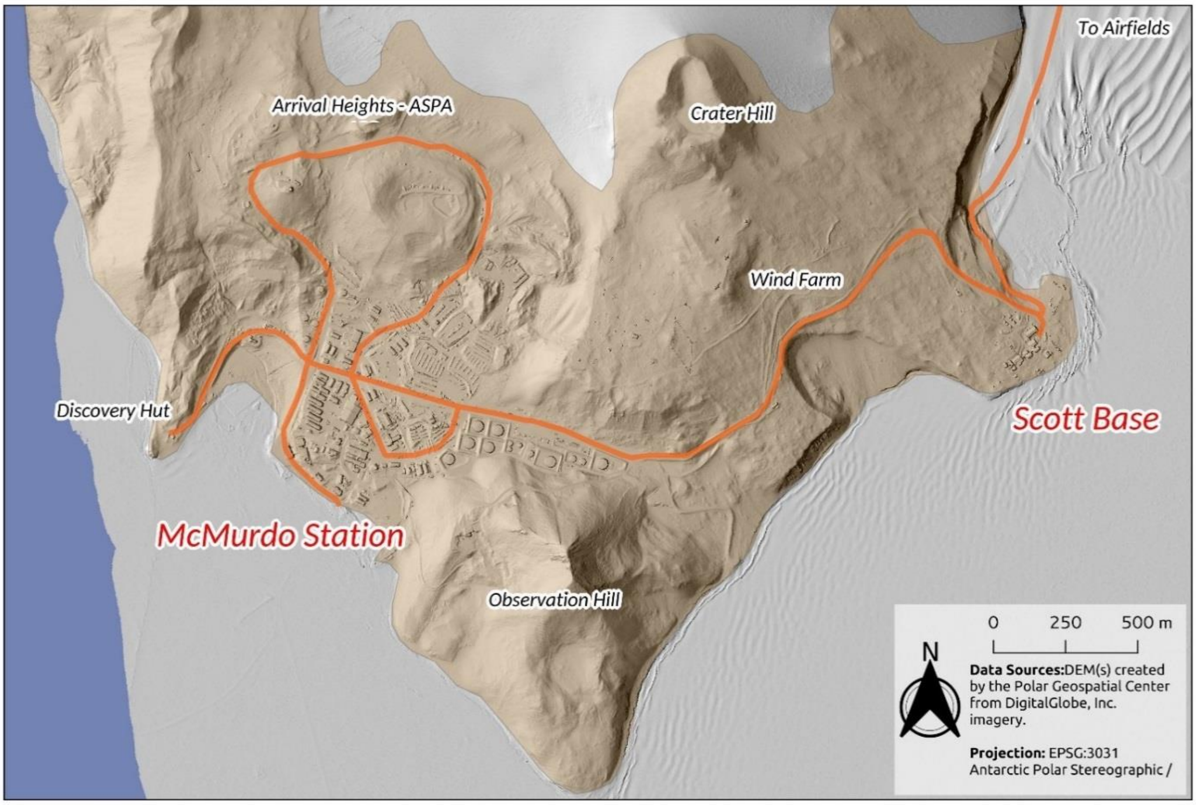


Figure 2: McMurdo Station and Scott Base, Hut Point Peninsula, Ross Island

Figure 3: Map of planned field activities

Table 1: Anticipated areas of Antarctica New Zealand operations 2019-2023

Location	Description
Boggs Valley	The area within a 50km radius of Boggs Valley, -71° 55' 12" S, 161° 30' 0" E
Byrd Glacier	The area within a 50 km radius of the Byrd Glacier (80° 19’ S, 159° 0’ E)
Cape Adare	The area within a 50 km radius of Cape Adare in Northern Victoria Land (71° 17' S, 170° 14' E)
Cape Hallett	The area within a 50 km radius of Cape Hallett in Northern Victoria Land (72° 19’ S, 170° 14’ E)
Crary Ice Rise	The area within a 50km radius of Crary Ice Rise, -71° 55' 12" S, 161° 30' 0" E
McMurdo Sound area	The area within an approximately 250 km radius of Scott Base (77° 51’ 00” S, 166° 45’ 46” E), including all of Ross Island, Beaufort Island, Bratina Island, Black Island, White Island, the Minna Bluff area, Coulman High on the Ross Ice Shelf, the McMurdo Dry Valleys ASMA, Mackay Glacier and Southern McMurdo Sound
Rockefeller Mountains	The area within a 50km radius of the Rockefeller Mountains (78°0’S 155°0’W)
Ruppert Coast	The area within a 50km radius of the Rupert Coast (75°45’S 141°0’W)
Siple Coast	The area within a 200km radius of Siple Coast Camp 1, 82.5417S, 152.1667W
Terra Nova Bay	The area within a 100 km radius of Mario Zucchelli Station at Terra Nova Bay (74° 41’ S, 164° 07’ E), including Korea’s Jang Bogo Station, Adélie Cove, David Glacier and the Drygalski Ice Tongue, Priestly Glacier, Mt Rittman and Mt Melbourne

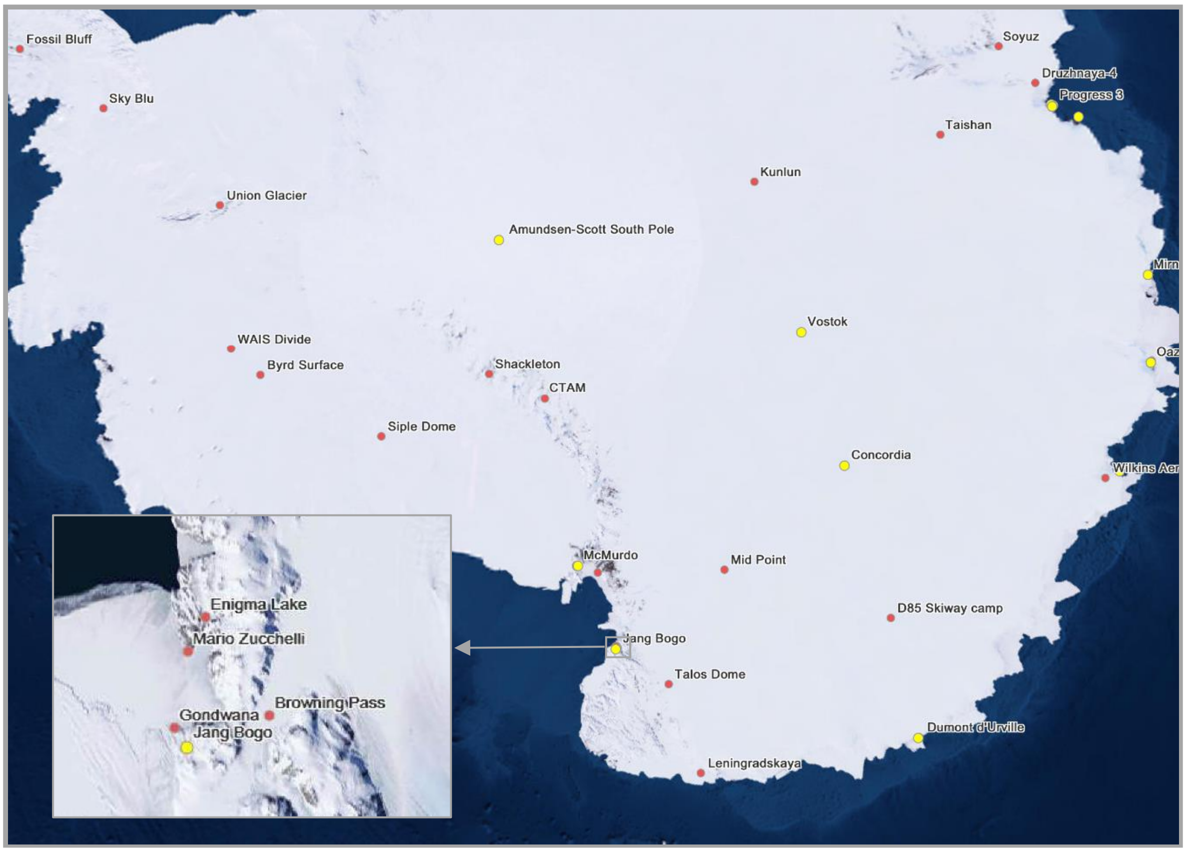


Figure 4: Stations and facilities. Yellow dots indicate year-round stations, red summer-only (Source: COMNAP)

4. Duration

Antarctica New Zealand will continue to operate year-round in Antarctica from 1 September 2019 to 31 August 2023. Each annual cycle has summer and winter phases of operation.

The **summer** season (the “mainbody” of intercontinental flight scheduling) lasts from October to February. During this period frequent flights (approximately every two days) bring passengers and cargo to and from Scott Base, base occupancy is high (up to 85 people) and fieldwork is carried out. Bulk cargo arrives by ship in late February.

Winter, from March to September, has much less frequent intercontinental flights (approximately six to eight-week intervals) and limited exchange of cargo and personnel. Scott Base occupancy typically drops below 20, and very little to no fieldwork occurs.

Staff are employed to maintain and run Scott Base either as summer-only crew (October to March) or winter-over crew (October to October). The staff are augmented in the summer by New Zealand Defence Force personnel.

5. Nature and intensity of Scott Base and field support operations

Every year around 300-350 people are supported by Antarctica New Zealand, travel to Antarctica (Figure 5). Approximately 35% of these are associated with science events, covered by separate environmental impact assessments. The remainder are part of the Antarctica New Zealand operations covered by this IEE[4].

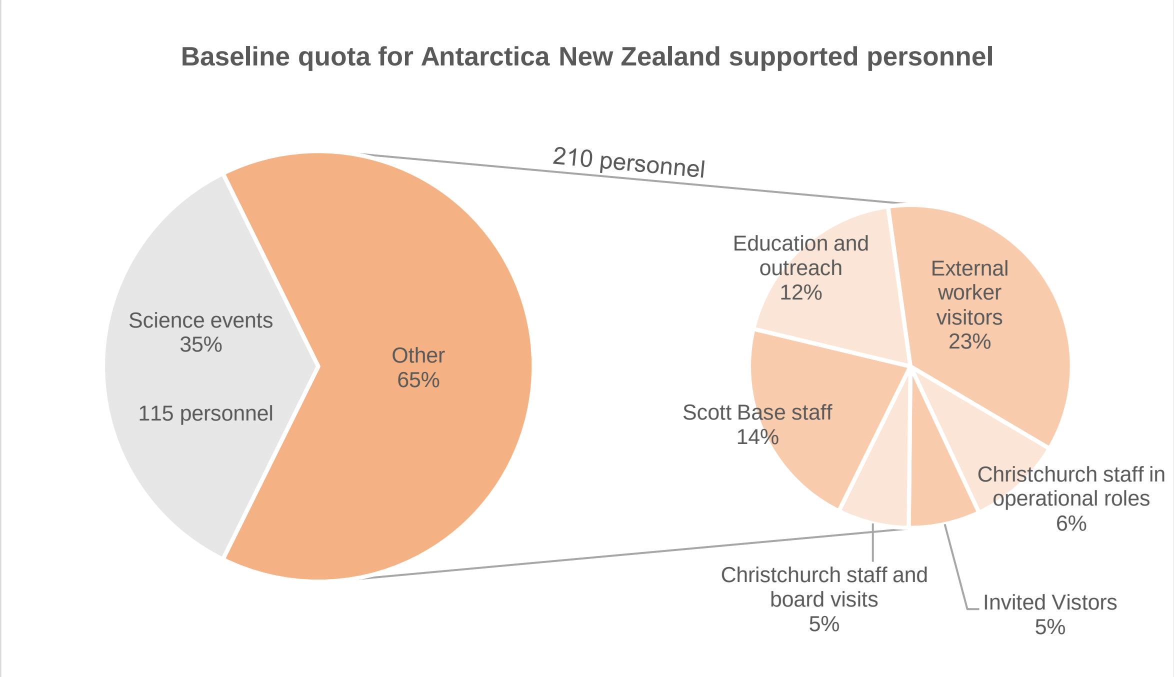


Figure 5: Breakdown of Antarctica New Zealand supported personnel travelling to Antarctica annually

The maximum capacity of Scott Base is c.86 people. Although occupancy is not scheduled above this level, transport delays can cause bottlenecks that require temporary accommodation arrangements to be made, for numbers above 83. Around 10,000 bed nights are spent at Scott Base each year (Figure 6).

[4] These numbers will include personnel working on Antarctic Heritage Trust restoration projects or Traverse Operations, which have separate IEEs.

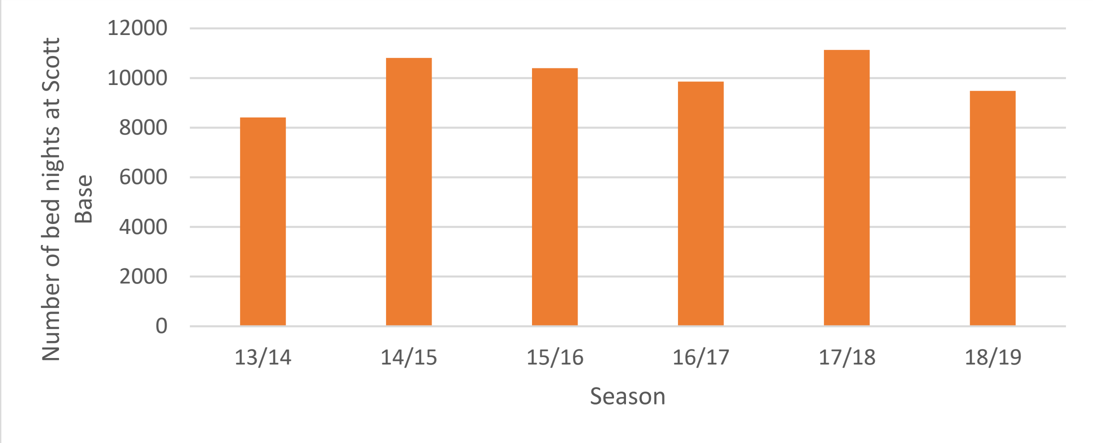


Figure 6: Scott Base bed nights, 13/14 – 18/19

The base acts as a hub for logistics to support science and education in the field. Essential infrastructure is maintained at key sites, remote from Scott Base, to enable fieldwork (Section 5.6). Around 1500 person-nights are spent in the field each summer (Figure 7).

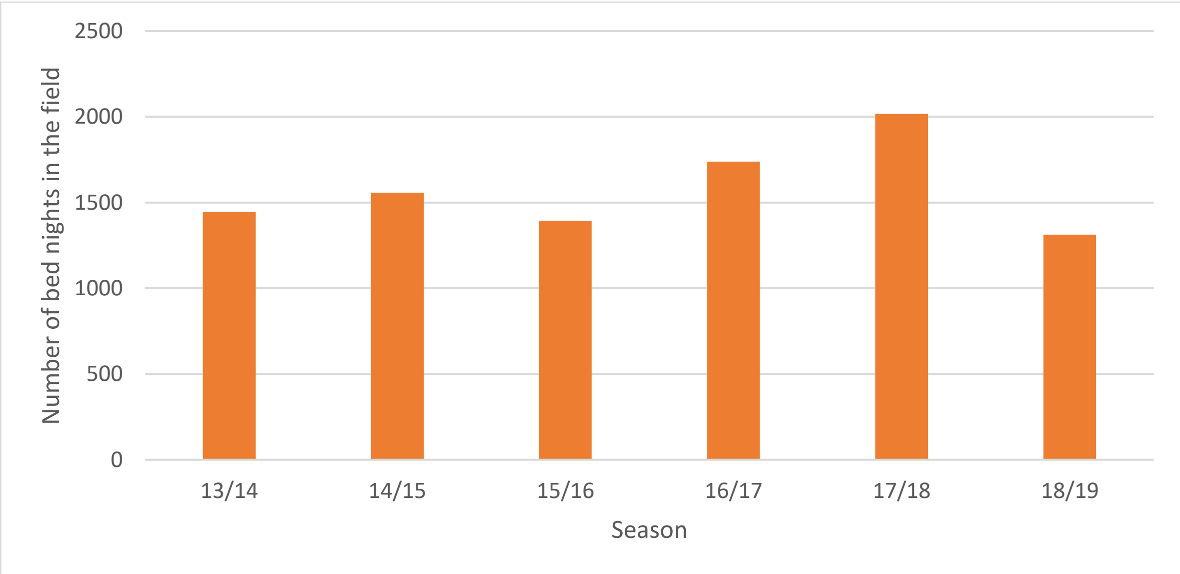


Figure 7: Field bed nights, 13/14 – 18/19

5.1. Power generation

Electricity is used at Scott Base for cooking and cleaning, water production (by means of a reverse osmosis plant), lighting, communications and other operations. Heating is distributed through the base is generated from diesel generators (waste heat from power production) and diesel boilers. On average Antarctica New Zealand uses 290,000 litres of fuel per year.

A three-turbine wind farm on Crater Hill between McMurdo Station and Scott Base is designed to generate a maximum output of 990 kW. The introduction of the wind farm reduced fuel consumption at Scott Base by 23% in the five years between 2008/09 and 2013/14. The running and maintenance of Scott Base currently uses wind generated energy but is reliant on fossil fuels in periods of low wind and as a necessary backup in power failures. As part of the joint logistics pool with the United States Antarctic Programme, all wind energy generated is shared with McMurdo Station as part of a Ross

Island Wind Energy grid. Approximately 450,000 litres of diesel use is avoided annually across both stations as a result.

In the field, solar panels are used for communications equipment where possible and are installed at some huts. Portable generators are used for back up and to power higher demand operational and scientific equipment. Heating is provided in huts and camps with diesel burning stoves.

5.2. Hazardous substances storage and use

5.2.1. Fuel

Fuel is stored at Scott Base for use throughout the season for maintenance and operations at Scott Base as well as field operation (facilities and camps). The primary types of fuel stored at Scott Base (Table 2) are JP8 (aviation fuel used in diesel engines and the Scott Base generators (Figure 8), mogas (cold temperature petrol blend used in vehicles and generators), kerosene (used primarily for cooking in the field), LPG (liquid petroleum gas used for cooking and heating), white spirits (used for cooking), and methylated spirits (used for cooking and priming).

The largest unit of bulk fuel storage at Scott Base is the 52,000 litre diesel tank, and smaller amounts are stored in a variety of tanks. Two 2,000 litre tanks and two 15,000 litre AN8 tanks remaining from the ANDRILL project are stored at Scott Base and Williams's Air Field. These are available for use for transporting fuel to and from field locations as required.

Figure 8: Bulk JP8 fuel tank, Scott Base

5.2.2. Other chemicals

Chemicals are transported to Antarctica to be used for maintenance of Scott Base, implementation of safety equipment, production of water and heat, operation of the wastewater treatment plant, cleaning and washing, vehicle maintenance and transportation. In total approximately 3,000 litres of chemicals are stored at Scott Base and remote facilities, mostly in very small quantities. A full list of the chemicals held as at winter 2019 is provided in Appendix 2.

All fuel and chemicals are accompanied by a Safety Data Sheet (SDS), recorded in the Hazardous Substances Register (Appendix 2), and stored in approved cabinets. The SDS provides workers and emergency personnel with procedures for handling or working with the chemical in a safe manner, and includes information such as physical properties (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures.

Explosives are occasionally transported to Antarctica for use in seismic scientific studies (covered under a separate environmental impact assessment of the appropriate level) or construction activities (covered by a specific environmental impact assessment of the appropriate level). Any such explosive materials will be stored at the McMurdo Station magazine.

Field fuels are described in Section 5.6.

Table 2: Fuel storage at Scott Base

Fuel	Maximum quantity	Storage
JP8	65,000 litres	Double skinned main bulk tank of 52,000 litre capacity, two 2,000 litre generator tanks and one 1,000 litre tank for the Hilary Field Centre - 209 litre drums, 5 and 20 litre containers
Mogas	4,000 litres	Trailer mounted tank - 209 litre drums, 5 and 20 litre containers
Kerosene	1000 litres	209 litre drums and 1, 5 and 20 litre containers
LPG	5,000 kg	45 kilogram cylinders
White Spirits/White Gas	600 litres	209 litre drums and 1 and 5 litre containers
Methylated Spirits	100 litres	20 litre and 15 litre containers

5.3. Waste

Waste is generated through the day to day operation of Scott Base and at field sites. With the exception of wastewater, all unwanted material is carefully contained and sorted at Scott Base for return to New Zealand in accordance with the provisions of Annex III to the Environmental Protocol to the Antarctic Treaty. Between 25,000 and 50,000 kilograms of material is typically shipped back each year, with occasional spikes due to construction, renovation and demolition projects (such as the 2014-2016 peak related to the Hillary Field Centre upgrade, Figure 9). Around a quarter of the material returned to New Zealand is recycled and half is sent to landfill (after appropriate treatment where necessary).

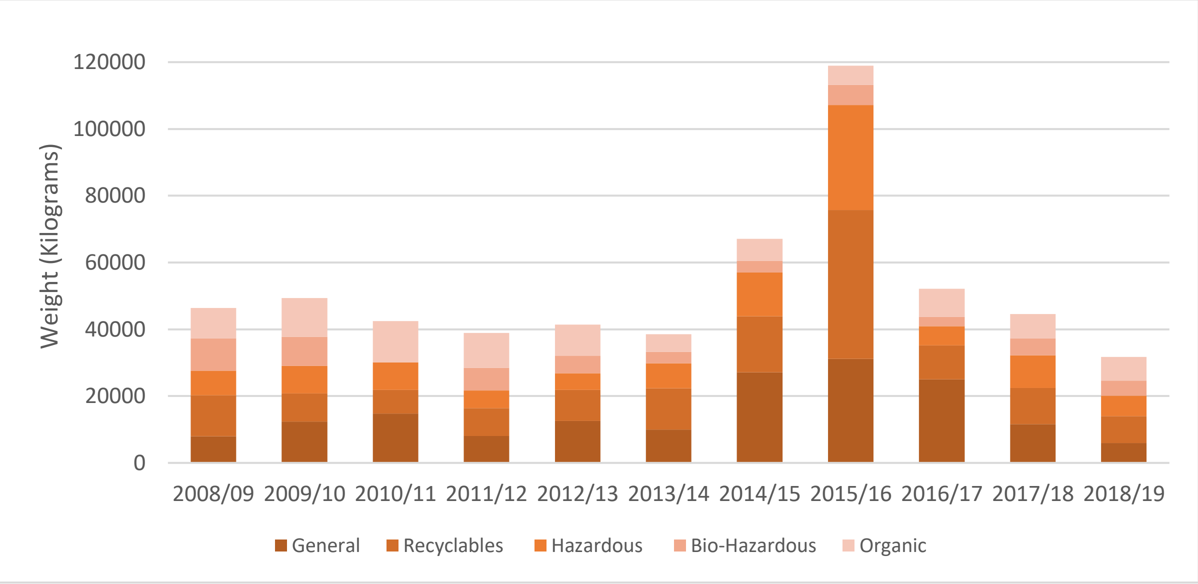


Figure 9: Annual quantities of waste between the 2008/09 and 2018/19 seasons

5.3.1. Wastewater

Human solid and liquid waste (sewage) and domestic waste (grey water) created at Scott Base is treated and processed in the wastewater treatment plant (screening, biological reduction and ozone exposure) at Scott Base and piped directly into the sea off Pram Point.

The sludge that is generated during the screening process runs through a “dewatering” process whereby the liquids are separated from the solids using a flocculent. The dewatering plant is separated from the normal wastewater treatment plant running to avoid having the flocculent enter the plant and kill the biology. All liquids separated from the dewatered sludge are drained to sea.

During service and maintenance, various parts of the wastewater treatment plant may need to be placed into bypass mode resulting in untreated or partially treated waste being released into the sea, with a maximum of 11,000 litres per day. However, all waste released at such times will have been macerated so that large particles are removed before release to the sea, the minimum requirements as per the Protocol (Annex III, Article 5, 1b). Wastewater quality is monitored, at least once every month.

The biological beds are a living organism in that they consist of microbes that increase or decrease in biomass depending on the quantity of food (or waste) being processed. Over the winter months, the number of people on base decreases and remains stable for roughly eight months. The biomass in the wastewater treatment plant decreases to the amount required to process the waste. At the start of summer, the base receives an influx of people and therefore a higher amount of waste needs to be processed by the wastewater treatment plant. In order to ensure that the waste effluent quality remains high during the transition from winter to summer operations, the biological beds need to be augmented with new microbes to build up biomass in the biological beds prior to the arrival of more people on base. A commonly used sewage treatment plant, EcoSock, containing powdered bacteria and nutrients effective in digesting organic waste is added to the beds. The bacteria are ubiquitous and found worldwide.

In addition to the wastewater treatment plant, there is a grease trap within the kitchen that captures fats, oils and grease (FOG) before it goes to the wastewater treatment plant. The grease trap is dosed with microbes from a grease-specific EcoSock to minimize the FOG accumulation. Remaining FOG must be removed manually approximately once a month. At this time the wastewater treatment plant is bypassed for 24 hours and all waste is sent to sea.

5.4. Maintenance activities

Due to the isolation, maintenance of life supporting systems such as heating, electricity and fresh water supply form a large part of the activity undertaken at the base. To ensure the safe and reliable operation of the existing Scott Base infrastructure until the redevelopment is complete, work is required. Some maintenance and upgrade works require “worker visitors”, i.e. contracted specialists in addition to staff, to visit Scott Base and occasionally the field.

Much of the ongoing maintenance and upgrade will take place within existing facilities. Planned outdoor works are described here.

5.4.1. Minor earthworks

Minor earthworks will continue in high and intensively impacted areas of Scott Base, e.g. making drainage channels and levelling sites for container or wannigan storage[5]. Snow clearing in the immediate operational area can also result in movement of soils.

[5] This sometimes involves use of fine gravel supplied from McMurdo Station, which USAP obtains by scraping hillsides.

5.4.2. Water intake and outfall structure replacement

The gantries that support sea water intake and wastewater outfall are planned for replacement in the 2020/21 season. This will involve highly localized disturbance and installation of concrete footings. In the 2019/20 season it is proposed to drill approximately 10 holes to test where the most suitable locations for footings for the gantries are and potentially to install anchors if suitable conditions are found. The drilling will be in association with the Scott Base Redevelopment site investigation (Section 5.12). Excavation of approximately 1.5m^2 area may also be required. In 2020/21, the proposed activities are to drill and install new foundations and anchors for the water intake and outfall.

5.4.3. Satellite dome replacement

The satellite dome which facilitates New Zealand communication systems at Arrival Heights (Figure 2) is nearing its end of life. It is proposed to undertake site investigation in the 2019/20 season in order to plan its replacement for the 2020/21 season. Initially a prefabricated concrete pad was the preferred design for the foundation. However, a drilling rig and a geotech engineering will be allowing a full geotechnical investigation for a piled solution. One core of up to 9m will be collected. This may be returned to NZ with cores from the other drilling work for the Scott Base Redevelopment. The geotech work will be followed up with a visual inspection of the First Crater site.

It is anticipated that the replacement dome will be on a site very close to the existing dome. The current dome is just within the boundaries of Arrival Heights ASPA 122. Consultation with scientists conducting long term research within the ASPA will be required to identify the detailed location, timing and approach to minimize disruption to experiments. It is noted that helicopter movement of a geotech drill rig via sling load is a preferred way of transporting the equipment and not over land using heavy plant. Further detail of the satellite dome replacement will be provided to MFAT before it is undertaken.

Following the 2019/20 season, it was decided that the replacement of the satellite dome would take place later than 2020/21. For the 2020/21 season, the proposed activity is to drill a hole for geotechnical investigation at T site. A core will be extracted and returned to New Zealand for testing and the results will inform the foundation design for the new satellite earth station.

5.4.4. Water tank replacement

Following the failure of Tank 4 in 2018 the available potable water storage was reduced by over 30,000 litres. As well as meeting the daily needs of Scott Base, the potable water supply contributes to firefighting water reserves. Replacement of water tanks (two in 2019/20 and two in 2020/21) is needed to avoid further tank failures and maintain adequate water supplies for the health of Scott Base residents and emergency preparedness.

The replacement is essentially like for like on the existing site. The new tanks and fittings must be disinfected prior to use, to ensure they are fit for potable water supplies. Calcium Hypochlorite will be used to chlorinate the water to the correct level. Achieving the correct residual level will require careful dosing control. Should the chlorine levels get too high for consumption, the water in the new tank will need to be further diluted. In the unlikely event that this can’t be achieved in a reasonable time frame, controlled discharge of chlorinated water directly into to the sea (i.e. bypassing the wastewater treatment plant) may be required to avoid freezing in the tank and fittings. In this event, the water will be neutralised with a thiosulfate compound prior to discharge.

5.4.5. Unforeseen maintenance

The need may also arise to include other maintenance activities as new priorities emerge. Notification will be provided to MFAT for approval in advance of such activities taking place, with supplementary information of an appropriate level.

5.5. Transport

5.5.1. Intercontinental aircraft

Antarctica New Zealand personnel and cargo transport between Christchurch and McMurdo Sound is primarily via the joint logistics pool between the United States and New Zealand. New Zealand also has collaborative arrangements with Italy, Korea and China.

The National Science Foundation (NSF) through the United States Air National Guard supplies the majority of flights which move passengers and cargo to and from the continent using a C-17 (Figure 10), C-130 and LC-130 aircraft. The Royal New Zealand Air Force (RNZAF) contributes around five C-130 Hercules and six Boeing 757 (Figure 11) round-trip flights to the NZ-US joint logistics pool annually, and sometimes provides additional flights into Terra Nova Bay in cooperation with Italy. The RNZAF will be replacing the very old Hercules fleet with the new C-130J model in 2023.

A key pressure point in air logistics is the late summer, when the sea ice and ice shelf surface is unsuitable for wheeled landings. For inter-continental transport this leaves only United States Airforce ski-equipped Hercules. The Italian rock runway at Terra Nova Bay, due for completion in the 2020/21 season, will offer new opportunities for personnel and priority cargo movements during this period. Large wheeled aircraft could land at Terra Nova Bay, with passengers and supplies transferred by smaller ski equipped aircraft to McMurdo Sound.

During the period October to March, the RNZAF may also carry out fisheries surveillance flights of the Southern Ocean using a P3-K Orion aircraft. These flights may include a landing at Pegasus Airfield, with an overnight of personnel at Scott Base and departure the following day. RNZAF personnel who visit or overnight at Scott Base follow all of Antarctica New Zealand's environmental procedures for Scott Base visitors.

USAP manage and maintain the airfields in McMurdo Sound. Antarctica New Zealand personnel handle Antarctica New Zealand cargo in and out of the Christchurch warehouse and Scott Base.

Figure 10: USAF C-17 landing © Antarctica New Zealand Pictorial Collection

Figure 11: RNZAF B-757 taxiing in after landing on Pegasus Airfield. © Antarctica New Zealand Pictorial Collection

5.5.2. Shipping

NSF contracts an icebreaker, fuel tanker and cargo ship to resupply McMurdo Station annually. Currently, Antarctica New Zealand sends cargo to Scott Base on this resupply ship and purchases its fuel from the United States Antarctic Programme (USAP) in Antarctica.

The new Royal New Zealand Navy Polar-class support vessel HMNZS *Aotearoa* is expected to commence Antarctic operations in the 2020/21 season, transporting New Zealand cargo and fuel to McMurdo.

Italy, Korea and China have all provided cargo and personnel movements to and from the field for Antarctica New Zealand on their vessels in the past and such cooperation is likely to continue when opportunities arise. As of 2019, China will be operating two icebreakers (MV *Xue Long* and MV *Xue Long 2*) and Italy will be operating the *Laura Bassi* (formerly RRS *Ernest Shackleton*). Korea will continue to operate RV *Aaron.*

To date, New Zealand ship-borne research has been conducted largely independently of Antarctica New Zealand, either on RV *Tangaroa* (operated by NIWA) or utilizing fishing vessels, under their own IEEs. Looking beyond the 2019-2023 period there may be greater investment in marine based research as Scott Base capacity reduces during its redevelopment, and possibly greater Antarctica New Zealand involvement in these operations.

5.5.3. Surface transport

Scott Base is built on volcanic scoria and for about 8 months of the year it is covered in snow. The grounds and facilities need to be maintained with regular snow moving. During the busy summer months when most vehicle activities occur, the immediate area around the base building is usually snow free. A variety of vehicles are included in the fleet for various purposes (Table 3).

Minor landscaping works around the immediate logistics area of Scott Base are conducted, such as the creation of meltwater channels to drain melt water flows, ground levelling to create an area for the unloading of containers from trucks, storage of containers and equipment, marking of the helicopter landing pad, laying of power and other cables and various other maintenance activities. Vehicles used include caterpillar bulldozers and loaders, and a telehandler.

Currently quad bikes are used around Scott Base for moving cargo and other heavy or bulk items. A small electric vehicle is currently being trialled as a replacement for the current Yamaha model (Figure 12).

Figure 12: Polaris ranger electric vehicle in Christchurch cargo yard before shipping to Scott Base for trial

Scott Base is 3km from McMurdo Station. The two bases are separated by a large hill, over which runs a road. Throughout the year, cargo and personnel are moved between Scott Base and McMurdo Station, Arrival Heights, the wind farm site and transition zones between Ross Island and the surrounding sea ice or ice shelf using utility vehicles such as Toyota Landcruisers, or the Isuzu truck.

During parts of the season when the ice surface is firm, the Toyotas can also be used on designated safe sea ice routes in McMurdo Sound. For sea ice and ice shelf journeys further from Scott Base, Hagglunds and Kassbohrer vehicles are used. Skidoos are also used on sea ice and the ice shelf, and at glacial field sites. Long distance traverse operations are covered by a separate IEE.

Table 3: Scott Base vehicle fleet 2019-2023

Type of Vehicle (and quantity)	No.	Use of Vehicle	Changes 2019-2023 (subject to funding)
Toyota Landcruiser	6	Used for general movements between McMurdo Station and Scott Base, passenger runs to and from airfields and for general cargo movements between McMurdo Station and Scott Base.	As these are replaced the fleet will change to a mix of four-wheel drive vans and twin cab Landcruisers.
D6H Caterpillar	1	Used in various tasks from traverses and deployment of events to snow clearing.	D4 and D6 due for decommissioning in 2021, to be replaced with a D5. A Challenger MT700 or MT800 with blade and hiab is also proposed for purchase in 2021.
D4G Caterpillar	1	Used in various tasks from traverses and deployment of events to snow clearing.	
926K Caterpillar Loader	1	Used in various tasks from traverses and deployment of events to snow clearing.	
Merlo P28.8 Telehandler	1	Used for general base support and cargo moving	A second Merlo may be added in 2020/21.
Isuzu FTS650 4x4 Truck	1	Used for carrying cargo over the hill road to and from McMurdo Station, and snow clearing from around the base buildings.	Likely to be decommissioned in 2020 and not replaced.
Hagglunds	5	Amphibious all-terrain vehicle that can carry up to 11 people used in the support of events, AFT and SAR year-round.	
Skidoos	17	Over snow light vehicle to carry passengers and tow small sledges, used in McMurdo Sound and some field sites.	Only 16 in 2019/20 pending replacement of a damaged skidoo.
Kassbohrer Pisten Bully (PB300 and PB100)	3	Used for traversing sleds and wannigans in support of science events. The PB300s are designed for traverse operations with a towing capacity of 40 tonnes and a speed of 10km/hr. All of the PBs have grader capacity and two of the PB 300 vehicles are fitted with Hiab cranes. Passenger capacity varies with each machine between 5 – 15 personnel.	One Pisten Bully is due for decommissioning in 2021 and two new units are proposed for purchase in 2022/23. As noted above, a Challenger MT700 or MT800 with blade and hiab is proposed for purchase in 2021.
Yamaha 4x4 Quad Bikes / Polaris Ranger	3	Used to support Antarctica NZ activities around the base for general operational support, ranging from loading helicopters to moving frozen goods between the freezer and kitchen. They are also used on occasion in a field	One Polaris Ranger (small electric utility vehicles) is currently being considered trialled as the possible replacement model. The two

		support role either as a supplement or replacement of skidoos in certain areas.	remaining quad bikes are due for replacement in 2020.
312 D L Caterpillar Excavator	1	Used for general base support and earth works.	

5.5.4. Intra-continental flights

Helicopter and fixed wing aircraft support activities and events at locations further away from Scott Base. As with intercontinental flights, resources are shared in the joint NZ-US logistics pool, and at times also between other Ross Sea operators.

Antarctica New Zealand currently contracts Southern Lakes Helicopters to operate a single B3 Squirrel helicopter from mid-November to the end of January each season (Figure 13). A second helicopter may be contracted from 2020/21. The total helicopter hours flown in support of Antarctica New Zealand is expected to be in the range of 250 to 350 hours per annum over the 2019-2023 period.

Fixed wing aircraft support (Twin Otter DHC6 and/or Basler DC3 (Figure 13, Figure 14) is leased on an as required basis from Ken Borek Air either directly or by means of a sub-contract to another Antarctic programme. In light of increasing science at remote sites, Antarctica New Zealand is currently investigating a longer term direct contract. The scale of activity is anticipated to be similar to helicopter support, i.e. 250 to 300 hours per annum.

This balance of helicopter and fixed wing field logistics has developed over recent years (Figure 15), due to an increase in remote and ‘deep field’ research sites.

Figure 13: Southern Lakes Helicopter with Twin Otter DHC6 aircraft in the background. © Antarctica New Zealand Pictorial Collection

Figure 14: Basler DC3 aircraft operated by Ken Borek Air in Antarctica

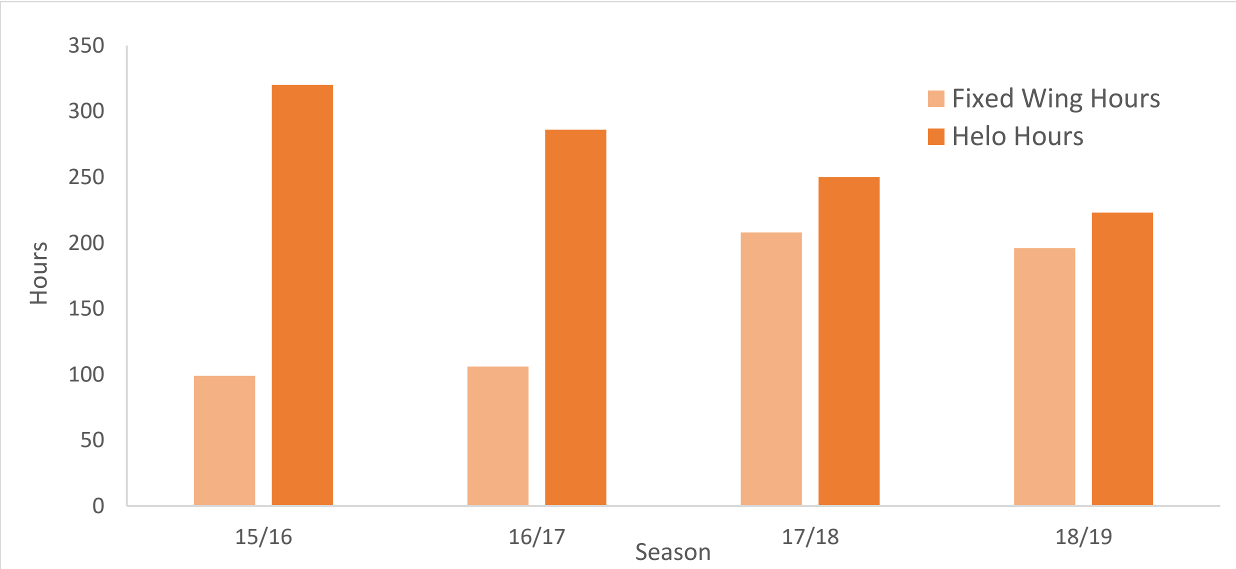


Figure 15: Fixed Wing and Helicopter hours 2015/16 to 2018/19 (Source: 2018/19 End of Season Review)

5.5.5. Penguin census

Antarctica New Zealand is funded to continue the long-term aerial photography of Adélie penguin colonies in the Ross Sea region. Aerial photos of the penguin colonies at Cape Bird, Cape Royds and Cape Crozier of Ross Island, and when opportunity arises, at Beaufort Island, are taken via helicopter. Surveys are to be conducted at colonies along the entire Victoria Land coast either from a C-130 (Hercules) aircraft or from a helicopter.

As set out in Table 4, the requested height of all overflights of Adélie penguin colonies in the Ross Sea region is 2,000 feet above ground level. This height is consistent with the 'Guidelines for the operation of aircraft near concentrations of birds in Antarctica' (ATCM Resolution 2 (2004)) and ensures consistency with past photography of the colonies. Some of the colonies are located at Antarctic Specially Protected Areas (ASPAs) which have overflight height restrictions, which are above the 2,000 ft requirement for the penguin census, except where permitted for scientific purposes (i.e. ASPA 105 Beaufort Island and ASPA 165 Edmonson Point, Wood Bay). Other penguin colonies are located in ASPAs which do not have an overflight restriction above 2,000 ft. ASPA entry for the purposes of aerial photography of Adélie penguin colonies to 2,000 feet above ground level is requested by this IEE.

Several of the monitored colonies in the Ross Sea region have been recognised as Important Bird Areas (IBA) by Birdlife International (Table 4). Recognition of these breeding sites as IBAs has not introduced any additional management controls but does emphasise the importance of the ongoing monitoring work undertaken on the status and trends of these colonies.

Table 4: Adelie penguin aerial census colonies

Colony	ASPA No.	ASPA overflight restriction	IBA	Latitude	Longitude
Beaufort Island	105	2500’	188	76° 56’S	167°03’ E
Cape Adare	159[6]	-	165	71° 18’S	170°09’ E
Cape Anne	-			73° 37’S	169°52’ E
Cape Bird Middle	-		186	77° 14’S	166°25’ E
Cape Bird North	-		186	77° 13’S	166°28’ E
Cape Bird South	-			77° 16’S	166°20’ E
Cape Cotter	-		296	72° 24’S	170°18’ E
Cape Crozier East	124	2000’	187	77° 29’S	169°33’ E
Cape Crozier West	124	2000’	187	77° 27’S	169°23’ E
Cape Hallett	106	2000’	170	72° 19’S	170°12’ E
Cape Jones	-			73° 17’S	169°10’ E
Cape Phillips	-			73° 04’S	169°38’ E
Cape Royds	121	2000’		77° 32’S	166°18’ E
Cape Wheatstone	-			72° 37’S	170°14’ E
Coulman Island	-		415,500	73° 30’S	169°50’ E
Coulman I. Middle	-			73° 26’S	169°54’ E
Coulman I. North	-			73° 22’S	169°51’ E
Coulman I. South	-			73° 31’S	169°54’ E
Downshire Cliffs	-		243	71° 33’S	170°32’ E
Duke of York Island	-		680	71° 37’S	170°02’ E
Edmonson Point	165	3281	175	74° 19’S	165°04’ E
Foyn Island	-		224	71° 57’S	171°09’ E
Franklin I. East	-				
Franklin I. West	-				
Franklin Island	-		129,419	76° 07’S	168°15’ E
Inexpressible Island	-		365	74° 53’S	163°45’ E
Mandible Cirque	-		121	73° 06’S	169°23’ E
Nella Island	-			70° 37’S	166°04’ E
Possession Island	-		276	71° 53’S	171°11’ E
Sentry Rock	-			70° 46’S	167°24’ E
Terra Nova Bay	161	-		74° 45’S	164°00’ E
Unger Island	-			70° 41’S	166°55’ E

[6] ASPA designation for historic huts, not penguins

5.5.6. Drones and Remotely Operated Vehicles

Operational use of drones (also known as Unmanned Aerial Vehicles, Unmanned Aircraft Systems or Remotely Piloted Aircraft Systems) is undertaken from time to time to support mapping and surveying for engineering and environmental management purposes, including ASPA management. This is usually undertaken by science events on behalf of Antarctica New Zealand, or specialist worker visitors. In some instances, as their use becomes more common, media and communications teams may request to use Remotely Piloted Aircraft Systems (RPAS) or aerial drones to capture footage.

Remotely Operated Underwater Vehicles (ROV) may also be used, as part of environmental monitoring or to collect information to support environmental management. As with aerial drones, ROV operation will be undertaken by scientific events with the relevant planning and approvals in place.

All use of RPAS will follow the "Environmental guidelines for the operation of remotely piloted aircraft systems" (Resolution 4 (2018). In addition, when RPAS or drones are used, the pilot must prepare a Concept of Operations document (CONOPS) with details and assurance of pilot training and competency and air frame worthiness, and plan to operate in accordance with:

- Environmental Guidelines for Operation of RPAS in Antarctica (Resolution 4 (2018)); and
- COMNAP – Antarctica Remotely Piloted Aircraft Systems (RPAS) Operators Handbook (current version Nov 2017).

5.5.6.1. Season 2021/22 proposed RPAS operations

RPAS filming is proposed in a few selected locations, with the aim of the activities to support the Community Engagement Programme (CEP), and the documentation of the Scott Base Redevelopment.

A summary of the proposed RPAS activities and locations is shown in Table 5. RPAS photography/filming is proposed in combination with ground-based filming and in some instances, underwater filming using a fixed camera into an existing ice hole (K882A, K750F, K882U).

Table 5: Proposed RPAS operation locations

Month	Location	Event	Purpose of filming	ASPA/ASMA
October	McMurdo Sound sea ice	K063 Supercooling under ice shelves	CEP - Sea ice science and camp activities	No
	Cape Evans and Cape Royds	K882A Coastal seafloor communities	CEP - Diving and ROV science, dive camp, benthic ecosystems	No - filming activities will be on sea ice and underwater outside of the ASPA boundaries - no entry or overflight of ASPAs is required
	Scott Base sea ice	K750F SBR Bathymetric survey	SBR – Documenting the bathymetry survey	No
November	Ross Ice Shelf	K408 Traverse	CEP - Document logistics traverse work, show scale of Ross Ice shelf and size of traverse "caravan train"	No
December	Dry Valleys (Lake Brownsworth)	K064	CEP - Film science and capture scale of the area with aerial footage	Yes – McMurdo Dry Valleys ASMA

		Greenhouse gases in Antarctic permafrost		
	Dry Valleys (Lake Fryxell)	K882U Antarctic aquatic ecosystems	CEP - Film science and capture scale of the area with aerial footage. Use camera in drop hole in lake for underwater footage	Yes – McMurdo Dry Valleys ASMA
	Kamb Ice Stream on Siple Coast	K862A Antarctic Ice Dynamics (Platform science)	CEP - Film science and scale of scenery and camp on ice shelf	No
December	Historic Huts	K170 Historic hut conservation	CEP - Film conservation activities and huts within landscape	Yes - ASPA 155, 157, 158 NOT ASPA 121 Cape Royds

Of particular note are the proposed RPAS activities at Cape Bird and in the McMurdo Dry Valleys.

The McMurdo Dry Valleys Management Plan makes provision for a range of activities including "(…) media, arts, education or other official national program visitors (…) where these activities do not jeopardize the values of the Area". It is expected that RPAS operations conducted in accordance with the Guidelines and CONOPS documents will not jeopardize the values of the ASMA.

The alternatives to the proposed RPAS operations in the McMurdo Dry Valleys are to not proceed with the activities, which would diminish the value of the CEP event. Another alternative is to conduct the filming from a helicopter, which would lead to other environmental impacts including carbon emissions, noise and increased potential for the disturbance of wildlife,

5.6. Field support

Antarctica New Zealand provides operational support for scientific fieldwork. For the most part scientists run their own camps in accordance with their own EIAs, using Antarctica New Zealand supplied logistics and equipment. But Antarctica New Zealand staff provide on-site support in some instances, such as Antarctic Field Trainers in higher risk environments, or engineering staff for long vehicle journeys. Staff will also respond to emergencies in the field.

Occasionally, Scott Base staff may be called upon to assist science events with their field of study. Any participation will be consistent with the permits, ethics approvals and other relevant conditions of the science event concerned.

5.6.1. Camp equipment and set up

Science events are largely responsible for planning and managing their own field camps. Antarctica New Zealand provides equipment including tents (Figure 16), primus or LPG stoves, generators (with stands, drip trays and spill kits), and toilet facilities (tents, buckets). Through tools such as the environmental Code of Conduct, Field Manual and Event Manager training, Antarctica New Zealand encourages events to select previously used camp sites where possible and camp on snow where possible (rather than ice-free ground).

Solar panels for charging radios and iridium phones are offered, but other renewable energy solutions for the field currently need to be provided by events.

Figure 16: Tents supplied by Antarctica New Zealand for field use (clockwise from top left: Polar Haven, Rac Tent, Polar Tent, Endura)

5.6.2. Installations

Antarctica New Zealand installs, maintains and removes equipment in the field for safety (e.g. hand lines, bamboo route markers), science support (e.g. helicopter markers and landing pads, field huts and Wannigans), communication equipment (e.g. radio antennae), and environmental management and monitoring (e.g. ASPA signs, boundary signs, monitoring markers, dust collectors). Radio repeaters are installed every summer at Scallop Hill (Black Island), Hoopers Shoulder (Mt Erebus), Mt Newell, Mt Cerberus and Mt JJ Thompson (McMurdo Dry Valleys), as shown in Figure 3.

Figure 17: Clearing snow to open Cape Bird hut. © Antarctica New Zealand Pictorial Collection

Table 6 lists remote structures that Antarctica New Zealand maintains.

Table 7 records other semi-permanent or temporary installations Antarctica New Zealand is responsible for.

The Antarctic Heritage Trust is conducting restoration at Cape Adare under a separate IEE. Antarctica New Zealand has taken responsibility for some field installations to support this work. Two Automatic Weather Stations (AWS) at Cape Adare (one on Ridley Beach, the other on the ridge) allow the transmission of accurate weather data to ensure safe and efficient flight operations to the area. A time lapse camera recording images of the penguin colonies is also in place at Cape Adare, as this data collection is able to be supported efficiently alongside the AWS. It is currently envisaged that all installations will be removed when the restoration work is complete.

Five wooden 'sleeping pods' are currently stored at Red Castle Ridge. These were developed to ensure safe shelter options for staff working on the heritage restoration project, but were moved for secure winter storage and are intended for relocation.

Records of all science and non-science equipment installed away from Scott Base are kept in accordance with Article 8(3) of Annex III to the Protocol. This Article requires Parties to maintain an inventory of locations of past activities.

Table 6: Remote facilities owned and operated by Antarctica New Zealand

Name	Year	Description
RS02 - Bratina Island	1982	3 huts (each 10m^2) with reticulated solar power, AN8 heating, external toilet
RS03 - Cape Bird	1982	Large Hut (86m^2) with reticulated solar power, AN8 heating, shower, external store and external toilet (**Error! Reference source not found.**)
RS04 - Cape Evans	c. 2010	A retrofitted shipping container with kitchen facilities and a small toilet hut.
RS05 - Cape Royds	1982	2.5 x 2.5m plywood hut
RS06 - Cape Roberts	1982	Plywood kitchen/mess hut and bunk hut (20m^2)
RS07 - Lake Vanda	1983	3 huts (10m^2 each), no heaters or bunks. Removal intended due to rising lake levels.
RS08 - Lower Wright	1982	Plywood hut (10m^2) with two bunks. Also known as "Lake Brownsworth Hut"
RS09 - Arrival Heights	2007	Science facility (190m^2), steel portal frame with 250mm metal clad PIR panels
RS10 - Cape Adare	2018	Three retrofitted water tanks for living, sleeping and construction workshop.

Table 7: Antarctica New Zealand field installations

Item	Sites	No.	Purpose
A wind sock / marker	Cape Bird (Inclusion Hill and above middle rookery)	3	To aid helicopter pilots to find the safest route into Cape Bird.
ASPA boundary sign	Cape Bird	1	To indicate the ASPA 116 boundary to those collecting snow in gully that runs out of the ASPA.
Automatic Weather Stations	Cape Adare (Ridge and Ridley Beach)	2	To provide continuous accurate weather information to support fixed wing and helicopter

			services to support science and Antarctic Heritage Trust conservation work.
Bamboo poles	Scott Base, sea ice and Ross Ice Shelf	1,000 approx	Marking safe and unsafe routes.
Dust sample collectors	Scott Base	12	To monitor changes in dust deposition as part of the Scott Base Redevelopment project
Dust sample collectors	Cape Evans (to be installed 2019/20)	5	To compare dust deposition as part of the Scott Base Redevelopment project
Monitoring markers	Cape Evans (to be installed 2019/20)	10	To identify monitoring plots used for sampling and visual assessment of control site for SBR
Monitoring markers	Scott Base	25	To identify monitoring plots used for sampling and visual assessment of terrestrial impacts for SBR
Platform and plaque	Botany Bay	1	Polar haven platform structure with plaque to indicate that it is for a polar haven, belongs to AntNZ, and is not a helicopter landing pad.
Platform	Cape Roberts	1	Fuel staging platform structure
Safety hand line	Castle Rock access route	1	Provide safe access to Castle Rock walkway (chain anchor bolts for chain safety line along the walkway).
Ski tow and wannigan	McMurdo Ice Shelf, Ross Island	1	Provide recreation for Scott Base staff.
Sleeping pods	Red Castle Ridge	5	Sleeping accommodation.
Temporary anchors for setting up belays and safety systems	Ross Island and McMurdo Dry Valleys	not recorded	Safety of personnel on exercises or rescues (removed where practicable).
Time lapse cameras	Cape Adare	1	To provide continuous images of penguin activity at Cape Adare.
Time lapse cameras	Scott Base	5	To monitor changes in snow patch distribution, timing and location of runoff, local seal population dynamics for SBR.
Wannigans	Various temporary locations, one semi-permanent at Windless Bight ('the Square frame')	7	Provide shelter for Antarctic field training and other purposes such as cooking, sleeping, diving or lab work.

5.6.3. Field fuels

Fuels and small quantities of chemicals are used at field sites. Secondary containment is utilised for fuel in operational use in the field (i.e. drums and equipment at active field camps). Fuel stored in sensitive environments, including the McMurdo Dry Valleys, is also kept within secondary containment at all times.

Containment for field caches in other snow-free areas is assessed by the operations team and environmental team to determine the most appropriate set up for the location and conditions. Consistent with methods used by other National Programs, fuel caches located on sea ice, ice sheet and ice shelf do not have secondary containment as its use creates further environmental risks such as loss of material into the environment due to break-down of the bunds and in-fill with snow and ice which reduces containment potential, removes paint from drums and can cause damage to fuel vessels during removal.

The establishment and ongoing use of field fuel caches is necessitated by the increased levels of deep field science being undertaken at present. Caches are installed by air or surface traverse, to support onward transport and field operations. All fuel caches established by traverse operations will be reported (GPS location, fuel type and amount) annually in the Traverse Operations Initial Environmental Evaluation interim report. Any caches established by other means will be reported annually in the Antarctica New Zealand Initial Environmental Evaluation interim report.

An indication of type, quantity and location fuel currently stored in the field is provided in Table 8.

Empty drums are returned to Scott Base from the fuel caches when possible, but full drums remain in the field for use in future seasons if necessary, provided they are in good condition.

In addition to fuel caches, Antarctica New Zealand has seven wannigans for various purposes (kitchen, sleeping, diving or scientific facilities), each of which has a maximum storage capacity of 120 litres of fuel. These wannigans are not fixed to any one site and may therefore visit several sites within a season. They are kept at Scott Base throughout the winter. A semi-permanent wannigan is located at the Scott Base ski field and another on Windless Bight as a shelter for Antarctic field training.

Table 8: Fuels stored in the field (winter 2019)

Fuel type	Litres	Kilograms
JP8	**32898**	
Cape Bird Hut	*209*	
Cape Evans Huts	*259*	
Hot Water Drill site 2	*5016*	
Kamb Ice Stream Camp	*20082*	
Redcastle Ridge	*4812*	
Windless Bight	*2520*	
Mogas	**4306**	
Cape Bird Hut	*180*	
Cape Evans Huts	*20*	
Cape Hallett	*209*	
Cape Roberts	*20*	
Kamb Ice Stream Camp	*2936*	
Redcastle Ridge	*470*	
LPG		**144**
Cape Bird Hut		*36*
Cape Evans Huts		*18*
Cape Roberts		*36*
Kamb Ice Stream Camp		*45*
Redcastle Ridge		*9*
Total	**36877**	**144**

5.6.4. Sea ice thickness measurements

Antarctica New Zealand undertakes sea ice thickness measurements throughout the year and particularly during the summer season. The measurements inform the location of access tracks, transitions from land to sea ice as well as recreational trails. Sea ice thickness checks also inform when certain routes need to be closed, typically as the sea ice weakens later in the summer.

The measurements are completed by drilling holes into sea ice until the water is reached. Typically, 2-3 personnel are involved.

In 2020/21, further sea ice thickness measurements are proposed, further away from Scott Base as shown in Figure 18. The in-situ measurements will take place along the paths of two satellites and will serve to verify the accuracy of the satellite measurements. This validation of the remote sensing results will support Operations Planning by enabling better route planning for sea ice events in future seasons, resulting in increased safety for field events. 2 personnel using 2 skidoos will complete the work. They will drill holes into the sea ice along transects (grey rectangles in map below) and measure to measure sea ice thickness directly as well as the freeboard (amount of ice above the waterline), snow thickness and density.

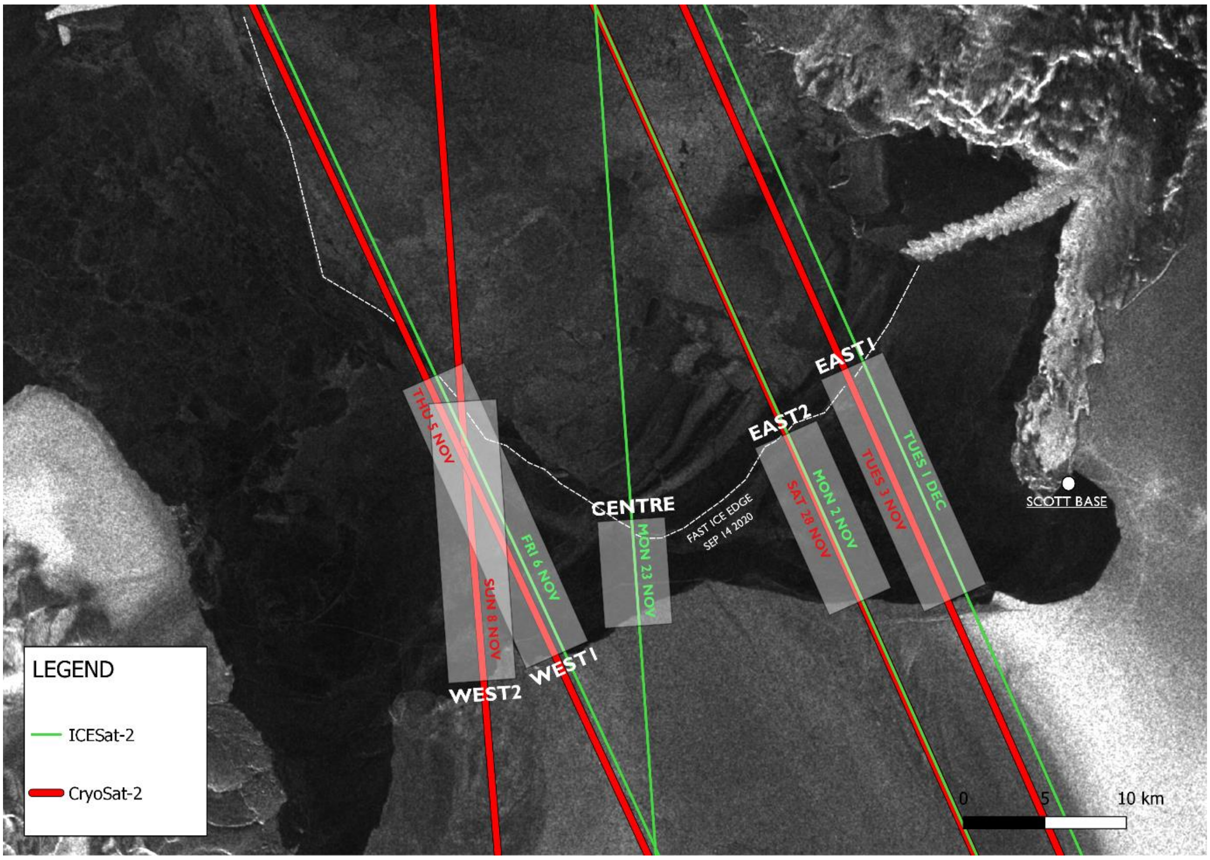


Figure 18: Proposed sea ice thickness measurement sites

5.6.5. Search and Rescue training

Antarctica New Zealand undertakes Search and Rescue exercises with Scott Base and USAP personnel as part of Joint Antarctic Search and Rescue Team (JSART) training in order to maintain operational readiness and SAR competence. Examples of areas used: Mt Erebus (the route from Fang Camp, Lower Erebus Hut, Upper Erebus Hut), Mt Discovery, White Island, Black Island, areas of the Royal Society Range and local sites such as Castle Rock, Silver City Ice Fall and Observation Hill.

5.6.6. Testing Battery/Solar Power supply setup

In 2020/21, it is proposed to test at least 2 different battery types connected to a solar panel. This test will inform the viability of using solar panels to power instruments in winter, which would help reduce reliance on fossil fuels for charging batteries at Scott Base and increase winter science data collection capability. A telemetry connection will send back comparative voltage data across the winter in in-situ light and temperature conditions on the ice shelf. A radar will be attached to the battery/solar setup to put a load on the system reflective of typical installations planned for future science.

The installation is proposed to be set up on the ice shelf at Windless Bight, near the A-Frame. The installation will take one day to put in place, this will be done before winter. No ongoing maintenance is expected and the installation will be in place for at least one winter.

5.6.7. Foreshore preparation for heated plates experiment

In season 2021/22, it is proposed to carry out some ground preparation on the foreshore of Pram Point, in the vicinity of the wet lab. The work is in support of science event K885A, which was deferred by one season to 2022/23 due to ongoing COVID-19 restrictions. The science event proposes to install 4 heated plates in the sea off the foreshore. The plates are planned to remain in place for one to two years before being relocated to Terra Nova Bay to continue the experiment. The science event will be assessed under a PEE for season 2022/23.

For 2021/22, the proposed work involves identifying a suitable location on the foreshore that is stable, accessible and will not conflict with other activities. The Scott Base team will complete all the work in season 2021/22. Some synergy is expected with the SBR enabling works (section 5.12) and the activities will be combined for efficiency where possible. For this reason, it was considered appropriate to include the 2021/22 proposed activities under this IEE.

Once a suitable location is identified, minor earthworks (see section 5.4.1) will be completed using the Scott Base plant. The earthworks will result in a trench or a series of holes. The ground conditions and location will dictate what type of earthwork is carried out. In 22/23, cables will be laid in the trench or fed into the holes from the wet lab to the heated plates as part of the event's work plan.

5.7. Recreation and familiarisation

Recreational opportunities are important for the wellbeing of Antarctica New Zealand personnel spending long periods in Antarctica. It is also important that staff experience and understand a range of Antarctic activities relevant to their role.

Recreation takes place at Scott Base and McMurdo Station, as well as around Hut Point Peninsula and further afield when opportunity allows.

The majority of sites visited are well known and have been visited when occasion allows for many years. Travel to areas outside the main areas of operation listed in Section 3 will be notified to MFAT for approval in advance of such travel taking place.

5.7.1. Observation and familiarisation

Antarctica New Zealand personnel undertake health, safety and environmental audits and other observations of science events in the field in order to improve their understanding of operations and identify improvements that may be made. This is planned to efficiently utilise available logistical capacity such as already scheduled helicopter flights.

5.7.2. Independent recreation

People can walk, bike and cross-country ski in the local area on designated trails, and using the small downhill skifield (Figure 19). Bikes and skis are provided at Scott Base but some personnel bring their own recreational equipment such as kites, fat tire bikes and ski touring gear.

Walking and photography along a designated safe route in the sea ice pressure ridges outside Scott Base is also popular during the early summer. Seals are likely to be encountered in this area. Occasionally Adélie or Emperor penguins may also transit the sea ice near Scott Base. Whenever safe to do so, personnel are required to maintain a 10-metre viewing distance from wildlife as part of Antarctica New Zealand's Code of Conduct (Appendix 1).

5.7.3. Organised activities

Additionally, group trips are taken to the historic huts at Cape Evans and Cape Royds when sea ice allows surface travel. Usually these take the form of 12-20 people on a Sunday day trip. The historic huts at Cape Evans and Cape Royds, and Discovery Hut near McMurdo Station, are ASPAs (Section 5.9) for which a permit to visit is applied for. Other organized outings can include:

- Climbing Trips to Castle Rock
- Skidoo trips
- Room-with-a-view
- Visits to Erebus Glacier Tongue ice caves
- Abseiling into a crevasse
- Local sea ice and ice shelf areas.

During observation or familiarisation trips away from Scott Base, wildlife may be encountered. The Cape Royds Adélie penguin colony is one such site but, but birds or seals can be found elsewhere, particularly when travelling on the sea ice. Under Antarctica New Zealand's Code of Conduct (Appendix 1), personnel are required to maintain a 10-metre viewing distance on foot and a 200m distance in vehicles, when safe to do so.

When it is operationally efficient, staff may travel to field sites to familiarise themselves with field activities to ground truth or improve operations, health and safety, environmental management or education.

Staff can utilize the Square Frame (trainers' hut at the field training site) for overnight breaks from Scott Base. Camping trips may also be undertaken, but no camping is undertaken within any ASPA. There are sometimes multi-day fam trips over the Christmas and New Year break.

5.7.4. Winter recreation

In winter staff still do local walks such as Observation Hill, Crater Hill and McMurdo Station, and make overnight trips to the Square Frame. Fam trips are organized such as to White Island (Mt. Nipha), Black Island (Mt. Aurora), the Constellation aircraft wreckage on the ice shelf near the former Pegasus runway, and viewing points for photography, stargazing and, final sunset and the first sunrise. The Search and Rescue Team undertake training exercises at field sites.

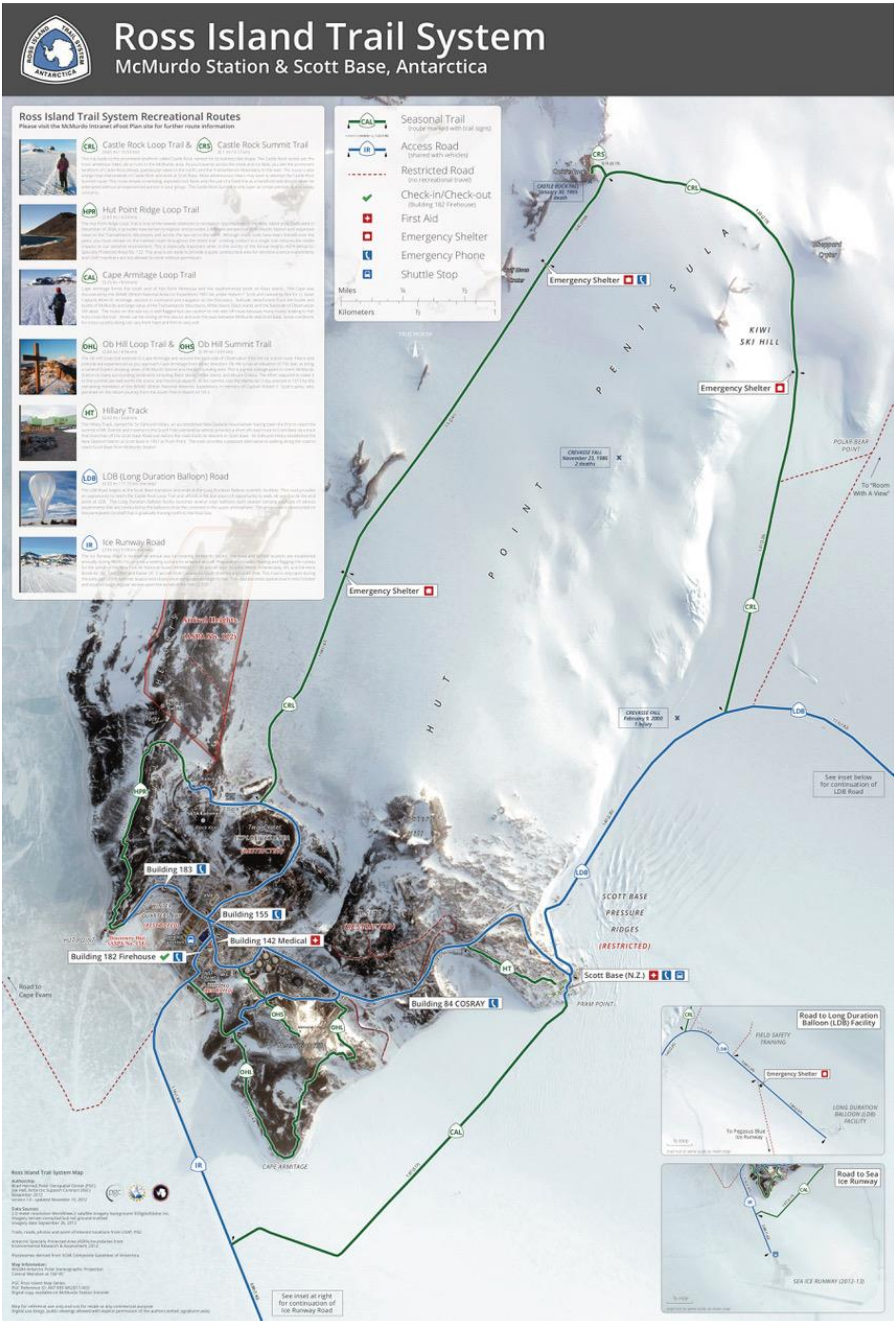


Figure 19: Ross Island Trail System. Source: Brad Herried, Polar Geospatial Centre (PGC) and Joe Heil, Antarctic Support Contract (ASC) November 2012

5.8. Community Engagement Programme

The Community Engagement Programme (CEP) encourages proposals from media, artists, educators and writers with a genuine interest in Antarctica and the environment, and demonstrated ability to reach target audiences. The selection process is highly competitive, as opportunities for travel to Antarctica are very limited and vary each year according to available logistical capacity. In the 2019/20 season one selected education CEP project involves a camera person and presenter from a popular TVNZ children's show travelling to Scott Base for ten days to make eight short articles along with accompanying educational resource. Three helicopter hours have been allocated for the crew to visit two science events working with wildlife at their field sites. This is indicative of the scale of CEP events likely to occur annually over the next four years.

5.8.1. 2021/22 season Community Engagement Programme

A new format of CEP is proposed for the 2021/22 season, in response to the reduced operations brought about by COVID-19.

A single event of one person has been selected to spend the majority of the season at Scott Base, instead of the multiple events and people that usually travel under the programme. The person selected is Anthony Powell, a filmmaker, photographer, multimedia consultant and specialist camera equipment designer and builder. He is the producer, director and cinematographer of the multi-award-winning film Antarctica: A Year On Ice. Anthony Powell has long been involved with Antarctica and the New Zealand Antarctic Programme. He has spent 10 winters in Antarctica in various roles. Anthony was selected because of his filmmaking and Antarctic experience.

The objective of the CEP event this season is to capture a variety of still images and video footage. The material captured will be shared with media organisations and used by Antarctica New Zealand for various purposes, including a recruitment video and documenting the Scott Base Redevelopment. Given the length of the event and the skills of the operator, it is efficient for Anthony to support other Antarctica New Zealand operational activities over and above the scope of the CEP programme. These other activities include completing the penguin census (described in 5.5.5), and documenting Scott Base operations, Antarctica New Zealand's recruitment activities, activities at Arrival Heights ASPA 122, and the Scott Base Redevelopment.

Is it proposed that the work will take place at Scott Base and in the field where Anthony will join science events and document their work.

The proposed activities include filming and photographing using hand-held cameras, fixed cameras and in some instances, Remotely Piloted Aircraft System (RPAS). Hand-held filming and fixed filming is proposed on land and from aircraft (fixed wing or helicopter). Fixed cameras may be used on land and underwater, where an ice hole has been created for a science event. The proposed RPAS operations for the 2021/22 season are described in 5.5.6.

5.9. Invited Visitors

An important component of New Zealand's summer activities in Antarctica is the hosting of invited visitors to Scott Base, including ministers, public sector CEOs, business leaders and foreign dignitaries. These visits provide an important opportunity to showcase New Zealand's research and environmental management activities in Antarctica to senior decision-makers, funders and political supporters. Additional value is achieved by providing invited visitors with Antarctic experiences, usually involves a day's helicopter support to visit key locations of historic, aesthetic and scientific value.

Antarctica New Zealand is keen to constrain such visits to a set series of locations, that maximises opportunities for invited visitors whilst minimising the environmental footprint of such events.

To this end, invited visitor field events will normally be limited to only the following locations:

- Cape Evans (Scott's Historic Hut),
- Cape Royds (Shackleton's Historic Hut, penguin colony),
- Cape Bird (field hut, penguin research), and
- A viewing location in the Olympus Mountain Range in the Dry Valleys, north of the Dais at the eastern end of the Wright Valley (spectacular Dry Valleys scenery); and
- the Canada Glacier Visitor Zone in the McMurdo Dry Valleys.

Additional visits may occasionally be made by invited visitor events to:

- US facilities in the Dry Valleys, e.g. Lake Fryxell, Lake Hoare or Lake Bonny, for the purpose of US collaboration, or
- A specific New Zealand field event where there is a direct interest of an invited visitor in that particular research programme.

5.10. Management of Antarctic Specially Protected Areas

Entry into some ASPAs is undertaken routinely throughout the summer and winter periods by the New Zealand Antarctic programme staff, when permitted to do so. Reasons for access include:

- Monitoring, mapping and other observations to support ASPA management plan reviews.
- Supporting permitted science events and long-term data collection.
- Familiarisation, education and recreation, where ASPA management plans allow these.

Entries take place throughout the year and may be made by any person officially supported by Antarctica New Zealand, subject to the approval of the principal permit holder (the Chief Executive of Antarctica New Zealand) or their nominee.

Section 6.3 provides details on the ASPAs regularly entered by the New Zealand Antarctic programme, routine activities conducted within these Areas and the proposed number of visitors per year (over the period September to August) over the next four years. ASPA visits are for operational reasons and for environmental management.

In accordance with Article 6 of Annex V to the Protocol, Antarctica New Zealand takes the lead in conducting reviews of protected and managed area management plans that New Zealand originally proposed for designation. These reviews are initiated at least every five years. In the next four years, New Zealand will undertake a joint review with the United States of the McMurdo Dry Valleys ASMA and will initiate reviews of nine ASPA management plans, including all four historic hut sites (Table 9).

Much of the review work involves consultation with the science community and Antarctic operators and does not necessarily require site visits. However, some areas may need on-the-ground inspection, monitoring or surveying.

Table 9: New Zealand ASPA and ASMA Management Plan Reviews 2019-2023

No.	ASPA/ASMA name	Review due
ASMA 2	McMurdo Dry Valleys, Southern Victoria Land	2020
ASPA 104	Sabrina Island, Balleny Islands	2020
ASPA 105	Beaufort Island, McMurdo Sound, Ross Sea	2020
ASPA 116	New College Valley, Caughley Beach, Cape Bird, Ross Island	2021
ASPA 131	Canada Glacier, Lake Fryxell, Taylor Valley, Victoria Land	2021

ASPA 155	Cape Evans, Ross Island	2020
ASPA 157	Backdoor Bay, Cape Royds, Ross Island	2020
ASPA 158	Hut Point, Ross Island	2020
ASPA 159	Cape Adare, Borchgrevink Coast	2020

5.11. Managing sites of past activity

The Scott Base area has been continuously occupied since 1957. Environmental management practices have developed over this time, with a significant shift when the Protocol on Environmental Protection to the Antarctic Treaty was signed in 1991. The environmental legacy of past activities and practices is still present at Scott Base and some field sites, often reflecting eras when practices differed from today.

Article 1(5), Annex III of the Protocol requires Parties to clean up past sites of waste disposal, with the exception of historic sites and those where clean up would cause worse environmental impacts. An inventory of sites of past activity is maintained in accordance with Article 8(3) of Annex III to the Protocol. This includes records of deployed field equipment (including all field huts and fuel caches) as well as reported sites of waste and other remains from past activities.

5.11.1. Clean up

New Zealand has undertaken clean-up efforts at several sites. Structures removed include:

- The remains of a platform at the CIROS 1 drill site at Butter Point, removed in 2016/17
- Hallett Station (joint US-NZ station operating 1957-1973), cleaned up in two phases, 1984-1986 and 2003-2006
- Vanda Station (1967-1974), removed in 1994/95
- Dry Valleys huts (Asgard, Bull Pass, Lake Fryxell, Miers Valley) and stream weirs and flumes in the Miers and Victoria Valleys dating from the 1970s and 1980s, removed in the 1990s and early 2000s.

Despite best efforts, some remnants of materials and contaminants such as hydrocarbons and paints may still remain at these sites.

Many smaller items remaining from past activities have also been reported from a variety of locations such as fuel containers, food caches, markers and equipment. In over 50 instances the remains have been removed, and others remain recorded in the inventory of past sites for action when there are efficient logistics opportunities and personnel and helicopter hours available. Sites identified for potential clean up in 2019-2023 are:

- Vanda huts (reaching end of life and not suitably located long term due to rising lake levels)
- Cape Roberts fuel staging platform
- Botany Bay polar haven platform.

Debris from past operations at Scott Base is sometimes exposed by melt, and removed when safe to do so. The Scott Base Redevelopment project will provide an opportunity to clean up some of the historic contamination at Scott Base (Section 5.12). An asbestos management plan is in place to mitigate risks associated with material in the soil. These risks are primarily to human health rather than the environment.

5.11.2. Historic sites and artefacts

Items discovered in the field may have historic or heritage value. Antarctica New Zealand has developed an evaluation process (SOP PA-003) to assess whether such items should remain in situ, and whether or not they should be proposed for listing on the list of Historic Sites and Monuments maintained by the Antarctic Treaty Parties.

Antarctica New Zealand is committed to the protection of historic artefacts and sites, which are significant in terms of their scientific, explorative, technical, architectural, symbolic or commemorative value to New Zealand or the wider community. New Zealand is responsible (either solely or jointly with other Antarctic Treaty Parties) for managing and maintaining 20 listed Historic Sites or Monuments in Antarctica. Antarctica New Zealand either undertakes such work directly or provides logistical support to others (e.g. the New Zealand Antarctic Heritage Trust) for such maintenance work.

5.12. Enabling works for the Scott Base Redevelopment

Construction of the current Scott Base began in 1976/77. More than 40 years on, buildings and essential plant are reaching the end of their life. The New Zealand Government has committed funding through to 2021 for the detailed design of a redeveloped Scott Base. A Comprehensive Environmental Evaluation (CEE) is being undertaken for the Scott Base Redevelopment (SBR) project, which will cover all construction and associated activities from the second half of the 2021/22 season. However, some works are required prior to the construction phase, such as site investigations, setting up monitoring programmes, and possibly some staging of equipment or materials.

5.12.1. Season 2019/20

Site investigations will be undertaken to determine the type of foundations required for the new buildings (example in Figure 20, sampling locations in Figure 21) and the nature and scale of earthworks needed. Actions will include:

- 19 boreholes, 6cm diameter, 10m deep
- 2 boreholes for water intake and wastewater outlet gantry replacement
- 6 boreholes, 6cm diameter, 3.5m deep
- 2 boreholes, 6cm diameter, 4m deep
- 4 test pits approx 1.5m deep
- Ground penetrating radar surveys (non-invasive)
- 5 samples for asbestos analysis on spoil from boreholes (i.e. top layer of loose material removed to access target substrate)
- Ground penetrating radar survey (non-invasive)

Figure 20: Drilling during Hillary Field Centre Site investigations.

Baseline data collection and set up of monitoring programme for the redevelopment project for the CEE process will also be undertaken. At Scott Base the proposed activities include:

- Revisiting the network of monitoring sites established in the 2018/19 season (biology survey, depth to ice cement investigation) to capture natural variations.
- LIDAR (Light Detection and Ranging) survey of Scott Base and Pram Point on foot and by helicopter.
- Maintenance of dust samplers installed in the 2018/19 season and collection of dust accumulated since installation.
- Hand-held x-ray fluorescence (XRF) spectrometer transect surveys from the road into the wider Scott Base area, to measure extent of heavy metal contamination.
- Opportunistic collection of meltwater if this occurs while the monitoring personnel are on site.

- SCUBA diving to establish, video and sample two 25 m seabed transects at up to 5 sites at varying distance from Scott Base, to characterise faunal assemblages and contaminant levels.
- Installation of Acoustic Doppler Current Profilers (ADCPs) at two sites for one tidal cycle (14 days) and removal.

In addition, it is proposed to establish a control site at Cape Evans, which will involve identifying up to five monitoring plots, installing up to five dust collectors, soil and biology samples, a vegetation survey and an XRF survey.

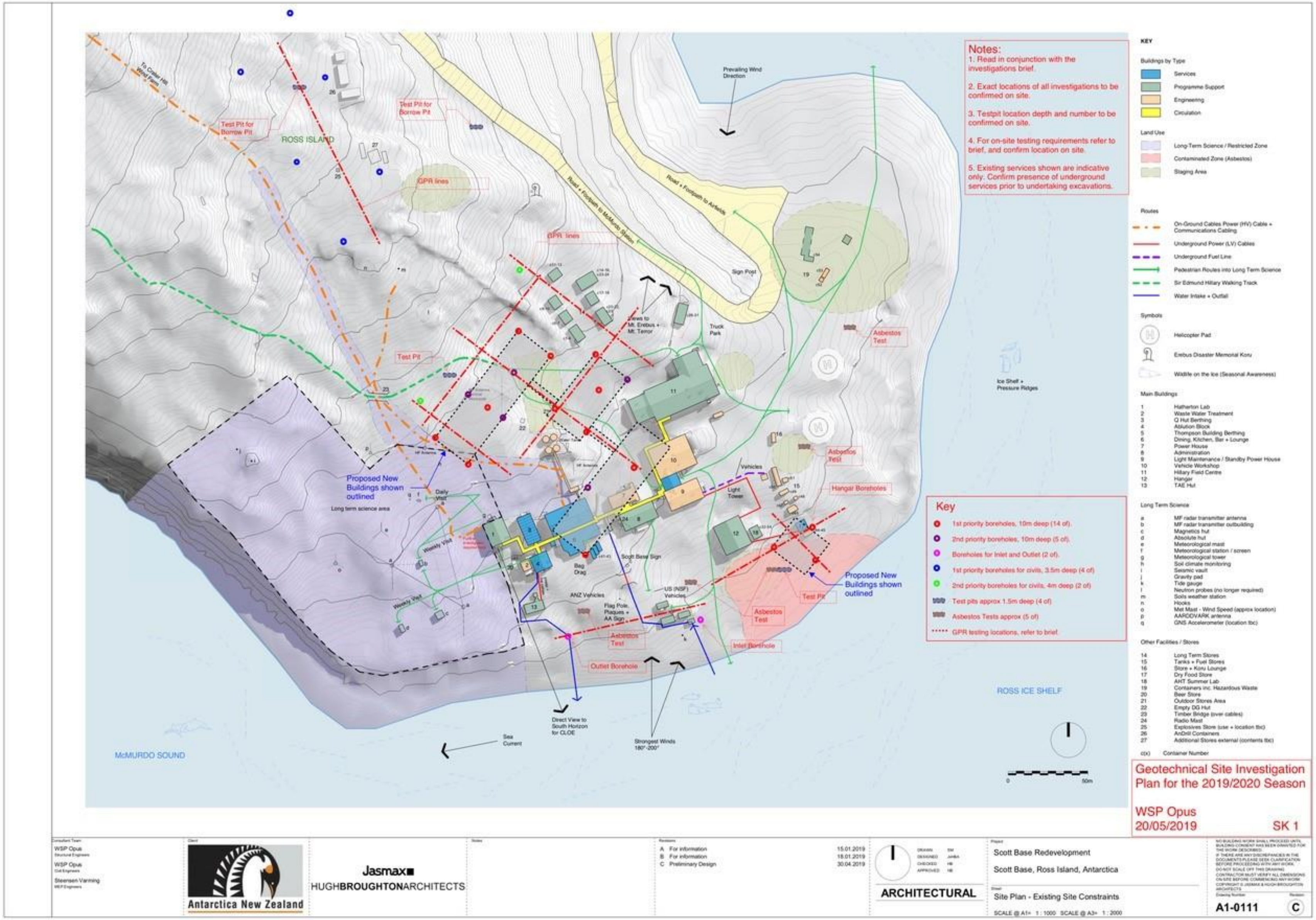


Figure 21: Indicative locations of site investigation work

5.12.2. 2020/21 and 2021/22 Long-term science (LTS) location surveys and relocations

The site to the west of Scott Base currently hosts a number of ongoing long-term science experiments that collect year-round data. Some experiments have been in operation since 1957 and their data sets are of national and international scientific importance. SBR and its associated earthworks are expected to disrupt the experiments, either directly because the proposed new buildings are in the location of some experiments, or through indirect disruptions such as magnetic waves. Some experiments need to be duplicated in a new location before SBR works begin, in order to ensure that sufficient overlapping data is captured. Once sufficient overlapping data has been captured (between a few months and 3 years depending on the dataset), the original experiments will be removed. The duplicate data collection is proposed to begin in 2020/21, for completion by season 2022/23 when SBR earthworks are scheduled to start.

All of the experiments identified for duplication over the 2020/21 to 2022/23 period are listed in Table 10, together with the SBR planned activities (K750S). Several location options were identified in 2019/20 as potential relocation sites. The sites are identified in Appendix 3 provided separately to this document. The 2020/21 surveys will focus on identifying one preferred location for each experiment. These foot surveys will be completed by the science events and are covered under each event's PEE. The SBR team will oversee the surveys and ensure that the new instruments are sited together as much as possible in order to minimise the area of disturbance.

Once locations are confirmed, Antarctica New Zealand staff will prepare the identified sites for the installation of the experiment.

The preparation of the new sites involves the activities listed below:

- 2020/21: Removal of large rocks to create a vehicle access track (Toyota Landcruiser) to the new LTS area
- 2020/21: Ground levelling at some new instrument sites, to prepare a level platform on which to set up the experiments
- 2020/21: Drilling of anchor points and/or installing foundation pads to secure the instruments
- 2020/21: Laying of power and data cables to connect the instruments to Scott Base utilities. Temporary connections will be installed in 2020/21, followed by a permanent solution to the long-term science building (converted 20ft container) once installed:
- 2021/22: Installation of a new LTS building that will act as mini lab and receive the power and data cables from Scott Base, and distribute power and data to the experiments in the field. This new LTS building replaces the Hatherton Lab in function.
- 2021/22: Installation of a second 20ft containerbuilding to house the ChlOE experiment to be collocated as close as possible to the LTS wannigan
- 2021/22: Installation of a gravity mark to support GNS and LINZ measurements (listed under GNS, K102 below), in the Gap.
- 2021/22: Installation of the new geomag huts at Arrival Heights ASPA 122 (further information below)

Table 10: Summary of SBR - LTS activities 2020/21-22/23

Experiment	Institution	Event number	K750S activities 2020/21	K750S activities 2021/22	K750S activities 2022/23	Data duplication period
Soil climate station	Landcare Manaaki Whenua	K123A	Prepare ground and install new instrument	None identified	Remove original instrument	2 – 3 years
Automatic Anemometer and Mast	NIWA	K085	Prepare ground and install new instrument	None identified	Remove original instrument, connect new instrument to new LTS building	2 years
Stevenson Screen	NIWA	K089	Prepare ground and install new instrument	None identified	Remove original instrument, connect new instrument to new LTS building	2 years
ChIOE	NIWA	K085	None	Install building	Install new instrument	TBC – original ChIOE to be removed in 2023/34
Antenna array	University of Canterbury	K055	Ground preparation for new installation in 21/22[7]	Upgrade existing antenna array and transmitter hut in same location		
AARDDVARK Mast	Otago University	K060	Support K060 survey	Ground preparation, drill anchor points Relocate mast to new site	Connect new instrument to new LTS building	None required
Geomagnetic huts	GNS	K102	Support K102 survey	Install new huts in ASPA 122 Arrival Heights	The instruments inside the existing huts are decommissioned.	1 year
Gravity mark	GNS	K102		Install gravity mark at the Gap (location identified as part of 2019/20 survey in previous line)	N/A	1 year

5.12.2.1. 2021/22 Arrival Heights proposed activities for geomagnetic huts installation

Two geomagnetic huts are proposed to be installed in ASPA 122, Arrival Heights. The huts will duplicate and ultimately replace the existing geomagnetic observation on Pram Point. The huts comprise a Variometer Hut, Absolute Hut, and a survey mark. The existing huts will be decommissioned from 2022/23, under the SBR CEE. The decommissioning process will consider the heritage value of the original buildings and their potential for designation as Historic Sites and Monuments, similar to the TAE Hut (HSM No.75).

The proposed location for the new huts was determined through the surveys conducted in 2020/21 and is shown in Figure 22 and Figure 23 shows a 3D view of the buildings.

The proposed activities are scheduled to start in November and include:

[7] This activity did not occur in 2021/22 as it was found that the existing location was still suitable

- An access track for the installation of the huts. There are two options under consideration, shown in Figure 24. Option 1 is to use the existing track that leads to Second Crater before turning right and down towards the site. Option 2 involves a new track off the existing track network. Option 1 is preferred to minimize new ground disturbance; however, it is noted that it may not be practical due to the steepness of the contour. The area will be assessed by the SBR team together with the USAP Fleet Operations team who will be carrying out the transport and delivery of the new huts. The safest option will be selected.
- The crane, piling rig, and delivery vehicle will use the access track.
- The Scott Base piling rig will be used to drill 24 x 500mm diameter holes in which hollow piles for the buildings and pier for experiment instrumentation will be installed. The piles and piers will be backfilled using a water and local scoria, no imported soils are proposed. The inside of the piers will be filled using a polyurethane mix for added structural rigidity, to compensate the buildings' elevation above the ground.
- The two new huts will be transported to Ross Island by ship and moved from the pier to Arrival Heights by truck. They will be lifted onto their piles with a crane. This work will be performed by the USAP Fleet Operations team, who have the equipment and experience to complete the work.
- Once the buildings are installed, services will be connected. There is a power cable, a fibre cable (for data) and a copper cable (for phone and PA system). All cables will be shielded to prevent noise interference with other installations.
- The services access and route will need to cross two access tracks. The cables will be protected by a conduit or a concrete culvert under each track. If used, the culvert will be precast in New Zealand and shipped to Ross Island.
- All services will be connected back to the New Zealand Arrival Heights Lab. The operational distribution board will be upgraded to cope safely with the increased load.

Proposed activities in relation to the Management Plan for ASPA 122:

The proposed relocation of the geomagnetic huts to the ASPA seeks to allow continuous operation of the experiment in an environment with as little interference as possible. Arrival Heights provides this environment, and geomagnetic surveys confirmed a suitable location in 2020/2021. The proposed activities were developed to meet the Aims and Objectives of the Management Plan, in particular:

- Allow scientific research in the Area, in particular atmospheric research, while ensuring protection from incompatible uses and uncontrolled equipment installation that may jeopardize such research;
- Minimize the possibility of generation of excessive electromagnetic noise interference within the Area through regulating the types, quantity and use of equipment that can be installed and operated in the Area;
- Avoid degradation of the viewing horizon and shadowing effects by installations on instrumentation reliant on solar and sky viewing geometries;
- Avoid / mitigate as far as practicable anthropogenic gaseous or aerosol emissions from sources such as internal combustion engines to the atmosphere within the Area;

The Arrival Heights Working Group contributed to the development of the proposed activities and provided robust consideration of the Management Plans provisions. A commissioning plan will be developed to prevent unwanted interference with the existing installations and values of the ASPA. As a resulted the proposed activities demonstrate that the geomag huts and instruments are:

- compatible with other experiments and located to minimise potential disturbance;
- designed to eliminate where possible any potential electromagnetic noise interference (the huts will not contain any magnetic materials);
- inconspicuous in the context of Arrival Heights, and will not interfere with any line of sight of other experiments; and
- will not emit gaseous or aerosol emissions, other than that from construction activities.

In accordance with the Arrival Heights ASPA 122 Management Plan, Antarctica New Zealand and the GNS Geomagnetic Project Lead developed a proposal seeking comment from the Arrival Heights Working Group. The proposal sought to evaluate the feasibility of locating the replacement geomagnetic huts in Arrival Heights and to identify any potential impacts on the ASPA. Feedback from the Working Group is summarised in Table 11.

Table 11: Summary of feedback from members of the Arrival Heights Working Group

ASPA 122 Experiment	Institution	Event number	Feedback	Supportive Y/N	Action
Dobson instrument	NIWA	K085	No concerns	Y	Keep informed
Weather station	NIWA	K089	No concerns	Y	Keep informed
MF Radar	University of Canterbury	K055	Concerned about the potential noise generated from the addition of new buildings and the associated cabling in the 2.9mHz range	Y	Keep informed and work together
AARDDVARK Mast	Otago University	K060	Concerned about the potential noise generated from the addition of new switch mode power supplies and the associated cabling in the VLF range	Y	Keep informed and work together
US lab	New Jersey Institute Technology (Andrew Gerrard)	n/a	Noted the potential power/electrical interference and general RFI, but happy with mitigation efforts	Y	Keep informed
n/a	NSF (Polly Penhale)	n/a	No concerns	Y	Keep informed

The concerns of K060 are being addressed collaboratively by K060, GNS, and Antarctica New Zealand. The first mitigation to this was for the K060 team to perform a noise survey on existing Geomagnetic Huts in Christchurch. This noise survey alleviated a number of K060's concerns. A report from this survey can be found in Appendix 5.

In addition, the proposed location of the huts was compared with the terrestrial characteristics of the site. Section 8.3 describes the initial environmental state of ASPA 122, which includes the presence of sand-wedge polygons and lichens. No data is available regarding the precise locations of these features. However, satellite imagery was reviewed to identify sand-wedge polygons in the proposed area, shown in Figure 25. The figure shows a small overlap between the proposed area and visible polygons, however further investigation on site is required to confirm the accuracy of the image.

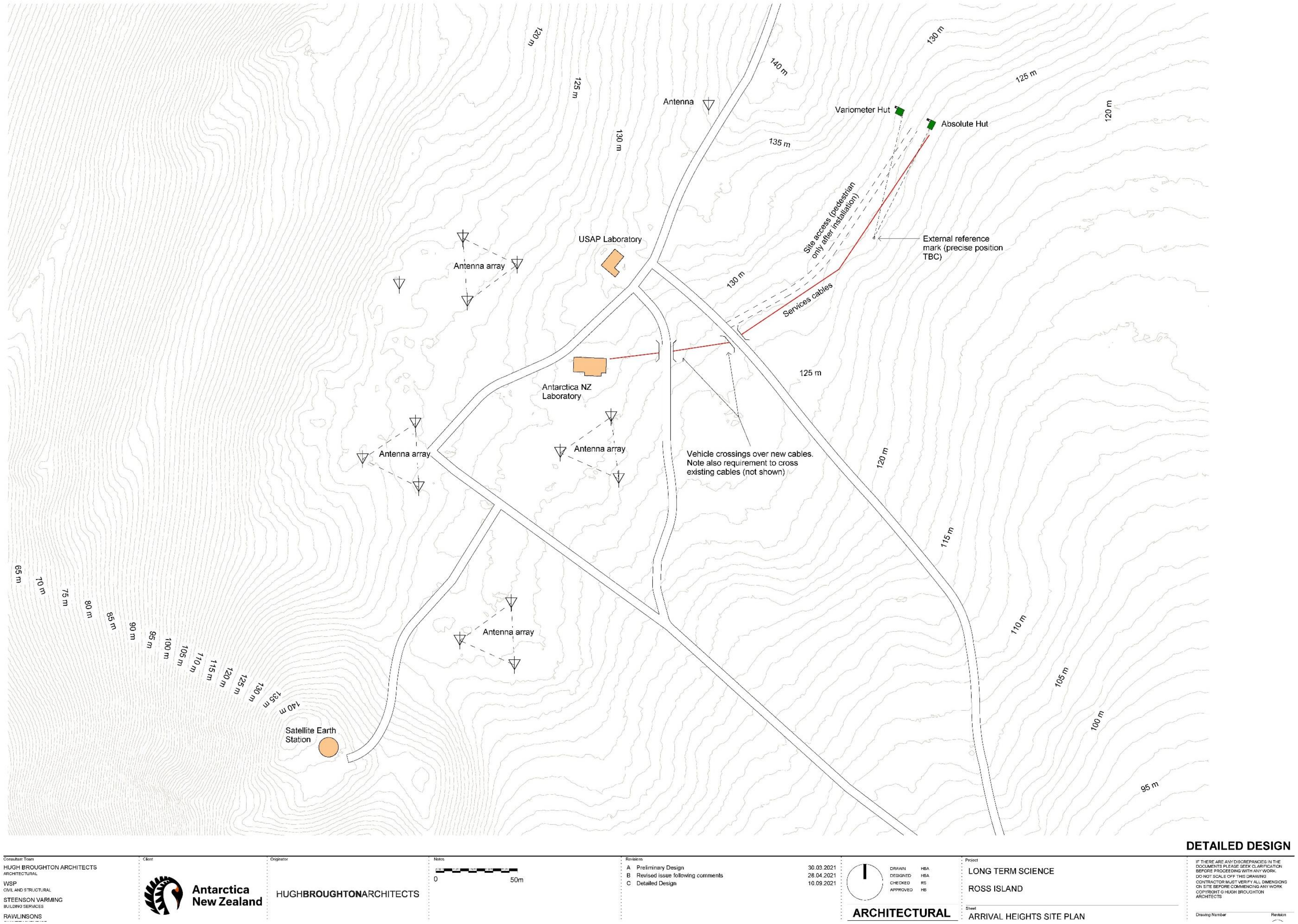


Figure 22: Proposed location for geomagnetic huts

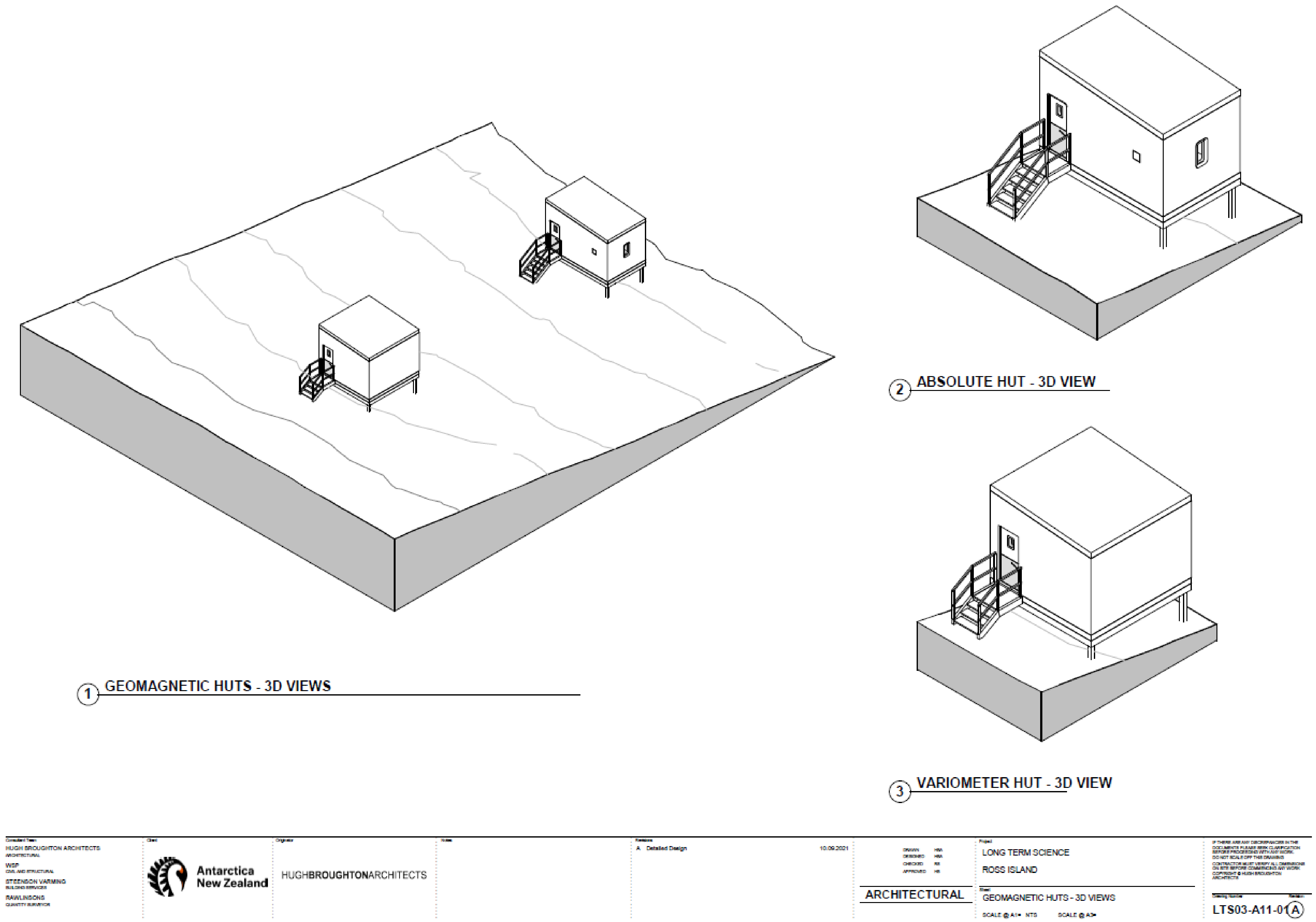


Figure 23: 3D view of the new huts

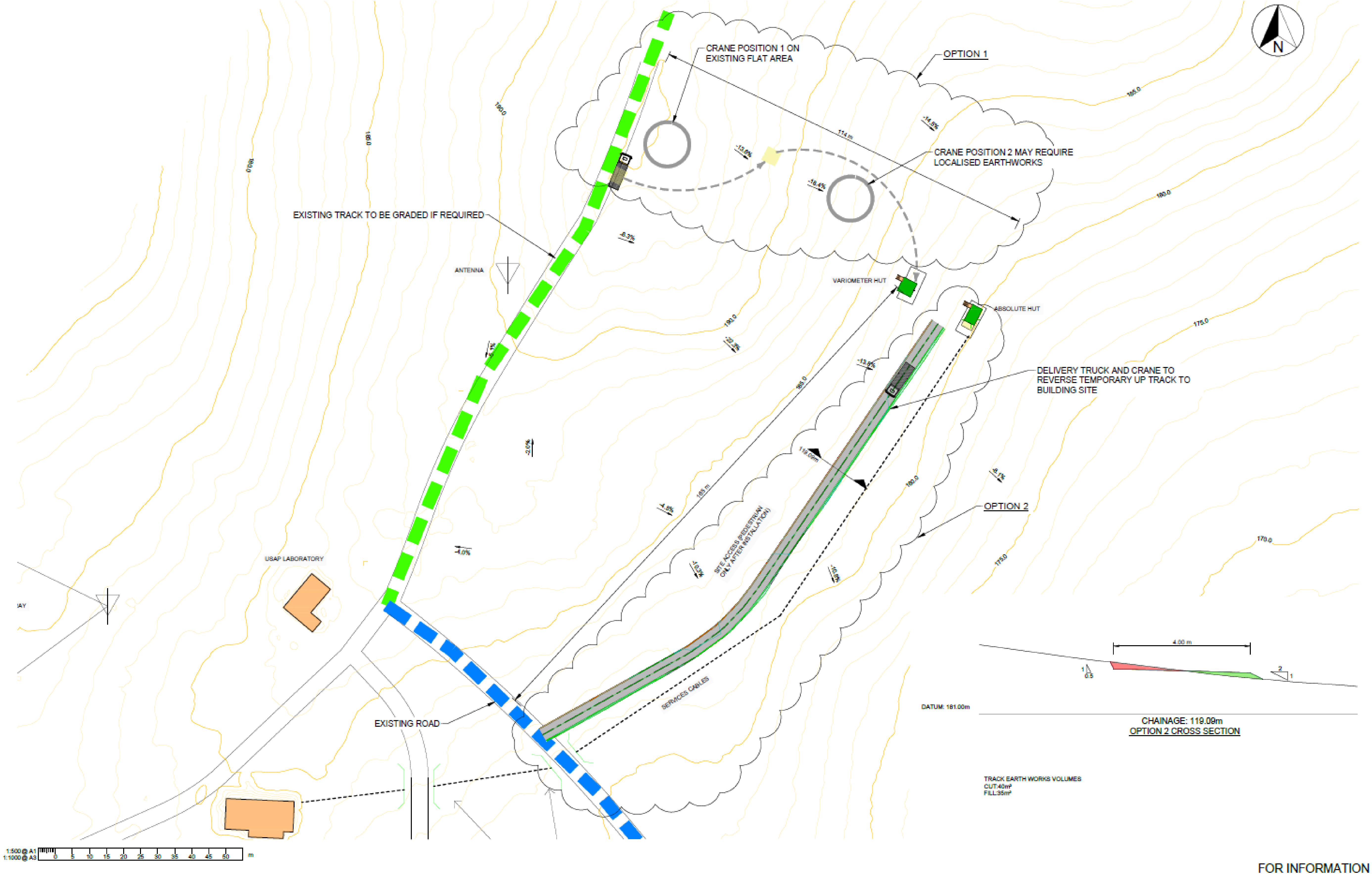


Figure 24: Options for accessing the proposed geomag huts location

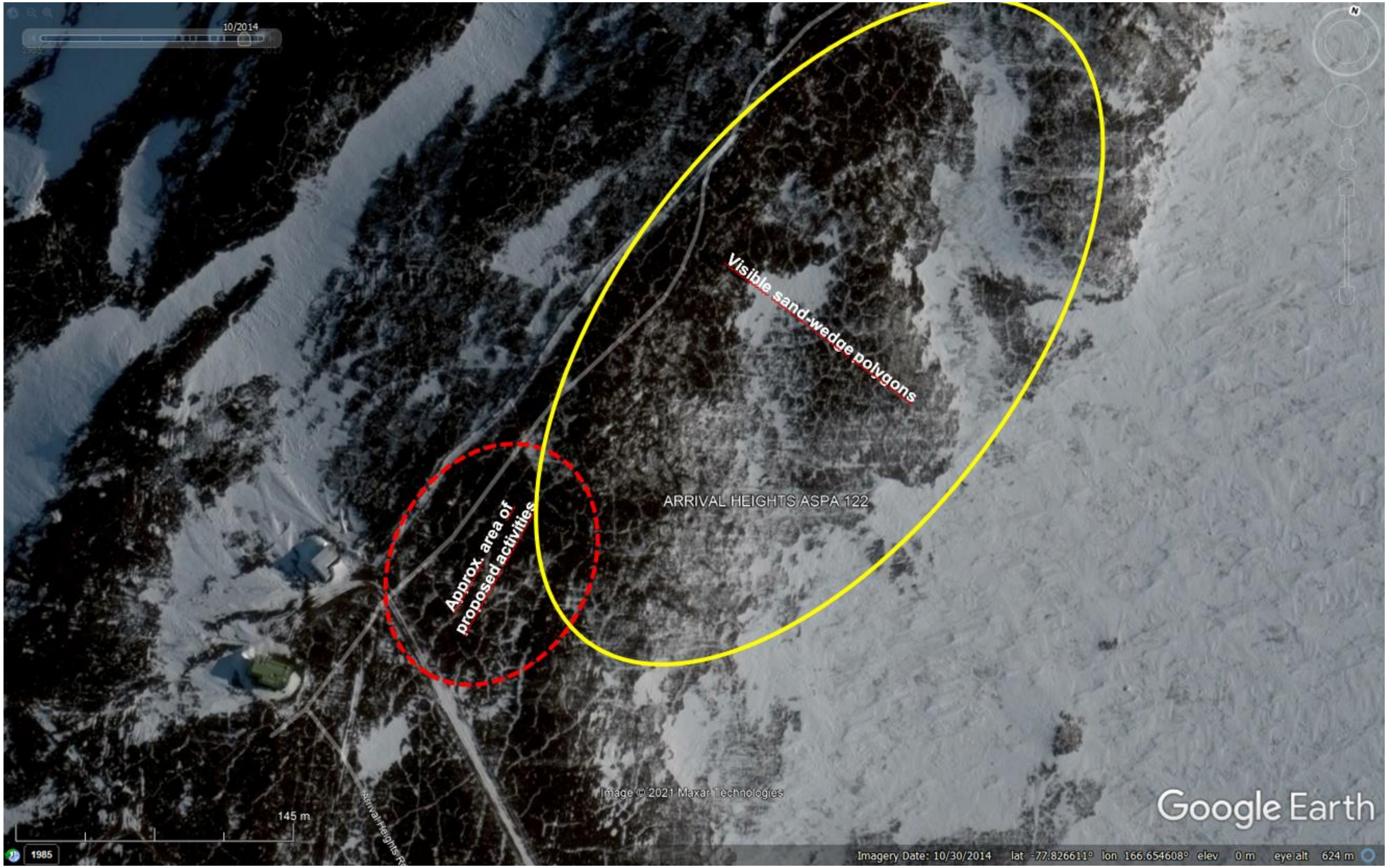


Figure 25: Area of proposed activities in relation to visible sand-wedge polygons

5.12.3. 2021/22 Civil engineering – Pile testing

The pile testing activities were initially planned for season 2020/21 but were postponed due to COVID-19 restrictions in 2020/21. They are proposed for 2021/22 instead.

The purpose of the proposed full-scale pile test is to confirm that the proposed pile installation system will provide sufficient long-term foundation support and be removable at the time of decommissioning.

5.12.3.1. Background

For the proposed Scott Base Redevelopment, an adapted “adfreeze” pile design is being considered. This adapted pile design is based on the traditional adfreeze methodology with modifications to suit the project’s requirements. The design of the pile is a closed-end hollow structural steel pipe that will be placed into an oversized borehole, itself drilled into volcanic bedrock. The space between the edge of the borehole and the outside of the pipe (the annulus of the borehole) would be backfilled with either water or a water/sand mix. The boreholes are expected to be around 4m deep.

This adapted pile design differs from conventional pile designs in several respects. The aspects relevant to this IEE are highlighted below:

1. Where volcanic rock is present, the conventional approach is to drill into the bedrock and to backfill the annulus with grout (cement mix) to secure the pile in place. Here, water will be used instead of grout, so that the piles can be eventually removed by melting the water. A grout plug will be placed at the bottom of the hole for the pile to sit on. The plug can be removed by drilling it and removing the fragments.
2. A conventional adfreeze pile uses a sand/water slurry within the annulus of the borehole. This provides more strength than water/ice alone and a better bond with the mineral soil. For the test, water alone and water/sand will be trialled (thus the requirement for two full-scale tests). It is not considered that using water only for the adhesion will be a significant issue, and the very cold ground temperatures (typically -15°C) will provide a high strength to the ice within the annulus.
3. A conventional adfreeze pile is open-ended and its interior is filled with slurry. For the adaptive removable adfreeze pile, the pile will have a closed end and the interior of the pile will be left empty. This is to facilitate pile removal.

5.12.3.2. Proposed works

The full-scale test of piles includes the installation, load testing and removal of piles. For the test results to be relevant it needs to be undertaken on the ground where the new base is to be constructed i.e. at Scott Base. Two locations have been identified for the tests. These are shown in Figure 28 (note that the base map may not reflect the current SBR design).

The proposed tests are as follows:

- 1 x Pile test “Water only” - a complete installation using the adaptive adfreeze design as described above. Load tests will be completed and the pile extracted. The pile will be secured in place with a grout plug and water only. The test will show the full installation productivity, load capacities using water only and the ease of extraction.

- 1 x Pile test “Water and sand” – this test will begin with a partial installation (1.5m depth instead of 4m) and extraction of a 2.5m pile. This shallow borehole test is necessary to check how easily the pile can be released from the water and sand mixture. The sand might provide too much friction and make the full-length pile impossible to remove. If the removal is deemed feasible, the installation to 4m and load tests will be completed. The pile will be secured in place with a grout plug and a water and sand mix. The test will show the full installation productivity, load capacities using a water/sand mix and the ease of extraction.

- 2 x Drilling test. This test will consist of the excavation and probe drilling only. The aim of the tests is to obtain additional information on excavation rates, suitability of probe drilling to detect cavities, suitability of methodology to fill cavities, impact of cavities on drilling rates.

5.12.3.3. Equipment and materials

The main piles are expected to be 5m long and 406mm in diameter, with a circular hollow section and would weight around 500kg. Two such piles will be used during the tests. A shorter pile of 2.5m in length will be used for the partial installation. Typically, sand is required to create the slurry for the "water and sand" test. Scoria, dust, and crushed rock sourced from Pram Point are proposed to be used to create the slurry. Water will be added to this mix and poured down the hole and left to freeze to lock the pile in place. The slurry will be left in the ground once the pile is removed. The remainder of the hole will be backfilled with this slurry.

The main pieces of equipment required for the activity are a 20T excavator that will be equipped with the required tools to bore holes and manipulate the piles (Figure 26 and Figure 27). A compressor will also be used to power a pneumatic hammer to drill through hard rock.

Figure 26: Proposed excavator with excavating tool

Figure 27: Vibro-hammer used to install piles

All plant, equipment and materials will be transported to Scott Base by C17 and returned, minus any materials consumed during the event, by ship at the end of the season.

5.12.3.4. Removing the piles

Pile removal will be attempted. This is proposed to be done by heating the pipe so that the water, or water and sand mix melts and the pile can be lifted from the borehole. A high-capacity heating unit will be connected to the top of the pile and will blow hot air into the interior of the pile. It is expected that the heater will run on AN8 supplied by Scott Base.

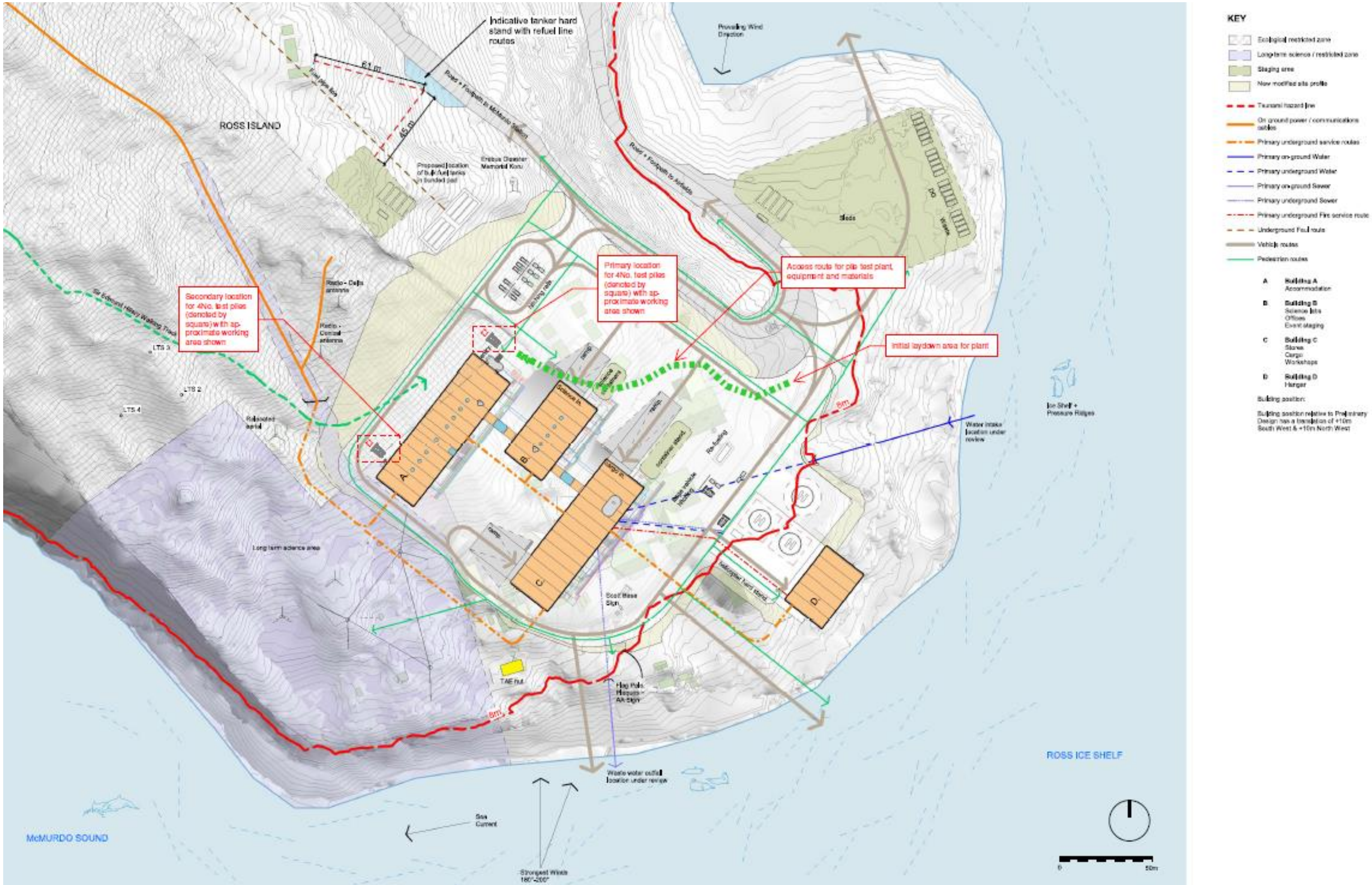


Figure 28: Primary and secondary locations for the pile tests

5.12.4. Other SBR enabling works

5.12.4.1. 2021/22 Ground Contamination Investigations

The investigations are a continuation of the 2017/18 events and their objective is to verify the extent of asbestos and hydrocarbon contamination in the Scott Base area. This will inform the earthworks strategy and the deconstruction methodology for the existing Scott Base buildings.

The key areas that will be investigated this season are shown in

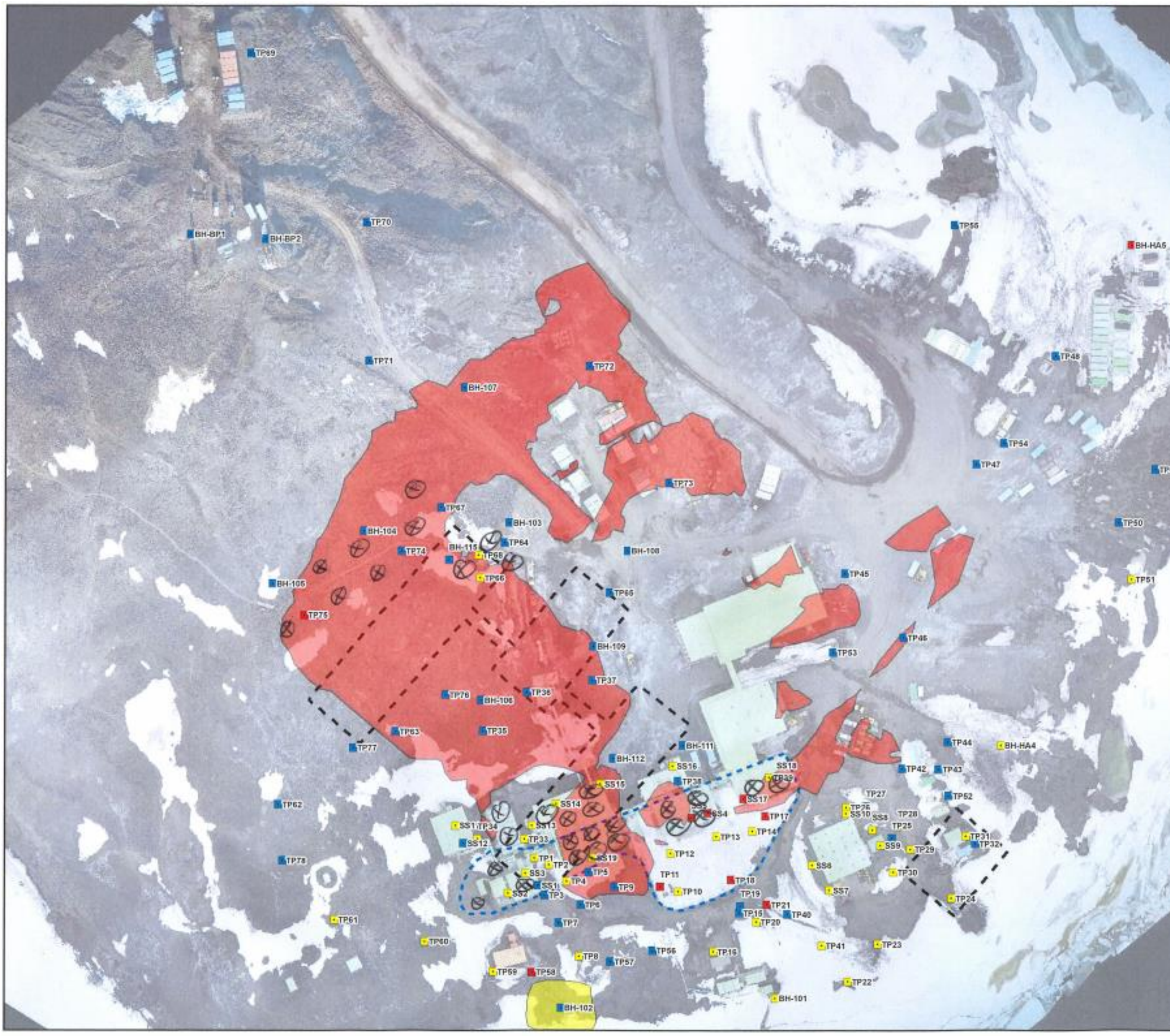


Figure 30. The excavation sites will be around the current base, down towards the foreshore and along the Hillary Trail. Each excavation site will disturb an area of around 4m in diameter. The Scott Base excavator will be used for this work.

Smaller excavations will also take place underneath the existing Scott Base building, where access is typically difficult. These excavations will require the use of smaller excavation equipment (jackhammer/ground drill) due to the constrained access.

5.12.4.2. The total maximum volume of soil proposed to be taken as samples is 2 cubic metres, one each for hydrocarbon and asbestos testing. The samples will be taken from multiple sites around Scott Base and will be returned to New Zealand as samples for analysis. 2 cubic metres is the maximum volume of soil that may be taken, the exact volume will depend on the on-site investigation findings. Individual samples are typically expected to be up to 500ml each. Geotechnical Site Investigations

Geotechnical investigations on Crater Hill for the new RIWE and on Pram Point for the temporary base are proposed. These will use the core drill from Scott Base and will consist of drilling into the ground to assess its composition and condition.

5.12.4.3. Test rig and test rope barrier

A test rig is proposed to be installed on Pram Point. The rig will contain an array of equipment, or building systems that need to be tested throughout a full year at Scott Base. This is in order to inform design considerations for the new base. The rig will include a PV panel, a motorised damper, LED outdoor floodlights and other items that need to be tested in situ before they are confirmed as suitable for the new buildings.

The rig will travel to Antarctica on the ship. It will be assembled and set up on Pram Point, where it will remain for 12 months. Throughout the 12 months, the equipment on the test rig will be operated and/or monitored by Scott Base staff who will report back to the SBR design team.

In addition, a test wire rope barrier is proposed. The wire rope barrier is part of the design for the road realignment, in order to separate vehicle traffic from the Scott Base operational area. The test barrier will be erected covering a span of approximately 25m consisting of metal bollards fixed in the ground threaded with wire rope (Figure 29).

Figure 29: Wire rope barrier (main barrier and terminal ends)

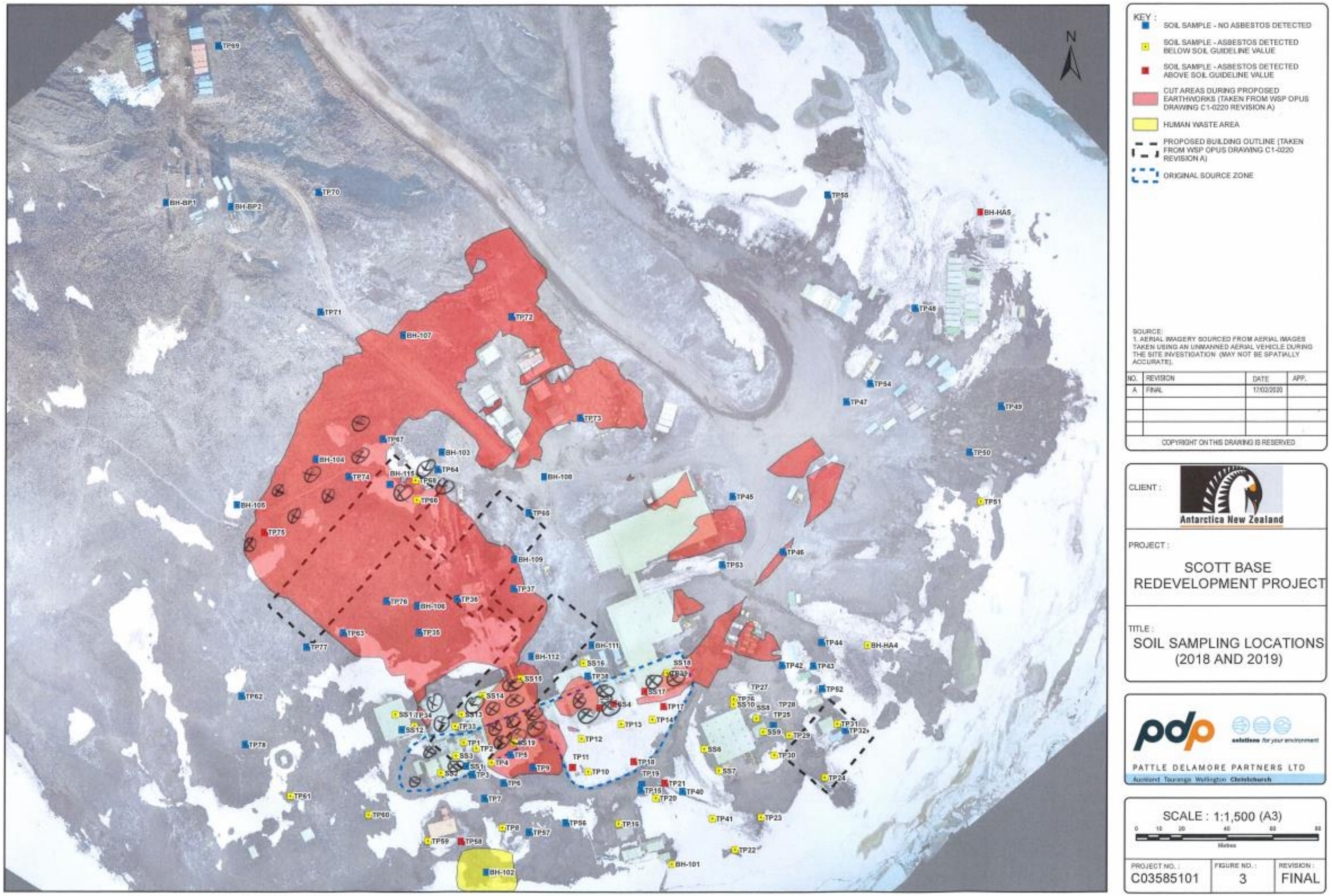


Figure 30: X marks the sampling spot - Scott Base ground contamination survey

5.12.4.4. Shoreline survey

The Royal New Zealand Navy Military Hydrography Group has been contracted to complete a range of underwater survey activities. These are planned along the shoreline out the front of Scott Base and will assess the condition and profile of the shoreline and surrounding seabed.

The work is required because there is currently little information available on the local hydrography. The stability and shape of the foreshore immediately outside Scott Base are also poorly understood but known to incorporate ice and probable historical wastes. The activities will also map the underwater topography. to assess whether a large vessel would be able to access Pram Point. This work will support decisions on the SBR logistics strategy, which currently plans for a large vessel to access Pram Point. The surveys will also inform design for the new base, for example the location of the water intake and wastewater outlet.

The work is planned in the early part of the season (late Oct-early Nov), when the seasonal sea ice is thick enough to support the activity.

Six personnel will perform the surveys using a single beam echo sounder instrument. There will be no diving activities and no boats involved and all work will be supported from Scott Base. Ice holes will be melted by Scott Base staff. The instrument will be lowered into the sea through each ice hole to take depth measurements.

The investigation will survey 3 zones:

- “Zone A”, an area of 40x80m will be surveyed. 80m in frontage between, approximately, the water intake and the front transition and 40m out into McMurdo Sound. This is the measure the water depth in the proposed berthing area. 45 holes will be drilled at 10m intervals.
- 2 transect lines (Transects 1 and 4) within the above survey area but extending to 130m in length, at 10m intervals, a further 56 holes.
- 2 potential anchor points

It is expected that a full bathymetric survey may be carried out in season 21/22, this IEE will be updated are further information becomes available.

21/22 Bathymetric survey

BoxFish, a specialist ROV company, and LINZ are contracted to undertake an underwater/sea ice multi-beam bathymetric survey using an ROV at the start of the season. The survey area will expand on the initial Navy survey of the immediate berthing pocket increasing the overall survey area to approximately 12 hectares. Holes will be drilled into the sea ice and the tethered ROV will be lowered into the sea. It will “swim” a grid pattern and collect bathymetric information.

In addition, at the end of the season, if there is open water and the new Navy vessel Aotearoa has the capability and capacity they will undertake a wider bathymetric survey using small boat operations. This will be a fully self-sufficient Navy operation based of the vessel. Permitting for Aotearoa activities is the responsibility of the New Zealand Navy.

5.12.4.5. Operational area tidy-up and preparation

The site will begin to be prepared for the SBR earthworks. Redundant equipment and storage containers will be identified and prepared for return to New Zealand by ship.

An estimated 30 containers will be shipped south and staged on site in the 2020/21 season. After the 2021/22 season, it is expected that activities related to the redevelopment will take place under the project's CEE.

The installation of two survey marks in the Scott Base area is proposed. The survey marks will act as reference points for the SBR earthworks and construction activities. The survey marks will be installed by K150 (LINZ) and a permit for the installations has been requested under this event.

5.13. Monitoring programmes

The non-science programme of Antarctica New Zealand does not normally collect samples. However, Antarctica New Zealand staff have in the past been requested to assist with the collection of dead fauna (such as penguins, seabirds and, rarely, seals) for return to New Zealand, and such requests may occur again in the future. Such material is collected from time to time for taxidermy and display in New Zealand museums and Antarctic attractions. Such activities have usually been pre-approved for collection by a permit issued to those requesting the materials.

It is also possible that physical sampling may take place for environmental, health and safety or other management reasons (e.g. soil samples from contaminated sites; support requests such as Air New Zealand's Erebus crash memorial ceremonies). Sample sizes for analysis or use will normally be very small and would not be expected to exceed a few hundred grams. Permits for import to New Zealand will usually be held by the laboratory which will undertake the analysis.

In the 2019/20 season, a total of 30 soil samples will be collected along transects at both Scott Base and Cape Evans for the purpose of establishing a pilot study to analyse the ground for microplastics. At Scott Base sampling will occur along two transects, with 10 samples on each transect running from the shore to the top of the road on Pram Point (20 samples in total). Cape Evans will be the control site, and 500g samples will be taken along one transect going from the beach up onto the land, and five other targeted sites will be sampled (10 samples in total). The Pram Point transects are shown in Figure 31.

Monitoring plots established in 2018/19 (Figure 32) will be re-visited and soil samples taken. Appendix 4 provides an overview of the biological values of the plots. In the 2019/20 season, a variety of sampling is planned in order to better understand the biodiversity of the Scott Base area as part of the redevelopment project Comprehensive Environmental Evaluation (CEE) process, including up to:

- 25 soil samples for invertebrate identification
- 36 dust samples (500ml bottles)
- 40 runoff water/sediment samples (500ml bottles)
- 100 benthic macrofauna (cores)
- 200 benthic epifauna (individuals)
- 100 sediment dwelling microbiota (cores)
- 100 benthic microalgae (cores)
- 100 sea ice algae (litres)
- 100 benthic macroalgae (individual samples)
- 50 litres sea water (plankton)
- 2000 infauna individuals (e.g. polychaetes, echinoderms, molluscs, isopods, amphipods, etc.)

Up to 15 soil samples will also be taken for invertebrate identification and soil analysis from Cape Evans, to provide a comparison to Scott Base. The 2019/20 season is the second of two years of baseline establishment for the redevelopment monitoring programme. Monitoring thereafter will be under the CEE.

In the season 2020/21, a continuation of the CEE environmental baseline monitoring activities that began in 2018/19 is proposed. 2020/21 activities are:

Scott Base:

- Maintenance of the dust samplers installed in the 18/19 season
- Collection of dust accumulated since 19/20 season, 36 dust samples (500ml bottles)

Cape Evans:

- Maintenance of the dust samplers installed in the 19/20 season
- Collection of dust accumulated since installation, 9 dust samples (500ml bottles)

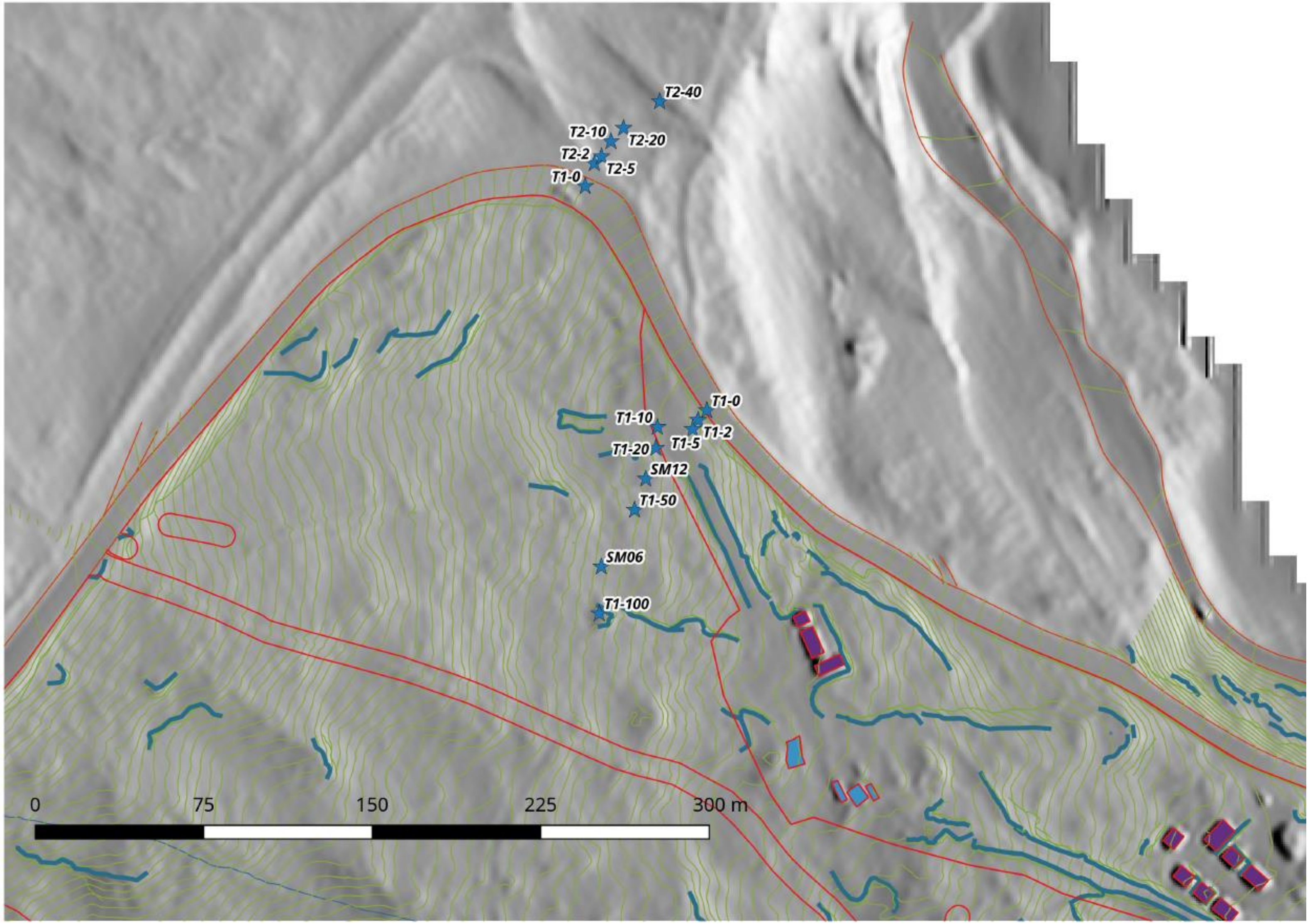


Figure 31: Soil microplastics transects on Pram Point

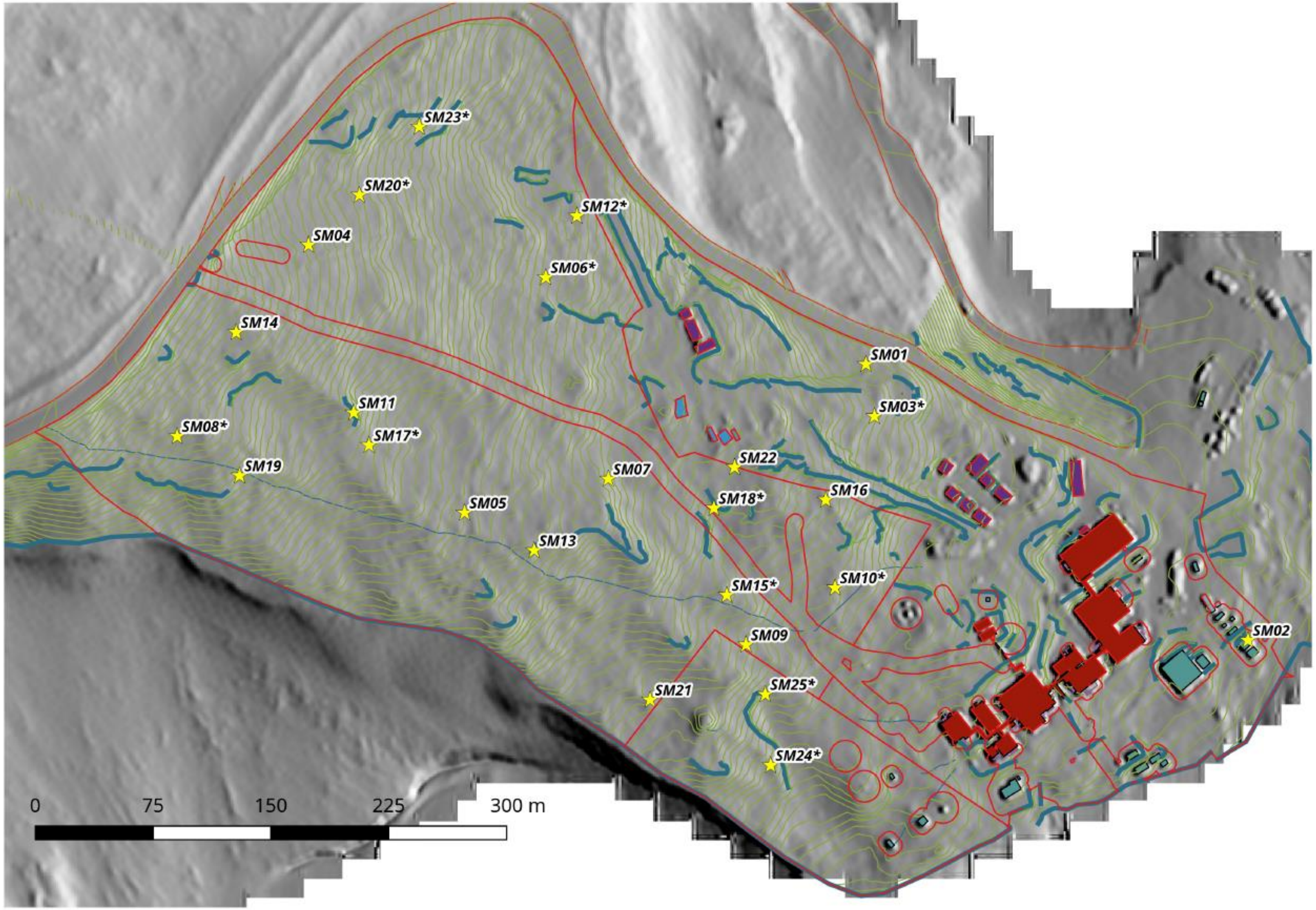


Figure 32: Soil and biology monitoring plots on Pram Point

5.13.1. **2021/22 CEE environmental baseline monitoring**

The proposed activities for 2021/22 are presented under this IEE for continuity and to ensure that they are permitted when they are planned to occur, while the CEE Ministerial process is underway.

The SBR monitoring and sampling activities planned for 2020/21 were postponed due to the COVID-19 pandemic. These activities are proposed for 2021/22 instead. Contaminated soil samples are also proposed to be taken, as described in 5.12.4.1. The sampling activities proposed for 2021/22 are shown in Table 12.

Table 12: Sampling activities in season 2021/22

Sample type	Permanent removal	Location	Quantity	Unit	Purpose
Contaminated soil samples	Yes	Scott Base	1	M3	For asbestos testing
Contaminated soil samples	Yes	Scott Base	1	M3	Hydrocarbon contamination testing
Dust samples	Yes	Scott Base	36	samples	10g Samples for various analysis
Dust samples	Yes	Cape Evans	9	samples	10g Samples for various analysis
Freshwater samples	Yes	Scott Base	15	samples	500g Samples for various analysis
Soil samples	Yes	Scott Base	20	samples	500g Samples for various analysis

Temporary monitoring equipment is proposed to be installed as part of this monitoring programme. Two time-lapse cameras are required to monitor seal presence and activity to complete the baseline data collection started in 2019/20. One camera will be installed on Crater Hill near the road, not on the RIWE site, to monitor the Pram Point area. Another camera is proposed at Turtle Rock as a control site. The proposed locations (approximate area for Crater Hill) are shown in Figure 33and Figure 34. The camera and power equipment (solar panel, battery) will be removed and re-installed every season until 2 years after the completion of SBR. The tripod will be left in situ for the duration of the activity. After season 2021/22, the cameras will be included under the CEE permit.

A marine acoustic monitoring array is proposed to be installed on the sea ice outside Pram Point for one month, to record underwater anthropogenic and environmental noise. This data will be used in conjunction with the time-lapse imagery to monitor any disturbance to seals.

At Arrival Heights, a before and after visual site assessment will be undertaken on two transects through the work area and adjacent to, to allow for description of impacts and identification of any sand-wedge polygons within the work area.

Figure 33: Crater Hill area of interest to install 2x cameras

Figure 34: Turtle Rock circled in red, Erebus Glacier Tongue above

6. Summary of permit applications

Consistent with the Protocol on Environmental Protection to the Antarctica Treaty, the Antarctica (Environmental Protection) Act 1994, Section 28, prohibits the following unless a permit is obtained:

- entering or carrying out any activity in an Antarctic Specially Protected Area (ASPA)
- taking any native bird or mammal in Antarctica
- removing or damaging native plants so their local distribution or abundance is significantly affected
- harmfully interfering with native plants, mammals, birds or invertebrates
- introducing any species of non-native animal, plant or micro-organism
- importing any non-sterile soil into Antarctica
- removing any part of or the contents of any historic site or monument

The following sections summarises the activities for which such permits are requested under Section 29 of the Act.

6.1. Interfering with native plants and invertebrates

To establish the baseline for ongoing monitoring of the impacts of the Scott Base Redevelopment project, it is proposed to take samples of plants and invertebrates at Scott Base and at Cape Evans (as a control site for comparison). These are set out in Table 13. These are the only planned activities which will intentionally interfere with native plants or animals.

Table 13: Plant and invertebrate samples 2019/20

Site	Number	Type
Scott Base	25	Soil samples for invertebrate identification
Scott Base	100	Marine benthic macrofauna cores
Scott Base	200	Marine benthic epifauna (individuals)
Scott Base	100	Sediment dwelling microbiota (cores)
Scott Base	100	Benthic microalgae (cores)
Scott Base	100	Sea ice algae (lires)
Scott Base	100	Benthic macroalgae (individuals)
Scott Base	50	Sea water (plankton)
CAPE EVANS	15	Soil samples for invertebrate identification

6.2. Importing non-native micro-organisms

Dry powdered bacteria contained in the commercial EcoSock product are imported to Scott Base for use in the wastewater treatment system. The bacteria are ubiquitous waste digesting species. Dosing the kitchen grease trap and the biological treatment beds with these products improves the function of the system and its ability to cope with fluctuations in personnel numbers, minimizing the need to discharge untreated waste due to maintenance tasks, and the risk that treatment quality to be compromised. Without biological treatment of the wastewater there would be an increased risk that unintentionally introduced pathogens could be discharged to the sea. Yoghurt cultures are also imported to Scott Base for food purposes.

6.3. ASPA entries

Entries to ASPAs are required to undertake ASPA management (Section 5.10), support science and other events and, where allowed by the relevant Management Plan, to make educational or recreational visits. Expected visits each season for the 2019-2023 period are set out in Table 14.

Table 14: Annual entries to Antarctic Specially Protected Areas

ASPA	Activities to be conducted within the ASPA	Visitors[8]
ASPA 105 Beaufort Island, Ross Sea	• Event support • Helicopter support as helicopter landing site is within ASPA 105 • Aerial photography of Adélie penguin colonies to 2,000 feet above ground level[9]	3
ASPA 106 Cape Hallett, North Victoria Land	• Event support • Helicopter support as the helicopter landing site is within ASPA 106 • Aerial photography of Adélie penguin colonies to 2,000 feet above ground level[8] • Download and maintenance of AWS installed for the LGP project • Environmental monitoring	6
ASPA 116 New College Valley, Caughley Beach, Cape Bird, Ross Island	• Event Support • Environmental inspection of Area in accordance with the 5-year review process • Collection of water from the snow gulley	3
ASPA 121 Cape Royds, Ross Island	• Event support • Aerial photography of Adélie penguin colonies to 2,000 feet above ground level[8] • Environmental inspection of Area in accordance with the 5-year review process	5
ASPA 122 Arrival Heights, Ross Island	• Event support, including geomag huts installation described in 5.12.2.1 • Science technician visits in support of science being conducted within the Area • Maintenance and repairs to the Telecom satellite earth station • Geotech investigations including drilling one core for foundation investigations • Access to the site via helicopter for transport of the drilling rig via sling load. • Facilities inspection • Familiarisation/observation/education - no more than 10 people at any one time. • Community Engagement Programme event and recruitment footage, under 7(ii) of the ASPA Management Plan “Activities with educational aims (such as documentary reporting (photographic, audio or written) or the production of educational resources or services) that cannot be served elsewhere” • Some will have multiple visits, e.g. technicians	95

[8] Predicted maximum number of visitors per season

[9] Individuals will not enter the ASPAs for this activity; rather a C-130 or helicopter will fly over the ASPA to obtain aerial shots of the penguin colony. The “number of visitors” column does not account for individuals on the plan.

ASPA	Activities to be conducted within the ASPA	Visitors[8]
ASPA 124 Cape Crozier, Ross Island	• Event Support • Helicopter support for Stone Igloo as the helicopter landing site is within ASPA 124 • Helicopter support for events requiring landings within the ASPA on the sea ice, away from the penguin colonies (Adélie and Emperor). • Environmental monitoring • Aerial photography of Adélie penguin colonies to 2,000 feet above ground level[8] • Education and outreach activities, which includes the use of RPAs	9
ASPA 131 Canada Glacier, Taylor Valley, Victoria Land	• Event Support • Helicopter support as an alternative helicopter landing site is within ASPA 131 • Environmental inspection of Area in accordance with the 5-year review process	5
ASPA 138 Linneaus Terrace, Asgard Range, Victoria Land	• Event Support • Helicopter support as the helicopter landing site is within ASPA 138	2
ASPA 154 Botany Bay, Cape Geology, Victoria Land	• Event support • Environmental inspection of Area in accordance with the 5-year review process	3
ASPA 155 Historic Hut, Cape Evans, Ross Island	• Event support • Field audit Familiarisation/observation trips - no more than 8 (including guides) in the hut at any one time; or 40 within the Area at any one time (including guides and those within the hut). This may include personnel from science or other events not otherwise covered by this IEE. • Environmental management support activities including soil sampling. • Education and outreach activities, which includes the use of RPAs in accordance with the Management Plan	250
ASPA 157 Historic Hut, Cape Royds, Ross Island	• Event support • Field audit • Familiarisation/observation trips - no more than 8 people (including guides) in the hut at any one time; or 40 people within the Area (including those within the hut). This may include personnel from science or other events not otherwise covered by this IEE. • Education and outreach activities, which includes the use of RPAs in accordance with the Management Plan	250
ASPA 158 Historic Hut, Hut Point, Ross Island	• Familiarisation/observation trips - no more than 8 people in the hut at any one time. This may include personnel from science or other events not otherwise covered by this IEE. • Education and outreach activities, which includes the use of RPAs in accordance with the Management Plan	350
ASPA 159 Cape Adare, Borchgrevink Coast	• Event support • Aerial photography of Adélie penguin colonies to 2,000 feet above ground level[8]	5
ASPA 165 Edmonson Point, Wood Bay	• Aerial photography of Adélie penguin colonies to 2,000 feet above ground level[8]	
ASPA 175 High Altitude Geothermal Sites of the Ross Sea region	• Event support • Environmental inspection of Area in accordance with the 5-year review process	3

7. Alternatives

Other approaches to the proposed operations have been considered, in order to ensure that viable options with less environmental impact are not overlooked. The consideration of alternatives also provides for a re-examination of options should unacceptable impacts occur during implementation of approved activities. Alternatives, and the rationale for decisions made on them, are presented here.

7.1. Do not proceed

To not proceed with Antarctica New Zealand operations would clearly minimise the impacts on the Antarctic environment. Not flying personnel to Antarctica, not using vehicles and aircraft in Antarctica and undertaking no field activities for non-scientific events would remove the impacts identified in this environmental impact assessment.

The consequences of taking this course of action would, however, be significant. Scott Base itself would need to be closed if it could not be maintained. Under the provisions of Annex III to the Protocol on Environmental Protection to the Antarctic Treaty, the base and all associated infrastructure would need to be removed (unless to do so would cause greater environmental harm than leaving the infrastructure in place). Complete removal of Scott Base would be a massive undertaking with significant environmental impacts, particularly in terms of fossil fuel use for transport.

Not proceeding with Antarctica New Zealand's Antarctic operations would drastically reduce the amount and variety of scientific research conducted by New Zealand Universities and Crown Research Institutes and failure to deliver on government interests in Antarctica as set out in the New Zealand Antarctic Institute Act (1996). New Zealand's status as a Consultative Party under the Antarctic Treaty could be called into question by other Parties. This would reduce New Zealand's influential role as a leading player within the Antarctic Treaty System.

As a result, the "do not proceed" option is considered to be non-viable, despite the obvious and significant environmental benefits. Instead, the preference is to continue to look for improvement opportunities so as to mitigate the environmental impacts of New Zealand's activities in Antarctica as effectively as possible.

7.2. Reduce period of operation

Due to the extreme weather conditions, summer is the best period to operate in Antarctica. Some Antarctic Treaty Parties operate summer-only facilities in Antarctica. Operating only in the summer season would reduce the environmental impacts of the non-science programme during the winter period (e.g. air emissions from generators, boilers and a small amount of vehicle use). Typically, only 12-15 people remain on base through the winter, and operations are largely constrained to Scott Base and McMurdo Station. Wildlife sensitivity is at a minimum as most animals spend winter elsewhere and no breeding takes place. Plants and soil microbes are under snow cover and at very little risk of disturbance.

Conversely, activity levels would remain the same or even higher (due to the extra activity needed to open the base at the start of the season) during the summer period when there is greater environmental sensitivity.

A further practical constraint is that the existing Scott Base facilities are not designed to be winterised. A basic level of heating and maintenance is required to keep all systems working, without which, the base could not withstand freezing. Significant redevelopment of the base would be needed to make it a summer-only facility.

7.3. Reduce level of activity

The scale of Antarctica New Zealand's activities in Antarctica is reviewed annually by its Board and Senior Leadership Team. Events and activities are only supported if they add value to the programme and to New Zealand, and can be safely and adequately resourced.

A certain level of staffing and activity is essential to safely operate Scott Base and support science. Non-essential events and activities could be cut from Antarctica New Zealand's operations. Alternative methods of communication and information gathering could be used to understand and manage Antarctica New Zealand's operations. This could, however, reduce the quality, health and safety and environmental standards of operations. Therefore, drastic reduction of discretionary non-science activity is not proposed, but all Antarctic activities will continue to be scrutinised to ensure they are justifiable in terms of value to the organisation and New Zealand.

7.4. Reduce the area of operations

The number of potential sites to be visited by the non-science programme could be minimised or activities could be restricted to Scott Base. Although this would have the advantage of reducing the impacts on the Antarctic environment away from the station, certain objectives of the programme would not be met.

The number of non-science personnel operating away from Scott Base is low. Most field operations are to provide support to science, and the sites have been identified by scientists as the best locations for their research. Reducing our activities in these areas would impact on the scientists that the programme supports.

In addition to reducing the area where we operate, the amount of field infrastructure could be reduced. As discussed in this IEE (Section 5.6), Antarctica New Zealand maintains a number of field huts, installations and fuel caches away from Scott Base. These could be removed or reduced in quantity so as to reduce the overall "footprint" of the programme.

Any field infrastructure that has been installed has been necessary to support the running of Scott Base (e.g. radio antennae), to provide a safe operating environment (e.g. safety hand lines and bamboo route markers) and to support science and environmental monitoring.

Such facilities and installations are regularly reviewed to ensure that no more than are necessary are in the field. For example, in the 2018/19 season huts were removed from Cape Evans. Such reviews will continue to ensure the footprint is minimised without compromising safety.

7.5. Reduce the size of Scott Base

Scott Base could be reduced in size, either by limiting the maximum number of personnel on station (which would reduce energy consumption and wastewater production), or removing buildings and associated infrastructure (which would reduce physical footprint and energy demand).

The Scott Base Redevelopment design process has considered the future scale of Scott Base operations. This has included setting the occupancy capacity and the acceptable physical footprint. A modest increase in capacity is intended from 86 (which is already exceeded at peak times) to 100 beds. While space can be rationalized, the overall footprint of Scott Base can't really be reduced owing to changes in standards (e.g. the amount of space required in bedrooms) and requirements (e.g. larger vehicles to be serviced in the garage) since the 1970s and 1980s when the current base was constructed.

7.6. Change energy sources

Currently Antarctica New Zealand operations are highly dependent on fossil fuels. Since 2010, Scott Base has utilized renewable electricity from the wind farm at Crater Hill, resulting in significant reductions in fuel use. However, the existing systems necessitate fossil fuel burning for heating either through generators ('waste' heat captured and redistributed) or diesel boilers. Until the redevelopment, it is not practicable to change heating systems to primarily electrical.

Antarctica New Zealand offers solar panels for field use, but generators are often needed for back up or to meet energy demands of equipment.

The largest fossil fuel user in Antarctica New Zealand operations is intercontinental transport.

7.7. Change location

The environmental impacts of construction at a new site, or of a significantly larger station on the existing site, were considered unacceptably high compared to redeveloping the facilities on the existing site with only a modest increase in capacity. Antarctica New Zealand aims to keep its activities at Pram Point within its existing operational footprint area, to minimise modification of undisturbed ice-free land, which is scarce across the continent.

Retaining Scott Base's proximity to essential infrastructure such as airfields, McMurdo station and to both the sea ice and the ice shelf, provides logistical efficiencies that would be impossible to replicate at a different site.

7.8. Summary

Antarctica New Zealand continuously assesses the size and scale of the Antarctic programme to ensure that it is providing value to the Government, by supporting international quality research and effective environmental management. The options noted above are, and will continue to be regularly considered and discussed with Government. At present however, the impacts that are occurring as a result of the current size of the non-science programme are considered to be outweighed by the benefits that the New Zealand programme is providing to Government and New Zealand more broadly.

8. Initial environmental state

The establishment of an environmental baseline is an essential component of any environmental impact assessment. An understanding of the current and likely future state of the environment for the duration of the planned activity, allows for more complete assessments of the likely consequences of the activity on species, habitats and ecosystems.

For the Ross Sea region, a comprehensive state of the environment report was prepared in 2001 by Waterhouse et al. This state of environment report concluded that:

> *…most of the Ross Sea region environment is in a pristine state, exceptionally so by global standards. The region contains some of the most undisturbed ecosystems in the world, and its value as a vast natural area, and for the conduct of scientific research is immeasurable.*

Although 18 years old, this reference state remains largely valid today due to only modest change in human activity and impacts in the area over this time.

The primary areas of activity for the non-science component to Antarctica New Zealand's activities are: Scott Base and the immediate area of Pram Point, Ross Island; the McMurdo Sound area more widely (including Beaufort Island, McMurdo Ice Shelf, Bratina Island, Black Island and White Island and the Minna Bluff area); and the McMurdo Dry Valleys. Other less frequented sites covered here include Cape Adare, Cape Hallett, Terra Nova Bay, Cape Colbeck, Rockefeller Mountains, and the Ross Ice Shelf including Crary Ice Rise and the Siple Coast. The sub-sections below describe the current state of these environments

8.1. Scott Base and Pram Point

Scott Base is situated on Pram Point at the southern tip of Hut Point Peninsula, Ross Island. It is estimated that Scott Base and the surrounding areas of disturbed land bring the total of 'occupied' land on Pram Point up to 0.24km^2 (Waterhouse, 2001). The topography of Pram Point and the southern tip of Hut Point Peninsula slopes gently southwards to where the land meets the sea and sea ice. The soils are derived from basaltic lava, which is loosely compacted containing variable sized rocks. Permafrost generally occurs at a depth of approximately 450 mm (Waterhouse, 1996).

Climate data has been recorded at Scott Base since 1957. The highest recorded temperature is +6.0°C, the coolest -57°C and the mean annual temperature -19.6°C. The prevailing wind at Scott Base is from a northeast direction blowing towards Cape Armitage to the southwest of Pram Point. The maximum wind velocities experienced have been gusts up to 185 km/h with steady velocities under blizzard conditions of 95–115 km/h (NIWA).

The ice-free terrestrial environment of the southern tip of Hut Point Peninsula has been modified significantly since 1956 as a result of activities associated with the operation of both Scott Base and McMurdo Station. The impacts on soils in the vicinity of the stations arise mainly from construction activities (ground scraping, ground levelling and quarrying for building construction, maintenance and road formation), the release of a variety of contaminants, vehicle movement and helicopter operations.

8.1.1. Soils

Pram Point is formed from black volcanic rock (basaltic scoria), weathered into 2 cm of desert pavement gravels over stony gravelly sands, with ice-cemented permafrost from depths of around 30 cm (Aislabie et al., 2008). Armoured desert pavements exist in undisturbed areas, while elsewhere clasts have been overturned exposing the salts beneath.

Crater Hill takes its name from the shape left by an extinct volcano caldera. The cold desert soils lack topsoil, or accumulations of organic matter. They are derived from naturally occurring volcanic rocks, largely scoriaceous basaltic lava. Soils are loosely compacted with a pebbly surface. Permafrost generally occurs at a depth of 450mm (Waterhouse, 1996). Sand-wedge polygons were a feature of the area but have been diminished at the turbine site by vehicle operation and earthworks associated with McMurdo Station and Scott Base operation. Vehicle tracking and evidence of surface scraping to collect fine material for roading and construction are clearly visible.

Scott Base soil is very alkaline (with a pH around 9), generally with very low electrical conductivity (although this can be high in disturbed areas where salt has accumulated - Campbell et al. 1993; O'Neill et al. 2012; O'Neill et al. 2015). Organic carbon and nitrogen content is very low, but phosphorus very high (ibid). Ice-cemented permafrost typically lies around 45cm below the surface and may contain 10 to 60% moisture as ice (Campbell et al., 1994 cited in Sheppard, 2000). Soil surfaces can dry to as little as 2% moisture over summer, but can also become saturated during summer melt periods (Sheppard, 2000).

As described in Sections 11.5 and 11.6, the soils have been impacted in the past by physical disturbance and spills.

8.1.2. Biota

Moss, lichen and algae are found around the Scott Base environment. In 2018/19, 25 monitoring sites and eight transects were established for the redevelopment project, building upon past vegetation surveys (Figure 35). Mosses (*Bryum argenteum*) were relatively common throughout the sites (although often inactive) and were most abundant in drainage cracks and under snow packs. Mosses were absent from the most highly impacted sites, which were physically disturbed and in one case exposed to high levels of dust from the road. However, mosses were also observed inhabiting old tractor paths, indicating ability to recover over time (Beet and Lee, 2019). Lichens occurred in drier areas, most frequently *Caloplaca* spp. Examples are shown in Figure 36.

20 genera of algae have previously been identified in the external environment of Scott Base (Broady and Smith, 1994). In 2018/19 cyanobacterial (algal) mats were frequently observed, although they were often in a desiccated inactive state except where running water was present. They were most abundant in drainage cracks and under snow packs.

The 2018/19 survey found that invertebrate abundance and diversity were largely correlated with moisture levels and vegetation abundance. Of the most highly disturbed sites (which had no vegetation), two had no invertebrate life at all (along with a gravelly site with no visible vegetation), and one had only rotifers.

Total microbial counts in Scott Base soils are high – around 100 million cells per gram of soil (dry weight) in uncontaminated samples, comprising Fibrobacter / Acidobacterium, Cytophaga / Flavobacterium / Bacteroides, Proteobacteria, Deinococcus / Thermus, Low G + C gram positive and Actinobacteria (Saul et al, 2005). Hydrocarbon contaminated soils are less diverse, being dominated by Proteobacteria, particularly Pseudomonas, Sphingomonas and Variovorax, some of which degrade hydrocarbons (*ibid*.).

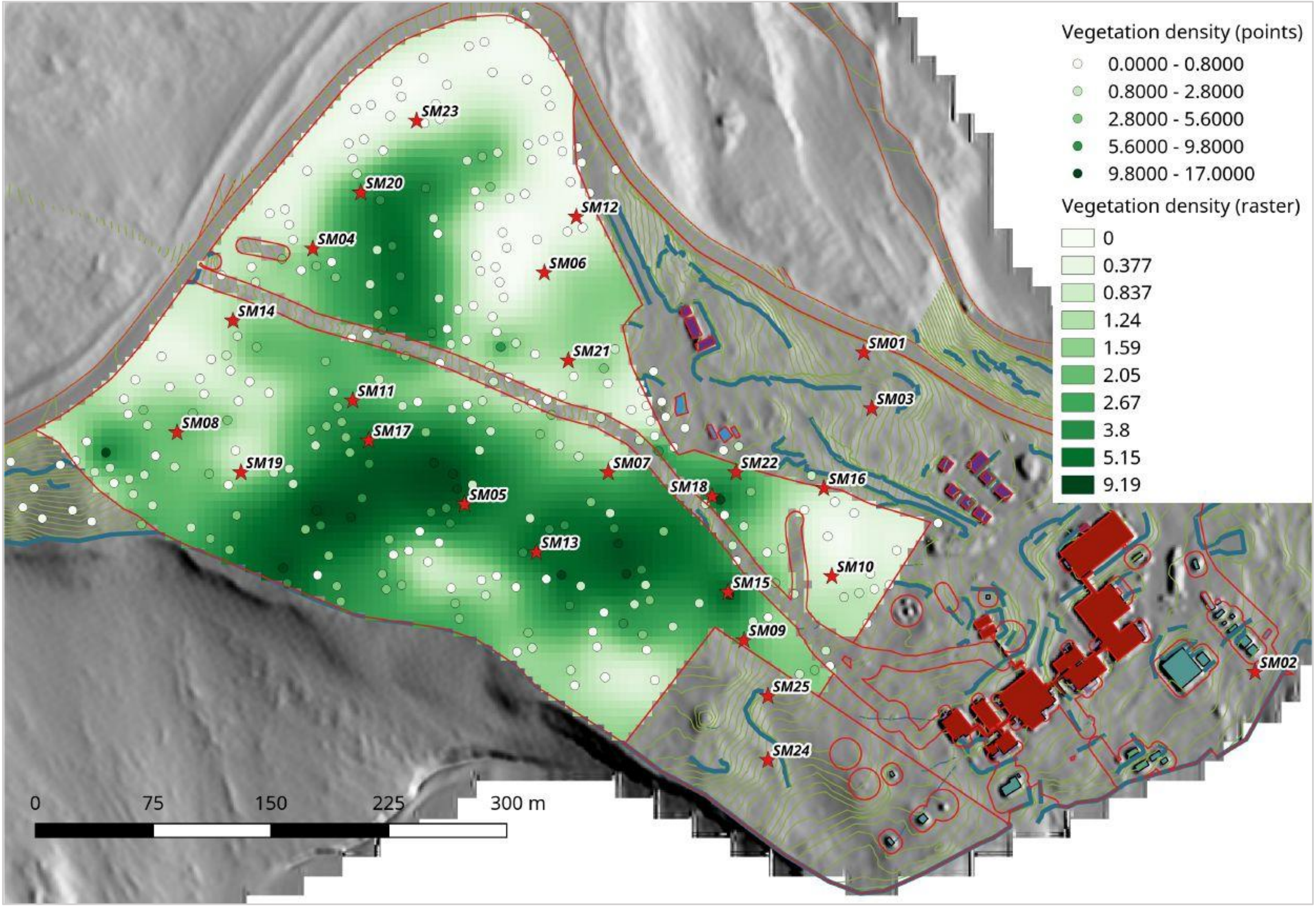


Figure 35: Vegetation density and SBR monitoring plots (SM01-25)

Figure 36: Lichen close to Scott Base © Antarctica New Zealand Pictorial Collection

Seals are present on the sea ice outside Scott Base, mostly non-breeding adults (Oct-Dec) or adults that have relocated to Scott Base after completing the breeding season (Dec-Mar). However, one or two pups have been born each year there over the last four years, indicating that this area could become a breeding colony again in the near future. Seals were harvested for dog food from the 1950s to the 1980s and the population may still be recovering.

South Polar skuas were common around Scott Base and McMurdo Station due to scavenging opportunities until the 1980s when waste dumps were removed. Small numbers of skuas still visit and breed in the vicinity of Scott Base, with one or two nests in a restricted science area to the west of the base buildings each season.

Adélie penguins are occasional visitors to the sea ice near Scott Base, and less frequently also emperor penguins. The nearest breeding colonies are at Cape Royds for Adélies and Cape Crozier for Emperors (the southernmost emperor colony). Minke whales (*Balaenoptera acutorostrata*), Orca whales (*Orcinus orca)* and Leopard seals (*Hydruga leptonyx*) have also been sighted in McMurdo Sound and occasionally come close to shore in front of Scott Base when the sea ice has broken out.

Over a million snow petrels breed in Ross Sea region, the nearest colony being at Franklin Island (Ainley et al, 1984). Snow petrels disperse widely to feed in pack ice, including the Ross Island area (*ibid*.).

8.1.3. Air

Mt Erebus is the largest point source of many chemicals, which impact air quality including sulphur dioxide, particulates, heavy metals, fluoride, hydrogen sulphide and nitrous oxides (Fisher, 2001). It is estimated that 1000 times more sulphur dioxide comes from Mt Erebus than from Scott Base and McMurdo combined, and airflows pass from Mt Erebus directly over Hut Point Pensinsula (Godfrey and Clarkson, 1998). Emissions from stations are considered to be highly localized and have “extremely minor” effects on air quality (Fisher, 2001).

8.1.4. Sea

The immediate nearshore environment off Scott Base consists of steep scree slopes with medium diversity and medium to high abundance (Figure 37, Figure 38). The benthic communities are dominated by echinoderms and crustacea, and in places sponges, coelenterates and polychaete worms (Negri et al, 2006). At depths greater than 30m, where it is not so steep and stony, there is suitable habitat for a diverse array of sedentary fauna (Battershill, 1992, cited in Williams, 2012). Historic waste disposal practices have left point sources of contamination (Negri et al, 2006).)

Figure 37: Four species of anemones and for sponges compete for space in the marine environment near Scott Base. The large predator nudibranch Tritonia challengeriana is centre right. Photograph: Ian Hawes

Figure 38: Large volcano sponge at about 50m depth outside Scott Base: Image from video by Ben King

8.2. Ross Island and McMurdo Sound surrounds

Ross Island (2,460 km^2) was formed through the coalescing of four large volcanic cones - Mt Erebus, Mt Terror, Mt Terra Nova and Mt Bird - and their smaller radially distributed volcanic vents. Mt Erebus is the youngest cone and remains active. These four volcanoes are part a wider volcanic field in the area which also includes Franklin Island, Beaufort Island, Mt Discovery and Mt Morning and their associated volcanic vents (Kyle and Cole, 1974). The lavas of Mt Erebus and Mt Discovery and the surrounding area are predominantly alkali basalt with trachyte and phonolite. Soils and ice-free areas occur sporadically on Ross Island and other islands and landmasses in the area. The soils are mostly "cold desert soils" and lack topsoil, or accumulations of organic matter.

The prevailing winds around Ross Island and McMurdo Sound are from the south due to the Transantarctic mountains turning the easterlies in a northward direction (O'Connor et al. 1994). Southerly winds are turned towards both the east and west as they run up against the mountains of Ross Island (Waterhouse, 2001). Temperatures on Ross Island tend to be lower than temperatures further up the Ross Sea coast as Ross Island is influenced by the Ross Ice Shelf. Temperatures vary greatly on Ross Island itself with significant differences in air temperature between Scott Base and McMurdo Station, although only 3 kilometres apart (Hatherton, 1990). Scott Base temperatures are influenced by the cold air originating in the Windless Bight area, to the northeast.

A large amount of research is conducted at various locations on Ross Island, as both the New Zealand and the United States Antarctic programme have stations on the island. There are currently nine ASPAs designated on Ross Island to protect areas of outstanding Antarctic wildlife and vegetation, as well as the historic huts and artefacts that remain from explorers (Captain Robert F. Scott and Sir Ernest Shackleton) during the Heroic era (1901-1913), and the crash site of the Air New Zealand flight TE901 which crashed into Mt Erebus. An area northwest of White Island was also designated an ASPA (137) because an unusual breeding population of Weddell seals, which is the most southerly, has been physically isolated from other populations by the advance of both the McMurdo and Ross Ice shelves.

Extensive biotic communities occur sporadically on Ross Island where there is light, warmth, water and shelter from the wind (Waterhouse, 2001). Some of the richest stands of mosses and associated microflora and fauna in the Ross Sea region occur at Cape Bird (ASPA 116). Tramway Ridge (ASPA 130) on Mt Erebus supports an unusual ecosystem of fumarolic activity and associated vegetation of exceptional scientific value to botanists, phycologists and microbiologists. The most southerly Adélie penguin colony is found at Cape Royds (ASPA 121) and Cape Crozier (ASPA 124) supports a rich bird and mammal fauna and vegetation assemblages.

Other sites in the wider McMurdo Sound area that are visited include sites in the vicinity of the McMurdo Ice Shelf (including Bratina Island, Black Island and White Island and the Minna Bluff area) and Beaufort Island.

The McMurdo Ice Shelf encompasses an area roughly 1,500 km2 known as dirty ice because it is an ablation zone covered in gravel. A large portion of this gravel originates from marine sediments but also from the nearby islands. Much of the ice shelf is frozen sea water. During the summer melt period, the surface forms an abundance of fresh and saline ponds. The bottom of these ponds is covered with thick mats of cyanobacteria, diatoms and green algae and is the largest concentration of non-marine biota in the Ross Sea area (Mountfort et al., 2003).

Beaufort Island, north of Cape Bird, was designated as an ASPA because of its varied avifauna and importance as a reference site for the future due to it being relatively isolated and difficult to access and therefore not impacted by human activity. It is visited infrequently and only by researchers and support personnel.

Weddell seals, Adélie penguins, emperor penguins and South Polar skua breed at locations around Ross Island and McMurdo Sound. Minke whales, Orca, Leopard seals and Crabeater seals (*Lobodon carcinophagus)* are also often seen in the area.

The marine area away from the bases is considered to be pristine. Extensive research is conducted on the Weddell seals, penguin colonies, benthic invertebrate communities, fish fauna (ecology, biochemistry and physiology), sea ice algae and phytoplankton.

8.3. Arrival Heights ASPA 122

Arrival Heights (area: 0.73 km2) is a small range of low hills located near the southwestern extremity of Hut Point Peninsula (Figure 39(, Hut Point Peninsula is composed of a series of volcanic craters extending from Mount Erebus, two of which, namely First Crater and Second Crater, respectively form part of the southern and northern boundaries of the Area. The Area is predominantly ice-free and elevations range from 150 m to a maximum of 280 m at Second Crater. Arrival Heights is located approximately 1.5 km north of McMurdo Station and 2.7 km northwest of Scott Base. The Area has a broad viewing horizon and is comparatively isolated from activities at McMurdo Station and Scott Base, with the majority of McMurdo Station being hidden from view.

The soils at Arrival Heights consist mostly of volcanic scoria deposited from the eruptions of Mount Erebus, with particle size ranging from silt to boulders. The thickness of surface deposits ranges from a few centimetres to tens of metres, with permafrost underlying the active layer (Stefano, 1992). Surface material at Arrival Heights also includes magma flows from Mount Erebus, which have been weathered and reworked over time. Sand-wedge polygons cover an area of approximately 0.5 km2 at Arrival Heights and, because physical disturbance has been limited by the protected status of the Area, are far more extensive than elsewhere in the southern Hut Point Peninsula vicinity (Klein et al. 2004).

Lichens at Arrival Heights were surveyed in 1957 by C.W. Dodge and G.E. Baker, with species recorded including: *Buellia alboradians, B. frigida, B. grisea, B. pernigra, Caloplaca citrine, Candelariella flava, Lecanora expectans, L. fuscobrunnea, Lecidella siplei, Parmelia griseola, P. leucoblephara* and *Physcia caesia*. Moss species recorded at Arrival Heights include *Sarconeurum glaciale* and *Syntrichia sarconeurum* (BAS Plant Database, 2009), with *S. glaciale* documented within drainage channels and disused vehicle tracks (Skotnicki *et al*. 1999).

The Arrival Heights facilities are used year-round by personnel from McMurdo Station and Scott Base. In addition to two laboratory buildings, numerous antenna arrays, aerials, communications equipment, and scientific instruments are located throughout the Area, along with associated cabling. The scientific instruments used for atmospheric research in the Area are sensitive to electromagnetic noise and interference, with potential local noise sources including VLF radio transmissions, powerlines, vehicle emission systems and also laboratory equipment. Noise sources generated outside of the Area that may also affect electromagnetic conditions at Arrival Heights include radio communications, entertainment broadcast systems, ship, aircraft, or satellite radio transmissions, or aircraft surveillance radars. In order to provide some degree of protection from local radio transmissions and station noise, some of the VLF antennas at Arrival Heights are located within Second Crater.

Recent installations within and close to the Area include an FE-Boltzmann LiDAR in the New Zealand Arrival Heights Research Laboratory in 2010, the Super Dual Auroral RADAR Network (SuperDARN) Antenna Array (2009-10) and two satellite earth station receptors. The SuperDARN Antenna Array transmits at low frequencies (8 – 20 MHz), with the main transmission direction to the southwest of the Area, and its location was selected in part to minimize interference with experiments at Arrival Heights. Two satellite earth station receptors (Joint Polar Satellite System (JPSS) and MG2) are located nearby. One of the receptors has the ability to transmit (frequency range 2025 – 2120 Hz) and measures have been taken to ensure that any irradiation of the Area is minimal.

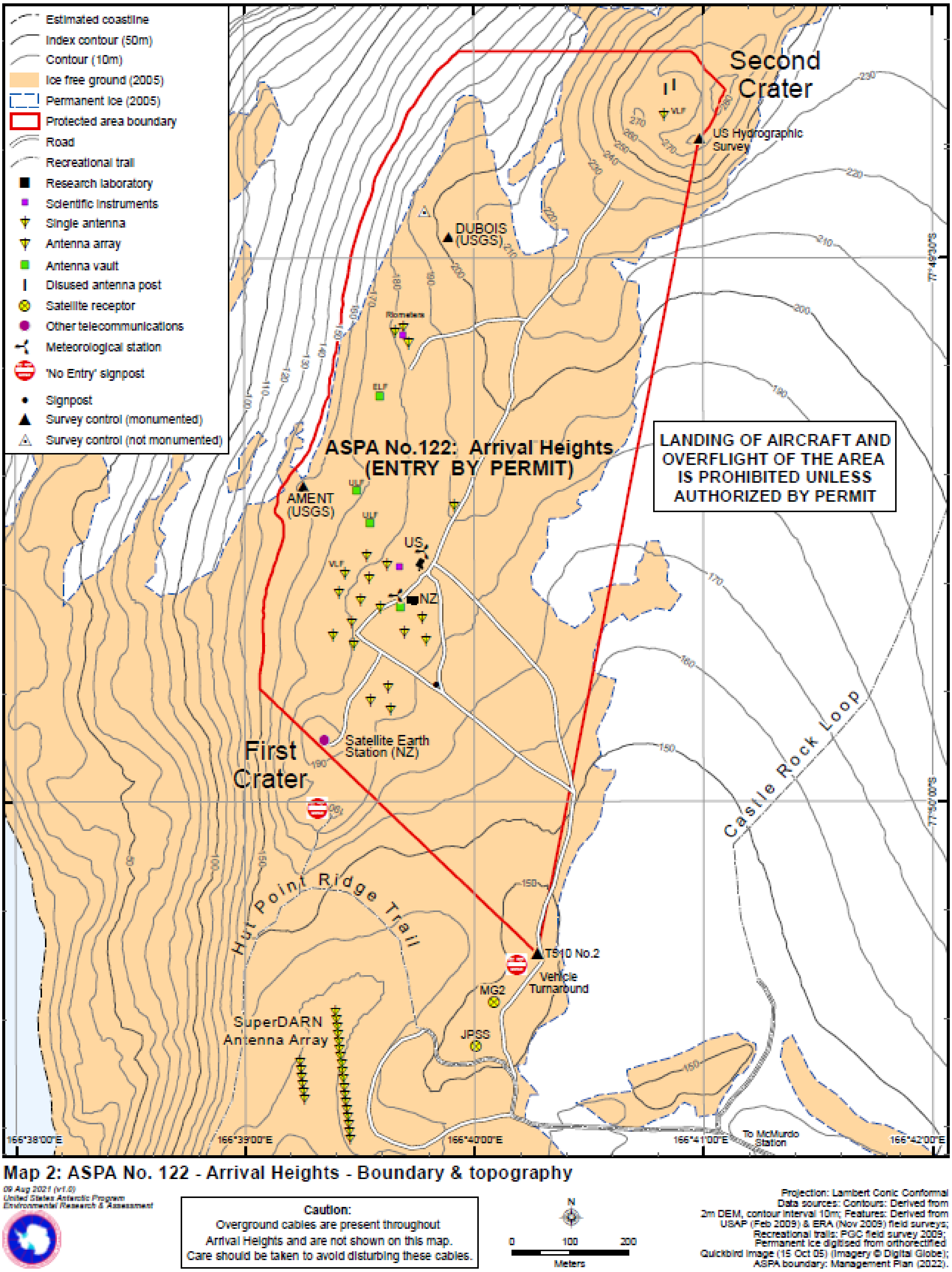


Figure 39: Map of ASPA 122 (Source: USAP)

8.4. McMurdo Dry Valleys (ASMA)

The McMurdo Dry Valleys (Figure 40) covers an area roughly 17,500 km^2 and contains mountain ranges, glaciers, ice-covered lakes, meltwater streams and interconnected watershed systems, arid patterned soils, permafrost, sand dunes, unique geological features and minerals (e.g. salt deposits and desert pavements). The surface deposits include glacially deposited and modified sediments, sand dunes, desert pavement, glacio-lacustrine sediments, and marine fjord sediments. Low precipitation in the McMurdo Dry Valleys means that they are commonly referred to as cold deserts and their soils described as cold dessert soils. There is widespread occurrence of a pebble or boulder surface pavement, wide variations in soil salinity, and the presence of permafrost at variable soil depths (Waterhouse, 2001).

The McMurdo Dry Valleys are characterised by unique ecosystems of low biodiversity and reduced food web complexity. The habitats that exist in this area are simple and relatively diverse compared to other ice-free areas. There are no vertebrates or vascular plants, and very few insects. Unusual microhabitats and biological communities are found throughout the valleys. The ecosystem of the Dry Valleys is largely driven by the melt from surrounding glacier as the area receives very little precipitation.

The McMurdo Dry Valleys generally experience the warmest temperatures in the Ross Sea region in summer but have colder winters. The ice-free surfaces absorb most of the solar energy in summer. The mean annual air temperature in the Dry Valleys is between -17° to -20° C. The Dry Valleys have low precipitation, low surface albedo, and dry katabatic winds descending from the Polar Plateau which result in extremely arid conditions (Clow et al., 1988). The strong katabatic winds from the polar plateau flow into the valleys, which also receive strong local glacier drainage winds. The wind regime dominates the local climate over the austral winter (Clow et al., 1988).

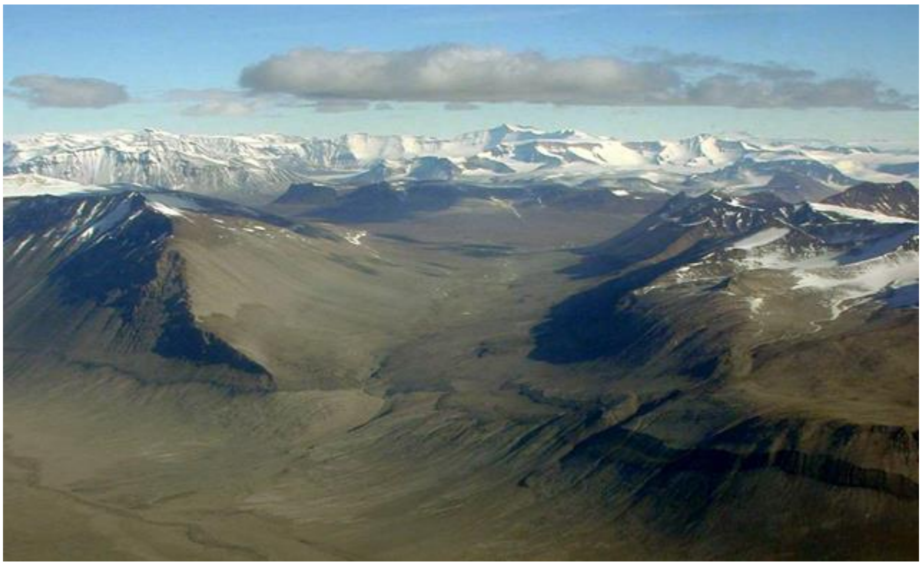


Figure 40: Bull Pass in the McMurdo Dry Valleys. Image: Josh Landis, USAP Photo Library

8.5. Cape Adare

Cape Adare (71° 18' S, 170° 09' E) is a generally ice-free prominent headland at the northern tip of the Adare Peninsula at the extremity of Victoria Land in the Ross Sea (Figure 41). To the south west of the headland, there is a triangular shaped low pebbled beach called Ridley Beach which extends into Robertson Bay. The surface of the beach is, for the most part, undulating. The entire area and the lower western slopes of the Adare Peninsula is occupied by one of the largest Adélie penguin colonies in Antarctica. The colony has recently been recognised as an Important Bird Area (IBA; reference ATCM Resolution D (2015)).

The Adare Peninsula has steep slopes rising behind Ridley Beach and dropping away into the Ross Sea on the eastern side of the peninsula (Reid, 1962).

Figure 41: Cape Adare, Northern Victoria Land

Cape Adare is significant in history as the site where people first stepped on the Antarctic continent. The whaler 'Antarctic' visited the site in January 1895, where Norwegian explorers Henrik Bull and Carsten Borchgrevink landed at Cape Adare, collecting geological specimens. Carsten Borchgrevink returned in 1899 (Southern Cross Expedition) and erected two huts, the first human structures in Antarctica, and spent the winter at the site, the first party to overwinter on the continent. These structures and a further hut erected by the Northern Party of the Terra Nova Expedition (1910-1913) remain at this site. Tourist ships visit this site when it is accessible but weather and ice conditions often prevent this. The Antarctic Heritage Trust plans to conserve the artefacts at this site in the future.

8.6. Cape Hallett

Cape Hallett (72° 19´S, 170°16´E) is located at the southern end of Moubray Bay, northern Victoria Land, in the western Ross Sea (Figure 42). It forms the northern tip of the 32 km long by 8 km wide, north-south aligned, Hallett Peninsula that extends south to Cape Wheatstone and is joined to the mainland by a narrow ridge between Tucker Glacier and Edisto Inlet. The low point of this ridge is the broad Football Saddle (700 m). Projecting about 1,200 m west from the high rocky ridge forming Cape Hallett is Seabee Hook, a low (generally less than 5 meters above sea level), a curved spit composed of coarse volcanic material, between 130 and 575 m wide, with a total area of approximately 41.1 ha. Willett Cove is a small bay enclosed on the south side of Seabee Hook (Brabyn et al., 2006).

Cape Hallett was the site of a joint US/NZ station (1957-1973), the site of which has gradually been cleaned up over the last 30 years. It is also home to approximately 40,000 breeding pairs of Adélie penguins. The colony has recently been recognised as an Important Bird Area (IBA; reference ATCM Resolution D (2015)).

The area inland of the spit is rich in moss and lichen. This site was originally designated as an ASPA (106) to protect the vegetation. The ASPA boundaries have since been expanded to include the penguin colony.

The Korean Antarctic programme, KOPRI, installed a hut, storage module and fuel cache at Cape Hallett in 2017/18 which they intend to keep in place to support a science programme until 2022.

Figure 42: Aerial view of Seabee Hook at Cape Hallett. Image: Kevin Pettway, USAP Photo Library

8.7. Terra Nova Bay

The Terra Nova Bay area is predominantly a snow-free low coastal foothill along the Victoria Land Coast, which lies between large outlet glaciers which drain from the inland ice sheet and local high inland ranges. The bay is approximately 64 km long from the Drygalski Ice Tongue in the south to Cape Washington in the north. The coastline of Terra Nova Bay is characterised by rocky cliffs, with large boulders forming occasional beaches. The geology of the area is composed of variable strata including granites, diorites, schistose, metamorphite, amphibolites, basalt and different types of lavas. Three bases are located at this site; Italy's Mario Zucchelli Station (Figure 43), South Korea's Jang Bogo Station (Figure 44) and Germany's Gondwana Station.

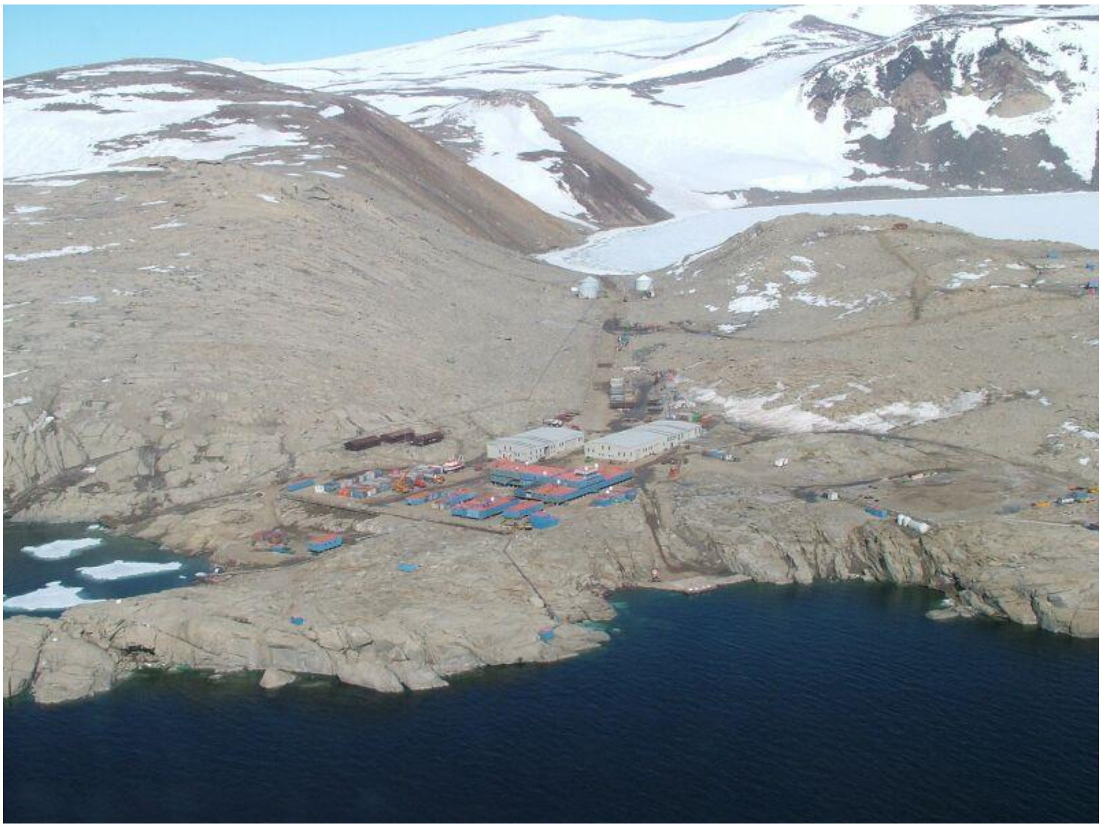


Figure 43: Mario Zucchelli Station, Terra Nova Bay. © Antarctica New Zealand Pictorial Collection

Average monthly temperatures range from -2°C to -30°C with the average annual temperature around -18°C. The predominant wind direction is from the west and north as katabatic winds move from the interior of the continent. The presence of several glaciers connecting the interior plateau with the coast makes Terra Nova Bay a windy area. Wind speed often reaches more than 150 km/hour.

A large area of open water persists throughout most of the Southern Hemisphere winter, even while most of the rest of the Antarctic coastline is frozen. This pocket of open water, a polynya, results from the exceptionally strong katabatic winds which drive the sea ice eastward. Since the dominant ice drift pattern in the area is northward, the Drygalski Ice Tongue prevents the bay from being re-populated with sea ice.

Terra Nova Bay is one of the most studied coastal habitats in the Ross Sea region. The area supports a rich benthic invertebrate community and macroalgal assemblage (Thrush et al., 2006). The coastal marine area immediately to the south of Mario Zucchelli Station has been designated as ASPA 161 due to the marine community, encompassing 29.4 km^2 between Adélie Cove and Tethys Bay.

There is an Adélie penguin colony at Adélie Cove and an Emperor penguin colony at Cape Washington. Minke whales and Orca also visit the area. There is considerable eutrophication of rocks and soil near bird colonies which favours the establishment of floral communities. 57 species of lichens and lichenicolous fungi are found in Terra Nova Bay (Castello and Nimis, 2000).

Built just a few kilometres to the north of Mario Zucchelli Station, Jang Bogo Station in Terra Nova Bay is a recently completed, permanent South Korean research station (Figure 44). It is the second base of the South Korean Antarctic research mission and the first Korean station located in mainland Antarctica. The station houses 15 people in winter and 60 in summer in a 4,000 square-metre building with three wings. It is now one of the larger permanent bases in Antarctica.

The base, named after an eighth-century maritime ruler of Korea, was opened on 12 February 2014.

Figure 44: The Republic of Korea's Jang Bogo Station. Image from The Korea Times

8.8. Cape Colbeck

Cape Colbeck is an ice-covered feature at the northwestern extremity of the Edward VII Peninsula, Marie Byrd Land, at the entrance to Bartlett Inlet. It is over 800km from McMurdo Station and Scott Base, the nearest occupied research facilities. It is a relatively unexplored area, other than a *Nathanial B. Palmer* research cruise in 1996 which collected multibeam bathymetry data.

Cape Colbeck has been identified as an Important Bird Area (IBA ANT191) due to the Emperor Penguin colony, which satellite imagery showed has more than 11,000 adults in 2009 (Fretwell et al. 2012). This represents more than 1% of the global population. This meets the following criteria:

- A4i: "The site is known or thought to hold, on a regular basis, 1% or more of a biogeographic population of a congregatory waterbird species."
- A4ii: "The site is known or thought to hold, on a regular basis, 1% or more of the global population of a congregatory seabird or terrestrial species."
- A4iii: "The site is known or thought to hold, on a regular basis, at least 20 000 waterbirds, or at least 10 000 pairs of seabirds, of one or more species.

No other birds are known to breed in the area. An Emperor penguin colony is located on sea ice at Cape Colbeck, as well as a Weddell seal colony.

8.9. Rockefeller Mountains

The Rockefeller Mountains are a group of low-lying, scattered granite peaks and ridges, almost entirely snow covered, approximately 50km south south-west of the Alexandra Mountains on Edward VII Peninsula. Discovered by the Byrd Expedition in 1929, they were named by Byrd for a patron of the expedition.

8.10.Ross Ice Shelf

The Ross Ice Shelf is the world's largest body of floating ice, lying at the head of Ross Sea, itself an enormous indentation in the continent of Antarctica (Figure 45). The ice shelf lies between about 155° W and 160° E longitude and about 78° S and 86° S latitude. The current estimate of its area is about 182,000 square miles (472,000 square km). The shelf has served as an important gateway for explorations of the Antarctic interior, including those carried out by many of the most famous expeditions.

The great white barrier wall of the shelf's front, first seen in 1841 by the British polar explorer James Clark Ross, rises in places to 160 or 200 feet (50 or 60 m) high and stretches about 500 miles (800 km) between fixed "anchor points" on Ross Island to the west and the jutting Edward VII Peninsula on the east. With its immense, gently undulating surface reaching back nearly 600 miles (950 km) southward into the heart of Antarctica, the Ross Ice Shelf provides the best surface approach into the continental interior. The McMurdo Sound region on the shelf's western edge thus became the headquarters for Robert F. Scott's 1911–12 epic sledging trip to the South Pole and also served several Antarctic research programs later in the century. The eastern barrier regions of the ice shelf were headquarters for the Norwegian Roald Amundsen's first attainment of the South Pole on Dec. 14, 1911; for Richard E. Byrd's three U.S. expeditions of 1928–41 at Little America I–III stations; and for several subsequent expeditions and research programs.

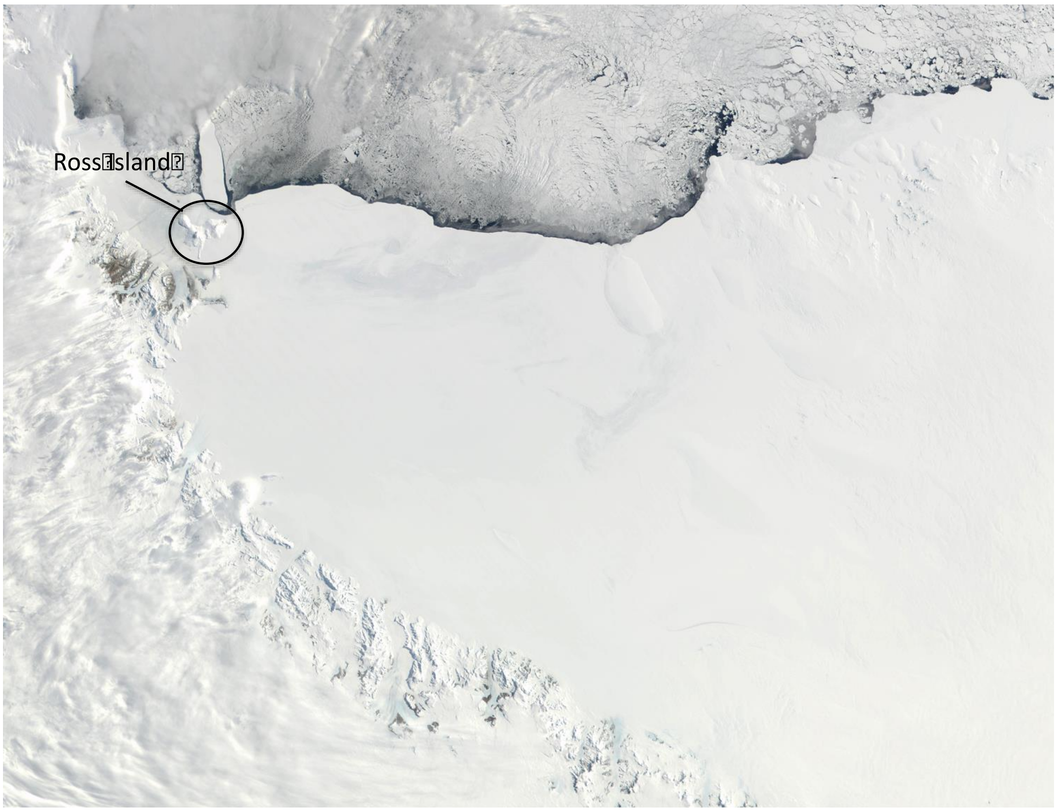


Figure 45: Ross Ice Shelf

The Ross Ice Shelf is fed primarily by giant glaciers, or ice streams, that transport ice down to it from the high polar ice sheet of East and West Antarctica. The ice shelf has been likened to a vast triangular raft because it is relatively thin and flexible and is only loosely attached to adjoining lands. Giant rifts develop behind the ice shelf's barrier wall and occasionally rupture completely to spawn the huge tabular icebergs that are characteristic of the Antarctic Ocean. Thus, although the barrier's position appears almost stationary, it actually undergoes continual change by calving and melting that accompany northward movement of the shelf ice. The shelf's mean ice thickness is about 1,100 feet (330 m) along a line at about 79° S latitude.

In a southward direction along about 168° W longitude, the ice shelf's thickness gradually increases to more than 2,300 feet (700 m). Estimates suggest that at distances of 100 to 200 miles (160 to 320 km) inland from the barrier, 15 to 20 inches (380 to 500 mm) of ice may be added to the shelf each year by bottom freezing. Melting on the bottom of the ice shelf also occurs, and oceanographic data suggest that the net effect is the dissolution of the ice shelf by about 47–87 inches (120–220 cm) per year.

8.10.1. Crary Ice Rise

Crary Ice Rise is the largest and southernmost ice rise on the Ross Ice Shelf and lies directly in the path of ice discharged from Ice Stream B. The name honours American geophysicist Albert P. Crary (1911–87).

8.10.2. Siple Coast and Siple Dome

The Siple Coast is the middle portion of the ice-covered coast along the east side of the Ross Ice Shelf, between the northern end of the Gould Coast and the southern end of the Shirase Coast. The area was named by the New Zealand Antarctic Place-names Committee in 1961 after Paul A. Siple, a noted American scientist-explorer who accompanied R. Admiral Richard E. Byrd on all of his Antarctic expeditions. Siple Dome is an ice dome approximately 100 km wide and 100 km long, located 130 km east of the Siple Coast. The US Siple Dome field camp in West Antarctica is located about 500 miles from Scott Base. It is used as a deep field camp with a US-maintained skiway that serves as an emergency landing strip for planes to use if they should be diverted on their way to or from the South Pole. It also acts as a staging point for science teams heading even deeper into the field (Figure 46).

Figure 46: The USA Siple Station, situated on Siple Dome

9. Interaction of activities with the environment

The EIA Guidelines recommend identification of ways in which the component parts of the activity (‘actions’) may interact with the environment (‘environmental aspects’). The actions were determined by reviewing event planning information for 2019-2023 and by talking to Antarctica New Zealand staff responsible for planning and managing operations. For efficiency, actions which do not lead to interaction with the environment are generally excluded.

Table 15 defines the aspects of interaction with the environment and Table 16 shows the relationship between actions and aspects in matrix form. The aspects are inter-related, for instance transport is a specific action, but it also plays a part in maintenance activities, field support, and recreation. As much as possible, environmental aspects of the actions are ascribed to the most relevant action, e.g. atmospheric emissions are ascribed to transport but not to the other actions which involve transport.

In Table 17, the components of the environment which the aspects interact with are identified.

Table 15: Definition of environmental aspects

Aspect	Definition
Atmospheric emissions	Discharges such as greenhouse gasses and particulates entering the air
Noise and vibration	Movement of air or substances arising from e.g. the operation of vehicles
Light and heat	Transmission of light from windows and other sources during dark period
Heat	Transmission of heat into surrounding environment
Electromagnetic radiation	Oscillations of electric and magnetic fields caused by accelerating electrical charges, e.g. radio transmissions
Mechanical action	Physical movement of material, e.g. digging, grading and subsequent natural transport of the material (e.g. windblown dust, runoff)
Spills	Unintended release of hazardous substances to the environment and their possible migration
Discharge to sea	Release of liquids into the sea
Species transfer	Unintended introduction of species not native to Antarctica, or the movement of species within Antarctica from one biogeographic zone to another
Presence	The presence of people and human-made objects in Antarctica
Interaction with flora and fauna	Direct or indirect contact with flora and/or fauna

Table 16: Actions which occur as part of Antarctica New Zealand operations and the aspects in which they interact with the environment

ENVIRONMENTAL ASPECTS / **ACTIONS**	**Atmospheric emissions**	**Noise and vibration**	**Light**	**Heat**	**Electromagnetic radiation**	**Mechanical action**	**Spills**	**Discharge to sea**	**Species transfer**	**Presence**	**Interaction with flora and fauna**
Power generation - generators - wind farm											
Handling of hazardous substances - bulk fuel storage - drums and containers - field fuel caches - cookers, field hut heaters											
Waste management - sewage and grey water - accidental release of other wastes											
Maintenance activities - snow removal, minor earthworks - operation of heavy plant - removal of obsolete equipment - replacement of equipment											
Transport - surface vehicles - helicopters and fixed wing aircraft - use of shipping											

ENVIRONMENTAL ASPECTS ACTIONS	Atmospheric emissions	Noise and vibration	Light	Heat	Electromagnetic radiation	Mechanical action	Spills	Discharge to sea	Species transfer	Presence	Interaction with flora and fauna
Field support - provision of camp equipment - maintenance, removal, relocation of huts - travel of personnel, search and rescue											
Field installations - structures - signage - equipment											
Recreation - walking, skiing, biking (Hut Point Peninsula) - day trips (McMurdo Sound area) - overnight stays at camp sites / huts - observation of field activities											
Site investigations - drilling / coring - soil sampling, runoff sampling											

Table 17: Aspects and environmental receptors

ENVIRONMENTAL RECEPTORS / ASPECTS	Fauna	Freshwater	Snow and ice	Marine	Ice free land including flora	Atmosphere	Wilderness and aesthetic value
Atmospheric emissions							
Noise and vibration							
Light							
Heat							
Electromagnetic radiation							
Mechanical action							
Fuel spills							
Discharge to sea							
Introduced species							
Presence							
Interaction with flora or fauna							

10. Mitigation measures

The planning and conduct of all activities by Antarctica New Zealand closely follow the environmental principles outlined in the Protocol on Environmental Protection to the Antarctic Treaty (1991), the Antarctica (Environmental Protection) Act (1994), guidelines adopted by the Antarctic Treaty Parties, and managed and protected area management plans (ASPAs and ASMAs). The environmental impact assessment process outlined in Section 1 is integral to this planning.

The mitigation measures described here apply to all Antarctica New Zealand's activities. In addition, event-specific mitigation plans are under development for the Scott Base Redevelopment events, in collaboration with the various contractors. This is to account for the specific potential impacts associated with the events, for example the risk of introducing non-native species through imported materials, plant and equipment, which require specific mitigation measures in New Zealand, before the event begins in Antarctica.

10.1. Antarctica New Zealand's Environmental Management Policy

Antarctica New Zealand will demonstrate leadership in environmental management across all our activities in Antarctica and New Zealand. We are committed to protecting our environment and undertaking all of our activities in a sustainable manner.
To achieve this, we will:

- Comply with, and where possible exceed, all relevant national and international environmental and energy legislation and Antarctic Treaty System requirements.
- Implement an Environmental Management System which sets out our environmental and energy objectives and targets.
- Provide education and training for all staff and visitors to ensure environmental and energy requirements are understood and implemented.
- Prevent environmental pollution and clean up the legacy of our past activities.
- Minimise our energy demands through management and awareness of high energy activities, support the purchase of energy-efficient products and services, and plan for energy performance improvements.
- Monitor and audit our activities for compliance.
- Report on and continually strive to improve our environmental and energy performance.

All programme participants have a responsibility to protect the environment. We will review this policy annually and communicate it to all programme participants and the public.

10.2. Environmental Management System

Antarctica New Zealand is committed to minimising impacts on the environment. To achieve this commitment, Antarctica New Zealand has developed an Environmental Management System (Figure 47). This system establishes organisational policies and objectives and sets out a series of processes and personnel accountabilities to drive high environmental standards.

The purpose of the organisation's environmental management system (EMS) is: to undertake all our activities in a sustainable manner. The EMS applies to all activities undertaken by Antarctica New Zealand, in both Christchurch and Antarctica, and to all staff, visitors and event personnel operating in the Antarctic environment. The EMS is designed to be consistent with both the international standard for Environmental Management Systems (ISO 14001:2015), and the provisions of the Protocol and the Antarctic Treaty System. Since 2011 the EMS has maintained Diamond certification with Enviro-Mark. An important component of the EMS is Antarctica New Zealand's Energy Management System, which is certified under Energy-Mark and CEMARS (Certified Energy Management and Reduction Scheme).

All Antarctica New Zealand staff working in Antarctica participate in an awareness programme prior to departure for Antarctica, where they are introduced to the policies, procedures and guidelines used by Antarctica New Zealand in scenario and role-playing exercises.

Once in Antarctica, all personnel are required to complete Antarctic field training whereby practical demonstrations and experience is gained in minimising potential environmental impact and operating safely in the Antarctic environment. For those visiting specially protected and managed areas (ASPAs and ASMAs), a briefing is provided to outline the provisions of the management plans for that area. The Environmental Code of Conduct is provided to all staff, workers and visitors and it sets the requirements for managing one's impacts while in Antarctica.

Figure 47: Overview of Antarctica New Zealand's Environmental Management System

10.3. Atmospheric emissions

Antarctica New Zealand has formalized its commitment to reducing carbon and greenhouse gas emissions through accreditation with Energy Mark and CEMARS (Certified Emissions Management and Reduction Scheme). While Antarctica New Zealand is committed to sustainability and reducing our environmental footprint, increases in emissions are likely in the medium term due to increased deep field support and the redevelopment of Scott Base. Therefore, the current target is reduction of emission intensity (tCO2e/$Millions) by 10% by 2021 (against the 2015/16 baseline).

The Ross Island Wind Energy system continues to avoid considerable fossil fuel use at Scott Base and McMurdo Station. The planning and engineering teams are constantly working to maximize efficiency, and the redevelopment of Scott Base will provide the opportunity for step changes in energy systems in future.

Alternatives to fossil fuels for air and sea transport are not currently available, but Antarctica New Zealand is currently trialling its first electric vehicle at Scott Base. Replacement schedules for vehicles and generators mean that equipment continues to be cleaner burning as technology improves.

Antarctica New Zealand’s Environmental Code of Conduct (Appendix 1), provides the following advice:

- Turn off lights, equipment and other appliances when not in use.
- Keep doors closed to avoid heat loss.
- Reduce your shower time to conserve water – aim for three minutes.
- Reduce the amount of laundry you do when at Scott Base. Take your last load of laundry home and use the drying room rather than the clothes dryers.
- Minimise vehicle use by ride-sharing, or walking.
- Minimise food waste by taking only as much as you can eat.

10.4. Noise and wildlife disturbance

Continuing maintenance and rolling replacement of vehicles and equipment will help to minimize noise from these sources. Impacts on wildlife (from noise and visible presence) are mitigated through careful control on personnel and vehicle activity around animals. The Code of Conduct provided to all personnel stipulates:

- Do not interfere with animals unless you have a permit to do so.
- Keep noise to a minimum in the vicinity of wildlife.
- Always give wildlife the right of way, and do not block their access routes.
- Stay 10 metres away from any animal unless it comes to you. Increase this distance if the animal appears disturbed, and take particular care around nesting birds.
- Wherever it is safe to do so, keep vehicles a minimum of 200 metres away from wildlife.
- Take special care when photographing, and do not walk through bird or seal colonies.

As described in Section 8, several penguin colonies are protected by Antarctic Specially Protected Areas (ASPAs). Entry into an ASPA is prohibited except in accordance with a permit and the Code of Conduct requires personnel to be aware of the location of and restrictions associated with ASPAs when planning activities. Helicopter Guidelines are updated annually and provided to all Ross Sea operators to give pilots easy access to clear instructions and maps detailing exclusions, overflight restrictions and landing sites at ASPAs.

When RPAS or drones are used, the drone operator must prepare a Concept of Operations document (CONOPS) with details and assurance of pilot training and competency and air frame worthiness, and plan to operate in accordance with:

- Environmental Guidelines for Operation of RPAS in Antarctica
- COMNAP – Antarctica Remotely Piloted Aircraft Systems (RPAS) Operators Handbook (current version Nov 2017)

- SCAR Guidelines (submitted to ATCM April 2017) – Best Practice for Minimising RPAS Disturbance to Wildlife in Biological Field Research
- Animal Ethics Approvals where relevant
- New Zealand Marine Mammals Protection Regulations 1992.

Tests flights are conducted in safe areas at Scott Base before any field deployment of drones, to minimise the risk of malfunction or failure.

The use of RPAS for remote sensing and filming activities often replaces the use of helicopters, which have the potential to create more disturbance when flying over wildlife and wilderness areas. RPAS are also battery-powered and therefore do not generate air emissions at their place of use.

10.5. Waste management

The Antarctica New Zealand Waste Manual provides staff with practical procedures for the handling, storage and disposal of waste in Antarctica and Christchurch. The Environmental Code of Conduct details the waste handling requirements for all people supported by Antarctica New Zealand:

- Minimise the generation of waste by removing unnecessary packaging and other potential waste before it is sent to Antarctica or into the field.
- Choose reusable packing materials like bubble wrap, cardboard or paper.
- Polystyrene beads, chips or similar forms of packaging, nonsterile soil, polychlorinated biphenyls (PCBs) and pesticides are prohibited and should not be sent to Antarctica.
- Vermiculite should only be used for packaging hazardous liquids.
- Separate the waste you produce and dispose of it in the correct waste stream at Scott Base.
- Open burning of waste is prohibited.
- All field waste must be collected and returned to Scott Base, including grey water and human waste.
- Be prepared – carry a personal pee bottle when travelling away from Scott Base or your field camp

10.6. Light, heat and electromagnetic radiation

Heat loss is avoided wherever possible, for the viability of facilities and energy efficiency, for instance windows are generally small and are triple glazed. The age of the current buildings means some heat loss is unavoidable and major gains will only be able to be made when the base is redeveloped. Energy efficiency is taken seriously and only necessary lighting and electrical equipment is operated.

The 2021/22 proposed relocation of the geomagnetic huts to ASPA 122 was developed in order to minimise the risk of electromagnetic radiation, as described in 5.12.2.1, with the following mitigation measures:

- Surveys of electromagnetic noise to confirm that scientific research is not significantly affected will be undertaken post installation
- Installations will be made of materials that pose minimal risk of interference to the area (non-magnetic materials only);
- Precautions will be taken to ensure that electrical equipment used within the area is adequately shielded to keep electromagnetic noise to a minimum during the installation
- Selection of machinery and timing of activities to be coordinated with the Arrival Heights Working Group

10.7. Mechanical action

There is a clear expectation that any physical disturbance of terrestrial environments needs to be assessed and approved through the EIA process. Around Hut Point Peninsula, vehicle use is restricted to formed roads and the highly impacted operational areas of Scott Base and McMurdo Station. Elsewhere, vehicles are not used on ice-free ground without specific approval. Likewise, minor earthworks are restricted to the immediate vicinity of Scott Base in already-disturbed areas, unless part of an approved EIA.

The Environmental Code of Conduct provided to all personnel provides guidance for avoiding physical disturbance to field sites:

- Where possible, place tents and equipment on snow or previously used campsites
- Where possible, use established tracks. Otherwise, take the most direct route that avoids fragile terrain and plant and animal communities.
- Never paint or deface rocks or ice-free surfaces.
- Leave no sign of your visit. Remove everything you take into the field, and make every effort to return sites to their natural state.

For the 2021/22 proposed activities at Arrival Heights, the following mitigation measures are proposed:

- Vehicle tracks will take the shortest approach line from existing tracks where it is safe to do so
- Vehicle tracks will be formed by the least disruptive means, with absolutely no unnecessary earthworks
- A before and after visual site assessment will be undertaken on two transects through the work area and adjacent to, to allow for description of impacts
- All foot traffic will follow the same track as vehicles to minimize the extent of ground disturbance

10.8. Fuel spills

Antarctica New Zealand's Hazardous Substance and Fuel Spill Prevention and Response Manual details the management of fuel at Scott Base and in the field, to avoid spills and ensure readiness to respond. Key measures include:

- Secondary containment of all bulk fuels at Scott Base, and of generators and in-use fuel supplies in the field
- Spill kits carried in all vehicles
- Spill kits carried and with fuels or other hazardous substances taken into the field (to match the size of the largest single unit)
- Spill prevention and response training for Antarctica New Zealand personnel.

10.9. Discharge to sea

Wastewater from Scott Base is treated by screening, biological reduction and ozone exposure. The performance of the treatment plant is carefully monitored, with monthly testing of the effluent itself as well as the seawater intake (for Scott Base supply). Monthly monitoring data for the 12 months preceding the 2018 inspection showed overall good quality, with the only detectable bacteria occurring in the summer months, when the base population fluctuated. There were no coliform bacteria detected in the seawater intake or RO2 water over this time. The biological treatment beds are carefully maintained and action taken (such as the addition of Ecosocks) to improve microorganism community healthy when needed. The ozone dosing system did not perform reliably in 2018/19 but has been fixed and will be carefully monitored.

As of the 2019/20 season, microbeads that are found in liquid soaps and scrubs and glitter (including on clothing) are prohibited from use at Scott Base. All personnel are also advised to avoid silver, parabens, UV filters, SLES (sodium lauryl sulfate), SLS (sodium laureth sulfate), PEGs, ethanolamines

(DEA, MEA and TEA), parfum or fragrance (unless it is natural-based), triclosan, Aluminium, Aerosols, Formaldehyde, Mineral Oil, Oxybenzone, Propylene Glycol, BHT, and polyethylene/PE. Options for mitigating release of microfibers from laundry are being investigated (e.g. laundry bags or washing machine filters).

Scott Base cleaning supplies are also carefully selected to avoid harmful chemicals.

Contamination to meltwater runoff is minimized as much as possible through spill prevention and response (see Section 10.8).

10.10. Introduced species

Antarctica New Zealand's Biosecurity Prevention and Response Plan sets out the measures taken to avoid introductions and respond effectively to any introduction incident. Invertebrate traps are in place at Scott Base (Standard Operating Procedure BS – 002) to aid detection.

The Environmental Code of Conduct instructs personnel to clean clothing, boots and equipment before travelling to Antarctica, paying particular attention to boot treads, velcro fastenings and pockets which could contain soil or seeds.

Antarctica New Zealand does not operate a hydroponic unit for growing of fresh vegetables because of the risk of introducing species. Fresh food sent from New Zealand is provided by a trusted supplier, avoiding high risk items (e.g. leeks likely to contain soil, varieties which deteriorate quickly and may harbour mould or insects), and is carefully checked before sending and on arrival (SOP BS - 001 Minimising the Risk of Non-Native Species reaching SB through AntNZ's Freshies Supply).

To minimize the risk of avian diseases being introduced, poultry products are not taken to penguin colony sites and no poultry products are disposed of in Antarctica. All poultry wastes are put into the food waste stream for disposal in New Zealand.

10.11. Presence

Scott Base has been operating in the same location since 1957, very close to the United States' McMurdo Station. Antarctica New Zealand is committed to keeping the most intensive activities within this highly impacted area. Activities elsewhere are planned to reoccupy previously used sites where possible, and to leave as little trace of presence as possible. Measures to mitigate the effects of human presence on wildlife are described in Section 10.4 above.

11. Identification of impacts

The EIA Guidelines describe an environmental impact as "*a change in environmental values or resources that is attributable to a human activity. It is the consequence of an interaction between an activity and the environment, not the interaction itself.*"

The guidelines distinguish between a direct impact, being "*a change in environmental values or resources that results from direct cause-effect consequences of interaction between the exposed environment and an activity or action*" and an indirect impact, which "*is a change in environmental values or resources that results from interactions between the environment and other impacts*".

The following sections takes each aspect identified in Section 0 and describe the resulting impacts. Direct and indirect impacts are identified where applicable. A panel at the beginning of each section summarises the activities, the environmental receptors, and direct and any indirect impacts. The aspects, actions and impacts are summarized in Table 18.

Cumulative impacts are also included, i.e. where the effects of Antarctica New Zealand operational activities will add to those of other activities (past, present or foreseeable future) to create a greater combined impact, this is noted.

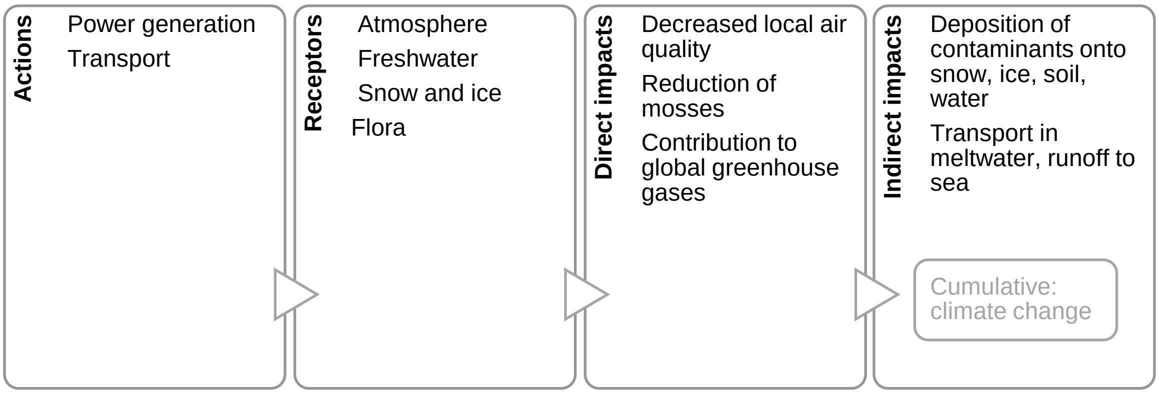
The impacts have been identified drawing on previous EIA documents, past environmental incidents and near misses and literature review. Issues identified by the Committee for Environmental Protection (e.g. introduction of non-native species) are also reflected.

Table 18: Summary of aspects, actions and potential impacts

Aspects	Actions	Potential impacts
Atmospheric emissions	Power generation	• Pollution, contribution to climate change • Decreased surface albedo due to dust • Changed distribution, abundance or diversity of fauna and flora
	Transport	
Noise and vibration	Power generation	• Disturbance to wildlife • Disturbance of scientific values requiring certain noise conditions • Diminished wilderness values
	Maintenance	
	Transport	
	Field support	
	Recreation	
	Site investigations	
Light	Maintenance	• Disturbance to wildlife • Temporary disturbance of wilderness and aesthetic value of Ross Island • Temporary disturbance of scientific values requiring certain light conditions
	Transport	
	Field support	
	Recreation	
Heat	Power generation	• Melting of permafrost, changes to ice cement depth • Increased meltwater
	Transport	
	Site investigation & monitoring	
Electromagnetic radiation	Transport	• Disturbance of science requiring certain environmental conditions
	Field Support	
	Recreation	
	Maintenance	
	Transport	
Mechanical action	Maintenance	• Changes to landscape (e.g. erosion, tracks) • Changes to watercourses • Modification in distribution, abundance or diversity of fauna and flora • Lowering of permafrost • Loss of wilderness/aesthetic values
	Transport	
	Field support	
	Recreation	
	Site investigation & monitoring	

Aspects	Actions	Potential impacts
Spills	Power generation	• Pollution of marine, terrestrial or freshwater environments • Modification in distribution, abundance or diversity of fauna and flora • Loss of wilderness value
	Fuel and chemical storage	
	Waste management	
	Transport	
Discharge to sea	Waste management	• Release of pollutants e.g. phosphorus, nitrogen, hydrocarbons, heavy metals, endocrine disruptors and organic matter • Introduction of microplastics to marine environment • Transmission of pathogenic microorganisms
	Maintenance	
	Transport	
Species transfer	Waste management	• Establishment of a species not naturally occurring in an environment • Modification in the distribution, abundance or diversity of fauna and flora Introduction of wildlife diseases
	Transport	
	Field support	
	Recreation	
	Site investigation & monitoring	
Presence	All actions	• Diminished wilderness and aesthetic value

11.1. Atmospheric emissions



The primary source of airborne pollution at Scott Base is vehicles and generators run on aviation fuel (jet kerosene with cold additives, known as AN8), used in place of diesel. A higher grade of the same fuel is used in Antarctic aircrafts. Emissions from combustion of AN8 can include CO2, light volatile organic compounds, semi-volatile organic compounds including polycyclic aromatic hydrocarbons (PAHs – some of which are listed as bio-accumulative toxins by the EPA), particulate emissions, oxides of nitrogen (NO_X) and oxides of sulfur (SO_2) (Topal et al, 2004). In the 2017/18 season, 986 tonnes of carbon dioxide[10] was emitted by transport and power generation at Scott Base and field sites, and at least this much can be expected annually between 2019-2023.

Little air quality work has been done at Scott Base but at nearby McMurdo Station carbon monoxide, sulphur dioxide and nitrogen dioxide concentrations measured were below U.S. National Ambient Air Quality Standards (Luger, 1993).

The potential for deposition and accumulation of airborne contaminants is not well understood (Fisher, 2001). Modelling suggests poor dispersal of atmospheric pollutants from Hut Point Peninsula in the light northeasterly winds which are most common at Scott Base. When waste was still burned at Scott Base, smoke lingered in these conditions (ibid.; Godfrey and Clarkson, 1998). Ambient air monitoring has identified an anthropogenic increase in the toxic metal composition of suspended particles (Kennicut et al, 1998). Comparison of contaminant levels in Scott Base soils with background levels has suggested accumulation, with arsenic attributed to generator emissions and lead to vehicle exhausts (Sheppard et al, 2000). These contaminants penetrate the soil and are further dispersed by freeze-thaw, water flow and wind. Nonetheless, the impact of emissions from stations are considered to be highly localized and have “extremely minor” effects on air quality (Fisher, 2001). The same can be expected of field sites where fuel is burned.

Aerosols (fine solids or liquids suspended in air) have been studied at the Cosray site near Scott Base. The project identified short term local contamination events (i.e. spikes of anthropogenic aerosols). These were attributed to site maintenance and nearby road traffic, characterized by an average duration of around half an hour, rapid rate of concentration change ($8520 \pm 36\,780\ cm^{-3}\ min^{-1}$), and concentrations exceeding $1000\ cm^{-3}$ (Liu et al, 2018).

In addition to playing a role in dispersal of contaminants, the dust caused by vehicle movements and earthworks at Scott Base causes physical changes to the snow and ice environment by lowering albedo and accelerating melting. This in turn exposes more bare soil which can release further dust. It has been estimated that 200 tonnes of regional windblown dust may result from Scott Base operations annually (compared to 2400 tonnes from McMurdo Station) (*ibid*.).

---

[10] This includes a very small quantity of other greenhouse gases expressed as CO_2 equivalent.

Beet and LEE observed an absence of mosses in sites close to the road, subject to high levesl fo dust (2019). Invertebrate and microbial distribution may also be affected by dust and/or deposited contaminants but this has not been specifically researched.

Table 19 shows the total CO_2 emissions from Scott Base and field transport and generators, as well as Antarctica New Zealand's contribution to intercontinental transport, as calculated for the 2017/18 CEMARS audit. Figure 48 shows that fuel use for Scott Base and field operations remains relatively static, likely due to relatively consistent Scott Base operational demands and financial and logistical constraints on field operations. In contrast, fuel use from Antarctica New Zealand's portion of intercontinental logistics rose over the past three years. This reflects an increase in short-stay visitors to Scott Base, e.g. invited visitors, worker visitors and staff. Some of the increase is due to the need to familiarise contractors for the Scott Base Redevelopment project and undertake site investigations and baseline data collection.

The CO2 emitted by Antarctica New Zealand operations is part of an unprecedented rapid increase in CO_2 since the mid-20th century. In May 2019, atmospheric carbon dioxide (CO_2) measure at Mauna Loa, Hawaii was 414.66 ppm. CO_2 had not been over 400ppm for several millennia until since 2016. The increased level of CO_2 has resulted in a 0.9^{o}C global temperature rise since the industrial revolution in the late 1800s (Callery, 2019).

> *"Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century."*
>
> *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen."*
>
> *IPCC Climate Change 2014 Synthesis Report: Summary for Policymakers Chapter*

Table 19: Carbon emissions from Antarctic New Zealand's Antarctic operations 2017/18

Activity	Fuel type	Tonnes CO_2 equivalent
Intercontinental shipping (proportion of USAP shipping based on weight of New Zealand cargo carried)	Marine diesel oil	2,630.71
Intercontinental air travel (proportion of joint logistics based on New Zealand passengers and cargo carried)	Jet kerosene	1,476.16
Scott Base and field generators and transport	Jet kerosene	985.60

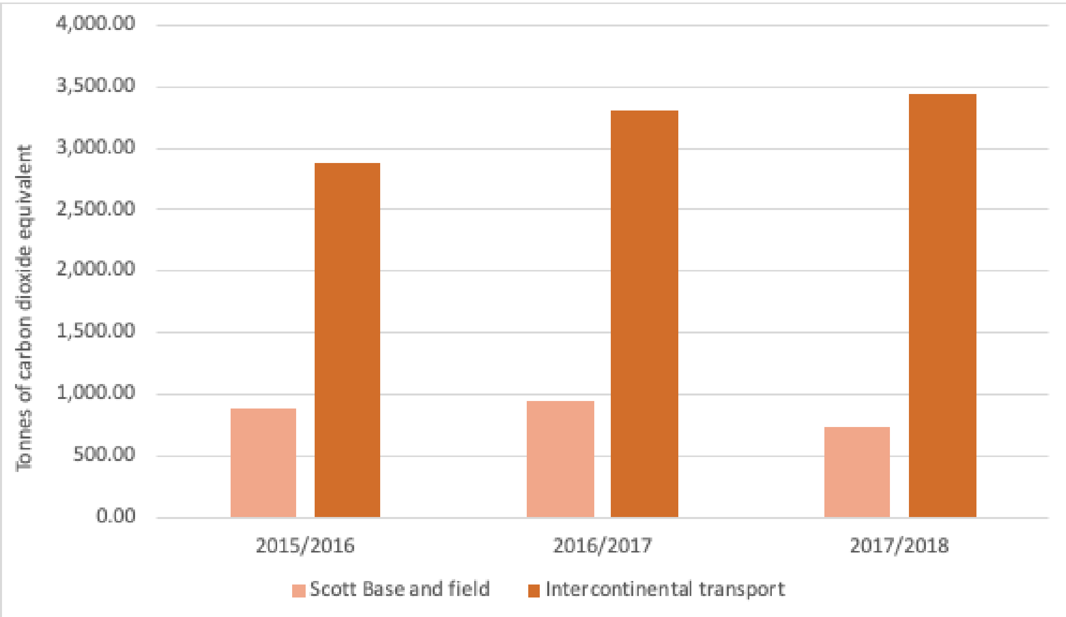


Figure 48: Carbon emissions from Antarctica New Zealand operations, 2015/16 to 2017/18, excluding one off projects. Source: CEMARS inventory

11.2. Noise and vibration

Actions	Receptors	Direct impacts
Power generation Transport Maintenance Field support RPAS operations	Fauna Wilderness and aesthetic values	Disturbance to wildlife Diminished wilderness value

Vibrations are movements. When vibrations move through the air and are received by an ear, they are called noise. Vibrations can also travel through substances or material, with or without creating noise. No recent, systematic measurements have been made of noise and other vibration produced by Antarctic New Zealand operations. The main sources of vibration are vehicles, aircraft and generators, but almost all activities create some noise, for instance simply walking.

According to manufacturers' specifications, generators issued by Antarctica New Zealand for field use range in noise level from 58db at 7m (Honda EU10 1 KVA generator) to 84dB at 7m (Yanmar 5.5KVA generator). Generators at Scott Base are within buildings and barely audible outside the specific plant rooms.

Vehicle noise probably ranges from 37db at 12m for a Toyota Landcruiser to 85dB for a Hagglunds vehicle at 18m distance (Aars et al, 2005). Hagglunds vehicles have been recorded to cause $10mm/s^2$ acceleration in the ground and $11mm/s^2$ in snow at a distance of 18m (*ibid*.).

An Australian study has modelled the audibility of anthropogenic noise sources including pedestrians, quad bikes, hagglunds, helicopters and twin otter aircraft to Weddell seals in Antarctica (Table 20 and Table 21). Studies have found other seals species adjust the amplitude of most used calls to compensate for noise (*ibid.*). Weddell seals exposed to continuous low-amplitude underwater noise (i.e. Hagglund operation over-snow) did not alter individual call types but did decrease their calling rate, suggesting either individuals left the area or did not attempt as much communication (*ibid.*). The study colonies were approximately 10km from stations. Seals in the Pram Point colony may be more habituated to anthropogenic noise than seals at more distant colonies, but this research indicates that noise from transport and recreation as part of Antarctica New Zealand operations could influence seal behaviour.

A study identified behavioural reactions in Adélie penguins whenRPAS was flown at the highest tested altitude of 50m and the reactions increased markedly when the RPAS was flown at low altitudes of 10–20m (Rummler, 2018). It is impossible to distinguish the effects of the noise from the visible presence of the RPAS in stimulating the response.

Table 20: Audibility of noise sources to Weddell seals underwater

Noise source	Distance clearly audible	Distance barely audible	Distance inaudible
Pedestrian	-	1m	>50m
Quad bike (15kmh)	1m	10m	100m
Hagglunds	1m	30m	300m
Single engine helicopter (take off, idle, cruising 200m ASL)	-	10m	>750m
Single engine helicopter (landing)	10m	100m	>750m
Twin otter on ground	10m	500m	>500m
Twin otter in air	500m alt	300m alt	>5000m

Table 21: Audibility of noise sources to Weddell seals at surface

Noise source	Distance clearly audible	Distance barely audible	Distance inaudible
Quad bike (15kmh)	-	50m	>250m
Hagglunds	-	100m	>400m
Single engine helicopter on ground	10m	100m (idle) 250m (landing) 750m (take off)	>750m >2500m ASL
Single engine helicopter in air	200m ASL	750m and 800m ASL	>750m and 2500m ASL
Twin otter on ground	100m	500m	-
Twin otter in air	3000m ASL	5000m ASL	-

Disturbance to penguins from human activity is well demonstrated, although studies do not distinguish between the effects of noise and those of visible presence. Stress responses are important for increasing alertness and reallocating energy reserves ready to react, e.g. to flee a predator. But ongoing stress can negatively affect an individuals' health and behaviour, and reduce parents' ability to care for young (Poppick, 2014) A study of human visitation to Adélie penguin colonies found that in smaller colonies subjected to repeated scientific observation, hatching success was 35% lower than the control colony and colonies subjected to recreational visits had 47% lower hatching success than the control. For chick survival these reductions were 72% and 80% respectively (Giesse, 1996). Giesse's work was a key influence in establishment of Antarctica New Zealand's Environmental Code of Conduct which stipulates a 10m distance from penguins when on foot.

These studies do not distinguish between the effects of noise and those of visible presence. With the exception of the Adélie penguin census, Antarctica New Zealand operations generally do not occur near penguin colonies or can easily avoid the type of disturbance identified in these studies.

Little information is available regarding the effects of vibration independent of noise. Noise, light, and vibration (including non-audible vibrations) from railways have been observed to reduce the abundance and richness of some insects and birds (Lucas et al, 2017). The noise level of a Hagglund is comparable to a train (85dB, *ibid.*) but obviously it does not frequently and repeatedly travel the same exact path.

The effects of anthropogenic noise on recreationists in New Zealand have been recognised for over 30 years, and is studied worldwide (Harbrow, 2011). Antarctica New Zealand personnel are in the unusual position of working, living and recreating in an extraordinary wilderness environment. Noise above 55dB is considered noise pollution for humans and levels above that can cause physical stress (Lucas et al, 2017). Many factors (loudness, frequency, proximity, environmental conditions, tolerance) determine whether sounds become unwanted noise that diminishes wilderness experience, and perception varies between individuals (Harbrow, 2011). In all likelihood, noise such as generators, helicopters and vehicles are both part of the Antarctic experience and, at times, an intrusion into it.

11.3. Light and heat

Actions	Receptors	Direct impacts
Maintenance Transport Field support Recreation	Wilderness and aesthetic values Fauna	Diminished wilderness value

Antarctica in general has very low levels of light pollution. 24-hour daylight during the summer months means lighting at Scott Base is not discernible in the environment during summer and lighting is not needed for outdoor activities. Lighting is important for operations during the winter, including externally mounted lights outside and headlamps used by personnel.

Wildlife during winter is limited to a few seals remaining on the sea ice. In other parts of the world, artificial night lighting in known to disrupt predator–prey relationships, for instance harbour seals were observed to congregate under artificial lights to eat juvenile salmon and turning the lights off reduced predation levels (Longcare and Rich, 2004). However, in the Scott Base setting, lights are not directed at the sea, which is shielded by sea ice and snow, and prey species are generally further offshore.

Changes to animal behaviour from artificial lighting can also have negative effects on biological rhythms (Raap et al, 2009). However, circadian patterns regulated by melatonin release have been shown to be absent in adult Weddell seals during 24-hour sunlight in summer (Barrell and Montgomery, 1989), and presumably are also absent in 24 darkness. A small amount of light reaching the sea ice from Scott Base or the occasional transit of vehicle headlights would therefore not be expected to trigger an unusual sleep/wake pattern. No information was found suggesting behaviour change in seals remaining at Pram Point through winter due to light emissions.

Viewing of the night sky (particularly the clarity of stars with minimal light pollution and the Aurora Australis, Figure 49) is a key part of the wilderness experience for personnel over wintering at Scott Base and a significant contribution to wellbeing. Light emission from Scott Base can diminish this somewhat and outdoor lighting may be turned off when not needed for operational safety for this reason.

Light-sensitive scientific experiments are located away from Scott Base, e.g. at Arrival Heights.

Some heat is inevitably lost to the environment from base buildings, particularly given their age. Because buildings are raised off the ground, heat is directly emitted into the air only, not soils. Other than raised temperature immediately around the building (particularly ceiling panel joins and doorframes), there are no known changes to the environment from heat loss.

Figure 49: Aurora viewed from Scott Base. © Antarctica New Zealand Pictorial Collection

11.4. Electromagnetic radiation

Actions	Receptors	Direct impacts
Power generation Maintenance Transport Field support Recreation	Wilderness value (including scientific measurement of 'pristine' conditions) Values of ASPA 122	Diminished wilderness value

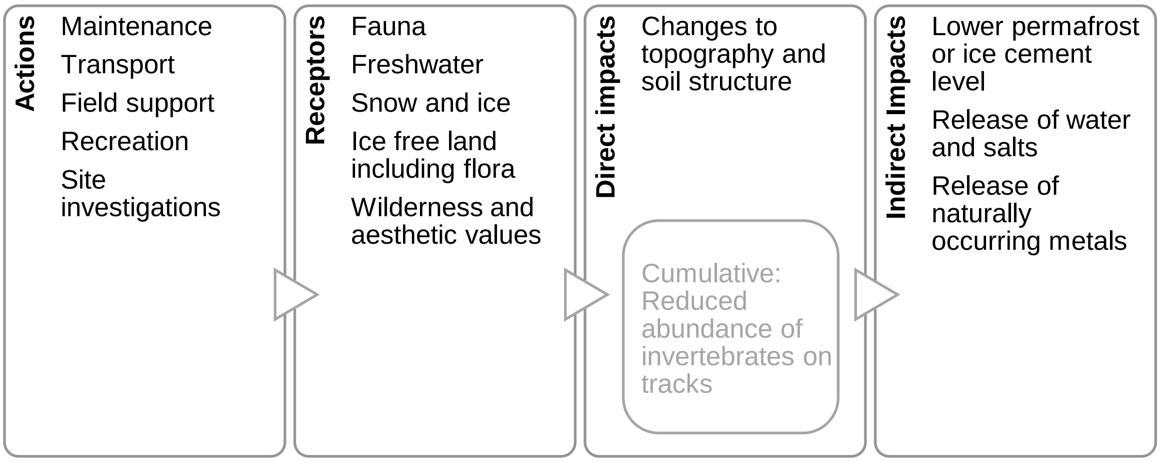
There are many sources of electromagnetic radiation associated with Antarctica New Zealand operations including power generation, cabling, radio equipment, vehicles, computer systems and other electronic equipment, and cordless phones. There are concerns that "electrosmog" could adversely affect the health of humans and other organisms, but reliable research is equivocal. A survey at Mario Zucchelli Station found a magnetic field extended up to 650 metres from the station with a peak strength of 2800 nanotesla (nT) up to 100 metres from the station on the ground (Armadillo et al, 2012). The authors note this may have implications for local organisms that are negatively affected by magnetic fields, but further research is needed.

Many scientific measurements are made in Antarctica because of the lack of anthropogenic interference. In general, 'transmitting' equipment is located at Scott Base and 'receiving equipment' is located at Arrival Heights to try to avoid interference. However, the proximity of major infrastructure such as the wind turbines, and the range of science activity at Arrival Heights means it is no longer as "electromagnetically quiet" as when it was originally designated as Site of Special Scientific Interest No. 2 (now Antarctic Specially Protected Area 122). For the most part, current management of this issue is focused on coordination of science rather than operational activity, but any future changes to infrastructure such as wind turbines or satellite receivers will need to be carefully assessed and planned to avoid disruption to experiments.

The 2021/22 proposed relocation of the geomagnetic huts to ASPA 122 has the potential to create electromagnetic disturbance.

Scientific equipment at Scott Base such as antenna which detect lightning activity and magnetic observations which have continued since 1956/57, would be adversely affected by vehicle movements or installation of metal objects nearby. For this reason, they are in an area of restricted access.

11.5. Mechanical Action



Earthworks such as meltwater channels, ground levelling, snow clearing and digging for installation or removal of equipment physically alter the topography and the structure of the soil. These direct impacts can cause further changes to the soil profile including lowering the permafrost, release of water and salts, and slumping and shrinkage of the ground surface (Campbell et al, 1994). Naturally occurring metals such as iron, aluminium, nickel, chromium and manganese are also thought to be released from clay in the soil during earthworks due to a combination of mechanical action and melting of permafrost, mobilizing the metal particles in alkaline solutions (Sheppard et al, 2000). Evidence of these kind of changes is common in the vicinity of Scott Base, much of which is highly impacted (Figure 50).

Vegetation surveying in the 2018/19 season in preparation for the Scott Base Redevelopment project identified some mosses inhabiting previously disturbed sites (old tractor paths), indicating their ability to recover with time.

Ice-free ground within ASPA 122 has the potential to be disturbed during the relocation of the geomagnetic huts.

The walking trails around Hut Point Peninsula have changed fine-scale topography in the past and soils on the trails are compacted compared to surrounding soils. These trails had 693 passes over two years for the least used trail and 5084 for the most used trail. However, higher usage of established tracks has little cumulative impact in terms of soil structure or chemistry (O'Neill et al, 2012. On highly trampled footpaths in the McMurdo Dry Valleys (up to 80 passes per year), abundance of the two most common nematode species was 52% and 76% lower than in untrampled areas (Ayres et al, 2008). Reduction was more pronounced the longer the path was in use (ten years compared to two). Antarctica New Zealand support personnel occasionally use paths in the Dry Valleys and in these instances will contribute to the cumulative impact of trampling on the soil biota.

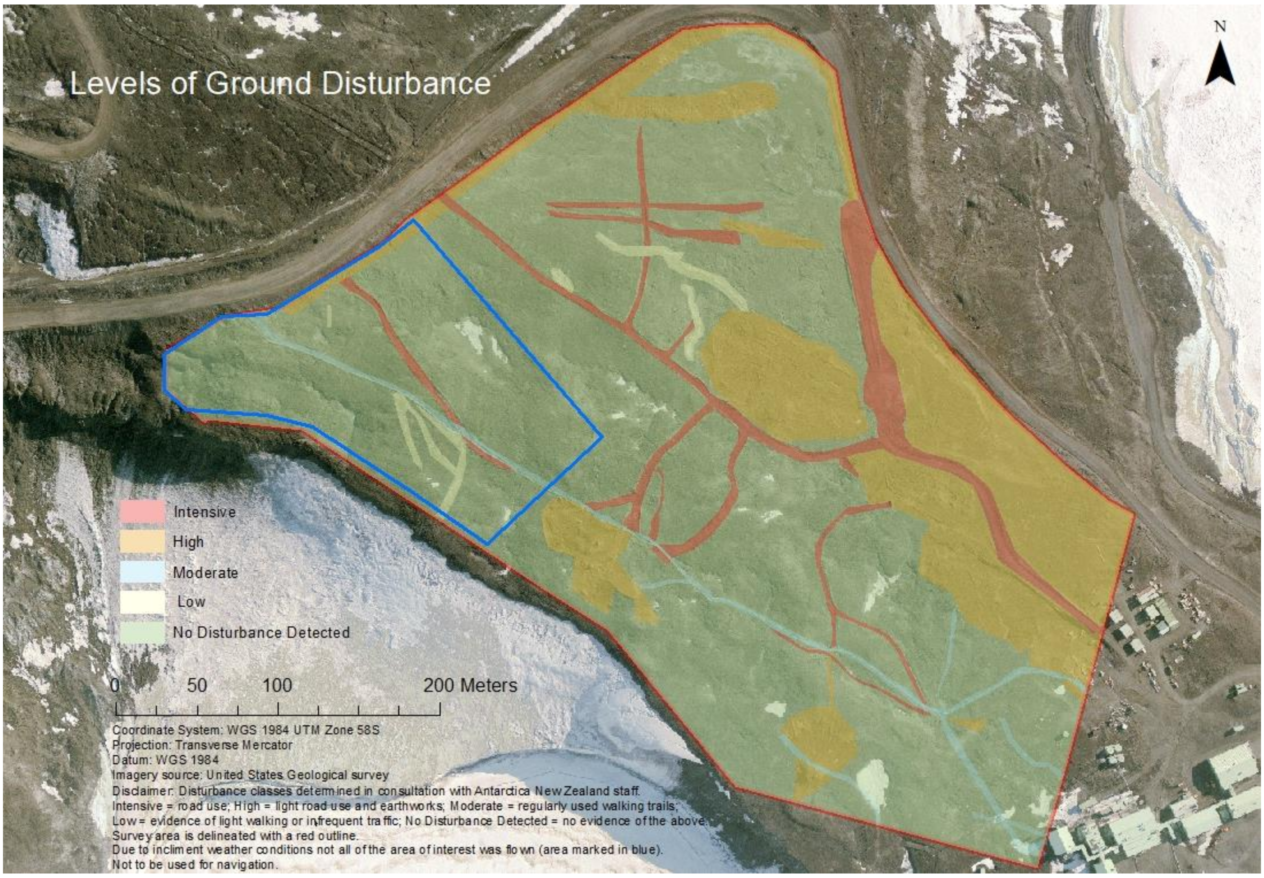


Figure 50: Ground disturbance levels at Scott Base 2018/19[11]

[11] Scott Base buildings shown actual colour (green). Intensive = heavily used roads, High = light road use and evidence of regular earthworks, Moderate = regularly used walking trails, Low = evidence of light walking or infrequent earthworks or traffic, No Disturbance Detected = no evidence of the above. Source: Barbara Bollard-Breen, Auckland University of Technology, for Antarctica New Zealand.

11.6. Spills

Actions
- Power generation
- Hazardous substances
- Waste management
- Maintenance
- Transport
- Field support
- Recreation
- Site investigations

Receptors
- Fauna
- Freshwater
- Snow and ice
- Marine
- Ice free land
- Flora
- Wilderness and aesthetic values

Direct impacts
- Contamination of soil, water, snow
- Runoff to marine environment
- Changes to soil microbial communities
- Diminished wilderness values

Given its huge dependence on fossil fuels, spills have been an undesirable side effect of operations since Scott Base was established. However, the quality of hazardous substances storage systems and attitudes and practices have improved dramatically and the quantity of substances spilled has continued to reduce over the twenty years detailed records have been kept (Figure 51). The vast majority of spills by volume are hydrocarbons, and 70% is AN8, which is stored and used in the greatest volumes (Figure 52). Preparedness and response to spills has also increased greatly. Over the last five years, 67% of substances spilled have been recovered (by volume).

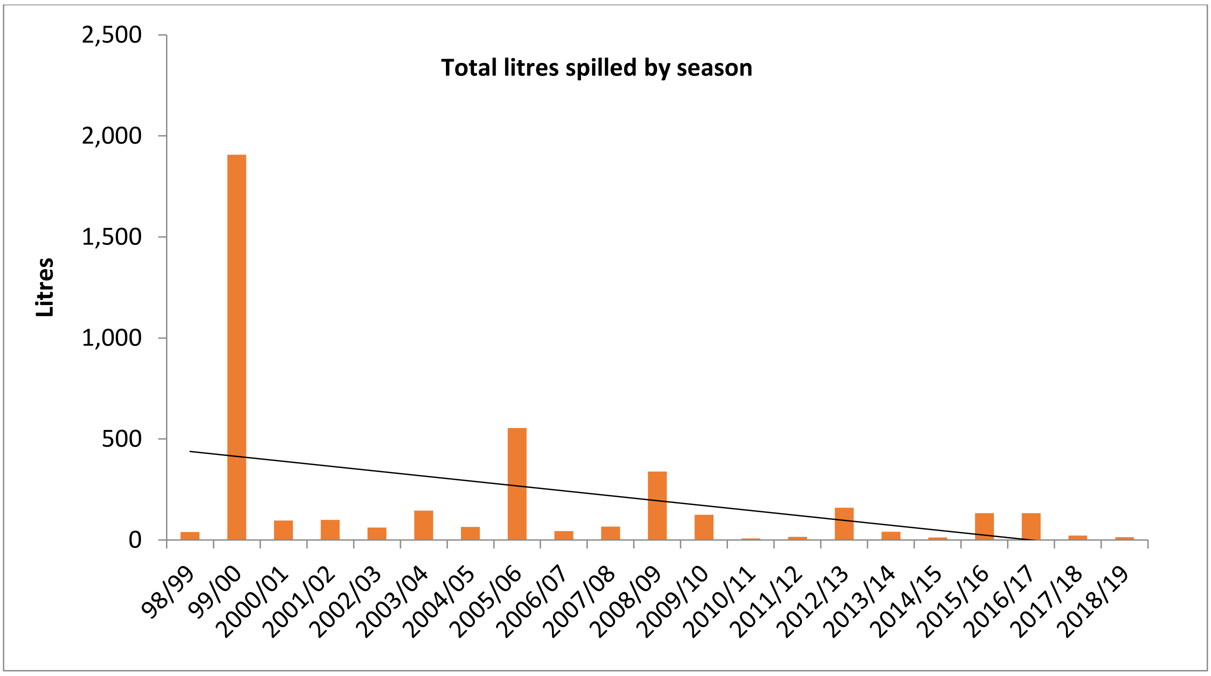


Figure 51: Twenty years of spills, Scott Base and Antarctica New Zealand field operations

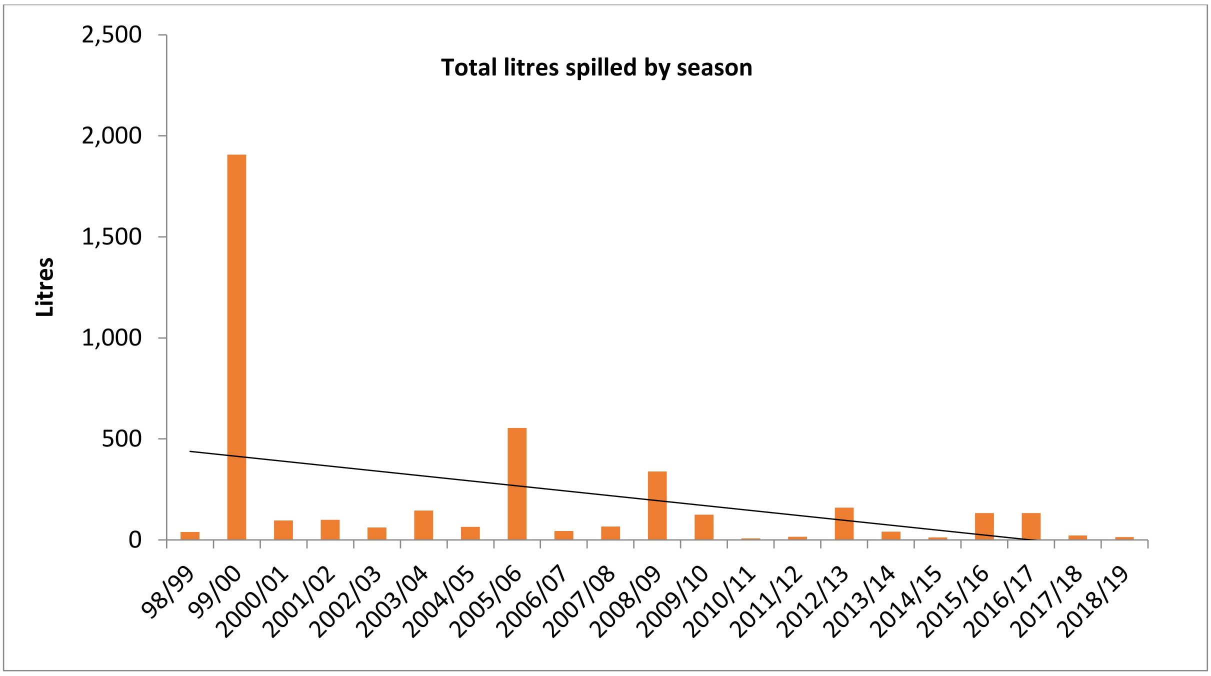


Figure 52: Twenty years of spills by type, Scott Base and Antarctica New Zealand field operations

Past studies have found measurable silver, arsenic, cadmium, copper, lead and zinc contamination in soils around Scott Base, particularly where materials have historically been dumped or stored, and in surface waters overlying the soil contamination (Sheppard et al, 1997; Sheppard et al, 2000). A 2012 study also found leachable levels of metals in Scott Base soils (Williams, 2012). However, analysis of Scott Base soils for heavy metals in 2017/18 found very low concentrations of heavy metals in soils across the Base, including those containing historic demolition debris (PDP, 2018).

The most significant past spill events were associated with bulk fuel storage facilities and underground fuel lines. The analysis detected hydrocarbons in the majority of soil samples from area of known major past spills and leaks, ranging from 59 mg/kg to 5,935 mg/kg Total Petroleum Hydrocarbon (PDP, 2018). The highest results were lighter kerosene type hydrocarbons (i.e. the jet fuel used as diesel for generators and vehicles) associated with a past 2,500-gallon fuel tank, while low levels of heavier oils were found around old workshop areas. Even the highest levels were below New Zealand soil acceptance criteria for protection of nearby water bodies (Ministry for the Environment, 2011), which was identified as relevant due to potential for ecological impacts of runoff to sea. (See below for more information on discharge to sea).

As the major historic spills have been in highly impacted areas, it is difficult to evaluate the impact of spills (as opposed to physical disturbance) on flora. However, the numbers and diversity of culturable microbes from Antarctic soil have been shown to differ between ‘pristine’ and hydrocarbon contaminated sites in the Ross Sea region. Elevated numbers of culturable hydrocarbon degraders, bacteria and fungi were detected in soils from oil-contaminated sites and culturable yeasts were not detected in soil from control sites, yet reached >105 organisms g^{-1} dry weight in contaminated soils. The fungi *Chrysosporium* dominated control soils, while *Phialophora* was more abundant in oil-contaminated soils (Aislabie, 2001).

11.7. Discharge to Sea

Actions	Receptors	Direct impacts
Waste management Power generation Transport Maintenance	Marine environment Wilderness and aesthetic values	Plume of changed seawater characteristics Changes to bacterial and eukaryotic communities

The only planned discharge to sea is treated wastewater from Scott Base. Since the wastewater treatment plant was commissioned in 2002, a plume has been detectable approximately 50m long-shore, and 30m offshore (Williams, 2012), a considerable reduction from prior to 2002 when macerated and otherwise untreated waste was discharged. Faecal coliforms are no longer detectable within the plume, while dissolved oxygen and total organic carbon concentrations in the plume have increased, and conductivity has decreased (*ibid.*). In recent years the few, occasional positive faecal coliform bacteria results detected in routine monitoring of seawater intake have been attributed to seal activity near the intake.

Pharmaceutical and personal care products (PPCPs) are a common source of micropollutants and microplastics and have harmful effects on marine life. Research has found sewage effluents from Scott Base and McMurdo Station contained bisphenol-A, ethinylestradiol, estrone, methyl triclosan, octylphenol, triclosan, and three UV-filters (Emnet, 2012). Coastal seawaters and sea ice contained bisphenol-A, octylphenol, triclosan, three paraben preservatives, and four UV-filters Antarctic clams (Laternula elliptica), sea urchins (Sterichinus neumayeri), and fish (Trematomus bernachii) were shown to bioaccumulate PPCPs (mParaben, pParaben, BP-3, E2, EE2, OP, Cstanol) (Emnet, 2018). PPCPs were detected in seawater and biota at distances up to 25 km from the stations. UV filters in sunscreen are known to exhibit estrogenic activity, OP can cause endocrine disrupting effects in marine species, and triclosan is toxic to algae, micro-organisms, and fish larvae, however the maximum aqueous concentrations of detected PPCPs are orders of magnitude lower than those reported to induce biological effects (*ibid.*).

It has been estimated that up to 500kg of microplastics from personal care products and 25.5 billion microplastic fibres from laundry are released south of the polar convergence from research, tourism and legal fisheries (Waller et al, 2017). Research at Mario Zucchelli Station found 1.18 plastic particles per m^3 of seawater, predominantly polyethylene and polypropylene fibres and fragments (Cincinelli, 2017), as well as fibres in sediments (Munari, 2017 cited in Waller et al, 2018). The effects of micropollution from PPCPs and laundry fibres have similar effects on marine life in Antarctica to elsewhere in the world, but this has not yet been researched.

Pollutants emitted to air (Section 11.1) which are deposited onto ice, snow and soil; the remains of fuel and other spills, and contamination from past waste disposal practices may all be mobilised and transported by meltwater and reach the sea. Wastes were historically stockpiled near the shoreline and burned or pushed onto sea ice. For many years untreated wastewater was discharged onto the shore rather than direct to sea, resulting in elevated levels of copper, zinc, lead and nickel in the effluent, seawater and sediments near the outfall (Anderson and Chague-Goff, 1996). More recent research has found that the greatest concentrations of readily leachable metals at Scott Base are along the shoreline (Williams, 2012), with clear potential to be transported into the marine environment.

Soil disturbance and changes to meltwater flows cause by earthworks (Section 10.7) may exacerbate transport of contaminants.

Copper and zinc in seawater near Scott Base are below the 95% species protection level in the Australian and New Zealand Environment Conservation Council (ANZECC) water quality guidelines for marine water, but the limit of detection is above the 99% species protection level (Williams, 2012). ANZECC trigger values could not be determined for iron, manganese or nickel.

Contamination of the marine environment at Scott Base does not appear to have negatively affected the macro benthic community (Battershill, 1992, cited in Williams, 2012), although it is likely to have altered the composition of bacterial and eukaryotic communities, including those associated with coral (Webster and Negri, 2006; Webster et al, 2006; Webster and Bourne, 2007).

11.8. Species transfer

Actions	Receptors	Direct impacts
Waste management Transport Field support	Marine environment Wilderness and aesthetic values	Potential for: Establishment of species not native to region Displacement of native species by introduced species Introduction of diseases to wildlife

The presence of humans in Antarctica inevitably brings other species, such as the microbial communities that live in and on our bodies. Efforts are made to exclude larger hitchhikers such as seeds, soil or insects. Changes to the natural Antarctic environment can only occur where an introduced species is able to survive and establish in the environment. While invertebrates and plants are known to have established in the Antarctic Peninsula region, no examples of this occurring in the Ross Sea region have been identified.

Records are kept of any introduced species found at Scott Base or elsewhere in Antarctica New Zealand operations (Figure 53). On average, 11 introductions are reported each season. Spiders are frequently found in boxes and bags, while bugs and slugs tend to be found in fresh food. Temporary breeding populations of flies and moths have occurred in food stores at Scott Base in the past but have been eliminated.

Many of these species may never be able to survive in the external environment, however 35% of the invertebrates intercepted in the 10 years to 2017/18 belonged to 16 species known to be invasive elsewhere in the world (Newman et al, 2018). Some Antarctic sites also have habitats buffered from extreme cold, such as beneath snow, in ponds that do not freeze, and marine environments. Terrestrial habitats could have suitable nutrients and other biota (moss, lichen, algae, fungi, invertebrates and microorganisms) to sustain introduced organisms, marine ones even more so. It is therefore very possible that sufficiently cold-tolerant introduced organisms could find habitats and nutrition to survive. Climate change is likely to make Antarctic ecosystems more vulnerable to introduced species.

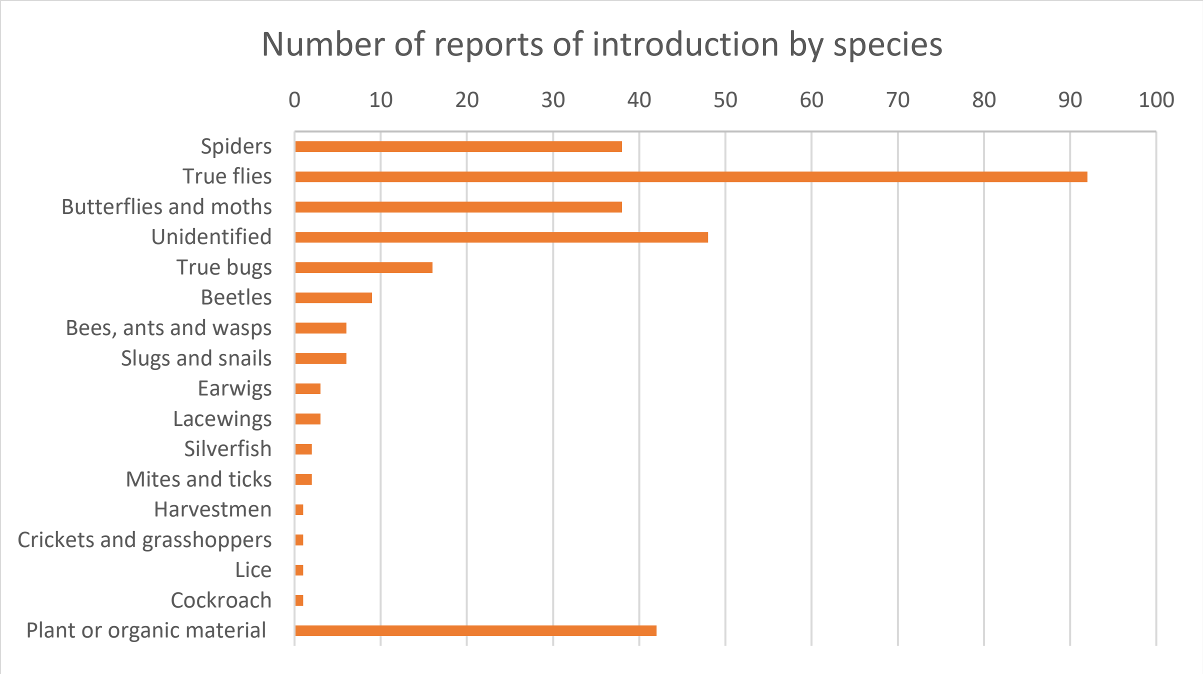


Figure 53: Introduced species intercepted at Scott Base, 2007/08 – 2017/18

In addition to species being transferred from outside Antarctica to Scott Base or field sites, there is also potential for fieldwork to transfer Antarctic species between sites or between biogeographic regions within Antarctica. Antarctic species are already adapted for the cold climate so may readily establish if moved between sites.

A further concern is the possibility of wildlife diseases being brought to the Antarctic or from one site to another. Information on the presence of pathogens and diseases in Antarctic wildlife is very limited and introduction of new diseases could be due to natural, not only human-influenced, transmission pathways.

Further details on the risks of species and disease transfer and its management is available in Antarctica New Zealand's Biosecurity Prevention and Response Plan (2018).

11.9. Presence

Actions	Receptors	Direct impacts
All operations	Wilderness value Fauna	Diminsihed wilderness value Disruption of scientific research and monitoring Disturbance to wildlife

Because Antarctica is such a unique wilderness, all human presence impacts its intrinsic value. Conspicuous human activity can also diminish the wilderness experience of personnel, and other visitors to the region. Much of the scientific research conducted in Antarctica is undertaken there because of the lack of background anthropogenic interference in observations. Noise, light, heat, pollution and electromagnetic radiation as described in the preceding sections can all interfere with scientific measurements.

Presence is also closely associated with the effects of noise on wildlife described in Section 10.4.

Snow petrel fatalities have occurred due to striking the wind turbines which power Scott Base and McMurdo, located at Crater Hill. Two dead snow petrels were identified from this cause in 2012/13, and one more is suspected from 2018/19.

12. Significance of impacts

Table 22 shows the impacts identified in Section 11 with a judgement of their extent, intensity, duration and probability, taking into account the mitigations outlined in Section 10. These terms and an associated numerical score are described in Table 23.

Only impacts within Antarctica New Zealand's control have been evaluated in this way. The major cumulative effect of worldwide fossil fuel use on climate change, described in Section 11.1, is not assessed here.

Table 22: Definition of impact extent, intensity, duration and probability

Score: Level:	Low 1	Medium 2	High 3	Very high 4
Extent of impact	Confined to site of activity / only a few individual organisms affected	Parts of an area affected / several organisms affected	Whole area affected / community affected (e.g. reduced breeding success)	Large scale / population level impact
Duration of impact	Short term, e.g. one year or growing season	Medium term, e.g. multiple years or growing seasons	Long term, e.g. decades	Permanent
Intensity of impact	Minimal effect, e.g. small changes with no known consequences	Moderate changes to natural processes	Major changes to natural processes	Severe negative effects on natural processes
Probability of impact occurring	(NOT AVAILABLE)	Possible but unlikely	Likely	Certain

The extent, intensity, duration and probability scores are multiplied together to give a combined score which is used to determine the level of significance of the impact (Table 23 and Table 24), as follows:

More than minor or transitory: Combined scores of over 100 have at least one variable (extent, duration, intensity, or probability) very high, and none below medium. Therefore, the impact may or will be more than minor (in extent or intensity) or more than transitory (duration).

Minor or transitory: Combined scores between 40 and 100 have either no 'very high' variables, or one or more 'medium'. Therefore, the impact may or will be at most minor (in extent or intensity) or transitory (duration).

Less than minor or transitory: To achieve a combined score of less than 40, a maximum of two variables may be 'very high' and at least one must be 'low'. This means that either the extent or intensity render the impact less than minor, and/or the duration can be considered less than transitory. Because only possible impacts have been considered, 'low' probability has not been used and therefore cannot be a reason for a "less than minor and transitory" determination.

Table 23: Scoring of impact significance

Combined score (EXTENT X DURATION X INTENSITY X PROBABILITY)	Significance of impact
< 40	Less than minor or transitory
40 - 100	Minor or transitory
> 100	More than minor or transitory

Table 24: Significance of impacts

Environmental receptor	Potential impact	Spatial extent	Duration	Intensity	Probability	Combined score	Significance
Atmosphere	Decreased local air quality	1	1	2	4	8	Less than minor or transitory
	Changes to snow and ice melting due to dust deposition	2	4	3	4	96	Minor or transitory
Flora and fauna	Disturbance to wildlife from noise, vibration, presence	1	1	2	4	8	Less than minor or transitory
	Bird strike in wind turbines	1	4	4	3	48	Minor or transitory
	Reduction of invertebrates by tracking	2	2	3	4	50	Minor or transitory
	Change of microbial communities due to spills	2	2	3	4	48	Minor or transitory
	Introduced species establish	3	4	3	2	72	Minor or transitory
	Mosses killed by dust	2	3	4	4	96	Minor or transitory
	Mosses killed by physical disturbance and soil compaction	2	3	4	4	96	Minor or transitory
Freshwater, snow and ice	Contamination from spills and deposition of emissions to air	2	3	2	3	36	Less than minor or transitory
	Increased melting due to lowered albedo from deposited particulates	1	4	4	4	64	Minor or transitory

Environmental receptor	Potential impact	Spatial extent	Duration	Intensity	Probability	Combined score	Significance
Marine	Lower seawater quality "plume"	2	1	1	4	8	Less than minor or transitory
	Micropollutants from PPCPs and laundry	3	3	2	4	72	Minor or transitory
	Runoff to sea of contamination by spills, deposition of airborne contaminants	2	2	2	2	16	Less than minor or transitory
Soils	Release of water and salts	2	4	2	4	64	Minor or transitory
	Contamination from spills, atmospheric deposition	2	3	3	4	72	Minor or transitory
	Lower permafrost or ice cement level	2	4	3	4	96	Minor or transitory
	Release of naturally occurring metals	2	4	3	4	96	Minor or transitory
	Altered topography, compaction	2	4	4	4	64	Minor or transitory
Wilderness	all	2	2	3	4	48	Minor or transitory

13. Monitoring Programmes

Antarctica New Zealand collects data about its activities and the aspects in which these interact with the environment. This information is used to check compliance with the Antarctic (Environmental Protection) Act 1994, to check the effectiveness of policies and procedures, to track progress against goals, and to contribute to understanding of the state of the Ross Sea region.

Incidents, near misses and hazards affecting the environment are recorded through the Health, Safety and Environmental reporting system. Details of occurrences such as spills, and non-native introductions are collated and reported to the Ministry of Foreign Affairs annually.

Faecal coliform bacteria, chemical oxygen demand, dissolved oxygen and residual ozone in treated effluent tested monthly (reviewed annually by Professor Jenny Webster-Brown, Waterways Centre for Freshwater Management, University of Canterbury).

Energy use data is continuously collected and is compiled annually as part of the Certified Emissions Measurement and Reduction Scheme (CEMARS), Energy-Mark programme, and greenhouse gas emissions calculated.

The monitoring of impacts associated with the Scott Base Redevelopment, including the relocation of Long-Term Science experiments is covered under the SBR monitoring programme, which is part of the SBR Comprehensive Environmental Evaluation.

14. Conclusions

The proposed activities include power generation, storage and use of hazardous substances, waste management including discharge of treated wastewater to the sea, maintenance activities, surface and air transport, and field support. These activities take place primarily to support scientific research, but also for the purposes of education and staff recreation and wellbeing. Environmental management, including review of Antarctic Specially Protected Areas and Antarctic Specially Managed Areas and environmental monitoring is also undertaken. Permits are sought for entry to Antarctic Specially Protected Areas, and for sampling of soil, vegetation and invertebrates for monitoring purposes and the import of non-native species (e.g. bacteria to ensure high quality wastewater treatment can be achieved).

The existing environment is a pristine wilderness at the regional scale, but highly impacted at the local scale, particularly at Scott Base. Ongoing operation of Scott Base and field support interacts with the environment in a number of ways, and causes direct, indirect, and cumulative impacts.

The direct and indirect impacts have been evaluated in terms of their extent, intensity, duration and probability. The impacts of greatest significance are:

- Changes to snow and ice melting due to particulate deposition (from emissions to air from generators and vehicle engines, and dust from vehicle movements); and
- Lowered permafrost or ice cement level, releasing naturally occurring metals contaminants (from physical disturbances such as earthworks).

While these have occurred in the past and will continue to occur, they are confined to the immediate area of Scott Base and occur on only a minimal scale at other sites.

The next most significant impacts are:

- Contamination of soils from spills and deposition from air emissions, which also leads to changes in soil microbial communities and runoff to the marine environment;
- The potential for introduced or transferred species to establish in the environment; and
- Marine micropollutants from pharmaceuticals, personal care products and laundry.

Under current operations spills are prevented well, with few, small incidents occurring and high rates of material recovery. Procedures and materials are in place to respond should more significant spills occur. Emissions to air (and consequent deposition to soil) are an unavoidable result of fossil fuel burning, which is minimised but necessary at present. Rolling replacement of vehicles and generators ensures that these become cleaner burning over time as technology improves, and alternatives such as electric vehicles are being actively investigated.

Little is known about the ability of many species from outside the Antarctic to survive if introduced, while native species transferred between sites or regions may be difficult to detect due to paucity of information on the existing biota in many places. Mitigation of the risk of introduced species establishing in the environment therefore very much relies on measures such as equipment cleaning to prevent transfer of species.

Marine micropollutants including microplastics are an emerging issue in the Antarctic. We now know this pollution is occurring but very little about its effects on local marine species. Cleaning products are carefully selected and personnel are advised on selection of personal care items in order to avoid harmful chemicals. Mechanisms for minimising discharge of microplastic fibres with laundry wastewater are being investigated.

Considering the nature, extent, intensity, duration and probability of these impacts, they are considered to be no more than minor or transitory.

It is also acknowledged that Antarctica New Zealand’s operational activities contribute to the major and long-term impacts of global climate change. At present use of fossil fuels in Antarctic transport and operations is unavoidable, but energy efficiency is actively pursued and the redevelopment of Scott Base in future is expected to reduce the facility's current fossil fuel dependency.

15. References

Aars, J., Lunn, N.J., Derocher, A.E. (eds). 2005. *Polar Bears: Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 20-24 June 2005, Seattle, Washington, United States*.

Aislabie, J., Fraser, R., Duncan, S. et al. 2001. Effects of oil spills on microbial heterotrophs in Antarctic soils. *Polar Biology*. 24: 308. https://doi.org/10.1007/s003000000210

Armadillo, E., Bozzo, E., Gambetta, M. & Rizzello, D. 2012. Impact of human activities on the geomagnetic field of Antarctica: A high resolution aeromagnetic survey over Mario Zucchelli Station. *Environment International*. 47: 1-7. Doi:10.1016/j.envint.2012.0 5.005

Ayres, E., Nkem, J.N., Wall, D.H., Adams, B.J., Barrett, J.E., Broos J., Virginia, R.A. 2008. Effects of human trampling on populations of soil fauna in the McMurdo Dry Valleys, Antarctica. *Conservation Biology*. 22(6): 1544–1551.

Barber-Meyer, S.M., Kooyman, G.L. & Ponganis, P.J. 2007. Estimating the relative abundance of Emperor Penguins at inaccessible colonies using satellite imagery. Polar Biology 30: 1565-1570.

Barrell, G. K., Montgomery, G. W. 1989. Absence of circadian patterns of secretion of melatonin or cortisol in Weddell seals under continuous natural daylight. *Journal of Endocrinology*. 122, 445-449. doi:10.1677/joe.0.1220445

Beet, C., Lee, C. 2019*. Scott Base Rebuild CEE Biological Assessment Report*. Prepared for Antarctica New Zealand.

Callery, S. (ed). 2019. Facts: The Effects of Climate Change. *Global Climate Change: Vital Signs of the Planet.* Earth Science Communications Team, NASA Jet Propulsion Laboratory, California Institute of Technology. http://www.climate.nasa.gov. Site last updated: July 1, 2019

Campbell, I.B., Claridge, G.G.C. and Balks, M.R. 1994. The effect of human activities on moisture content of soils and underlying permafrost from the McMurdo Sound region, Antarctica. *Antarctic Science*. 6: 307-314.

Cincinelli, A., Scopetani, C., Chelazzi, D., Lombardini, E., Martellini, T., Katsoyiannis, A., Fossi, M.C., Corsolini, S. 2017. Microplastic in the surface waters of the Ross Sea (Antarctica): Occurrence, distribution and characterization by FTIR. *Chemosphere*. Volume 175. Pages 391-400. https://doi.org/10.1016/j.chemosphere.2017.02.024.

Eisert, R., Oftedal, O. T. & Barrell, G. K., 2013. Milk composition in the Weddell seal Leptonychotes weddellii: Evidence for a functional role of milk carbohydrates in pinnipeds. *Physiological and Biochemical Zoology,* Volume 86, pp. 159-175.

Emnet, P. 2018. Micropollutants in Antarctic waters. *Antarctic Environments Portal*. https://doi.org/10.18124/D4V33X

Emnet, P., Gaw S., Northcott, G., Storey, B., Graham, L. 2015. Personal care products and steroid hormones in the Antarctic coastal environment associated with two Antarctic research stations, McMurdo Station and Scott Base. *Environmental Research*. Volume 136. Pages 331-342. https://doi.org/10.1016/j.envres.2014.10.019

Fisher J. 2001. Air. In Waterhouse E.J. (ed) *Ross Sea Region 2001: A State of the Environment Report for the Ross Sea Region of Antarctic*, pp 6.14-6.25*.* Antarctica New Zealand, Christchurch.

Fretwell, P.T., LaRue, M.A., Morin P., Kooyman, G.L., Wienecke, B., Ratcliffe, N., Fox, A.J., Fleming, A.H., Porter, C. & Trathan, P.N. 2012. An Emperor Penguin population estimate: The first global, synoptic survey of a species from space. PLoS ONE 7(4): e33751. doi:10.1371/journal.pone.0033751

Giese, M. 1996. Effects of human activity on Adélie penguin Pygoscelis adeliae breeding success. *Biological Conservation*. Volume 75, Issue 2, pp157-164.

Harbrow, M.A., Cessford, G.R., Kazmierow, B.J. 2011. The impact of noise on recreationists and wildlife in New Zealand's natural areas: A literature review. Science for conservation monograph series no. 314. Department of Convservation.

Klein, A.G., Kennicutt, M.C., Wolff, G.A., Sweet, S.T., Gielstra, D.A. & Bloxom, T. 2004. Disruption of Sand-Wedge Polygons at McMurdo Station Antarctica: An Indication of Physical Disturbance. 61st Eastern Snow Conference, Portland, Maine, USA.

Liu J., Dedrick J., Russell L.M., Senum G.I., Uin J., Kuang C., Springston S.R., Leaitch W.R., Aiken A.C., Lubin D. 2018. High summertime aerosol organic functional group concentrations from marine and seabird sources at Ross Island, Antarctica, during AWARE. Atmospheric Chemistry and Physics. 18, 8571-8587.

Longcore, T., Rich, C. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment*. 2004; 2(4): 191–198

Lucas, P., Carvalho, R., Grilo, C. 2017. Railway Disturbances on Wildlife: Types, Effects, and Mitigation Measures. *Railway Ecology* pp.81-99. 10.1007/978-3-319-57496-7_6.

Newman, J., Poirot C., Roper-Gee, R., Chown, S., Leihy R. 2018. A decade of invertebrate colonization pressure on Scott Base in the Ross Sea region. Biological Invasions 20(9):1-11. DOI: 10.1007/s10530-018-1722-3

PDP. 2018. *Land Contamination Assessment – Scott Base, Antarctica for Antarctica New Zealand Limited*. Pattle Delamore Partners Ltd, Christchurch, New Zealand.

van Polanen Petel, T.D., Terhune, J.M., Hindell M.A., Giese M.A. 2006. An assessment of the audibility of sound from human transport by breeding Weddell seals (Leptonychotes weddellii). *Wildlife Research* 33(4) 275-291. https://doi.org/10.1071/WR05001

O'Neill, T., Balks, M., López-Martínez, J. 2014. Ross Island recreational walking tracks: Relationships between soil physiochemical properties and track usage. *Polar Record*. 51. 10.1017/S0032247414000400.

Poppick, L. 2014. Stress Makes Antarctic Penguins Less-Attentive Parents. *Live Science.* https://www.livescience.com/43277-penguins-poorer-parents-under-stress.html

Raap,T., Pinxten, R., Eens, M. 2015. Light pollution disrupts sleep in free-living animals. *Science Reports.* 5: 13557. Published online Sep 4. doi: 10.1038/srep13557

Rümmler, M.C., Mustafa, O., Maercker, J., Peter, H.U., Esefeld, J. 2018. Sensitivity of Adélie and Gentoo penguins to various flight activities of a micro UAV. *Polar Biology.* Volume 41, Issue 12, pp 2481–2493.

Stefano, J.E. 1992. Application of Ground-Penetrating Radar at McMurdo Station, Antarctica. Presented at the Hazardous Materials Control Research Institute federal environment restoration conference, Vienna, USA, 15-17 April 1992.

Skotnicki, M.L., Ninham, J.A. & Selkirk P.M. 1999. Genetic diversity and dispersal of the moss *Sarconeurum glaciale* on Ross Island, East Antarctica. *Molecular Ecology* **8**: 753-62.

Topal, M.H., Wang, J., Levendis Y.A., Carlson, J.B., Jordan, J. 2004. PAH and other emissions from burning of JP-8 and diesel fuels in diffusion flames. *Fuel*. Volume 83, Issues 17–18, December 2004, pp 2357-2368.

Waller, C.L., Griffiths, H.J., Waluda, C.M., Thorpe, S.E., Loraiza, I., Moreno, B.C., Parcherres, C.O., Hughes, K.A. 2017. Microplastics in the Antarctic marine system: An emerging area of research. *Science of the Total Environment.* Volume 598. Pages 220-227.

Waller, C.L., Griffiths, H.J., Waluda, C.M., Thorpe, S.E., Loraiza, I., Moreno, B.C., Parcherres, C.O., Ryan, P., Suaria, G., Isobe, A., Hughes, K.A. 2018. Microplastics in the Southern Ocean. *Antarctic Environments*. https://doi.org/10.18124/D4JK8V

Webster-Brown, J. 2019. WCFM Technical Report 2019-001: Scott Base Environmental Inspection 2018. Prepared for Roger Kippenberger, Antarctica New Zealand. Reviewed by Dr Kevin Brown, GEOKEM. Waterways Centre for Freshwater Management, Christchurch, New Zealand.

Williams, T.M. 2012. *Monitoring the Impact of Scott Base in Antarctica: A Recent Evaluation of Wastewater, Water and Soil Quality at Pram Point, Ross Island*. A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Science in Environmental Science at the University of Canterbury.

16. Glossary

ASMA	Antarctic Specially Managed Area, designated under Annex V of the Protocol on Environmental Protection to the Antarctica Treaty
ASPA	Antarctic Specially Protected Area, designated under Annex V of the Protocol on Environmental Protection to the Antarctica Treaty
Bednight	A measure of occupancy – each person overnighting at a location counts as one bednight
dB	Decibel, the unit used to measure the intensity of a sound. It is a logarithmic scale where 0 is the smallest audible sound (almost silence), a sound 10 times more powerful is 10 dB. 100 times more powerful than near total silence is 20 dB, 1,000 times more powerful than near total silence is 30 dB and so on.
EIA	Environmental Impact Assessment
IEE	Initial Environmental Evaluation
IGY	International Geophysical Year
JP8	Aviation fuel with cold temperature additives, used as diesel in generators and vehicles
JSART	Joint Search and Rescue Team
Mogas	Cold temperature petrol blend used in vehicles and generators
PEE	Preliminary Environmental Evaluation
PIR	Polyisocyanurate – foam 'sandwich' panels used for high insulation construction
SBR	Scott Base Redevelopment
USAP	United Stated Antarctic Programme
Wannigan	A small hut on skis which can be relocated to field sites

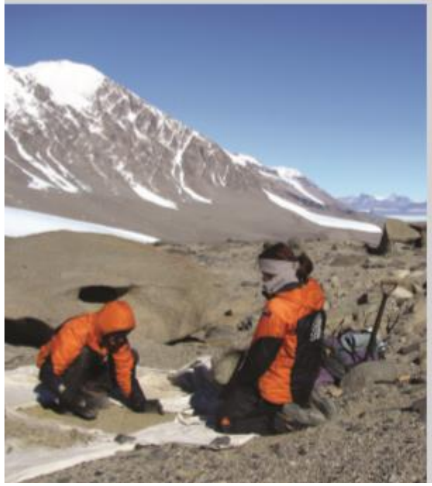
17. Appendices

Appendix 1: Environmental Code of Conduct

Field Activities

Every effort should be made to minimise the impact of scientific investigations and field activities.

- Camp away from lakeshores, streambeds, vegetated areas and wildlife to avoid contamination and/or disturbance.
- Where possible, place tents and equipment on snow or previously used campsites.
- Secure all waste and equipment to prevent it blowing away and to prevent foraging by wildlife.
- Where possible, use solar power to minimise fuel use.
- Minimise water use to reduce the volume of grey water returned to Scott Base. Use paper towels for wiping plates in the field instead of washing dishes.
- Where possible, use established tracks. Otherwise, take the most direct route that avoids fragile terrain and plant and animal communities.
- Never paint or deface rocks or ice-free surfaces.
- Leave no sign of your visit. Remove everything you take into the field, and make every effort to return sites to their natural state.
- Keep accurate records of your campsite including location, sites of tents and equipment (such as generators), amount of waste generated, and the location of any equipment left in the field. Include this information in your end of season report.
- Record all incidents, hazards or near-misses, and report them during your next scheduled radio contact with Scott Base.



Take Only Photographs

Removal of any natural material, unless it is part of an approved Environmental Impact Assessment, may be considered an offence under the Antarctica (Environmental Protection) Act (1994).

- Do not remove rocks, soil, minerals, fossils, volcanic bombs or ventifacts unless you have specific approval to do so.
- Do not remove feathers, bones, vegetation or other natural materials unless you have approval to do so.
- Do not build cairns, and minimise the use of markers or other objects to mark sites.
- Do not wash, swim or dive in lakes or streams unless authorised to do so; these activities contaminate the water body and physically disturb the water column, delicate microbial communities, and sediments.
- Report items discovered in the field (e.g. old food caches, old equipment, markers, etc.). Take photographs, record the GPS position and notify Scott Base. A decision to either remove the items or leave *in situ* will be made once an evaluation has been conducted.

Antarctica is one of the least disturbed places on Earth. To visit is a privilege, and the responsibility lies with you to protect the intrinsic and scientific values of its environment. This Environmental Code of Conduct is intended as a guide, but cannot be expected to cover every situation. You should always strive to minimise your impact.

CHECKLIST

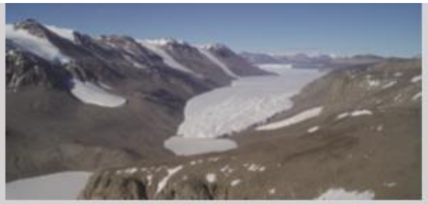
MAXIMISE your Antarctic experience with MINIMUM environmental impact

- ☐ **MINIMISE IMPACTS:** Understand what activities you have approval for, and minimise their impacts.
- ☐ **RESPECT SPECIAL AREAS:** Know where designated areas are and respect the access requirements.
- ☐ **PROTECT WILDLIFE AND PLANTS:** Leave foreign species at home, and give wildlife space.
- ☐ **CONSERVE RESOURCES:** Do your best to minimise water and energy use.
- ☐ **PREVENT SPILLS:** Take care when handling and storing fuel and hazardous substances.
- ☐ **MANAGE WASTE:** Reduce, recycle, and be prepared when away from facilities.
- ☐ **CAMP WITH CARE:** Reuse past sites, secure gear, and leave sites as close as possible to their natural state.
- ☐ **TAKE ONLY PHOTOS:** Enjoy the fantastic landscapes and environments of Antarctica and remember that natural materials (rocks, fossils, bones, feathers etc.) must stay where they are.

Antarctica New Zealand

Environmental Code of Conduct

MAXIMISE your Antarctic experience with MINIMUM environmental impact



Environmental Impact Assessment

Under the Antarctica (Environmental Protection) Act (1994), an Environmental Impact Assessment must be completed for all activities in Antarctica. The assessment should outline your intended activities, identify the potential environmental impacts, and describe how you plan to mitigate your impacts to the fullest extent possible. The assessment must be approved by the Minister of Foreign Affairs before the proposed activities can take place. Some activities are prohibited except in accordance with a permit. These are entering an Antarctic Specially Protected Area (ASPA), interfering with or sampling flora or fauna, and introducing non-native species to Antarctica. The Minister issues permits for these activities as part of the approval of your Environmental Impact Assessment.

- Be familiar with your Environmental Impact Assessment and your conditions of approval.
- Know the specific sites and activities your Event is approved for.
- Understand your reporting requirements before you depart for Antarctica.
- Seek an amendment to the approval if your proposed activities change.

Protecting Special Areas

Certain areas of Antarctica are set aside as Antarctic Specially Protected Areas (ASPAs), Antarctic Specially Managed Areas (ASMAs), or Historic Sites and Monuments (HSMs) in order to protect natural, physical and heritage values.

- Be aware of the location of and restrictions associated with ASPAs, ASMAs and HSMs when planning your activities.
- Entry into an ASPA is prohibited except in accordance with a permit, which must be carried when entering these areas.
- All historic huts in the Ross Sea region are ASPAs, and the entire McMurdo Dry Valleys are an ASMA.
- Always consult the Management Plan for any ASPA or ASMA you will be operating within or around. Copies are available on the Antarctic Treaty Secretariat's website: www.ats.aq

Protection of Wildlife and Plants

Antarctic wildlife and plants can be very sensitive to human disturbance. Unless you have a permit, disturbance of wildlife or damage or removal of plants may constitute 'harmful interference' which is prohibited under the Antarctica (Environmental Protection) Act (1994).

- Clean your clothing, boots and equipment before travelling to Antarctica. Pay particular attention to boot treads, Velcro fastenings and pockets which could contain soil or seeds.
- Introducing non-native species, including any animal, plant or non-sterile soil is prohibited except in accordance with a specific permit.
- Do not remove or interfere with plants or animals unless you have a permit to do so.
- Keep noise to a minimum in the vicinity of wildlife.
- Always give wildlife the right of way, and do not block their access routes.
- Stay 10 metres away from any animal unless it comes to you. Increase this distance if the animal appears disturbed, and take particular care around nesting birds.
- Wherever it is safe to do so, keep vehicles a minimum of 200 metres away from wildlife.
- Take special care when photographing, and do not walk through bird or seal colonies.
- Do not walk or drive on vegetation, including mosses and lichens.
- Do not take poultry or poultry products into or near bird colonies, due to the risk of introducing avian diseases.

Energy and Carbon Management

Antarctica New Zealand is committed to minimising our environmental footprint. Your behaviour can have a large impact.

- Turn off lights, equipment and other appliances when not in use.
- Keep doors closed to avoid heat loss.
- Reduce your shower time to conserve water – aim for three minutes.
- Reduce the amount of laundry you do when at Scott Base. Take your last load of laundry home and use the drying room rather than the clothes dryers.
- Minimise vehicle use by ride-sharing, or walking.
- Minimise food waste by taking only as much as you can eat.

Hazardous Substance Management

The impacts of fuel or other hazardous substance spills on the environment can be significant if appropriate action is not taken quickly. Prevention is the best defence.

- Minimise the handling and storage of fuel and hazardous substances, especially in the vicinity of sensitive areas such as freshwater lakes and streams, the marine environment, bird and seal colonies, and areas of vegetation.
- Store all fuel and hazardous substances using secondary containment such as bunding, drip trays or sorbent mats.
- Always have a spill kit nearby when handling fuel and hazardous substances.
- When possible, work in pairs when refuelling vehicles or equipment.
- Refuel vehicles and other equipment out of the wind, and use funnels or a spill pad to avoid spilling drips.
- Check equipment for faults and leaks prior to use.
- If a spill does occur, respond quickly using the procedures in your field manual.

Waste Management

Most activities carried out in Antarctica will produce waste, almost all of which is returned to New Zealand for treatment and disposal. All waste must be correctly handled, whether in the field or at Scott Base.

- Minimise the generation of waste by removing unnecessary packaging and other potential waste before it is sent to Antarctica or into the field.
- Choose reusable packing materials like bubble wrap, cardboard or paper.
- Polystyrene beads, chips or similar forms of packaging, non-sterile soil, polychlorinated biphenyls (PCBs) and pesticides are prohibited and should not be sent to Antarctica.
- Vermiculite should only be used for packaging hazardous liquids.
- Separate the waste you produce and dispose of it in the correct waste stream at Scott Base.
- Open burning of waste is prohibited.
- All field waste must be collected and returned to Scott Base, including grey water and human waste.
- Be prepared – carry a personal pee bottle when travelling away from Scott Base or your field camp.

Appendix 2: Chemicals stored at Scott Base and remote facilities, as of winter 2019

Hazardous substance / Common Name	**Type**	**HSNO Class.**	**Subsidiary HSNO Class.**	**UN No.**
3M High Strength Adhesive	Flammable aerosol			1950
50% β-Mercaptoethanol	Flammable liquid	6.1		1170
ABS Pipe Cement	Flammable liquid	3		1133
Aceclose 582	Not classified	NR		NA
Acetic Acid	Corrosive	3	8	2789
Acetone (Nail Polish remover)	Flammable liquid	3	6.3B	1090
Acetylene	Flammable gas	2.1.1A		1001
Acryclic Primer	Miscellaneous dangerous good	6.5B	8.3A	3082
Acrylic Plastic Spray can				
Ados F2 Adhesive	Flammable liquid	3		1133
Ados Pipe Jointing Compound	Flammable liquid	3		1133
Ados Solvent	Flammable liquid	3		1993
Aeroshell Grease #7	Non-hazardous	NR		NA
Alcohol reagent	Flammable liquid	3		1987
Almaplex 1275 Lubricant	Non-hazardous	NA		NA
Almasol 9200 Dry Film Lubricant	Flammable gas	2.1		1950
Ammonia	Toxic gas	2.3	8	1005
AN-8 / JP-8	Flammable liquid	3		1863
Anti static liquid (R5)	Non-hazardous	NR	NR	NA
Aquapoxy	Non-hazardous	NR		NA
Araldite	Corrosive		8	2735
Arandee Anti Static Spray	Not classified	NA		NA
Ardex WA98	Flammable liquid	3		1133
Argon	Non flammable gas	2.2		1006
Argoshield	Non flammable gas	2.2		1956
Armourcote 608	Flammable liquid	3		1263
Armourzinc 110	Flammable liquid	3		1263
Beta Plus Cleaner Primer	Flammable liquid	3		1993
Beta Plus Solvent Cement	Flammable liquid	3		1133
Bio Guard 1490	Corrosive	8	6.1E, 8.2C, 8.3A, 6.5B, 9.1B	3265
Biozyme	Non-hazardous	NR		NR
BMA Solvent	Flammable liquid	3		2227
Boiler Guard	Corrosive	8		1824
Boiler Guard 1710	Corrosive	8	6.1D, 6.1E, 8.1A, 8.2B, 8.3A, 9.1D, 9.3C	1824
Bond it on PVA glue	Not classified	NR		NR
Brake Fluid	Not classified	NR		NR
Brasso (LC23)	Flammable liquid	3		1987
Butane	Flammable gas	2.1		1965

Butyrate (tautering adhesive)	Not classified	NR		NR
Calcium Chloride (Water Treat.)	Not classified	NR		NR
Calcium glucanate	Not classified	NR		NR
Calcium hypochlorite	Oxidiser	5.1		1748
Carboline Fireproof paint	Flammable liquid	3.1	6.3A, 6.4A, 6.5B (contact), 6.7B, 6.8A, 6.9B, 9.1C	1263
Carbon Dioxide Gas	Non flammable gas	2.2		1013
CDT cutting Oil Spray can	Flammable aerosol	2.1		1950
Cement SC 4000	Flammable liquid	3		1133
Chamber Brite	Corrosive	NA		NA
Chornco 2082 fuel conditioner	Not classified	NR		NR
Chornco 2083 fuel conditioner	Not classified	NR		NR
Citric acid (10%)	Not classified	NR		NR
Clipsal Jointing Cement	Flammable liquid	3		1133
Compressed Air	Non flammable aerosol	2.2	Not hazardous	1002
Convocare	Not classified	NR		NR
Convoclean forte	Corrosive	8	6.1E, 8.1A, 8.2B, 8.3A, 9.1C, 9.3C	1760
Coppercote Compound	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
Corium 95	Corrosive	8		1760
Corroless Watershield 450	Flammable liquid	3		1263
CRC 2.26	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC 5.56	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC 66 Marine	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC 808 Silicone Spray	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC Anti-corrosive Primer	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC Battery Terminal Protector	Flammable aerosol	2.1		1950
CRC Black Zinc Rust Protect	Flammable aerosol	2.1	6.1D (dermal), 6.1D (inhalation), 6.1D (oral), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation), 9.1D	1950
CRC Brakleen	Flammable aerosol	2.1	6.1D (dermal), 6.1D (inhalation), 6.1D (oral), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation), 9.1D	1950
CRC Bright Zinc	Flammable aerosol	2.1	.1D (dermal), 6.1D (oral), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation), 9.1A	1950

CRC Builders Fill	Flammable liquid	3	3.1C, 6.1D (inhalation), 6.1D (oral), 6.1E (dermal), 6.3A, 6.4A, 6.7B, 6.8B, 6.9B (inhalation)	3269
CRC CO Contact Cleaner	Flammable aerosol	2.1		1950
CRC Copper Anti sieze compound	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC Cream hardener	Organic peroxide	5.2	3.1D, 5.2E, 6.1E (oral), 6.3B, 6.4A, 6.5B (contact), 6.7B, 6.8A, 9.1A, 9.2C	3108
CRC Destal 100 - antistatic spray	Flammable aerosol	2		1950
CRC Dry lube	Flammable aerosol	2.1	2.1.2A, 6.1E (inhalation), 6.1E (oral), 6.3B, 6.4A, 6.9 (narcotic)	1950
CRC Electronic Cleaner	Flammable aerosol	2.1	.1E (inhalation), 6.1E (oral), 6.9 (narcotic)	1950
CRC Engine start	Flammable aerosol	2.1	6.1E (dermal), 6.1E (inhalation), 6.1E (oral), 6.3A, 6.6A, 6.7A, 6.9 (narcotic), 6.9B	1950
CRC Graphite	Flammable aerosol	2.1		1950
CRC Leak detector spray	Flammable aerosol	2.1		1950
CRC NF Contact Cleaner	Non-flammable aerosol	2.2		1950
CRC 'Prime It'	Flammable aerosol	2.1	6.1D (oral), 6.1E (dermal), 6.1E (inhalation), 6.3A, 6.4A, 6.8B, 6.9 (narcotic), 6.9B (inhalation)	1950
CRC Switch Cleaner Lubricant	Flammable aerosol	2.1		1950
CRC Trefolex Cutting Compound	Not classified	NR	6.1E, 6.3B	NR
CRC Zinc It	Flammable aerosol	2.1.2A	6.1D	1950
CT 90 Cutting and tapping fluid	Flammable aerosol	2.1		1950
Danish Oil	Flammable liquid	3		1263
Delvac synthetic oil	Not classified	NR		NR
Dinitrol AV8	Flammable liquid	3		1139
Dispex AA140Ak	Not classified	NR		NR
Duram 195	Flammable liquid	3		1263
Durapipe ABS Solvent Cement	Flammable liquid	3		1133
Electro solv M3	Acutley toxic	6.1		1710
Electrolube Clear Protective Lacquer	Flammable aerosol	2.1.2A		1950
Electrolube Minimal Charging Freezer	Not classified	2.2		1950
Electrolube MR 8008 Insulating Varnish	Flammable liquid	3		1133
Energrease BP	Not classified	6.3	6.4	NA
Enviroscale Acid	Not classified	NR		NR
Ethanol/Ehtyl alcohol	Flammable liquid	3		1170
Ethylene glycol (Coolant)	Not classified	NR		NR
Expanding foam cleaner	Flammable gas	2.1		1950
Expoxy resin and hardener	Corrosive	8		2735

Ferric Chloride granules	Corrosive	8		3260
Fire Extinguisher (ABE Dry Chemical Powder)	Non Flammable gas	2.2		1044
Fire Paste	Flammable liquid	3		1263
Fleece Mark/Sprayline	Flammable aerosol	2.1.2A	9.1C, 6.3B, 6.9B	1950
Foamclean FCL300	Non flammable gas	2.2		1950
Fosroc primer	Corrosive	8		1760
Fuller Adhesive Synthetic Resin	Not classified	NR		NR
Galmet Metal Protection Cold Galvinising	Flammable aerosol	3.1C	6.1E, 6.3B, 6.4A, 6.9, 9.1A	1263
Gorilla DIY Expanding foam	Flammable aerosol	2.1.2A	6.1D, 6.3A, 6.4A, 6.5A, 6.5B, 6.8C, 6.9A, 9.1D	1950
Gorilla Expanding Foam	Flammable aerosol	2.1	6.1D, 6.3A, 6.4A, 6.5A, 6.5B, 6.8C, 6.9A, 9.1D	1950
Gorilla Expanding Foam Cleaner	Flammable aerosol	2.1	6.1D, 6.3A, 6.4A, 6.5A, 6.5B, 6.8C, 6.9A, 9.1D	1950
Gorilla Explanding Foam Pro	Flammable aerosol	2.1	6.1D, 6.3A, 6.4A, 6.5A, 6.5B, 6.8C, 6.9A, 9.1D	1950
Gorilla premium wood glue	Not classified	NR		NR
Hardener	Not classified	NR	6.5B, 9.1C, 6.3B, 6.4A, 6.9B, 9.1D	NR
Hardener ER-42	Flammable liquid	3		1133
Helium	Non flammable gas	2.2	Not hazardous	1046
Hempel Hi-build coating	Flammable liquid	3		1263
Hilti Insulating Foam	Flammable aerosol	2.1	6.1E, 6.1D, 6.3A, 6.4A, 6.5A, 6.5B, 6.9A	1950
Hydrasol - cable gel remover	Environmentally hazardous	9		3082
Hydraulic oil	Not classified	NR		NR
Inox Lubricant	Not classified	NR		NR
Insulfoam (Part A)	Not classified	NR	Not hazardous	NR
Iodosan	Environmentally hazardous	9		3082
Isopropyl Alcohol	Flammable liquid	3		1219
Janola/Bleach	Not classified	NR	6.1E, 8.2C, 8.3A, 9.1C	NR
Java Oil	Not classified	NR		NR
Kerosene	Flammable liquid	3		1223
Lascaux Acrylic adhesive	Non-hazardous	NR		NA
Lighter Fluid	Flammable liquid	3		3295
Linseed oil (Raw)	Not classified	NR		NR
Loctite 401	Flammable liquid	3	9	3334
Loctite 567 Master Pipe Sealant	Not classified	NR		NR
LPG	Flammable gas	2.1		1075
Lubricant	Not classified	NR		NR
Magnesium Perchlorate	Oxidising agent	5.1		1475
Marley Gold PVC Solvent Cement	Flammable liquid	3		1133
MCD 519 Cement	Flammable liquid	3		1133
MCD Primer cleaner	Flammable liquid	3		1193
Mercuric Chloride	Toxic	6.1		1624
Metalex End Seal Preservative	Not classified	NR	3.1D, 6.5B, 6.9, 6.1D	NR

Methanol	Flammable liquid	3	6.1	1230
Methyl ethyl ketone	Flammable liquid	3		1193
Methylated Spirits	Flammable liquid	3	6.4A	1170
Mobil 2-Stroke Oil	Flammable liquid	3.1D		NR
Mobil Aero HF Hydraulic fluid	Non-hazardous	NR		NR
Mobil Antifreeze	Non-hazardous	NR		NR
Mobil ATF 220	Not classified	NR		NR
Mobil Delvac 15W-40	Not classified	NR		NR
Mobil Delvac 5W-30	Not classified	NR		NR
Mobil Delvac 5W-40	Not classified	NR		NR
Mobil DTE Excel 46	Not classified	NR		NR
Mobil Grease 28	Not classified	NR		NR
Mobil Hydraulic Brake Fluid	Not classified	NR		NR
Mobil Mobilith SHC PM	Not classified	NR		NR
Mobil Waxrex 522 White	Not classified	NR		NR
Mobilcut 100	Not classified	NR		NR
Mobilgear OGL 461	Not classified	NR		NR
Mobilgrease XHP 222	Not classified	NR		NR
Mobiltemp SHC 32	Not classified	NR		NR
Mogas/Petrol	Flammable liquid	3		1203
Nitric acid	Corrosive	8	5.1	2031
Nitrogen	Non flammable gas	2.2		1066
Norstik epoxy glue	Environmentally hazardous	9	6.3A, 6.4A, 6.5B, 6.9B, 9.1B	3082
Oil - Unknown	Not classified	NR		NR
Orthophosphoric acid	Corrosive	8		1805
Oxygen	Non flammable gas	2.2	5.1	1072
Oxygen (Medical)	Non flammable gas	2.2	5.1	1072
Pacific Balsa Dope	Flammable liquid	3		1263
Paint Acrylic	Not classified	NR		NR
Paint Enamel	Flammable liquid	3	6.9, 9.1C, 6.3B, 6.4A, 3.1C	1263
Paraffin Oil	Not classified	NR		NR
Penetrant	Flammable gas	2.1		1950
Penetrol Wood Oil	Flammable liquid	3		1263
Petrol / Mogas	Flammable liquid	3		1203
Pickling paste	Corrosive	8	6.1	1790
Plastic dip rubber coating	Flammable gas	2.1		1950
Plastic Systems ABS Pipe Cleaner - MEK	Flammable liquid	3		1193
Polyurethane varnish Spray can	Flammable gas	2.1		1950
Primer	Flammable gas	2.1	2.1.2A, 6.1E (inhalation), 6.1E (oral), 6.3A, 6.6A, 6.7A, 6.9, 6.9B	1960
Propane & Butane Gas	Flammable liquid	3		1268
Propylene glycol	Not classified	NR		NR
Resene primer paints	Not classified	NR		NR

Rocol ASP Anti Scuffing Dry Film Paste	Not classified	NR		NR
Rocol Graphite Jointing Compound	Not classified	NR		NR
Rocol Nickel Anti Seize Compound	Not classified	NR		NR
Rocol RTD Metal Cutting Liquid	Not classified	NR		NR
Rocol RTD Metal Working Comp.	Misc dangerous good	9		3077
Rust Destroying Primer (Rust Roy)	Not classified	NR	6.3A, 6.4B	NR
Selley's RP7 Engine Start	Flammable aerosol	2.1	6.1E, 6.3B, 9.1B	1950
Shell Alvania Grease	Not classified	NR		NR
Sika Activator Pro	Flammable liquid	3		1866
Sika primer	Flammable liquid	3		1866
Skia Expanding Foam	Flammable aerosol	2.1	6.1, 6.4, 6.5, 6.9, 9.1	1950
Skia Foam Cleaner	Flammable aerosol	2.1	6.1, 6.3, 6.4	1950
Sodium hydroxide pellets	Corrosive	8		1823
Sodium Metabisulphite	Not classified	NR	6.3A, 6.4B	NR
Strip Off Floor Cleaner	Not classified	NR		NR
Spray Adhesive	Flammable aerosol	2.1	6.5B, 9.1C, 6.7B, 6.4A, 6.9, 6.1E, 6.3A, 9.1D, 3.1C	1950
Spray Paint	Flammable liquid	3		1263
Synthetic oil	Not classified	NR		NR
Thinner no 5	Flammable liquid	3	3.1B, 9.1C, 6.1E, 6.4A, 6.1D, 6.9B, 6.3A, 9.1D, 6.1D, 6.8B	1263
Thinner no 6	Flammable liquid	3	6.1D (dermal), 6.4A, 6.1D (oral), 6.9B, 6.1E, 6.3A, 9.1D, 9.3C, 6.8B, 3.1C	1993
Thinning solvent	Flammable liquid	3		1307
Tinter	Not classified	NR		NR
Toluene	Flammable liquid	3		1294
Tru bilt - Overhead door spray lube	Flammable aerosol	2.1		1950
Turpentine	Flammable liquid	3		1299
Uraflex				
Vinyl etch primer	Flammable liquid	3	9.1B, 6.1D, 6.7B, 6.3B, 6.4A, 6.1D, 6.9A, 9.1D, 6.1D, 3.1C, 6.6B, 6.8A	1263
Wattyl kill rust	Flammable liquid	3	3.1C, 6.1E, 6.9	1805
WD-40	Flammable aerosol	2.1		1950
Weld On Primer-P-70 PVC/CPVC	Flammable liquid	3		1993
White Gas/fuelite/shelite	Flammable liquid	3	3.1B, 6.1E, 6.3A, 6.8B, 6.9B, 9.1B	1268
Woodstain	Flammable liquid	3	9.1C, 6.7B, 6.4A, 6.9B, 6.3A, 3.1C, 6.8A	1263
X-20A Thinner	Flammable liquid	3		1307
ZG90 Cold Zinc Galvanising Spray	Flammable aerosol	2.1		1950
Zincilate 10	Flammable liquid	3	3.1C, 6.1D (oral), 6.3A, 6.4A, 6.8B, 6.9B, 9.1D, 9.3C	1263

1.

2.

Appendix 3: Long-Term Science relocation – Site plans – supplied as pdf files

Appendix 4: Summary of SBR monitoring plots biodiversity value

The biodiversity value of the monitoring plots is summarised in Table 1.

Note:

- The percent vegetation cover indicates the extent of vegetation present within a 1x1m monitoring plot (see Figure 54).
- Invertebrate abundance results are from the 2018/19 survey only.
- Soil salt is an indicator of relatively recent ground disturbance (e.g. digging or trampling, years, not decades old).
- The overall biodiversity value is based on the presence of vegetation and micro-invertebrates:
    - Green/High biodiversity = % Veg cover over 15%, Invertebrate abundance Medium to High
    - Amber/Medium biodiversity = % Veg cover 5-15%; Invertebrate Abundance Medium
    - Red/Low biodiversity = % Veg cover 0-10%; Invertebrate abundance None – Low

Figure 54: A= depiction of active Nostoc found at site SM24. B= Bryum spp. moss found at site SM25. C= example of Caloplaca spp. lichen at site SM09

Table 1: Biodiversity summary of monitoring plots

Monitoring plot number	Description	Percent vegetation cover	Invertebrate abundance (High/Med/Low)	Presence of soil salt	Overall biodiversity value
SM01	Operational area, near road. High dust exposure, very disturbed site	None	None	90% cover	
SM02	Highly disturbed site behind I-hut	None	Low	Absent	
SM03	Similar to SM01, Operational area, near road. High dust exposure, very disturbed site	None	None	90% cover	
SM04	Close to the road in old bulldozer tracks. Limited inactive moss, soils pretty dry. Likely subject to water runoff from the road.	10%	Medium	Absent	
SM05	Edge of old bulldozer tracks	30%, dried algae, moss and lichen	High, very high nematode count	Absent	
SM06	No visible vegetation but appeared recently wetted presumably from a melted snowpack. In a good drainage area although in reasonable proximity to the SB-MCM road.	None	None	Absent	
SM07	Near HV cable, rocky site in a good drainage area	15%, moss, some lichen	High	Absent	
SM08	Near the Hillary Track (HT) with little apparent moisture at time of sampling. Some biological soil crusts observed with lichens and a fair amount of salt present.	10%	High	50%	
SM09	Edge of LTS area, near Hillary track.	2%	Low	10% cover	
SM10	Close to the Hillary track bridge	5%, mainly lichen	Low	Absent	
SM11	Very rocky site on steepish slope with limited vegetation present. One of the driest sites sampled, soil was very fine.	1%, lichen	None	Absent	
SM12	In a patterned ground crack in a relatively disturbed site near the road. Appears to be periodically exposed to meltwater, some dried algae visible.	10%	Medium	Absent	
SM13	Near Hillary trail, on slight slope, rock and gravel	15%, moss, lichen, algae	Medium	Absent	
SM14	Close to the road, on a slight slope, potentially prone to runoff. Gravel and	None	Medium	80%	

Monitoring plot number	Description	Percent vegetation cover	Invertebrate abundance (High/Med/Low)	Presence of soil salt	Overall biodiversity value
	rocks with no visible vegetation. Site was also very salty.				
SM15	Near HV cable, very dry rocky site on a bit of a slope	65%, moss and lichenised moss	High (nematodes)	Absent	
SM16	Edge of operational area, on patterned ground, high moisture	10%, moss	High	10% cover	
SM17	In slight drainage (frost) crack although soils still appeared quite dry. Parts of moss patches also appeared to be partially active.	16%, mainly moss	Low	Absent	
SM18	Between HV cable and operational area, in a drainage area	60%, moss	High	Absent	
SM19	Immediately adjacent to HT with very dry/dead moss patches covered in lichen.	5%	Medium	Absent	
SM20	In a wider drainage area with running water flowing approximately 1m from plot.	8%, moss some active	Low	Absent	
SM21	Above operational area, in a drainage crack within an old bulldozer track	65%, moss and dried algae	High, extremely high nematode count	Absent	
SM22	Edge of operational area	1%, moss and lichen	Medium, 4 mites	50% cover	
SM23	Very disturbed site, no visible vegetation, located in an old bulldozer track. Close to the road	None	None	Absent	
SM24	In LTS area, at the edge of a running stream fed by a melting snowpack	50%, only plot with active algal mats	Low, with some mites	Absent	
SM25	In LTS area up from a basin which appears to periodically fill with snow before melting and running into SM24	15%, active moss	High, with some mites	Absent	

There are 12 High biodiversity value plots, and 7 Medium biodiversity value plots.

Appendix 5: VLF Radio Noise Survey at the Eyrewell Intermagnet Observatory (provided separately)